Handling of batteries in Energy Communities

1. Context

In a first phase, energy communities enable electricity producers to share surplus energy with other consumers, thereby increasing the producers' profitability while reducing energy costs for participating consumers. Energy sharing can take place across different layers, which are defined on the one hand by the physical area in which the sharing occurs and, on the other hand, by the participants involved in the energy community. Depending on the layer at which energy sharing is realized, grid fees may be partially or fully avoided or may still apply.

As electrical energy must be balanced continuously within the grid, this form of energy sharing is most efficient when the energy injected by producers into the energy community is matched in real time by consumption. However, renewable generation assets primarily solar and wind installations are inherently volatile and do not produce electricity continuously. As a result, production may occur at times when there is little or no consumption within the community, while consumption may take place when no local renewable generation is available.

The efficiency and flexibility of energy sharing can be significantly improved by enabling the storage of surplus renewable energy in batteries and making this energy available at a later time when consumption occurs. Battery integration allows temporal decoupling of production and consumption, thereby increasing local self-consumption of renewable energy and reducing reliance on external energy sources.

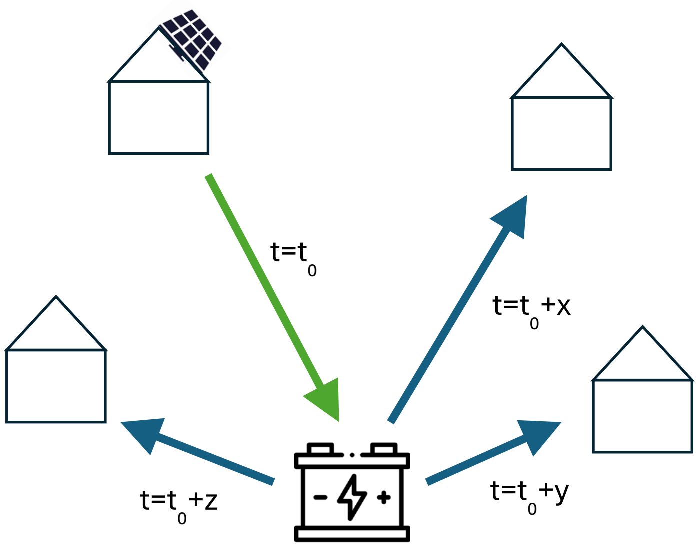
This document describes how the current calculation model for energy communities implemented in Leneda (the Luxembourgish Energy Data Platform) can be extended to allow batteries to participate in energy communities, while ensuring that energy sharing remains strictly linked to renewable energy production and continues to respect the underlying principles of energy community frameworks.

- **Initial use case:** The first use case to be addressed is a local, stand-alone battery installed at street level and participating in an energy community within the neighbourhood. The battery is operated by a dedicated operator who is responsible for defining the charging and discharging cycles and assumes full operational responsibility for the battery's performance and compliance.
- **Future extensions:** In a subsequent phase, the concept can be extended to additional use cases, including batteries owned by private customers that actively participate in the energy market and in energy communities. These use cases introduce a higher level of decentralisation and user involvement, and may require more advanced coordination, market integration, and control mechanisms

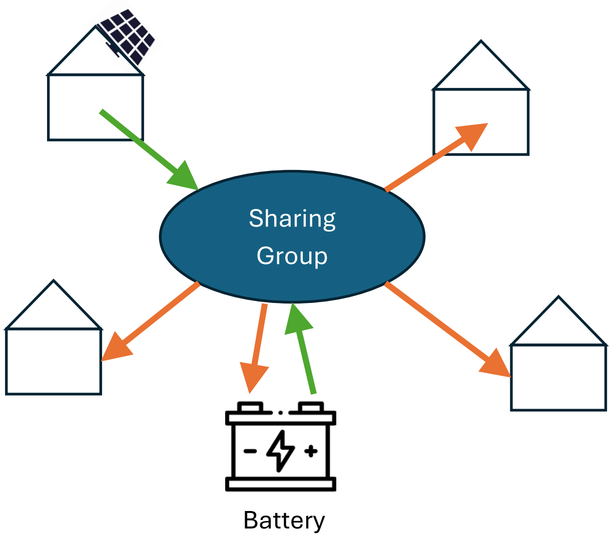
2. Concept

2.1. Problem statement

The current energy community calculation model implemented in Leneda shall be enhanced to enable the participation of batteries as active components within energy communities, allowing surplus renewable energy to be stored and reused at a later point in time. The model must ensure that only energy originating from renewable energy sources is eligible to be re-injected and shared within the energy community.



