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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:

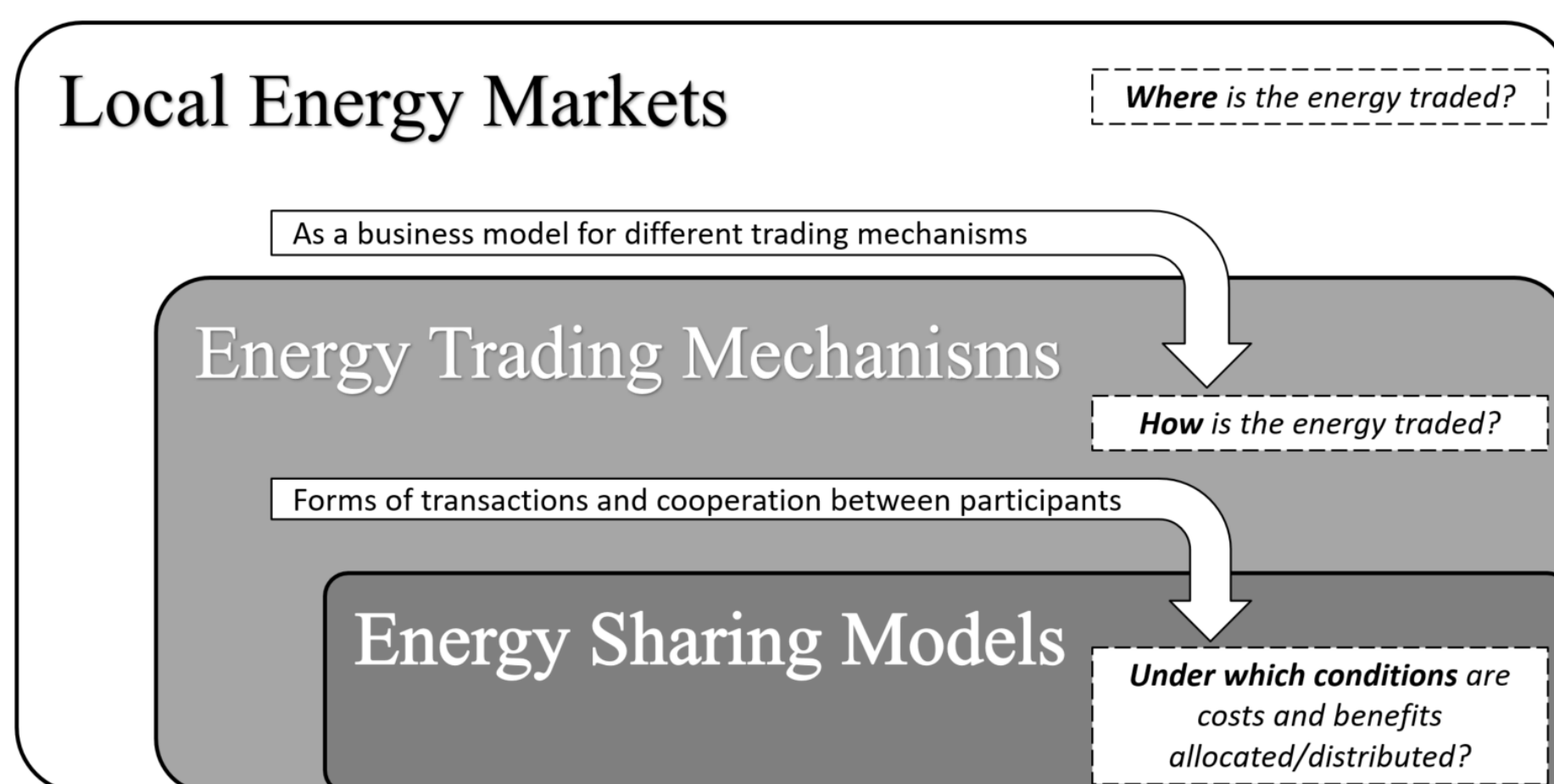


Figure 1: Connection between energy trading concepts.

