SIZING AND DISPATCHING OF LOCAL ENERGY COMMUNITIES TO ASSESS THEIR POTENTIAL ECONOMIC IMPACT THROUGH REGULATION AND COMMUNITY DESIGN

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ABSTRACT

The rise of distributed energy resources due to their rapid cost reduction is leading to the appearance of new business models in the domain of energy sharing and local energy communities (LECs). Proper integration of local energy communities into the existing system is facing many challenges. One of those challenges is to assess the technical and economic feasibility of LECs from a double perspective, i.e. from the prosumer and community perspective and from the DSO perspective. This paper describes a model that assesses the technico-economic feasibility of LECs. An illustrative case in the French context is further analysed to show how the legal and regulatory framework is a key aspect to find the right balance between the different actors (community members, market players & distribution system operators).

CONTEXT AND PROBLEM STATEMENT

Significant cost reduction of distributed energy resources (DERs) combined with new customer's expectations in energy sharing and peer-to-peer trading have paved the way to a new range of disruptive business models to realize a more decentralized energy system. In this paper, the technical & economic feasibility of local energy communities (LECs) from a double perspective (prosumer perspective and DSO perspective) is investigated. On the one hand the economic opportunity for prosumers of joining a LEC will be assessed and, on the other hand, the impact that these LEC may induce to the distribution networks will be evaluated.

In order to assess this economic impact, several parameters as well as influencing factors must be taken into account, such as the legal and regulatory framework, the technological assets (including their economical parameters) and the community design. Therefore, the cost-optimal combination of behind-the-meter DERs will be investigated for a community located in a specific European country (naming France in this case) and whose members are located close to each other, i.e. behind a same Medium Voltage / Low Voltage transformer. These prosumers and their DERs are forming a LEC at distribution level, where power, heating and cooling can be co-optimized, both in terms of sizing and dispatching to reach the lowest total cost over the studied time horizon.

MODEL DESCRIPTION

This paper describes a simulation tool that aims at assessing the potential impact of a local energy community (both technically from the DSO perspective and economically from the community and prosumer perspective) based on different parameters such as the location, composition, assets potential, energy costs, regulation, community design, etc. The potential of LEC is more specifically evaluated through a proper sizing and dispatch (related to operational planning) of the various flexibility DERs available in the LEC. A local energy community is represented with three layers:

- Community layer (upper level);
- Prosumer layer (lower level);
- Decentralized Energy Resource layer (sub-prosumer level).

Each prosumer is individually modelled and can be associated with different DERs. The community is represented as the aggregation of all prosumers belonging to the community. A schematic of the structure and the different layers of the model can be found in Figure 1. To evaluate and limit the grid impact of local energy communities, the grid constraints are taken into account in the form of maximum consumption and injection limits at community level (that can be seen as the usage of a share of the MV/LV transformer capacity behind which the LEC is located). The following sections describe in more details the specifications of this model.

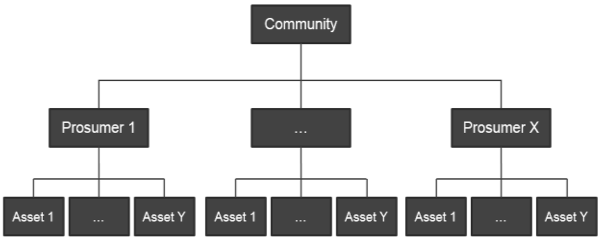

Figure 1 – Schematic of the structure of the model

Inputs of the model

The model takes as inputs different parameters to define the community, the prosumers, the DERs as well as the regulation scheme(s) that will be applied at both community and prosumer levels.

Community

This part of the parametrization is linked to the community definition:

- Community composition: how many and what types of prosumers are part of the community;
- If any, what are the grid constraints to be considered at community level;
- Legal & regulatory framework applied to the community (community design that virtualizes the power flows and split them between community members and the associated grid tariffs to translate those virtual power flows into economic outcomes).

Prosumers

Different types of prosumers have been modelled to compose the community, such as (non-exhaustive list):

- B2C: Household (house/flat);
- B2B: Supermarket or office;
- Utility producer (prosumer that centrally produces energy for the community, e.g. with ground mounted photovoltaic panels and a centralized battery).

To each prosumer are assigned different load profiles:

- Electricity demand;
- Electrical heating demand;
- Electrical cooling demand.

DERs and flexibility

As already explained, each prosumer is associated with flexibility assets that can differ from one prosumer to the other. The prosumer model supports the following DERs:

- Demand side management for both electrical heating and cooling demands;
- Stationary batteries;
- Electrical vehicles (with smart charging capabilities);
- Photovoltaic panels.

Different parameters characterize each of the assets. For instance, PV installations are characterized by a minimum and maximum installation size, unitary capital expenditures, unitary operational expenditures, lifetime, etc.

