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14th, June 2021

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

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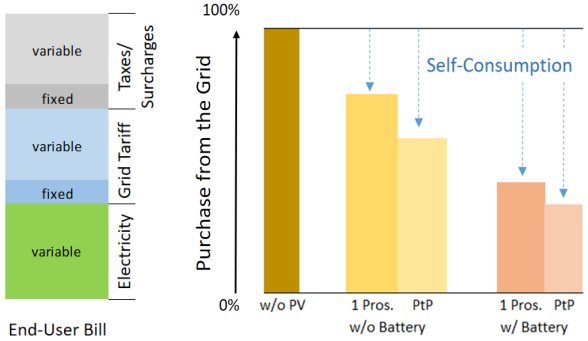
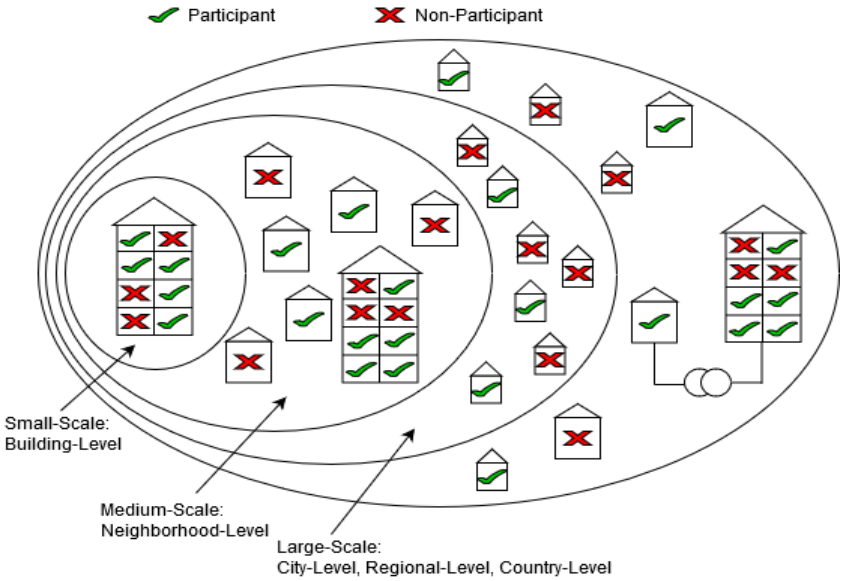
PowerTech 2021, Madrid (online)
28th June – 2th July 2021

