RESIDENTIAL BATTERY STORAGE – DRIVER OR INHIBITOR OF THE SOLAR REBOUND EFFECT?

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Overview

The transition to a climate-neutral society with renewable energy requires the participation and involvement of citizens. With 3.4 million installed PV systems with a capacity of 81.5 gigawatts, private households were already making an important contribution to the energy transition in Germany in 2024 (Statistisches Bundesamt 2024). However, the availability of cheaper (if not free) electricity may tempt individuals to consume more. In recent years, several articles have appeared, giving evidence that consumers increase their electricity consumption after installing PV systems (Aydın et al. 2023; Beppler et al. 2021; Kim and Trevena 2021). The so-called "solar rebound effect" (SRE) can be defined as the increase in a household's total electricity consumption per unit of solar power generated. This phenomenon is not only ecologically but also economically undesirable. The SRE may lead to additional costs and more CO_2 being emitted at the system level, compromising the achievement of climate targets. Moreover, the change in consumption behavior complicates the operational and long-term planning for electricity suppliers and system operators.

While there is a consensus on the existence of the SRE, there is still uncertainty regarding the exact underlying causes. On the one hand, microeconomic factors like price and income effects due to lower electricity prices (Deng and Newton 2017) or substitution effects (Galvin et al. 2021) may be the cause. On the other hand, psychological reasons such as moral licensing are also cited as possible causes (Dütschke et al. 2018). This study aims to investigate whether and how the presence of a battery storage device in a PV household affects the SRE. If the SRE is significantly higher for storage owners, this suggests that a consistently low electricity price (not just during solar radiation) increases electricity consumption. This would substantiate the microeconomically motivated hypothesis. However, if the SRE is significantly lower for storage owners, this could indicate that consumers no longer feel the pressure to consume more electricity in times of high solar generation. Consequently, they may return to their old behavior before the PV installation.

In a preliminary study (Poier and Bucksteeg, 41st USAEE North American Conference, 2024), we were already able to show that both positive and negative SRE are possible at the household level. In this investigation, the focus is on the co-adoption behavior of households. By this means, the drivers of a negative or positive SRE arising from replacing old electric appliances with new energy-efficient devices or adopting additional power-consuming devices will be analyzed.

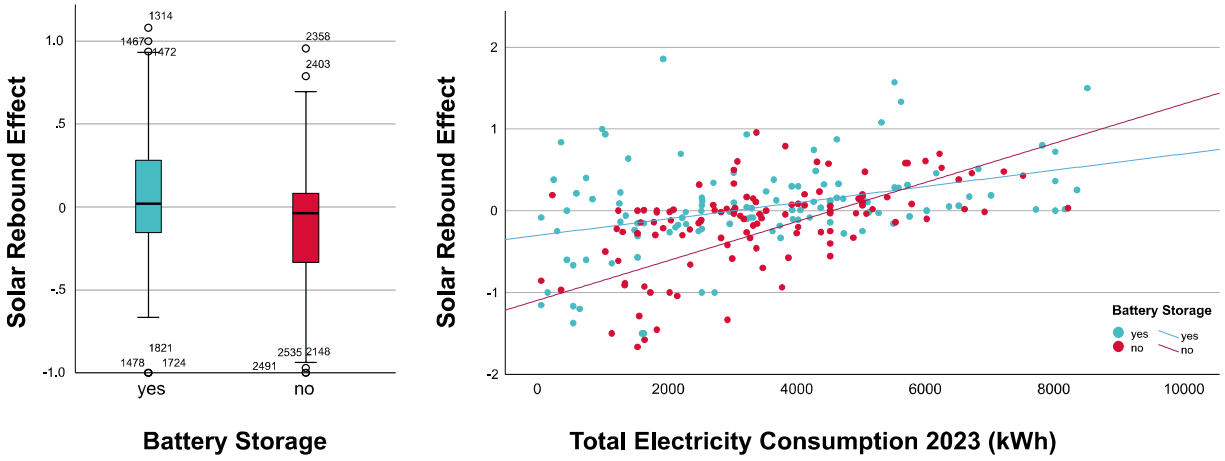
Methods

For our study, we conducted an online survey using an incentivized consumer panel (n = 2,240) in February 2024, where the respondents should report their current electricity consumption and consumption before PV installation. In addition, households were asked about their equipment with electrical devices and large consumers such as electric cars or heat pumps.

