

Storage and Signals: Solar and Battery Storage, Time-of-Use Pricing and Household Peak Demand in the Australian NEM

Non-technical summary

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Electricity systems increasingly face a problem of when, rather than simply how much, electricity households consume. Demand is much more costly to meet at some times than at others, particularly during periods when electricity networks and generation are under greatest pressure. Time-of-use (TOU) electricity tariffs are intended to address this problem by charging households more during peak periods and less at other times. In principle, households should respond by moving some of their electricity consumption away from expensive peak hours.

Whether this actually happens has been debated for many years. Earlier studies have generally found that household responses to time-varying electricity prices are modest and vary considerably between customers. At the same time, the rapid growth of rooftop solar and, more recently, household batteries has changed the issue. A battery gives a household a practical way of avoiding purchases from the grid at particular times without necessarily changing when household activities take place. Electricity generated by solar panels or bought from the grid at another time can be stored and used during the evening peak. The question is therefore no longer simply whether consumers personally respond to electricity prices, but whether batteries make TOU tariffs more effective.

This paper investigates two related questions. First, do households consume less electricity during peak periods when the difference between peak and off-peak prices becomes larger? Second, do households with solar panels and batteries have different patterns of peak electricity consumption from other households, and does this depend on whether they are actually on a TOU tariff?

Data

The study uses detailed electricity consumption data supplied by a major retailer for 5,096 households in New South Wales, Victoria, Queensland and South Australia. The sample includes three groups: households without solar panels, households with solar panels but no battery, and households with both solar and a battery. Electricity purchases from and sales to the grid are recorded at half-hourly intervals, providing more than three million household-day observations. The households are also observed under different types of electricity tariff: conventional flat tariffs, two-rate TOU tariffs and three-rate TOU tariffs.

This is particularly useful because the study observes the tariffs that households actually faced rather than imposing an experimental tariff or assuming how a battery would operate. It therefore examines revealed behaviour in the real electricity market.

There are important differences between the three groups. Solar and battery households are more likely to be on TOU tariffs than households without solar. For example, 28.8 per cent of solar-plus-battery households in the sample are on a two-rate TOU tariff, compared with only 4.7 per cent of households

without solar. This matters because households choosing, or being placed on, different tariffs may differ from one another for reasons unrelated to the tariff itself. The statistical analysis therefore attempts to control for differences such as state, overall electricity consumption, electric vehicle ownership and controlled-load appliances.

Do households respond to bigger price differences?

The first part of the analysis examines households already on TOU tariffs. Retail electricity prices changed for many households during the period covered by the data. This makes it possible to observe whether the same household changed its behaviour when the difference between its peak and off-peak price changed.

The result is striking. There is no statistically significant evidence that households respond to the size of the peak-to-off-peak price difference. This applies to households without solar, households with solar alone and households with both solar and batteries. Even when the analysis is restricted to those households that experienced the largest changes in relative prices, the result is essentially unchanged.

This finding is consistent with earlier Australian research by Burns and Mountain, which also found little evidence that residential customers adjust their electricity use in response to the relative size of peak and off-peak prices. The present study extends that earlier result by using panel data from four states and, importantly, by separately identifying households with batteries.

The implication is not that electricity prices never matter to households. Rather, there is no evidence here of the particular form of response on which conventional TOU pricing is based: households progressively shifting more consumption away from peak periods as the peak/off-peak price difference becomes larger.

Batteries nevertheless make a difference — but only with a TOU tariff

The second part of the paper produces a different and more interesting result.

To make households comparable, the study constructs what it calls a “shadow peak”. Every household's consumption is classified according to the standard peak hours applying in its state, regardless of whether that household is actually on a TOU tariff. It is therefore possible to ask, for example, whether a battery household on a flat tariff uses less grid electricity between the hours that would constitute the peak than an otherwise comparable non-battery household.

The central finding is that households with solar and batteries consume significantly less grid electricity during peak periods than other households when they are actually on a TOU tariff. At the average level of consumption in the sample, the estimated difference is about 13 per cent compared with households without solar on the same type of tariff.

