Noncooperative Game Theory for Resource Scheduling and Planning in Renewable Energy Community

Louise Sadoine[1], Zacharie De Grève[2], Thomas Brihaye[1]

[1]UMons, Effective Mathematics Department, Mons, Belgium - [2] UMons, Power Systems and Market Research Group, Mons, Belgium

Context

Renewable Energy Community (REC):

- Organized entity of consumer and prosumers of electricity established on the public electricity distribution network.
- Members can buy electricity from the local pool of excess renewable production or from their retailer.
- Members may benefit from economic, environmental or social advantages.

Formalized by the EU Commission:

- Enabling citizens to play an active and central role in the electricity supply chain.
- Creating a local stable economic framework, less subject to market price spikes.

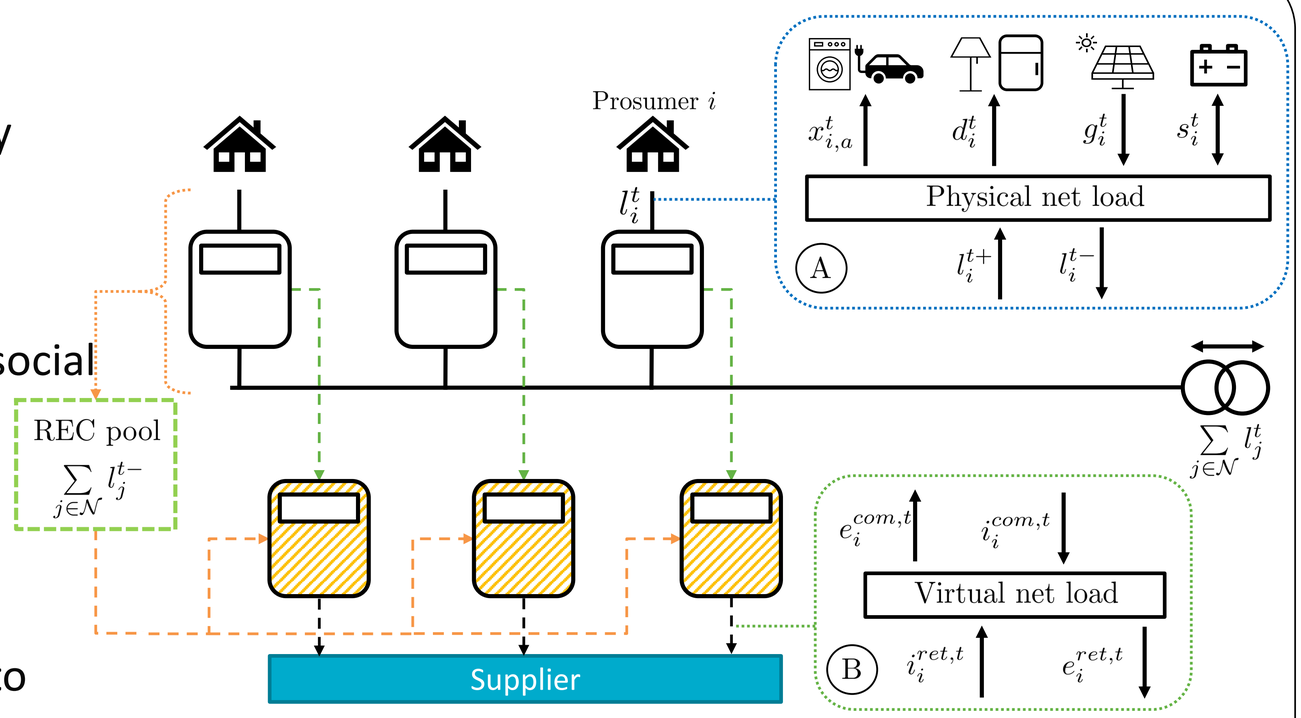


Figure 1 – Renewable Energy Community Model

Objectives Modelling scheduling and resource planning in the REC

Short-term (ST) operational management:

- How to optimally allocate daily energy and costs among REC members?
- How do the retail electricity price and grid tariff structure impact the problem?

Long-term (LT) planning:

- How to model the user entry/exit in a pre-existing REC?
- Does users' non-rationality deviate the SPEs obtained?

Short-term

Generalized Nash Equilibrium Problem (GNEP)

Agent 1

$$\min_{\Theta_1} b_1(\Theta_1, \Theta_{-1}) \quad \text{s.t. } \Theta_1 \in \Omega_1(\Theta_{-1})$$

...