Outline

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

1. PV-Sharing / PtP-Trading on different Geographical Scales (1/5)

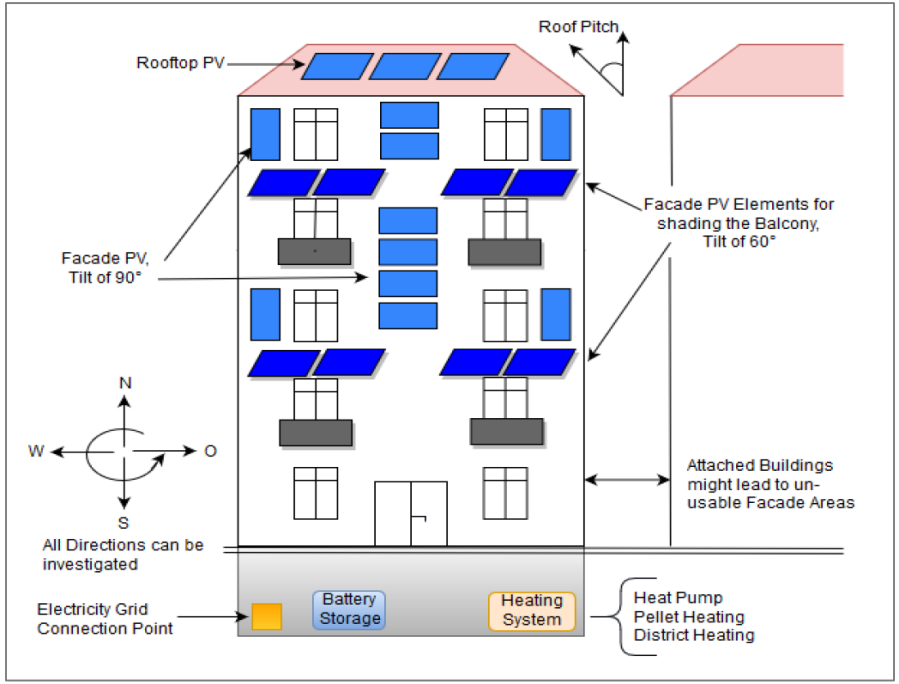




<u>Advantage of energy community compared to microgrid:</u> neither physical connectivity nor mandatory participation is expected; however, an energy community can also perfectly coincide with a microgrid

PV-Sharing Concepts in Multi-Apartment Buildings (2/5)

BAPV / BIPV Sharing in Multi-Apartment Buildings incl. Deep Renovation



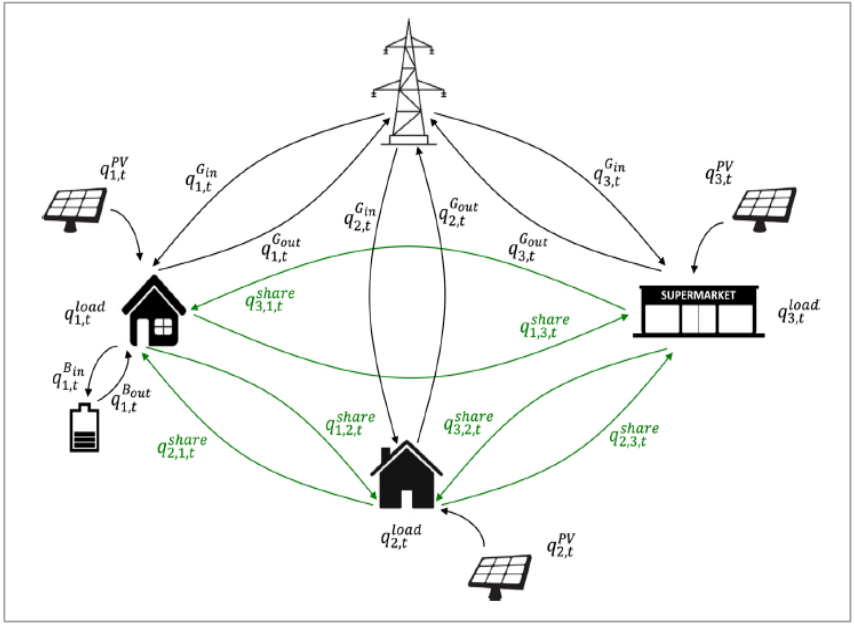
<u>Optimization Model (determining optimal Technology Capacities, Net Present Value):</u>

- 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 Piches, Tenant Portfolio, Building Quality, Retail Electricity and CO_2 Prices,…

Fina et al (2019), Profitability of Active Retrofitting of Multi-Apartment Buildings: Building-Attached/Integrated Photovoltaics with Special Consideration of Different Heating Systems. Energy&Buildings 190 (2019) 86-102, doi: 10.1016/j.enbuild.2019.02.034

Peer-to-Peer Trading in Local Energy Community (3/5)

