Community Battery Storage

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1. Introduction

In order to guarantee the security of supply with renewable energies, technologies are needed that can compensate for the temporal shift in generation and consumption of fluctuating producers. Community storage facilities, which are used collectively in settlements, could play a key role in the energy transition. These were investigated in more detail in the funding project "Quartiersspeicher" (Community storage) of the Cologne University of Applied Sciences in cooperation with the law faculty of the University of Cologne [3]. The project was funded by the Rheinenergiestiftung. Furthermore, discussion rounds were held with experts from the Solarenergie-Förderverein Deutschland e.V. (SFV). A collection of literature on the topic and example projects can be found in a compiled collection of links [5].

In the funding project, the basic technical advantages and disadvantages were determined, and various modes of operation and the necessary measurement technology and billing were discussed.

2. Data base

The study was carried out on a fictitious residential area (see Figure 1). It consists of 22 newly built buildings that differ in construction, orientation and size of the installed photovoltaic (PV) system. Nevertheless, the houses are geographically located in close proximity and are grouped together as a neighbourhood.

Figure 1: Illustration of the exemplary community.

As a simple mode of operation, surpluses from the PV systems installed in the house are fed into the respective storage units and withdrawn again as needed. Due to rising electricity purchase costs and falling EEG compensation rates, increasing self-consumption, i.e. the use of self-generated electricity, is much more attractive than feeding the electricity into the public grid [2]. Thus, the storage topologies in the project are operated with the strategy of optimising self-consumption.

For an investigation of such a purpose, load and generator profiles of each individual household have been artificially created. The load profile generator by Noah Pflugrath (dissertation at Chemnitz University of Technology, http://www.loadprofilegenerator.de) [4] was used for the load profiles, which creates behaviour-based individual usage profiles of electrical devices in a household. For the PV profiles, real measured data of an existing PV system in Cologne Porz for the year 2018 were used and scaled to the respective assumed system size. Figure 2 shows one of the load profies and one of the PV profiles for one day as an example. Random but typical peak outputs were selected for the system sizes, which would cover the annual electricity demand of the inhabitants, at least in balance sheet terms.

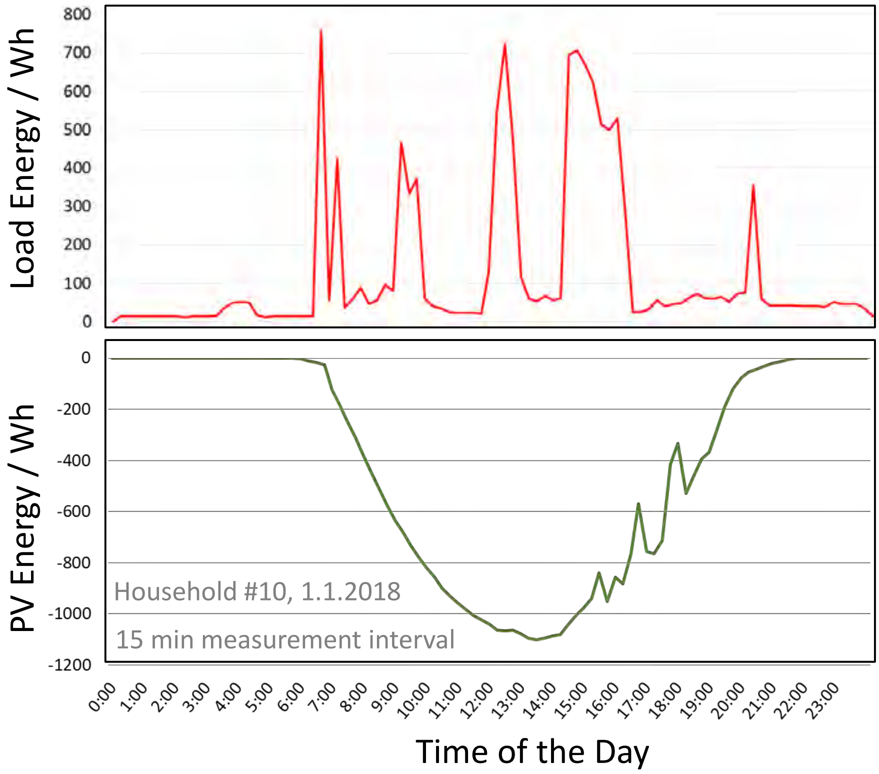

Figure 2: Exemplary load and PV profiles for one day.

