EC Report

Given data about production and consumption of each community member in each discrete timestep, the following report gives insights about a hypothetical community structure with an optimally and fairly allocating market with a community battery accessible to all members.

In each timestep, the community market consists of suppliers, i.e. community members with more production than consumption in the given timestep and consumers (defined analogously). It is assumed that a member uses its self-produced energy to cover its own demand after each timestep and either sells the left-over energy on the market, becoming a supplier, or asking for the uncovered consumption on the market, becoming a consumer. If there's supply that cannot be sold on the market due to a lack of demand, this is assumed to be fed into the grid. If there's demand that cannot be covered by the market due to a lack of supply, this left-over demand is assumed to be covered by purchasing energy from the grid.

In each timestep, the market is computed as an optimal allocation from buyers to sellers, i.e. the trading volume is the minimum of demand and supply. The computed allocation is fair in each timestep, i.e. if the supply overpowers the demand by a factor of n in a given timestep, each supplier/seller can sell 1/n'th of its supply. The same guarantee holds for the demand side if it overpowers the supply side. The allocation itself is computed using a max-flow algorithm.

This means that if the demand covered by trades is 100%, the community is self-sufficient and can cover its entire consumption by self-production and by buying from other community members. This requires having a higher overall production than consumption, which is usually not the case. A better goal is to have the percentage of supply sold at 100%. This means that all of the overproduction stays within the community and a minimum must be consumed from the grid. With PV, this is also rare, since the overproduction of each community member is highly correlated with that of other members, so the market oftentimes has either very little demand (sunny) or very little supply (cloudy).

In such a case, a community battery helps improve upon the ratio of sold supply. Supply that cannot be sold due to a lack of demand on the community market can instead be used to charge the community battery. In times of high demand, members can discharge from the battery. The allocation of battery charging and discharging is solved in the same way as the market; After each timestep, the market is computed optimally first and the stronger market side can then either charge or discharge the battery. The amount of charge/discharge per community member is again computed in a fair manner, i.e. if the remaining battery capacity allows to cover 1/n'th of the remaining demand, each member may discharge 1/n'th of its demand.

The goal of a battery is to get the ratio of sold supply close to 1. In this report, we distinguish the ratio of sold supply and the ratio of supply put to the battery. Thus, ideally, we would get the sum of the two metrics to 1.

Key Statistics Without Battery

- Overall consumption refers to the total amount of energy consumed by all community members over the timeframe of the dataset.
- Supply refers to the total amount of overproduction, i.e. a community member has supply if it produces more than it consumes during some time interval and thus has some quantity of energy to sell. It is assumed that all self-produced energy that is not consumed immediately is offered on the community market and counts towards supply. Analogously, all consumption that is not covered by self-production is asked for on the community market and thus counts towards demand.
- The trading volume is the total amount of energy traded on the community market.
- An overproduction (overconsumption) datapoint is defined as a single community member having more production (consumption) than consumption (production) in a single timestep. For most prosumers, the number of overconsumption datapoints significantly outnumbers the number of overproduction datapoints.
- The ratio of demand covered by trades refers to the ratio of demand (consumption not covered by self-production) covered by purchases on the community market. If this ratio is 1, the community would be self-sufficient and able to cover its entire consumption by self-production and trading. This metric indicates how helpful the market is for this community in times of overconsumption. If it is close to 0, it means that there's almost no supply when there's demand.
- The percentage of supply sold indicates how helpful the market is for the community in times of overproduction. If close to 100, it means that there's still sufficient demand when there's overproduction (supply).

