Multi-stage optimisation of day-ahead local energy community trading based on end-user energy preferences

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Summary

- Multi-stage optimisation of the day-ahead scheduling of demand and energy trading of a local energy community.
- Multi-agent systems approach that captures differentiation in end-users' energy preferences and flexibility.
- Tool for exploration of scenarios and prosumer preferences for energy trading and participation in local energy markets (LEMs).
- Practical application shown for the Findhorn energy community.

Context

Increasing number of *prosumers*: energy consumption + production from own distributed generation and energy storage assets.

Formation of *energy communities:* local community of prosumers that operates in a collaborative fashion for optimising their use of resources.

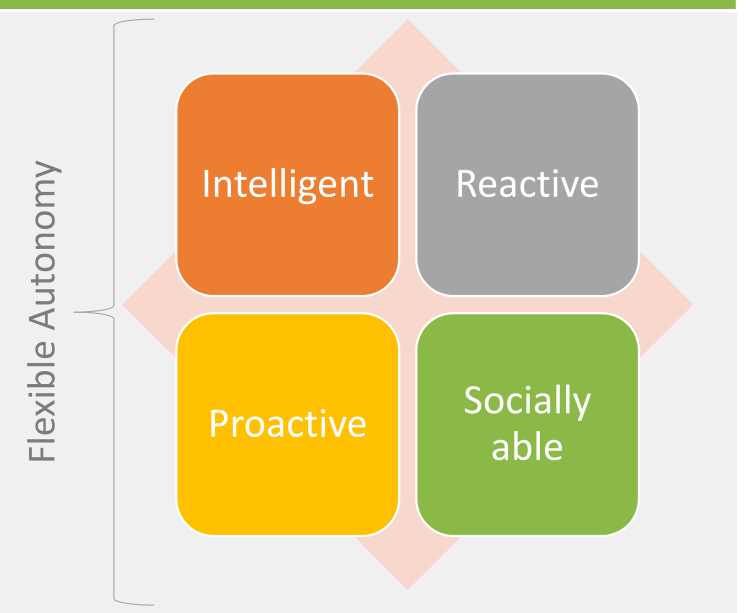
Source: European Commission Report, "Energy communities: an overview of energy and social innovation"

Transformation of the power grid: Decentralised + Complex

➡ New modelling paradigms: Multi-agent systems (MAS)

Multi-Agent Systems

- Agent = computational entity able to autonomously react to changes in its environment
- In our model: a software agent encodes the decisions of a prosumer, its energy preferences and information.
- MAS modelling: way of testing (through simulations) how complex system behaviours emerge from local decision-making and large number of agents



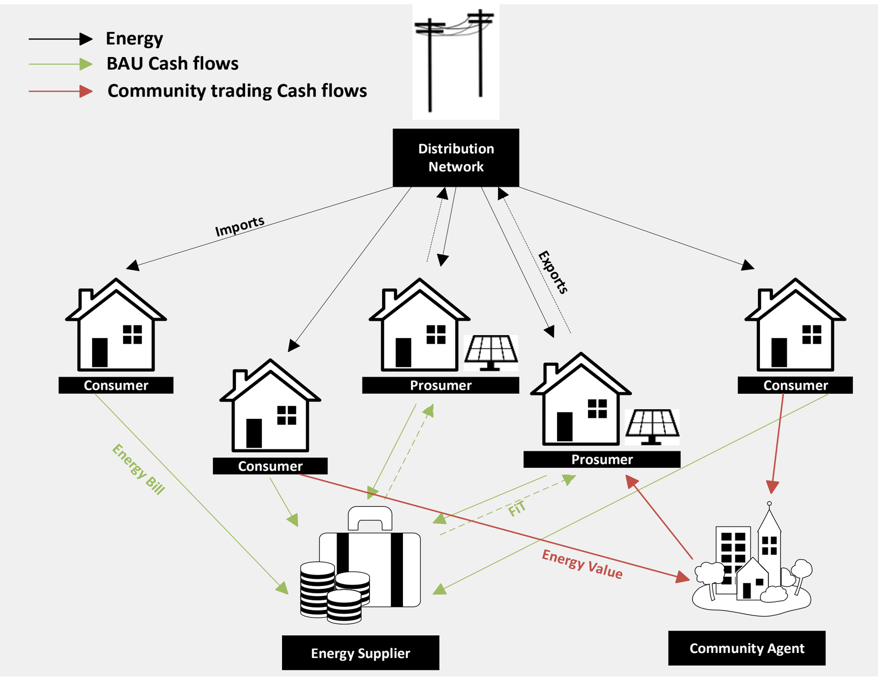
Local Energy Market (LEM)