To calculate the electricity balance, the load and PV profiles were subtracted by calculating the difference for each point in time. A surplus calculated from this is considered as fed-in grid electricity and a shortage as the purchase of grid electricity. Figure 3 shows the yearly energy consumption, PV generation, the energy used from the grid and the grid feed-in for each individual household without any storage.

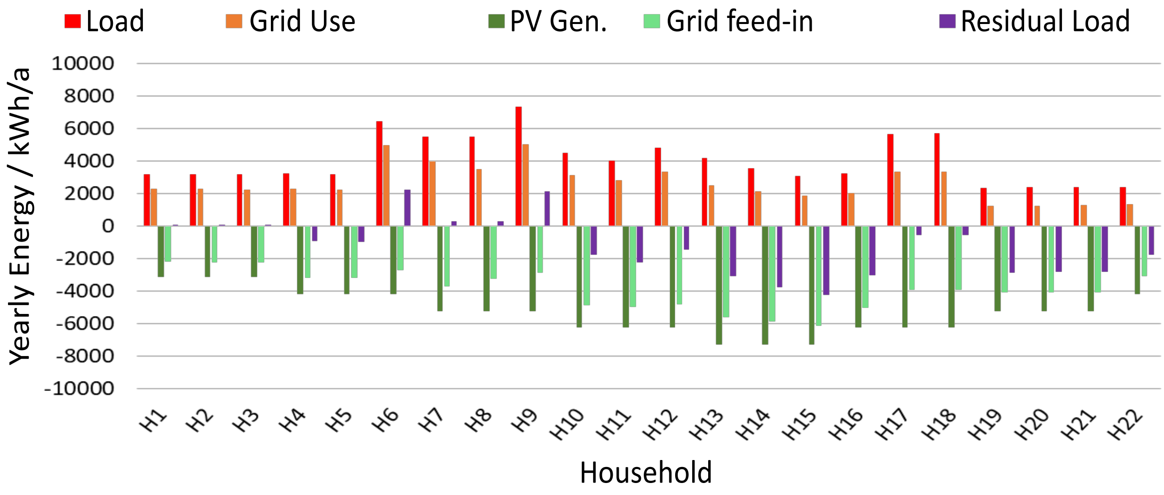

Figure 3: Yearly consumption, PV generation, grid use and grid feed-in for each individual household without storage.

In the calculation, an overall efficiency of 90% was assumed for a storage cycle. This can typically be achieved using lithium-ion technology, which is practically standard for home and community storage systems today [1].

3. Technical advantages

3.1. Degree of self-sufficiency and storage size

The degree of autarky (self-sufficiency) is used here as a criterion for comparison. This is a measure of the desired independence from an external power supply and financial optimisation. At the same time, a high degree of self-sufficiency means minimising the purchase of grid electricity, which today still contains a considerable amount of fossil-generated energy, whereas the self-generated electricity is produced with only low climate gas emissions from photovoltaics.

First, the effect of shared energy use without storage was investigated. This is based on the assumption of a mutual use of PV surplus in the energy community. In the case of individual self-use of PV, the individual households achieve a degree of self-sufficiency of about 35% on average, because PV electricity is not always available at times of energy demand, while at other times the generated PV electricity cannot be used and is fed into the grid instead. In the case of mutual use, it is more common that the generated PV electricity still finds a buyer in the community. Therefore, in the energy community assumed here, the degree of community self-sufficiency increases to 43% (see also Figure 5, far left).