Overall consumption (kw/h): 6135.30

Overall production (kw/h): 2390.86

Overall trading volume (kw/h): 435.69

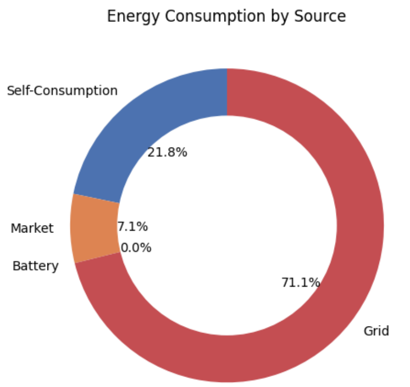
Nr of overproduction vs overconsumption datapoints: 3762, 20238

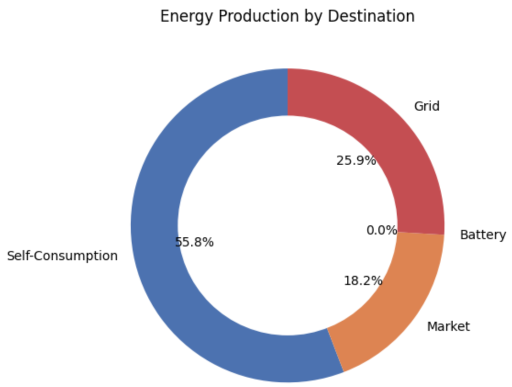
Demand covered by trades (%): 9.08

Percentage of supply sold (%): 41.26

Energy Consumption/Production by Source

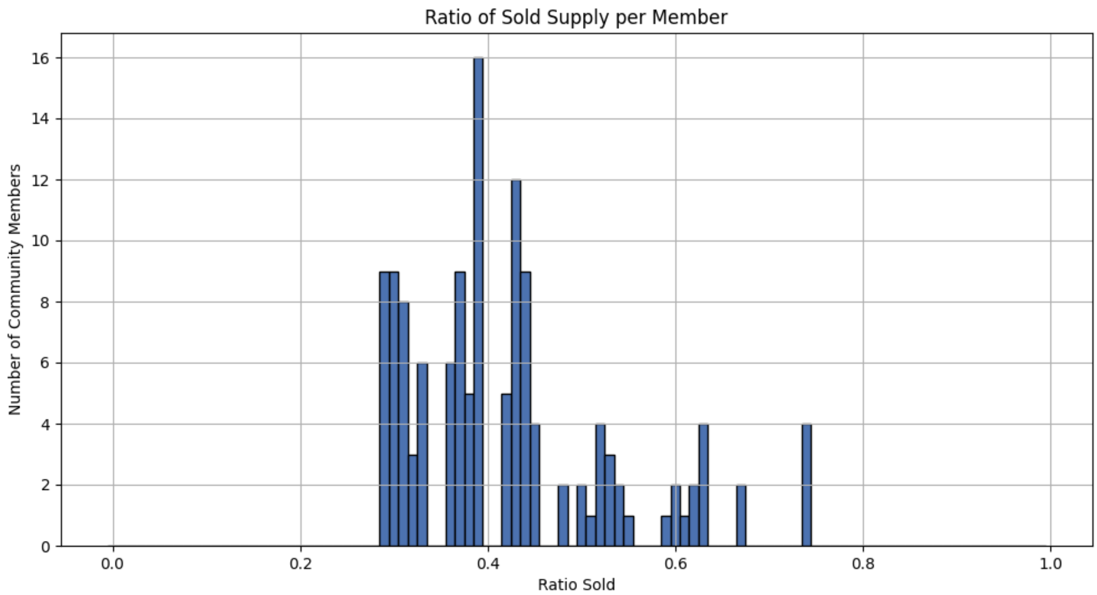
The following figure visualizes where the consumed energy comes from and where the produced energy goes to (self-consumption, community market, battery, grid). Since we assume no community battery here, none of the energy goes to or comes from the battery.