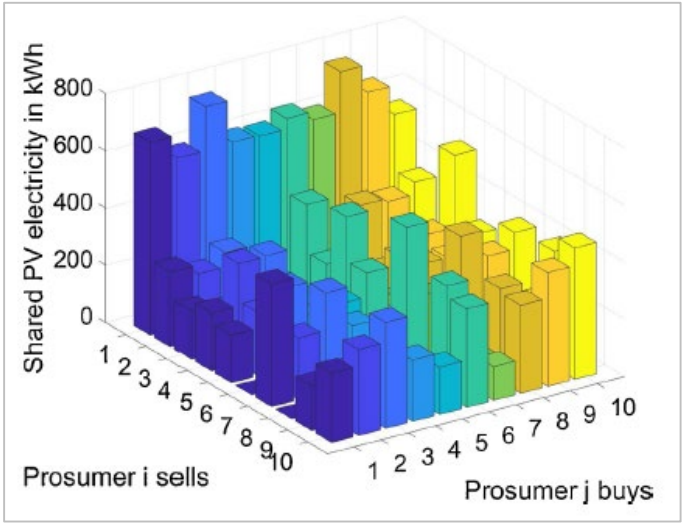
Peer-to-Peer Trading in Local Energy Community



Willingness-To-Pay (WTP) of Prosumers

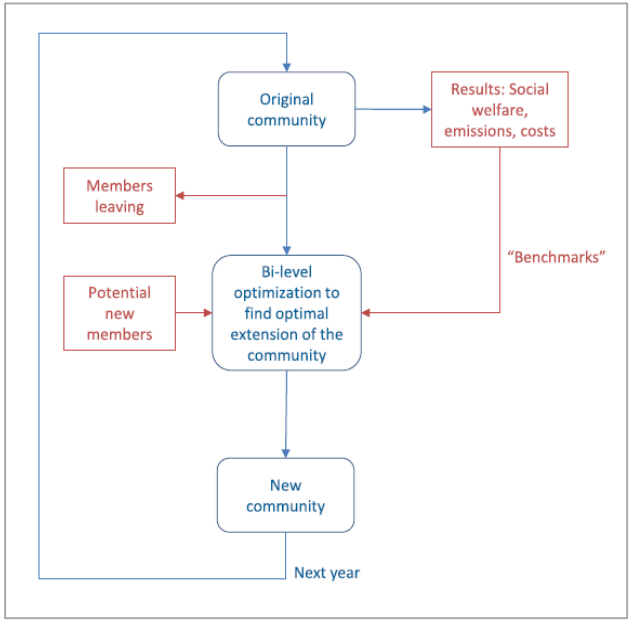
WTP of Prosumers depends on: (i) Marginal CO2-Emissions
(ii) Spatial Distance

Annual shared PV-Electricity



Perger et al (2021), PV Sharing in Local Communities: Peer-to-Peer Trading under Consideration of the Prosumers' Willingness-to-Pay", Sustainable Cities and Society 66 (2021), 102634, doi: 10.1016/j.scs.2020.102634

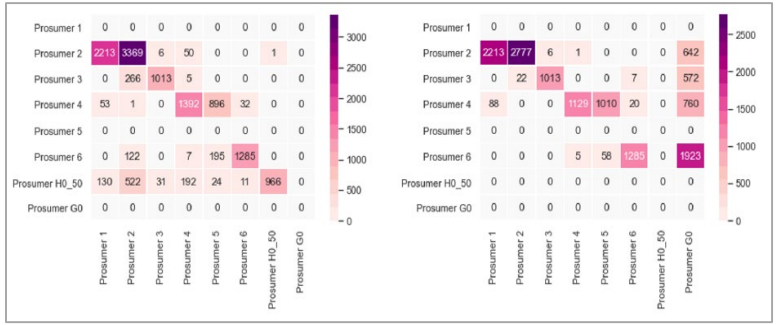
Dynamic Participation in Energy Community (4/5)