In the next step, the benefits of individual storage units and a community storage unit were investigated. The individual storage units were dimensioned in such a way that they correspond to half the average daily demand for electrical energy. Such a dimensioning has proven to be the most sensible in previous publications [6]. With this, the degree of autarky was now calculated for each household with individual storage. The result is shown as grey bars in Figure 4. The red bar and the corresponding red line represent the mean value of these individual degrees of autarky. Here, the average degree of autarky is just under 70%. In comparison, a community storage system was assumed, the size of which corresponds to the sum of the individual storage contents. For this, a joint degree of autarky of around 73% was determined (orange bar). The blue bar shows the degree of autarky of a storage unit of infinite size, which, at 100%, represents the balance sheet autarky. In the figure, the slightly higher degree of autarky already shows a small advantage for the community storage system, although the difference would not really be decisive for the investment.

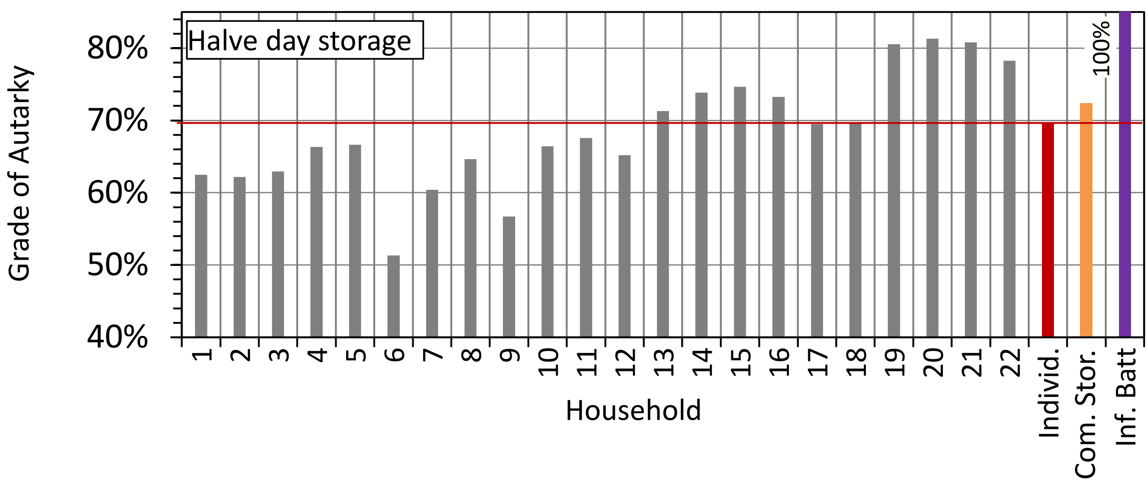

Figure 4: Degree of autarky of all 22 households with integrated PV for operation with individual storage, community storage and infinite battery.

However, the diagram also shows that this advantage does not apply to all participants. The question here is to what extent everyone would benefit and what a "fair" operation would look like (see also Chapter 4).

Another calculation examines the influence of the storage size on the degree of autarky (see Figure 5). Here, the storage size is shown on the horizontal axis in relation to the annual average daily energy demand. One can see a characteristic progression of the degree of autarky already described in [6]: First, the degree of autarky increases as the storage becomes larger, until it then remains on a plateau at the size of about a day's storage. Full autarky can only be achieved with a much larger battery. This effect results from the seasonal variation in PV generation and makes an extremely large seasonal storage unit necessary for full autarky.

The figure shows the average degree of autarky for individual storage units (red) and the mutual degree of autarky with a community storage unit (orange). As soon as more than the daily energy demand can be stored, there is no difference between individual storage and community storage. However, a greater degree of autarky with the community storage system can be seen with smaller battery sizes. As a reason for this, a more detailed analysis revealed that with smaller storage, the mutual energy use can use more direct PV energy. With a larger battery, direct PV use is no longer decisive for the degree of autarky and therefore there is no longer any difference.

Considering the necessary battery size for the same degree of self-sufficiency yields another insight: A typical dimensioning of individual storage units as half-day storage results in an average degree of autarky of just under 70%. However, the same degree of autarky can be achieved with a community storage system that is 24% smaller than the sum of the individual storage systems, as shown in Figure 5. The reduction of the battery size by a quarter is a clear, possibly investment-decisive advantage of a community storage system.

