

Project Title: Grid-Aware, Fair and Adaptive Formation of Local Energy Communities

Project Type: Master's Thesis

Project Description: This thesis develops a scalable method that recommends which buildings should form a local energy community, how benefits are shared, and how the community adapts over time. Communities are formed from complementary energy profiles and grid conditions, and operated with optimisation-based control of heat pumps, storage, and electric vehicles (EVs) within limits set by the distribution system operator (DSO).

Motivation. Since January 2026, Swiss local electricity communities (LEG) let neighbours share electricity over the public grid at a reduced tariff; over 1,800 were founded in the first half of 2026 [4]. They form bottom-up, yet composition decides their value: complementary profiles share more energy, well-placed communities can relieve congested feeders, and unfair ones break up.

Research gaps.

- Most studies optimise a fixed community; composition is taken as given [1].
- Coalition studies maximise savings but ignore feeder congestion [2].
- Exact game-theoretic formation scales exponentially with size [3].
- Heat-pump and EV flexibility is simplified; communities are static.

Research question: *Which buildings should form an energy community, and how should benefits be shared, so that the community maximises self-consumption, relieves congested feeders, stays stable as members change, and leaves no member worse off?*

Methodology.

- *Scalable formation:* split by feeder, cluster by profile complementarity, refine with a fast surrogate model, verify with full optimisation.
- *Grid-aware operation:* predictive control of heat pumps, storage and EVs within DSO limits.
- *Fair sharing:* Shapley, nucleolus and pro-rata rules, tested for stability [5].
- *Adaptation:* voluntary invitations and sharing updates as members change.

Expected outcomes. Gains split into effects of composition and control, a method scaling to thousands of buildings, fair sharing guidance, and open-source code feeding a region in Switzerland.

Key tasks during the project:

1. Literature review and problem formulation,
2. Data and model setup: grid and housing data, feeder and flexibility models,
3. Scalable grid-aware coalition formation and fair sharing,
4. Optimisation-based operation within DSO limits,
5. Adaptation to membership changes.

Useful software skills:

- Good knowledge of power systems and distribution grids.
- Programming experience in Python.
- Familiarity with pandapower, Pyomo, or Gurobi is desirable.
- Basic knowledge of mixed-integer programming or game theory is an advantage.

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Reference:

- [1]. V. Z. Gjorgievski et al., "Social arrangements, technical designs and impacts of energy communities: A review," Renewable Energy, 2021, ideas.repec.org
- [2]. L. Han et al., "Incentivizing prosumer coalitions with energy management using cooperative game theory," IEEE Trans. Power Systems, 2019, renewableenergy.ox.ac.uk
- [3]. L. Han et al., "Improving the scalability of a prosumer cooperative game with K-means clustering," IEEE PowerTech, 2019, arxiv.org/abs/1903.10965
- [4]. Solarserver, "Schweiz gründet 1.860 lokale Stromgemeinschaften (LEG) im ersten Halbjahr 2026," 2026, solarserver.de
- [5] Park, Hyeongon, Kyuhyeong Kwag, Daniel K. Molzahn, and Rahul K. Gupta. "Fair cost allocation in energy communities: A dmp-based bilevel optimization with a shapley value approach." *arXiv preprint arXiv:2510.22321* (2025).