

# Common battery storage for an area with residential houses

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**Abstract**— In this publication the technical benefits of a mutual battery storage compared to a solution with three individual battery storages is investigated. This has been done in the context of the EU funded project “GrowSmarter” in collaboration with Rheinenergie in the living area Stegerwaldsiedlung in Cologne.

In the project area each of the three buildings has its own battery storage (size varies by building). This publication investigates the options for 3 buildings connected by a private residential grid instead of a public grid, with a central battery storage and the chance of energy self-consumption. This part consists of 3 houses with 167 apartments arranged around a common yard. The roofs are covered with photovoltaic modules with an installed power of 202,5 kWp. For this area Li-Ion batteries are installed in separate containers. They have a combined capacity of 200 kWh (130, 60 and 10 kWh) with varying maximum power (30, 20 and 5 kW). It is primarily used to optimize the use of the PV power. As a result, the grade of autarky can be improved from 41 % to 45% by use of a common battery storage.

## 1 INTRODUCTION

In the EU-project “GrowSmarter” in cooperation with several partners, including RheinEnergie AG, the City of Cologne has set itself the task of integrating energy, mobility and information and communication technology into urban planning. This is to be implemented in the “Stegerwaldsiedlung” in Cologne-Mülheim. As illustrated in Figure 1, in this context, 16 buildings were or are being renovated in terms of energy efficiency, equipped with photovoltaic modules, heat pumps and battery storage devices and networked via a central, intelligent energy management system.

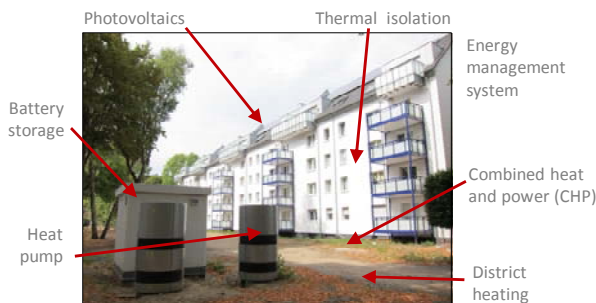


Figure 1: Stegerwaldsiedlung

The district is supplied additionally with heat by the local district heating network of RheinEnergie AG in order to cover the peak load of the heat demand. These arrangements are intended to reduce the primary energy consumption of the settlement by up to 60 % and also reduce greenhouse gas emissions by 60% to 70%.

There are realized projects, which aim to improve the grade of autarky, e.g. [2] or where the common use of a battery is used in microgrid with islanding operation capability [3][4].

In this publication the technical benefits of a mutual battery storage compared to a solution with three individual battery storages is investigated. In the project area each building has its own battery storage (size varies by building). This publication investigates the options for 3 buildings connected by a private residential grid instead of a public grid, with a central battery storage and the chance of energy self-consumption. This publication is based on the bachelor thesis of the co-author Till Paulzen [1].

## 2 CONSTRAINTS

Figure 2 shows a map of the Stegerwaldsiedlung (left) and the considered area for the investigations (right). The relevant area consists of three building blocks with apartments: The block on Deutz-Mühlheimerstraße (DM), the block on Gaußsstraße (GA) and the block on Sonnenscheinstraße (SO). They are arranged around a common yard. Figure 3 shows a photograph of this yard. All buildings are owned by a company, which rents the apartments to in total 167 tenants. This company also owns and operates the energy infrastructure including the battery storages. The total yearly energy demand of the households is 250 MWh/a

Each building block has a photovoltaic (PV) System on its roof. As the buildings are differently oriented, also the PV systems have different orientations. The total installed PV power is 203 kWpk with an annual energy generation of 167 MWh/a. This is less than consumed in the area, such that full autarky cannot be achieved.

To each PV system a battery storage is related. The batteries are not placed inside the buildings but in external containers of different sizes. Figure 4 shows a photograph of a small size container. The doors are made from glass, such that the neighbors and visitors can always have a

look at the technique. The batteries are Li-Ion batteries of different sizes. Figure 5 shows a photograph of the inside of such a container. The total capacity is 200 kWh with an inverter power of in total 55 kW. They have a very high efficiency of 98% and the inverters have an efficiency of 96%.

