Local Energy Sharing Considering Different Technologies, Individual Preferences, and Contributions

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Overview

The concept of optimizing local photovoltaic (PV) self-generation and consumption on 'prosumers' level is already well established in many European countries. Recently, a further development of this concept beyond individual prosumer boundaries to neighborhood and district level has been triggered not least by the 'EC Clean Energy Package' (the establishment of energy communities and further 'democratization' of the energy system is explicitly mentioned). Moreover, favorable amendment of legislation and regulations in this context have been made in some European countries (e.g. Germany, Austria). Thus at present local energy communities are arising, being different in e.g. terms of renewable technologies, system boundaries (building level, spatial extent, distribution grid anatomy, peer-to-peer matching/trading in a wider context, etc.), diversity of actors involved, individual objectives of actors and available synergies among them, and many others. It is important to note that several of these types of energy community concepts are on a voluntary basis. Therefore, it is possible to talk about full democratic participation in energy systems, only when considering the individual needs of several actors.

Methods

A local energy community in Austria with a small number of households (single-family houses or multi-apartment buildings in a small village or local district/neighborhood of a city) with photovoltaic systems (PV) and battery storages of different dimensions is considered. Each household i is assigned a different load profile $q_i(t)$ and a willingness-to-pay WTP_i for the locally generated PV energy according to the individual preferences avoiding emissions. Considering the WTP of each prosumer, the generated PV-energy is distributed within the community. The goal is to maximize the total community welfare CW[1], which means maximizing the PV-self-consumption of each prosumer as well as maximizing the profits from sharing energy considering the WTP.

The next step is to find out the optimal technology portfolio for each actor (prosumer) of the community. Not all participants are willing to invest in photovoltaic systems or battery storages. The other members of the community are participating as consumers with a WTP depending on individual preferences. For those investing in PV and storage, an investment model over 25 years is created in order to find the optimal technology portfolio of the community.

Finally, it should be possible for each prosumer to phase-in or phase-out of the community or changing one's willingness-to-pay on a yearly basis resulting in frequent reallocations of the default set-up. This study is conducted again over the period of 25 years.

Results

The default case considers an energy community with 10 prosumers with different load profiles, each of them equipped with PV and battery storage of different scale. The model generates an optimal output for the community over a year. Prosumers with a relatively large photovoltaic system and storage are the most economical actors within the community, because they can share a lot of their PV generated energy and minimize the amount of energy sold to the grid. This result shows that for each prosumer there is an optimal peak power of the PV and optimal storage capacity and that there is an optimal case for the community welfare. Therefore, this work gives an optimal design of the renewable technology portfolio tailor-made to the actors' characteristics and the size of the local energy community. The investment model considers not only the income from selling PV energy, but also expenditure from different parts of the community.

Conclusions

Based on the results achieved from the quantitative studies together with analyses made in Austria, further studies for other European ‘reference countries’ are interesting. Finally, a quantitative upscaling of the short- and long-term local energy community potential should be conducted for Europe as a whole.

References

[1] Fleischhacker, Andreas, Hans Auer, Georg Lettner und Audun Botterud (2018). Sharing solar PV and energy storage in apartment buildings: resource allocation and pricing. In: IEEE Transactions on Smart Grid, ISSN: 1949-3053. DOI: 10.1109/TSG.2018.2844877