Analysis of electric vehicle usage patterns in New Zealand

Statistical Report

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Last run at: 2019-02-01 13:38:11

Contents


```
## Warning in id != c("4e48f4155c29c763ffe6d9e17a495200",
## "01583b8a5f0344cc4aa3b3939a27af2a", : longer object length is not a
## multiple of shorter object length
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##
##    first charging     last     <NA>
##     9478   891085     9487   605583
```

1 Introduction

The New Zealand government has set a target of increasing the number of EVs in New Zealand to 64,000 by 2021. High penetration of EVs would cause EV recharging to contribute a substantial potion of total electricity load. A report prepared for lines companies Orion, Powerco and Unison by Concept Consulting Group entitled "Driving change - Issues and options to maximise the opportunities from large-scale electric vehicle uptake in New Zealand" predicts that if all current light private vehicles were electric, annual residential electricity consumption would increase by approximately 30%, whereas if all vehicles including trucks were electric, this would increase the total electricity consumption of New Zealand by approximately 41%[concept_2018].

New Zealand's total electricity demand varies throughout the day, with two distinct "peaks"; one in the morning, and one in the evening. Providing the electicity to meet these demand peaks is a costly and inefficient process. Concurrent electric vehicle (EV) charging, especially in the early evening when many motorists return home, would have the potential to negatively impact the operation of the grid through drastically increasing peak loads [Azadfar2015], leading to an increased cost of electricity due to the requirement of expensive upgrades to the electricity grid[@stephenson_smart_2017].

Our results showed that… [when/where is the greatest amount of charging occurring? What is the power demand per vehicle/household/place of charging? What might this look like if 50% of households had an EV? What about if it matched current ICE ownership (eventually)?]

The Concept Consulting report considers different methods of EV charging. The assumption that most drivers would begin charging immediately after returning home is referred to as "passive" charging, while charging that is programmed (either by the driver or by an external entity) to occur during off-peak periods is referred to as "smart". The key findings of the Concept Consulting report are as follows.

Under a scenario whereby 57% of the current private vehicle fleet were EVs (corresponding to one EV per household): * If all were charged in a passive fashion, New Zealand's peak electricity demand would increase by appproximately 3,000MW * If all were charged in a "smart" fashion, there would be no increase in peak demand

This report extends the work done by Concept Consulting, but utilises actual data collected from electric vehicles, as opposed to using models based on current usage patterns of internal combustion engine (ICE) vehicles.

2 Note

Based on and inspired by the UK DoT statistical report 2018.

Data used: /run/user/1001/gvfs/smb-share:server=storage.hcs-p01.otago.ac.nz,share=hum-csafe,user=student%5Cparra358/R
Projects/GREEN Grid/externalData/flipTheFleet/safe/testData/2019_01_25/EVBB_processed_all_v1.0_20180125.csv

Observations: 1515633 Observed charging: 915718 observations (power demand > 0)

3 Data information

The data used has been provided by "Flip the Fleet", a community organisation that hopes to increase uptake of electric vehicles in New Zealand. Flip the Fleet have been collecting data on electric vehicle usage patterns, collected using Exact IOT Limited's blackbox recorder, a small electronic device that connects to the vehicle's internal computer and sends detailed data about the battery health, consumption, speed, etc.

The data consisted of 1515633 data points from 50 vehicles over 8 months (April 2018 - January 2019). The recorder provided measurements at 1 minute frequency of charging behaviour and battery charge state.

Due to the possiblilty of the identity of participants being ascertainable, the remaining data is not publically available.

3.1 Definition, Cleaning and Preparation

Charging data has been broadly seperated into two seperate catagories, "standard" and "fast". Standard charging is when the charger is reading less than 7kW - this is considered the upper limit of what can be obtained from a standard home charging scenario without an expensive wiring upgrade[@concept2018]. Fast charging is all charging above 7kW, and would likely occur at designated and purpose-built fast charging stations.

The data was also catagorised according to whether it was a weekday or not. This allows analysis to occur of differing charging patterns between weekdays and weekends, allowing for further accuracy in determining the effects of electric vehicles on grid peaks.

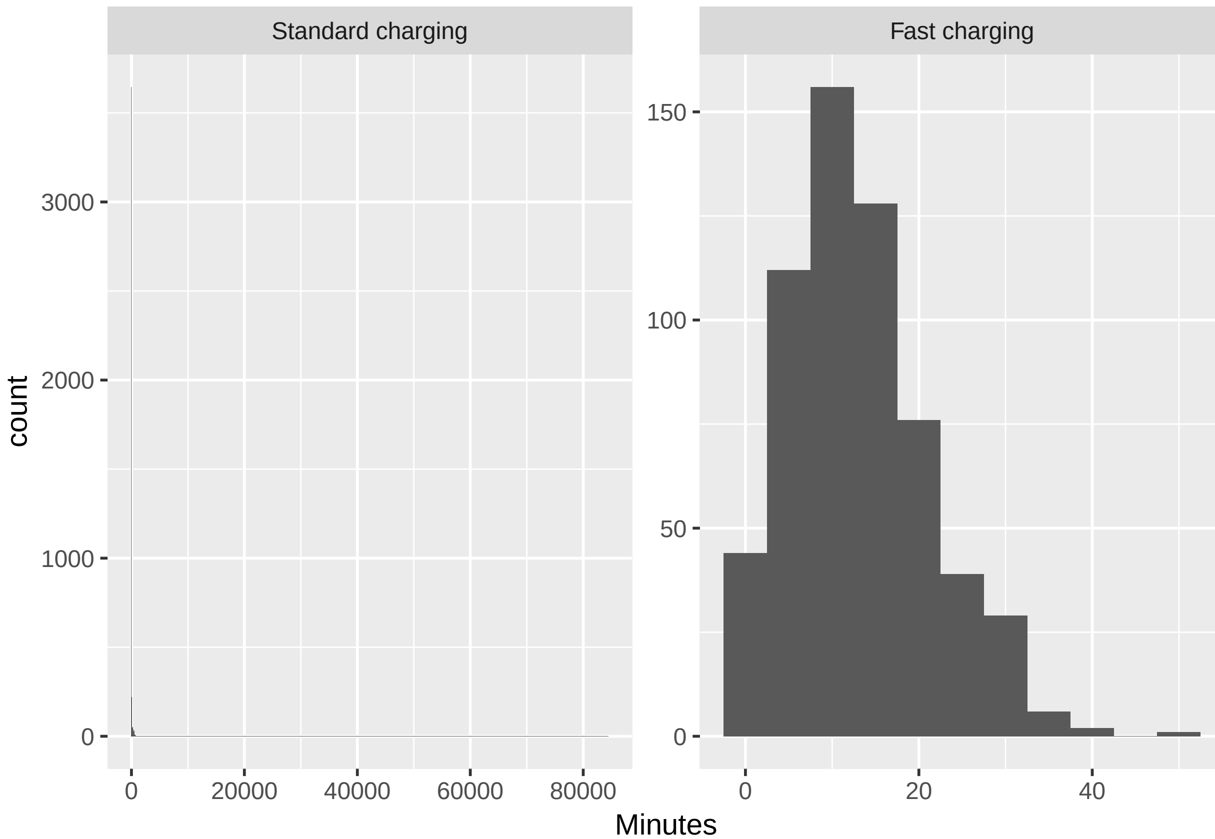

Figure 1: Duration of charging sequences

Some instances of charging power greater than 120kW were recorded. These were considered anomolies and discarded, as these exceed the capacity of the highest charging stations available in New Zealand[concept2018].

Instances of battery state of charge being greater than 100% or less than 0% were also discarded.

A charging event was defined as a continuous sequence of 1 minute observations per vehicle when > 0 kW of demand was observed.

In order to determine charging durations, rows were initially flagged as “charging begins” if the charging power was greater than zero and the previous and following row’s charging power were (respectively) equal to zero and greater than zero. Similarly, rows were flagged as “charge ends” if the charging power was greater than zero and the previous and following row’s charging power were (respectively) greater than zero and equal to zero.

Using this method we obtained 9478 instances of charge beginning, and 9487 instances of charge ending. The additional 9 instances of the charge ending than there are of the charge beginning may be due to the first instance of data collection occurring during mid-charge for some vehicles.

Fig: Histogram of charging event durations (faceted by fast vs standard)

If we assume that the first non-zero charge observation is the ‘start’ and the last non-zero charge observation within the vehicle id is the ‘end’ we can calculate the duration between the two. This assumes there is no missing data.

Figure 1 shows the overall distribution of all charging sequences. Clearly there are very small and a few very large values for Standard Charges but this is not the case for Fast charges.