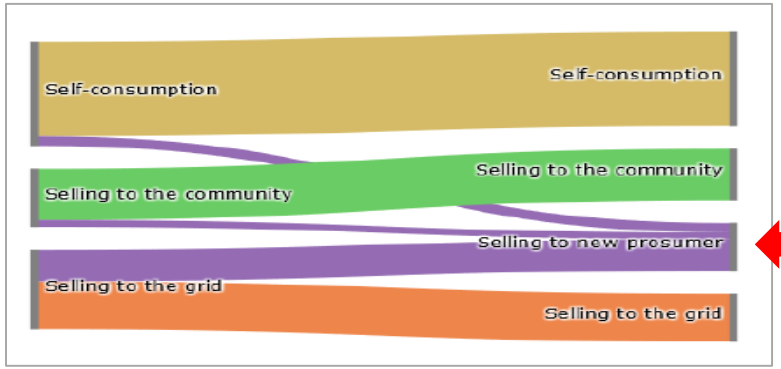


$$SW = \underbrace{\sum_{t\in\mathcal{T},i\in\mathcal{I}} p_t^{G_{out}} q_{i,t}^{G_{out}} - \sum_{t\in\mathcal{T},i\in\mathcal{I}} p_t^{G_{in}} q_{i,t}^{G_{in}}}_{\text{I}} + \underbrace{\sum_{t\in\mathcal{T},i,j\in\mathcal{I}} wtp_{i,j,t} q_{i,j,t}^{share}}_{\text{II}}$$

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

Selecting new prosumer(s)

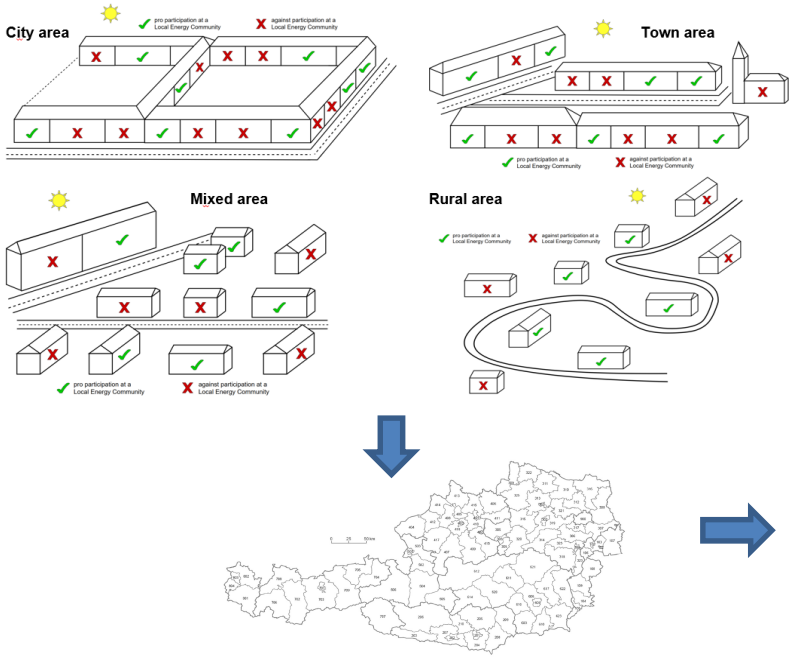




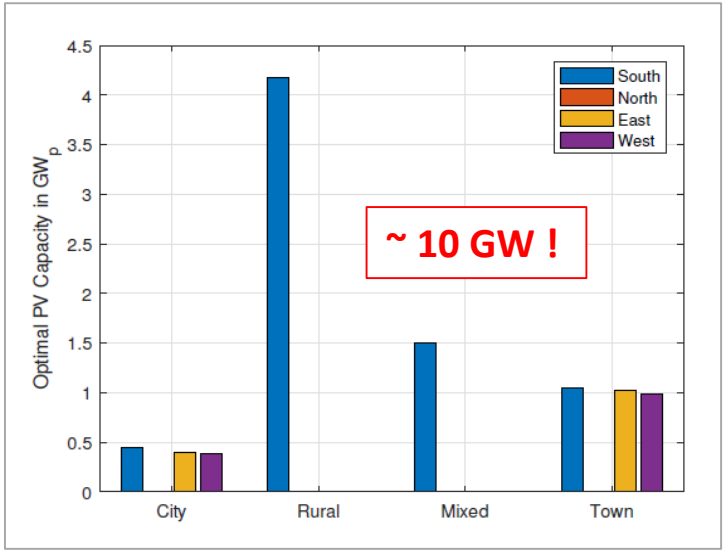
Perger et al (2021), Dynamic Participation in Local Energy Communities with Peer-to-Peer Trading, Open Research Europe (Open Access Publishing Platform), https://open-research-europe.ec.europa.eu, to be submitted soon