Energy drawn from the public grid is considered to originate from conventional energy sources. Such energy may be traded on the market in accordance with existing market rules but must not be attributed to, or redistributed within, the energy community. The enhanced calculation model must therefore clearly distinguish between renewable energy stored for community use and grid-supplied energy, ensuring transparency, traceability, and regulatory compliance.



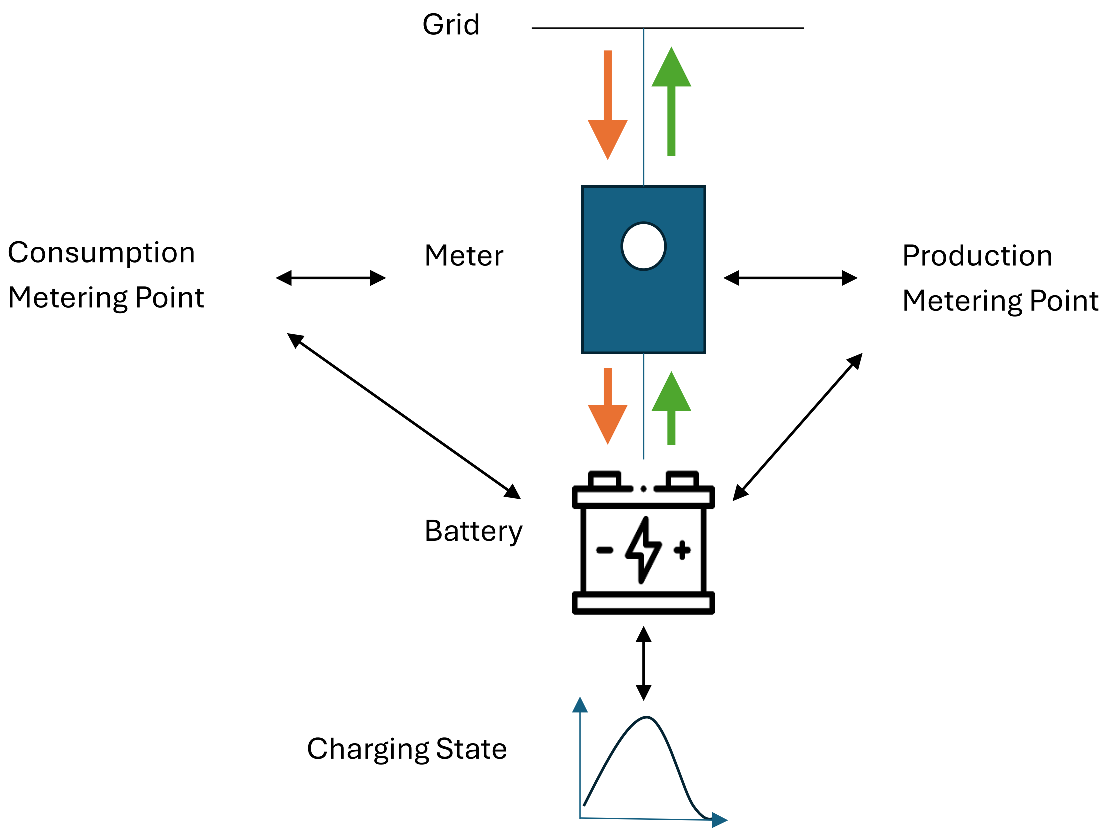
2.2. Modelling of the stand-alone battery case

2.2.1. Stand-alone battery

From a physical perspective, the battery is connected to the public grid through a dedicated electricity meter without any other consumption or production. This electricity meter records the energy flows related to both charging and discharging of the battery, using 15-minute load curve values.

During a given 15-minute interval, the battery's operation may change. For example, it may charge during part of the interval and discharge during another part of the same interval. As a result, the meter may record both grid consumption, when the battery is charging, and grid injection, when the battery is discharging, within the same 15-minute period.

However, the calculations for sharing groups are performed based on aggregated 15-minute values. The system therefore cannot determine the exact timing of charging or discharging within that interval. For this reason, for each 15-minute period, the net value will be used: grid consumption and grid injection will be offset against each other. The resulting balance will determine whether the battery is considered to have been in charging mode or discharging mode during that interval.