The batteries are used to optimize the grade of autarky and the PV self-consumption of the houses. To make a better use of the PV power, also the heat pumps are operated preferably on PV power and on energy stored in the batteries.

Detailed numbers about the buildings, the PV systems and the batteries are listed in Table 1.

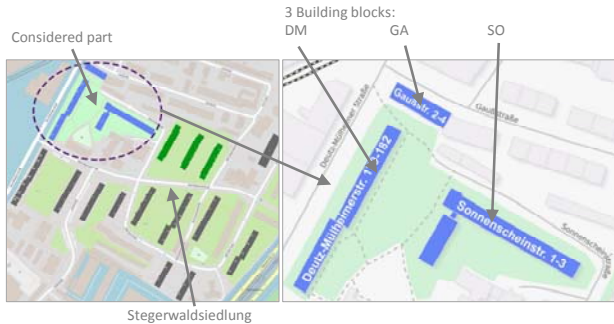


Figure 2: Map of the considered area (Map: open street map)



Figure 3: Photograph of the common yard between the houses as well as one of the battery containers.



Figure 4: Photograph of a battery container (small container version).



Figure 5: Photograph of the battery racks inside the container (large container version).

TABLE 1: DATA OF THE CONSIDERED AREA.

	DM	GA	SO	Sum
Number of tenants	65	20	82	167
Living area before refurbishment / m <sup>2</sup>	3059	1080	4797	8936
Living area after refurbishment/ m <sup>2</sup>	3792	1266	4797	9855
PV-Orientation	East/West	South	East/West	-
PV-Angle / deg	45	45	12	-
PV-Power / kWp	99.55	9.88	93.6	203.03
PV-Generation / kWh/a	76184	9536	81446	167166
Spez Generation kWh / kWpk	765.28	965.18	870.15	823.36
Consumption households / kWh	84477	28864	137362	250703
Consumption heat pumps / kWh	126807	41904	158241	326952
Battery capacity / kWh	130	10	60	200
Battery power / kW	30	5	20	55

### 3 METHODOLOGY

The existing three battery containers are arranged as illustrated in Figure 6. The batteries for Building DM and GA are located in the same container, but are not interconnected. Instead, each battery is connected individually to each its related building. Figure 7 shows the assumed arrangement of a common storage for all buildings. For the investigations, it is assumed to have the same total capacity and power rating of 200 kWh / 55 kW.

The existing batteries are operated in a mode to improve the PV self-consumption. If the PV generates

excess energy, it is first stored in the batteries. If the batteries are completely charged, excess power is fed into the power grid. Correspondingly, the batteries are first discharged, if there is more power demand than generation. If the batteries are empty, power is taken from the grid. This operation mode is also assumed for the simulations of the common battery storage.

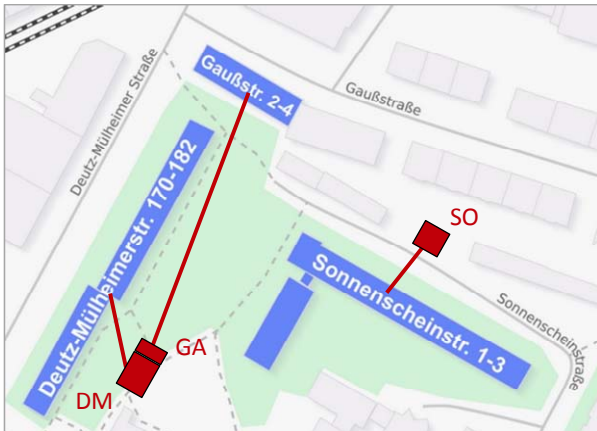


Figure 6: Map of the houses with the existing individual batteries. (Map: open street map).



Figure 7: Map of the houses with the assumed common battery storage. (Map: open street map).

As figures of merit for the investigation the PV self-consumption and the grade of autarky are used. In this context, autarky is defined according to [5] as the amount of energy, which can be provided at each point of time from PV and battery. It is *not* based on summed-up yearly energy. The figures of merit are discussed here for the whole area in total. Some individual results for the buildings (in case of three individual batteries) can be found in Table 2.