EMERGING SOLUTIONS

- LEM: marketplace to coordinate energy and flexibility from distributed energy resources and consumption within a confined geographical area.
- Smart Local Energy Systems (SLES): energy management is optimised locally before trading with the main grid.

LEM Model

- Energy trading within the local community via a coordinating community agent (Peer to Community model) – Price determined by community agent
- Energy scheduling and trading result from a combination of optimisation at a household level and a community optimisation.



Methodology

- Household agents (prosumers and consumers) may have:
  - Generation
  - Demand (uncontrollable and flexible demand)
  - Willingness to shift flexible demand

  Discomfort from demand shifting: willingness to shift, load shifted and time distance between desired and actual schedule.

  Objective: optimisation of energy consumption according to their type:

Cost-driven agents: act to minimise their energy bills or increase profits

Low-carbon agents: act to consume green and low-carbon energy

Social agents: act to maximise trading with peers in the community

- Community agent objective: optimisation of aggregate community scheduling for community self-consumption

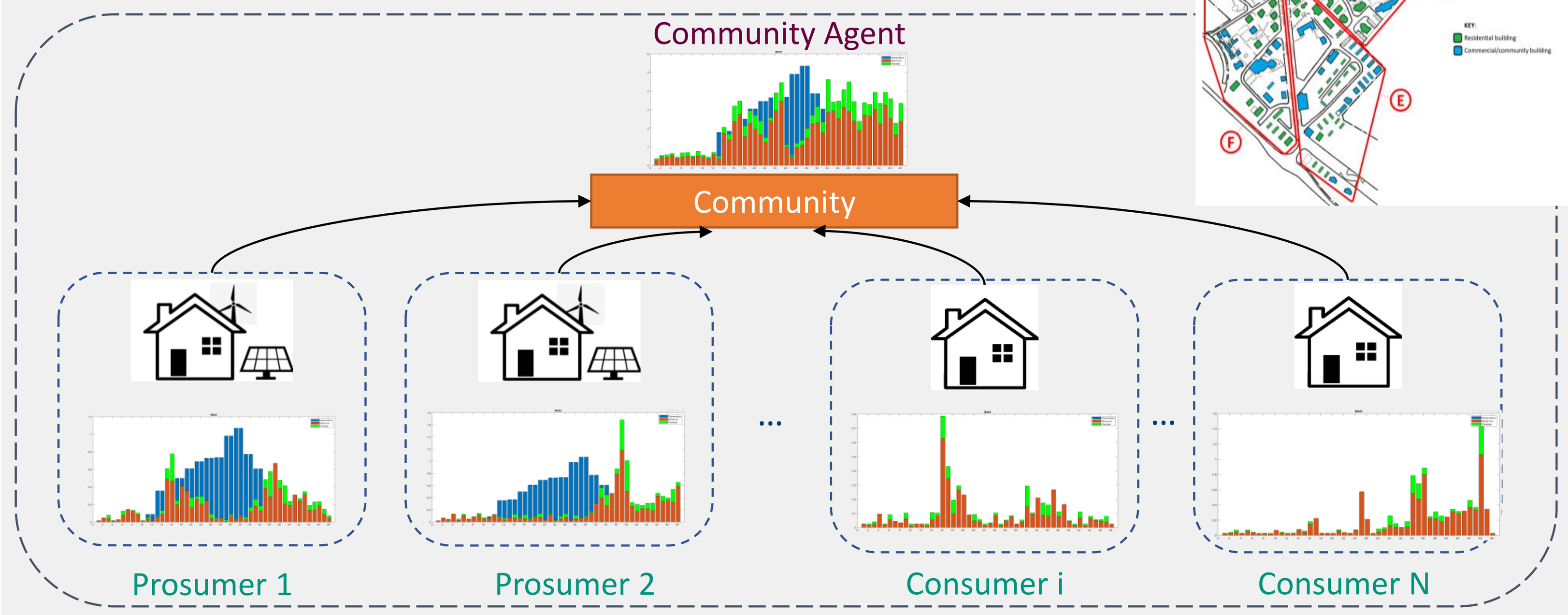
Multi-Stage Optimisation

	Cost-driven	Low-carbon	Social
Stage 1	Individual agents MILP • Maximise individual RES self-consumption (largest cost savings)*	Individual agents MILP • Maximise individual RES self-consumption (green energy utilisation)*	No optimisation
Stage 2	Community agent MILP • Maximise community RES self-consumption* Agents collaborate to achieve optimal community schedule.		
	Utility value: cost savings from community trading	Utility value: green energy utilisation from community trading	Utility value: social value from community trading
Stage 3	Individual agents MILP • Maximise savings from TOU tariffs*	Individual agents MILP • Maximise CO2 savings (carbon intensity of energy imported from main grid)*	No optimisation

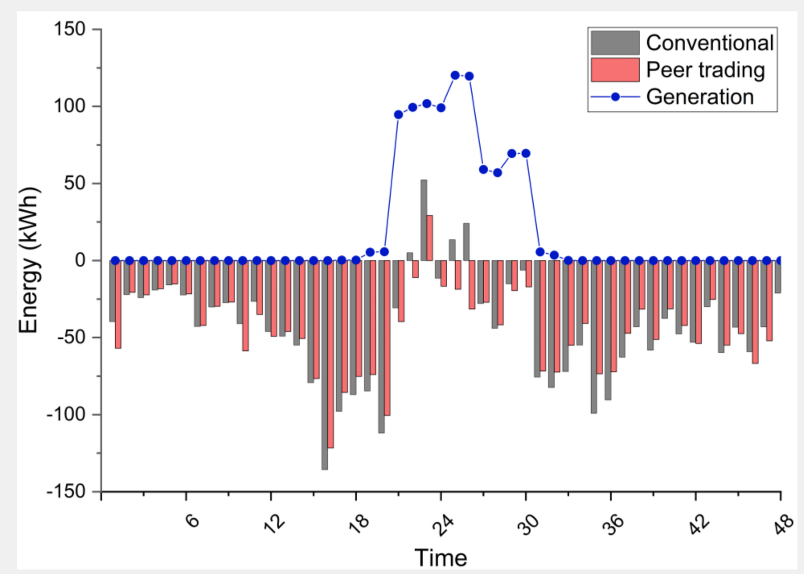
*Optimisation also aims to minimise discomfort caused by demand shifting

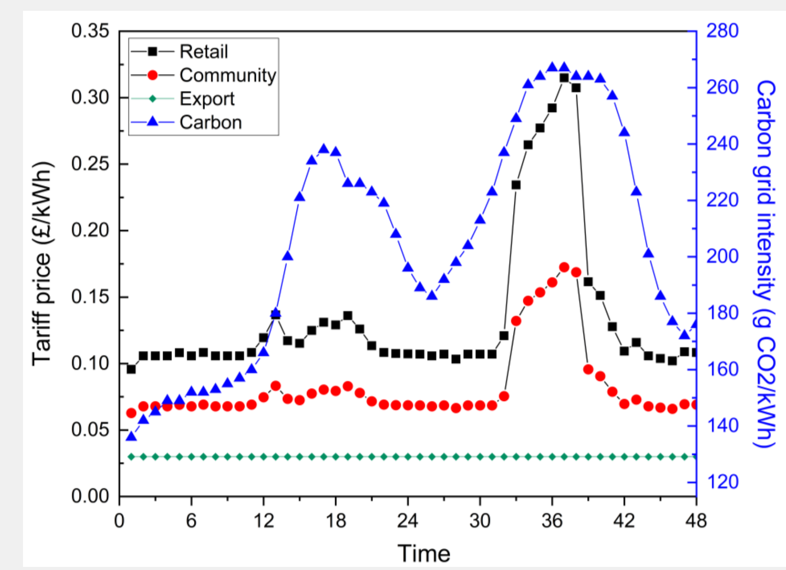
Case-Study Findhorn

- **210 household agents:** from representative types (heating, dwelling type, size, use)
- **4 days:** Winter/Summer, Weekday/end
- **Multiple scenarios:** Agent types, flexibility, PV rate



