Where can Drivers Charge Their Electric Vehicle for Free in the U.S.?

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Introduction

The ability to charge conveniently and reliably is one of the prerequisites for the widespread adoption of electric vehicles (EVs). However, with over half a million stations deployed worldwide (IEA, 2020), EV charging is still a nascent industry.[1] Charging services are currently offered by very diverse market players such as utilities, original equipment manufacturers (OEMs), specialized charging companies, but also outsiders like shops and malls with customer parking. These companies have very different incentives for installing charging stations. It is thus unclear how the EV charging landscape will evolve as EV adoption increases.

The U.S. is the second largest car market in the world and therefore a primary area of both academic and industry research (e.g., Idaho National Lab (2017), Li (2016), Muehlegger and Rapson (2018)). Substantial efforts have, for example, been directed to the study of the optimal placement of charging stations (e.g., Zhang et al., 2015) or drivers' charging behavior (e.g., Nicholas et al., 2017). By contrast, the analysis of current business practices has drawn less attention in the academic literature. Understanding economic incentives and business opportunities is, however, crucial to design public policies in an environment where private investment is substantial.

This work focuses on how the service of EV charging is currently priced in the U.S. This is important for at least two reasons. First, fuel costs represent a large fraction of the operating costs of a vehicle, and thus play an important role in car purchasing decisions. Second, the expected revenue from the provision of charging services is one of the main determinants of investment decisions by charging station providers. Based on the analysis of a widely used public dataset (made available by the Alternative Fuel Data Center (AFDC)), we surprisingly find that drivers may be able to charge their EVs for free at more than half of the stations listed in the dataset. We explore and discuss several possible explanations for this unexpected stylized fact. First, we note that many "free" charging stations are implicitly or explicitly bundled with some other service, and may thus require to consume a distinct service and/or pay for parking. Second, we present evidence that the share of free charging stations is likely to decrease as the market becomes more mature, although a significant amount of free slow-charging stations may very well remain an important feature of the EV charging landscape.

Data

We use the publicly available dataset on charging stations provided by the Alternative Fuel Data Center (AFDC). This data source was launched by the U.S. Department of Energy and is administered by the National Renewable Energy Laboratory. It has been used in many empirical studies on EVs (e.g., Li et al. (2017)) and contains information on more than 20,000 EV charging stations in the US.[2]

Besides information on the location and design of charging stations, the dataset also describes the price schedule faced by EV drivers. This information is, however, provided in a descriptive text format. For the purpose of this work, we thus manually converted the text into a standardized format, making it possible to run quantitative analyses on the observed pricing strategies of EV charging station providers. In this article, we focus on "free" charging stations, i.e., stations where drivers do not need to pay for charging. By contrast, at "paid" stations, a charging fee applies. Ambiguous or absent textual descriptions of price schedules are labeled as "unknown". Because manually-filled text information can be error-prone and prices may change over time, we compared the AFDC database to Plugshare.com, a private platform listing public charging stations.[3] For a sample of a few hundred charging stations, we find that, for about 8% of the charging stations labeled as "free" in the AFDC dataset, Plugshare.com lists instead a non-zero price. These discrepancies may however stem from differences in how ambiguous price schedules are reported (e.g., parking fees) or mistakes by either of the two information providers. Overall, this sanity check suggests that, while not perfectly accurate, price information listed in the AFDC dataset seems to be of sufficient quality for the purpose of our study.

Main result

A high-level analysis of our three pricing categories (free / paid / unknown) yields a very surprising and striking result: *more than half of the charging stations listed in the dataset seem to offer at least one free charging option.* In what follows, we explore in more detail possible explanations for this unexpected stylized fact.

Possible explanations

Characteristics of free charging stations. In this paragraph, we analyze the relationship between the characteristics of charging stations and their pricing category. First, EV charging is not a homogenous commodity, but is differentiated by speed of charge.

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See footnotes at end of text.

Three different categories are generally used to capture this feature which are, by increasing speed of charge: Level 1 (L1), Level 2 (L2), and direct current fast charging (DCFC). A faster charging speed is typically associated with a higher quality of service as it reduces customers' waiting time. We thus start by computing the share of free charging stations conditional on a given charging speed. A minority of charging stations host chargers of two or more distinct speeds (most often L2 and DCFC). Such stations may use a different price schedule for each technology, in which case we retrieve pricing information for both charging speeds. Table 1 reports the obtained results. We observe that 76.3% of L1, 60.7% of L2, and 17.5% of DCFC stations are free. This fraction is smaller for DCFC stations, which is consistent with basic economic intuition. First, drivers are likely to have a higher willingness to pay for faster charging due to shorter waiting times. Second, investment costs for DCFC stations are at least ten times higher than the 2,000 to 3,000 USD required to install a "slow" charging station (L1 or L2; Idaho National Lab, 2017).