Table 1 shows the overall distributions and indicates the extent to which the means are skewed by the very

Table 1: Duration of all charge sequences by charge type (minutes)

chargeType	N	mean	median	min	max
Standard charging	8586	101.47	3.43	0.27	84435.00
Fast charging	593	13.03	11.88	0.32	48.78

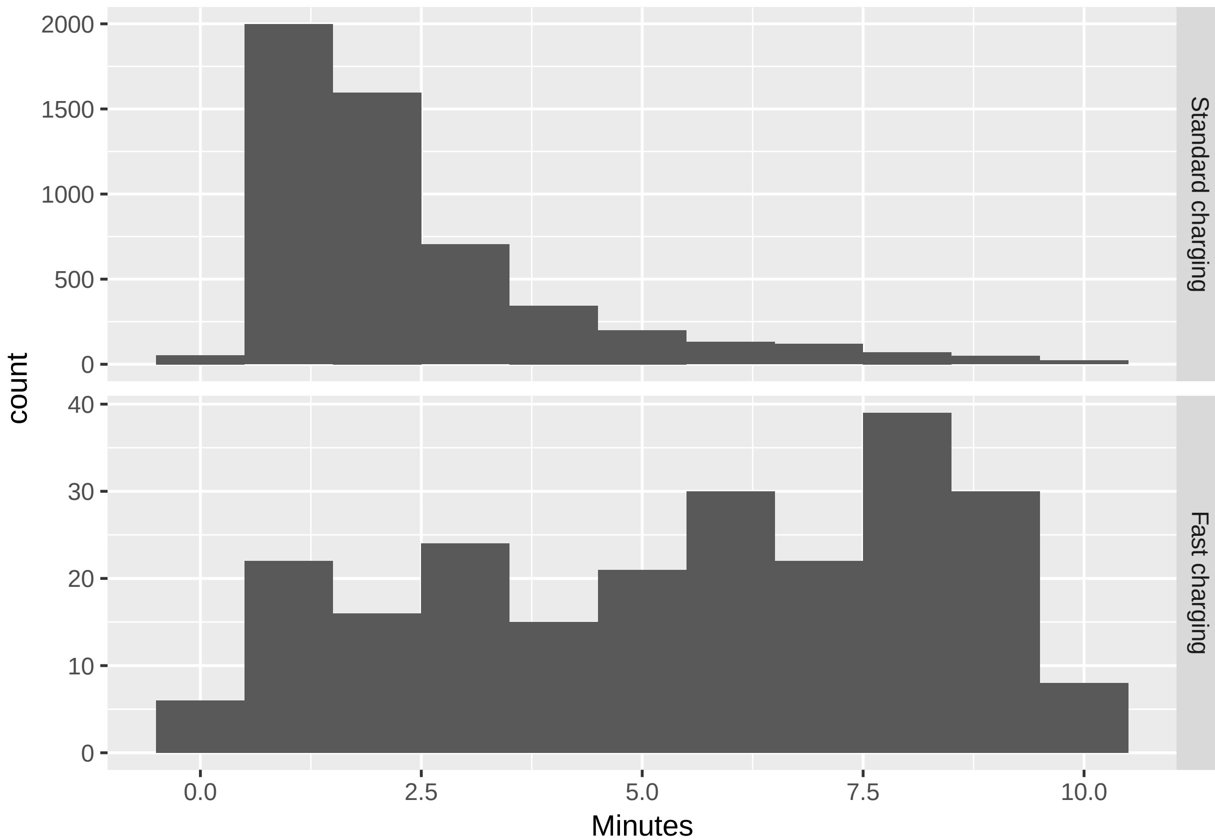

Figure 2: Duration of charging sequences < 10 minutes

small and a few very large values shown in Figure 1.

Figure 2 shows the distribution of very short charging sequences which are likely to be 'top-ups' occuring towards the end of a longer charging period. As we can see these appear to be generally less than 8 minutes in length for Standard Charges.

Table 2 shows the same descriptive statistics but for all sequences of greater than 8 minute duration. Now we can see that the mean and median durations for Standard Charge sequences are closer to one another.

Manual inspection of the data showed that these short-duration charging "events" generally occurred near the end of a longer-duration charging event. It appeared that once the vehicle had reached its highest state of charge, charging would intermittantly stop and start again, often at low power (< 1kW). This is likely due to the behaviour of the charger once the battery was almost full. As these can not be considered truly independent charging events, they have been removed from the data for the rest of the analysis.

In addition to the myriad "small" charging duration values, two very large charging durations (longer than 100 hours) were calculated. As even a very high capacity vehicle using the slowest standard charger would not take this long to charge from empty, these were assumed to be anomalies and were discarded.

Figure 3 shows the distribution of charging sequences with the excessively long or short events removed. As we can see these appear to be generally less than 3 hours in length for Standard Charges.

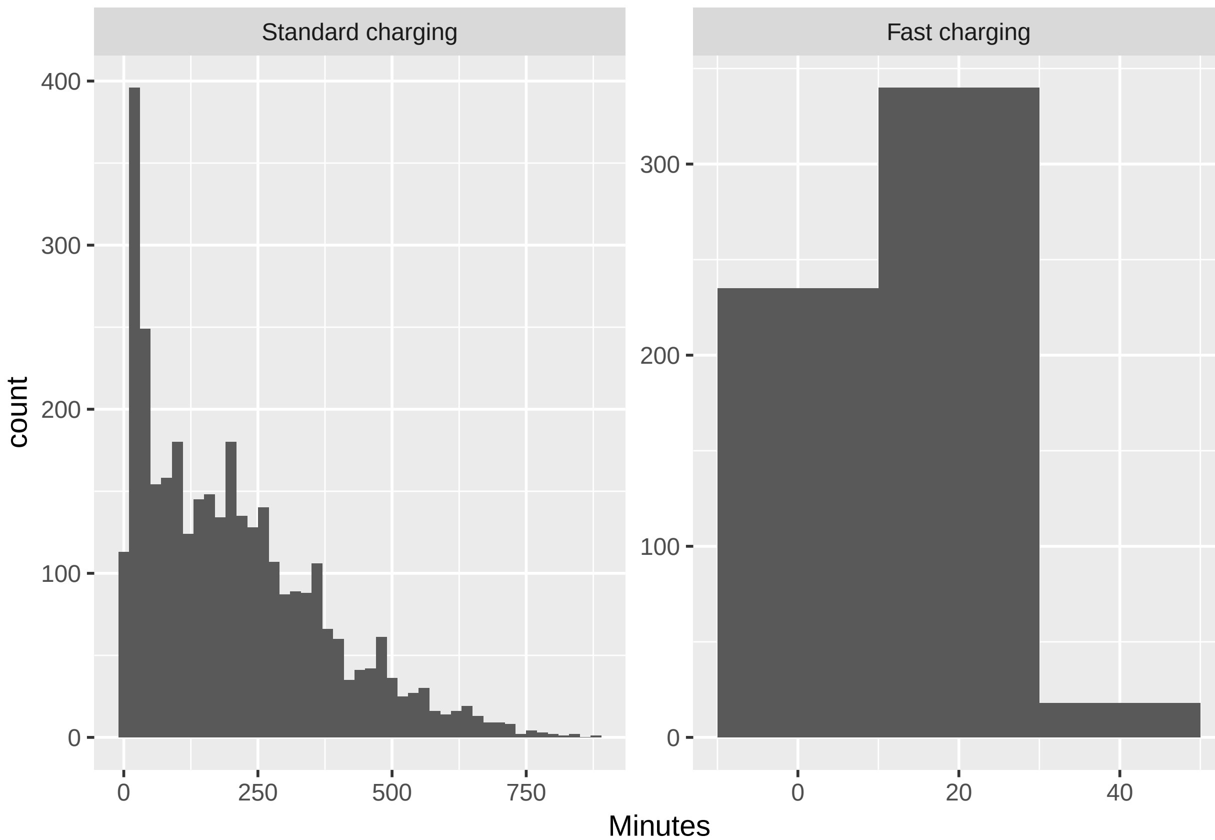

Figure 3: Duration of charging sequences > 8 minutes

Table 2: Duration of charge sequences > 8 minutes by charge type (minutes,)

chargeType	N	mean	median	min	max
Standard charging	3404	252.57	176.78	8.02	84435.00
Fast charging	417	16.64	15.18	8.05	48.78

Table 3: Mean duration of charge events by charge type

chargeType	N	mean	median	min	max
Standard charging	3404	252.57231	176.77500	8.016667	84435.00000
Fast charging	417	16.63513	15.18333	8.050000	48.78333

4 Key Findings:

- *Power supplied*: The median power supplied during a standard charging was 1.78 kW. The mean was slightly lower at 2.11 kW. Fast charging observations had a higher median of 23.35 kW (mean = 27.18);
- *Charging duration*: Charging durations tended to fall into one of two groups - longer 'overnight' charges with a median of XX hours and shorter events during the day both at standard and fast charge rates with a median duration of XX hours.
- *Time of Day*: charging events were more frequent at specific times of the day and day of the week with more evening and over-night charging during weekdays and more day-time charging at weekends. The power demand also varied according to time of day and day of the week.

5 Observed demand

Figure 4 shows the distribution of observed charging kW demand by inferred charge type. This plot shows that fast charges are relatively rare in the dataset whilst standard charges are much more common and, partly due to our definition, are concentrated around 3 kW. At the present time charging at home is likely to be predominatly standard charging whilst charging outside the home is likely to be a mix of the two.

```
## `stat_bin()` using `bins = 30`. Pick better value with `binwidth`.
```

75% of standard charging observations were 1.46 kW or more but the figure was 16.78 kW or more for fast charging

6 Daily demand

```
## Warning: Removed 45 rows containing non-finite values (stat_boxplot).
```

Figure 5 shows the distribution of observed charging kW demand by day of the week. We can see that fast charging varies in demand but standard charging is relatively constant across days.

