A community microgrid architecture with an internal local market

MeryGrid

"Collective self-consumption framework in Wallonia and in Europe" study day

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CWaPE
4 avril 2019

Bertrand Cornélusse

Community microgrids: Introduce a local layer in the energy market

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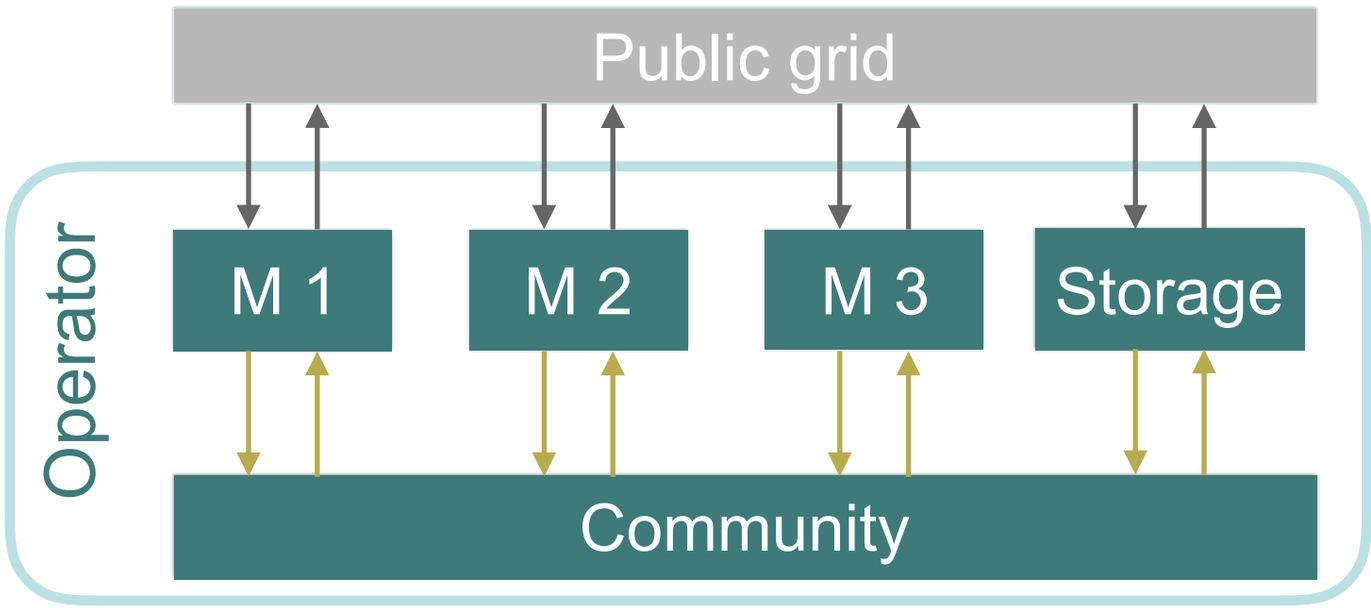
Community microgrids

A **community microgrid** is composed of several **single microgrids** and an **operator**. Single microgrids are in an electrical neighborhood.

The operator objectives are:

- to minimize the cost of energy consumed,
- to maximize revenues from the sale of energy and services,
- to manage relationships between community members.



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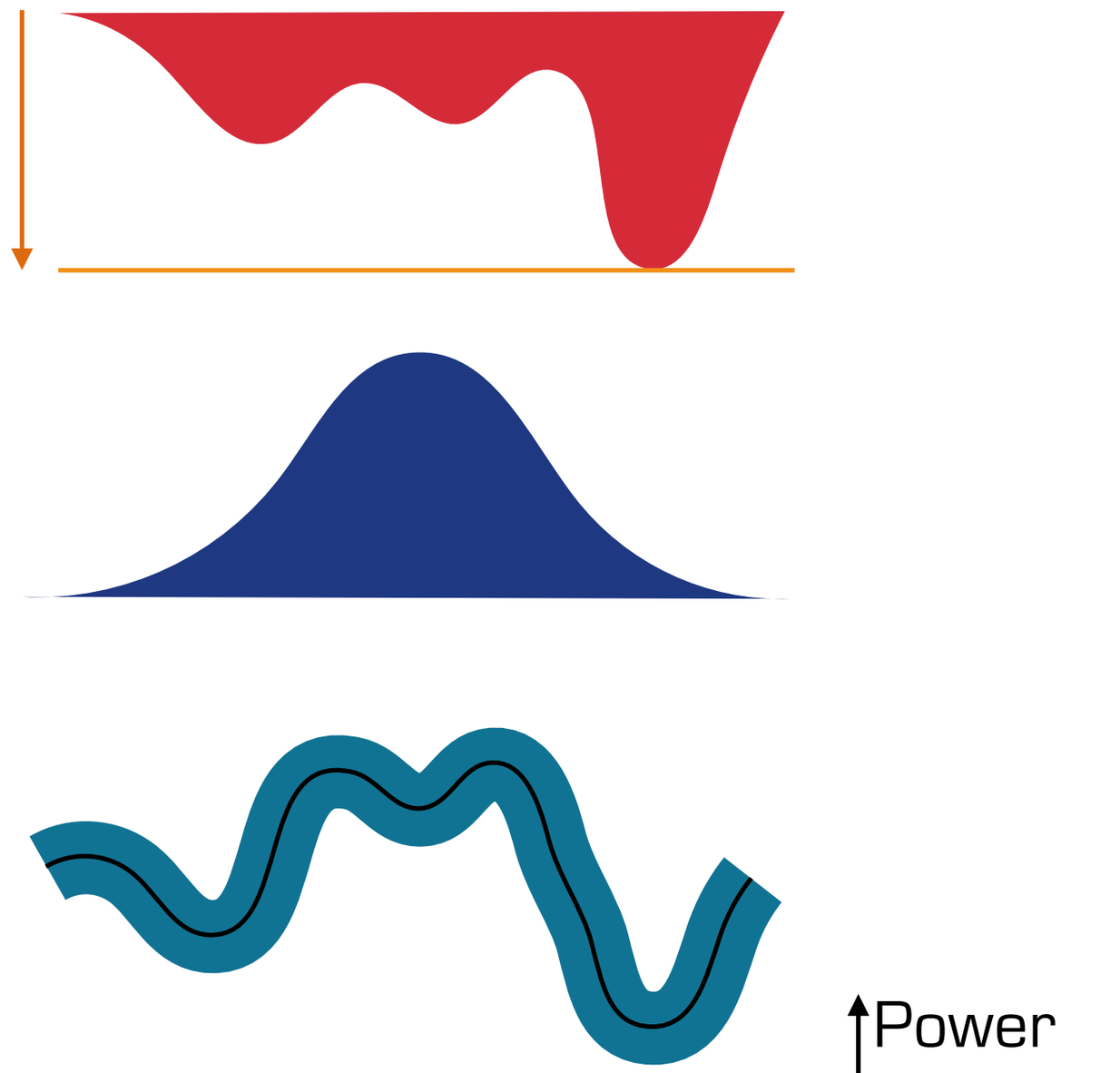
Costs and revenues considered