Longitudinal studies have previously shown that there has been a negative trend in the total electricity consumption of households in Germany over the last 10 years. To account for this trend and differences in household characteristics regarding the SRE, we conduct a two-way fixed effects regression with least squares dummy variables to isolate the global SRE. To ensure that differences between adopter and non-adopter households do not distort the results, a propensity score matching is done between both groups beforehand. In addition to the global SRE, the SRE at the household level is also determined as the quotient of the change in total electricity consumption and the amount of electricity generated. With the help of linear regression at the household level, the effect of battery storage and other devices on the SRE will be determined.

Results

A preliminary analysis for PV households shows a slightly higher total electricity consumption (mean = 3,416.27 kWh) and also significantly higher electricity generation (mean = 5,066.70 kWh) among battery owners versus non-adopters (3,324.88 kWh and 4,626.04 kWh, respectively). After calculating the SRE at the household level, PV households without battery storage have a negative SRE on average (mean = -0.277, SD = 0.974). In contrast, battery households have a more extensive, positive SRE (mean = 0.048, SD = 0.555). The scatterplot indicates that battery households have a higher SRE on average for total consumption of up to almost 6,000 kWh. However, the steeper slope suggests that non-adopter households have a higher SRE for very high consumption.



Conclusions

The low SRE for many households (both adopters and non-adopters of battery storage) indicates that they want to save money with the PV system and reduce their total electricity consumption. Above a limit of approx. 4,000 kWh, the average SRE becomes positive, indicating increased consumption. The differentiated results could suggest that adopter households with lower consumption are more likely to be tempted to consume more electricity. At the same time, this is only the case for non-adopter households when electricity demand is high. It could also mean that battery storage stabilizes the SRE over electricity consumption. Further research will focus on the co-adoption and the drivers of the SRE arising from replacing or adopting additional devices.

References

Aydın, Erdal; Brounen, Dirk; Ergün, Ahmet (2023): The rebound effect of solar panel adoption: Evidence from Dutch households. In *Energy Economics* 120, p. 106645. DOI: 10.1016/j.eneco.2023.106645.

Beppler, Ross C.; Matisoff, Daniel C.; Oliver, Matthew E. (2021): Electricity consumption changes following solar adoption: Testing for a solar rebound. In *Economic Inquiry* 61 (1), pp. 58–81. DOI: 10.1111/ecin.13031.

Deng, Gary; Newton, Peter (2017): Assessing the impact of solar PV on domestic electricity consumption: Exploring the prospect of rebound effects. In *Energy policy* 110, pp. 313–324. DOI: 10.1016/j.enpol.2017.08.035.

Dütschke, Elisabeth; Frondel, Manuel; Schleich, Joachim; Vance, Colin (2018): Moral Licensing—Another Source of Rebound? In *Front. Energy Res.* 6, Article 38. DOI: 10.3389/fenrg.2018.00038.

Galvin, Ray; Dütschke, Elisabeth; Weiß, Julika (2021): A conceptual framework for understanding rebound effects with renewable electricity: A new challenge for decarbonizing the electricity sector. In *Renewable Energy* 176, pp. 423–432. DOI: 10.1016/j.renene.2021.05.074.

Kim, Jae D.; Trevena, William (2021): Measuring the rebound effect: A case study of residential photovoltaic systems in San Diego. In *Utilities Policy* 69, p. 101163. DOI: 10.1016/j.jup.2020.101163.

Statistisches Bundesamt (2024): 3,4 Millionen Photovoltaikanlagen in Deutschland installiert. Edited by Statistisches Bundesamt. Available online at https://www.destatis.de/DE/Presse/Pressemitteilungen/2024/07/PD24_N038_43.html, updated on 7/29/2024, checked on 1/8/2025.