Agent N

$$\min_{\Theta_N} b_N(\Theta_N, \Theta_{-N}) \quad \text{s.t. } \Theta_N \in \Omega_N(\Theta_{-N})$$

REC costs

$$\sum_{i\in\mathcal{N}} b_i(\Theta_i^*, \Theta_{-i}^*)$$

i's individual constraints $\overline{\Omega}(\Theta_i)$

+

Shared constraints

$$\sum_{m\in\mathcal{N}} i_m^{com,t} = \sum_{m\in\mathcal{N}} e_m^{com,t} \quad \forall t \in \mathcal{T}$$

=

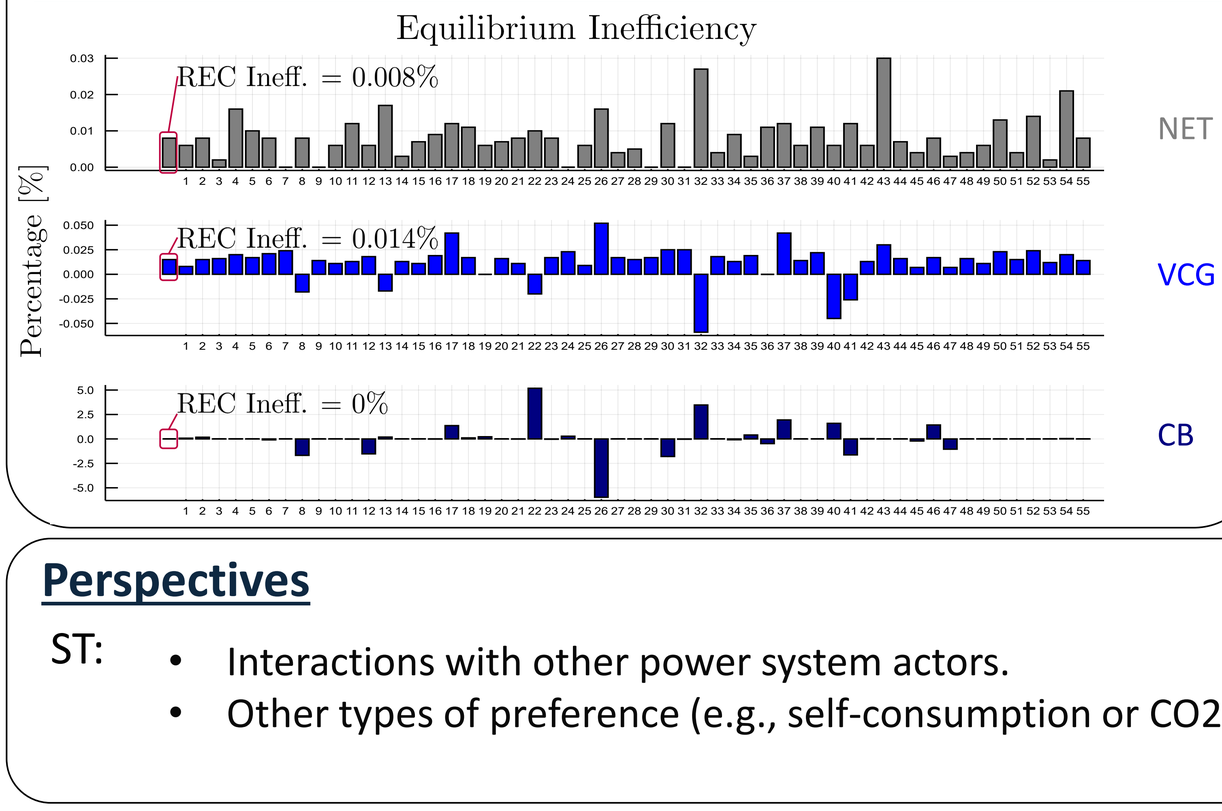
Feasible set $\Omega(\Theta_{-i})$

Decision variables: Physical and virtual power flows, Flexible appliance consumption, Battery charging/discharging power.

Goal: Minimizing her own daily electricity bill.

