Battery Storage and Grid Integration Program

Flat fees for flexible EVs

How simple retail offers could incentivise flexible electric vehicle (dis)charging

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Acknowledgements

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Reference for this report:

Sturmberg, B. C. P. *Flat fees for flexible EVs: How simple retail offers could incentivise flexible electric vehicle (dis)charging.* Australian National University (2024)

Executive summary

This study builds upon the recently published *Unplugged is inflexible* report to explore one avenue by which EV drivers could be incentivised to:

1. **plug their EVs in for extended durations, and**
2. **permit their vehicles to be charged flexibly.**

While there are many avenues by which this could be done, we here explore the potential for EV drivers to be offered **very simple, flat retail offers based solely on how often they plug in their EVs and how much energy their EV consumes**. This approach entirely removes considerations of when in the day vehicles are plugged in, which lightens the mental burden on drivers and may contribute to greater acceptance of managed charging.

This concept is motivated by the belief that creating price-certainty, and ideally cost-certainty, is a core way in which electricity retailers create value for their customers. This EV charging arrangement engages customers (EV drivers) is a quid pro quo where retailers contribute their expertise and diversity of customers to manage pricing risk, and EV drivers contribute the flexibility of their charging demand.

Our modelling shows that doubling the amount of time EVs are plugged in for reduces the cost of charging by half. To be clear, this requires nothing of EV drivers other than having their EV connected to a charger for longer periods, which enables more flexibly charging behaviour.

To quantify the risk for retailers we conduct a statistical analysis in terms of the cost of EV charging per day or per kWh. This suggests that offering a fixed price per day may go beyond retailers' risk appetite, making a fixed price per kWh the more attractive option. This is likely also fairer for customers as it charges for the precise amount of energy used.

The addition of vehicle-to-grid increases the benefits of longer plug-in times by facilitating market arbitrage. Vehicles that are driven less than 40km per day and are plugged in to chargers for more than 8 hours a day (with vehicle-to-grid) can, on average, be charged at zero or negative cost.

While outside of the scope of this study, we note that this same tariff concept (and simulation model) could be applied matching flexible EV charging with the generation of a collection of wind or solar farms. This would provide another way for a retailer to manage/fix their price exposure while simultaneously creating value for customers by charging vehicles with zero emissions power.

Certainty as a core value

This report is an extension to *Unplugged is inflexible: How drivers' plug in behaviour determines the flexibility of electric vehicle (dis)charging*, published in June 2024.

That study introduced a novel modelling approach that quantifies the range outcomes that EV charging could have on the electricity system and, crucially, **how these outcomes are enabled/constrained by the length of time that drivers plug their EVs into chargers for**. The central takeaway from that study was that the primary policy goal and public messaging should be to encourage EV drivers to plug their vehicles in whenever possible. Having EVs plugged in 25% of the time – 6hrs a day or most of the weekend – was suggested as a good target that balances (dis)charging flexibility with practicality.

This study builds upon this work to explore one avenue by which to incentivise EV drivers to:

3. **plug their EVs in for extended durations, and**
4. **permit their vehicles to be charged flexibly.**

There are of course many avenues by which EV driver behaviour could be incentivized and shaped. These range from exposure to highly volatile price signals (market or network), social expectations/norms, care for the environment. Each of these represents motivation by distinct human values.

This study concerns the **value of certainty** (or equivalently, protection from risk). Specifically, it explores the potential for EV drivers to be offered **very simple, flat retail offers based solely on how often they plug in their EVs and how much energy their EV consumes**. These factors could be discretised into broad bands to simplify the agreement, and charges could be further simplified into a fixed daily amount charged each month. Such agreements entirely remove consideration of when in the day vehicles are plugged in, which lightens the mental burden on drivers and may contribute to greater acceptance of managed charging.

This concept is motivated by the belief that creating price-certainty, and ideally cost-certainty, is a core way in which electricity retailers create value for their customers. This EV charging arrangement engages customers (EV drivers) is a quid pro quo where retailers contribute their expertise and diversity of customers to manage pricing risk, and EV drivers contribute the flexibility of their charging demand.

While outside of the scope of this study, we note that this same tariff concept (and simulation model) could be applied matching flexible EV charging with the generation of a collection of wind or solar farms. This would provide another way for a retailer to manage/fix their price exposure while simultaneously creating value for customers by charging vehicles with zero emissions power.

