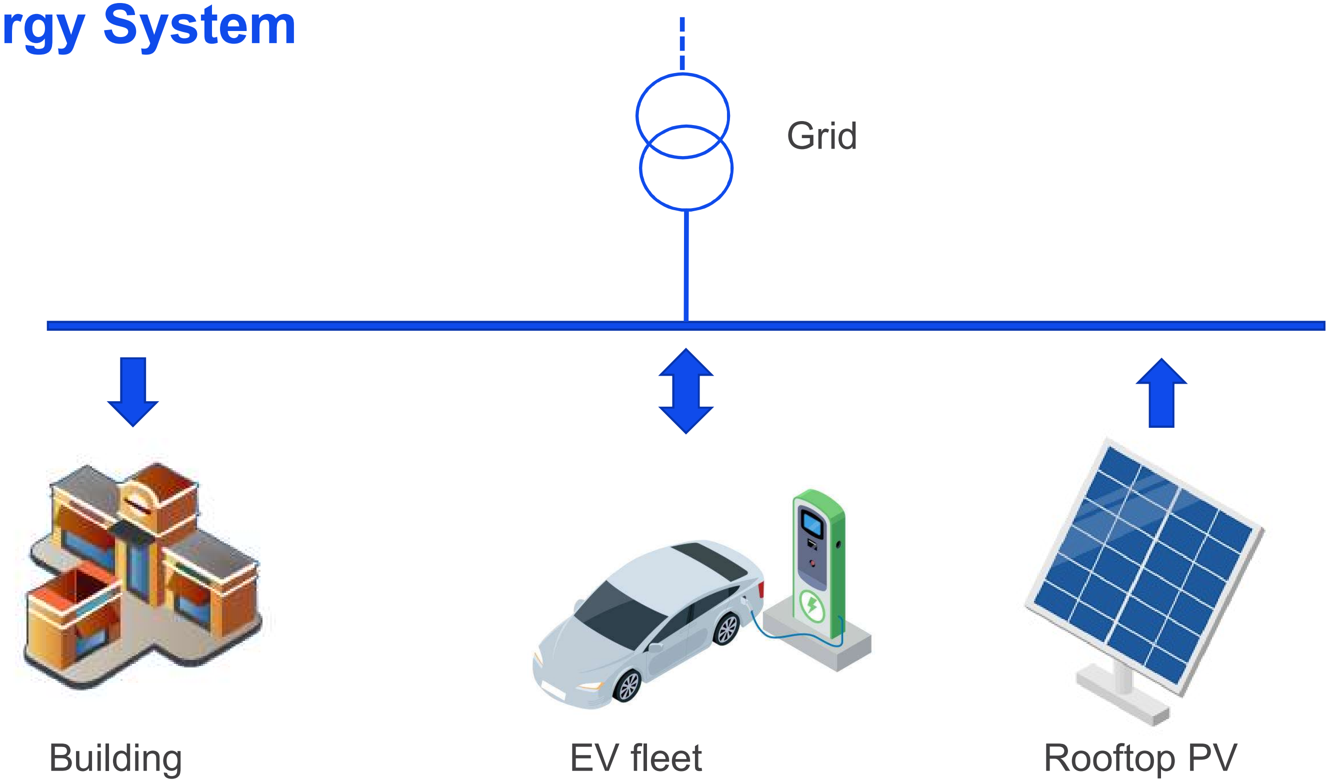
Preliminary Energy Analysis – Lake Macquarie City Council

June 2022

UTS Institute for Sustainable Futures

About the Analysis

Model – Energy System



The model encompasses three main energy assets:

- Building load.
- EV fleet, which can provide storage capabilities to the site. EVs can be charged from the grid or PV systems, and they can discharge energy for self-consumption or export to the grid.
- Rooftop PV systems.

