Energy sharing in citizens communities

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Abstract. ***A fossil free society will not only change the generation of energy to 100% renewable energy, but also the use of energy. Therefore, every person will be involved in the change individually. Energy sharing in citizens communities will thus become an important aspect in a fossil free society.***
The publication will give examples for the realisation of such projects. It discusses the problems of a neighbourhood energy sharing scheme. Furthermore, it shows, which effort is necessary to manage an energy sharing communities using the example of a community battery store in a climate protecting settlement. The effort is much dependent on what people consider as "fair" for the sharing of energy. The role of administration and legislation to trigger citizen's activities will be discussed as well.

Keywords: energy sharing, renewable energy, communal storage.

1 Involvements of citizens

The energy transition towards a fossil free energy use is something, where everybody is involved. In Germany in 2019, the majority of renewable energy owners were citizens with 53.6%, which include private persons (30.2%), farmers (10.2%) and crafts and trades (13.2%) [1]. This results in the energy transition generating significantly lower cost for the energy users, because typically based on own experiences private investors are satisfied with lower profits compared to institutional investors, as illustrated in Fig. 1. While the investments are needed anyhow, the expenditure for the profits can be significantly lowered with expectations of private persons.

Investment in renewable energies does not only pay back to the individual investors, but a whole region may benefit from it. As an example, the region Rhein-Hunsrück-Kreis in Germany had spent 290 Million Euros on energy imports. After changing the energy structure to renewable energy generation to more than 100% the region could generate a profit of 44.175 Million Euros in 2017 [2].

Therefore, the involvement of citizens remains very important and this contribution shows two examples to stimulate citizens involvement into energy transition. The first shows a proposal for neighbourhood energy sharing and the problems that may appear. The second example shows the use of a mutual battery storage for a climate friendly settlement and discusses possible business cases.

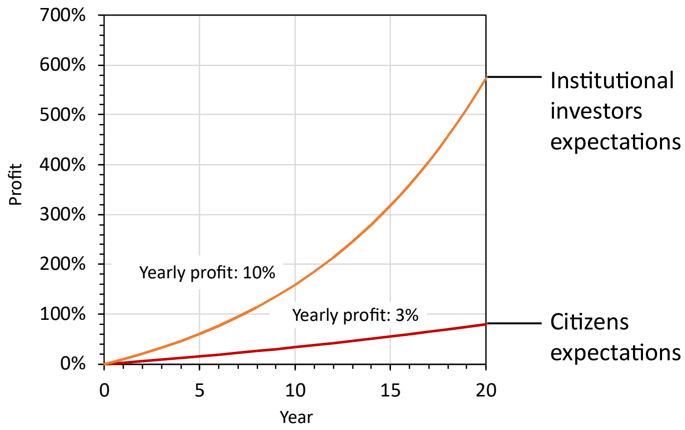

Fig. 1. Expected profit for institutional investors compared to private citizens.

2 Neighbourhood energy sharing

One possibility to involve citizens in energy generation is energy sharing. While energy sharing over a larger distance appears abstract to most people, sharing self generated energy with neighbours is something many can imagine. The idea would be to deliver excess generated energy, e.g. by a photovoltaic (PV) system on the own roof, with neighbours, who do not have the possibility to generate their own energy.

A technical amateurs may think of straightforward solution, which is simply a power cord connecting the neighboured households as illustrated in fig. 2. However, this is a dangerous solution, because the circulating currents may appear, which can not be controlled and possibly exceed limits. In addition, the power flowing through the energy counters is not defined and thus no suitable energy counting is possible.

Therefore, the only technical solution is to share energy over the power grid, which connects the households. This is usually a public grid and therefore public rules apply. This however raises legal aspects. The challenge here is a fair energy counting, which takes into account the acquired energy from the neighbour. The different modes are explained in the following paragraphs.

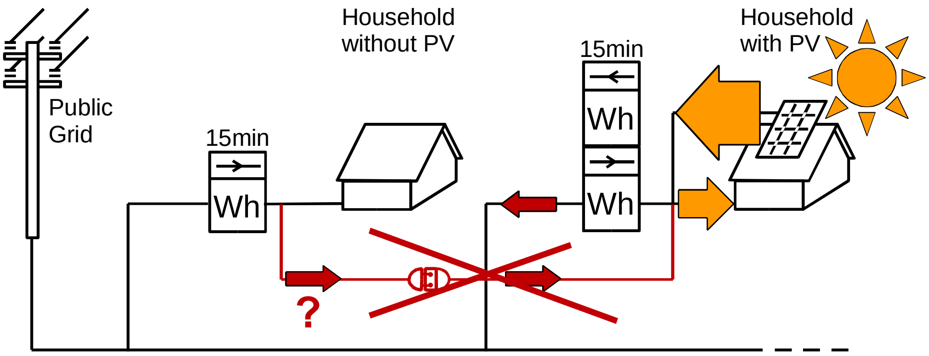

Fig. 2. Energy sharing with a power cord. Take care: This leads to uncontrollable current flow!

