Are Households Ready to Pay for Solar Panels and Smart Grids?

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Given climate change related issues, it is often asserted that renewable energy (RE), such as wind and solar power, will replace fossil fuels, therefore, justifying public policies that promote RE technologies (Van Benthem et al., 2008; Hirth, 2015). The fact that approximately 28% of global electricity consumption comes from residential buildings, RE investments at the household (HH) level can significantly contribute to the expansion of RE capacity in several regions of the world.[5] However, because the amount of RE generated depends heavily on prevailing weather conditions, and, hence, is intermittent and unpredictable, there are challenges associated with a higher penetration of RE sources (Speer et al., 2015); e.g., decrease in system efficiency, and mismatches between supply and demand.

Such developments call for grid-integration technologies and flexibility options that can enable a smooth integration of intermittent and uncertain RE, with feasible cost and stability. Effective storage capacity and demand management are some of the ways to accommodate intermittent RE (Jeon et al., 2015; De Castro and Dutra, 2011). Motivated by the fact that there is a lack of economic analysis of a decentralized clean energy investment and provision (Baker et al., 2013), we investigate the willingness to pay (WTP) of an HH for a 1.9kW peak PV system, a smart meter, and a home storage battery (Tesla Powerwall). We are particularly interested with how and whether the WTP for one of these technologies is affected by the complementary technologies. Some questions that we seek to answer are: how do smart meters and batteries affect solar PV installations?; or how do solar PV and smart meters affect battery installations? Better knowledge, in this regard, will help policy makers design public policy that is aimed at providing incentives for RE generation.

The economic profitability of PV installations is usually appraised in the literature using the concept of LCOE (Levelized Cost Of Electricity) that completely ignores the intermittency feature of PV electricity generation as it is based on annual electricity generation.[6] An exception is Mundada et al. (2016) that quantifies the economic viability of a system including off-grid PV but also a battery (and a combined heat and power system): to some extent, considering a battery in the system implicitly accounts for the intermittency of PV generation. Nevertheless, even though electricity demand management and smart grids have recently received a lot of attention both in the academic literature (see De Castro and Dutra, 2013, Leautier2014, or Hall and Foxon, 2014 and Bigerna et al., 2016) and in the media (see The Economist, 2009; The Telegraph, 2015b,a), not much work has been done that investigates the WTP of HHs for solar PV systems and smart devices.

MODELLING SMART SYSTEMS

We account for two levels of equipment in smart systems. The first one concerns the installation of smart meters, which are relatively widely used in Europe (e.g., Linky in France). Smart meters allow end-use consumers in electricity markets to monitor and change their electricity consumption in response to changes in the electricity price at different times of day (Durmaz, 2016, Borenstein and Holland, 2005 and Joskow and Tirole, 2007).[3] The second level relates to energy storage. The costs of implementing the smart grid devices is usually assumed to be borne by consumers who may, therefore, have strong resistance to the adoption of these devices (Madigan, 2011). Nevertheless, the cost of dedicated storage is high and Jeon et al. (2015) argue that deferrable demand would be a cheaper way to tackle RE intermittency.

The WTPs are likely to differ, depending on whether the legislation allows grid feed-ins from RE sources or energy storage devices. Feed-ins of power can simply be achieved by net metering, as long as this is not in conflict with the country's legislation. While the European Union and the United States allow net metering, Hong Kong and some African countries do not. Accordingly, we consider both cases to account for the two types of legislation on grid feed-ins.

We generalize Dato et al. (2017) and calibrate it on observed HH behaviors to derive WTP for solar panels and smart devices. Accounting for RE generation intermittency and grid price uncertainty, Dato et al. (2017) analyze the efficient mix of investments in intermittent RE (namely, solar panels) and smart systems (namely, smart meters and batteries). In this model, the HH can choose at each period whether to feed (resp. purchase) electricity to (resp. from) the grid or to store energy (or to use stored energy) upon RE installations. Results point out that smart devices do not automatically imply less reliance on the electric grid and that curtailment measures to avoid grid congestion can discourage investment in RE generating and energy storage capacities. We generalize the aforementioned study by accounting for more periods within a day (i.e., four periods instead of two) and by considering a whole distribution for PV generation instead of two possible realizations.

CALIBRATING ON AN EXISTING HOUSE

We use the data from a low energy dwelling, the performance of which was extensively monitored, provided by Ridley et al. (2014). This case study was chosen due to the availability of a high quality monitored data. The findings of this analysis are, therefore, based on this particular dwelling and location. The methodology outlined and tested here could of course be applied to any data from other regions and dwelling types of interest or indeed to data produced by simulation exercises.

The house was constructed in 2010 in South Wales, and monitored for 24 months to evaluate the energy and environmental performance. The two bedroom detached dwelling has a floor area 78 m2, is owned and constructed by a social housing provider and rented and occupied by a 3 person family. The low energy dwelling was designed to meet the Passive House standard to minimize space heating and was fitted with a 1.9 KW peak PV installation on the south facing pitched roof. The PV system was designed with the aspiration to produce enough electricity to offset the carbon emissions from heating, lighting and hot water consumption of the dwelling. The dwelling has no electricity storage system, but could sell surplus generated electricity to the grid, at the same price as imported electricity it bought from the grid. The extensive monitoring system logged 85 sensors, including a weather station, in the dwelling every 5 minutes for 2 years, including all electricity sub circuits and the quantity of electricity exported to and imported from the grid. Hourly data from May 2012 to April 2014 was used in this study.

