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Economic Trades in Energy Communities and Optimal Allocation

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Introduction

Energy Communities (ECs) constitute an important market design of Local Energy Markets

- ▶ which create more decarbonised energy systems,
- ▶ reduce energy costs due to shared DER assets,
- ▶ and provide users with a platform to generate, store, and trade energy within their local area.

A **critical research gap** lies in investigating

- ▶ the **effectiveness of trading schemes** for ECs,
- ▶ their influence on the **equitable sharing of costs and benefits** among community members,
- ▶ and their implications for the **financial and technical viability of ECs**.

To analyse the factors influencing the **local trading process**, **three interconnected concepts** are highlighted:

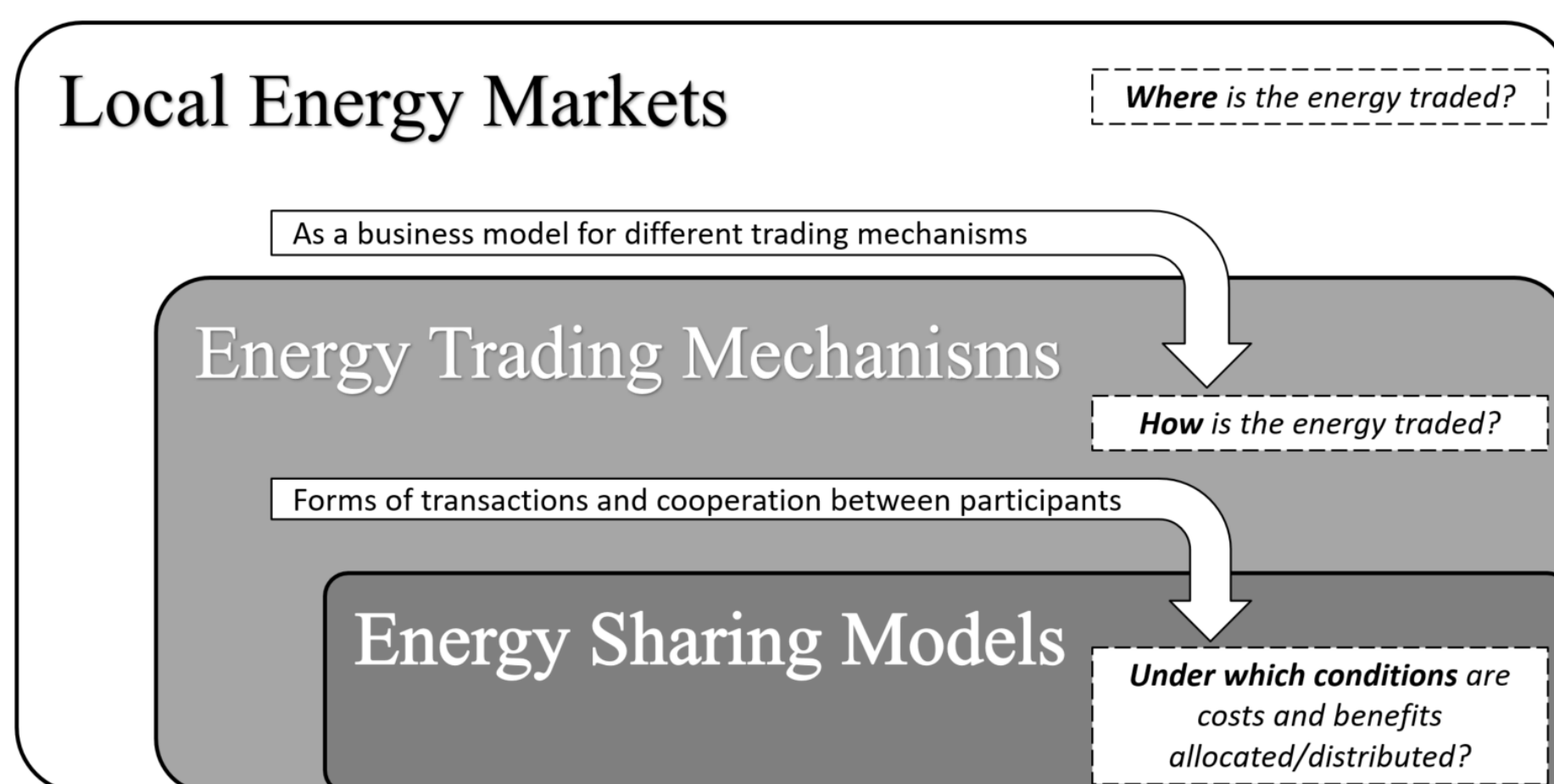


Figure 1: Connection between energy trading concepts.