Fig. 3 illustrates the case on a sunny day, where the generated PV power is sufficient to supply the own and the neighboured household. In this case the total consumed power by the household without PV is delivered from its neighbour. Therefore, then the power consumption must not be charged to the usual energy supplier. Furthermore, in this case only a fraction of the excess power of the PV owner is finally fed into the public grid. Then the PV owner has to get compensation for fed-in PV energy. And finally, the two household need to know, how much power is shared to establish a fair financial compensation.

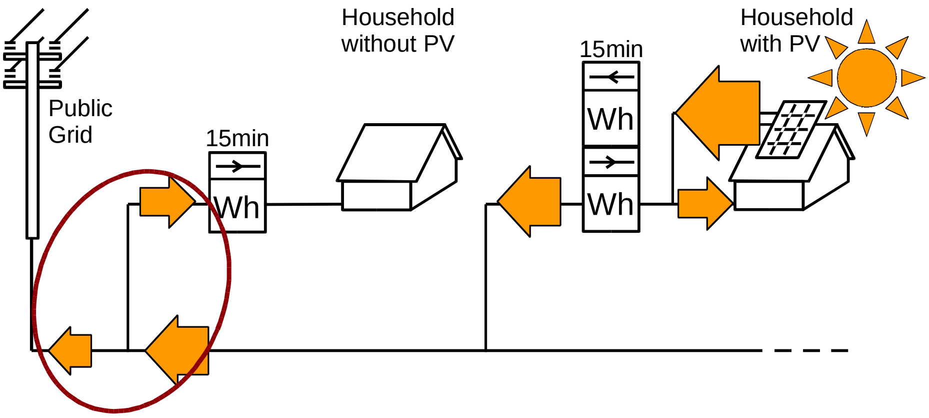

Fig. 3. Energy sharing over the power grid at a sunny day.

An even more complex case is a cloudy day as shown in fig. 4. Here a case is illustrated, when the generated PV power is not sufficient to supply both households completely. Instead, the household without PV gets a mixture of a little excess PV power from the neighbour and in addition the remaining power from the public grid. This shows that the neighbour's PV cannot be the only source of power, and also that one cannot easily switch completely from one to the other source. Instead, two power sources must be billed at the same time.

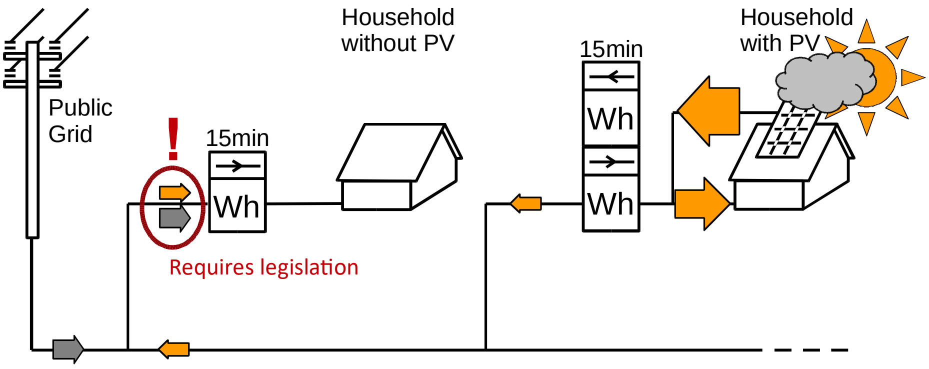

Fig. 4. Energy sharing over the power grid at a cloudy day.

If there is only little or no PV generation, as e.g. during night, all households must be supplied by the public grid (see fig. 5). This is the conventional case and is handled by energy providers already now.