- Costs
  - Energy consumed
  - Peak power
- Revenues
  - Energy produced
  - Services (reserve)



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Interests of the community microgrid

- For the <u>members</u>, in addition to the advantages of the single microgrid:
  - ✦ an exchange of energy at a more attractive price than with the public network
  - ✦ a group effect on
    - peak
    - reserve

- For the <u>public network:</u>
  - ✦ a larger entity to discuss with, and able to respond to solicitations to help run the network.
  - ✦ Valorisation of local energy reduces the need for subsidies

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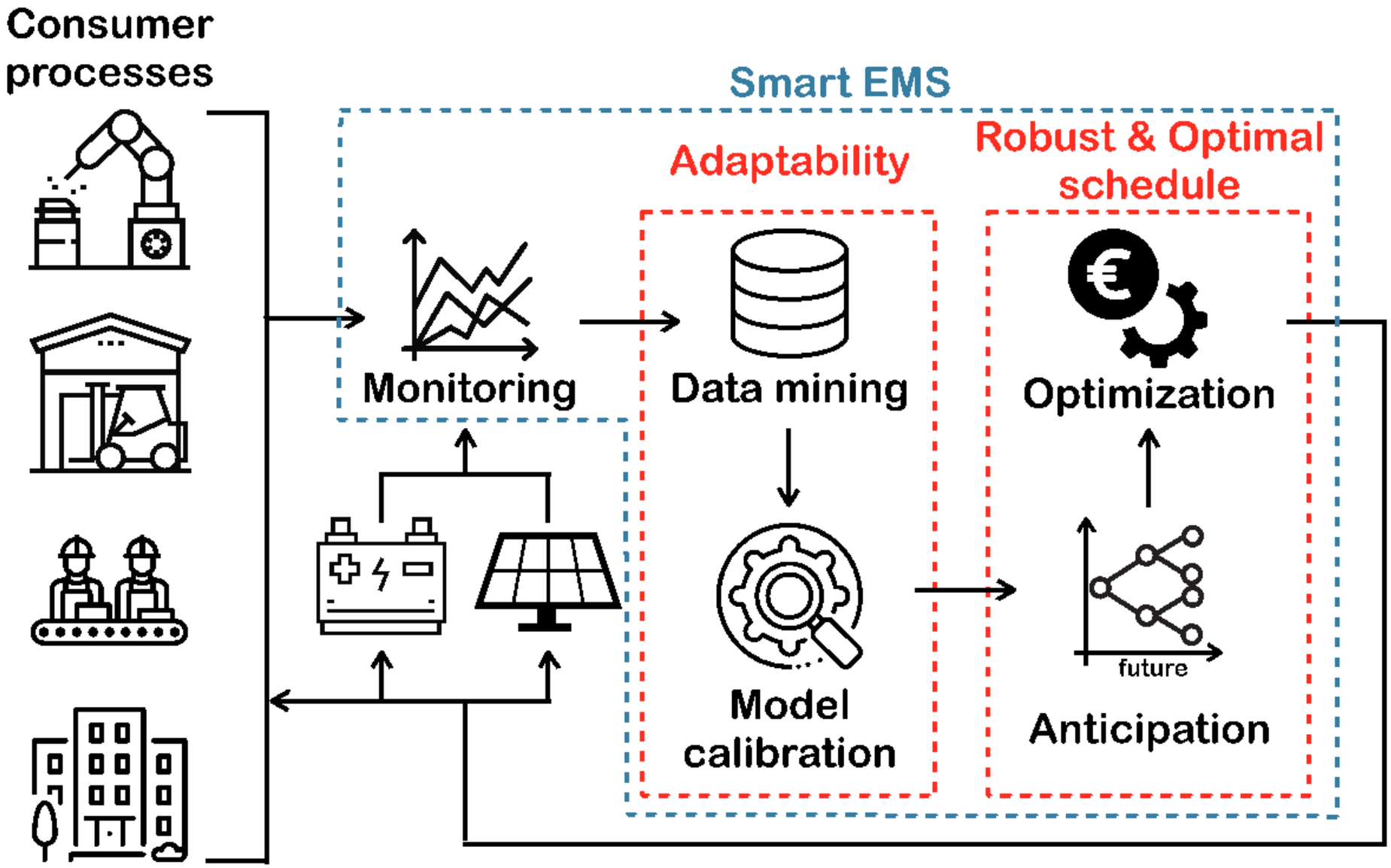
Research questions

- Postulate: we know how to manage a simple microgrid!
- How to
  - optimize the functioning of the community microgrid?
  - ensure that members follow the plan?
  - ensure a fair distribution of the gain?
- Underlying issues:
  - how to remunerate storage?
  - how to remunerate the operator?