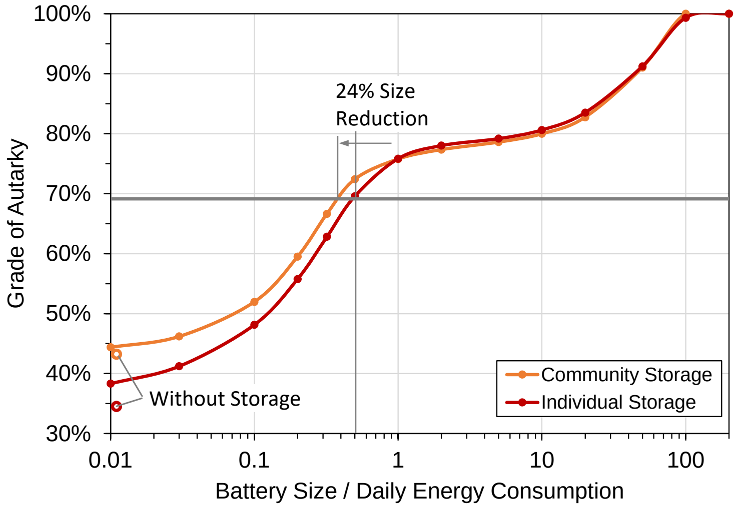

Figure 5: Degree of autarky for home and community storage scaled to varying battery sizes and duration of storage.

3.2. Number of cycles

In addition to efficiency, the ageing of a technology plays an important role. For this purpose, cyclic ageing was examined with regard to the number of full-load cycles of both conceptual designs. Basically, the community storage system has fewer full-load cycles than the home storage system and therefore ages proportionally more slowly. This is due to the fact that the storage and retrieval of the produced energy of the varying load and generator profiles can be better balanced.

3.3. Inverter power

Another aspect is the number and power of the necessary inverters. For individual households, the inverter should have a capacity to cover either the full load or the full PV output of the household. However, in the case of an inverter in the community storage, the full sum of the individual outputs is not necessary. Since households practically never need the full power at the same time, the simultaneity factor of households must be taken into account accordingly.

Specifically, in the fictitious neighbourhood, the summed power of all individual inverters would be 130 kW (discharging) or 84 kW (charging from PV). Due to the overlapping of the individual profiles, an inverter for the cross-animal storage would only amount to 50 kW when discharging, i.e. 38% of the individual accumulated power. For charging, there is hardly any difference due to the high simultaneity of the PV with 81 kW. If the charging power is reduced to 50 kW (as with discharging), the degree of autarky is only minimally reduced by less than 1 percentage point over the year, since times with full solar irradiation occur only rarely.

Overall, this can have a positive effect on the investment sum, especially if the number of inverters is also included in the price.

4. Modes of operation and measurement technology

On the one hand, the measurement technology enables the operation of the district storage tank. It determines when the community storage facility is charged and discharged. On the other hand, the measurement technology also enables financial accounting among the participants.

Figure 6 shows a schematic plan of the types of metering technology that may be necessary depending on the operating scenario. On the one hand, meters for billing are shown, typically bidirectional meters. In the simplest case, these are meters that are read annually. In a more elaborate scenario, quarter-hourly values must be recorded and billed. These meters cannot be used for technical operation, because real-time access and a corresponding data connection is not provided for smart meters and smart meter gateways. Therefore, depending on the scenario, real-time capable electricity or power sensors must be provided at more or fewer points, as well as a corresponding data connection infrastructure. Preferred scenarios are those with the simplest possible infrastructure, preferably with a simple annual reading without complex real-time measurements.

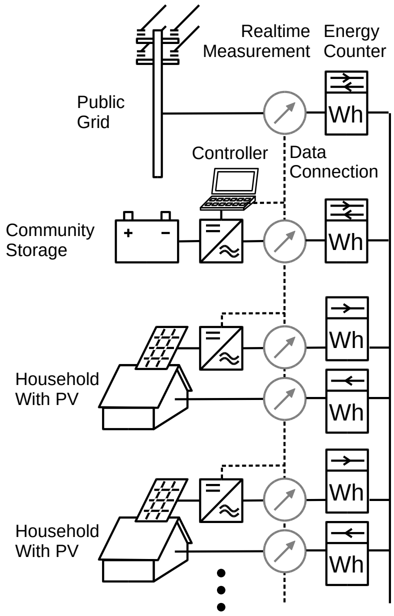

Figure 6: Interconnection of measurement technology in the neighbourhood, optional or necessary depending on the scenario.