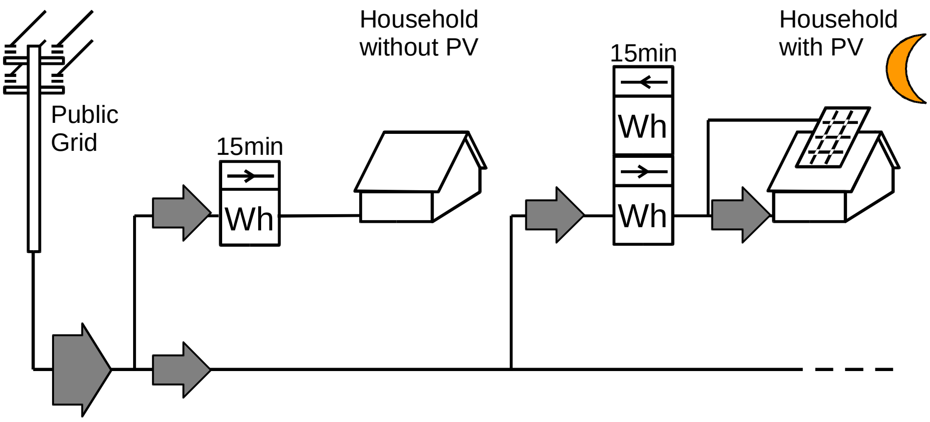

Fig. 5. Energy sharing over the power grid at night.

The above shown examples illustrate that neighbourhood energy sharing is basically a commercial issue. Neighbourhood energy sharing would not change the physical power flow on the lines. But this commercial aspect would have some additional benefit: It would be considered as "fair" to many users. It would possibly even trigger additional PV installation, because many people would be more willing to deliver excess energy by their additional PV system go well known neighbours instead to an anonymous power provider. It would also improve acceptance by those who are not able to install an own PV system, if they could commercially benefit from their neighbours PV.

The examples also made clear that it requires appropriate organization and legislation. It can be solved only with a sophisticated measuring system like smart meter systems. It requires timely energy counting in both directions at every household,, e.g.

in 15 min time slots. Then, a balance can be calculated taking the meter readings into account. The calculation can sort out the power flows as illustrated in the previous figures.

It is obvious that such tasks cannot be done by normal consumers. Therefore, it is proposed by SFV (Solarenergie Förderverein Deutschland e.V., Solar Energy Promotion Association Germany) [3] that power providers should be obliged to this task. This includes

- billing with multiple suppliers,
- considering excess PV energy
- using individual power profiles
- 15 min energy counting and billing

The energy sharing should be limited to the neighbourhood. The related distance has jet to be defined, either by air distance or by the power grid.

There are several legal aspects to be considered:

At the moment, multiple suppliers are not foreseen by legislation. This would be the first step to be changed. This would also require a complete redesign of the billing systems of energy providers, which actually do not have the option of multiple suppliers.

As a further aspect, this would deeply change the way how the balancing group equalisation (in German: Bilanzkreisausgleich) is done for power grids with private households. Today, it is done with standard load profiles, which are scaled to the last year's energy consumptions. This does not require real time or 15 min balancing, and it allows an easy prediction of the future consumption. Changing to multiple supplies with much less predictable use of the neighbour's PV power would require a complete new setup of the whole system for balancing group equalisation.

Even worse, fed-in PV power by households is usually treated a EEG-energy and is related to a special balancing group, where it is also treated with standard feed-in profiles [4]. Neighbourhood energy sharing would therefore require a change also in the EEG-energy balancing group equalisation. In fact, the local energy exchange would require balancing locally power from one balancing group to the other.

Concluding, introducing neighbourhood energy sharing in Germany would require a change in legislation and a remarkable effort for the power supplier to change their billing and power balancing systems. However, EU legislation already demands such a provision.

3 Community Battery

3.1 Use case

A further option for energy sharing are settlements with mutual energy use. Here, a n example for a climate friendly settlement is shown, which is going to use a common community battery storage. Each of the houses in the settlement have photovoltaic (PV) systems on their roofs. There is one connection to the public grid for the whole settlement. From there the power grid is non-public. The primary function of the battery storage is to enhance the autarky of the settlement from the public grid by storing excess PV energy and providing it, when there is less PV generation. This improves the use of “green” energy from the PV, while import of grid power always include “grey” energy from fossil based power generation.

In a previous publication [5] it could be shown that a mutual storage requires less capacity than individual storages in each household. Fig. 6 shows the main results. Details are explained in the paper. The figure shows that the advantage for a common storage appears for battery sizes, where the energy capacity is less than the daily energy consumption. About halve of the daily energy consumption would be a typical case for the dimensioning of such a battery storage. As an example indicated in the figure a typical grade of autarky of about 70% requires 24% smaller size of a common battery storage compared to individual batteries in each household. The reduction appears, because in the mutual power grid generated PV power can be exchanged between households, which avoids the need for storing and the need for receiving energy from the public grid.