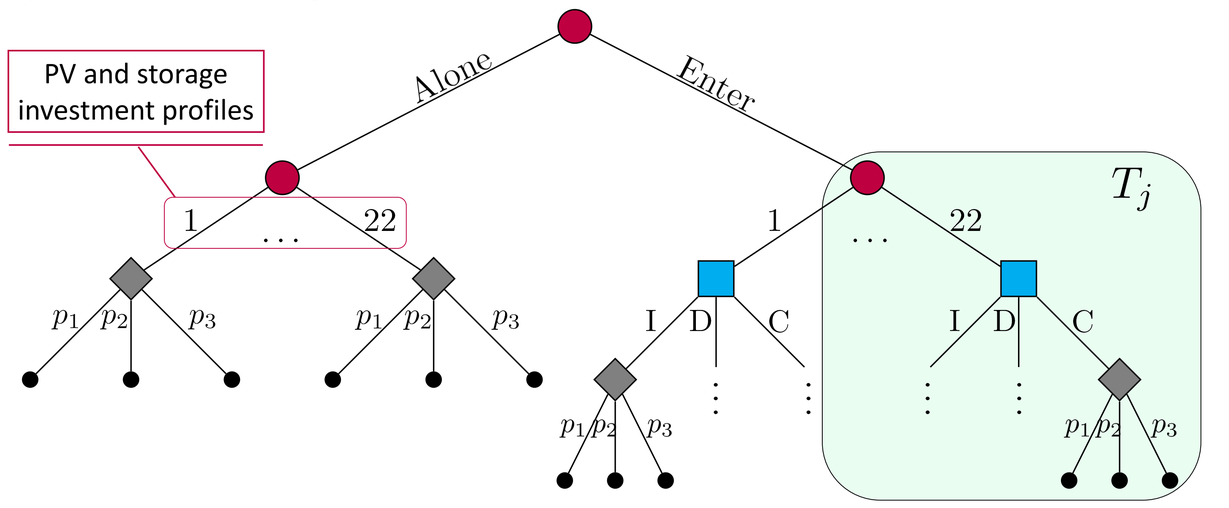
Conclusion:

- There always exists an equilibrium that is a social optimum.
- Community and individuals' bills obtained with the centralized and decentralized approaches are equivalent for the 4 cost allocation methods.

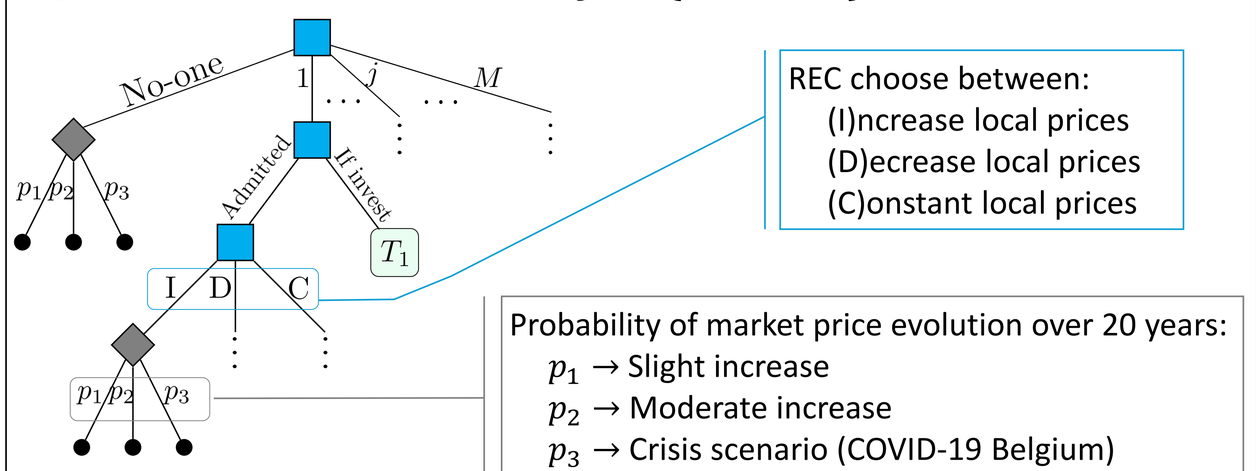


Long-term

1) New User's point of view



2) REC selects a new user $j \in \{1, \dots, M\}$



Ongoing work:

- 3 types of 55-member REC (deficit, surplus and stable).
- Gains obtained with ST problems over 20 years (264 leaves, 26 880 optimizations).
- There always exists a subgame perfect equilibrium (SPE).

Perspectives

ST:

- Interactions with other power system actors.
- Other types of preference (e.g., self-consumption or CO2).

LT:

- Computed SPEs according to different type of user gain (economic, technical, environmental).
- Compared SPEs with those obtained with Prospect Theory.