Input Data & Assumptions – Baseline Case

INPUTS

- **Import tariff:** Flat rate: 7.8 ¢/kWh
- **Export tariff:** Feed-in tariff: 4.95 ¢/kWh
- **Main connection to grid:** 3-phase 800A
- **Charging stations:**
  - 4 x 7 kW (single-phase)
  - 2 x 22 kW (3-phase)
- **EV data:**
  - 4 x Nissan Leaf 2021. 40kWh/6.6kW

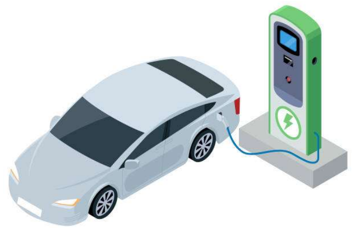
ASSUMPTIONS

- **EV behaviour:**
  - **Departure time:** 8am-10am
  - **Arrival time:** 3pm-6pm

  - **EV Energy consume**: 30%-70% ~(70km-160km)
  - **Charging strategy**: EVs should be charged prior to their departure time. Also, EVs are constrained to charge up to 90% of their maximum capacity.

Building

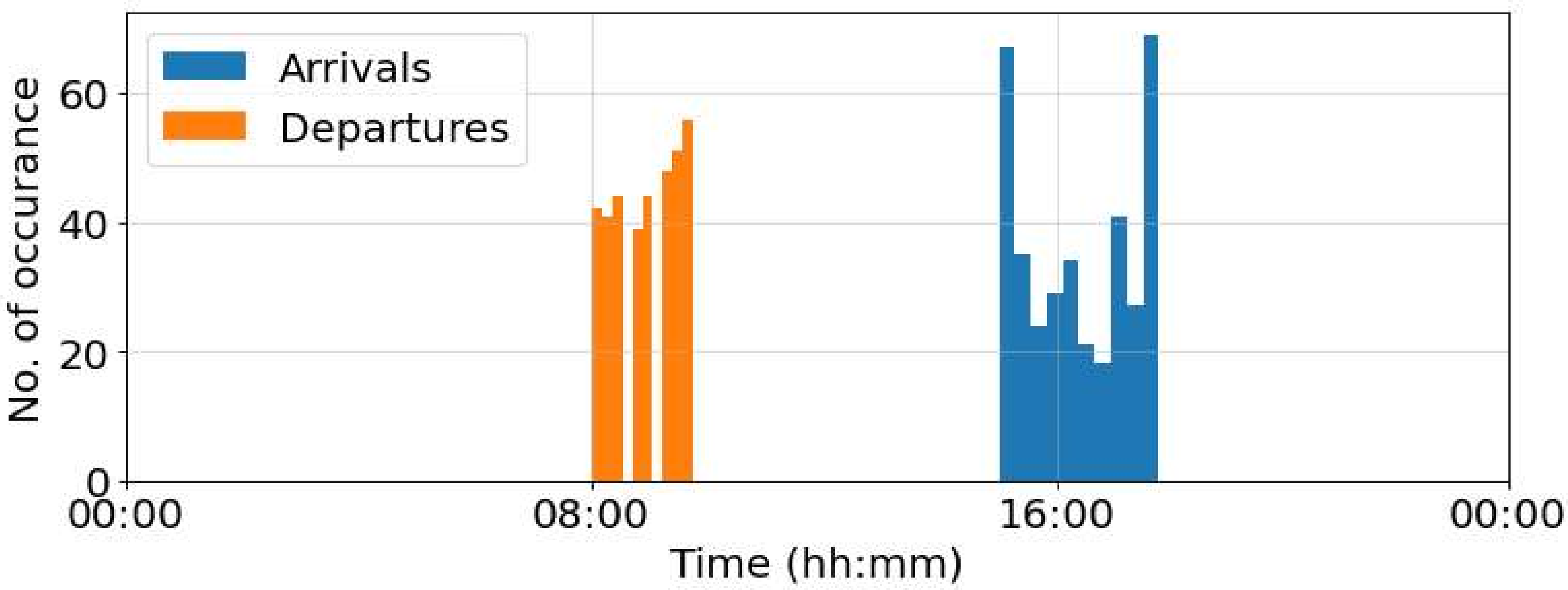
Local PV generation



EV fleet

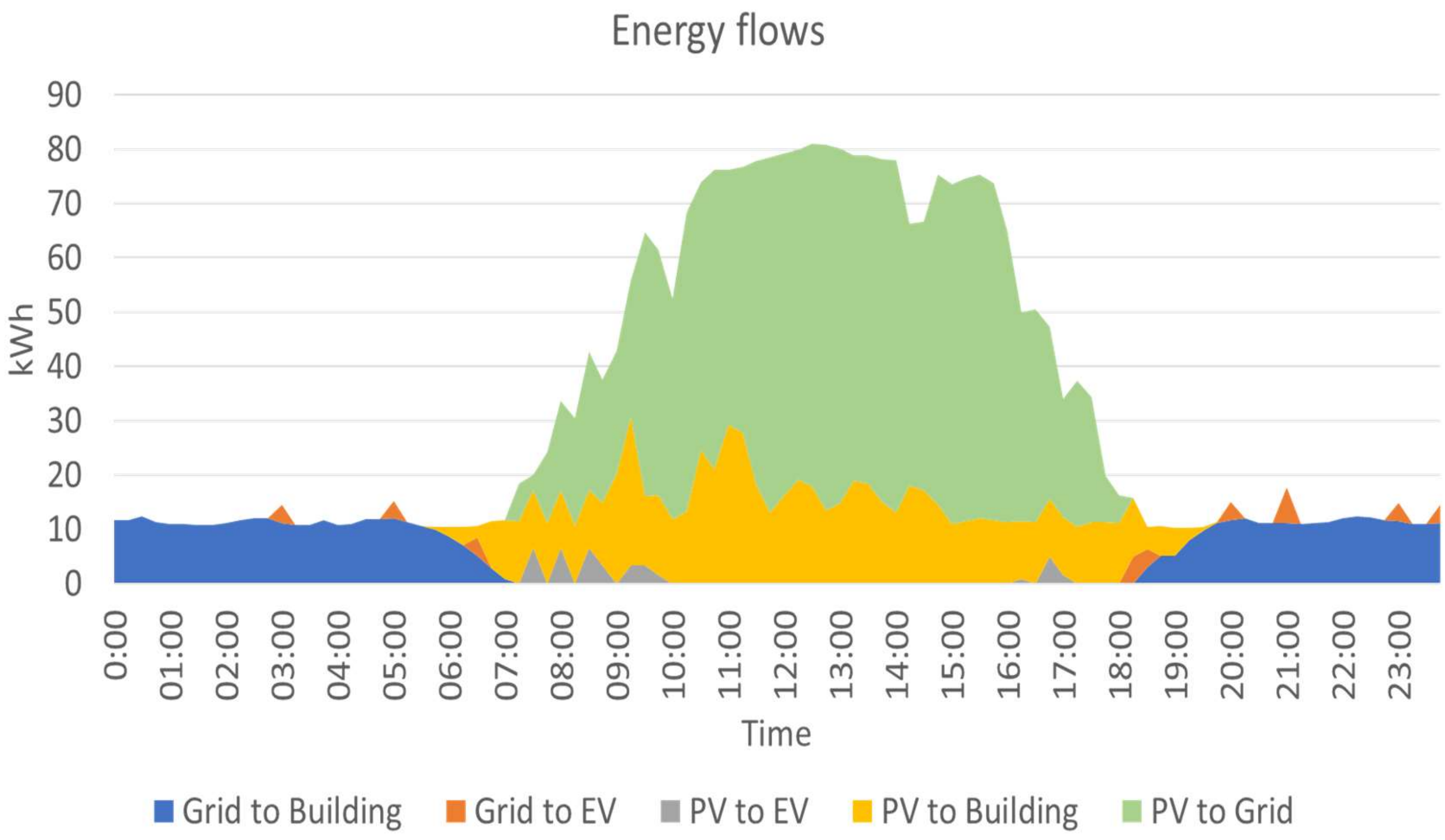
Baseline Scenario

