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Impact of retail electricity prices and grid tariff structure on the operation of resources scheduling in Renewable Energy Communities

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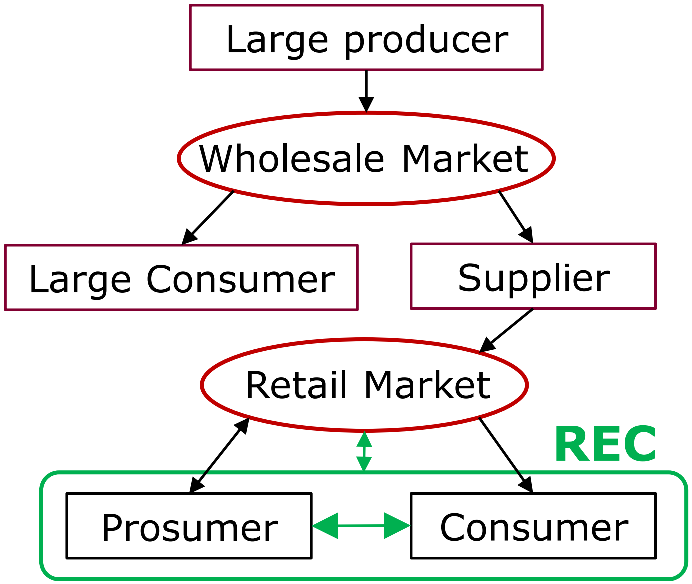
What is a Renewable Energy Community?

- An organized entity of consumers and prosumers of electricity established on the public electricity distribution network,
- In which exchanges of local renewable electricity can occur,
- Without necessarily resorting to the wholesale/retail market,
- Where members may benefit from economic, environmental or social advantages

Why a REC?

- Responding to growing desire of the citizen to play an active and central role in the electricity supply chain,
- Stimulate investment in local distributed energy resources,
- Stimulate mobilization of local flexibility provision
- **Creating a local stable economic framework, less subject to wholesale/retail price spikes.**



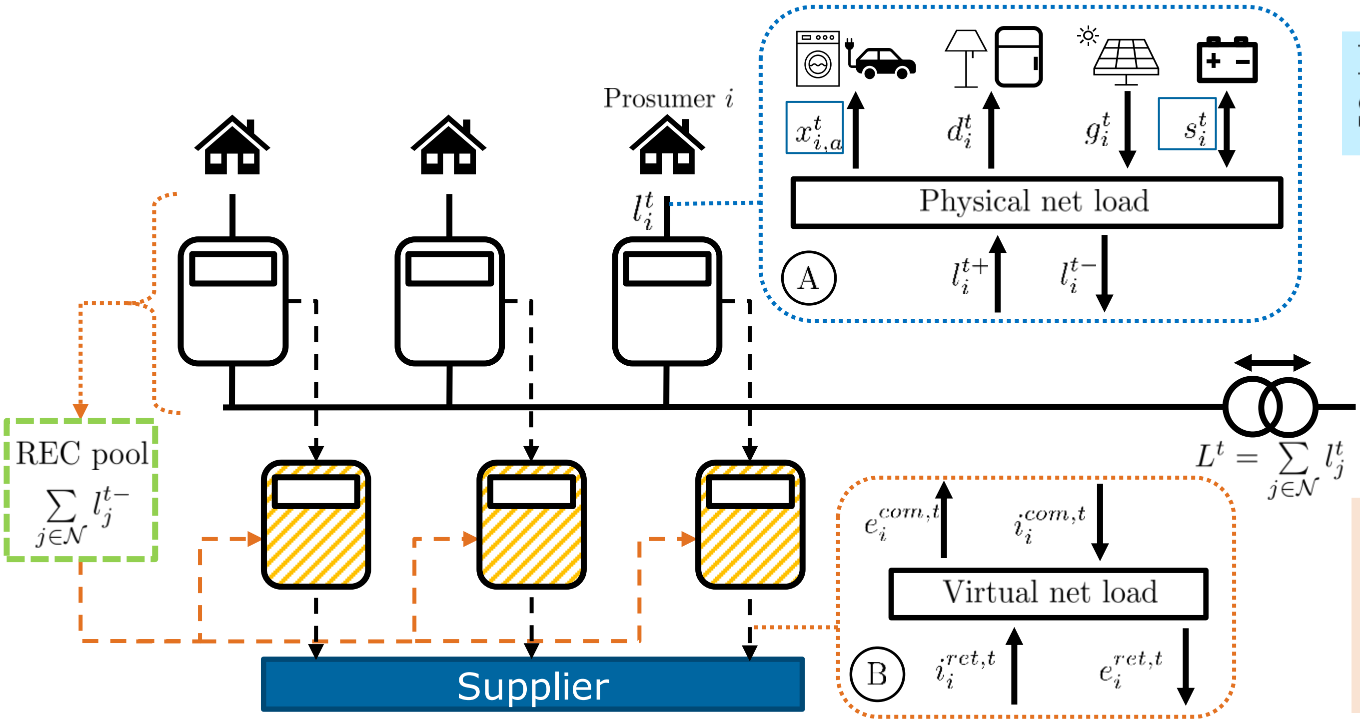
Research questions and contributions

- **How do the retail electricity price and grid tariff structure impact the daily optimal dispatch of resources in RECs (total REC cost, individual costs)?**
- We formulated mathematically the coordinated day-ahead scheduling of energy assets in residential communities with cooperative local mechanisms.
- The interdependence between community members who share a common resource has been modeled adopting centralized (convex optimization) and decentralized (game theory) approaches [1].
- Different internal costs allocation mechanisms have been implemented [1].