Systematic literature review: to identify effective trading models for the coordination of **allocation & distribution between community members**.

Methods

P2P market models are highly discussed and enable local & direct exchange of energy. In relation to local energy market approaches, **three types of P2P trading models** were identified [1]-[4]:

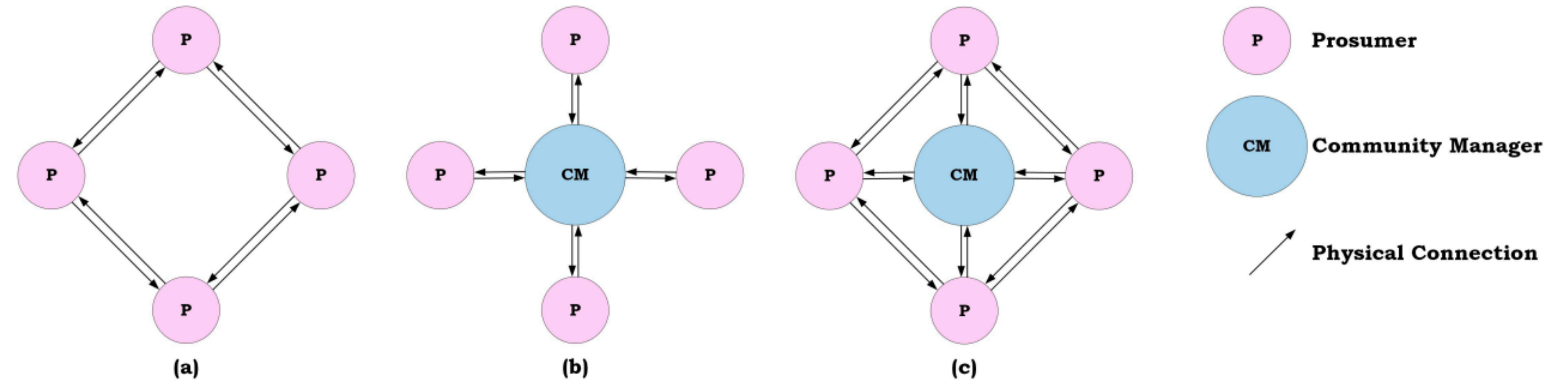


Figure 2: (a) Full P2P market, (b) Community-based P2P market and (c) hybrid P2P market.

→ The main difference between these models lies in their level of **cooperation**, defined by the centralisation of **trading mechanisms and communication**:

Table 1: P2P trading models and their characteristics.

Trading model	Level of trading	Communication of information	Level of cooperation
Full P2P	decentralised	decentralised	low
Community-based	centralised	centralised	very high
Hybrid P2P	decentralised	centralised	high

To share energy within the EC, **cost allocation** is a crucial step and a key issue that **determines the success of ECs** [5]. Cost allocation methods can be categorised into:

- ▶ **Energy consumption-based methods:** charge members based on their energy consumption and their energy-related services.
→ for competition-based trading markets
- ▶ **Game theory-based methods:** charge members based on fairness criteria and solution concepts from coalitional game theory.
→ for cooperative trading systems