But battery households on flat tariffs do not show a corresponding reduction. Their peak-period consumption is statistically indistinguishable from that of non-solar households on flat tariffs. Solar panels on their own also do not produce the same clear pattern.

This combination of results is important. If batteries automatically reduced peak electricity purchases simply because households sought to maximise their use of their own solar generation, battery households on flat tariffs should also have shown lower peak demand. They did not. On the other hand, if households were continuously adjusting battery use in response to electricity prices, the amount of peak reduction should have varied with the size of the peak/off-peak price difference. Again, it did not.

The results instead suggest a third explanation. The existence of a TOU tariff appears to trigger a change in how a battery is operated, while the exact size of the price difference matters little. A battery might, for example, be programmed when installed to discharge during the tariff's peak hours. Alternatively, automated battery software or the household itself may set a schedule around the known tariff periods. Once this has happened, doubling or reducing the price difference may have relatively little further effect. The paper describes this as a discrete, tariff-triggered response, rather than conventional continuous price responsiveness.

There is some additional support for this interpretation. The battery effect remains strong when consumption is measured using peak periods that correspond to actual retail tariff structures, but disappears when an arbitrary 5 pm–9 pm peak period is imposed instead. This suggests that battery operation is linked to the hours defined by the tariff, rather than simply to evening electricity consumption in general.

What does this mean for electricity policy?

The findings raise questions about policies that promote TOU tariffs across the whole residential customer base as a way of reducing peak demand. In this study, simply making the peak price higher relative to the off-peak price did not produce a detectable response among households generally.

Batteries change the picture. Households with batteries appear able to respond to the structure of a TOU tariff even though they do not respond measurably to changes in the size of the price incentive. This suggests that TOU tariffs and household battery policies may be complements. If the policy objective is to reduce household demand on the grid during peak periods, encouraging appropriate TOU tariffs for battery households may achieve more than attempting to induce behavioural changes from households generally. The paper consequently suggests considering battery incentives and tariff policy together rather than treating them as separate policy instruments.

There are, however, important qualifications. The study can observe changes in prices for the same household, which makes the finding of little response to the size of the price differential relatively strong. But battery ownership and whether a household is on a TOU tariff generally do not change during the period studied. The comparison of battery and non-battery households therefore partly relies on comparisons between different households. Those households may differ in ways that the dataset cannot observe, such as household size, occupancy patterns or air-conditioning use. The paper finds one unexplained difference of this kind: non-solar households on TOU tariffs have somewhat higher peak consumption than non-solar households on flat tariffs even after several statistical controls are included. The preferred battery comparison avoids much of this problem by comparing battery and non-battery households facing the same tariff type, but the limitation remains relevant when interpreting the wider results.

There is also an important question about whether these findings will continue to apply as household batteries become larger. The batteries represented in this dataset were installed during an earlier stage of Australia's household storage market, when typical capacities were smaller than those now being installed. A larger battery might strengthen the pattern found here, because it gives households more stored energy with which to avoid peak purchases. Alternatively, very large batteries may allow households to maximise solar self-consumption almost regardless of their electricity tariff, in which case the distinction between TOU and flat-tariff households could weaken. Testing this is identified as an important next stage of the research.

Overall conclusion

The paper therefore produces two findings that at first sight appear contradictory but together tell a coherent story. Households do not appear to respond systematically to how large the peak/off-peak price difference is. Yet TOU tariffs do appear to matter when a household has a battery. Battery households on TOU tariffs consume materially less grid electricity during the tariff-defined peak periods, while battery households on flat tariffs do not show the same pattern.

The evidence therefore suggests that the main effect of TOU pricing may not operate through the traditional mechanism of consumers repeatedly adjusting their behaviour in response to marginal prices. Instead, TOU tariffs may provide a relatively simple signal around which battery operation is configured. This distinction becomes increasingly important as batteries spread through Australian households. It suggests that the effectiveness of future electricity tariff reform may depend less on expecting millions of consumers to monitor and respond continually to price differences, and more on how tariffs interact with technologies capable of responding automatically on their behalf.