A fixed daily EV charge

To illustrate the concept, and quantify the risk involved, we use the statistical Monte-Carlo method introduced in *Unplugged is inflexible*. We calculate the outcomes of optimised EV charging across 3000 possible EV *plug-in-profiles* across a year, each of which is catagorised by the fraction of time that EVs are plugged in to a charger (the *plug-in-fraction*). For each sampled *plug-in-profile*, charging is optmised to occur at the lowest cost, in terms of wholesale energy costs in the Australian National Energy Market.

We consider EV charging in the absence of vehicle-to-grid (V2G) and with V2G enabled.

We furthermore consider three levels of daily EV energy consumption:

- 7.4kWh, the energy required to drive the Australian daily average of 30-40km,
- 3.7kWh, the energy for half the average daily travel distance, and
- 14.8kWh, the energy for twice the average daily travel distance.

Utilising a 7.4kW Level 2 charger this energy can be charged in 1, 0.5, and 2 hours respectively.

As *plug-in-fractions* we consider:

- 16.6%, on average 4 hours a day,
- 33.3%, on average 8 hours a day, and
- 66.6% on average 16 hours a day.

The distilled output of our findings is shown in Table 1. This presents the average daily cost of charging a non-V2G EV based on a coarse, three-by-three matrix of energy consumption and *plug-in-fractions*. Note that this is only the cost of wholesale energy (excluding network charges etc.).

While doubling the amount of energy consumed roughly double costs (moving downwards in the table), the striking result is that doubling the plug-in-fraction reduces the cost of charging by half (moving left to right in the table). To be clear, increasing the plug-in-fraction requires nothing of EV drivers other than having their EV connected to a charger for longer periods, which enables more flexibly charging behaviour. The increases in cost by a bit more than double for each doubling of demand because each extra unit of energy being bought at more expensive prices.

Table 1 – Average daily costs of charging under various plug-in rates and energy demands, with V2G not enabled

c/day	16.6% plug-in rate	33.3% plug-in rate	66.6% plug-in rate
Halved demand	27.6	18.3	8.9
Average demand	70.6	54	35.1
Double demand	209	170	124

This table exemplifies how simple an EV retail offer could be, and how clearly such an offer would communicate the value of keeping EVs plugged in as much as possible.

In Table 2 we recast the daily cost into a per unit energy cost. This would provide EV drivers with less cost certainty but may provide a more practical distribution of risks. The trends are the same as in Table 1 and still present EV drivers with a compelling proposition for managed charging. Particularly as this formulation demonstrates that doubling the amount of time plugged in has a greater effect at reducing the average price per kWh than reducing the amount of energy by half.

Table 2 – Average per kWh costs of charging under various plug-in rates and energy demands, with V2G not enabled

c/kWh	16.6% plug-in rate	33.3% plug-in rate	66.6% plug-in rate
Halved demand	7.5	4.9	2.4
Average demand	9.5	7.3	4.7
Double demand	14.1	11.5	8.4

Tables 1 and 2 provide a snapshot of the relationship between plug-in behaviour, charging energy demand and average market costs. Key to the concept of a flat daily retail price for EV charging is that increased flexibility in EV charging should decrease the variability, ie. price-risk – thereby creating value for retailers.

This is quantified in Figure 1, which presents the median cost of charging (per day) together with the 50% Confidence Interval that quantifies the spread of outcomes. Note that these median values can differ from the mean values in the Tables. For a more complete view of the statistical spread see the histograms in the Appendix.

Figure 1 reaffirms that increasing the *plug-in-fractions* reduces charging costs. Doing so furthermore reduces the variability in charging costs, although reducing the daily EV charging demand (freeing the EV to pick a smaller number of price intervals) has a more pronounced impact on reducing cost variability.

Figure 2 reframes these data into cost per kWh, which highlights that increasing the *plug-in-fraction* is very effective at reducing the market price paid per kWh, as shown in Table 2. All scenarios with a *plug-in-fraction* of 66.6% (green text) have lower median costs per kWh than when the *plug-in-fraction* is 16.6% (red text), even when consuming four times more energy.

This statistical analysis suggests that offering a fixed price per day may go beyond retailers' risk appetite, making a fixed price per kWh the more attractive option. This is likely also fairer for customers as it charges for the precise amount of energy used.

