THE GROWTH OF HOUSEHOLD PV EXPORTS WITH ENERGY EFFICIENCY AND THE OPPORTUNITY FOR BATTERY STORAGE SYSTEMS

Sebastian Oliva H., Energy Centre, University of Chile, Phone: +56 9 5702 9312, E-mail: sebastian.oliva@centroenergia.cl

Overview

A growing range of energy efficient consumer technologies (EE) combined with extraordinary declines in photovoltaics system (PV) prices has seen household electricity demand fall whilst an increasing proportion of the remaining load is provided by household self-generation. This clean energy deployment has proven to be a key way to mitigate the risks of a catastrophic climate change (Akorede et al., 2010). However, existing retail and feed-in tariffs can create mixed incentives for households contemplating both PV and EE options. This is certainly the case of net billing arrangements (NB) that value self-consumption of PV far more than PV exports to the grid. Falling household demand due to EE can considerably reduce the financial value of a PV system (Oliva H, 2017). Meanwhile, the continuously falling cost of battery storage systems (BS) has encouraged more PV customers to contemplate storing PV exports in order to maximize PV self-consumption. In particular, the addition of BS could significantly change the financial interaction between PV and EE, and only limited studies on this effect area available. In this work we use real household load and PV data in Sydney to assess the financial interactions between PV, EE and BS installed in combination. Our results highlight how existing feed-in tariffs (FiTs) may reduce the value that EE and PV offers to households, as well as the opportunities that battery storage can offer to facilitate the further needed uptake of these two key clean energy technologies.

Methods

We have estimated hourly household revenue under NB in Australian dollars from 3 kW PV systems combined with typical residential EE measures, with and without BS, for the first year of operation. We use real life hourly PV generation and electricity consumption data obtained from 300 households located in the city of Sydney in order to capture representative energy performance. We simulate the operation of the BS system. We also average the results of this household sample to obtain annual values in $/house/year. Details are provided below.

Net Billing

Under NB arrangements, customers with PV systems first self-consume their PV generation and any excess of generation is exported to the electricity grid. In this way, customers with PV experience savings in their electricity bill, valued at the customer retail electricity rate. They also typically get paid a FiT for their PV exports that represents only the wholesale energy value of generation. As such, with NB, the value of PV self-consumption is far greater than the value of PV exports as avoided retail rates are three to four times higher than the FiT rates.

Modelling the energy efficiency measures

The fall in household electricity consumption caused by EE energy savings under NB arrangements can potentially significantly reduce the household revenue gained from the PV system. This is because less household consumption reduces the PV generation that is self-consumed and increases PV exports.

The EE measures explored in this work consist of upgrading a typical residential air conditioner, a refrigerator and a lighting system. We aggregate the EE energy savings of the three appliance EE measures to define our 'with EE' scenario. An hourly profile of EE energy savings (ES_t) has been built for a whole year period using a representative appliance energy usage profiles for the Sydney residential sector. We also considered a flat 68%, 73% and 88% of reduction of the air conditioner, refrigerator and lights electricity consumption respectively (Energy rating, 2017).

Adding the battery storage system

Batteries could increase the value of PV under hourly NB by maximising PV self-consumption. Hence, BS could potentially remove competition between PV and EE for the household bill savings. In this work, the BS system stores excess generation from the PV system and supplies it during times of low or zero solar resource availability. This configuration increases PV self-consumption. The PV generation is used to meet the household demand first, then used to charge the BS before exporting to the grid. Similarly, household demand is met from the BS before electricity is imported from the grid, and the BS is not allowed to discharge to the grid at any time. BS systems could be especially valuable in this combined PV-EE context.

For every hour of the year period the battery is charged with all the PV generation that exceeds the load, assuming that enough storage is available. Otherwise, the BS is just fully charged and the left excess of PV generation is exported to the grid. The battery discharges to meet all the load that exceeds PV generation if enough electricity is available in the battery. Otherwise, the BS is just fully discharged based on a minimal state of charge of 30% of the BS capacity. For the battery electric flows we use a roundtrip efficiency of 90%. The battery state of charge is updated every hour.