In practice

We need an energy management system to monitor and optimize decisions



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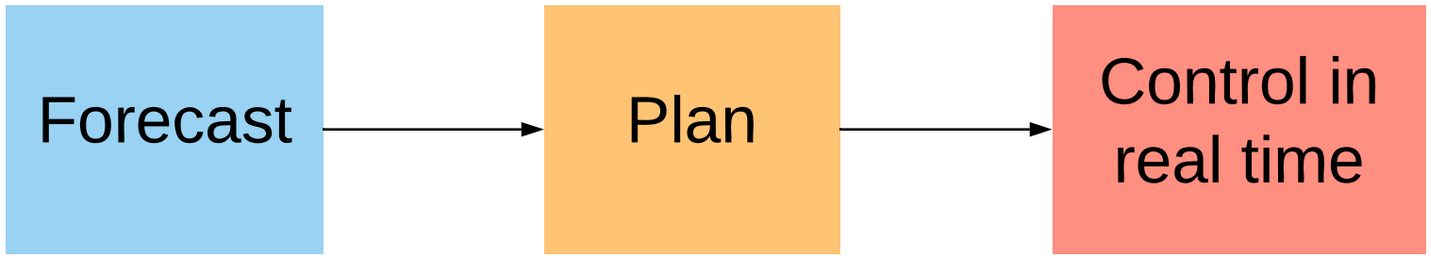
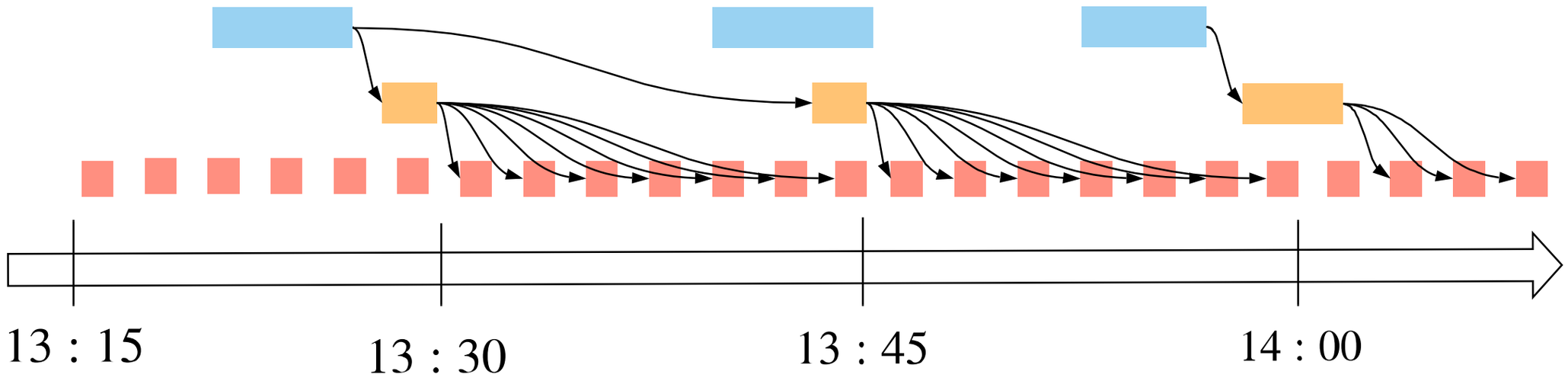
We need an energy management system to apply decisions back to the system in real time





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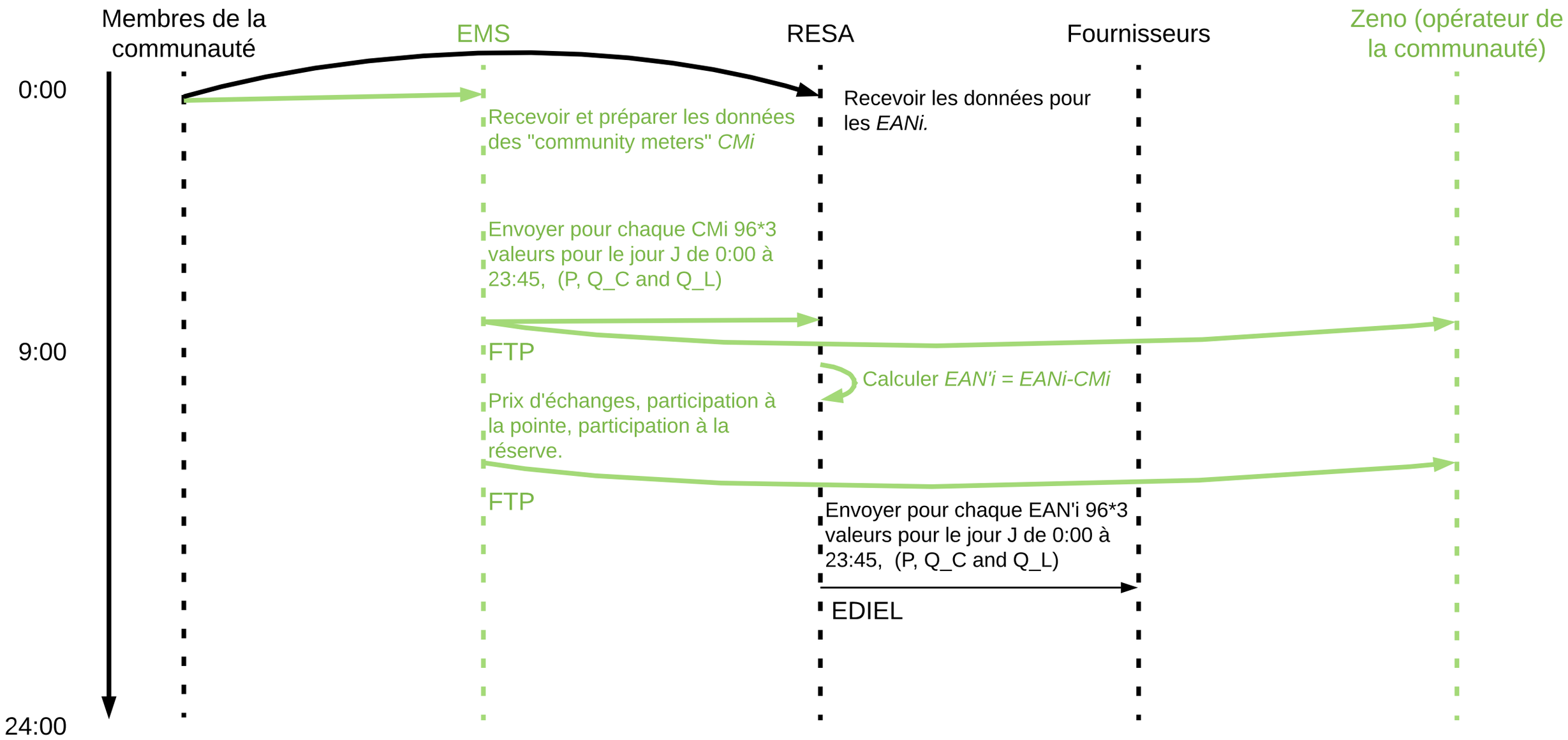
Daily integration in DSO's metering process