7 Charging duration

8 Duration by time of day

Discuss any other patterns

What was the research question? :-)

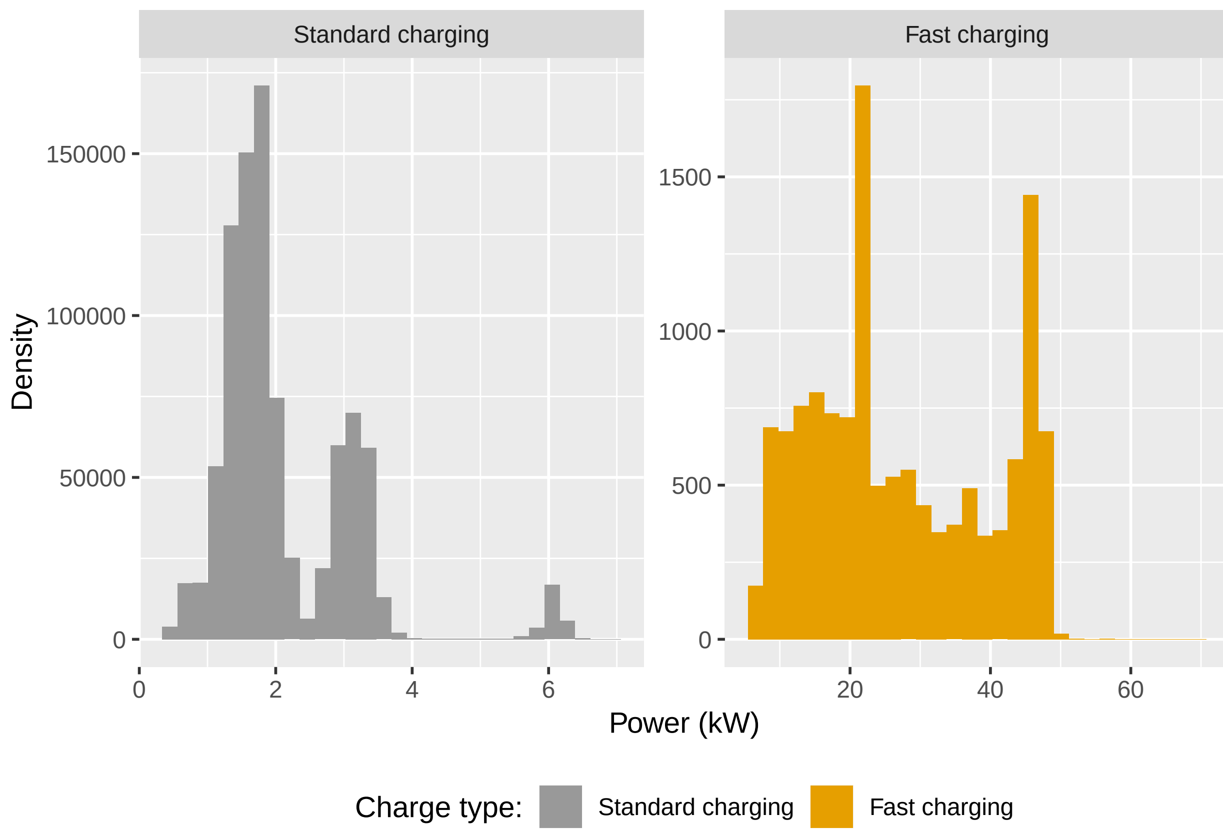

Figure 4: Observed power demand distribution by day of the week and charge type where charging observed