As such, the combined hourly revenue gained for households investing in combined PV, EE and BS systems is semi-empirically modelled as in Eq. (1).

$$\textit{Combined household revenue from PV, EE and BS}_t = R_t \times (SC_t + ES_t + BS_t) + FiT \times Exp_t \qquad (1)$$

Where at hour t, R_t is a flat retail tariff rate (27¢/kWh), SC_t is the PV self-consumption, BS_t is the BS self-consumption, Exp_t is the PV export and FiT is the feed-in tariff paid for PV exports (6¢/kWh).

Results

In this section we show the operation of the combined PV-EE-BS system for three days in summer (Fig. 1) and the average first-year result of applying Eq. (1) to our household sample data (Fig. 2). The scenarios explored are: households without EE ('woEE') and with EE ('wEE'), for both cases without and with Lithium-Ion batteries of 7 and 14 kWh of storage capacity. All scenarios include 3 kW PV systems.

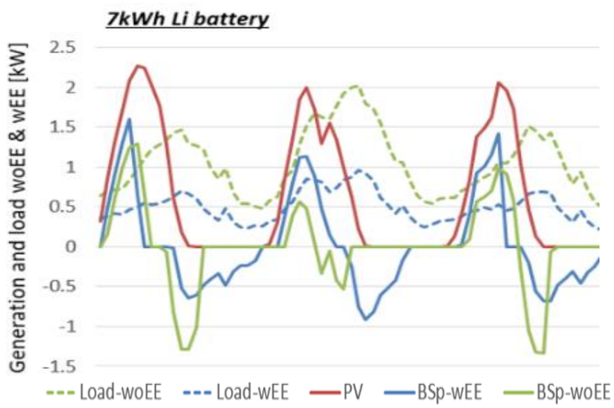

Fig. 1. Summer operation of the household (BSp is the BS power).

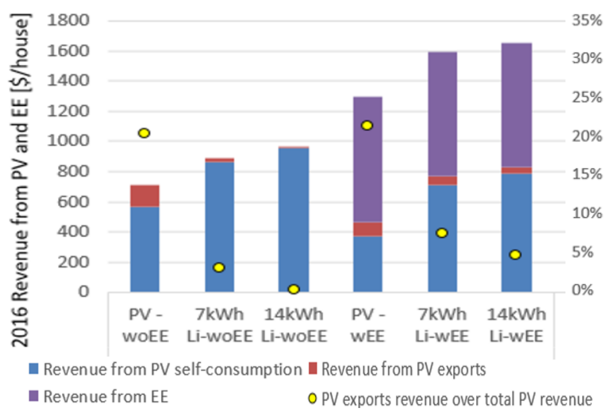

Fig. 2. First year revenue from PV and EE, with and without BS.

Fig. 1 shows the reduction of household load with EE and how BS is used to maximise PV self-consumption. While woEE the battery discharges mainly in the evening, wEE the discharge is overnight (at a lower discharge rate). This suggests that adding EE to a PV-battery system could have a large impact under a Time-of-Use tariff (not our case). EE will also have an impact on the battery capacity degradation over time and further research is required here.

Fig. 2 shows that while the addition of EE clearly reduces the PV revenue, the addition of BS increases it, although the total PVBS value is still reduced when EE is used. EE measures take considerable revenue from the PV system as EE energy savings match well the PV generation, especially on hot summer afternoons. BS ameliorates considerably the negative impact of EE on the PV value. Fig. 2 shows that by including BS about 80% more PV revenue is generated when EE has been implemented. However, we have not included the cost of BS here. In summary, BS could remove barriers to the combined uptake of these two clean energy technologies. This would be especially the case in the near future which expects a significant cost decline of battery technologies.

Conclusions

- We found that under current NB arrangements installing efficient residential appliances can increase considerably PV exports to the grid. This reduces the value of PV systems for households.
- BS systems could mitigate this unfortunate NB outcome, especially considering the expected decline in BS costs.
- Further research is required to understand the impact of EE on the long term BS capacity degradation.

References

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