From a logical perspective, battery operation involves two distinct energy flows: consumption of electricity from the grid during charging and reinjection of electricity into the grid during discharging. To correctly represent and process these flows within the calculation model, two logical metering points are required:

- one for the consumption (charging of the battery)
- one for injection (discharging of the battery)

These metering points must be explicitly linked to each other to ensure consistent attribution of energy flows to the same physical battery asset.

In Leneda, the battery will be represented as a new object of type appliance that will be registered by the DSO on both logical metering points. The battery object will contain the following technical characteristics:

- Appliance type: Stand-alone battery
- Date Range (Start and potential End Date)
- Maximal capacity of the battery in kWh
- Maximal charging power in kW
- Maximal discharging power in kW

A 15min time series with a new OBIS code (1-0:5.8.1) will be linked to the battery object. In a first phase this curve will track the amount of green energy stored at each 15min time point inside the battery. In the future it is possible to add another OBIS code (1-0:5.8.2) tracking the amount of grey energy stored at each 15min time point inside the battery.

2.2.2. Sharing group constellation

To support the stand-alone battery use case, the standard energy community layers (2, 3 or 4) can be applied. The battery is, however, restricted to participation in a single sharing group, as allowing participation in multiple sharing groups would compromise the consistency and traceability of the energy sharing calculations.

Both logical metering points associated with the battery must be members of the same energy community to:

- absorb renewable (“green”) energy from the energy community during charging via the consumption metering point, and
- re-inject this renewable energy into the energy community during discharging via the production metering point.

It is recommended that the consumption and production metering points of the battery are being assigned the highest priority (rank) within the energy community to ensure that:

- any excess renewable production injected into the community can be preferentially absorbed by the battery, thereby maximising local self-consumption

- any injection of green energy from the battery is firstly absorbed by the consumers of the energy community before being sold to the energy market

The manager of the energy community is, however, free to define a different logic.

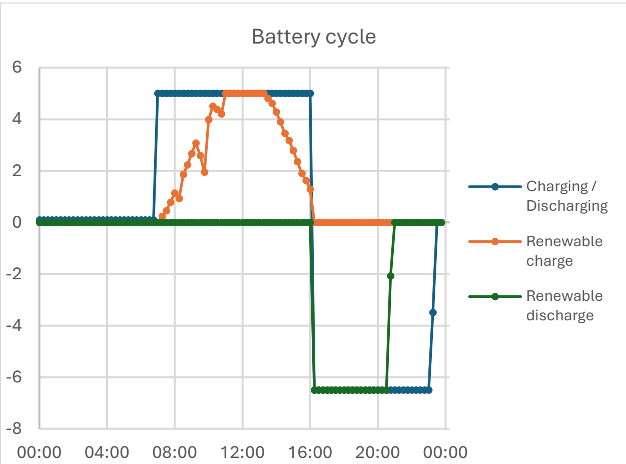
In a first phase as only, the green energy will be tracked, it is assumed that the discharge of the battery will firstly be realized with green energy.

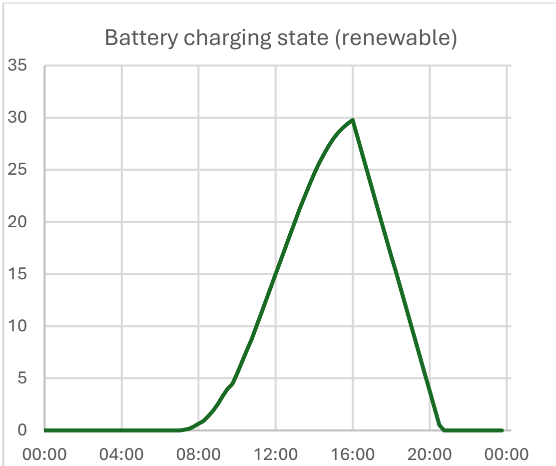
2.2.3. Sharing group calculations

To enable proper tracking of the amount of renewable energy stored in the battery, the OBIS code (1-0:5.8.1) that is attached to the battery object will be used. The amount of green energy will increase in case the battery is charged with energy originating from the sharing group. This energy is eligible for later release in the sharing group.

The energy provided by the sharing group to charge the battery will be tracked by OBIS code 1-65:1.29.X on the consumption metering point of the battery.

During battery discharge, the stored renewable energy of OBIS code (1-0:5.8.1) is released with priority, up to the calculated available amount recorded under this OBIS code in the previous quarter. Any remaining discharge beyond this amount is treated as conventional energy and is therefore excluded from further sharing within the energy community.





The energy provided by the battery to the energy community will be tracked by the OBIS code (1-65:2.29.X) on the injection metering point.