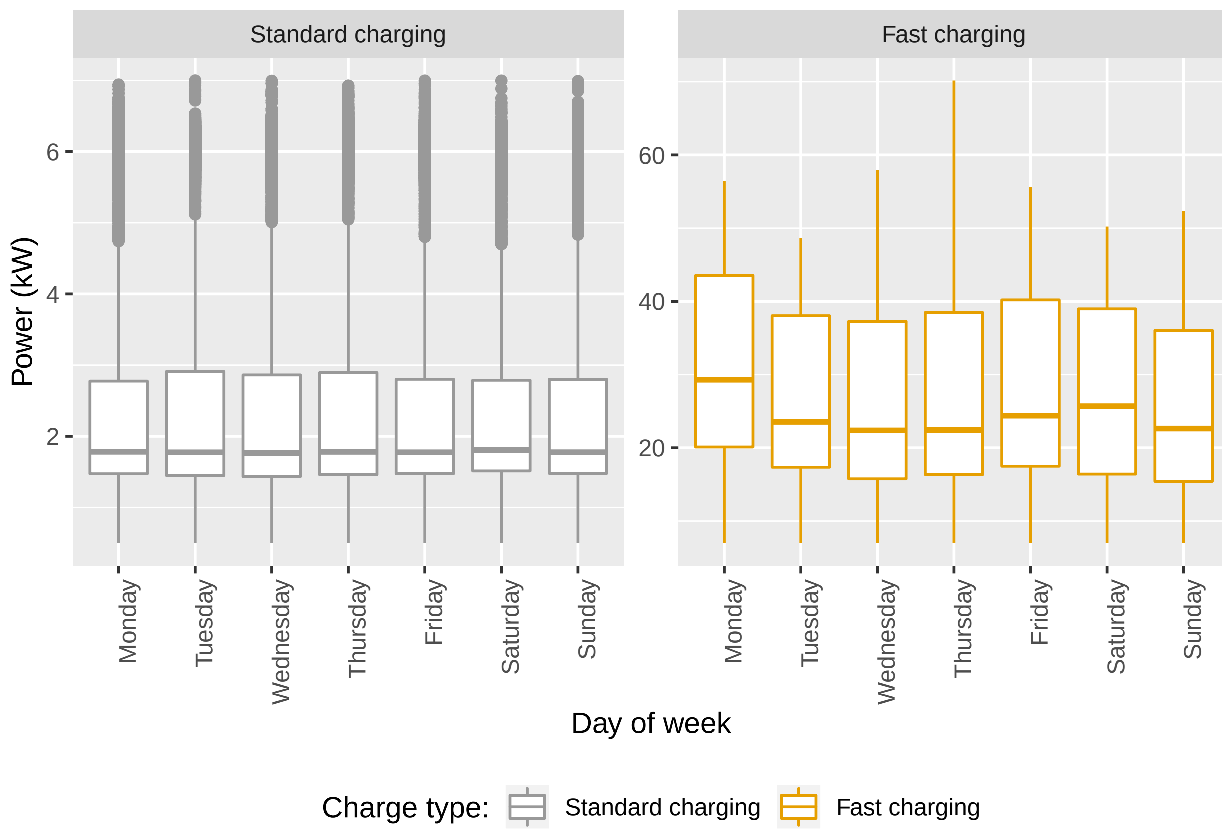

Figure 5: Observed power demand distribution by day of the week and charge type

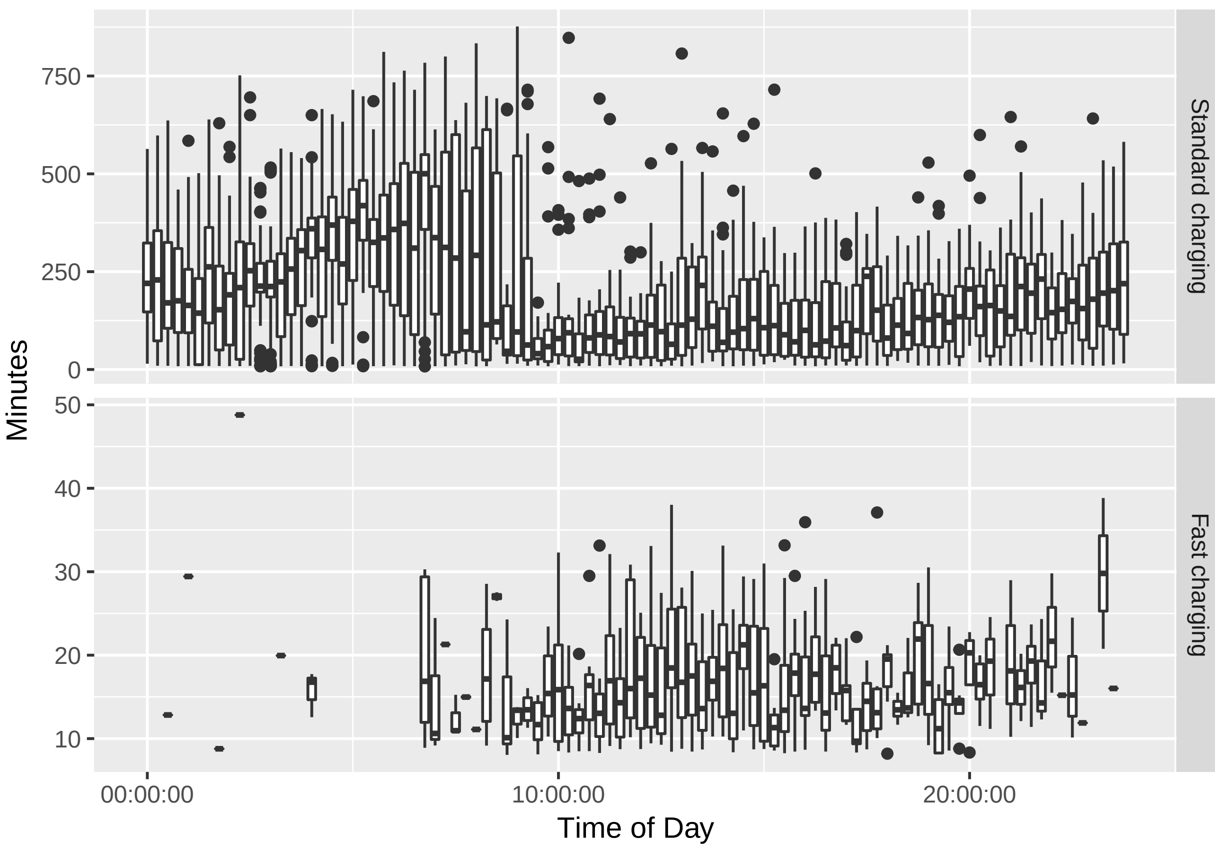

Figure 6: Duration by time of charging start for sequences > 8 minutes

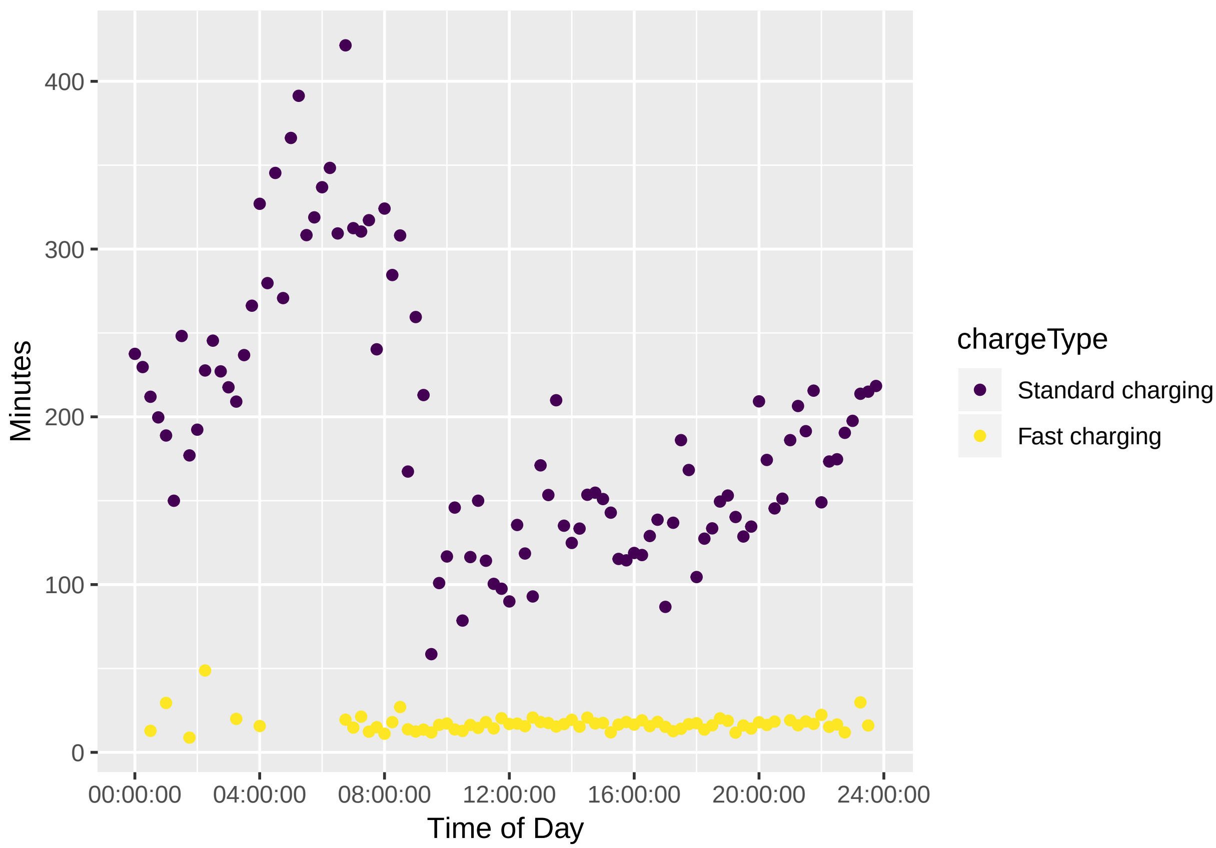

Figure 7: Mean duration (within quarter hours) by time of charging start for sequences > 8 minutes

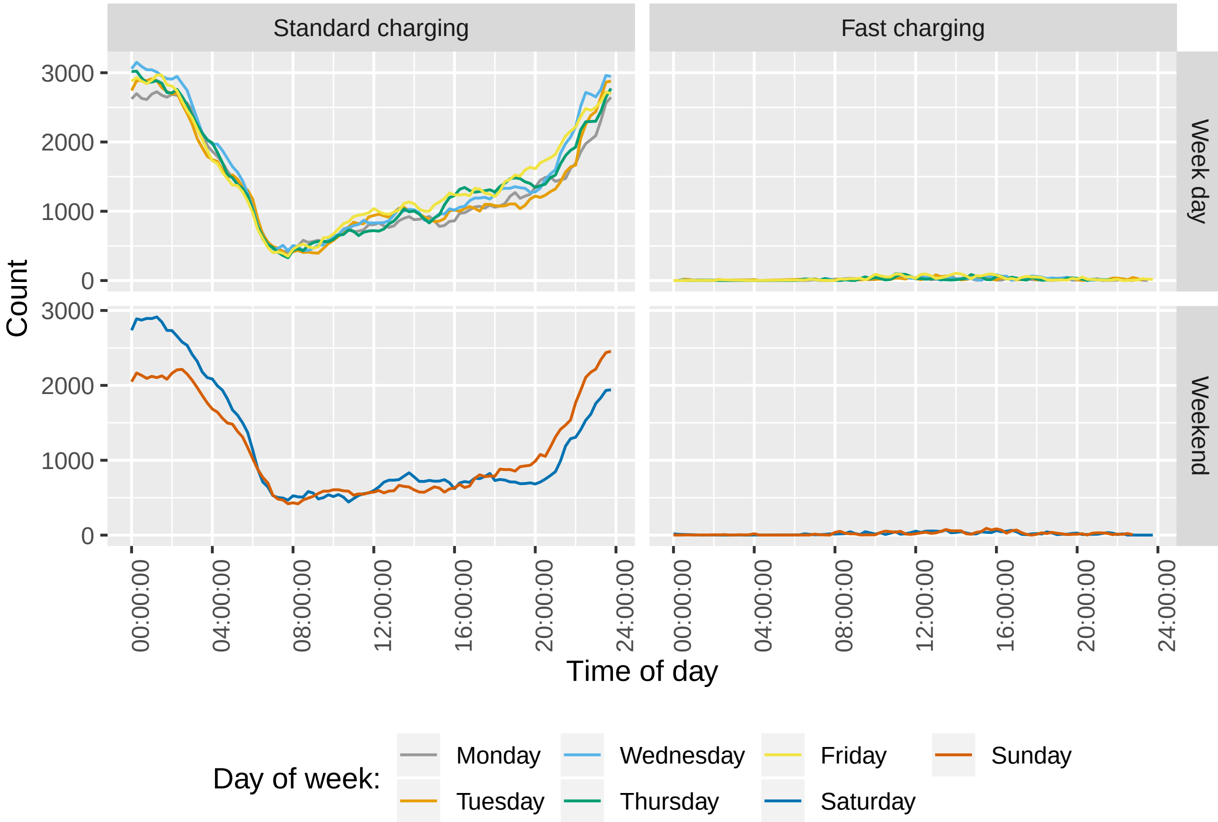

Figure 8: Count of observed charging events by type, day of week and time

9 Time of charging

Figure 8 shows the distribution of observed charging by time of day and day of the week. Aggregating counts in this way emphasises the times at which charging most commonly occurs and we can see…

Fig: profile of median charging demand by time of day and day of the week faceted by at home vs not at home

Charging demand varies somewhat by time of day and day of the week. Weekdays show … whilst weekends show. Saturdays and Sundays vary with…