Austrian Residential PV Energy Community Potential (5/5)

Representative Residential PV Energy Communities for typical Austrian Settlement Patterns



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

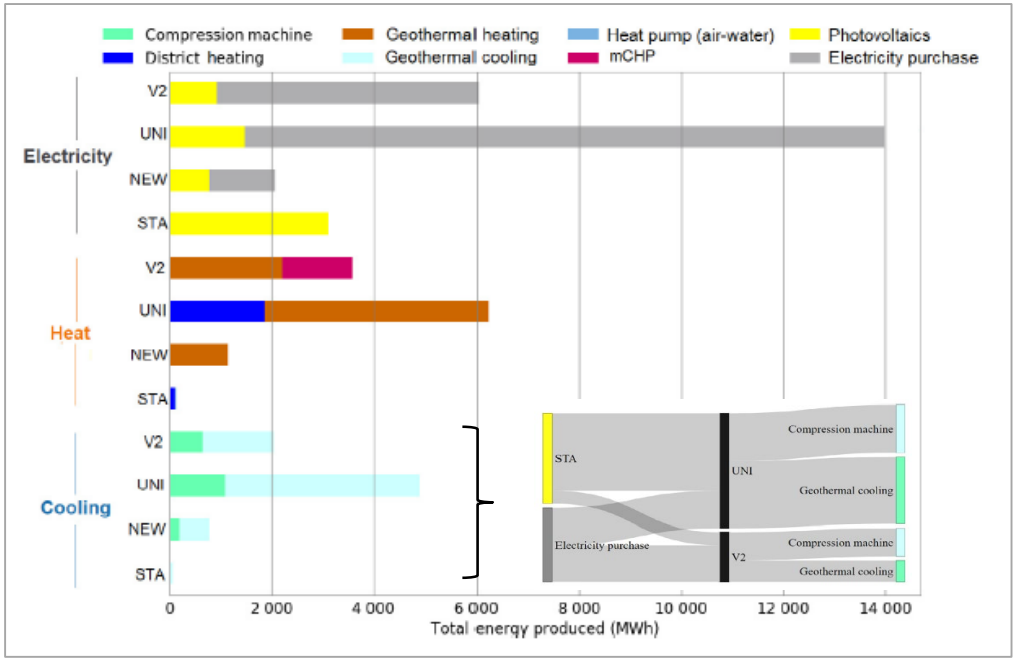


Fina et al (2020), Cost-optimal economic potential of shared rooftop PV in energy communities: Evidence from Austria", Renewable Energy 152 (2020), 217-228. doi: 10.1016/j.renene.2020.01.031

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

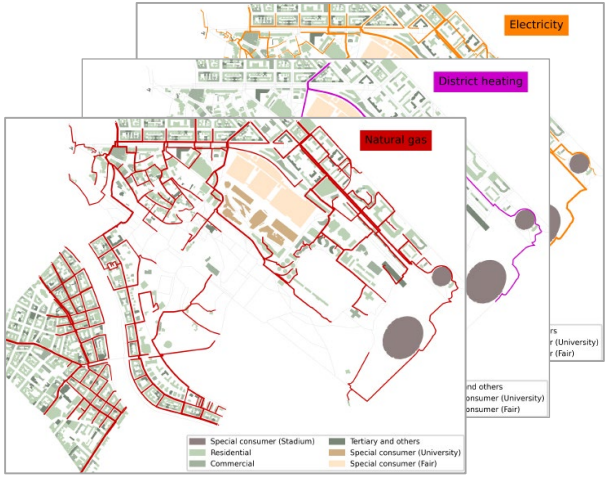
Section in the city map where the energy community is embedded

