Community battery storage dimensioning and scalability analysis with rule-based energy flow simulations

Active end customer-/prosumer participation

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Motivation and research question

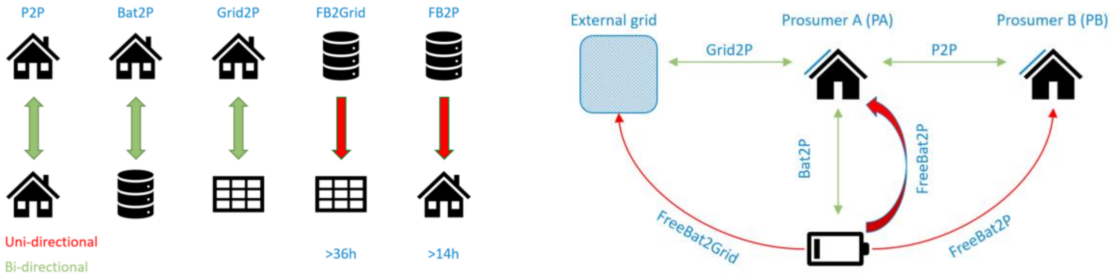
Energy communities exhibit a high share of decentralized local energy generation which in general do not chronologically fit to the local energy demand. Flexibilities are needed to match the time series of demand and generation inside the community to allow an efficient operation and thus, to increase the self-consumption of the community. This work tackles this issue through using a central electrical community storage. The focus is in determining a proper storage capacity according to the community setup through incorporating technical and economic related aspects. A couple of defined KPIs are used to investigate the scalability. The shown work is done in course of the research project CLUE.

Methodology

This work investigates an energy community in Styria, Austria with a high share of local photovoltaic energy generation (157 MWh/a) compared to consumption (160 MWh/a). Since the time series of local generation and consumption do not chronologically match, flexibility in form of an electrical battery storage system is used. The aim is to determine a proper capacity of such a storage. This is done through doing annual energy flow simulations, based on a predefined set of rules for the virtual energy flow. After executing these simulations, tariffs are applied on the resulting energy flows to get detailed cash flows for the subsequent economic analysis. The predefined rules for the energy flow simulations between prosumers, public grid and the central storage are shown in Figure 1. The most relevant part for the battery dimensioning is the implemented *"discharge strategy"* algorithm of the central storage:

1. If a prosumer charges battery, the energy can be reused by the same prosumer for 14 hours.
2. If the energy is not used within 14 hours, it is offered to other prosumers for another 22 hours.
3. If the energy is not used within these 36 hours from anyone in step 1 or 2, the remaining energy is sold to the energy retailer via the public grid.

This discharge strategy supports an optimal utilization since the state of charge of the battery does not stagnate at full-charge state caused by "over-feed-in" and motivates the community members to use the energy for better prices in a 36-hour time window.



(a) **(b)**

Figure 1: (a) Individual possible energy flows inside the community
(b) Interconnection of defined rules and participants

Results and conclusion

Four different scenarios are investigated and compared among each other:

1. Basic scenario: The entire demand of the community is covered through the external grid only
2. P2P trading scenario: P2P trading (within the community) is done primarily
3. Storage scenario: Self coverage is done primarily
4. Storage scenario with P2P trading: Self coverage is done primarily followed by P2P trading

In all scenarios, the external grid covers the remaining needed energy exchange of the community.

The annual energy flow simulations with a 15-minute time resolution are executed for each scenario with following different storage sizes: 50, 100, 150, 200, 300 and 400 kWh. Following KPIs are evaluated based on the simulation results:

- Charging and discharging of the battery.
- Amount of P2P traded energy
- Energy exchange with the external grid

Figure 2 show four KPIs derived from the annual energy flow simulations. It describes the freed unused energy out of the battery absorbed through the external grid, forced by the implemented discharge algorithm. Until a size of 200 kWh, all generated energy inside the community can also be used over the whole year in a 36-hour time window. The depicted KPIs show a saturation or change point at 150 kWh, which can be interpreted as the optimal size for this community setup.

