Impact of tariffs and system costs on optimal PV system size

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The popularity of small-scale residential solar photovoltaic (PV) systems continues to rise in Australia, as demand for affordable sources of renewable energy grows and PV costs decrease. However, there is still a large variation in the financial benefits of PV systems between different users due to several performance and cost factors. From a residential customer's perspective, this can make it difficult to determine the optimal PV system size to install and the most suitable metric to optimise for. Gaining a better understanding of the factors impacting the financial viability of PV systems in Australia is important for future developments in both policy and system design.

Standard methodologies for assessing the economic performance of different PV systems include an evaluation of the system's simple payback period (PBP) and the return on investment (ROI), both of which were employed in this study. Detailed studies analysing the return on investment of simulated PV systems suggest that many factors can impact both PBP and ROI (Formica & Pecht, 2017), and that government incentives and rebates play a significant role in determining the economic viability of certain PV systems (Yang, et al., 2015). A review of the literature also reveals that the variation in electrical load between users contributes to the variability of PV systems' ROI and PBP (Lau, et al., 2021 and Rauf, et al., 2021). The goal of this study is to provide a broad analysis of the impacts that variations in tariffs and upfront system cost can have on the estimated optimal PV system size for residential households.

Case Study

Data from 1146 Victorian residential sites collected by Solar Analytics[1] was used to implement a broad analysis of the effects of changing tariff rates and initial PV system costs on both PBP and ROI. Across the 1146 sites the average annual consumption for 2021 was just over 11,000kWh, with an hourly average load of 0.4kWh. Each site had a half-hourly load profile and PV profile for a minimum of 1 year, and the PV profiles for each site were scaled to estimate output of the same system at varying capacities between 1-15kW[2]. Three rates (low, medium, and high) for each tariff type were considered, using typical values for residential feed in tariffs (FiT), flat rate (FR) and time of use (ToU) tariffs in Australia. A typical all-year, every day, 2-8pm peak, 10pm-7am off-peak and a 7am-2pm and 8-10pm shoulder was also applied to each site when evaluating ToU tariffs. System cost data from Solar Choice in August 2022 was used to provide average system prices by state and territory,[3] noting that some $/W prices for systems between 1-2kW were derived by simple extrapolation from 1.5kW system prices (Solar Choice, 2022a). For Tasmania, the Northern Territory, the Australian Capital Territory and Western Australia, <3kW system prices were extrapolated from 3kW systems, and for systems between 8-9kW and >10kW, prices were also derived by extrapolation from 7kW and 10kW systems (Solar Choice, 2022b).

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[1] Accessed through the UNSW Data Resource Time-series Hub (DARTH) Energy Database.

[2] This may result in some overestimation of output from larger residential systems, due to the likelihood of larger systems using less optimal roof areas alongside areas with the greatest solar insolation.

[3] Prices are quoted as total retail prices after STCs and GST.

Table 1. Overview of tariff values used at low, medium, and high rates

Rate	Feed in Tariff c/kWh	Flat Rate c/kWh	Time of Use		
			Peak c/kWh	Off-Peak c/kWh	Shoulder c/kWh
Low	7	22	30	9	18
Medium	9	27	40	18	30
High	10	37	54	21	38

In this study a simple payback period was calculated for each site[4], with the assumption made that in all cases a FiT is afforded to each consumer and no cap is applied to FiT revenue[5]. Here, the net profit is taken to be the amount saved by self-consuming PV generated electricity, plus the amount "earned" from exporting to the grid with a FiT.

$$PBP = \frac{Total\ Investment}{Net\ Annual\ Profit}$$

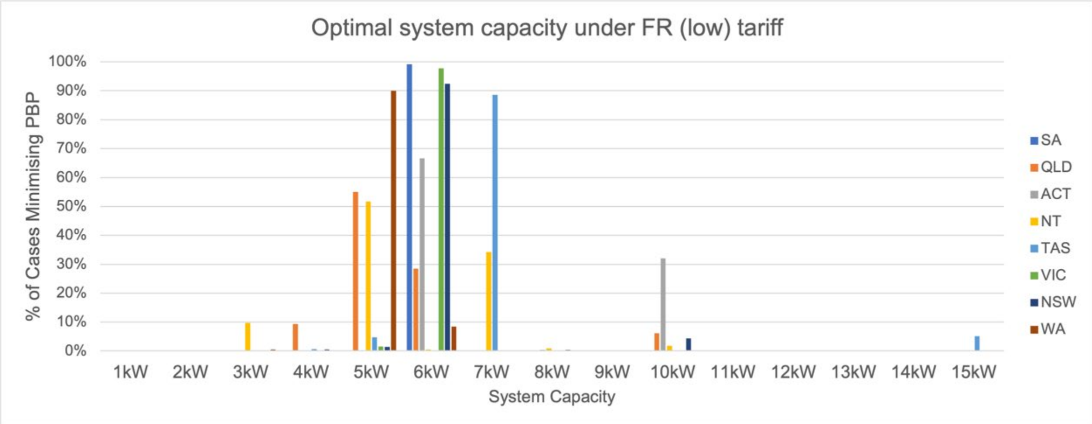

Figure 1. Optimal system sizes under low FR tariffs by minimising PBP.