**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]:

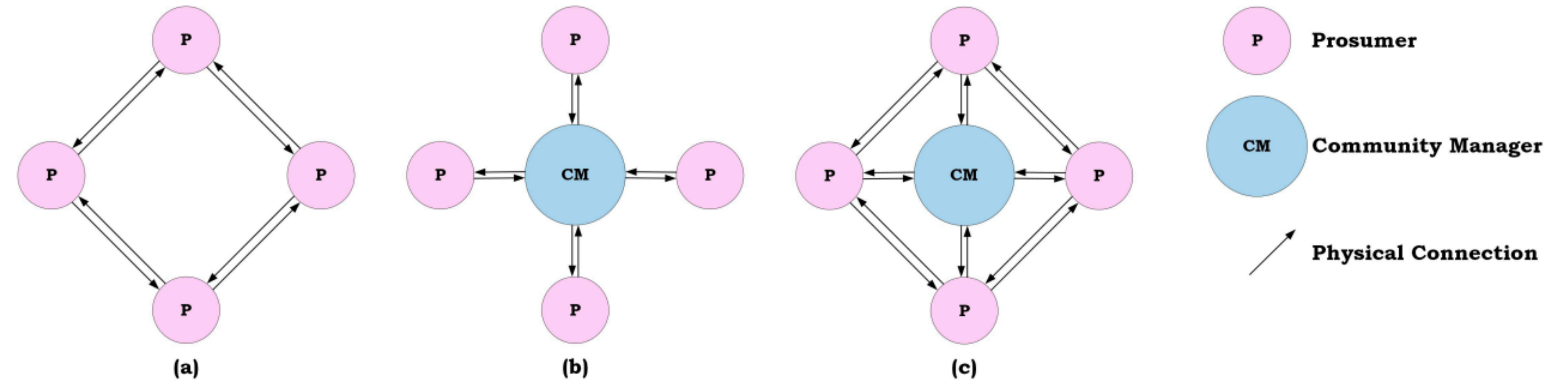


Figure 2: (a) Full P2P market, (b) Community-based P2P market and (c) hybrid P2P market.

