Role and Potential of Energy Communities in the Decarbonisation of the European Energy System

Hans Auer
Energy Economics Group (EEG)
Technische Universität Wien
Email: auer@eeg.tuwien.ac.at

PowerTech 2021, Madrid (online)
28th June – 2nd July 2021
1. PV-Sharing / PtP-Trading on different Geographical Scales
   - Multi-Apartment Buildings incl. Deep Renovation
   - PtP-Trading in Energy Community incl. Willingness-to-Pay
   - Dynamic Participation in Energy Community
   - Austrian Residential PV Energy Community Potential

2. Deep Decarbonisation in Multi-Energy System Communities
   - Optimal Allocation of Flexible Local Resources among Prosumers
   - Gas Grid Decommissioning in Urban Energy Community
   - Impact of Energy Communities on European Energy System

3. Concluding Remarks
Advantage of energy community compared to microgrid: neither physical connectivity nor mandatory participation is expected; however, an energy community can also perfectly coincide with a microgrid
BAPV / BIPV Sharing in Multi-Apartment Buildings incl. Deep Renovation

Optimization Model (determining optimal Technology Capacities, Net Present Value):

- BAPV & BIPV
- Static/dynamic PV/Load Allocation
- Voluntary Participation
- Operational Model
- Incl. Investments (Retrofitting, Heating System Changes, etc.)
- System Boundary: Multi-apartment Building
- Sensitivity Analyses: PV Integration Concept, Heating System, Roof Pitches, Tenant Portfolio, Building Quality, Retail Electricity and CO₂ Prices,…

Peer-to-Peer Trading in Local Energy Community

Willingness-To-Pay (WTP) of Prosumers

WTP of Prosumers depends on: (i) Marginal CO2-Emissions (ii) Spatial Distance

Annual shared PV-Electricity

Dynamic Participation in Energy Community (4/5)

Selecting new prosumer(s)

\[ SW = \sum_{t \in T, x \in \mathbb{Z}} p_t^x q_t^x - \sum_{t \in T, x \in \mathbb{Z}} p_t^{\text{comm}} q_t^{\text{comm}} + \sum_{t \in T, x \in \mathbb{Z}} w t p_t^x q_t^x \]

- self-consumption of the community
- optimal assignment to each member

Representative Residential PV Energy Communities for typical Austrian Settlement Patterns

Cost-Optimal Rooftop PV System Capacities in Austria (upscaled on Country-level)

~ 10 GW !

2. Deep Decarbonisation in Multi-Energy System Communities (1/4)

Optimal Allocation of Flexible Local Resources among Prosumers (Base Case)

Scenario: Electrification

Scenario: District Heating & Cooling
Network Expansion

Impact of Energy Communities on European Energy System (3/4)

Link of Open Source Models EMPIRE & GUSTO

Flexibility Aggregation of Energy Communities


https://github.com/ntnuiotenergy/OpenEMPIRE
https://github.com/sebastianzwickl/GUSTO
Results (Highlights): ECs in European Countries AT, FR, NO, PL, PT, ES

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline</td>
<td>5.776e+12 (0.0%)</td>
<td>7 881 (0.0%)</td>
<td>2 062 (0.0%)</td>
<td>118 (0.0%)</td>
</tr>
<tr>
<td>Community Flexibility Optimization (local)</td>
<td>5.745e+12 (-0.5%)</td>
<td>7 828 (-0.7%)</td>
<td>2 053 (-0.4%)</td>
<td>118 (0.0%)</td>
</tr>
<tr>
<td>European Flexibility Optimization (global)</td>
<td>5.742e+12 (-0.6%)</td>
<td>7 819 (-0.8%)</td>
<td>2 019 (-2.1%)</td>
<td>118 (0.0%)</td>
</tr>
</tbody>
</table>

Generation & storage capacities - slightly decreased; transmission capacities - not affected
Shift towards offshore wind (on the expense of onshore wind); South -> North shift in Europe
ECs invest in hydrogen storage (seasonal) in highly electrified neighborhoods (rather than batteries)
CO₂ price mainly governs technology exchange and thus energy transition (> 500 Euro/t in 2060)

Concluding Remarks

- Energy Communities can/will play a significant role on several geographical levels
- We need both top-down and bottom-up energy transition to meet carbon neutrality goals
- Holistic multi-energy system EC concepts should be considered as early as possible
- EC implementation is no longer a techno-economic challenge, but a legislative/regulatory one
- Distribution Grid Operators’ revenue streams must be guaranteed:
  - Amendment of distribution grid regulation / tariff design towards an increased fixed tariff component
  - Additional dynamic component that sends correct price signals about the current state of the grid
- A sharply rising CO₂ price that governs energy transition sends correct price signals to all agents
- Still open questions and future research needs:
  - Dynamic entry/exit of prosumers into/from ECs needs to be studied and better understood
  - Incentives for formation of stable ECs (incl. optimal size) depending multi-energy system boundary
  - Many others....
Definition of a Natural Monopoly (Grid):

• Subadditivity of Cost (necessary condition)
• Economies of Scale (sufficient condition)
• Sunk cost (additional attribute)
• Capital intensive grids lead to declining average cost

PV Self-consumption & Energy Communities lead to more elastic electricity demand:

Less grid electricity delivered -> increase of fixed grid tariff component (over time not only once) -> negative feedback loop for PV self-consumption -> seeking for more diversified & aggregated loads in bigger energy communities -> Peer-to-Peer trading
Incentive to increase fixed grid tariff component (right figure) to compensate for (parts of) revenue losses...

[Diagrams showing the relationship between revenue and share of PV-self-generation in the distribution grid]