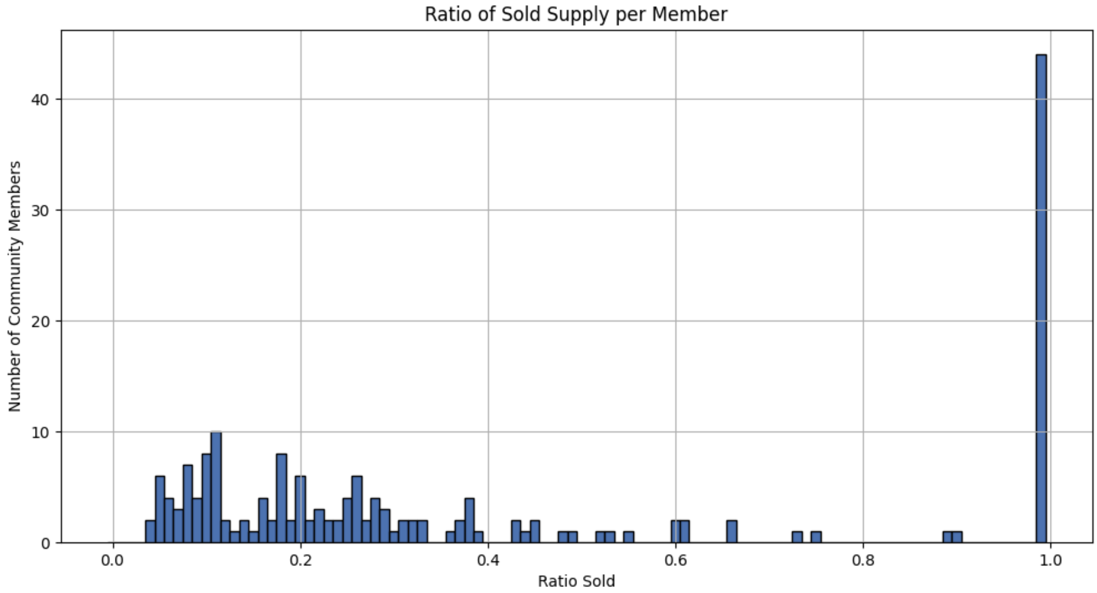
Sell Ratio

The following bar chart aims to visualize the fairness of the employed market mechanism. For each community member, the ratio of their overproduction sold on the community market is shown, discretized to single percentage points. If a bar has height 10, it means that 10 community members have sold this percentage of their supply on the community market. Each member wants this to be as high as possible, since selling on the local market yields higher prices than feeding into the grid.



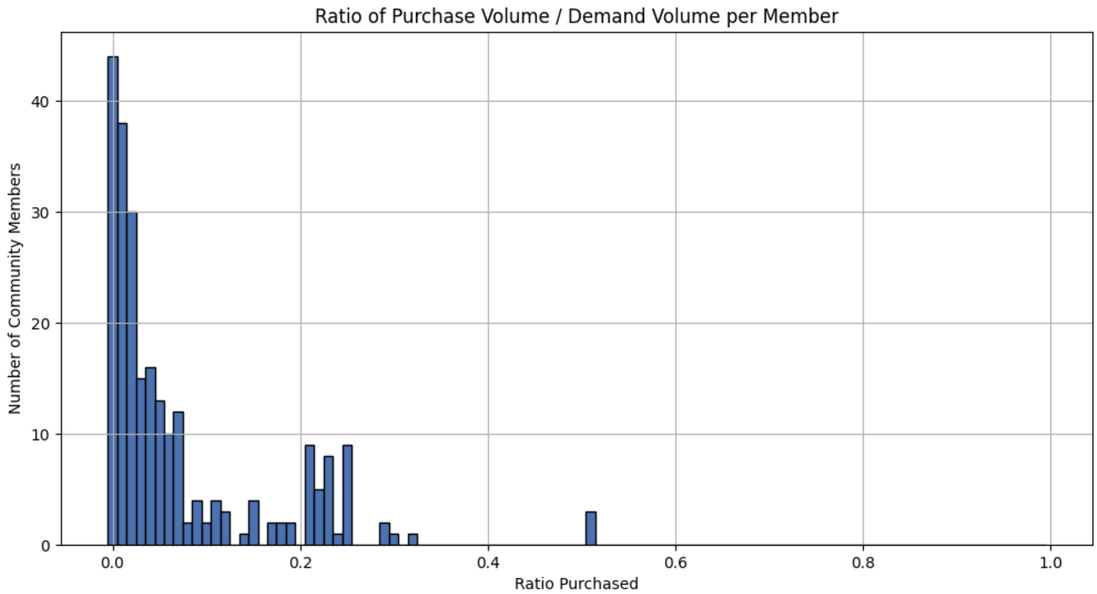
Sell Ratio without Per-Timestep Fairness