EV Behaviour Simulation based on assumptions



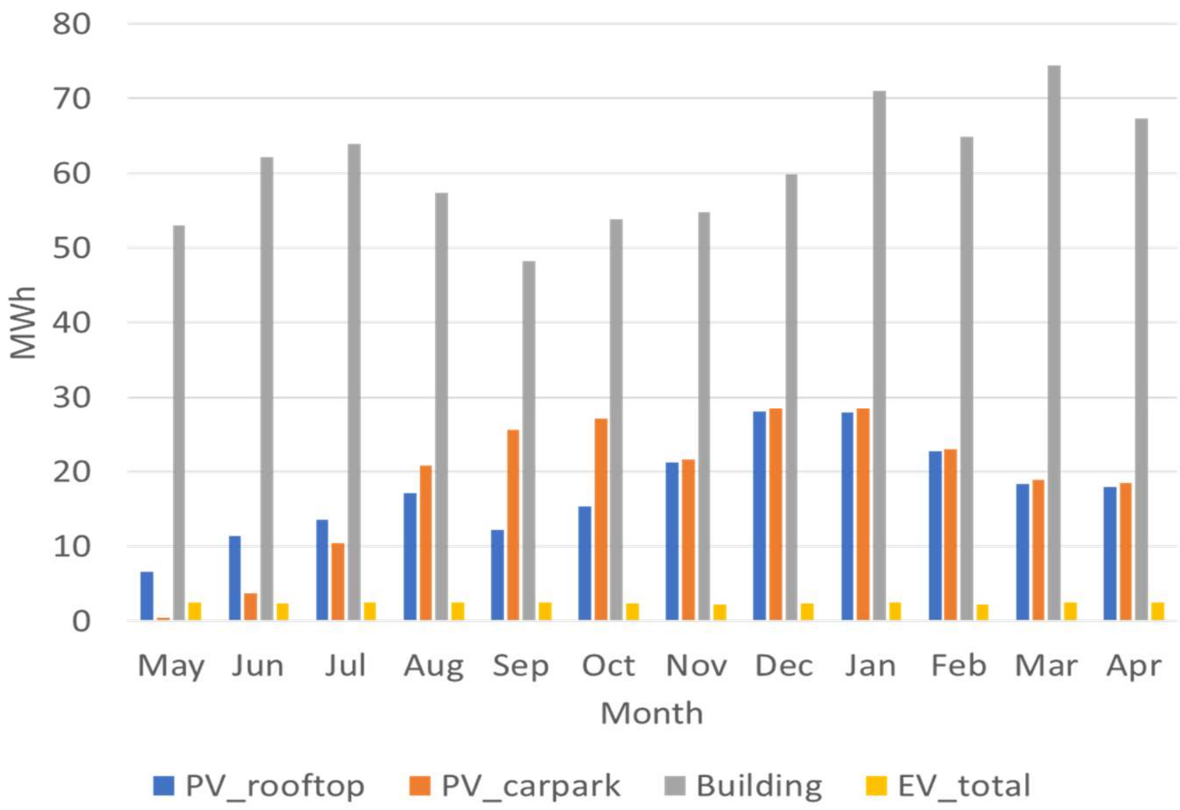
This graph shows the arrivals and departures of EVs over a year. Specifically, EVs left the carpark between 8 am and 10 am (orange), while EVs go back to the carpark between 3 pm & 6 pm (blue). This process is simulated through random variables in the model; therefore, it may not reflect the real scenario.