Using the data, we produce three figures (Figure 1). The first figure from the left presents the 2x365x24 observations for solar power generation and electricity consumption for the passive and low carbon Welsh house. While the second figure demonstrates the expected values for solar power generation and electricity consumption each hour, the last figure presents a smoothed version of the second one. As is also indicated in the last figure with the dashed-green line, the first period is the late-night and early-morning period. While the first peak from the left, that is, morning peak load, covers the second period, the midday does this for the third period. Lastly, the second peak, which is the evening peak load, is incorporated in the fourth period. For a constant price of electricity (15pence/kWh during the period in consideration) and for a given amount of consumption, c, the electricity is relatively valued the most on the margin in the evening-peak period. While the electricity is valued relatively less on the margin in the morning-peak period, it is valued the least in the first and third periods. This analysis is carried out for each season.

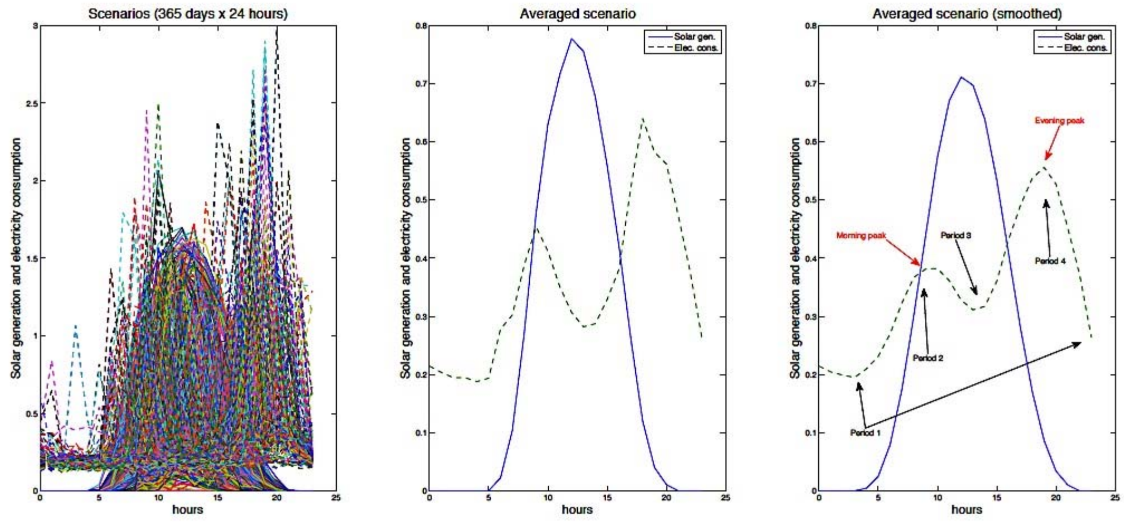

Figure 1: Solar power generation and electricity consumption.

COMPUTING THE WILLINGNESS TO PAY

We consider 8 different scenarios/cases, whose features are described below, and compute the total daily welfare for each season. In all of the cases, electricity consumption decisions are taken optimally.

Case 1. storage + solar panels + dynamic pricing
Case 2. solar panels + fixed pricing (storage is then irrelevant)
Case 3. storage from solar panels only +dynamic pricing (note: we can decide whether to consume or store from PV)
Case 4. storage from solar panels only and PV generation first fills the battery
Case 5. storage + no solar panels + dynamic pricing
Case 6. no storage + solar panels + dynamic pricing
Case 7. no storage + no solar panels +dynamic pricing
Case 8. no storage + no solar panels + fixed pricing (storage irrelevant)

By computing the discounted difference between these welfares, we can derive the WTP for each device. Comparing this WTP with the actual cost of the device we can then conclude whether it is profitable for the HH to install it or not. Our results indicate that having access to a storage device can allow a HH to take a better advantage of a smart meter, whose cost of installation, as put by the Department of Energy and Climate Change (DECC), is £214.50. Complementing the storage device with a PV system induces a further willingness for the HH to install a smart meter. Yet, this impact is rather limited. Having an HH that cannot store energy but can still generate electricity through the PV system would not justify the installation of the smart meter. Considering the 1.9kW peak PV system with an establishment cost of £2755, we find that it would significantly be beneficial for the HH to install the PV system regardless of the pricing scheme and the possession of the storage device. Furthermore, having access to solar PV does not contribute significantly to the willingness of the HH to install the battery pack with a cost of approximately £2300 (3000 USD). While in some regions and countries, such as the European Union and the U.S., net metering is allowed, it is not in some others like Hong Kong and some African countries. Therefore, we also investigate the WTP for smart meters, solar panels and storage devices when legislation prohibits net-metering. Consistent with the intuition, our results indicate that the WTPs for solar panels or smart grid devices are always smaller than the WTPs when the HH can feed-in the grid.

These results suggest that the first public policy to be implemented to foster the adoption of RE should concern the possibility of net-metering. However, net-metering is already possible in some countries and where it is not, this implies changes in legislations that may be difficult to implement due to the lobbying of some reluctant electric utilities concerned with their market shares. In countries where it is already possible to feed the grid, public policy should be focused on storage and smart devices. On the contrary, solar panels themselves seem to be already profitable and do not require any public policy support. In countries where net-metering will not be easily implemented soon, subsidizing storage would have the joined positive effect of making smart meters profitable as well, even without any targeted policy. However, the most efficient public policy should probably focus on solar panels as their net present value is not very negative, meaning that even a small subsidy can be enough to trigger solar PV installation.

Footnotes

[1] The share of the global electricity consumption is calculated from the data provided in Table F1 in EIA (2016).

[2] Note that LCOEs have been computed both in the context of residential systems (Reichelstein et al. 2013 or Branker et al, 2011, and Hagerman, 2016) and at the utility scale (see Darling et al, 2011).

[3] Do note that the export of PV generated electricity to grid can be achieved with the installation of an extra dumb meter that measures generation. Accordingly, it does not necessarily have to be smart.

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