The following bar chart shows the resulting sell ratio distribution if no fair market mechanism is employed. In this case, the max-flow algorithm just finds some optimal allocation in each timestep without any fairness guarantee.



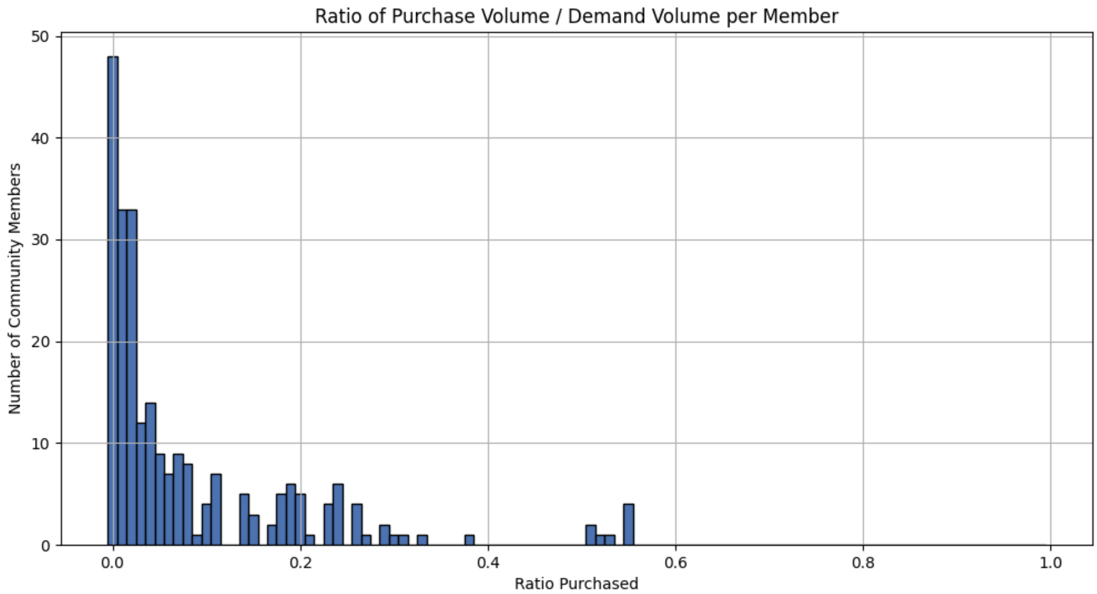
Buy Ratio

The following bar chart aims to visualize the fairness of the employed market mechanism. For each community member, the ratio of their demand (consumption not covered by self-production) covered by purchases on the community market is shown, discretized to single percentage points. If a bar has height 10, it means that 10 community members have purchased this percentage of their demand on the community market. Each member wants this to be as high as possible, since purchasing from the local market is cheaper than purchasing from the grid.



Buy Ratio without Per-Timestep Fairness

The following bar chart shows the resulting buy ratio distribution if no fair market mechanism is employed. In this case, the max-flow algorithm just finds some optimal allocation in each timestep without any fairness guarantee.


Ratio of Purchase Volume / Demand Volume per Member
Number of Community Members
Ratio Purchased
0
10
20
30
40
50
0.0
0.2
0.4
0.6
0.8
1.0

Statistics With Battery

Now we add a hypothetical battery to the community. Every member has the ability to charge the battery (similar to selling to a community member) and discharge from the battery (similar to buying from a community member). The charging/discharging privileges are allocated in an analogous way to the market clearing algorithm.

