The Life of the EV: Some Car Stories

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### Summary

Electric cars might be just like any other cars, right? Or, does the data show drivers live a little differently? Are they driving to Las Vegas every weekend? What does range anxiety look like? Is there any place we should put charging stations that isn't obvious? Do electric car drivers speed a lot? FlexCharging will walk through car stories, showing how users charge, operate their electric vehicle, and show the hidden life of cars, encoded in our data.

*Keywords: smart charging, electric vehicle (EV), load management, battery management, user behavior*

### 1 Introduction

It’s easy to assume that electric vehicle drivers are all the same, and that the lives of their cars are all amazingly typical. Maybe they only drive their electric cars to their high tech companies, then to their rich suburbs, and make occasional trips to wineries or resorts, where they use one Tesla Supercharger. Or, is there more to the life of an electric car than that? Is the set of buyers of electric cars more diverse than just the typical “tech bro”?

FlexCharging has a data collection and managed charging platform for electric vehicles. Using this platform, we’ve collected data from different types of drivers in many different geographies. And demographics wise, we have data from drivers for a Transportation Network Company’s drivers, where they use their cars for work, live in apartments, and operate their cars much more heavily. They rely on Tesla Superchargers more during the day, especially during lunchtime.

#### 1.1 The Life of the EV

The FlexCharging Data and Managed Charging Platform provides key insights into “the life of the EV”. Unlike data platforms that focus on acquiring information about the EV through the charger, FlexCharging speaks to the EV automaker’s cloud service which means that the data captured covers the entire life of the EV: Charging, Driving and Waiting.

To get a good understanding of EVs it is important to focus not just on the charging experience and data, but how EVs are driven, for how long, and the interplay of driving to charging.

In Figure 1 below, the data pathway between the EV, the OEM’s cloud service and the FlexCharging EnergyNet Service is shown. The entire data pathway is accomplished via cloud-to-cloud telematics and does not require any hardware in the vehicle (for example, no dongle in the Onboard Diagnostics port).
By leveraging the ‘always on’ OEM cloud services, FlexCharging is able to form a deep and rich understanding of the Life of the EV. The data captured and analyzed can help utilities in:

- **Distribution planning**
  - Where will additional distribution system infrastructure be required to support additional load on the distribution system?

- **Rate and program design**
  - What rate schedules and program incentives can utilities use to help flatten the charging peak from the evenings to the overnight or midday periods?
  - Which ratepayers have met program incentive rules for billing credits or other incentive payments?

- **Capacity planning**
  - How much load can be shifted from peak periods to off-peak periods, mitigating the need for additional (and often expensive) generation peaking capacity?

The FlexCharging Managed Charging functionality can help EV drivers to:

- Automatically shift their EV’s load from high-cost periods (as defined in utility rate schedules) to lower cost periods – while respecting the driver’s needs and schedules

This paper will take the reader through some interesting visualizations and analysis of the FlexCharging managed EVs. Patterns in the data will be highlighted and discussed to understand the implications to the utilities and the drivers as the transportation sector becomes electrified.
2 EV Driving and Charging Data

FlexCharging’s polling produces status events describing what a vehicle is doing. From these status events, we construct charge sessions, charge intervals (every 15 minutes of a charge session), trip segments, dwell times, and identify data gaps. FlexCharging identifies charging location types based on a combination of user input, data from the EV, and an offline resolution process. With these pieces, we generate load profiles for drivers in aggregate, as well as identify at what type of location they are charging.

3 Understanding the Data

![Car Stories: The Life of the EV](Figure2: The Life of the EV)

Throughout this paper we will refer to EV “profiles” as defined by the Battery State of Charge (SOC) over time.

In Figure 2 above, each SOC is coded to a different color depending on what the vehicle is doing at that time: Charging, Driving, Disconnected, Connected and Complete, Connected and Not Charging, Connected and Starting Charging, Connected and Stopping Charging or Unknown.

By analyzing the different profiles, we can begin to get a sense of the different ways EVs go through their days and the different stories they tell about their driver’s lives.

We will examine three areas of EV Life:

- The EV Charging
- The EV Driving
- The EV Waiting

4 The EV Charging

The first, and most obvious, characteristic in the Life of the EV is charging.
Electric Charging is a complex and multi-faceted occurrence that bears little resemblance to the fuelling most of us associate with transportation – buying gasoline for an internal combustion engine (ICE) vehicle.