Scenario: 50% prosumers – 50% consumer, 1/3 of each agent type

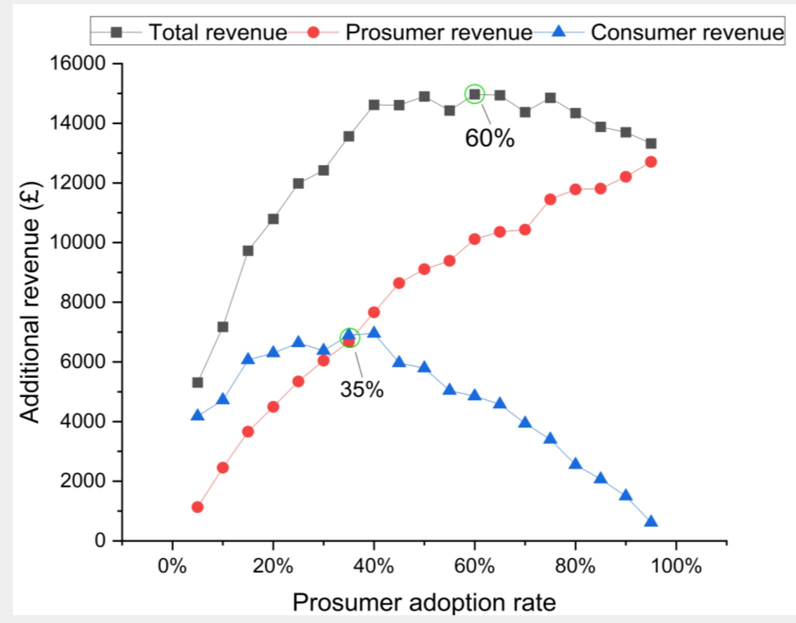


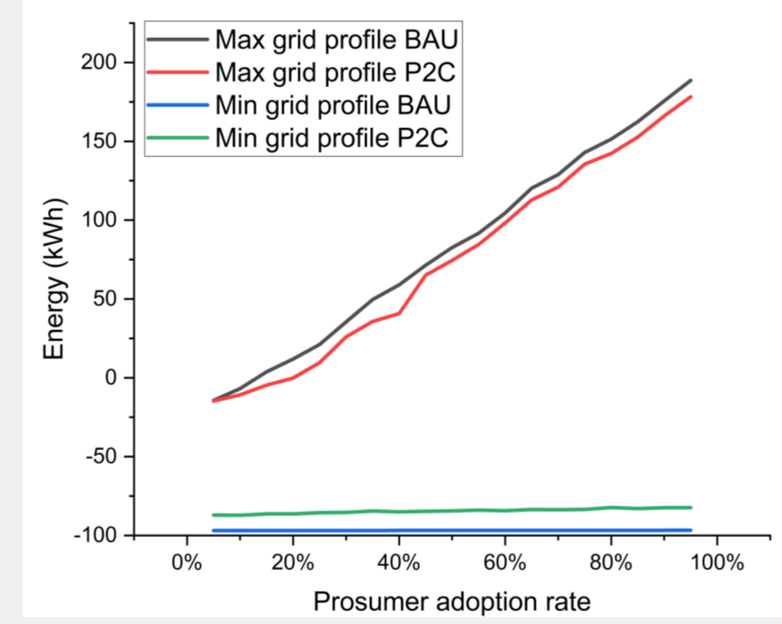


Comparison of Conventional Vs Community trading

- Average yearly revenue ↑**£90** (pros. income ↑£100, cons. bills ↓£80)
- Average max grid imports ↓**8.4%** in Winter, ↓**9%** in Summer
- Average max grid exports ↓**44%** in Winter, ↓**5.7%** in Summer
- Average green energy local consumption ↑**6.1%** (6,900 kg CO2 ~41 trees)

Increasing prosumer rate -> aggregate effects on revenue and grid profile





Remarks:

- Data are important! Results vary across seasons, load and gen profiles.
- Price formation matters! Different pricing strategies yield different results.

Future work:

- Decentralised approach for community trading with grid constraints
- Individual asset flexibility, Provision of grid services for profitability