The battery is only allowed to discharge to 15% of its maximal capacity and charge up to 85% of its maximal capacity. The initial capacity of the battery is 15% of the maximal capacity. Note that this initial energy storage may not be discharged by the members, since discharging beyond this threshold is not allowed.

The conversion loss for each battery transaction is 5% and the static loss is 0.1% per hour. The c-rate is 0.5, meaning that in each timestep, the battery may be (dis)charged by a fraction of at most c-rate * timestep/hour. For example if the timestep is 15 minutes and the c-rate is 0.5, the battery may be (dis)charged by at most 12.5% of its full capacity per timestep.

The required battery capacity for full communal self-consumption refers to the battery capacity required to be able to put the entire supply left-over from the market into the battery. Since the hypothetical battery is of this size, the percentage of supply put to battery plus the supply sold on the market consequently add up to 100%.

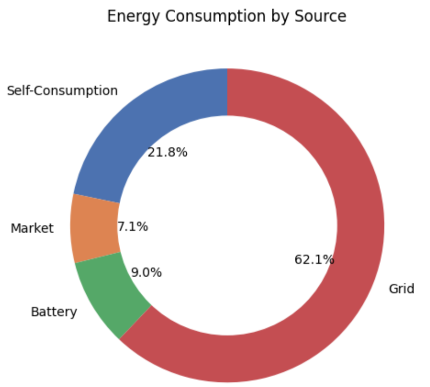
Required Battery Capacity for Full Communal Self-Consumption (kw/h): 805.69

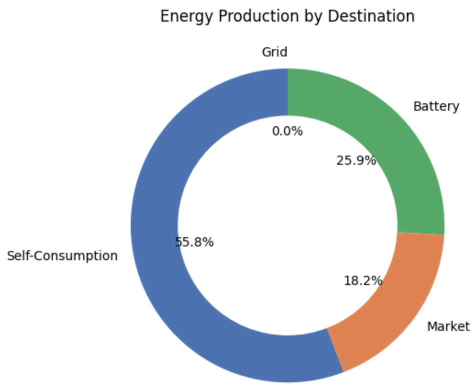
Consumption covered by battery (%): 9.05

Percentage of supply put to battery (%): 58.74

Energy Consumption/Production By Source

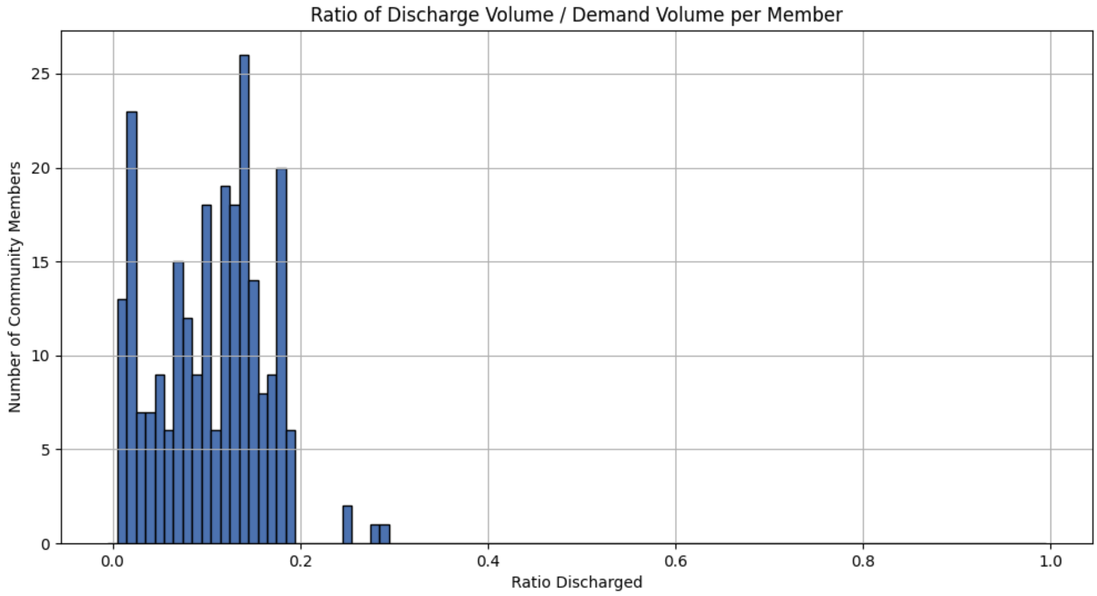
The following figure visualizes where the consumed energy comes from and where the produced energy goes to (self-consumption, community market, battery, grid).