	L1	L2	DCFC
Free charging	371	11,536	615
Paid charging	74	5,497	2,546
Unknown	41	1,966	356
Total	486	18,999	3,517
Percentage known to be free	76.3%	60.7%	17.5%

Table 1: Number of stations per pricing category and charging speed

We then identify the owners and/or operators of free charging stations which are responsible for designing price schedules. We find that virtually all DCFC stations labeled as "free" are part of ChargePoint or Greenlots charging networks, or not part of any charging station network at all. Both ChargePoint and Greenlots have adopted a business model under which they are responsible for the installation and maintenance of charging stations, but leave most operational decisions, including pricing, at the discretion of the hosting facility. Similarly, the majority of free L2 stations are operated by Tesla Destination and ChargePoint or are non-networked stations. By contrast to ChargePoint and Greenlots, however, Tesla Destination is centrally operated by Tesla, an OEM that offers free charging to their customers exclusively.

We thus analyze the nature of the hosting facilities where free charging stations are located. This information is available from the original AFDC dataset for about two thirds of the sample of free charging stations. Whenever feasible, we further use the names and locations of stations to manually label the type of hosting facilities for the remaining stations. We then group facilities into broad categories, such as hotels, college campuses, gas stations, etc. The obtained results are shown in Figure 1. First, hosting facilities usually have a distinct core business, and may offer free charging as a way to differentiate their service (e.g., hotels, public facilities for entertainment, parking spaces for shopping) or to be more attractive for employees (e.g., office buildings, public facilities, college campuses). Second, the vast majority of DCFC stations labeled as free are located in car dealerships or other car-related businesses, possibly as an additional benefit to customers or employees and/or as a tool to familiarize prospective EV buyers with charging stations.

Our results suggest that the charging networks and hosting facilities providing charging for free do not deploy charging stations to generate revenue from

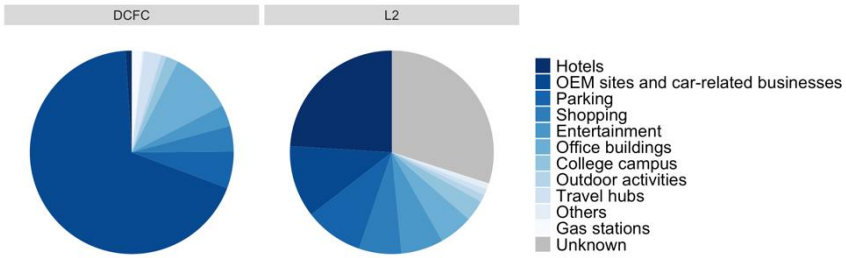

Figure 1: Type of facilities hosting free DCFC (left) and L2 charging (right)

charging services, but rather because they derive other benefits from it. More specifically, charging stations can have a positive impact on the network's or hosting facility's business, for instance by increasing EV sales (e.g., Tesla Destination) or attracting customers (e.g., stations installed in shopping centers).

Furthermore, we analyze the typical size of charging stations, as measured by the number of available chargers. While both paid and free L2 stations host an average of 2.7 chargers, we find that free DCFC stations have on average 1.5 chargers and paid stations 4.8.[4] This difference in means has strong statistical significance,[5] indicating that DCFC stations labeled as "free" tend to be smaller installations. This observation suggests that facilities hosting paid DCFC stations may pay more attention to whether they have sufficient charging capacity for drivers to be able to reliably charge there on a regular basis.

Overall, we find that the majority of free charging stations are hosted or operated by companies whose primary business objective is not the sales of charging services to drivers. Instead, these hosting facilities get distinct benefits from installing a charging station, which seem to exceed the investment and operating costs. A corollary is that, in practice, many stations labeled as "free" may not be readily accessible to drivers and cannot be used on a regular basis, as their usage is likely to be restricted, for example to customers or employees.

Market maturity and free L2 charging. EV charging is still a rather immature market. It is therefore an open question whether our main result will persist as the EV industry grows. To start exploring this question, we first analyze how the share of free charging stations among newly commissioned stations has evolved over time.

For each year between 2011 and 2019, Figure 2 shows the fraction of non-networked L2 charging stations commissioned in that year that are free. We choose to focus on non-networked stations because (i) many charging network providers have a centralized pricing policy, and (ii) opening dates are available for the vast majority of these stations. We find that the share of free stations among this sample exhibits a downward trend, from nearly 90% down to about 65%, suggesting that the provision of free charging might become less attractive over time.

