Incentivizing Electricity Consumers to Match their Consumption with Local Solar Production

Rudolf Kapeller, Energieinstitut an der Johannes Kepler Universität Linz, +43 732 2468 5642, kapeller@energieinstitut-linz.at
Jed J. Cohen, Salt River Project, Tempe, AZ (USA), jedcohen@vt.edu
Andrea Kollmann, Energieinstitut an der Johannes Kepler Universität Linz, +43 732 2468 5660, kollmann@energieinstitut-linz.at
Johannes Reichl, Energieinstitut an der Johannes Kepler Universität Linz, +43 732 2468-5652, reichl@energieinstitut-linz.at

Overview

The European Union's ambitious greenhouse gas emission goals, which target a reduction of 60% until 2030 (compared to 1990), demand for a significant increase of renewable energy generation capacities. The EU's renewable energy policy for the next decade is driven by the recast Renewable Energy Directive (RED II), in which a 32% share of renewable energy by 2030 (compared to 1990 levels) is targeted.

In the residential sector, photovoltaic systems have grown at an exceptional pace in the past and are expected to be deployed even more rapidly in the coming decades.[1] While this constantly increasing generation of electricity from decentralized photovoltaic power plants will play a significant, positive role in the achievement of the energy transition, it also comes with challenges for the existing electricity grid infrastructure, making balancing production and consumption increasingly complex. Traditional measures like grid extension or enforcement can deal with the arising need for higher grid capacity, but face opposition due to their costs, environmental impact and social acceptance.[2,3] Thus, low impact measures that allow for the feed-in of large amounts of renewably generated electricity and either accompany grid enlargement/enforcement measures or, wherever possible, substitute them, are called for.

As part of an Austrian research project, we aimed at quantifying the effect one such potential measure, load shifting in the residential sector, has on the local electricity grid. This paper presents the results of a 12-month field trial in which residential electricity consumers were given monetary incentives to shift their electricity consumption to times of high local solar production.

Methods

Within the project LEAFS [4], residents of an Upper Austrian village (Eberstalzell, Austria) were recruited to join our field test. In total, 184 households (about 20% of the local population) agreed to participate and were invited to download a specifically created smartphone app. Via this app they got access to their electricity consumption data (including their 15-min load profiles). Electricity consumption data was collected from April to October 2018 and additional surveys were done to collect socio-economic characteristics as well as information about their housing situation (type of house, size, appliances, etc.). The field test tested the 'Sonnenbonus' ('sun bonus') treatment, which sent a message over the app to participants informing them that during certain times of the following day their electricity price would be reduced by 10 cents/kWh and that they are encouraged to shift their electricity consumption to these time slots. The messages were sent out based on local weather forecasts to ensure that discounts coincide with actual times of high local solar energy production.

To analyze the causal effects of the treatment on households' load shifting, we employ a fixed effect panel data estimation strategy with electricity consumption as dependent variable and a treatment dummy as explanatory variable, as well as household and time fixed effects. Since the treatment coincides with sunny weather and there are no control households, we created a synthetic control group via a matching algorithm with data on Upper Austrian households from another project (PEAKapp, [5]), in which the same set of data as in the LEAFS project was collected in Upper Austria (15 min load profiles, socio-economic data, housing characteristics) and performed a second analysis.

Results

Analyzing the household consumption data revealed that households are able and willing to adjust their electricity consumption pattern to local PV production potentials. In times of discount, households increased their consumption by more than 5%. On the weekends, the Sonnenbonus treatment is less effective and effects are not statistically significant, with around 2% estimated treatment effects. In addition, there is no statistically significant effect on Wednesday. In contrast, Thursday shows the highest treatment effect with an 11% increase in household electricity consumption for times in Sonnenbonus. Turning to hourly effects, we observe positive effects from 8am to 3pm. Increases range from 4% at noon to 7.4% at 10am during times when the Sonnenbonus was active. Importantly, we observed a load shifting effect as households decreased their consumption in times of no discount on days when a discount was given at any time by around 3%. Overall, this decrease outweighed the increase in times of discount leading to a reduction in daily electricity consumption.

The design of the field trial tried to trigger manual loadshifting activities of households. By being informed on the day before the actual Sonnenbonus was active (the push message was sent at 4pm) the idea was that households can reschedule their electricity consumption, e.g., delay the use of the washing machine to the discounted times on the next day. In discounted times, households can increase their electricity consumption by undertaking delayed chores or performing other/additional electricity intensive actions. Interestingly, the results of a post-trial survey, in which we asked participants about how they perceived the trial and how they actually achieved loadshifting, a frequent answer was that they made use of the timing functionalities of their household appliances (eg washing machine), thus using semi-automatic processes to shift their consumption.

Conclusions

In order to reach the ambitious challenges of the European Union's Green Deal and the Paris Agreement to make Europe the first carbon neutral continent by 2050 swift action is needed involving a broad range of actors. In the recent past, the EU and its member states have made significant progress with the digitalization of the energy sector, the advancement of energy innovation and technologies, energy efficiency uptake, and the continuous shift towards renewable energy sources. Today, there are still significant open questions when it comes to understanding the positions, opportunities, barriers and motivations of electricity consumers in the energy transition. With ever increasing shares of (distributed) residential renewable energy generation, a better understanding of their consumption flexibility is paramount.

As part of the Austrian research project LEAFS, we designed a field trial in which we set out to see if there is a significant load shifting potential on the household level that can be utilized via financial incentives when the local electricity grid is under stress due to high local solar production. Households were informed via a smartphone app about times of high solar production in their municipality (based on actual local weather forecasts) the day before local solar production was particularly high. In such time slots, the Sonnenbonus, a 10 cents/kWh bonus on every kWh consumed in these time slots, was active. Analyzing consumption data from households participating in the field trial revealed that households are able and willing to adjust their electricity consumption pattern to local PV production potentials. In times of discount, households increased their consumption by more than 5% on average. Importantly, we observed a load shifting effect as households decreased their consumption in times of no discount on days when a discount was given at any time by around 3%. This decrease even outweighed the increase in times of discount leading to a reduction in daily electricity consumption.

References

1. Kougias, I., N. Taylor, G. Kakoulaki, and A. Jager-Waldau (2021). The Role of Photovoltaics for the European Green Deal and the Recovery Plan. Renewable and Sustainable Energy Reviews 144, 111017.
2. Cohen, J. J., J. Reichl, and M. Schmidthaler (2014). Re-focussing research efforts on the public acceptance of energy infrastructure: A critical review. Energy 76, 4–9.
3. Herding, L., R. Cossent, M. Rivier, J. P. Chaves- ́Avila, and T. G ́omez (2021, dec). Assessment of electricity network investment for the integration of high RES shares: A spanish-like case study. Sustainable Energy, Grids and Networks 28, 100561.
4. This project (2015-2018) was funded by the Austrian Research Promotion Agency (FFG) and its main goal was to evaluate the effects of increased consumer and energy market driven utilization of energy storages and load flexibility on power distribution grids. In addition, it was analyzed how customers can be motivated to adjust their electricity consumption and thereby possibly everyday habits to local electricity production. For more information please see https://energieinstitut-linz.at/portfolio-item/leafs
5. PEAKapp (2016-2019) was a Research & Innovation project funded by the European Union's Horizon 2020 programme under GA#695945. For more information please see http://www.peakapp.eu/