Regulatory framework

The regulatory framework – which determines what grid tariffs will apply to the community members - is an important topic for local energy communities because there are a very wide range of possibilities to define the cost structure of energy (electricity) costs, grid fees as well as taxes and levies. From an economic point of view, those costs can be applied at community level and/or at prosumer level by different means:

- Fixed charges [€/year]: fixed cost paid once a year no matter of the volume of energy consumed from the grid and the peak consumption/injection;
- Volumetric charges [€/kWh]: cost paid based on the volume of energy consumed from the grid;
- Capacity charges [€/kW]: cost paid based on the max consumed/injected power from/into the grid over a given period (month, year, etc.).

Those means and levels at which the costs can be applied lead to many potential regulatory frameworks that will be more or less in favour of local energy communities. This pricing structure (see Figure 2) has been implemented in the model in order to allow investigating the potential of LECs in different countries and regions since each country and region has its own characteristics.

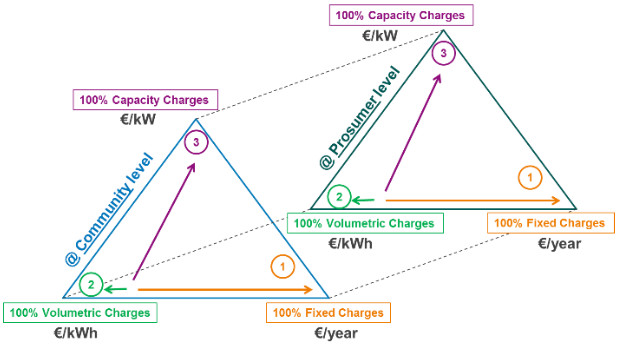

Figure 2 – Regulatory framework regarding grid tariffs

Mathematical formulation

The simulation time step of the model is one hour and the simulated period is four representative weeks chosen out of full year data [1]. The model includes:

- A standard linear problem (LP) for the LEC optimization;
- A mixed integer linear problem (MILP) for the selection of four representative weeks.

The optimisation of the community, its prosumers and the assets is centralised, meaning that they are all optimised together in a single objective function.

Outputs of the model

The outputs of model are numerous. This ranges from the sizes of the DERs for each prosumer and the dispatch of those assets between the members to different costs and economic parameters.

ILLUSTRATIVE CASE

In order to give an overview of the capabilities of the model, an illustrative case will be analysed in this section and meaningful conclusions will be drawn from the different simulated scenarios. The chosen case can be found in Figure 3. It shows a LEC behind a MV/LV substation. The LEC is specifically analysed in the current French regulatory framework and for a given community composition:

- 25 households;
- 1 office building (peak load ~50kW);
- 1 utility producer (depending on the scenario) that can invest in ground mounted PV and a centralized battery.

Through different scenarios, the objective is to show how the regulatory conditions and other parameters can strongly influence the value of a LEC.

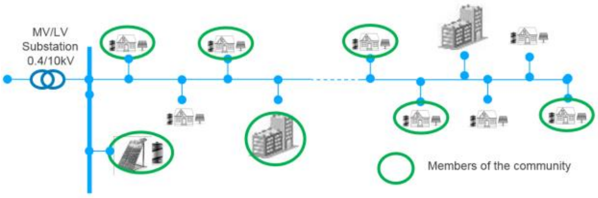

Figure 3 – Schematic of a local energy community behind a MV/LV substation

In the French regulation, the concept of local energy communities was introduced in an order in July 2016 [2]. However, it is not yet fully clear under which tariff structure the LEC will be placed, more specifically for the grid fees. Indeed, as represented in Figure 4 and Figure 5, the different costs (energy cost, grid fees, taxes and levies), can be either applied on individual net consumption/injection or on collective net consumption/injection. In this order [2], the collective self-consumption concept is introduced as follows: a pool grouping all the production of the community can be used to (virtually) dispatch the production between the different members of the community. For example, if member A has an excess of production compared with his load, the excess of production can be assigned to member B that has a deficit of production. While it is clear that energy costs can be applied on the collective net consumption/injection flows, some uncertainties remain for the grid fees. It appears that the grid fees could be applied on different flows:

- Option A: On the collective net consumption /injection flows;
- Option B: On the collective net consumption /injection and on the collective self-consumption flows;
- Option C: On the individual net consumption /injection flows.

Therefore, scenarios will be simulated for each of these options (A, B and C). Regarding the type of grid fees that are used in France (cfr. Figure 2), grids fees include fixed, capacitive and volumetric costs even though most of the bill is paid through volumetric costs [3].