To calculate the figure of merits, yearly load profiles with a resolution of 1 h are used. All profiles are measured data for household demand, heat pumps demand and PV generation. Figure 8 Shows exemplary profiles for one specific day of the year. The figure of merits of the existing solution with three battery storages can be directly derived from the measurements. For the single common storage, the common profiles are used to

calculate the residual load (see Figure 9 as example) and from this, the figures of merit are simulated using the described operation mode. In addition, the figures of merit are calculated for two additional cases: For the case without any storage and for the case with an infinite large common storage. So, in total 4 cases are investigated:

- No storage
- Single battery storages
- Common battery storage
- Infinite storage

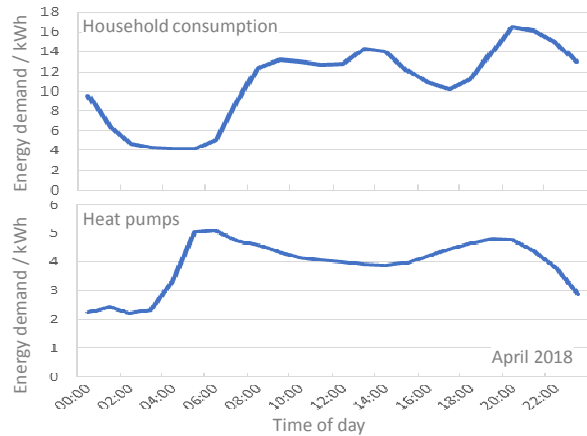


Figure 8: Exemplary load profiles for household consumption and heat pumps demand.

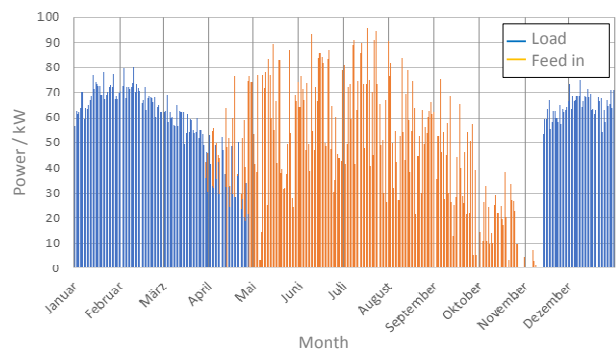


Figure 9: Residual load for infinite sized battery.

#### 4 RESULTS

The resulting figures of merit for the existing case with three individual batteries is shown in Figure 10. The results are shown for each month of the year. As expected typically, one can observe a significantly higher demand of energy in winter and an opposing curve of PV generation with maximum generation in summer. The amount of PV self-consumption nearly matches the total consumption in summer, however due to timely mismatch the grade of autarky reaches a maximum in summer of only 85% of the generated PC energy. The yearly average grade of autarky is 41.1 %.

The corresponding results for the common battery storage are shown in Figure 11. The consumption is the same by definition. In summer months, a slightly higher PV self-consumption can be observed. Apparently, the



common battery storage helps matching the generation with the demand. Also the grade of autarky nearly reaches 100% in July. The total yearly average grade of autarky is improved to 45.1%.

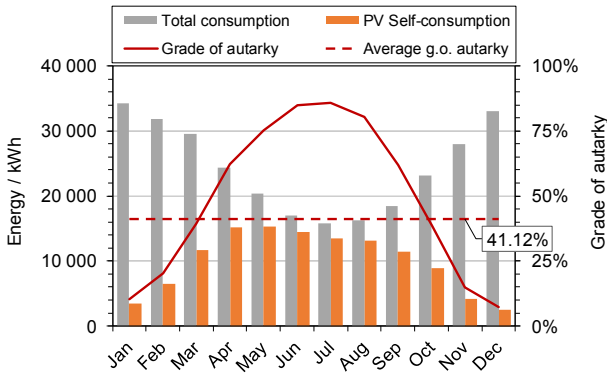


Figure 10: Grade of autarky and PV self consumption for the existing case of three individual batteries.