[1] L. Sadoine, Z. De Grève, and T. Brihaye, "Valuing the electricity produced locally in renewable energy communities through noncooperative resources scheduling games", arXiv preprint, arXiv:2305.04085, 2023.

Day-ahead resources scheduling problem

- We consider residential communities established on the public LV grid
- Individual excesses of local generation are pooled and can be purchased by members
- We assume perfect forecast of the nonflexible load and local production
- Decision variables: demand-side management and economics variables



Flexible appliance: $x_{i,a}$
Storage: s_i

Import from REC: i_i^{com}
Export to REC: e_i^{com}
Import from retail: i_i^{ret}
Export to retail: e_i^{ret}

Day-ahead resources scheduling problem

- Objective function: REC costs

$$f(\Theta) = \sum_{t\in\mathcal{T}}(\underbrace{\sum_{i\in\mathcal{N}} C^t_{i,supp}}_{\text{Commodity costs}} + \underbrace{C^t_{gr}) + \sum_{i\in\mathcal{N}} \beta.\overline{p}_i}_{\text{Network costs}}$$

  – Commodity costs: $C^t_{i,supp} = \lambda^t_{imp} i^{ret,t}_i + \lambda^t_{iloc} i^{com,t}_i - \lambda^t_{exp} e^{ret,t}_i - \lambda_{eloc} e^{com,t}_i$

  – Network costs = Volumetric-based costs + Peak-based costs

<u>Tariff T1 (academic):</u>

- quadratic costs (power losses)
- based on the aggregated load of all prosumers

$$C^{\mathrm{T1},t}_{gr} = \alpha(\sum_{i\in\mathcal{N}} l^t_i)^2$$

<u>Tariff T2 (real):</u>

- in line with the real grid tariffs applied in Flanders (Belgium)
- possible discount $\gamma \in [0,1]$, on the grid tariffs for the energy consumed locally as in Brussels (Belgium)

$$C^{\mathrm{T2},t}_{gr} = \sum_{i\in\mathcal{N}} \alpha(i^{ret,t}_i + \gamma.i^{com,t}_i)$$

- Models:

<u>Centralized:</u> Convex Opt.

$$\min_{\Theta} f(\Theta) \quad \text{s.t. } \Theta \in \Omega$$

Ex post cost allocation

<u>Decentralized:</u> GNEP

$$\min_{\Theta_i} b_i(\Theta_i, \Theta_{-i}) \quad \forall i \in \mathcal{N} \quad \text{s.t. } \Theta_i \in \Omega_i(\Theta_{-i})$$

Endogenous cost allocation

Use case

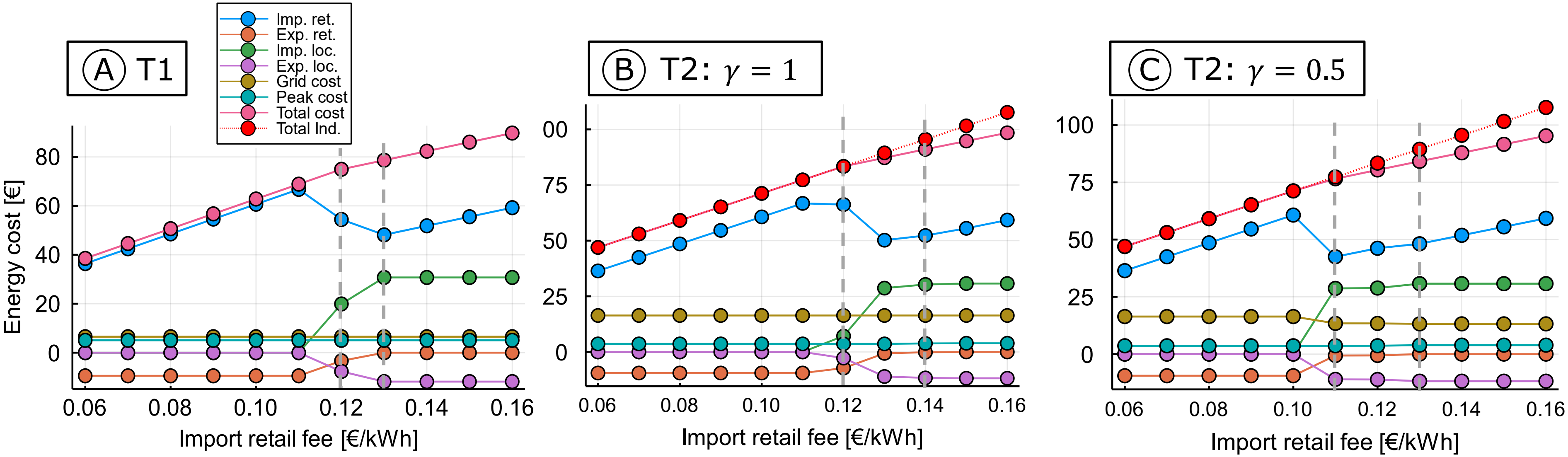
- Impact of retail price variation on the costs and behavior of the community and its members
  - 25 Users
  - 10 Days
  - 24 times steps
  - Value of retail import fee λ_{imp} varies from 0.06 to 0.16 €/kWh with steps of 0.01
- Ex post cost allocation via different billings methods: daily ([Clas. Net], [Net], [Clas. VCG], [VCG]) and hourly alloc. methods ([Cont.])