At a time point n, the green energy that can be retrieved from the sharing group during a charging operation and injected into the battery depends on the availability of green energy inside the sharing group ($SG_{injection}$) and the charging power retrieved from the grid (1-1:1.29.0). The calculation is done as following:

- If 1-1:1.29.0 > $SG_{injection}$ then 1-65:1.29.X = $SG_{injection}$
- else 1-65:1.29.X = 1-1:1.29.0

At a time point n, the green energy that is fed into the grid from the battery ($Grid_{GreenInjection}$) during the discharging operation depends on the previous charging state of green energy inside the battery (CS_{n-1} on OBIS code 1-0:5.8.1) and the discharging power retrieved from the battery (1-1:2.29.0). The calculation is done as following:

- If $CS_{n-1} = 0$ then $Grid_{GreenInjection}=0$
- Else if $1\text{-}1{:}2.29.0 < 4 * CS_{n-1}$ then $Grid_{GreenInjection} = 1\text{-}1{:}2.29.0$
- Else $Grid_{GreenInjection} = 4*CS_{n-1}$

The part of the green energy that can be used directly inside the energy community depends on the available consumption at that moment n. If, at the time of renewable energy discharge, there is insufficient consumption within the energy community, the surplus energy is exported to the market in accordance with applicable market rules.

The charging state (CS) of green energy for a time point n depends:

- On the charging state of the previous time point (CS_{n-1})
- The green energy that was retrieved from the sharing group during a charging operation of the previous time point ($1\text{-}65{:}1.29.X_{n-1}$)
- The green energy that was retrieved from the battery during a discharging operation of the previous time point ($Grid_{GreenInjection\ n-1}$)

And is calculated as following: $CS_n = CS_{n-1} + ¼ * 1\text{-}65{:}1.29.X_{n-1} – ¼ * Grid_{GridInjection\ n-1}$

2.2.4. Scenarios

Due to the number of dynamic variables within an energy community such as the volume of surplus energy injected into the community, the consumption behaviour of participants, and the charging and discharging strategies defined by the battery operator, a battery participating in an energy community may be exposed to a wide range of operational scenarios.

The operation of the battery is under the full control and responsibility of the battery operator. Based on the data available to them, the operator may define the charging and discharging setpoints according to different strategies. These strategies may consider real-time consumptions of the energy community members, real-time productions of the renewable generation units participating in the energy community, or predefined fixed schedules.

The operator may also use the battery in parallel for market-based optimisation, such as exploiting electricity price fluctuations, to enhance the overall profitability of the battery.

Injection of renewable energy into the sharing group ($SG_{injection}$)	Consumption behaviour	Charging / Discharging cycle	Renewable charging state of battery (CS)	Consequence
Low, High	Low, High	None	Low, High	Distribution of energy from SG directly to members without usage of the battery
Low	Low, High	Charging	Low, High	Small coverage of charging energy of the battery by the SG

				Other part of charging energy covered by conventional energy
Low	Low	Discharging	Low	Small injection of energy from battery into sharing group that might not totally be absorbed by members Remaining part of the discharge will be considered as conventional energy
Low	Low	Discharging	High	Small injection of energy from battery into sharing group fully covered by renewable energy but potentially not absorbed by members
Low	High	Discharging	Low	Small injection of energy from battery into sharing group totally absorbed by members Remaining part of the discharge will be considered as conventional energy
Low	High	Discharging	High	High injection of energy from battery into sharing group fully covered by renewable energy and mostly absorbed by member
High	Low, High	Charging	Low, High	High coverage of charging energy of the battery by the SG Remaining part of SG injection can be shared directly to the members and/or sold to the market
High	Low	Discharging	Low	Small injection of energy from battery into sharing group that might not totally be absorbed by members Remaining part of the discharge will be considered as conventional energy Remaining part of SG injection will be sold to market
High	Low	Discharging	High	Small injection of energy from battery into sharing group fully covered by renewable energy but potentially not absorbed by members Remaining part of SG injection will be sold to market
High	High	Discharging	Low	Small injection of energy from battery into sharing group totally absorbed by members Remaining part of the discharge will be considered as conventional energy Remaining part of SG injection not consumed by members will be sold to market
High	High	Discharging	High	High injection of energy from battery into sharing group fully covered by renewable energy and mostly absorbed by member Remaining part of SG injection will be sold to market

2.3. Modelling of other battery use cases

Still to be defined once it is clear how green and grey energy can be distinguished