Figure 1 Distribution of daily charging costs when V2G is not enabled. The blue vertical line marks a cost of 0c/day. Coloured text signifies the plug-in-fraction: green for 66.6%, orange for 33.3%, red for 16.6%.

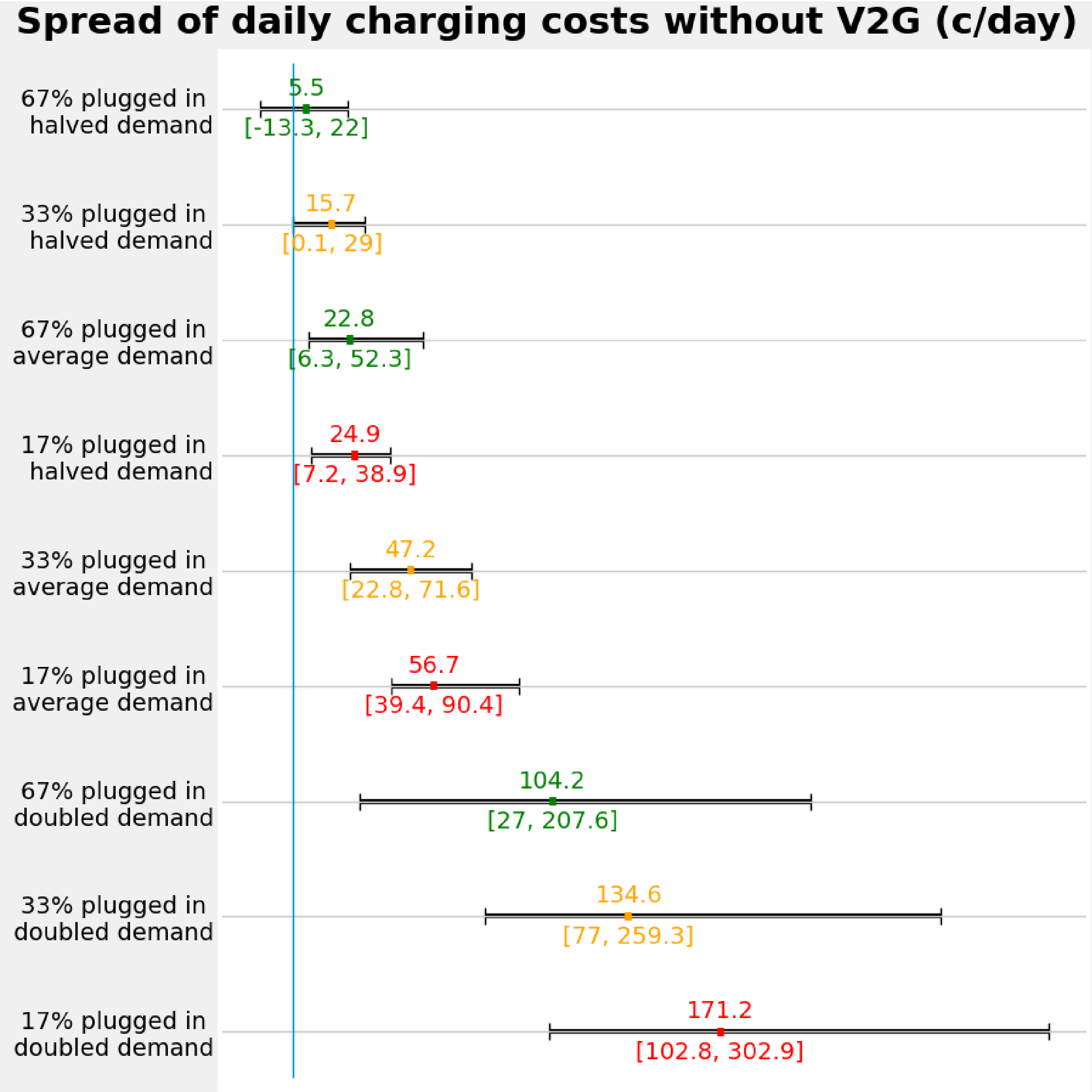
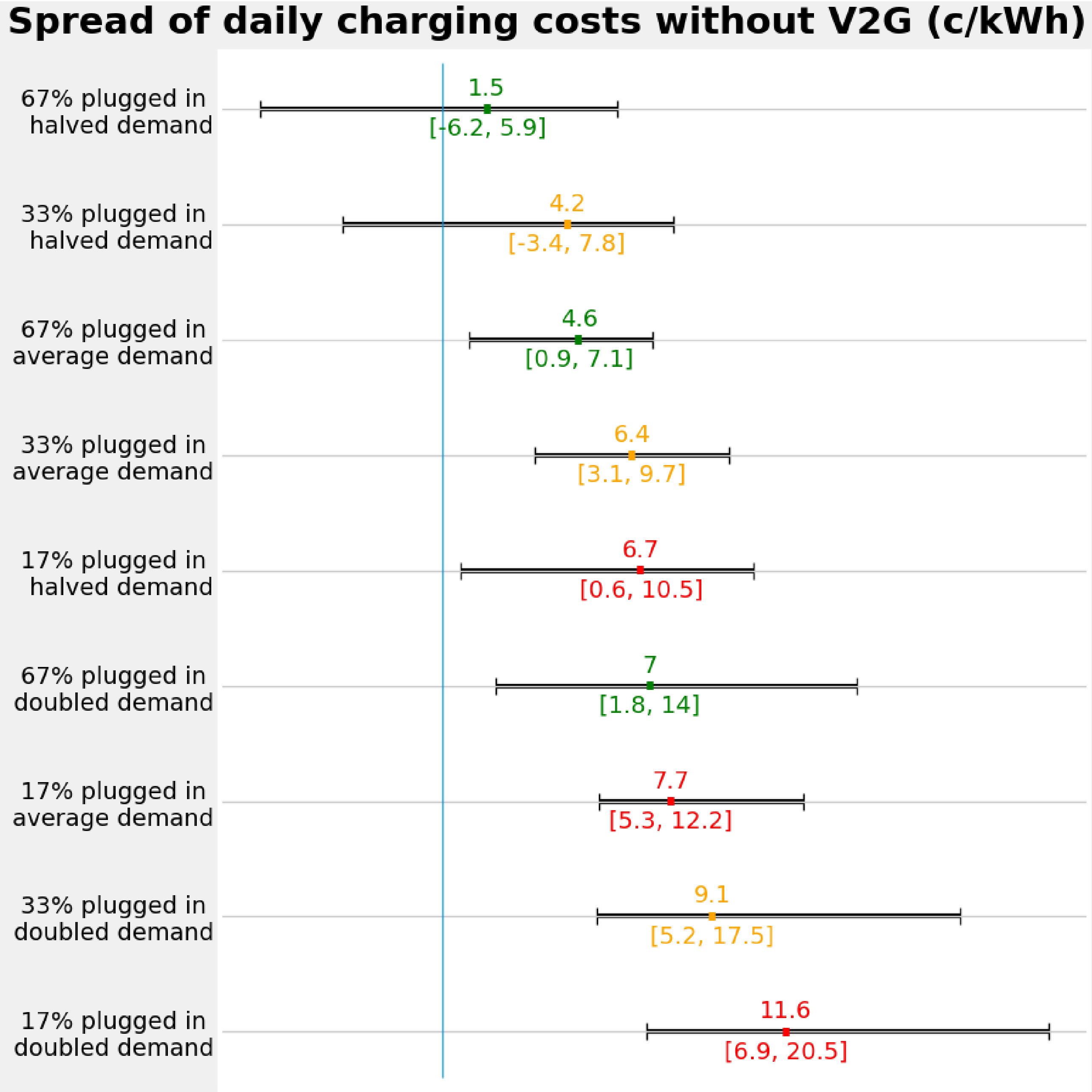