Table 1: Gasoline vs. Electric Fuelling

<table>
<thead>
<tr>
<th>History</th>
<th>Gasoline</th>
<th>Electric Charging</th>
</tr>
</thead>
<tbody>
<tr>
<td>People have had decades to understand how fuelling with gasoline works</td>
<td>EVs are new and confusing to many car buyers</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Metrics</th>
<th>Simple to understand:</th>
<th>Complex and new:</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Miles per gallon on the vehicle – an estimate of which is readily available by make, model &amp; year</td>
<td>- Miles/kwh or kwh/Mi - a confusing metric that most car buyers do not understand</td>
<td></td>
</tr>
<tr>
<td>- Dollars per gallon – which gas stations advertise on large signs outside of each gas station</td>
<td>- Cents/kwh rate from the utility or the charging station</td>
<td></td>
</tr>
<tr>
<td>- MPGe – Miles per Gallon equivalent – a measure to help compare EVs to ICE vehicles</td>
<td>- MPGe – Miles per Gallon equivalent – a measure to help compare EVs to ICE vehicles</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Locations</th>
<th>Gas stations are plentiful and easy to find</th>
<th>Charging stations are not yet as plentiful – especially in remote areas</th>
</tr>
</thead>
</table>

| Anxiety          | If you run out of fuel, you can bring the fuel to the vehicle instead of the vehicle to the fuel | Running out of electric charge is a concern as there is currently no easy way to refuel away from a charging station, requiring towing |

Educating drivers on the basic mechanics of fuel costs for an EV will take a concerted effort by automakers, dealerships, utilities and third parties.

FlexCharging’s user interface (UI) is being redesigned to help a driver understand their charging sessions in a way that helps simplify the confusion and get them accustomed to the new metrics discussed in Table 1 above.

One key difference in the Life of the EV from ICE vehicles is that the charging session can have different costs in different parts of the session. For example, if we focus in on the long charge in the top row of Figure 2 above, we see a charge session that began at 8:48 pm on March 17, 2020 (Figure 3) and ended at 4:31 pm on March 19, 2020 (Figure 4)
Though this is an unusually long charge session using Level 1 charging (110V), it is informative as that single charge session is priced at different rates over the session. For example, using the PG&E EVA rate schedule (Figure 5), that session would have been priced at anywhere from a high of $0.3890/kwh to a low of $0.1460/kwh and a midpoint of $0.230/kwh.
When fuelling on gasoline, the price of the gasoline per gallon may change ACROSS refuelling sessions. But it does not change WITHIN the length of a single refuelling session. So it is difficult to explain to drivers the concept of the complexity of costs of charging. This is one part of the Life of the EV that needs work to clarify for drivers the answer to a simple question: How much does it cost to charge my EV? The answer will vary session to session and even minute to minute within a charging session.

4.1 Charging ‘Styles’

We’ve noted two basic ‘styles’ of EV drivers’ charging patterns based on the data view above.

1. Empty battery style charging – these are chargers who tend to run the battery down to a very low state of charge (SOC) before recharging. Driver behavior implies they have a similar mental model for charging as drivers of gasoline cars, where you travel to a gas station perhaps once per week.

2. Scheduled style charging – these are periodic chargers who charge the battery every day at approximately the same time for the same length of time regardless of the plug-in SOC

Here is a visual on the difference between ‘empty battery’ style charge vs. the ‘scheduled’ style charge for a period of hours from March 1- March 20, 2020. The dark blue increasing lines represent charging. The light blue decreasing lines represent driving.
Here is a visual on ‘scheduled chargers’ for the same period.

We are still in the process of analyzing how to infer and automatically designate the charging style of different drivers for further analysis. We’re also at the beginning of understanding the impact of different charging styles on managed charge optimization opportunities. For example:

- Do scheduled chargers or empty battery chargers have more time over which to flex the charging?
  - The more time available, the more flexible the charge session can be when working in concert with other EVs to optimize charging beyond each individual EV
  - At first glance it seems that scheduled style charging offers the advantage of having an EV which needs less of a charge, therefore offering more opportunity to flex the charge to more different time periods within a single charge opportunity window

- Do scheduled chargers or empty battery chargers vary in terms of where they charge?
  - At first glance the data suggest that empty battery chargers tend to charge more in public – either because they have no home charging and/or because they are often ‘caught’ at a low SOC and need to charge before going home.

Further analysis on charging style will allow us to further refine our charge optimization algorithms. FlexCharging is working on extending the meaning of ‘optimized’ charging beyond an individual EV to the entire fleet of EVs which we manage. The more we understand about different charging styles, the more we can predict when we will most likely see an EV present itself for a charging session and how much time we will likely have to flex the charge so as to minimize the grid load of each EV, while respecting individual driver needs and schedules.

5 The EV Moving

The EV Moving is probably one of the most interesting views of the EV’s life. Since the advent of large capacity EV batteries, accelerated by the advent of the $39,900 Tesla Model 3 Long Range EV, the EV has been liberated from the model of daily charging. With over 300 miles of range on a full battery, the EV is taking on longer and longer road trips and becoming almost indistinguishable from its ICE cousin in terms of miles driven per day, week, month or year.

5.1 Long Trips

EV Drivers are taking long trips. We can see this in our data. Trips of many hundreds of miles are not uncommon when visualizing our driving data. For example, you can see trips up and down the west coast from the San Francisco area to the Seattle area. Also trips from Salt Lake City, Utah to Las Vegas, Nevada. With longer mile ranges offered on newer EVs, the idea of an EV as an ‘in-town’ only vehicle is disappearing. EVs can go on interstate trips, just like their ICE counterparts.
Looking at the data in Fig. 8 from a charging vs. driving perspective, long trips clearly require enough corridor chargers for drivers to feel comfortable embarking on road trips of several days in length.