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## Picking joint bandwidth of 0.11
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## Warning: Removed 45 rows containing non-finite values
## (stat_density_ridges).
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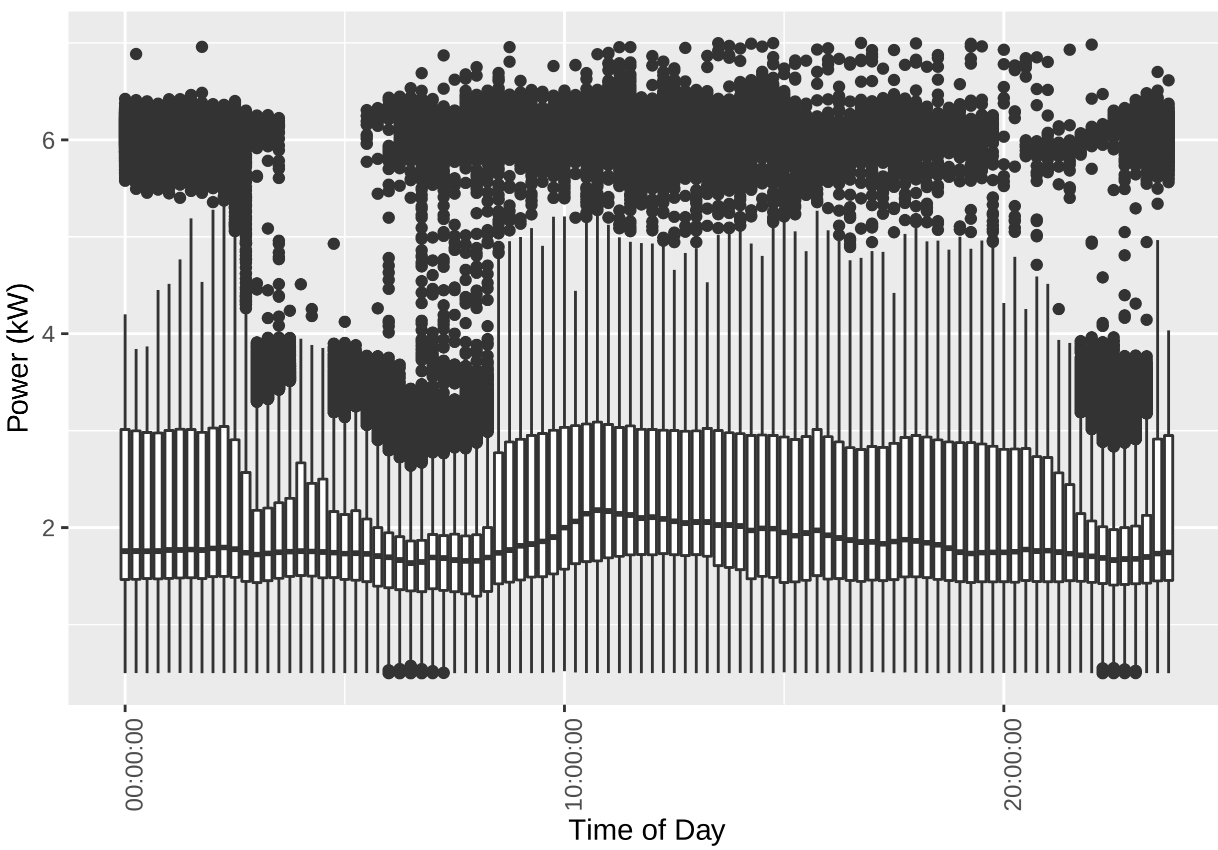
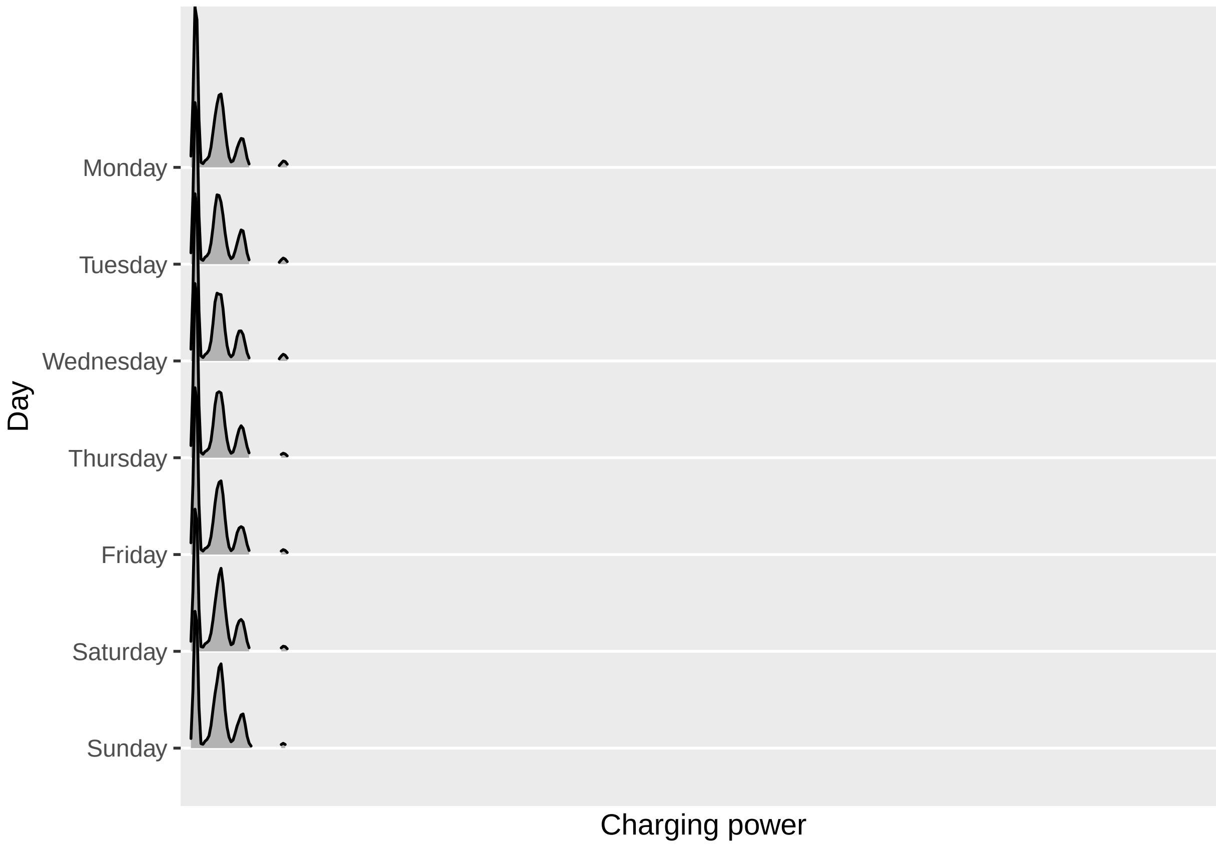


Figure 9: Boxplot of charging timing by charge rate

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## Warning: Removed 45 rows containing non-finite values (stat_boxplot).