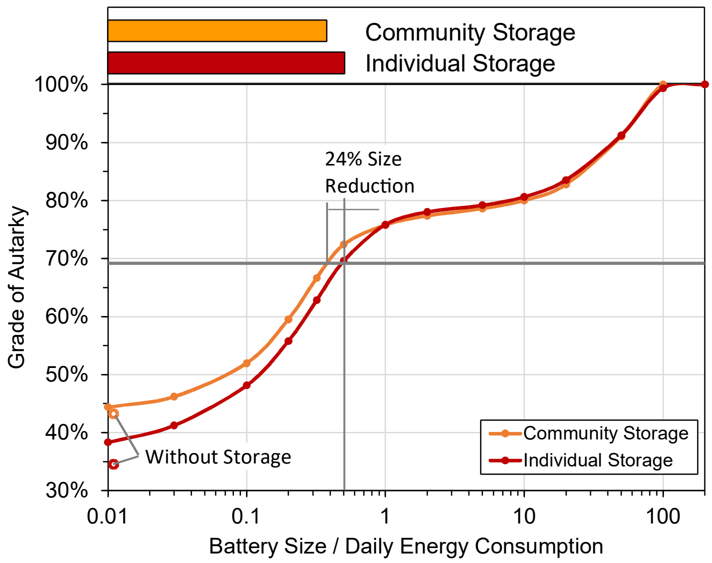

Fig. 6. Grade of autarky for the settlement with a community storage compared to average grade of autarky of the households with individual battery storages. Both storages have the same accumulated capacity.

3.2 Fairness

An important aspect for energy sharing is how fair the involved people consider the commercial aspect. Especially such a community as in the climate friendly settlement offers the choice for different models. The aspect, how fairness is achieved, influences to a great extend the effort, which is needed for billing and measuring. This will be explained in the following paragraphs.

Commercial Fairness: Most people consider commercial fairness as most fair when giving and receiving things. As an example, one can find this principle "Buy for what you get – Get what you pay for" in a market hall. Here, the energy exchanged is the considered as individual property of each involved person. It requires an individual measurement of each fraction of energy and a tracking, who got which energy from where. This requires a high effort for billing. A concept like this has been tested in a real life project involving a communal storage [6].

Such a concept requires a high effort for measurement and billing. Fig. 7 illustrates the technical needs. There are real-time measurement devices necessary in order to control the power converters according to the actual need. The measurement devices must be reliably connected with suitable bandwidth. Because the connection for the control is time-critical and because of the reliability a public data network like internet is not suitable. Instead it requires a proprietary communication solution. To track each energy package billing requires a 15 min metering. Since the billing is not time critical, public data networks can be used. However, in a public network data security must be considered. Upcoming smart meter infrastructure would be suited for it.

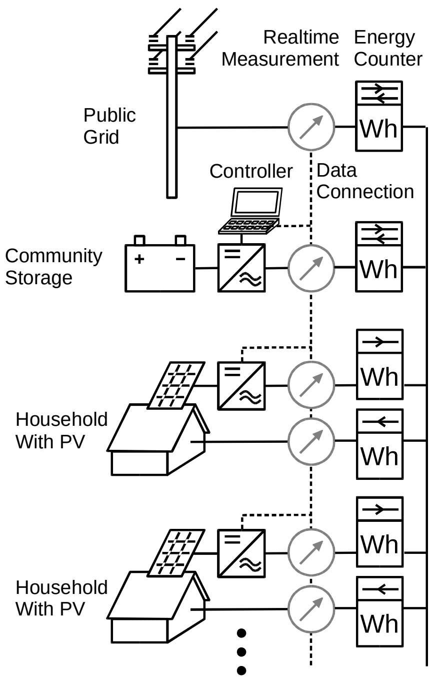

Fig. 7. Measurement setup for a community storage including real-time measurements to allow individual billing.

Social fairness: In families or groups of friends sharing can be obtained without keeping track of each transition. In such a case of "social fairness" the involved people agree that each person gets what is needed and consider this as fair. Property is treated as mutual property.

Transferred to the energy community all generated and consumed energy is treated as mutual. The no internal tracking of the energy flow is necessary. This makes the measuring setup very simple, as shown in Fig. 8. Only on common meter and one real-time sensor are necessary at the point of connection to the public grid. The common meter is necessary for the billing with the public energy supplier once a year. The current sensor is needed for the control of the battery converter.