Example of one day simulation



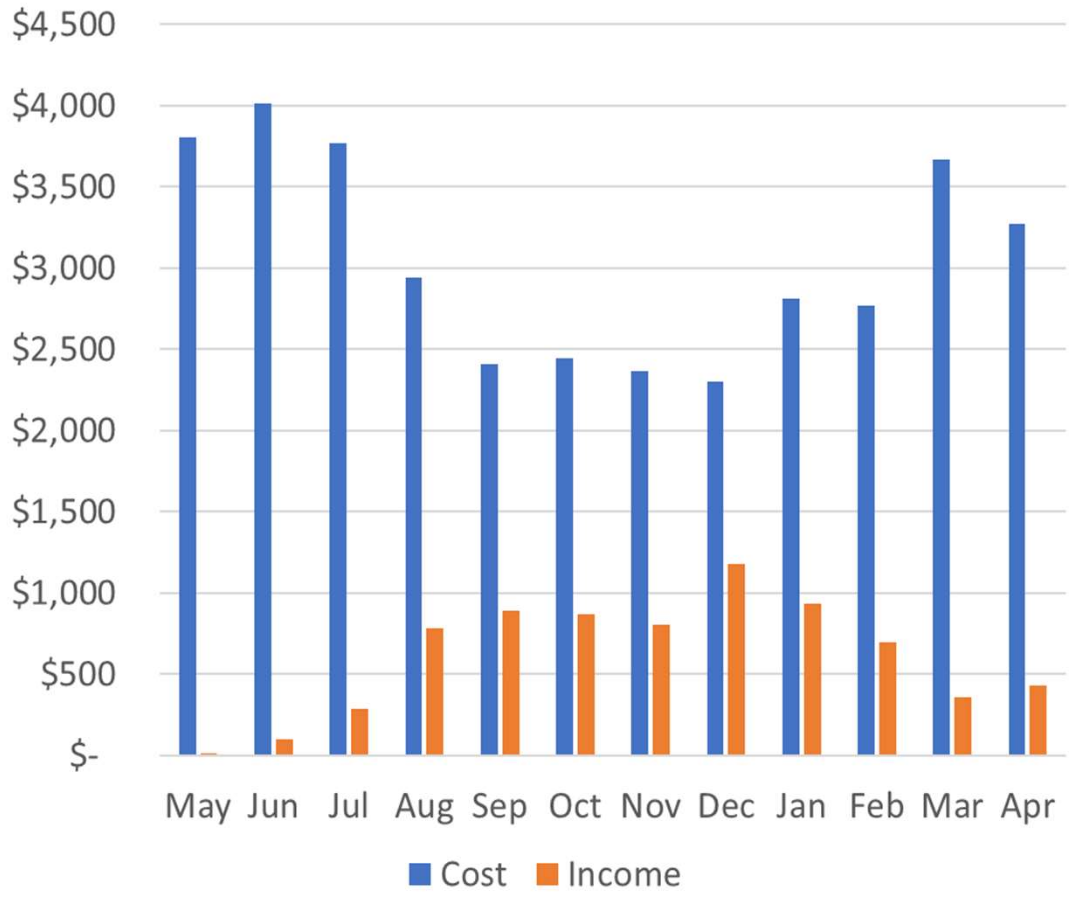
- Existing PV systems can produce energy to meet the building load (yellow) and charge EVs (grey). Also, the energy surplus (in green) is exported to the grid which can be used to offer other services to the network or retailer as a part of a VPP.
- The peak of PV generation around midday may match the peak of car utilisation. In other words, EVs, may not be in the carpark when PV generates more energy. Nonetheless, it can be seen that EVs charge from PV prior to their daily departure or immediately after their arrival at the carpark.
- If the building load can be broken down by loads, or at least more relevant loads such as AC, flexible loads could be incorporated in the model to be part of the energy management system model.

Annual energy flows



- Maximum PV production occurs in Spring and Summer. During this period, the total production is almost equal to the total building consumption.
- The site has a lot of PV resources that can be used for energy arbitrage.
- EV energy flows present minor variations throughout the year. In particular, the current EV charging profile doesn't have many variations due to the flat tariff.

Cost Analysis



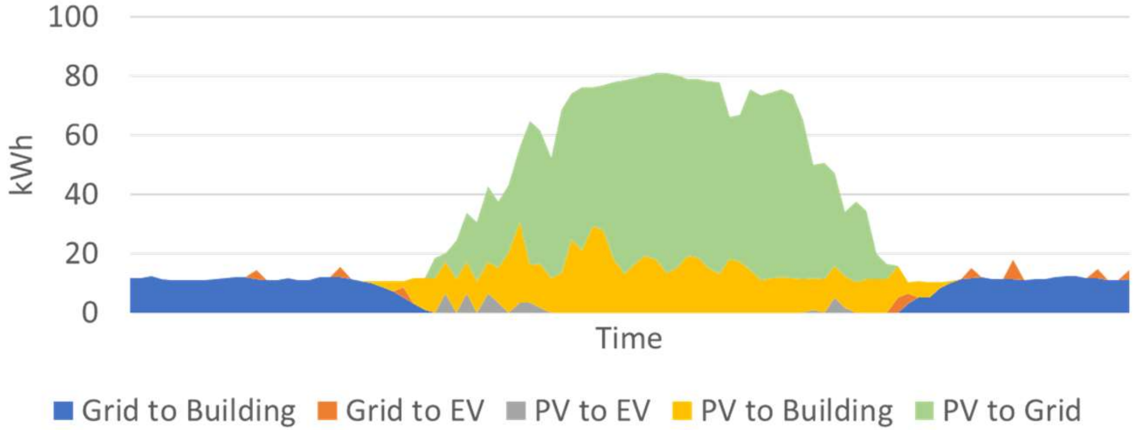
- This graph shows the income from energy exported to the grid (orange, from PV only), and costs due to the energy purchased from the grid (blue). It doesn't cover the total cost value.