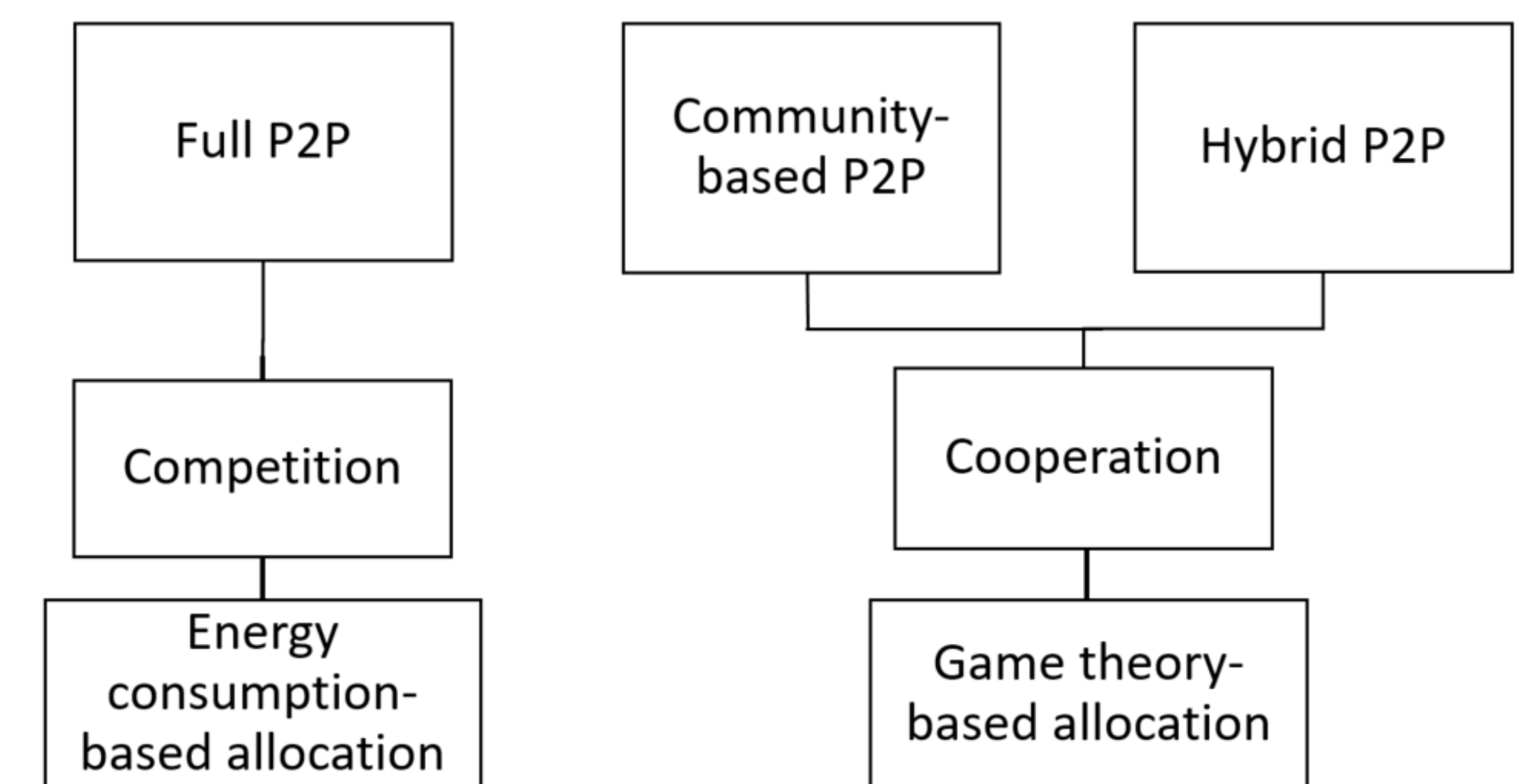


Figure 3: Cost Allocation Methods according to P2P Trading Models

→ The implemented trading model will influence the cooperation level between the agents and may impact the choice of cost allocation rules inside the EC.

Optimisation of P2P trading models for Energy Communities

This review provides an overview of **current trading problems in P2P and EC markets**, how they have been optimised, and **relates them to their implemented P2P market model**.

Table 2: Optimisation approaches in a P2P and EC context.

P2P market	Context	Objective functions
Full P2P	Direct P2P trading (without a CM) between prosumers in a local EC, connected to the public distribution grid.	Optimisation problem in [6] for the dynamic participation of prosumers, giving a leader at the upper level who minimises the cost-emission function (with optimal electricity demand and PV capacity of new prosumers) and a follower at the lower level who maximises community welfare (maximising exchanges of each member in the EC). $\min_{\{load_i, PV_i, b_i, Q_{i,t}\}} \sum_{i \in P_{old}} \alpha_i \Delta costs_i + (1 - \alpha_i) \Delta emissions_i$ $\max_{Q_{i,t}} \sum_{t \in T, i \in P} p_t^{Gout} q_{i,t}^{Gout} - \sum_{t \in T, i \in P} p_t^{Gin} q_{i,t}^{Gin} + \sum_{t \in T, i \in P} wtp_{j,t} q_{i,j,t}^{share}$
Community-based	Community-based P2P model with a CM that interfaces with retailers. Market organisation including agreements on the collective trading inside and outside the community.	Exchange problem in [7] that gives the optimal trading model by minimising the sum of the total costs of the prosumers (f_j) and the model of the CM (g). $\min_p \sum_{j=1}^n f_j(p_j, q_j, \alpha_j, \beta_j) + g(q_{imp}, q_{exp}, \vartheta)$

Conclusions

Among the assessed models, the **community-based P2P model** demonstrates its high adaptability for ECs and potential to foster cooperation among prosumers; particularly by integrating a **community manager**, who helps organising energy trading processes and provides essential services to community members.