→ 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

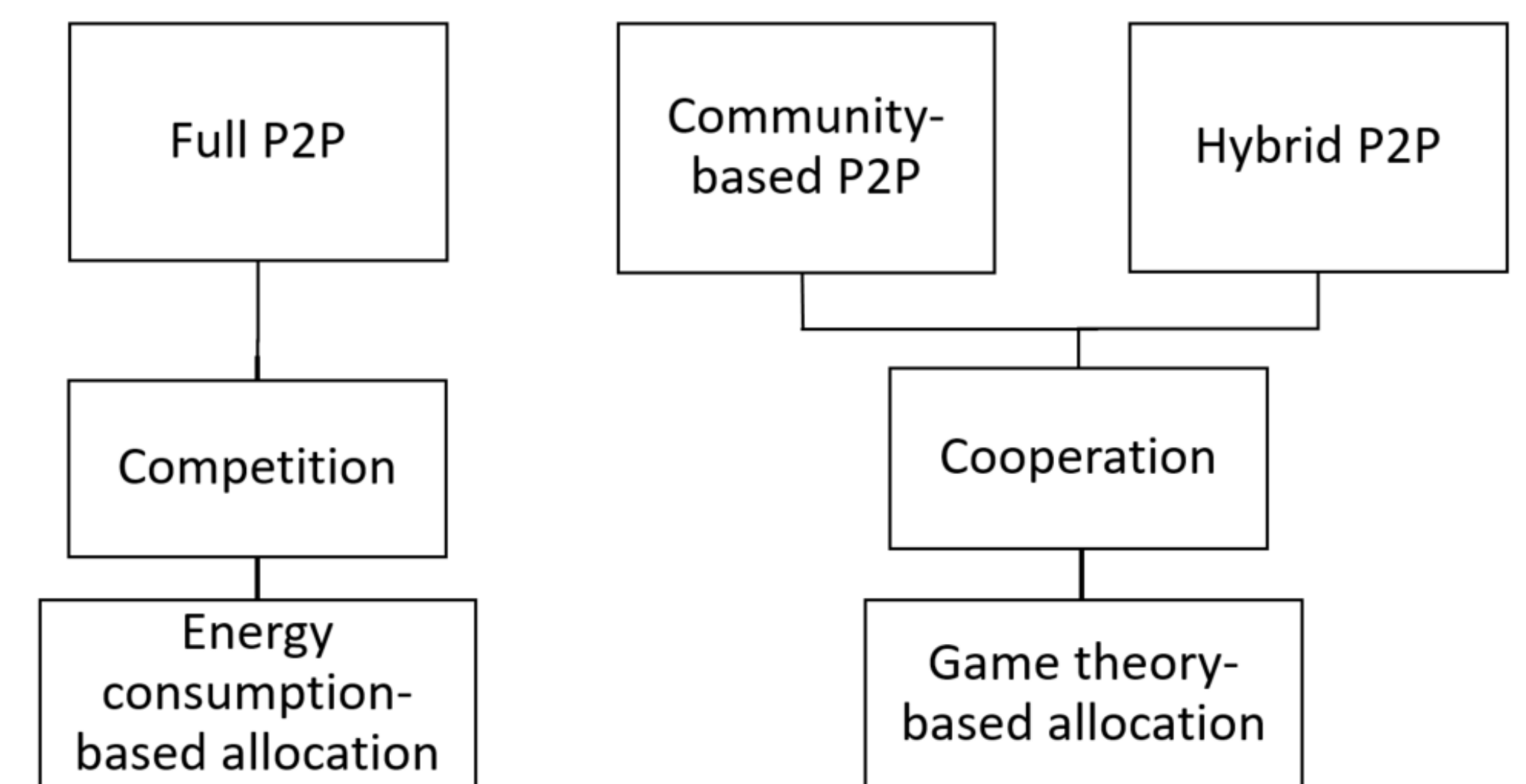


Figure 3: Cost Allocation Methods according to P2P Trading Models

→ 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). $\min_{\{load_i, PV_i, b_i, Q_{i,t}\}} \sum_{i \in P_{old}} \alpha_i \Delta costs_i + (1 - \alpha_i) \Delta emissions_i$ $\max_{Q_{i,t}} \sum_{t \in T, i \in P} p_t^{Gout} q_{i,t}^{Gout} - \sum_{t \in T, i \in P} p_t^{Gin} q_{i,t}^{Gin} + \sum_{t \in T, i \in P} wtp_{i,j,t} q_{i,j,t}^{share}$
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 ( $f$ ) 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.

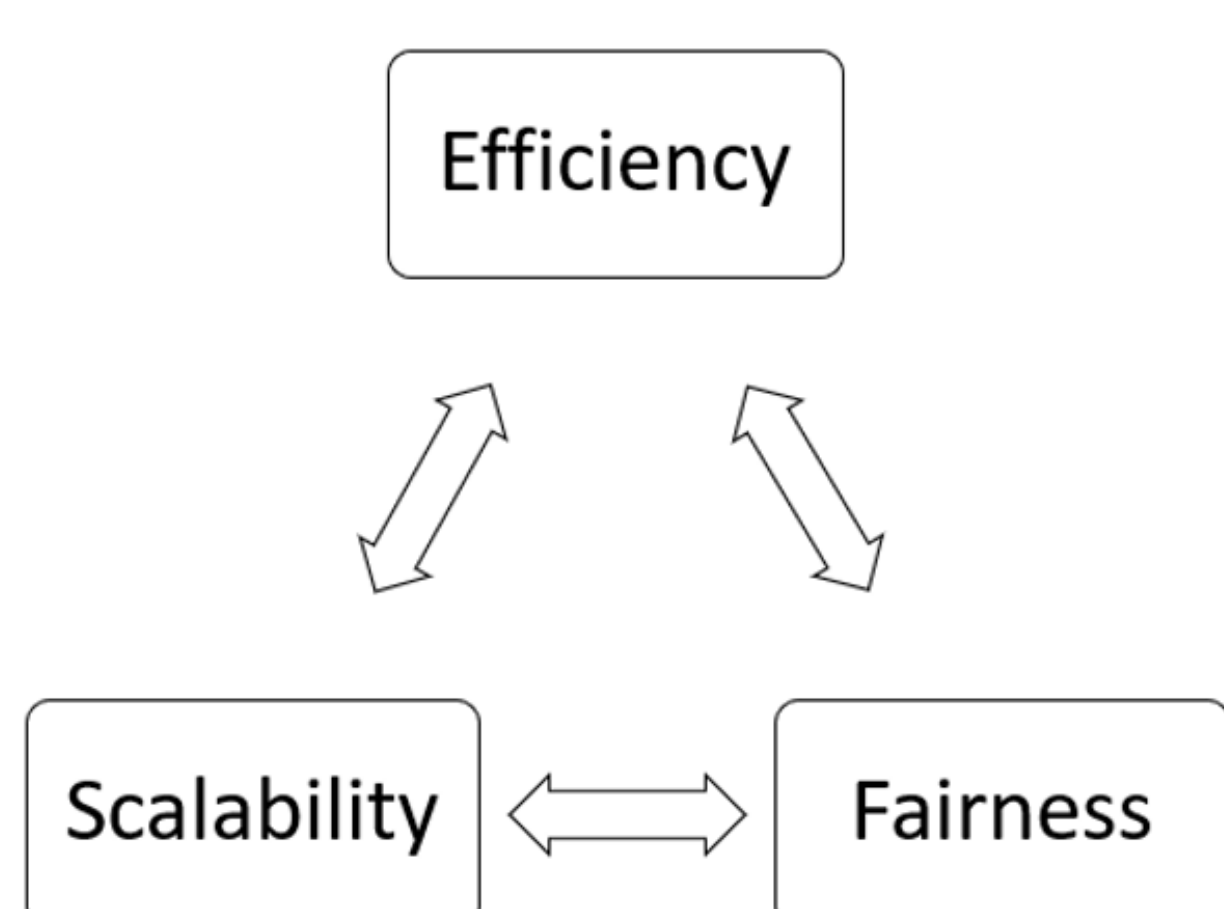


Figure 4: Trade-off between the three economic allocation goals

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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