## Picking joint bandwidth of 5700

## <ggproto object: Class FacetGrid, Facet, gg>
##     compute_layout: function
##     draw_back: function
##     draw_front: function
##     draw_labels: function
##     draw_panels: function
##     finish_data: function
##     init_scales: function
##     map_data: function
##     params: list
##     setup_data: function
##     setup_params: function
##     shrink: TRUE
##     train_scales: function
##     vars: function
##     super:  <ggproto object: Class FacetGrid, Facet, gg>
```

At home charging events tended to begin at HH:MM during weekdays and HH:MM at weekends. *We can get "Slow" charging events rather than "home"*

Standard charging has a noticeably different profile to charging patterns for fast charges. It suggests that it is common for plug-in vehicle owners to charge overnight at home, and perhaps use the more powerful public chargepoints to top up during the day.

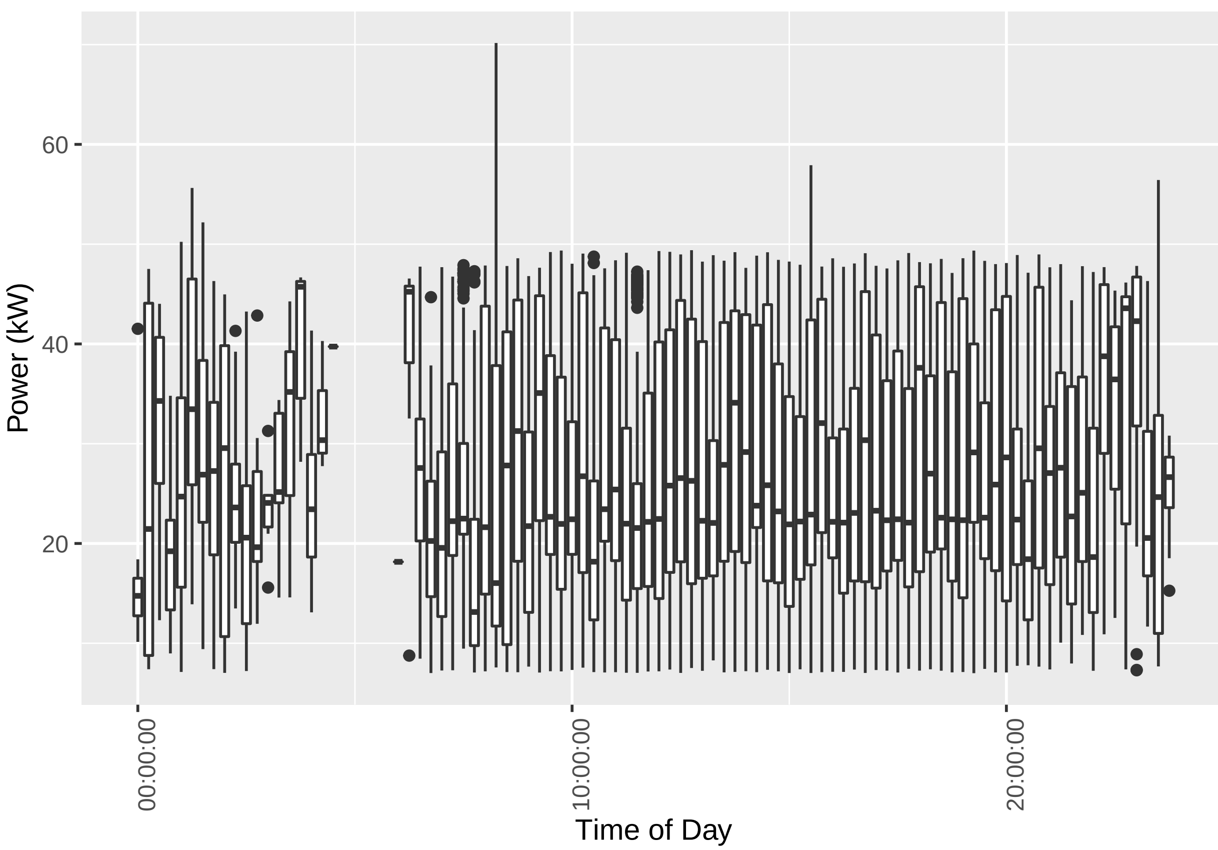

Figure 10: Boxplot of charging timing by charge rate