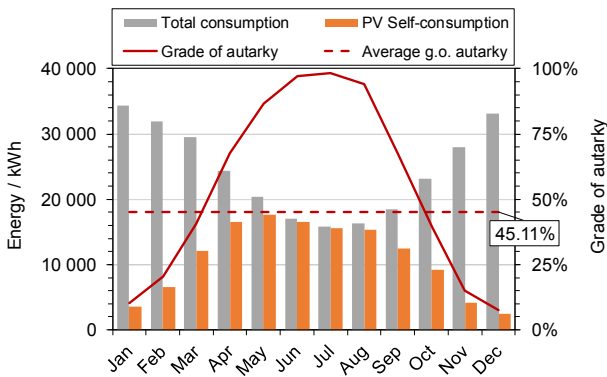


Figure 11: Grade of autarky and PV self consumption for the assumed case of a common battery.

The yearly results are summarized in Figure 12, including the cases “No storage” and “infinite storage”. As intuitively expected, all figures of merit improve from “No storage” over “Individual storages” and “Common storage” to “Infinite storage”: The amount of energy delivered from the grid (“grid demand”) decreases from 190 MWh/a to 125 MWh/a. Correspondingly, the PV self-consumption increases by the same amount of energy from 100 MWh to 165 MWh and the grade of autarky improves from 34% to up to 58%. The difference in the grade of autarky between the common storage of 200 kWh to an infinite sized storage shows that the battery size could still be increased with technical benefit. The figure also shows the improvement of the figures of merit from individual storages to a common storage of the same size. It is indicated by the gray and red ovals: The grid demand reduces from 172 kWh/a to 160kWh/a by 7%, and the grade of autarky improves from 41.1% to 45.5%. The PV self-consumption improves from 120 MWh/a to 131 MWh/a by 11 MWh/a, corresponding to 9.7%.

Alternatively, a smaller common battery storage could be used to achieve the same grade of autarky and PV self-consumption. For the given case a common battery size of only 110 kWh instead of 200 kWh with the same power rating of 50 kW is calculated (not shown as figure). Reducing the battery size in this amount with similar performance gives a significant commercial benefit.

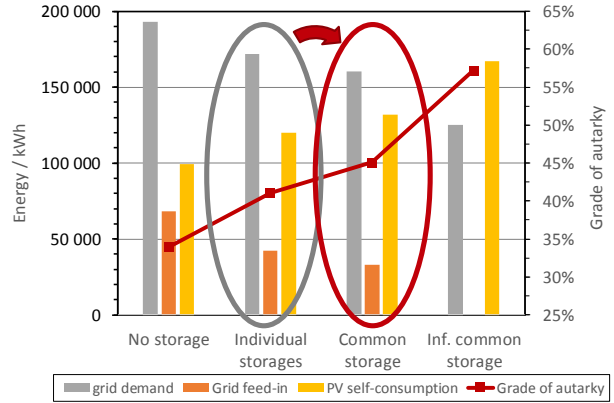


Figure 12: Comparison of grade of autarky and PV self-consumption for four investigated scenarios.

TABLE 2: AUTARKY DATA OF THE EXISTING CASE AND THE COMMON BATTERY STORAGE

	DM	GA	SO	Sum	Common storage
Battery load / kWh	18053	1017	11370	30441	34122
Number of cycles	139	102	189	-	171
Grade of autarky	48,9%	24,5%	39,3%	41,1%	45.1%
PV self-consumption				120155	131819
Grid demand / kWh	57064	27488	87510	172062	160399
Grid feed-in / kWh	18728	510	23702	42940	32789

## 5 CONCLUSIONS

A common battery storage for an area with residential houses is compared to the case of three individual battery storages for the same three buildings with a total capacity of 200 kWh. It is used to improve the self-consumption of the photovoltaic energy generation in the area. It could be shown that the for this particular case the common battery improves the grade of autarky from 41.1% to 45.5% and the PV self-consumption improves by approximately 10%. Alternatively, a battery of only 110 kWh would give similar performance as the three individual batteries with a total capacity of 200 kWh. This correspond to a significant cost reduction for the similar performance.

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