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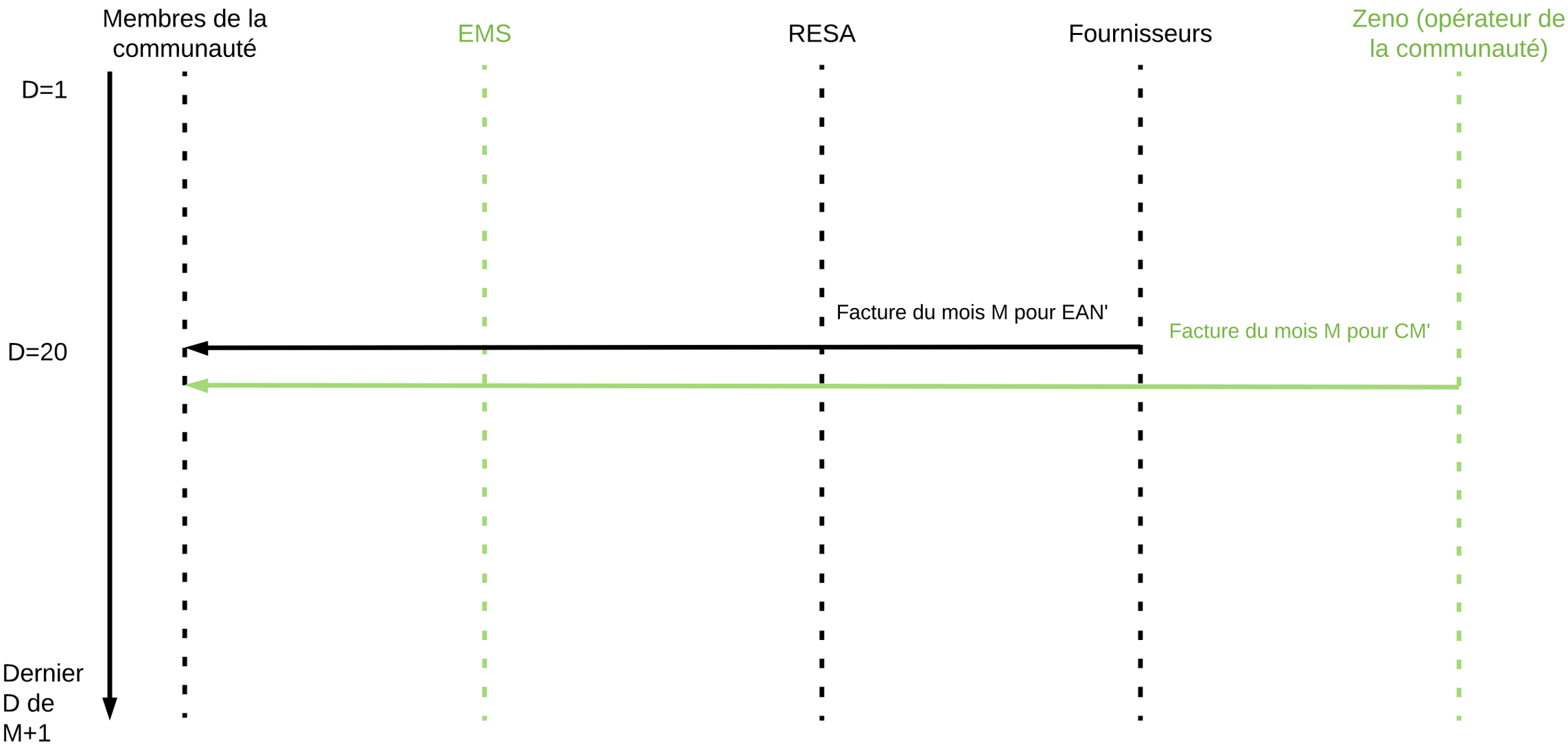
Monthly invoicing process



Remarques :

- les corrections éventuelles seront réalisées trois mois après le trimèstre échu sur base des communications de RESA (!!! communiquer le différentiel avec ce qui avait été envoyé).
- Intérêt de la communauté :
  - Calculer la facture sur base de l'EAN (et non de l'EAN') [nécessite accord du client].
  - Comparer à la somme des factures [nécessite accord du client] EAN' et CM.
- Problème lié au calcul de la pointe (devrait passer chez l'opérateur du microgrid, en lien avec RESA).

Principles

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References

Cornélusse, B., Savelli, I., Paoletti, S., Giannitrapani, A., & Vicino, A. (2019). **A Community Microgrid Architecture with an Internal Local Market**. *arXiv preprint arXiv:1810.09803*.

Cornélusse, B., Ernst, D., & Lachi, S. (2018). **Optimal operation and fair profit allocation in community microgrids**. CIRED workshop on energy communities.

Duchesne, L, Savelli, I.Cornélusse, B (2019). **Sensitivity Analysis of a Local Market Model for Community Microgrids.** To appear in proceedings of IEEE power tech 2019.

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A community microgrid architecture with an internal local market

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ABSTRACT

This work fits in the context of community microgrids, where members of a community can exchange energy and services among themselves, without going through the usual channels of the public electricity grid. We introduce and analyze a framework to operate a community microgrid, and to share the resulting revenues and costs among its members. A market-oriented pricing of energy exchanges within the community is obtained by implementing an internal local market based on the marginal pricing scheme. The market aims at maximizing the social welfare of the community, thanks to the more efficient allocation of resources, the reduction of the peak power to be paid, and the increased amount of reserve, achieved at an aggregate level. A community microgrid operator, acting as a benevolent planner, redistributes revenues and costs among the members, in such a way that the solution achieved by each member within the community is not worse than the solution it would achieve by acting individually. In this way, each member is incentivized to participate in the community on a voluntary basis. The overall framework is formulated in the form of a bilevel model, where the lower level problem clears the market, while the upper level problem plays the role of the community microgrid operator. Numerical results obtained on a real test case implemented in Belgium show around 54% cost savings on a yearly scale for the community, as compared to the case when its members act individually.