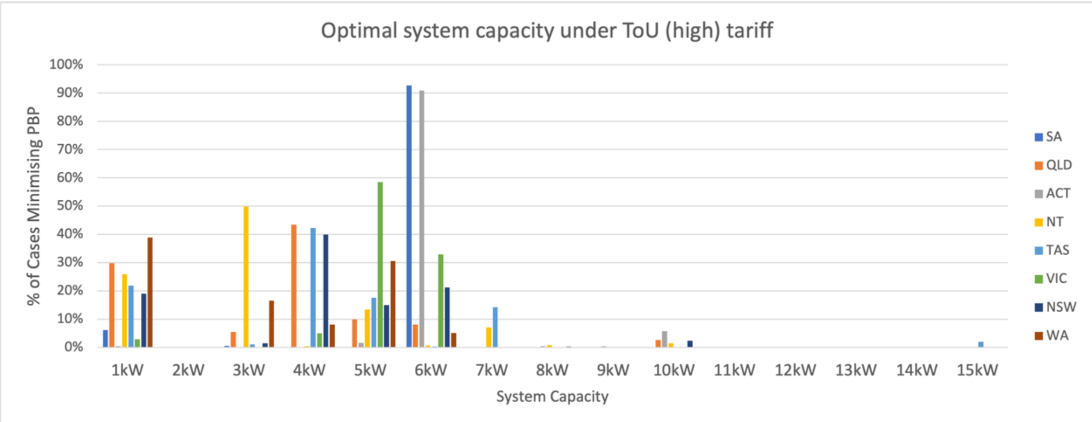

Figure 2. Optimal system sizes under high ToU tariffs by minimising PBP.

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[4] We decided to just use a simple PBP calculation due to the difficulty in choosing an appropriate discount rate. As the average estimated payback period was below 10 years, we did not consider the potential effects of inflation.

[5] Connection and export limits vary between DNSPs, with some installations limited to 5kW or 10kW, which could restrict FiT revenue for single-phase installations.

Figures 1 and 2[6] display a summary of the results for two different tariff structures, showing the percentage of cases (for that tariff structure) in which a given system capacity minimised the PBP. As pictured in the above figures, changing tariffs and initial system costs (estimated for each state and territory) influences the optimal PV system size (by the minimum-PBP metric). For flat rate tariffs, there is a clearer peak around the 6kW range across each tariff rate, which was found on average to minimise PBP in 44% of tested scenarios. By comparison, ToU tariffs showed a wider spread of optimal capacities ranging between 1-7kW, with approximate peaks for each state (different system costs) varying within this range. This result suggests that a further study of the factors influencing an individual system's PBP is necessary to determine the best system size for a single customer.

The estimated ROI for each site was calculated for a period of 10 years to reflect average inverter lifespans (Rahim et al., 2011). Here again we have ignored the potential effects of PV system degradation or inflation to simplify our estimations

$$ROI = \frac{Net\ Annual\ Profit}{Total\ Investment} \text{ x } 10$$

Figures 3 and 4[2] below illustrate a similar pattern between tariff types, with flat rate tariffs at all rates again showing a clearer peak around the 6kW range. On average, a 6kW system size maximised the ROI in approximately 35% of scenarios tested in total. Again, under ToU tariffs there is a larger variance in optimal system size, this time (for high ToU tariffs) with a peak around 2kW, a much smaller peak around 6kW and then in the range of 10+kW. Approximate peaks can again be found state-by-state, indicating that initial system costs could be a deciding factor in these scenarios. There is a limitation in the study where costs have had to be extrapolated for some system sizes, as realistically there are likely to be premiums associated with fixed installation and balance-of-system costs. The resulting 2kW peak may be in part due to this limitation.