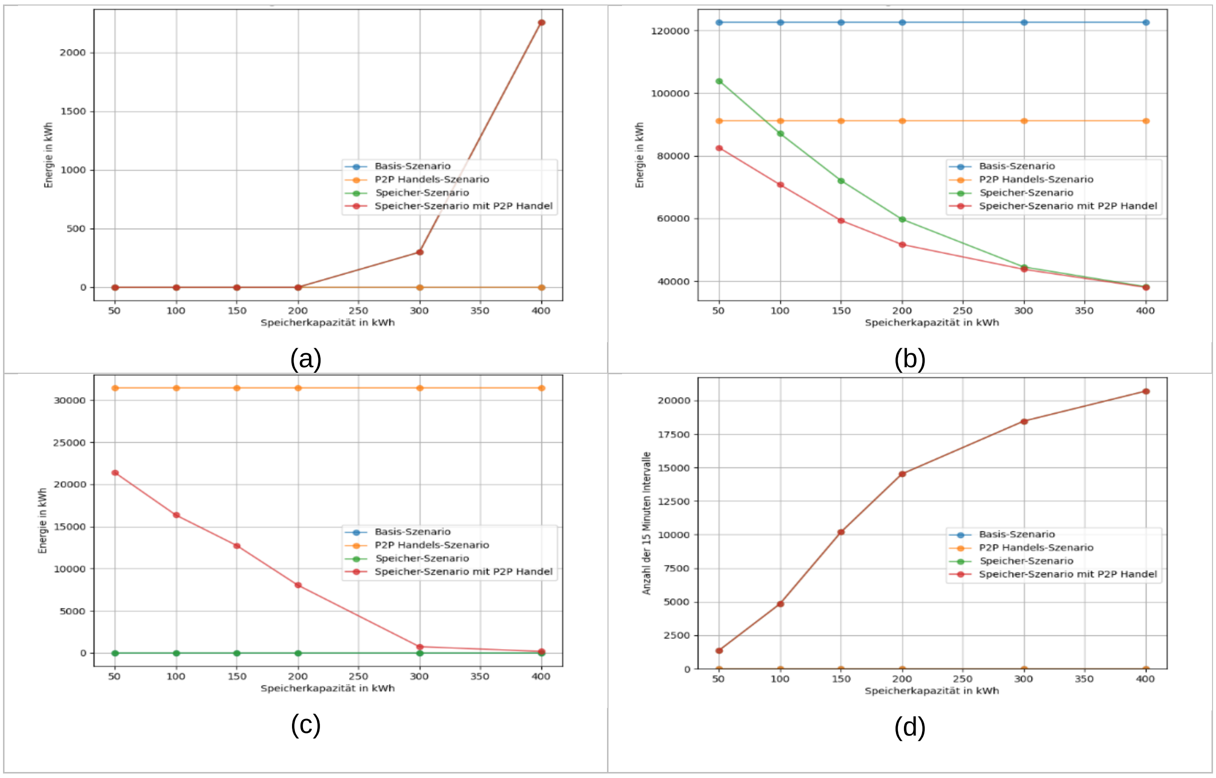


Figure 2: Calculated KPIs out of the annual simulations:
(a) Discharged energy from the battery to the external grid
(b) Energy provided from the external grid to the community
(c) Energy exchanged between prosumers inside the community
(d) External grid in idle mode

Figure 3 shows the result of the cash flow analysis with the applied tariffs on the resulting energy flows. The value on the y axes represents the savings of the respective scenario compared to the basic scenario. A saturation at about 150 kWh can be identified.

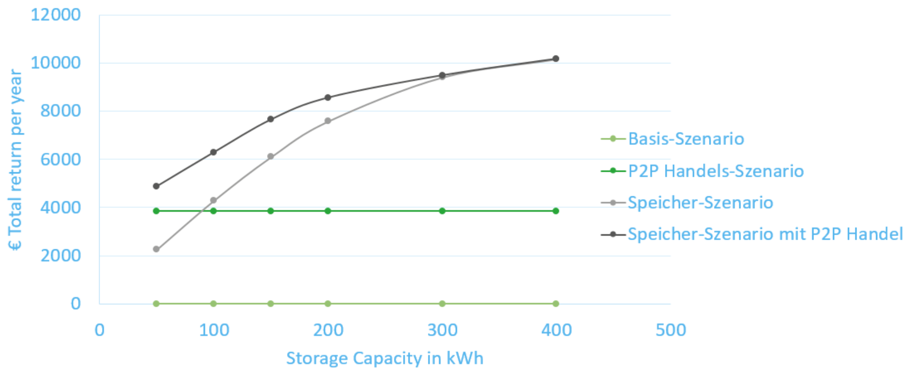


Figure 3: Cash flow analysis

Dependent on the community setup, it is meaningful to do a pre analysis based on the shown approach to allow an efficient planning flexibility utilization in an energy community. Investors can specify the planned rules and time frames in which the planned storage should be best utilized.