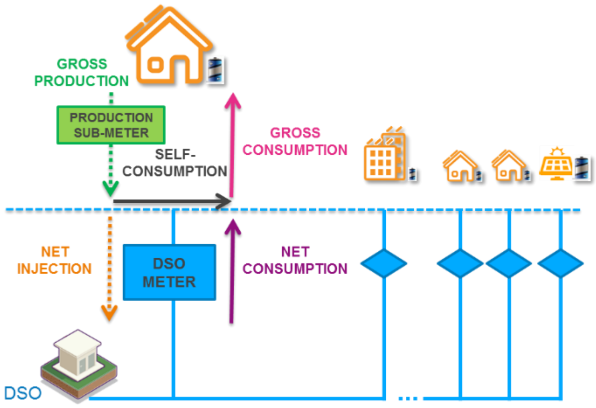

Figure 4 – Individual self-consumption concept

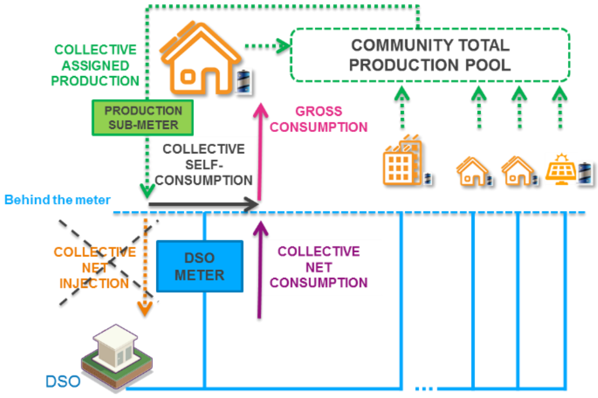

Figure 5 – Collective self-consumption concept (in French regulatory framework)

Scenarios

In order to show how the regulatory conditions and other parameters can influence the value of a LEC, 5 scenarios are simulated for the LEC defined in previous section:

- **Scenario 1**: without utility producer and with Option A for the grid fees
- **Scenario 2**: with utility producer and with Option A for the grid fees
- **Scenario 3**: without utility producer and with Option B for the grid fees
- **Scenario 4**: with utility producer and with Option B for the grid fees
- **Scenario 5**: without utility producer and with Option C for the grid fees

To evaluate the economic value of those communities, each scenario is compared to a reference case, i.e. a case that includes the same prosumers but without community and without DERs (PV, batteries, etc.).

Results analysis

Main results of the simulations can be found in Table 1.

Table 1 – Main results

	Sc. 1	Sc. 2	Sc. 3	Sc. 4	Sc. 5
Rooftop PV installation (total) [kW]	54	0	0	0	43
Ground mounted PV installation [kW]	0	75	0	20	0
Decentralised battery installation (total) [kWh]	0	0	0	0	0
Centralised battery installation [kWh]	0	29	0	0	0
Peak load at transformer [kW]	74	81	74	74	74
Energy exchanged (consumption) at transformer [MWh/year]	147	128	212	185	158
Energy exchanged (injection) at transformer [MWh/year]	6	12	0	0	3
Load factor [%]	23%	18%	33%	29%	24%
Added value of community compared with reference [€/MWh]	23	31	0	9	19
DSO loss of revenue [%]	31%	34%	0%	7%	25%

From those results, different observations can be drawn:

- Investment in assets:
  - When ground mounted PV is available (Scenarios 2 and 4), it is preferred over the rooftop PV installations;
  - Batteries are profitable only for scenario 2, i.e. when ground mounted PV is available and when grid fees are applied on collective net consumption only.
- The peak load at the transformer is not reduced due to the community, it even increases for the scenario 2 as batteries are charged when energy prices are low. However, the load factor tends to decrease for the different scenarios thanks to PV integration and batteries (if any);
- Scenario 3 has no value for the community since it does not invest in any asset. This is clearly due to the tariff scheme used for the grid fees that is too restrictive for the community;
- For scenarios 1, 2 and 5, the value for the community ranges from 19 to 31 €/MWh depending on the case. This value is created at different levels: by investing in DERs, by energy savings through collective self-consumption and by grid savings. For those scenarios, the DSOs loss of revenue ranges from 25% to 34%. Results clearly show that when the value of community is high, the loss of revenue for DSOs is also high.

Overall, results show that while creating value for communities, there is a loss of revenue for DSOs, leading to a conflict of interest. Therefore, knowing that each country has its own particularities, in order to correctly integrate the local energy community concept into the regulatory framework, a tailor-made analysis (specific to each country) is necessary to find the right balance between value for the community and loss of revenue for the DSO.

CONCLUSIONS

In conclusion, this paper shows that this model allows assessing the likelihood of LEC to develop on the market once the underlying technical, economic and regulatory conditions allow prosumers to join a LEC. Moreover, it shows that the regulatory framework, especially regarding grid fees, has a significant influence on the community value but also on the DSOs' revenues. Finally, the analysis shows that this kind of tool can also help the DSOs to develop their strategy with the rise of LECs by assessing the different potential solutions at their disposal to integrate the local energy community concept.

NOMENCLATURE

DER	Distributed Energy Resources
LEC	Local Energy Community
DSO	Distribution System Operator
LV	Low Voltage
MV	Medium Voltage
LP	Linear Problem
MILP	Mixed Integer Linear Problem

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