For example, the trip from Salt Lake City to Las Vegas – we can see 3 charging sessions (Figure 9), all at Tesla Superchargers. As charging infrastructure continues to be added along corridors, and drivers see examples of long road trips on social media, in news reports and in conversations with friends and colleagues, the comfort level associated with EV charging on road trips will likely continue to increase and expand the adoption of EVs for those drivers who wouldn’t consider a vehicle unless it can handle long-range trips.
Analyzing the longest trips for the last 30 weeks, several of our drivers regularly drive their EVs over 190 miles in a single trip instance (a trip is defined as a set of driving events between long stops). Figure 10 shows our longest drives from July 1, 2020 through March 15, 2020. The longest single trip was over a period of 6 hours and a distance of over 293 miles without a stop.

As we delve further into the data, we will be analyzing data about discrete trip interval data. This is 15 minute intra-trip data that we have recently added to the output data structures that we make available to our pilot partners. Understanding more about information within a trip, as well as the overall trip itself, will help us answer more questions for our utility partners and other interested stakeholders.

In addition, FlexCharging has been invited to participate in the development of a Mileage Purchase Agreement (MPA) [2] – a concept analogous to a Power Purchase Agreement (PPA), wherein part of a sustainable asset (in this case an EV) is financed by a third party and paid back on a per mileage basis. This is similar to the way solar panels have been financed in the past – a homeowner receiving all or part of the cost of a system and then paying back the financed amount on a per kwh basis. Because FlexCharging has deep, rich data on EV driving patterns, we can help forecast the payback periods for different types of drivers based on profiles. FlexCharging can help drivers save money through managed charging, if they are on time-of-use rates. In addition, our mileage data can form the basis of the MPA per-mile payback structure.

### Trip Distances

<table>
<thead>
<tr>
<th>Trip Segment ID</th>
<th>Device Type</th>
<th>Minute of Trip Start Time Local</th>
<th>Distance miles</th>
<th>Avg. Calculated Speed MPH</th>
<th>Trip Efficiency M/kwh</th>
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<td>11/07 21:16</td>
<td>175.7</td>
<td>61.0</td>
<td>2.4</td>
</tr>
</tbody>
</table>

Figure 10: Long Trip Mileage Data

### 5.2 Shorter Trips

Though EVs are being used for longer and longer trips, the vast majority of trips for EVs, like for ICE vehicles is between 15-25 miles/trip. The data in Figure 11 on the left shows average miles per trip per day (as bars) and the number of trips per day (as a line). The table on the right shows the total distance driven by EV and total number of trips – together with resulting miles per trip. As can be seen in the data below, there are some
spikes for long miles/trip on certain days, but many of the trips are much shorter in duration – the average miles per trip for some EVs being as low as 2 miles/trip.

![Figure 11: Daily Trip Mileage Data](image)

**6 The EV Waiting**

The EV not driving and not charging offers some of the most interesting insights, especially for our utility partners. Understanding where EVs “dwell” for long periods of time, where they are neither moving nor charging, offers utilities interesting insights into possible placement of additional charging infrastructure.

Here is a visualization of dwell times by latitude and longitude over the past several months of EV data (Figure 12 left). It shows the amount of time spent waiting in particular locations (waiting is defined as a vehicle stopped and disconnected from charging) as well as movement between long waiting locations (Figure 12 right).
By drilling down into these visualizations, overlaying the drill-down data with interstate highway or other transportation data and/or cross-referencing this data with Utility Geographical Information System (GIS) data, a utility can find locations where EVs are residing for long periods of time and where charging infrastructure would be most beneficial to EV drivers.

7 Summary

Transportation electrification is critical to making substantive changes to CO2 emissions. We are in the midst of a major transition to electric vehicles. It is projected by the Edison Foundation and the Edison Electric Institute that the number of Electric Vehicles (EVs) on the road in the US by 2030 will be 18.7 million [1]. Utilities aren’t truly prepared for this major addition to the load on the grid and we want to help support this transition as cheaply and easily as possible by giving utilities, regulators and other stakeholders insights into EVs on the road today and in the coming years. By getting a deep understanding of ‘The Life of the EV’ utilities and stakeholders can best plan for the coming transportation-related load in ways that minimize costs to the utilities, rate-payers and EV drivers.

Acknowledgments

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References

[1] Edison Foundation, Electric Vehicle Sales Forecast and the Charging Infrastructure Required
Through 2030


Authors

Laura McCarty, FlexCharging, Inc COO, brings over 20 years of utility expertise to the team. Laura has worked in Wholesale Power Market Trading and Risk Management projects for some of the largest utilities in the country. She has spent the past 4 years working on integrating distributed energy resources (DERs) into grid and distribution systems.

Brian Grunkemeyer is the founder & CEO at FlexCharging. A software engineer by trade with 22 years experience building developer tools and Big Data products, Brian produced the data collection and managed charging capabilities at the heart of FlexCharging’s managed charging solution. He got into energy by volunteering with the Sierra Club Energy Committee and attending his utility Integrated Resource Plan meetings for a decade, where he helped get an agreement to shut down half a coal plant.