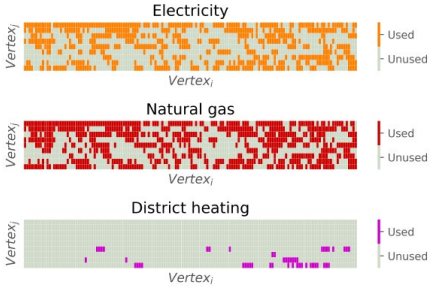
Side by side location of *V2* (green), *UNI* (blue), *NEW* (magenta), *STA* (yellow)



Zwickl-Bernhard et al (2020), Open-Source Modeling of a Low-Carbon Urban Neighborhood with High Shares of Local Renewable Generation, Applied Energy 282 (2021), 116166, doi: 10.1016/j.apenergy.2020.116166

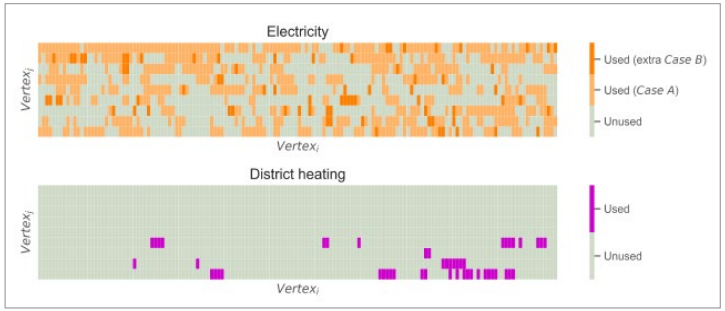
Gas Grid Decommissioning in Urban Energy Community (2/4)



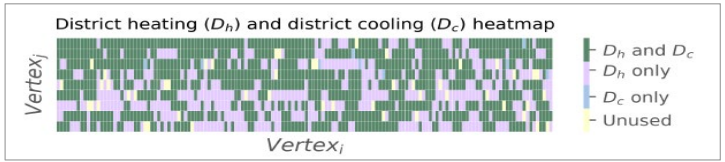


Gas Distribution Grid Decommissioning

Scenario: Electrification



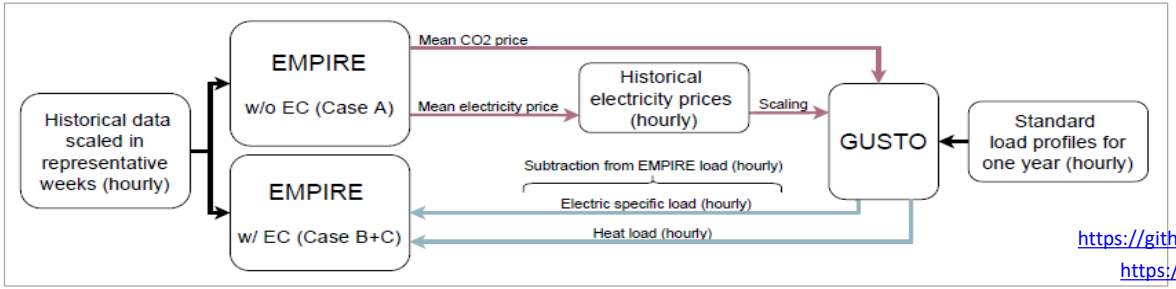
Scenario: District Heating & Cooling Network Expansion



Zwickl-Bernhard et al (2021), Demystifying natural gas distribution grid decommissioning: An open-source approach to local deep decarbonization of urban neighborhoods, submitted to Energy, Manuscript No. EGY-21-05117, under review