	PRICE	UNIT
Export retail λ_{exp}	0.04	[€/kWh]
Import local λ_{iloc}	0.13	[€/kWh]
Export local λ_{eloc}	0.05	[€/kWh]
Grid α	T1: 0.00109488 T2: 0.027	[€/kWh²] [€/kWh]
Peak β	0.11	[€/kW]

User	PV [kWc]	ESS	Total Consumption [kWh]	Flexibility level
8	9	0	37.36	0%
14	3	0	116.03	36.4%
21	9	1	11.8	138.24%

[2] Pecan Street Inc. (2020) Residential data New York 15 min.

Impact of retail price on total REC costs



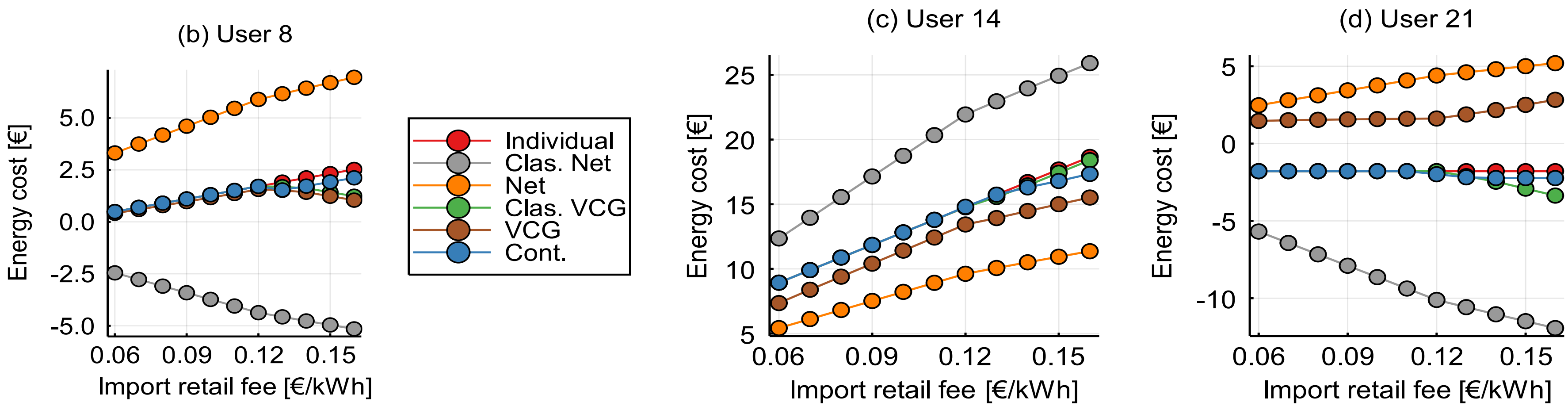
A:
- $\lambda_{iloc} - \lambda_{eloc} < \lambda_{imp} - \lambda_{exp}$
- $\lambda_{iloc} < \lambda_{imp}$

B:
- $\lambda_{iloc} - \lambda_{eloc} < \lambda_{imp} - \lambda_{exp}$
- $\lambda_{iloc} < \lambda_{imp}$
- $\lambda_{iloc} - \lambda_{eloc} + \alpha \leqslant \lambda_{imp} - \lambda_{exp}$

C:
- $\lambda_{iloc} - \lambda_{eloc} < \lambda_{imp} - \lambda_{exp} + \alpha.(1-\gamma)$
- $\lambda_{iloc} \leqslant \lambda_{imp}$

- We observe a threshold in the import retail price value, above which REC costs become lower than individual costs
- Tariff T1 has the lowest total costs and constant grid costs,
- Tariff T2 with $\gamma < 1$ increases the incentive for members to trade in the REC.

Costs allocation among members



Tariff T2: for each user type [Clas. VCG] and [Cont.] at least neutral or beneficial.

→ $0.13 \leqslant \lambda_{imp}$

Conclusion and outlook

- RECs mechanisms can partially protect consumers from price volatility.
- The importance of defining an appropriate grid cost structure and cost sharing method.
- Other types of preference (e.g., self-consumption or CO_2) must be considered when selecting a billing and sharing method.