While this is the most simple measuring arrangement, it requires trust between the participants. Since a settlement is installed for many years, trust between participants can change, e.g. because of unforeseen events, change of participants or change of individual needs. Therefore, such an arrangement is not highly recommended, even the technical solution would be most simple. This may also be the reason why no publication on such an arrangement could be found.

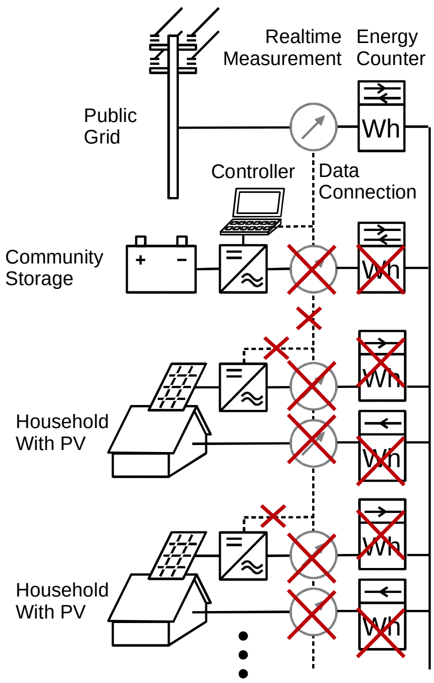

Fig. 8. Measurement setup for a community storage with only mutual energy metering.

Trusted Authority: To find a compromise between these solutions, a "trusted authority" might be introduced. This authority may supervise the use of energy. This may reduce the complexity of the measuring system maintaining fairness tog all participants. As a drawback, additional costs apply to pay the authority.

As a practical use case, a contractor can represent such a trusted authority. The following organisational aspects would be considered: The contractor own the community storage, the local power grid and the PV systems on the roofs of the individual buildings. The contractor provides the energy for a fixed, average electricity cost to each household. Because PV power is cheaper than power from the public grid the contractor is able to offer a cheaper electricity price. In addition, in Germany some additional fees may be reduced or omitted in a closed private power grid, which adds additional cost advantages.

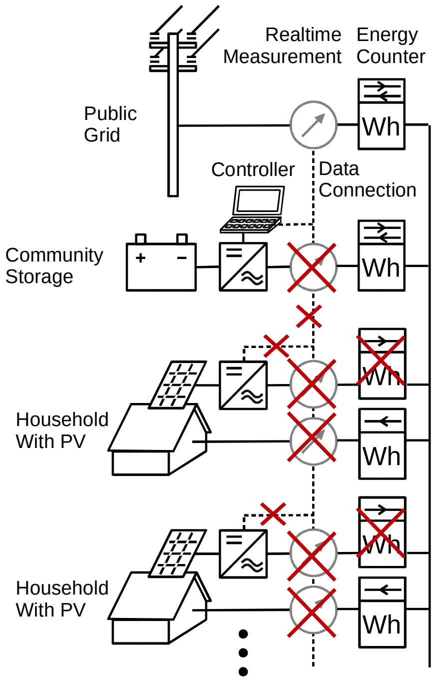

Fig. 9. Measurement setup for a community storage with operation by a trusted authority.

As technical aspects, the required measurements become much simpler compared to the case of individual trading (see fig. 9). Because the contractor owns the PV systems, an individual real-time control of each PV converter is not necessary, such that only one real-time sensor must be introduced at the common point of connection to the public power grid. Billing can be once a year (as long as no time-dependent tariffs are used) which makes it cheap and metering simple. A data connection is not needed, except to make the reading of the meters easier.

As a further aspect, a contractor can use additional modes to operate the battery to gain additional profit. As an example, in winter, when PV generation is low, the storage can be used to buy energy from the public grid, when it is cheapest. It could also provide grid services like balancing power or care for a capping of power transmission on the line.

Therefore, installing a contractor to manage the communal storage is our proposal for the case of a climate friendly settlement [7].

4 Conclusion

Involvement and empowering citizens to use renewable energy helps speeding up the energy transition towards climate neutral energy use. It enhances acceptance, thus leading to less time consuming objections, and it reduces the overall costs.

One way to involve people is by allowing them to share their energy. This must be simple and fair. An energy sharing scheme using the public power grid would increase acceptance and even installations of additional PV generation, but would require a change of legislation and a significant modification billing systems of energy providers.

It is shown that the way of how fairness is achieved influences the effort for measurement and billing for a communal storage in a climate neutral settlement. The operation by a contractor has been shown the best solution to achieve a fair but low effort energy sharing.

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