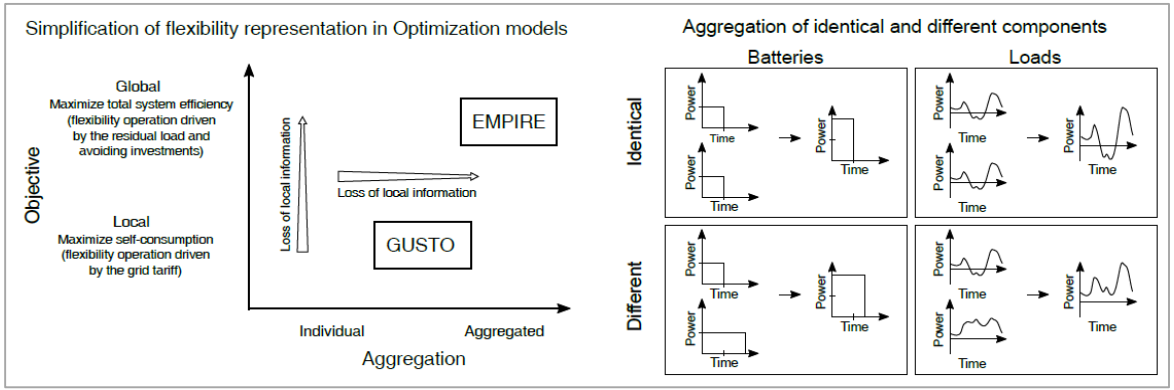
Impact of Energy Communities on European Energy System (3/4)

Link of Open Source Models EMPIRE & GUSTO



https://github.com/ntnuiotenergy/OpenEMPIRE
https://github.com/sebastianzwickl/GUSTO

Flexibility Aggregation of Energy Communities

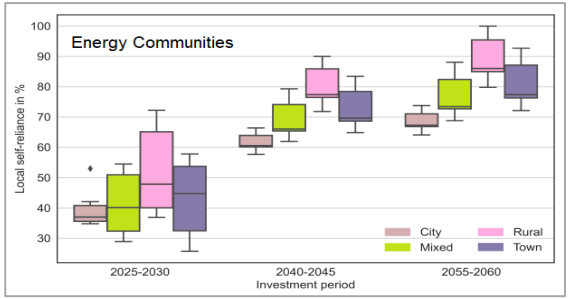


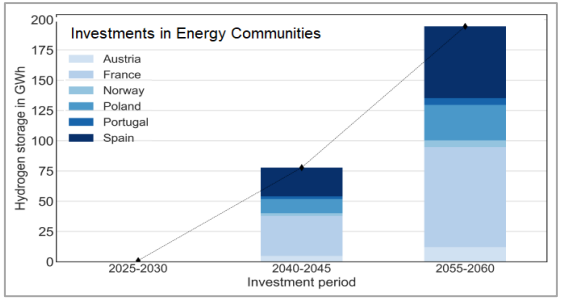
Backe et al (2021), Impact of Energy Communities on the European Electricity and Heat System Decarbonization Pathway: Comparing local and global flexibility responses, submitted to Applied Energy, Manuscript No. APEN-S-21-05896, under review

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

Results (Highlights): ECs in European Countries AT, FR, NO, PL, PT, ES

Case - Investment Period 2020-2060	Objective [EUR]	Generation Capacity Expansion [GW]	Storage Capacity Expansion [GW]	Transmission Capacity Expansion [GW]
Baseline	5.776e+12 (0.0%)	7 881 (0.0%)	2 062 (0.0%)	118 (0.0%)
Community Flexibility Optimization (local)	5.745e+12 (-0.5%)	7 828 (-0.7%)	2 053 (-0.4%)	118 (0.0%)
European Flexibility Optimization (global)	5.742e+12 (-0.6%)	7 819 (-0.8%)	2 019 (-2.1%)	118 (0.0%)