Figure 2 Distribution of per kWh charging costs when V2G is not enabled. The blue vertical line marks a cost of 0c/kWh. Coloured text signifies the plug-in-fraction: green for 66.6%, orange for 33.3%, red for 16.6%



Again, but with V2G

We now repeat the analysis with the inclusion of vehicle-to-grid (V2G) to generate greater value from parked (and plugged in!) EVs. In this modelling we enabled vehicles to perform V2G market arbitrage when the value (discharge sale price minus charge buy price) exceeded 50c/kWh.

The results mirror those in the preceding sections, but with an even greater emphasis on increased plug-in rates as these facilitate greater utilisation of V2G for arbitrage. Vehicles that are driven less than 40km per day and are plugged in to chargers for more than 8 hours a day on average are shown to be able to charge at zero or negative cost on average.

Comparing Tables 3 and 4 with Figures 3 and 4 reveals that these average costs are significantly lower than the median costs due to a small number of V2G arbitrage cycles that contribute very large revenues. The average results may therefore not provide sufficient confidence to offer zero cost charging, except for the case of halved demand and 66.6% plug-in rate, where the majority of days provide opportunities for zero or negative cost charging (see Figure 4).

Table 3 – Average daily costs of charging under various plug-in rates and energy demands, with V2G enabled

c/day	16.6% plug-in rate	33.3% plug-in rate	66.6% plug-in rate
Halved demand	15.9	-17.5	-65.7
Average demand	41.3	-1.1	-69.9
Double demand	188	120	20

Table 4 – Average per kWh costs of charging under various plug-in rates and energy demands, with V2G enabled

c/kWh	16.6% plug-in rate	33.3% plug-in rate	66.6% plug-in rate
Halved demand	4.3	-4.7	-17.8
Average demand	5.6	-0.1	-9.4
Double demand	12.7	8.1	1.4

Figure 3 Distribution of daily charging costs when V2G is enabled. The blue vertical line marks a cost of 0c/day. Coloured text signifies the *plug-in-fraction*: green for 66.6%, orange for 33.3%, red for 16.6%.

