On the Potential of Rooftop-PV as a Household Appliance with negative Electricity Demand – Evidence from Austria

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

1st IAEE Online Conference: Energy, Covid, and Climate Change
7th – 9th June 2021

Outline

PV Deployment – Two „Colliding“ Philosophies / Paradigms

PV Systems – Household Appliances with negative Electricity Demand & Distribution Grid Operators‘ Revenue Challenge

PV-Sharing/Trading Concepts – Multi-Apartment Buildings & Energy Communities at different Geographical Borders

Residential Building Integrated PV Energy Community Potential in Austria

Concluding Remarks

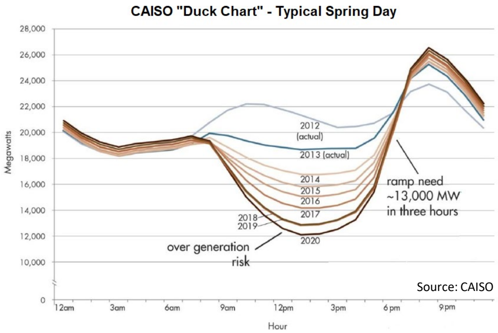
PV Deployment – Two „Colliding“ Philosophies / Paradigms

Energy Planners („Centralists!“) versus Energy Democrats („Dreamers?“)

Energy Planners („Centralists!“)

Status Quo:

- PPAs (Power Purchase Agreements) work out, but…
- Economic cannibalism of utility-scale PV in energy-only markets! *See e.g. Californian „Duck Curve“*



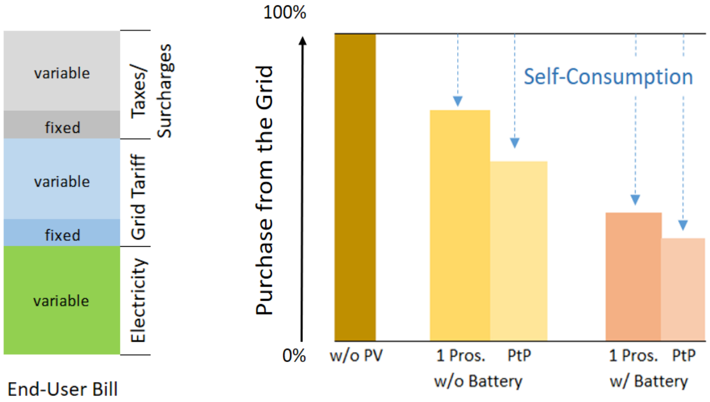
Future:

- PPAs (Power Purchase Agreements)
- Cross-sectoral demand bidding based on consumers‘ opportunity cost? *See e.g. Härtel/Korpås: Demystifying market clearing and price setting effects in low-carbon energy systems, https://doi.org/10.1016/j.eneco.2020.105051*
- Trading of other than current (firm) products, like flexibilities, power gradients, etc.?

Energy Democrats („Dreamers?“)

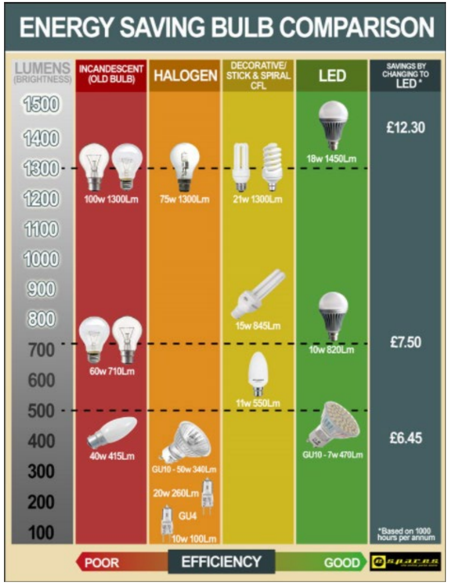
Status Quo:

- Building attached/integrated PV is „THE“ key technology enabling energy democracy (onsite generation, energy communities, local markets)
- Physics of energy management is looked at more closely again (individual supply/demand matching)
- At present mainly legal & regulatory barriers as well as techno-economic challenges for distribution grid operators



Purchasing less electricity from the grid…

…the brave ones!