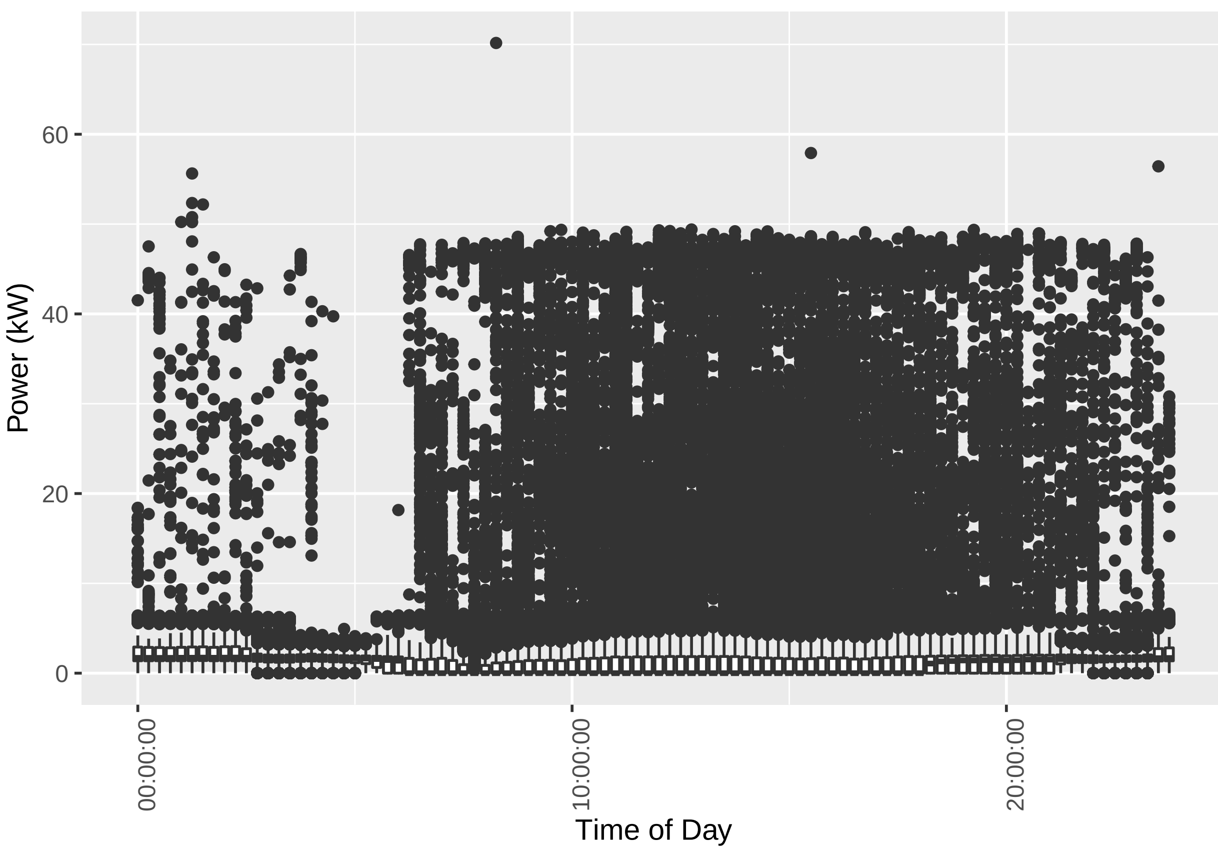

Figure 11: Boxplot of charging timing

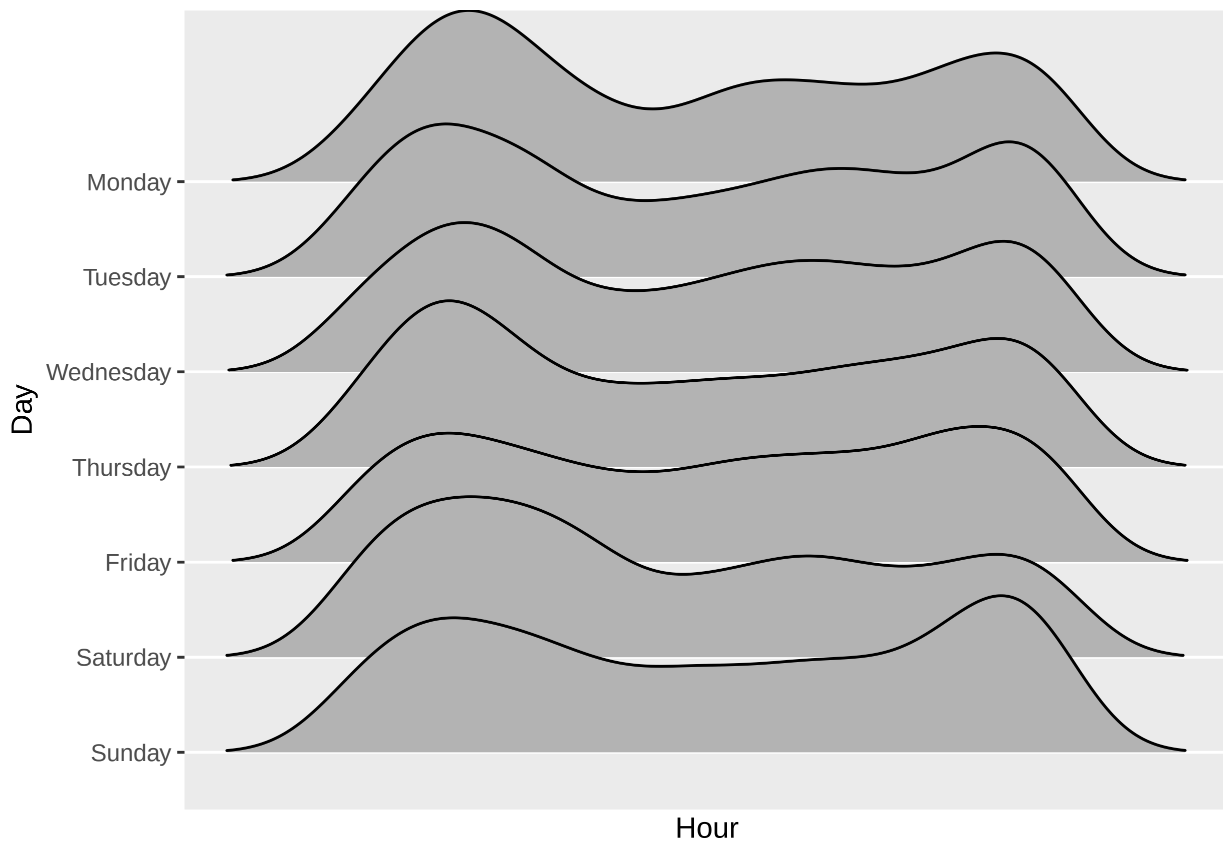

Figure 12: Time charging begins

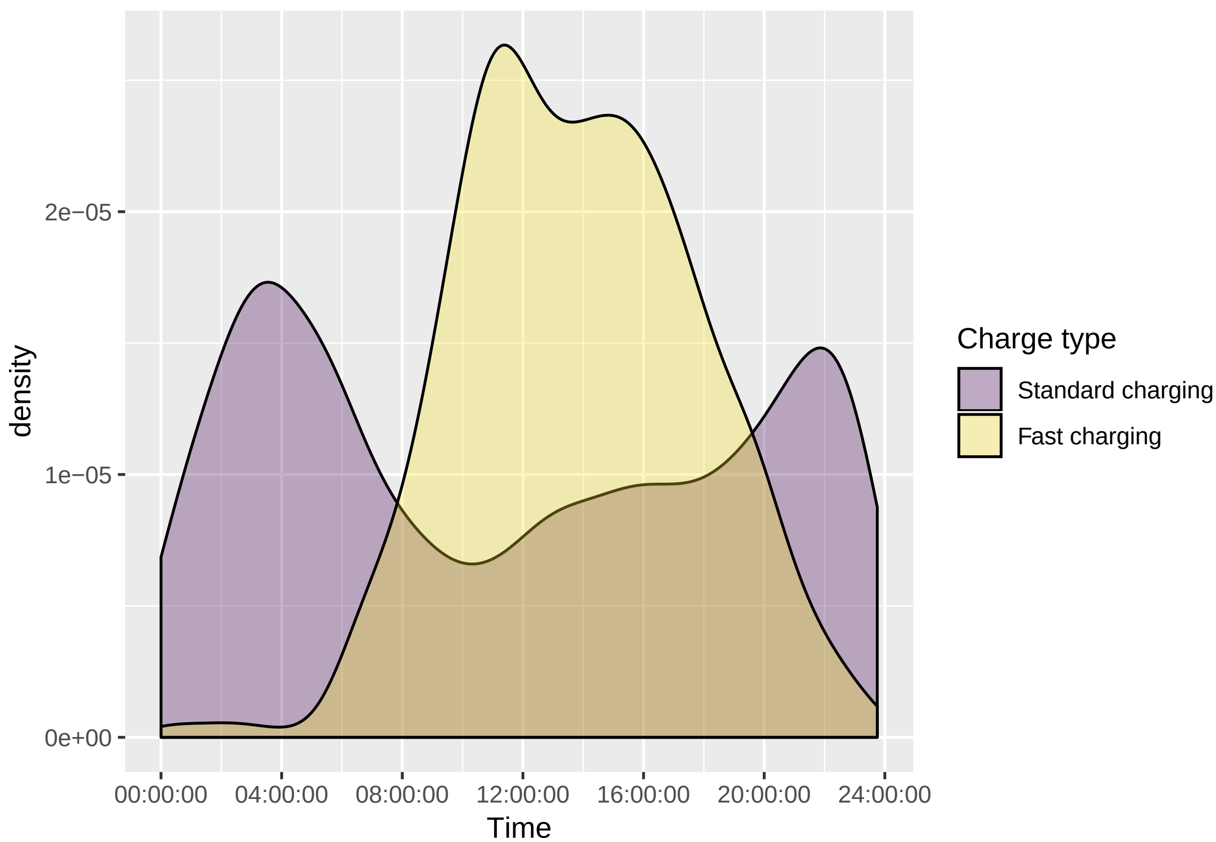

Figure 13: Density plot of charging start times during weekdays

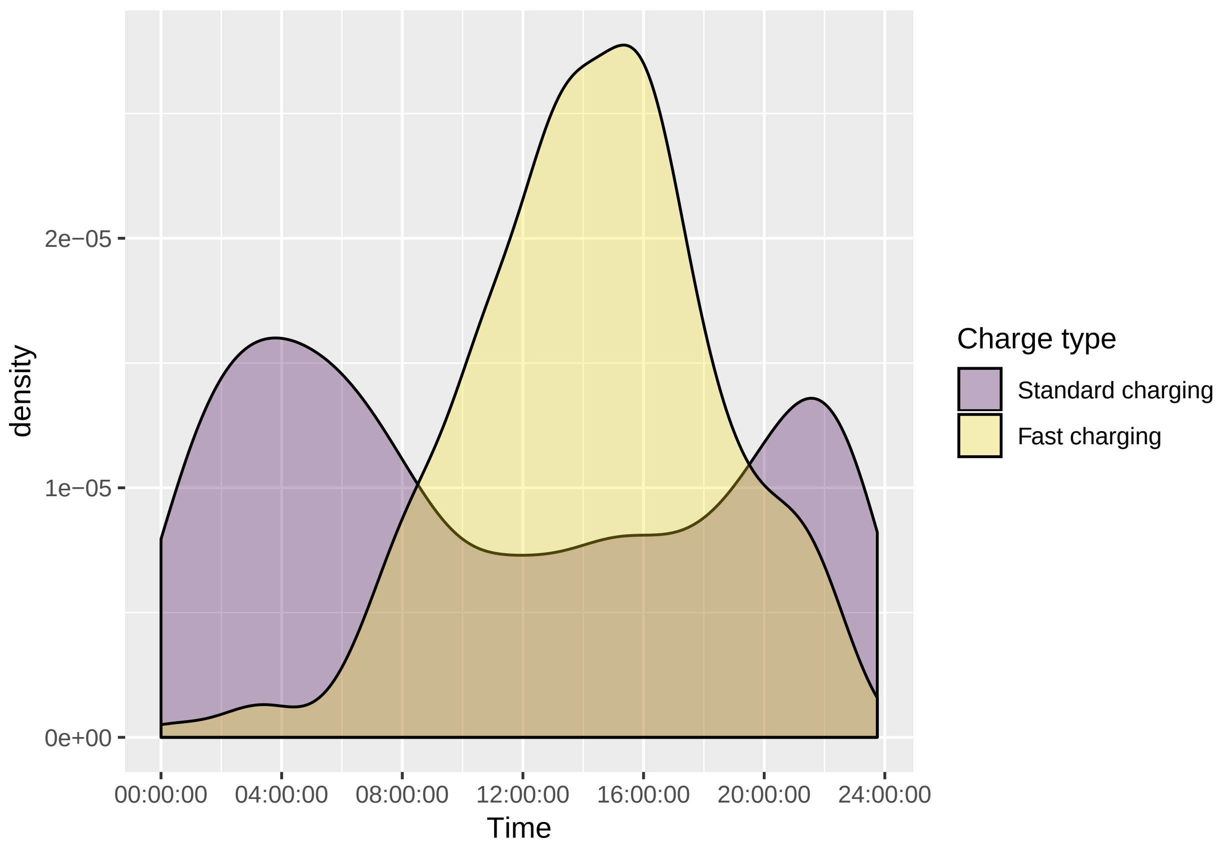

Figure 14: Density plot of charging start times during weekends

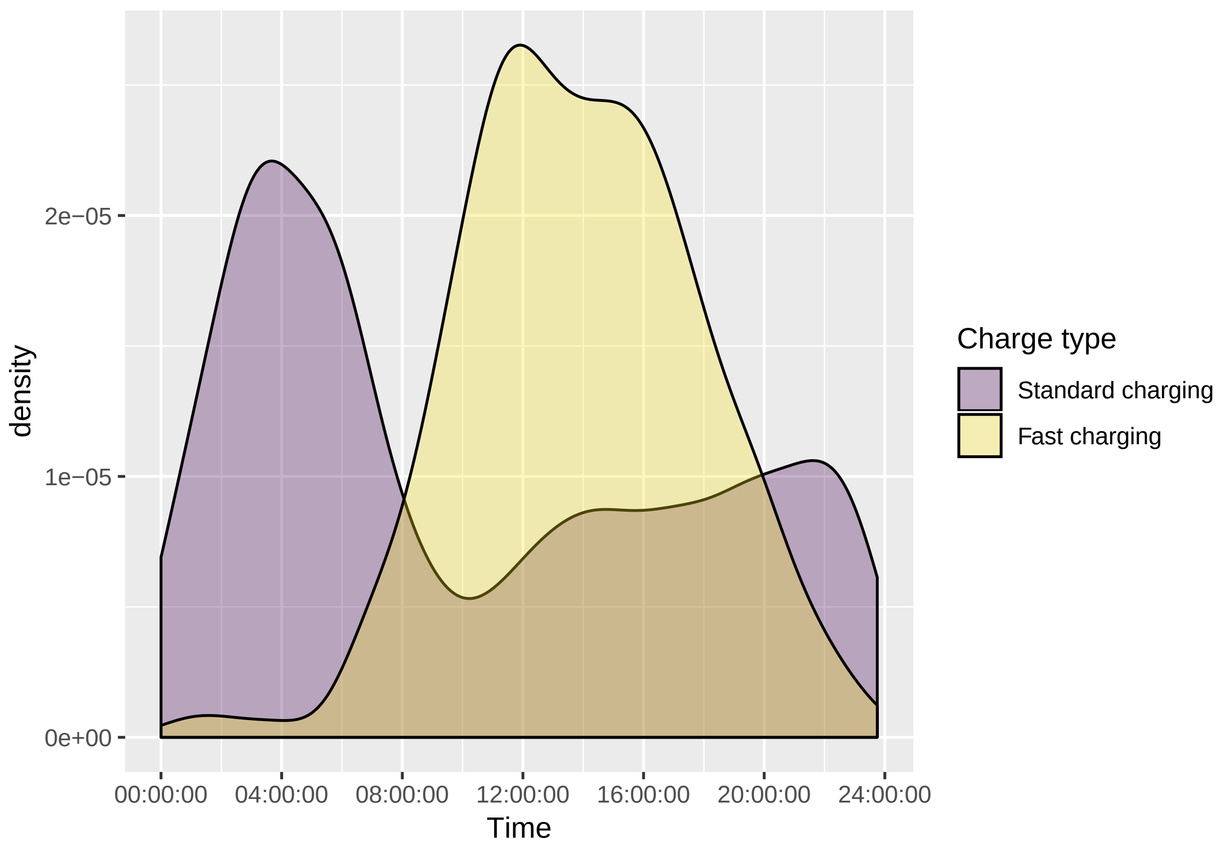

Figure 15: Density plot of charging end times during weekdays

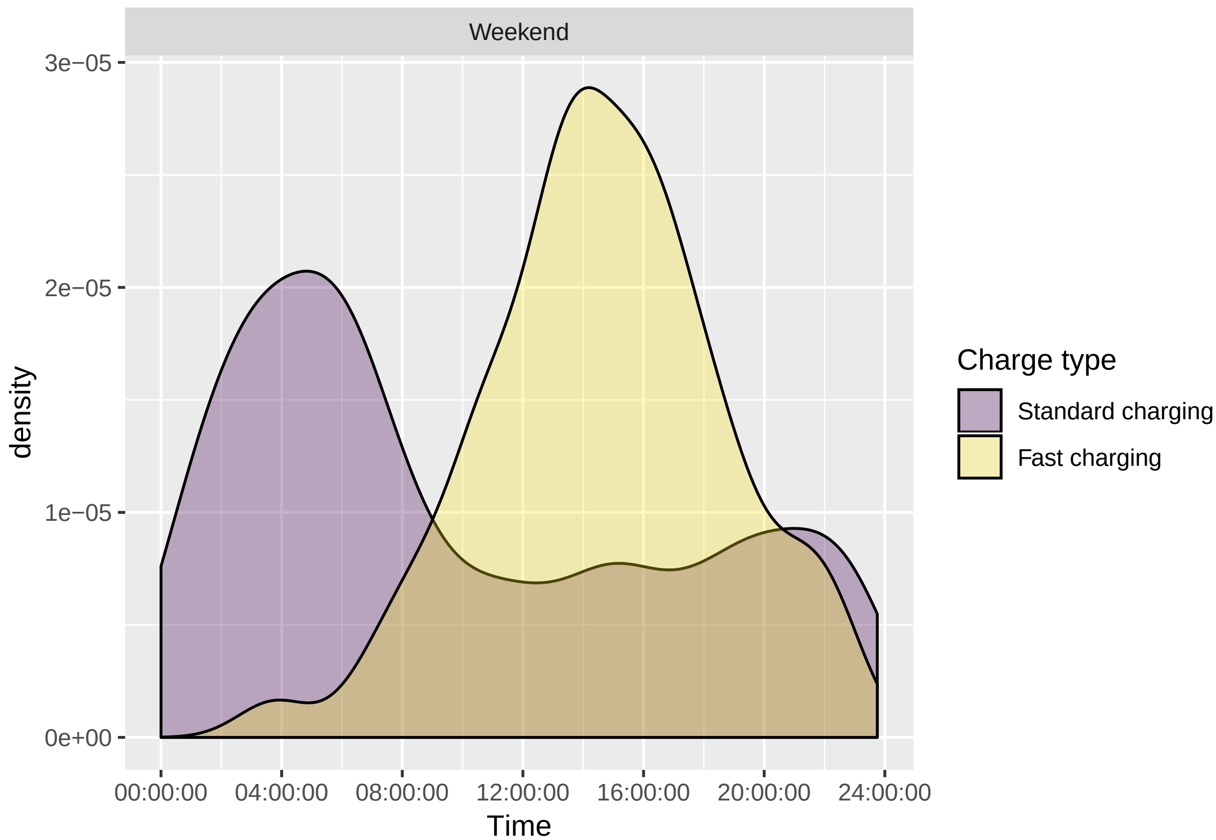

Figure 16: Density plot of charging end times during weekends

Discuss any other patterns

10 State of charge

The duration of charging events (see Section 7) suggests that EVs may be 'plugged in' at home (and elsewhere) for considerable durations.

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## Warning: Removed 1 rows containing non-finite values (stat_bin).
```
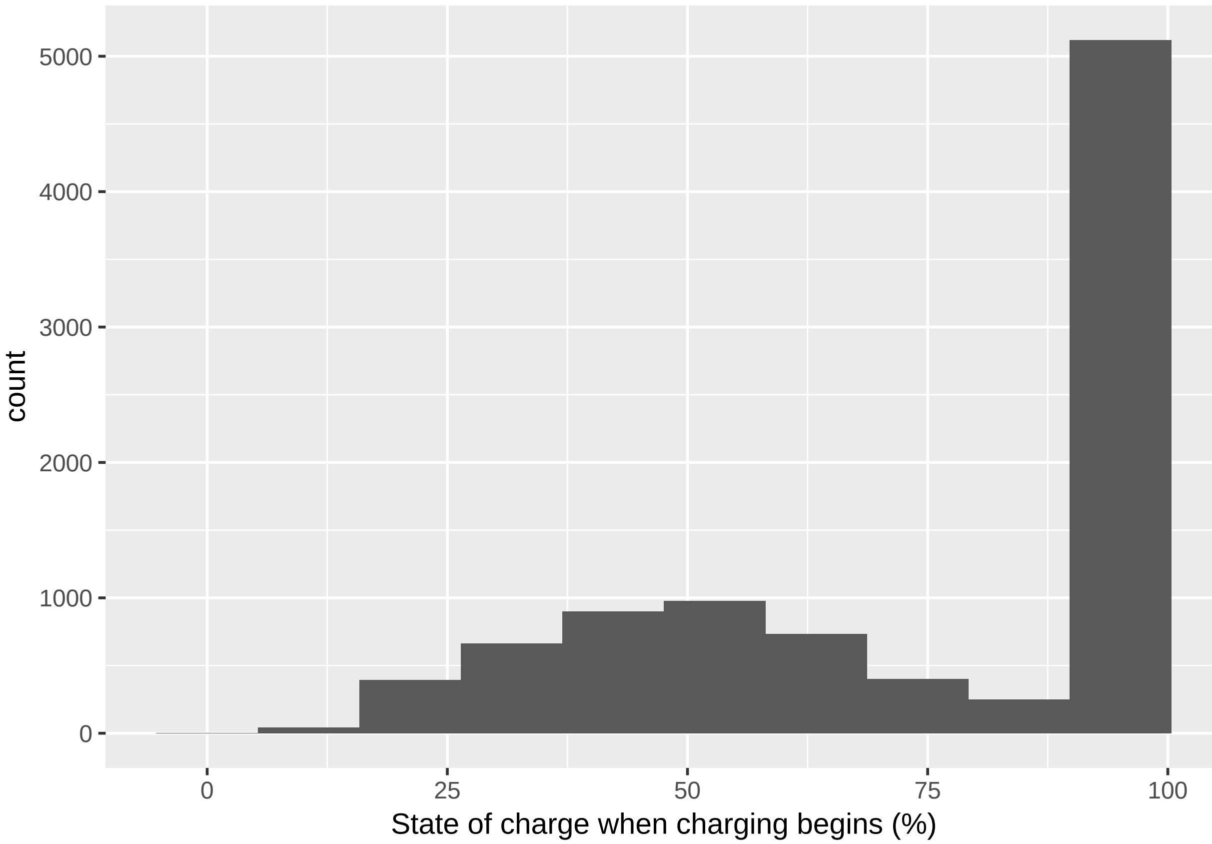
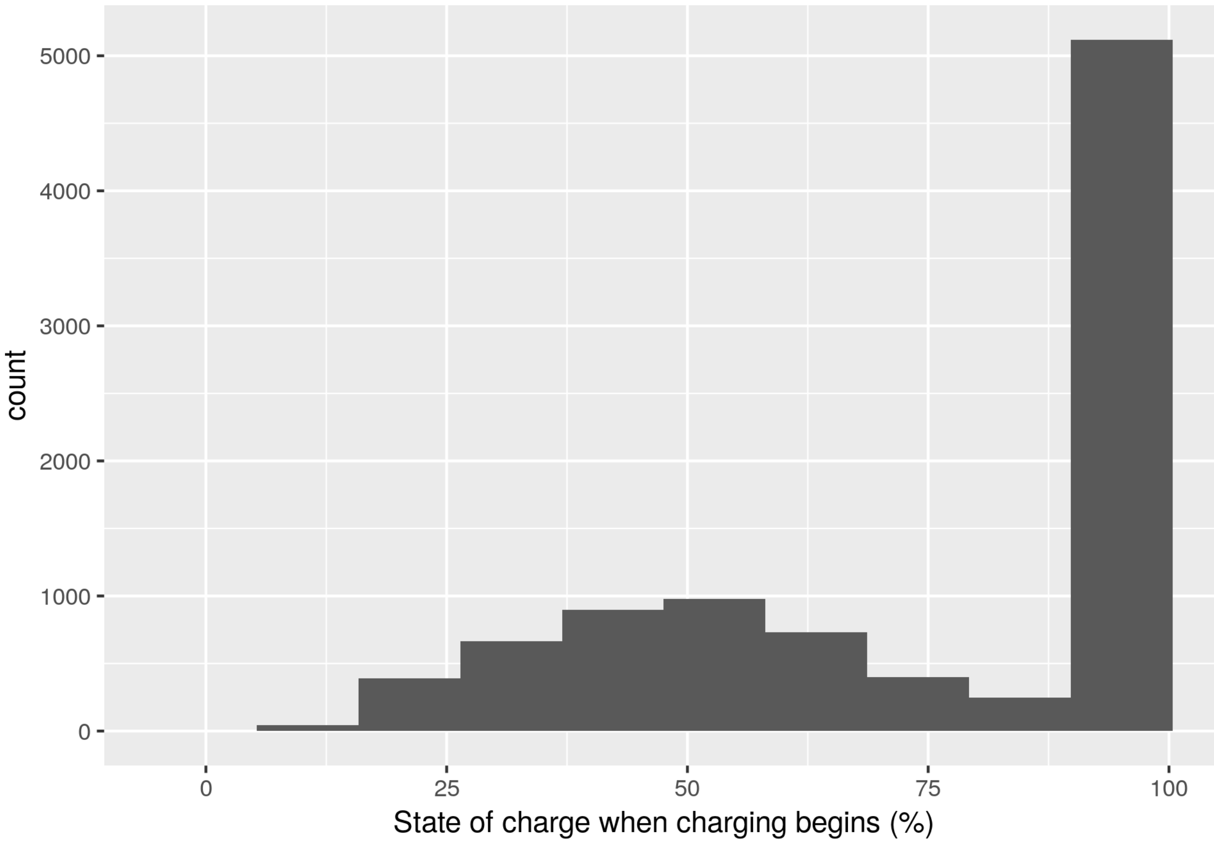




```
## Saving 6.5 x 4.5 in image
```

```
## Warning: Removed 1 rows containing non-finite values (stat_bin).
```

Fig: Distribution of state of charge when evening charge event starts 'at home' (histogram (or joy plot) by day of



week)

The figure shows that many vehicles arrive home with greater than 50% charge remaining and would therefore be able to transfer energy to the home during the evening grid peak as a form of demand response.

Fig: Mean state of battery charge at the first 'at home' charging observation by hour and day of the week *No "at home" data with SOC*

should show the timing of 'coming home' battery state?

Fig: Distribution of duration of charge events starting 'at home' in the evening (by day of the week) *Duration difficult to accurately determine without date due to charging occurring through the night*

The figure shows that vehicles may then be available for further demand response and/or re-charging for up to XX hours from this point.

Discuss any other patterns