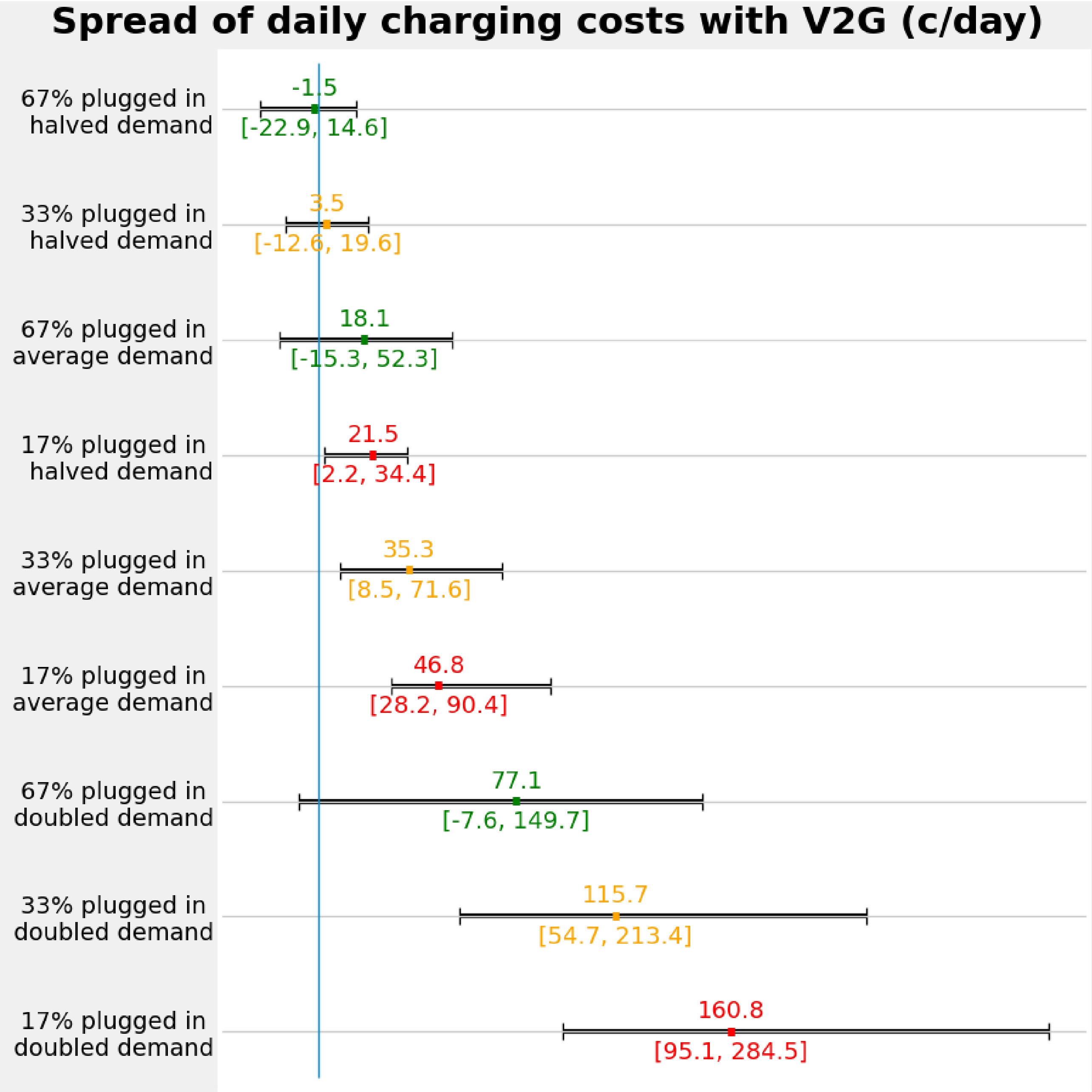
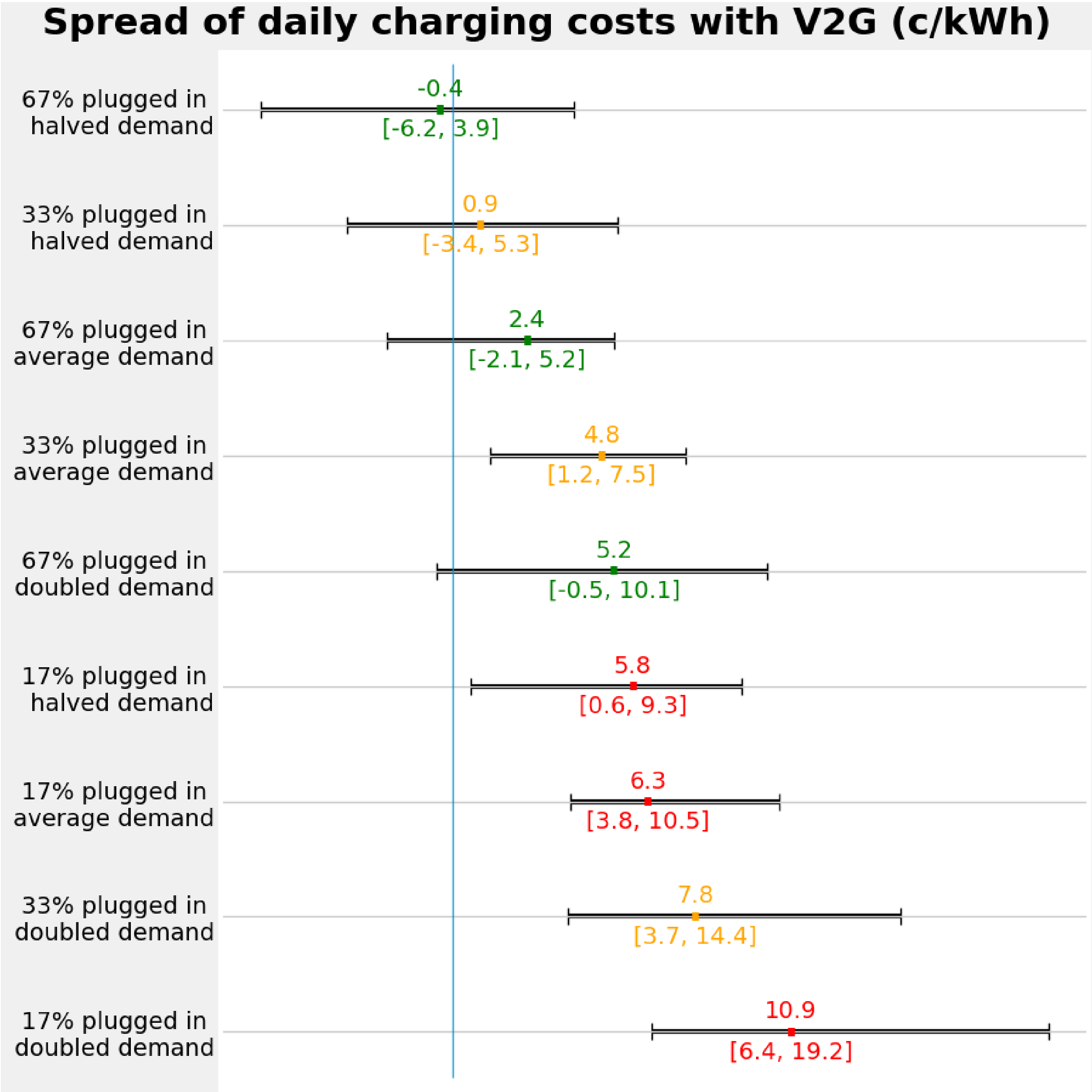