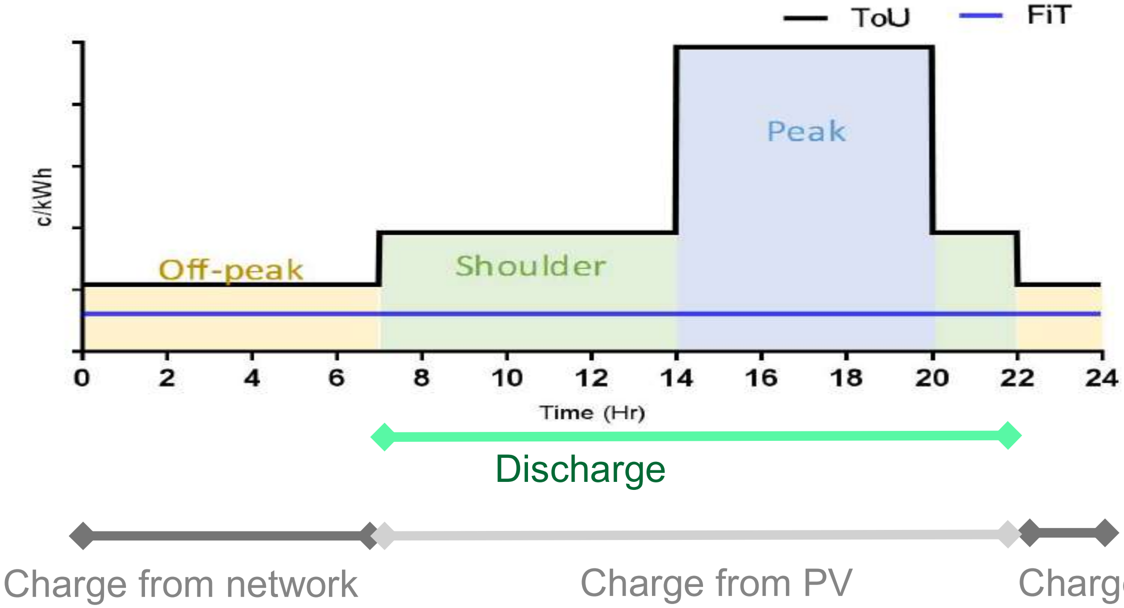
FUTURE POSSIBILITIES

- Energy surplus from this site can be used in other programs, such as VPPs or P2P trading. This will cause the income value to increase as a result.
- Also, EVs can be used to reduce the consumption during peak hours and store energy surplus from PVs to be used or exported during peak hours (energy arbitrage).
- In the future, there is a possibility of exploring incomes from EV either in the FCAS or inertia markets.

Alternative Scenario

Time of Use (ToU) Tariff





As a viable alternative to enable EV capabilities and advantages, a ToU tariff can be considered to take advantage of the inherent flexibility of EVs.

The next slides present a detailed analysis of the EVs behaviour during off-peak, shoulder and peak periods. In this way, potential savings and extra incomes could be identified.