4.1. Examples

One example for a realisation of a community storage is the project Flex4Energy [8]. In this scenario every household owns its own PV system. Only excess PV-power, which is not directly used in the household, is provided for the community storage. Every feed-in in the battery is individually monitored, and every household is entitled to get exactly the amount of energy back, which it has fed in. Energy flow between the participants is also monitored and individually billed according to a peer-to-peer trading scheme. The operator of the battery may use it for secondary purpose in order to create additional income. The system is managed by the local energy provider. Its benefit remains unclear. In the cited report the real time measurements are not described, but it shoud be clear that a dedicated real-time measurement for the control of the battery converter is necessary. The individual peer-to-peer billing requires a high effort on monitoring equipment and data processing. The cost for such a system is also not mentioned in the report.

To overcome the high effort in real-time measurement, monitoring and data processing a further scenario is proposed here: In this case, community storage is owned by a contractor. In addition, the PV systems in the area and also the power grid are also owned by the contractor. There is one mutual grid connection, where energy flow is monitored. Each household has consumption meter. The contractor delivers electrical energy to the household. This delivered energy is a mixture of directly generated PV power, power from the community storage and power taken from the mains grid. If the PV systems generate more power than needed, first the community storage is charged. If it is full, excess power is fed into the grid and the power can be marketed as “green power”. If there is not enough PV power available, first the community storage is discharged. If it is empty, more expensive power is delivered form the power grid. To ensure that excess power delivered to the power grid is “green energy” one real-time power sensor must be applied at the grid connection. It makes sure that the battery is charged only, if not power is received from the mains grid. Furthermore, a two direction meter is required a the grid connection point. This scenario requires a relaxed billing scheme with simple counting meters. Billing takes place once in a billing period, e.g. once a year. The contractor can set a fixed price for the energy the company sells to the household. This price is calculated from the mixture of sources and can be guaranteed and cost effective to a large extend for a long period, because the main contribution results from PV and the storage. The contractor benefits from a cost margin selling the energy. In addition, the contractor may implement a grid power limitation without any further measuring effort. This may save additional cost for the operator.

4.2. Fairness in the energy community

In addition to the legal boundary conditions, the mode of operation depends above all on the type of subsequent billing. And this depends above all on the sense of fairness of those involved, as became increasingly clear in the course of the project from the interdisciplinary discussions. In this context, a sense of fairness comes into play that is familiar in another context when paying the bill in a restaurant: who in Germany hasn't experienced that in a larger group everyone individually has their orders settled down to the last cent by the waitress. This "German paying", as it is also called in other countries in the south, finds its equivalent in the sense of fairness in energy communities, and legal interpretation and jurisprudence tries to correspond to this down to the smallest detail. Accordingly, questions arise such as: "Do I actually get the electricity I sent to the community storage back in the same way if I want it?" or "Who gets the electricity from the storage if in the end two want to use up the last bit at the same time and who then has to buy the expensive electricity from the grid?" Who is surprised then if, with this sense of fairness, legal regulation and metering become rampant.

Besides such an “individual fairness” there are, however, quite acceptable forms of fairness that circumvent this problem: A "flat fairness" is implemented with flat rates of data connections. A "solidary fairness" can be found in insurance contracts. Those who are annoyed that they have still not been reimbursed for their insurance premiums have not understood the principle. You can find "social fairness" in every family: those who urgently need something get it paid for out of the family income. In this way, decisive impulses could open up for simplification in the communal use of community storage and energy in general.

5. Conclusion

The mutual use of a community storage system can have technical and financial advantages: For the same degree of autarky, a smaller storage capacity than in the use of individual storage units can be sufficient (here, in the specific application case, 24% reduction). The shared community storage ages less due to fewer full-load cycles and the number and total power of the inverters can be smaller.

However, the billing and the necessary measurement and control technology are costly under the current boundary conditions. However, a different sense of fairness could greatly simplify this.

6. References

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