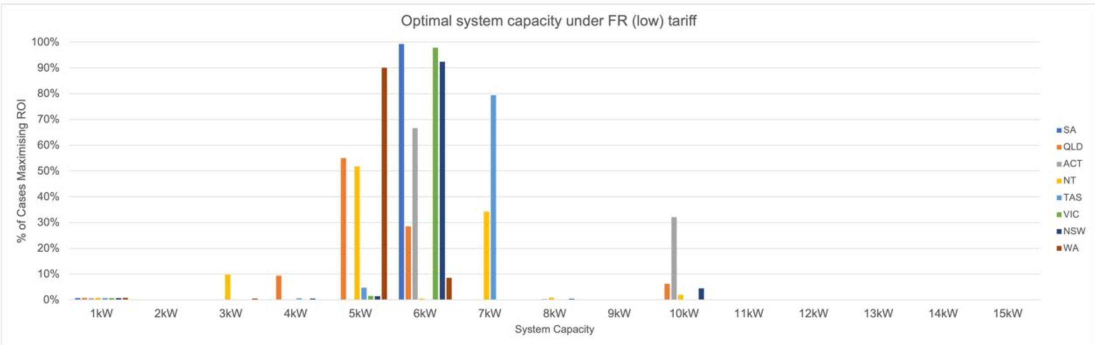

Figure 3. Optimal system sizes under low FR tariffs, by maximising ROI.

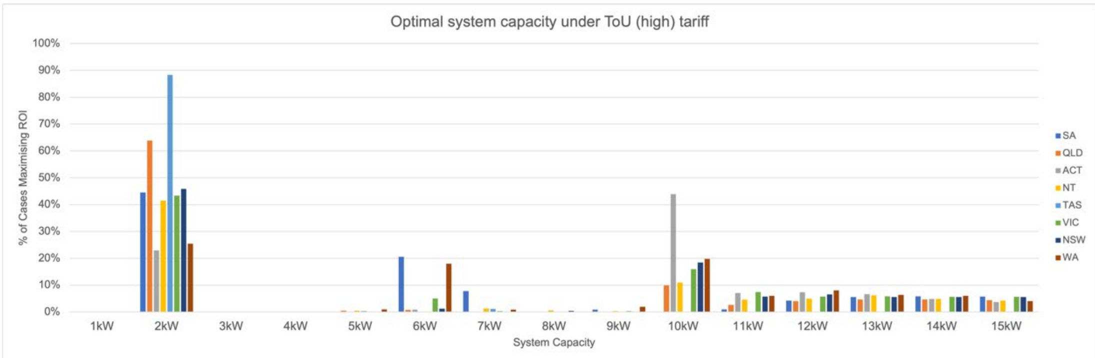

Figure 4. Optimal system sizes under high ToU tariffs, by maximising ROI.

[6] These figures have been chosen to demonstrate most starkly the differences between tariff types and rates.

Again, Figures 3 and 4 show the optimal system size as one that most frequently maximises the ROI for each tariff structure across all modelled sites. The tariff type (FR or ToU) rather than variations in the rate of the tariffs had a greater impact on the optimal system size ranges. As discussed above, all flat rate tariffs provided a consistent result that system sizes between 5-7kW and around 10kW (for the Australian Capital Territory) both maximised the ROI and minimised PBP. However, the different rates of ToU tariffs generated large variations in optimal system size, ranging between 1-10kW. This range more closely aligns with results from a study that found feasible PV system ratings to be between 1-12kW, with this range also found to be dependent on the customer load (Lau, et al., 2021). These findings suggest that further detailed analysis considering the impact of consumer load on both PBP and ROI is necessary to gain a more complete picture of the factors influencing the economic viability of different system sizes.

The variation in optimal ranges shown to maximise ROI and minimise PBP (particularly under ToU tariffs) indicates that the use of one simple metric to determine the optimal system size for a user may not be advisable. It is also important to note that the metrics of ROI and PBP are not reliable without considering risk factors, as parts replacement, installation cost differences and varying electricity costs from the grid can all impact both values (Formica & Pecht, 2017).

Conclusion

The above results provide an overview of the influence that tariff type, rate and initial system cost can have in determining the optimal PV system size for a consumer. When considering both minimum PBP and maximum ROI, results under flat rate tariffs and time of use tariffs showed significant variation in optimal system capacity ranges, ultimately suggesting that systems between 1-10kW serve the best chance of optimising both metrics. This study confirms the need for more detailed comparative studies examining the impact of PV production and consumer load, as well as DNSP connection and export constraints in optimising PV systems. These results can be used to suggest a starting point for would-be PV users looking to find the most financially viable PV system, however, their limitations as estimated findings validate the difficulty that many customers face when considering PV installation and demonstrate the importance of customer-specific load data and tariff information to optimal system design.

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