1. Introduction

The increasing penetration of distributed generation (DG) from renewable energy sources and energy storage systems in distribution networks paves the way to new market models that favor a local usage of the generated electricity [1]. In this context, microgrids are gaining increasing popularity as an architecture capable of making a more efficient use of resources at a local level [2], and maximizing the local consumption of electricity generated in a distributed manner [3]. When interconnected to the public grid, microgrids may also provide services, such as peak shaving and power balance.

The contribution of this paper focuses on *community microgrids*, where members of the community (termed *entities* in the following) decide to pool their resources (generation, load and/or storage devices) to reduce their costs, increase their revenues, and achieve a more efficient use of their assets. A schematic representation of an entity is shown in Fig. 1. The entities of the community are assumed to be connected to the same local bus, through which they exchange energy among themselves and with the public grid. After introducing a conceptual architecture of the community microgrid, this paper develops the model of an internal local market, based on the marginal pricing scheme, whose aim is to maximize the social welfare of the community.

1.1. Related work

Microgrid energy markets provide small-scale prosumers with a market platform to trade locally generated energy within their community. In some cases, the trading takes place without the need of central intermediaries. Blockchain-based local energy trading is proposed in [4], where prosumers can trade self-produced energy in a peer-to-peer fashion. A case study based on a real community microgrid project in Brooklyn is also reported. In [5], a non-cooperative game arises from the transferrable payoff allocation mechanism designed to aggregate renewable power producers in a two-settlement power market.

In most cases, the internal community market is managed by a third party. A coupled microgrid power and reserve capacity planning

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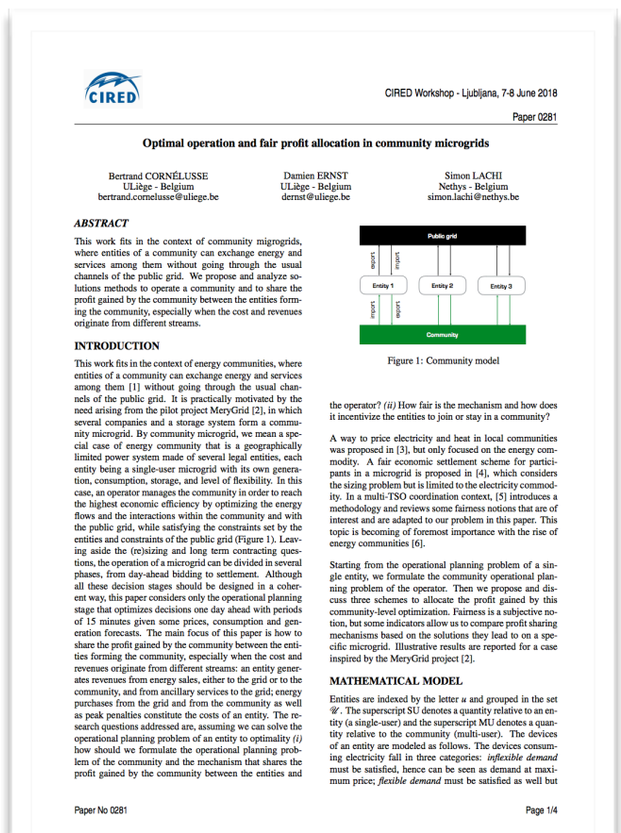

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Paper 0281

Optimal operation and fair profit allocation in community microgrids

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ABSTRACT

This work fits in the context of community microgrids, where entities of a community can exchange energy and services among them without going through the usual channels of the public grid. We propose and analyze solutions methods to operate a community and to share the profit gained by the community between the entities forming the community, especially when the cost and revenues originate from different streams.

INTRODUCTION

This work fits in the context of energy communities, where entities of a community can exchange energy and services among them [1] without going through the usual channels of the public grid. It is practically motivated by the need arising from the pilot project MeryGrid [2], in which several companies and a storage system form a community microgrid. By community microgrid, we mean a special case of energy community that is a geographically limited power system made of several legal entities, each entity being a single-user microgrid with its own generation, consumption, storage, and level of flexibility. In this case, an operator manages the community in order to reach the highest economic efficiency by optimizing the energy flows and the interactions within the community and with the public grid, while satisfying the constraints set by the entities and constraints of the public grid (Figure 1). Leaving aside the (re)sizing and long term contracting questions, the operation of a microgrid can be divided in several phases, from day-ahead bidding to settlement. Although all these decision stages should be designed in a coherent way, this paper considers only the operational planning stage that optimizes decisions one day ahead with periods of 15 minutes given some prices, consumption and generation forecasts. The main focus of this paper is how to share the profit gained by the community between the entities forming the community, especially when the cost and revenues originate from different streams: an entity generates revenues from energy sales, either to the grid or to the community, and from ancillary services to the grid; energy purchases from the grid and from the community as well as peak penalties constitute the costs of an entity. The research questions addressed are, assuming we can solve the operational planning problem of an entity to optimality *(i)* how should we formulate the operational planning problem of the community and the mechanism that shares the profit gained by the community between the entities and the operator? *(ii)* How fair is the mechanism and how does it incentivize the entities to join or stay in a community?