Figure 4 Distribution of per kWh charging costs when V2G is enabled. The blue vertical line marks a cost of 0c/kWh. Coloured text signifies the plug-in-fraction: green for 66.6%, orange for 33.3%, red for 16.6%



Appendix

Figure A1 Distribution of costs of charging ($/day) when EVs consume 3.7kWh per day and are plugged in to chargers 16.6% of the time or 66.6% of the time and V2G is not enabled

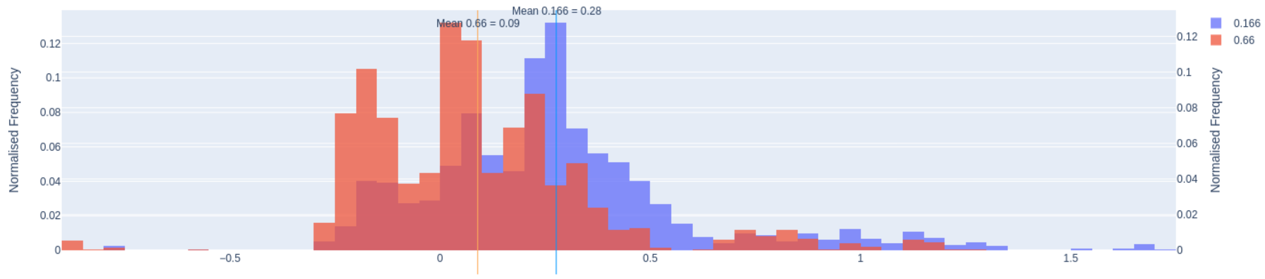


Figure A2 Distribution of costs of charging ($/day) when EVs consume 7.4kWh per day and are plugged in to chargers 16.6% of the time or 66.6% of the time and V2G is not enabled

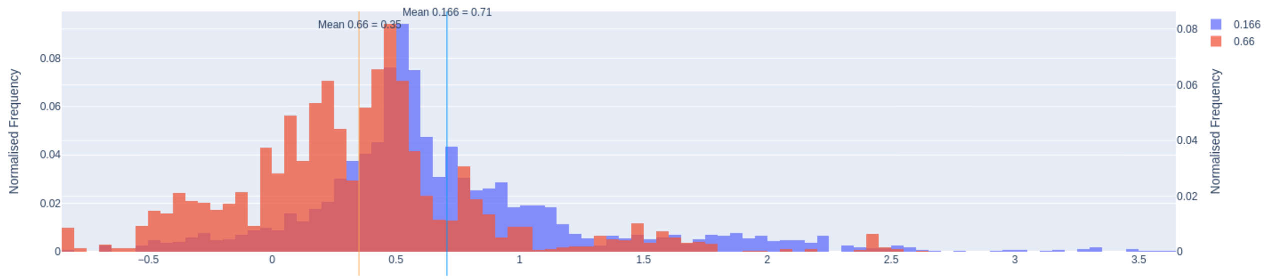


Figure A3 Distribution of costs of charging ($/day) when EVs consume 14.8kWh per day and are plugged in to chargers 16.6% of the time or 66.6% of the time and V2G is not enabled

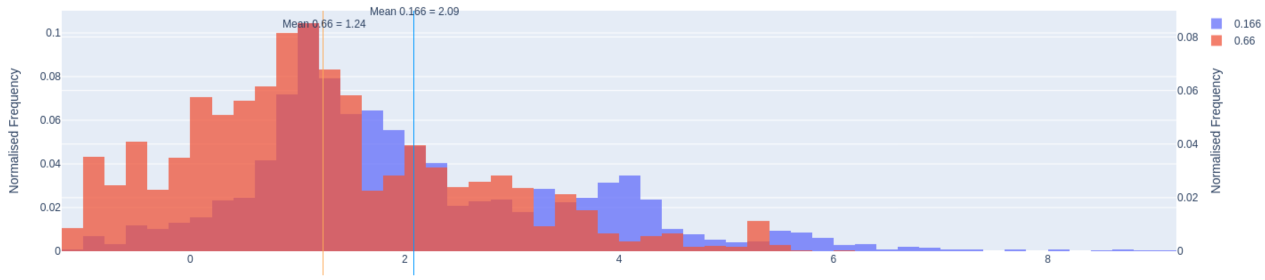


Figure A4 Distribution of costs of charging ($/day) when EVs consume 3.7kWh per day and are plugged in to chargers 16.6% of the time or 66.6% of the time and V2G is enabled