We then look in more detail at the subset of paid DCFC stations which are operated by companies

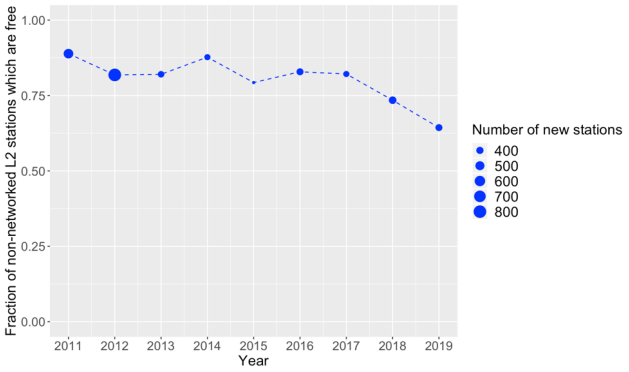

Figure 2: Fraction of non-networked L2 stations commissioned that are labeled as free

that derive their main revenue from the payment for charging services by drivers (similarly to existing gas stations).[6] As no opening dates are available for these stations, we leverage the fact that the maturity of the EV ecosystem differs significantly across U.S. states and use the state-level market share of EVs in the car market[7] as a proxy for market maturity. Figure 3 plots the fraction of these DCFC stations (out of the total number of DCFC stations in the state) as a function of our metric of market maturity. We find that the share of such stations is positively correlated with state-level EV market shares. This suggests that, in more mature markets, companies for which EV charging is the core business may serve a higher share of charging demand.

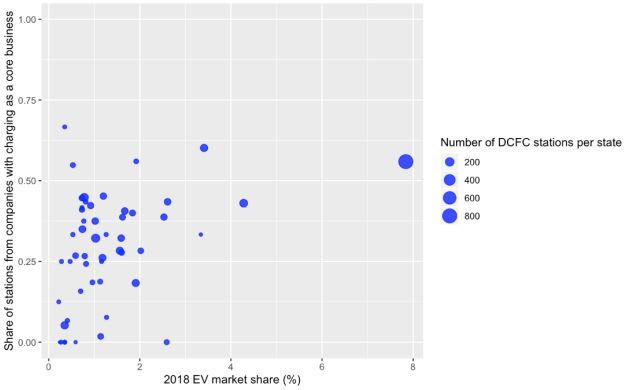

Figure 3: Share of DCFC stations owned by charging companies that derive their main revenue from the payment for charging services by drivers (each dot is a U.S. state)

Overall, our results suggest that EV charging stations may be more likely to be free in the early stages of deployment of the charging infrastructure. With the increasing adoption of EVs, however, potential profits from the charging market might attract companies that derive their main revenue from the payment for charging services by drivers. It is however an open question how, in the future, the market will be split between such specialized companies and charging providers which offer charging as a service to their customers or employees.

Conclusion

Although the academic literature on EVs is growing, surprisingly little attention has been dedicated to studying the business practices currently observed in the charging industry. This work makes a first step in shedding light on the price structures used by charging stations in the U.S. Quite unexpectedly, we find that more than half of the EV charging stations seem to provide charging services for free. However, further investigation suggests that such "free" stations are most often installed by companies or facilities that may derive indirect revenues from the provision of charging services (e.g., by selling more cars or attracting more customers). Although these stations may not be readily accessible to any driver willing to charge an EV, it came as a surprise that the perceived benefits from installing a charging station may be high enough to provide free electricity supply in so many instances. We further show suggestive evidence that, as market maturity increases, a larger fraction of the EV fast charging market is likely to be covered by paid and higher quality services provided by companies for which charging is their core business.

Footnotes

[4] For example, McKinsey (2018) estimated that around $50 billions of cumulative investment may be directed to the EV charging infrastructure over the next decade.

[2] Alternative Fuels Data Center (2020), Alternative Fueling Station Locator, https://afdc.energy.gov/stations/#/find/nearest?fuel=ELEC, last accessed on 07/07/2020. In this article, we use the database as downloaded on June 08, 2020. The database contains 21,645 public EV charging stations within the 50 US states and the District of Columbia.

[3] We are grateful to Michael Hohmann at the University of Freiburg for outstanding research assistance.

[4] The 356 DCFC stations for which the pricing schedule is unknown are excluded from this analysis.

[5] A t-test rejects with high confidence ($p < 0.001$) the null hypothesis that both populations have identical means for the number of chargers per charging station.

[6] As stated by their website. In our dataset, these companies are Blink, Electrify America, Webasto, and EVgo.

[7] Retrieved from https://evadoption.com/ev-market-share/ev-market-share-state/

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