PROSUMAGE OF SOLAR ELECTRICITY – THE ROLE OF POWER-TO-HEAT

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Overview

Spurred by technology development and regulatory frameworks, self-consumption of distributed renewable electricity generation has gained relevance in many power markets around the world. Building on the concept of "prosumers" (producers and consumers), the term "prosumage" has emerged. Prosumage additionally includes energy storage that can be used to increase self-consumption (producers, consumers and storage). Here we define prosumagers as grid-connected electricity consumers who own small-scale PV generators as well as batteries, and use these installations to produce their own electricity at times, draw electricity from the grid at other times, and feed electricity to the grid at yet other times. Further, we explicitly include potential additional grid interactions of prosumagers' batteries.

In a paper recently published in *EEEP*, we discussed arguments in favor of and against increasing prosumage, gave a brief overview of prosumage developments in Germany, and presented a quantitative model analysis to illustrate possible system effects of increased prosumage (Schill et al. 2017). Building on this approach, we now explore the effects of additional decentral power-to-heat interactions. Prosumagers may not only use batteries to increase their rate of self-consumption, but may also switch to electric heating (cp. Green and Staffell 2017). Compared to pure battery-prosumage, adding decentral power-to-heat options to the picture may lead to different system effects. We thus include electric storage heaters in the model and analyse their effect on system costs, battery storage requirements, and induced generation portfolio changes.

Methods

We use an extended version of the open-source electricity system model DIETER (www.diw.de/dieter) applied by Schill et al. (2017). The model's objective is to minimize overall system costs, consisting of investment and operational costs, over one year in hourly resolution. Input data is based on 2035 projections for Germany concerning both future costs and availabilities of technologies, and employs inelastic hourly demand and feed-in factors of variable renewables in Germany. 25% of overall solar PV capacities and a corresponding share of the electric load are attributed to the prosumage segment. We augment the model by a generic representation of electric storage heaters and residential heat demand. Heat demand profiles are derived from an ongoing European research project.

In each hour, energy generated by prosumage PV is either consumed directly, sent to the market, curtailed, enters the prosumager storage, or is charged into the storage heating system (Figure). An hourly prosumage energy balance ensures that prosumagers' electricity and heating demands are satisfied, by direct self-consumption, consumption of energy from the market or discharging from prosumager storage. Accordingly, our model setup does not explicitly consider prosumagers' incentives (like, for example, Borenstein 2015), but implicitly approximates such incentives by means of a minimum self-generation constraint. This requires that at least a specified exogenous share of prosumager energy demand stems from direct PV self-consumption or from PV energy discharged from the prosumager battery. We vary this share in different scenarios.

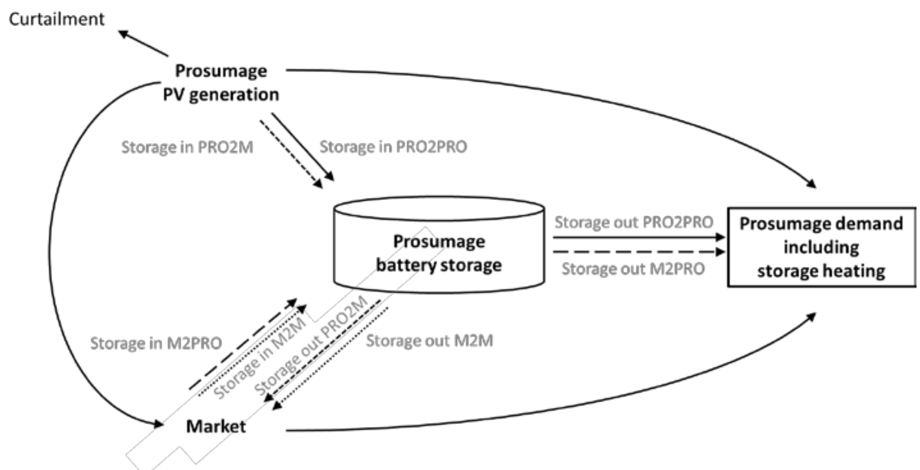

Figure 1: Schematic illustration of the prosumage segment in the augmented model

We analyze different cases which vary with respect to the degree of system orientation of prosumagers, ranging from myopic behaviour, i.e. purely focusing on self-consumption, to perfect system-orientation. We further separate the effects of additional power-to-heat aplpications by comparing scenarios with and without residential storage heaters.

Preliminary results

Notwithstanding potentially positive socio-economic aspects of solar prosumage, which are not quantified here (cp. Schill et al. 2017), an expansion of the prosumage segment entails efficiency losses. Total system costs rise with increasing self-consumption requirements as redundant storage infrastructure is built. Yet the cost increase is lower for higher degrees of market interaction of prosumage storage. In case the full flexibility of decentral batteries and storage heaters is available for the entire power system, efficiency losses can be mitigated to a substantial extent.

Focusing on electric heating, the analysis indicates that flexible stoage heaters not only lead to lower system costs, but also allow for higher self-consumption rates when compared to inflexible (direct or night-time) electric heating. Yet the introduction of electric heating requires an additional expansion of renewable power generation. Otherwise, the renewable share in the power sector would decrease, and storage heaters would ultimately increase the utilization of emission-intensive base- and mid-load plants. Further, we find that a shift toward electric heating triggered by prosumage can increase the system's peak load during the heating season.

Conclusions

Our model-based illustration of possible system effects of increased prosumage, calibrated to a German 2035 scenario, shows that growing self-generation shares increasingly require battery storage and trigger system cost increases. These are minimal for full market interactions of prosumage batteries. This market interaction will likely require appropriate communication infrastructure, respective aggregators, and a supportive regulatory framework.

With respect to electric heating, we show that flexible storage heaters are far superior as compared to inflexible or night time-charging electric heaters. Yet an expansion of electric heating should be accompanied by an according expansion of renewable power generation in order to prevent negative effects on overall emissions and renewable shares in the electricity sector. Most importantly, electric heating should not increase the system's residual peak load. According to our analysis, this could be only partially mitigated by increasing the flexibility of storage heaters; although not explicitly modeled here, the use of bivalent heating technologies that are able to operate without drawing electricity from the grid at times appears to be more promising in this respect.

References

Borenstein, S. (2015). The private net benefits of residential solar PV: the role of electricity tariffs, tax incentives and rebates. NBER Working Paper 21342. https://doi.org/10.3386/w21342

Green R. and I. Staffell (2017). "'Prosumage' and the British electricity market." *Economics of Energy & Environmental Policy* 6(1): 33–50. https://doi.org/10.5547/2160-5890.6.1.rgre

Schill, W.-P., A. Zerrahn, F. Kunz (2017). „Prosumage of Solar Energy: Pros, Cons, and the System Perspective." *Economics of Energy & Environmental Policy* 6(1): 7-31. https://doi.org/10.5547/2160-5890.6.1.wsch