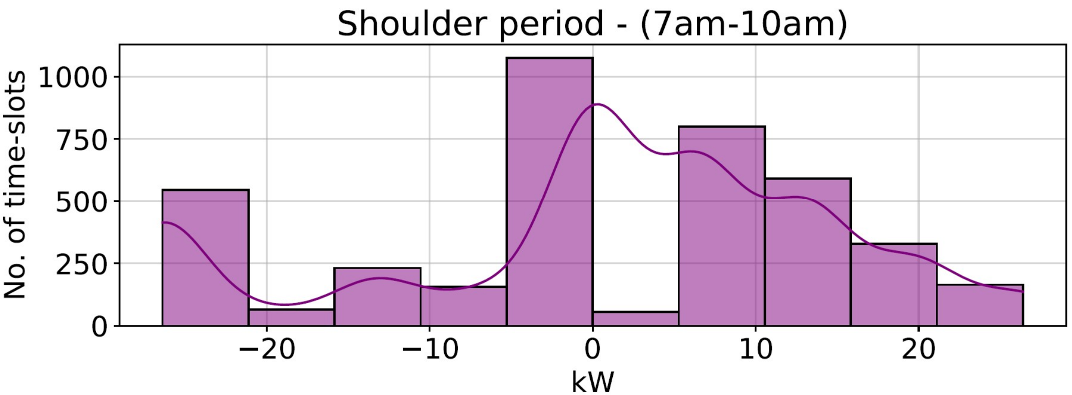
Tariff assumptions [$/kWh]*

Off-peak	0.055
Peak	0.100
Shoulder	0.070
FiT	0.0495

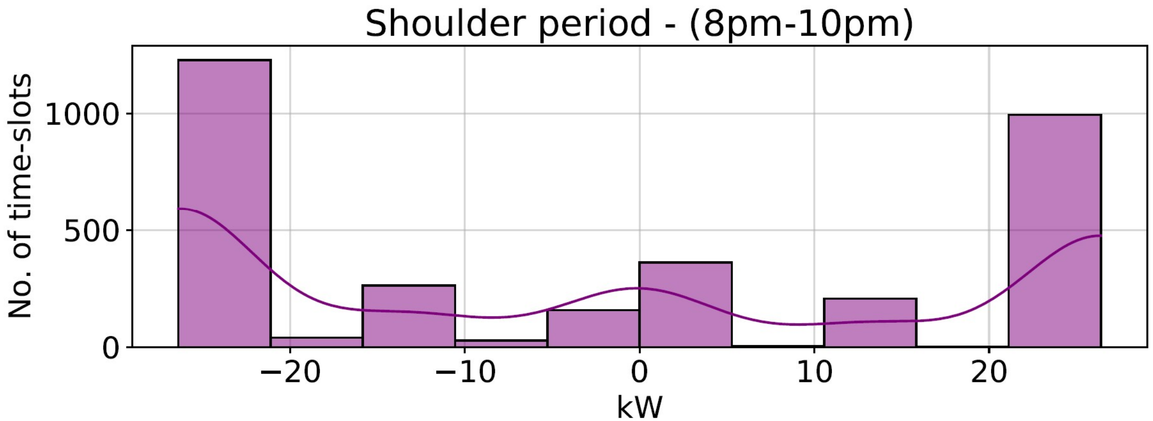
***Note:** Please note that ToU values considering in the study may not reflect real prices in the market. However, higher prices may represent more opportunities than the identified in this study

Simulation considering a ToU tariff – EV charging and discharging patterns

One-year simulation (using time-slots of 15mins): The purple line represents an approximation of the probability density curve of the discovered behaviour. The Y-axis accounts for the number of time-slots and X axis is the power from EVs (discharge) or to EVs (charge). Negative values in the X-axis represent discharging behaviour, while positive values represent charging behaviour.



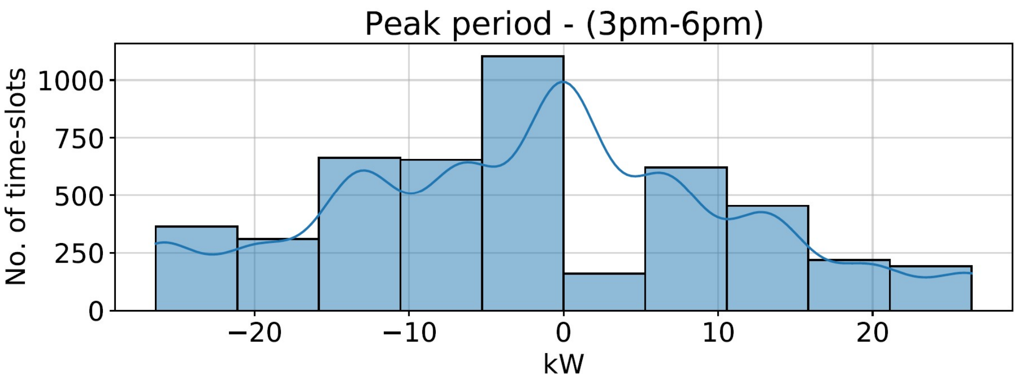
The graph shows that EVs were mainly charging during this period. This could be as a consequence of the charging strategy that requires to have full charge for prior to their departure, and also because PV started to produce energy. On the other hand, we can see that some EVs were discharging during some slots. This is because of EVs may discharge energy stored for self-consumption and charge energy from PV, which will represent financial savings.