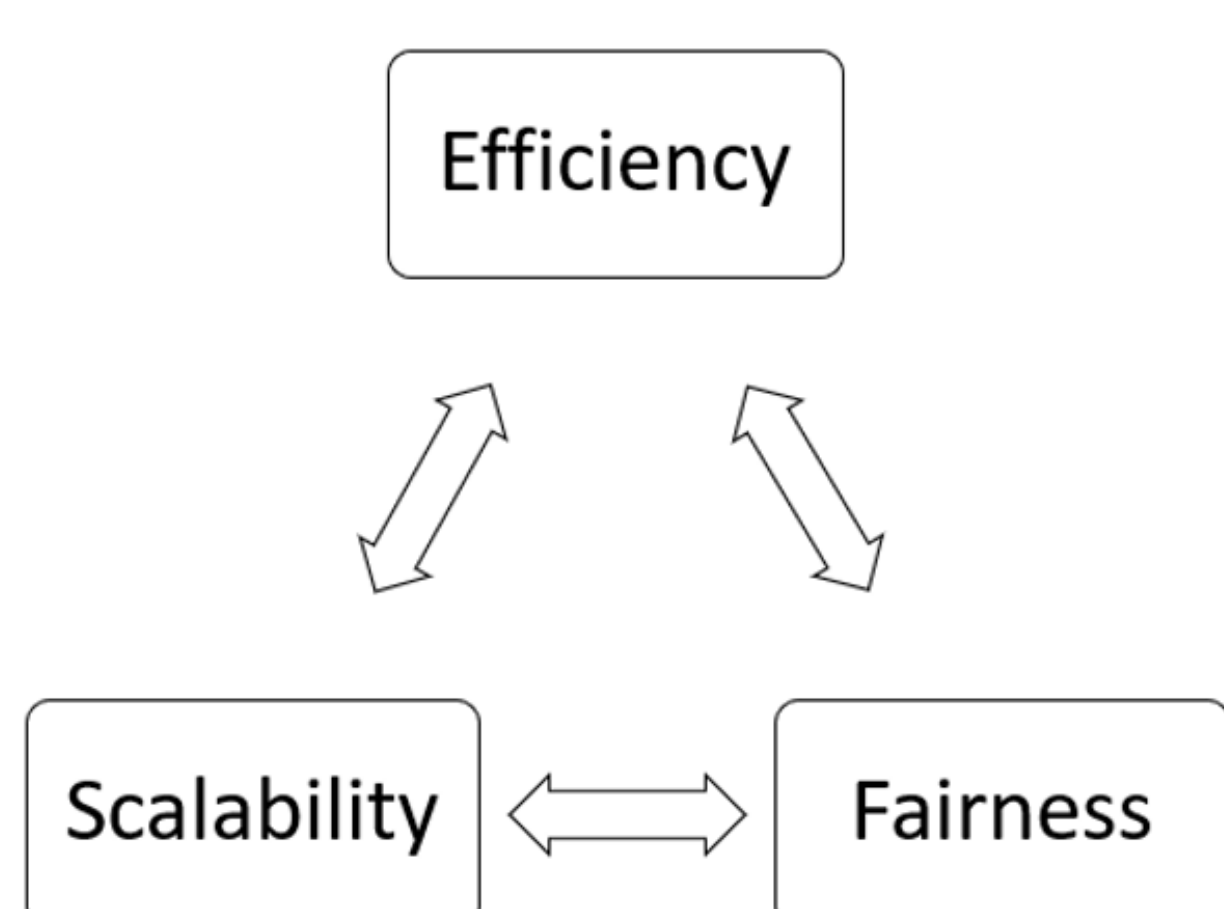


Figure 4: Trade-off between the three economic allocation goals

As ECs constitute a promising way to decarbonise and decentralise our current energy system, **trading and sharing models** need to be well-defined to make ECs **economically viable and sustainable** in the long term.

However, the choice of the trading model and their allocation rules within ECs **remains challenging**:

- ▶ The **adaptability of the schemes** largely depends on the characteristics and circumstances of the EC.
- ▶ There exists a **trade-off** between stable, efficient and fair allocation designs.
- ▶ Needs further investigation on **flexible and replicable designs** for large-sized ECs.

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