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)

CO_2 price mainly governs technology exchange and thus energy transition (> 500 Euro/t in 2060)

Backe et al (2021), Impact of Energy Communities on the European Electricity and Heat System Decarbonization Pathway: Comparing local and global flexibility responses, submitted to Applied Energy, Manuscript No. APEN-S-21-05896, under review

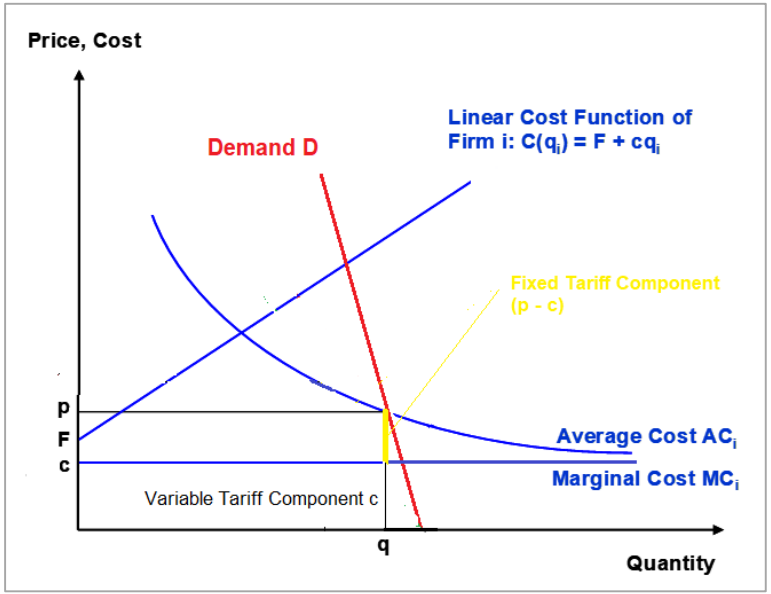
Concluding Remarks

- 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 CO_2 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….

Appendix - Distribution Grid Operators' Revenue Challenge (1/2)

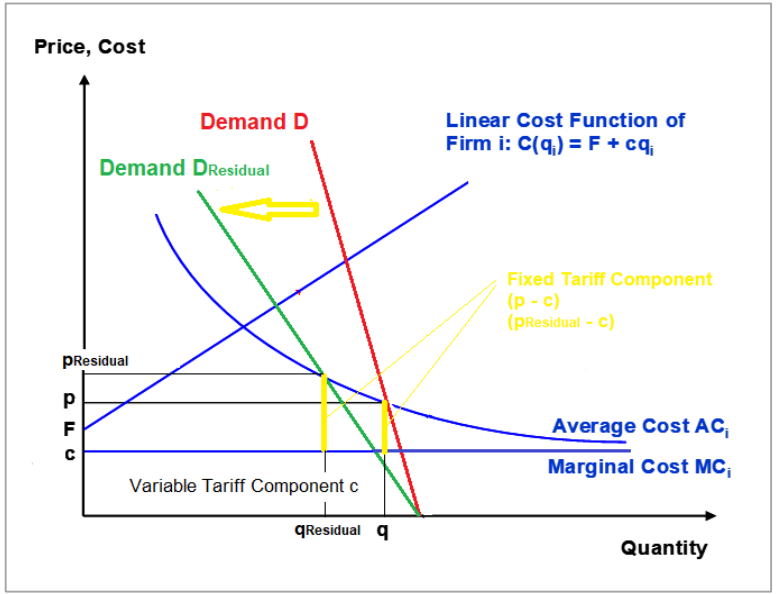
Definition of a Natural Monopoly (Grid):

- 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



Appendix - Distribution Grid Operators' Revenue Challenge (2/2)

Incentive to increase fixed grid tariff component (right figure) to compensate for (parts of) revenue losses…