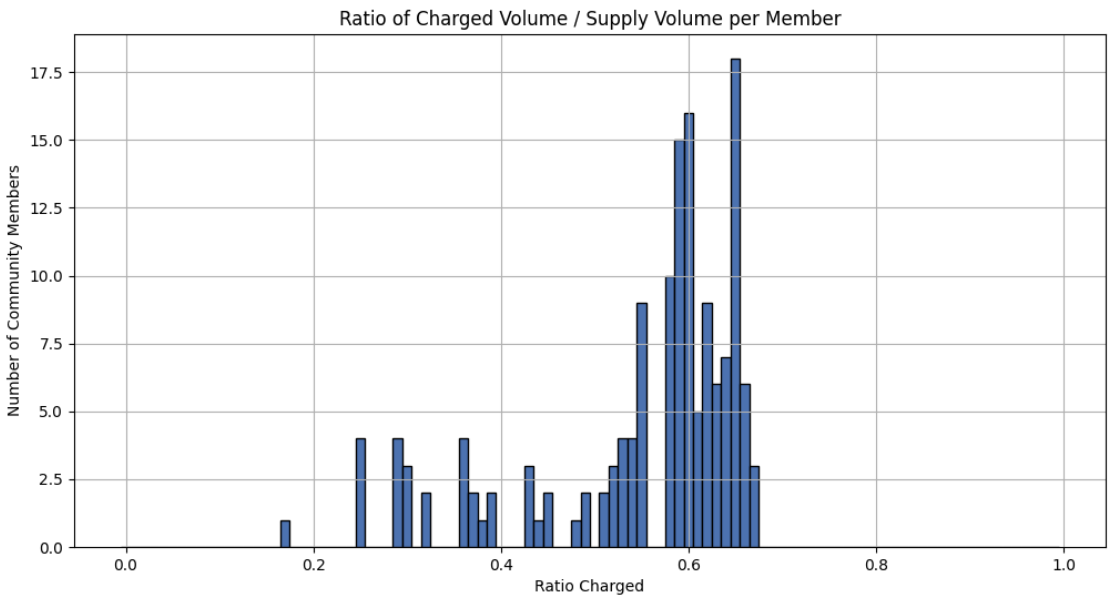
Ratio of energy obtained from battery of overall demand

The following bar chart aims to visualize the fairness of the battery discharging allocation algorithm. For each community member, the ratio of energy obtained from the battery of the overall demand (consumption not covered by self-production) is shown, discretized to single percentage points. If a bar has height 10, it means that 10 community members have purchased this percentage of their demand from the battery. Each member wants this to be as high as possible, since purchasing from the battery or local market is cheaper than purchasing from the grid.



Ratio of energy sold to battery of overall supply

The following bar chart aims to visualize the fairness of the battery charging allocation algorithm. For each community member, the ratio of energy 'sold to' the battery of the overall overproduction (production not used by self-consumption) is shown, discretized to single percentage points. If a bar has height 10, it means that 10 community members have sold this percentage of their supply to the battery. Each member wants this to be as high as possible, since 'selling to' the battery or local market yields higher prices than feeding into the grid.



Supply, Demand and Battery Capacity Curve

The following figure plots the battery capacity, supply and demand curves over the time period of the dataset.