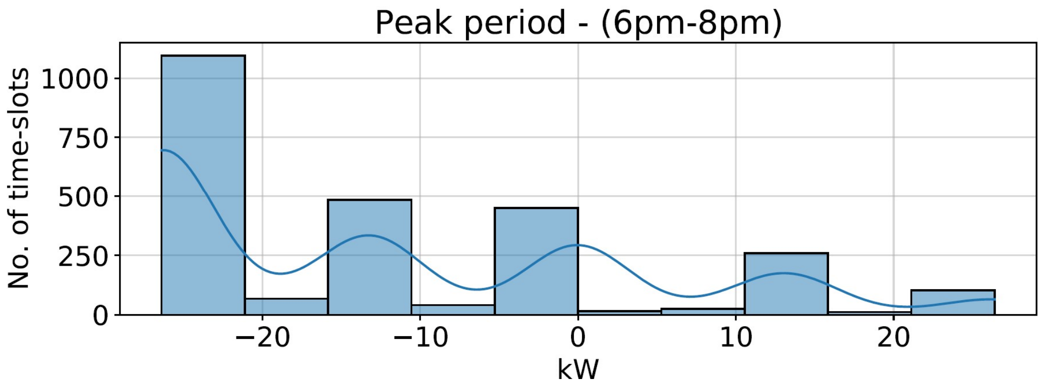
This graph considers the shoulder period after EVs arrival and the tariff rate change from peak to shoulder rate. It can be seen that EVs tend to discharge during this period as they may have energy stored that can be used for self-consumption or even export to the grid. There were also some time-slots in which EVs were charging, this could represent that EVs are charging from PV systems before the end of the day. This behaviour could be more frequent in Summer or Spring.

Simulation considering a ToU tariff – EV charging and discharging patterns

One-year simulation (using time-slots of 15mins): The blue line represents an approximation of the probability density curve of the discovered behaviour. The Y-axis accounts for the number of time-slots and X axis is the power from EVs (discharge) or to EVs (charge). Negative values in the X-axis represent discharging behaviour, while positive values represent charging behaviour.



EVs arrive during 3pm-6pm, so this graphs show the EVs behaviour after their arrival. It can be seen that EVs were discharging during the majority of the time-slots in this period, and this could represent additional exports to the network if PV generation was meeting local demand. Additionally, EVs also charged during this period as there were energy from PV systems that can be used to charge the batteries.



During the peak period, the role of EVs were mainly to supply (discharge) energy to cover local demand so the building is not expose to the peak price. Also, it can be seen that EVs were charging at some instances, this could happen during days with high PV generation.

Simulation considering a ToU tariff – EV charging and discharging patterns

Summary of potential economic benefits due to four EVs in one year

Period	Benefit
Shoulder	$992.1
Peak	$1,647.4
Total	**$2,639.50**

This estimation takes into account the periods when EVs are discharging and how that energy can be used. Reduction in peak charges would represent the highest economic benefit.

Note: This is a preliminary study to model EVs behaviour and shows the potential benefits that EVs can provide. However, further analysis is required to estimate the real impact and benefits.

Further Research

Future options for modelling

Optimise battery charge/discharge operation subject to:

ECONOMIC:
- Cost minimisation.
- Other pricing options, such as spot market price.
- Participation in VPPs or other DER coordination programs.

FUNCTIONAL:
- Provide network services.
- Minimise battery degradation.
- Prioritise specific charging patterns. (Charging sooner or at specific period of time).
- Coordinate local demand, generation, and storage assets.

ENVIRONMENTAL:
- Emissions reduction.

Assess trade-offs:

- Sacrifice charging priorities to reduce emissions or costs.
- Provide network services/grid support vs coordination of local/community assets (VPP).
- Sacrifice battery life to reduce costs.

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