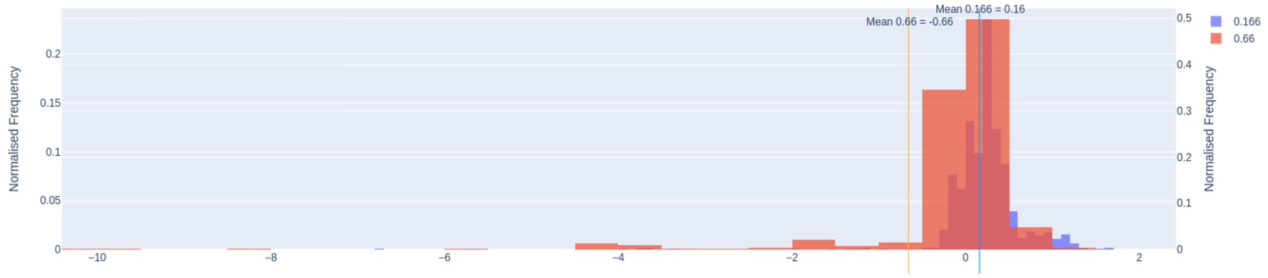


Figure A5 Distribution of costs of charging ($/day) when EVs consume 7.4kWh per day and are plugged in to chargers 16.6% of the time or 66.6% of the time and V2G is enabled

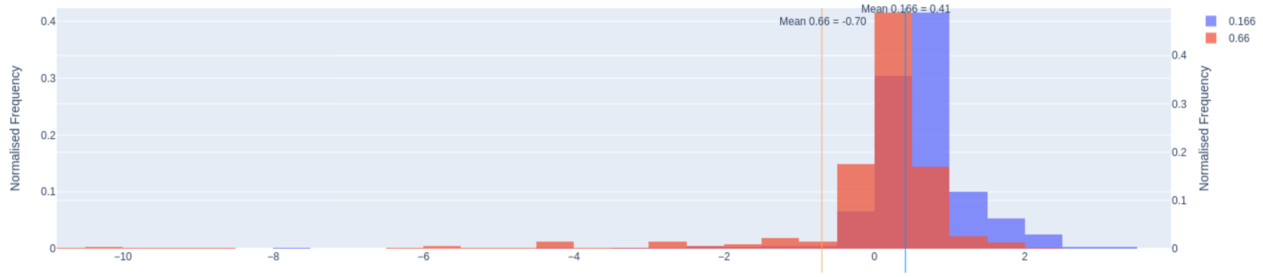
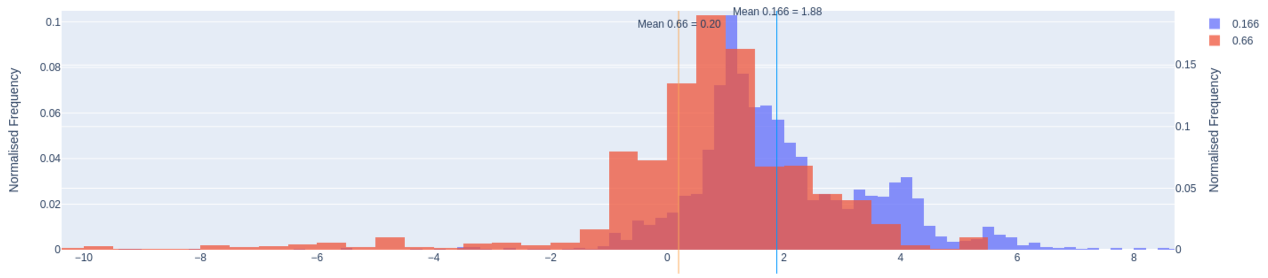


Figure A6 Distribution of costs of charging ($/day) when EVs consume 14.8kWh per day and are plugged in to chargers 16.6% of the time or 66.6% of the time and V2G is enabled



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