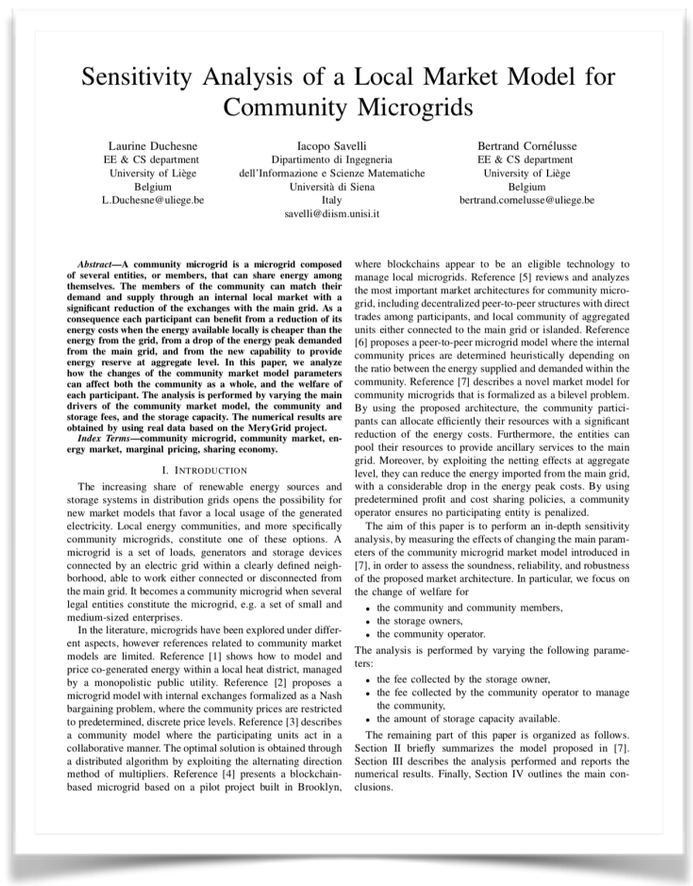
Figure 1: Community model

A way to price electricity and heat in local communities was proposed in [3], but only focused on the energy commodity. A fair economic settlement scheme for participants in a microgrid is proposed in [4], which considers the sizing problem but is limited to the electricity commodity. In a multi-TSO coordination context, [5] introduces a methodology and reviews some fairness notions that are of interest and are adapted to our problem in this paper. This topic is becoming of foremost importance with the rise of energy communities [6].

Starting from the operational planning problem of a single entity, we formulate the community operational planning problem of the operator. Then we propose and discuss three schemes to allocate the profit gained by this community-level optimization. Fairness is a subjective notion, but some indicators allow us to compare profit sharing mechanisms based on the solutions they lead to on a specific microgrid. Illustrative results are reported for a case inspired by the MeryGrid project [2].

MATHEMATICAL MODEL

Entities are indexed by the letter u and grouped in the set $\mathscr{U}$. The superscript SU denotes a quantity relative to an entity (a single-user) and the superscript MU denotes a quantity relative to the community (multi-user). The devices of an entity are modeled as follows. The devices consuming electricity fall in three categories: *inflexible demand* must be satisfied, hence can be seen as demand at maximum price; *flexible demand* must be satisfied as well but



Sensitivity Analysis of a Local Market Model for Community Microgrids

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***Abstract*—A community microgrid is a microgrid composed of several entities, or members, that can share energy among themselves. The members of the community can match their demand and supply through an internal local market with a significant reduction of the exchanges with the main grid. As a consequence each participant can benefit from a reduction of its energy costs when the energy available locally is cheaper than the energy from the grid, from a drop of the energy peak demanded from the main grid, and from the new capability to provide energy reserve at aggregate level. In this paper, we analyze how the changes of the community market model parameters can affect both the community as a whole, and the welfare of each participant. The analysis is performed by varying the main drivers of the community market model, the community and storage fees, and the storage capacity. The numerical results are obtained by using real data based on the MeryGrid project.**

***Index Terms*—community microgrid, community market, energy market, marginal pricing, sharing economy.**

I. Introduction

The increasing share of renewable energy sources and storage systems in distribution grids opens the possibility for new market models that favor a local usage of the generated electricity. Local energy communities, and more specifically community microgrids, constitute one of these options. A microgrid is a set of loads, generators and storage devices connected by an electric grid within a clearly defined neighborhood, able to work either connected or disconnected from the main grid. It becomes a community microgrid when several legal entities constitute the microgrid, e.g. a set of small and medium-sized enterprises.

In the literature, microgrids have been explored under different aspects, however references related to community market models are limited. Reference [1] shows how to model and price co-generated energy within a local heat district, managed by a monopolistic public utility. Reference [2] proposes a microgrid model with internal exchanges formalized as a Nash bargaining problem, where the community prices are restricted to predetermined, discrete price levels. Reference [3] describes a community model where the participating units act in a collaborative manner. The optimal solution is obtained through a distributed algorithm by exploiting the alternating direction method of multipliers. Reference [4] presents a blockchain-based microgrid based on a pilot project built in Brooklyn, where blockchains appear to be an eligible technology to manage local microgrids. Reference [5] reviews and analyzes the most important market architectures for community microgrid, including decentralized peer-to-peer structures with direct trades among participants, and local community of aggregated units either connected to the main grid or islanded. Reference [6] proposes a peer-to-peer microgrid model where the internal community prices are determined heuristically depending on the ratio between the energy supplied and demanded within the community. Reference [7] describes a novel market model for community microgrids that is formalized as a bilevel problem. By using the proposed architecture, the community participants can allocate efficiently their resources with a significant reduction of the energy costs. Furthermore, the entities can pool their resources to provide ancillary services to the main grid. Moreover, by exploiting the netting effects at aggregate level, they can reduce the energy imported from the main grid, with a considerable drop in the energy peak costs. By using predetermined profit and cost sharing policies, a community operator ensures no participating entity is penalized.

The aim of this paper is to perform an in-depth sensitivity analysis, by measuring the effects of changing the main parameters of the community microgrid market model introduced in [7], in order to assess the soundness, reliability, and robustness of the proposed market architecture. In particular, we focus on the change of welfare for

- the community and community members,
- the storage owners,
- the community operator.

The analysis is performed by varying the following parameters:

- the fee collected by the storage owner,
- the fee collected by the community operator to manage the community,
- the amount of storage capacity available.

The remaining part of this paper is organized as follows. Section II briefly summarizes the model proposed in [7]. Section III describes the analysis performed and reports the numerical results. Finally, Section IV outlines the main conclusions.

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Principles

- Each member of the community can decide, at any time, to exchange either with the network or with the community (or both)
  - Everyone can keep their suppliers
  - No simultaneous import-export
- Each member provides its information to the operator, and in return sees the community price, its participation to the peak, and its participation in the reserve
- The microgrid operator must send corrected data to the market: incoming and outgoing flows, 15' by 15', without the remaining flows in the community

Local market architecture

- Formulation as an optimization problem that simultaneously determines
  - dispatch" decisions -> charging / discharging the battery, providing flexibility, limiting the peak, etc.
  - the prices
  - the distribution of profit between entities => sharing rules
  - under minimum profit constraint (an actor cannot lose money if he is in community compared to his isolated situation)

Profit sharing rules are determined a priori

- Internal energy exchange at a fixed price, chosen at any time within a predefined range
- Determination of the impact on the peak of each actor
- Determination of the contribution to the reserve of each actor

Particularities of the model

- A tariff for the use of storage according to the quantities of energy stored / removed from storage
- A tariff for community use per kWh imported and exported
- No explicit constraints to avoid simultaneous charging / discharging, simultaneous import/export
  - (=> Non-linear or MIP)
  - But systematic verification after the fact.

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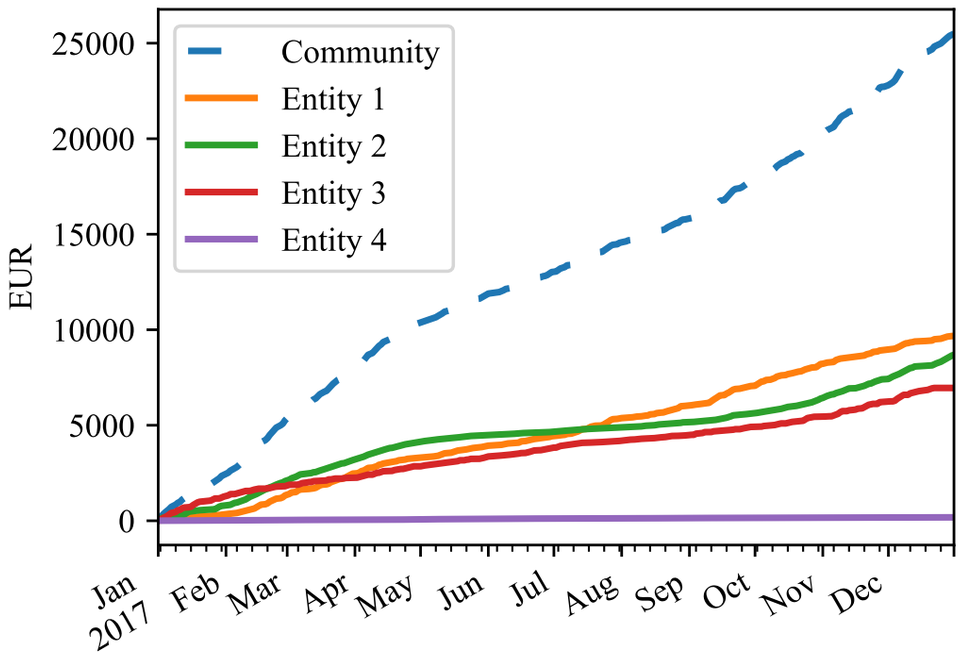
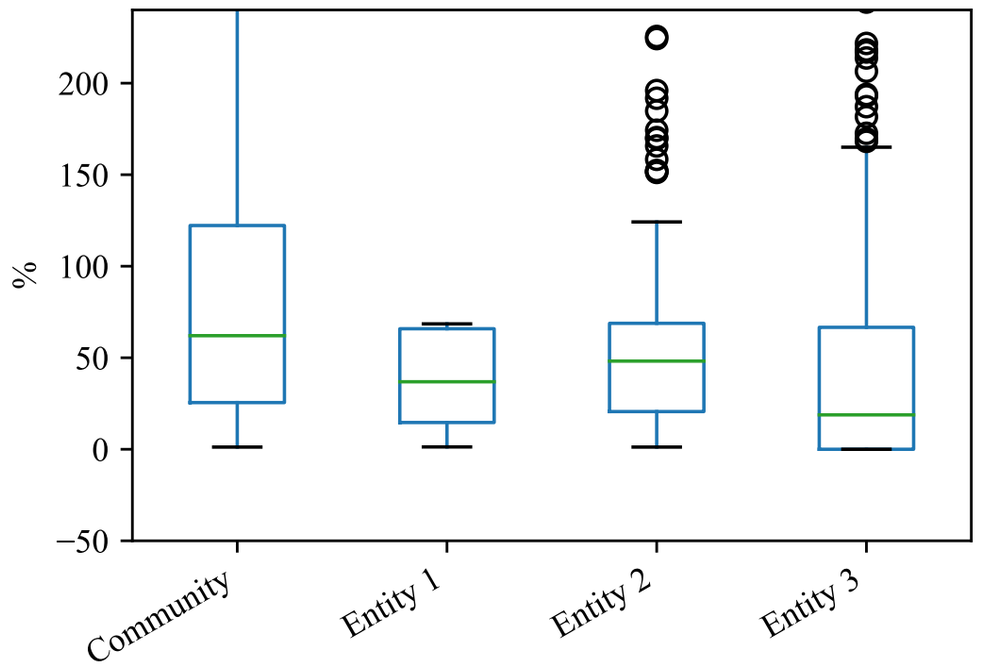
Examples and results

Results forMery (one year)

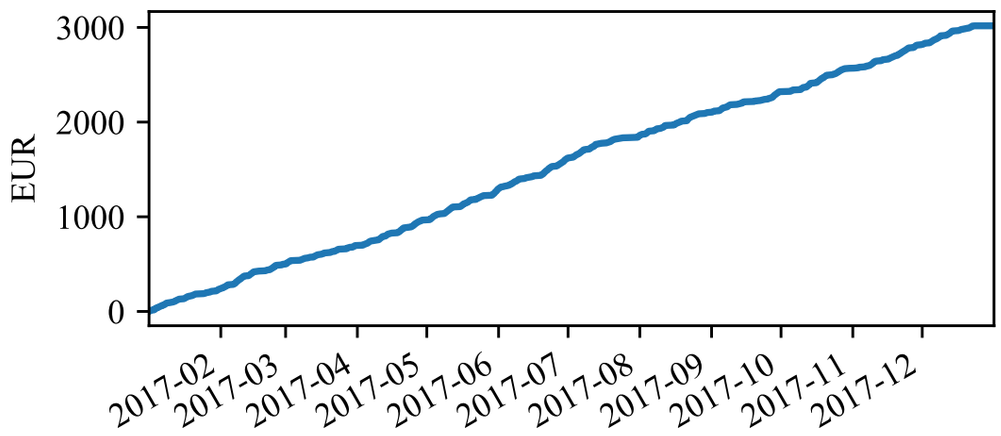
Gain cumulé, par entité



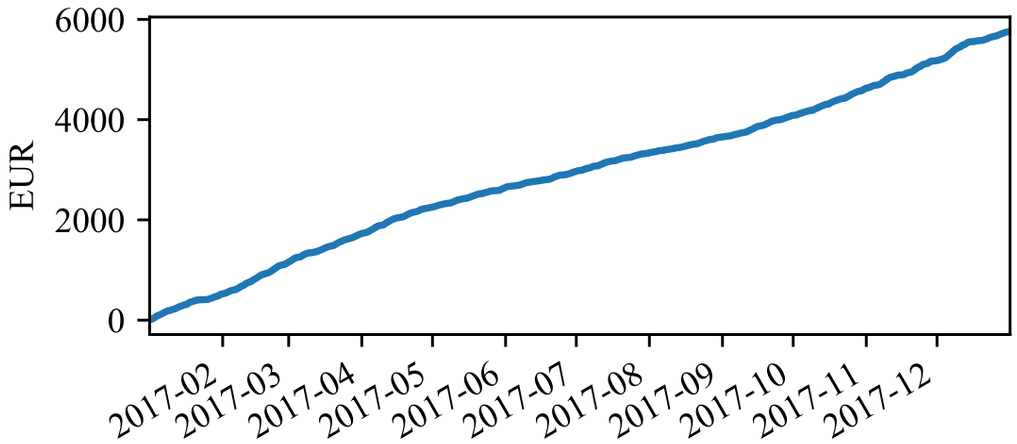
Distribution du gain relatif par entité



Stockage



Opérateur



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Sensitivity to the operator's tariff

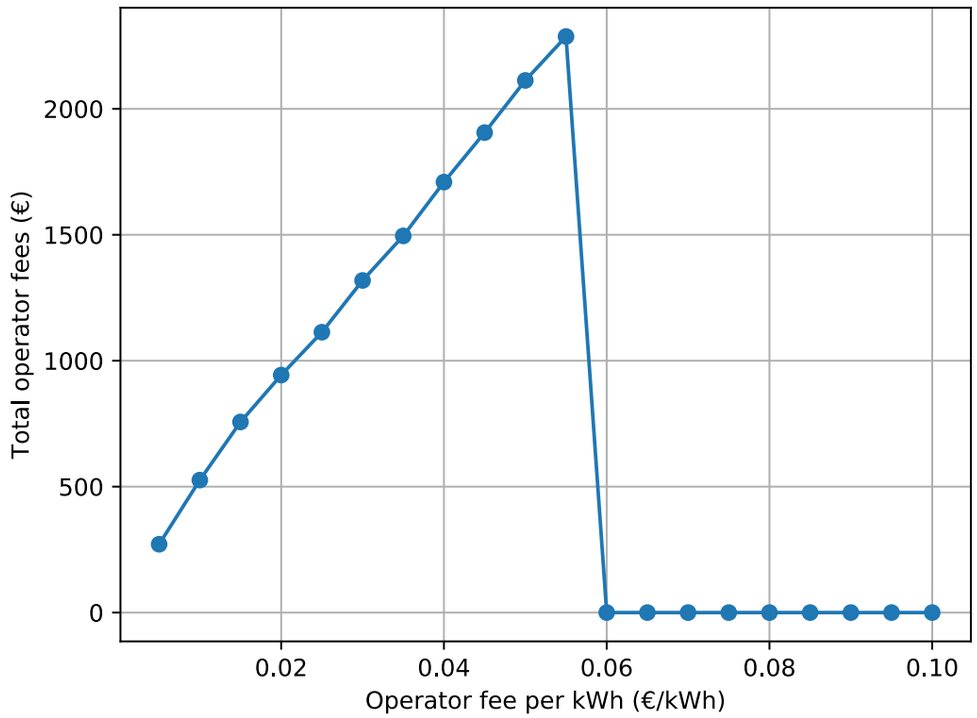

Fig. 3: Total fees paid to the operator during January 2017 as a function of the community operator fee per kWh.

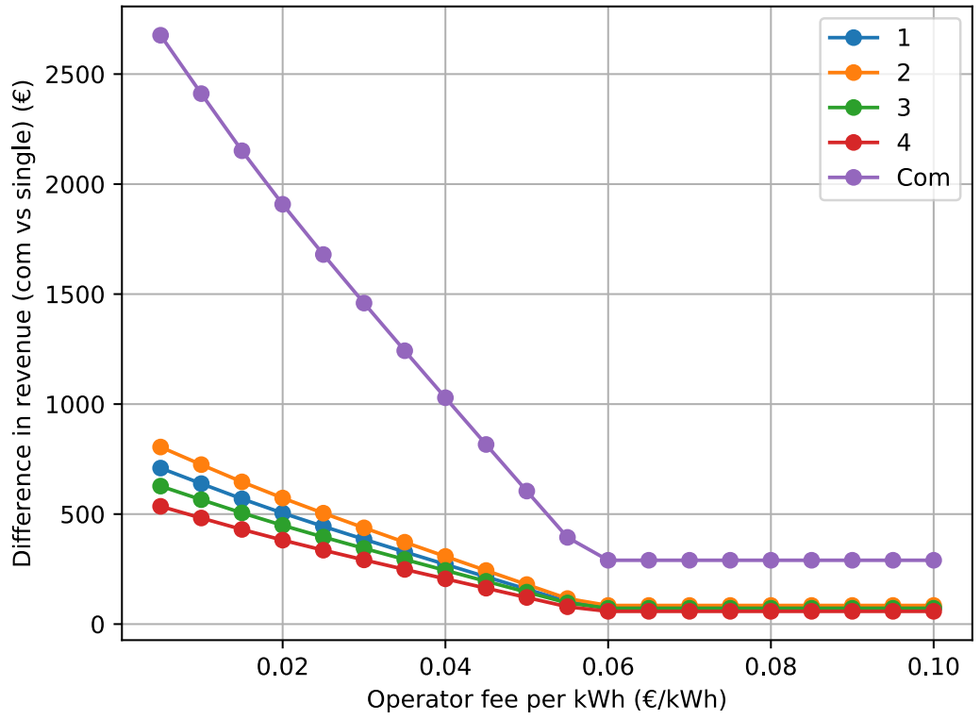

Fig. 4: Difference in revenue for being in the community compared to being a single entity during January 2017 as a function of the community operator fee per kWh.

The community operator's tariff is the adjustment variable that incorporates local network charges, taxes, etc.

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