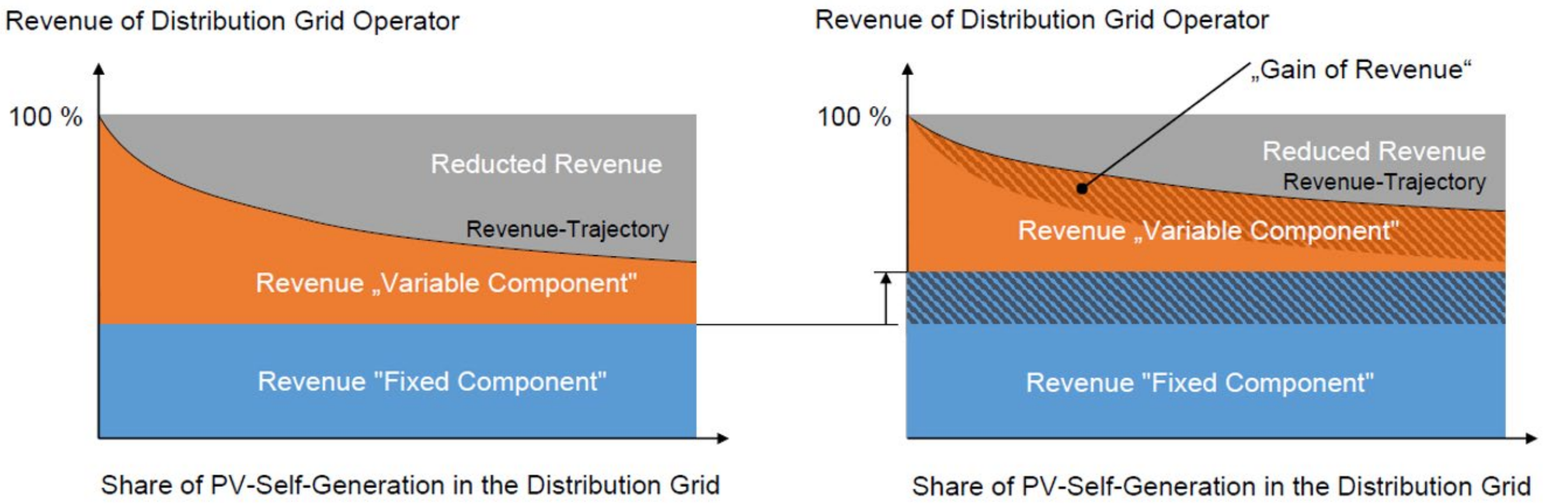


…the „nest defilers/selfish“ (quitting alleged solidarity)?

Solar PV tax (above 25,000 kWh) in Austria for contributing to the implementation of the EU Energy Efficiency Directive? There is something wrong, but maybe I do not understand the energy transition at all…;-)

The Distribution Grid Operators‘ Revenue Challenge

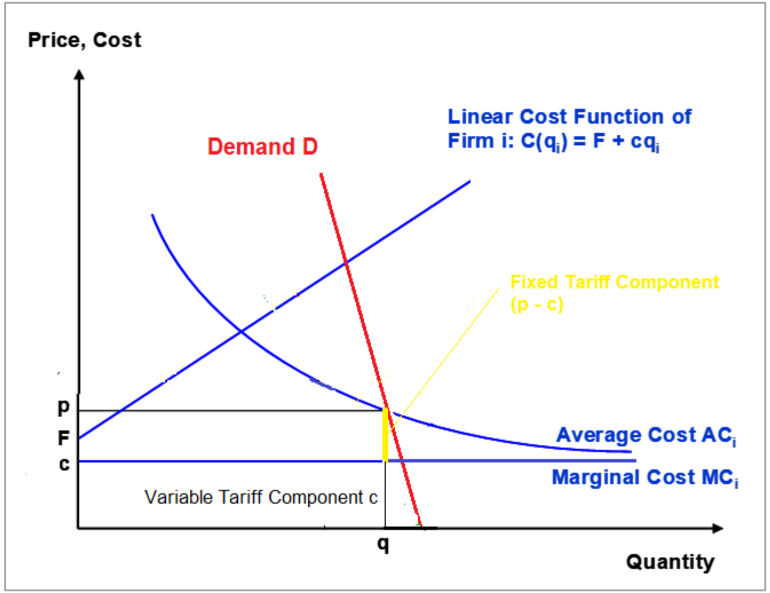
Incentive to increase fixed grid tariff component (right figure)
to compensate for (parts of) revenue losses…



Regulatory Theory – High Fixed Grid Tariff Component Justified?

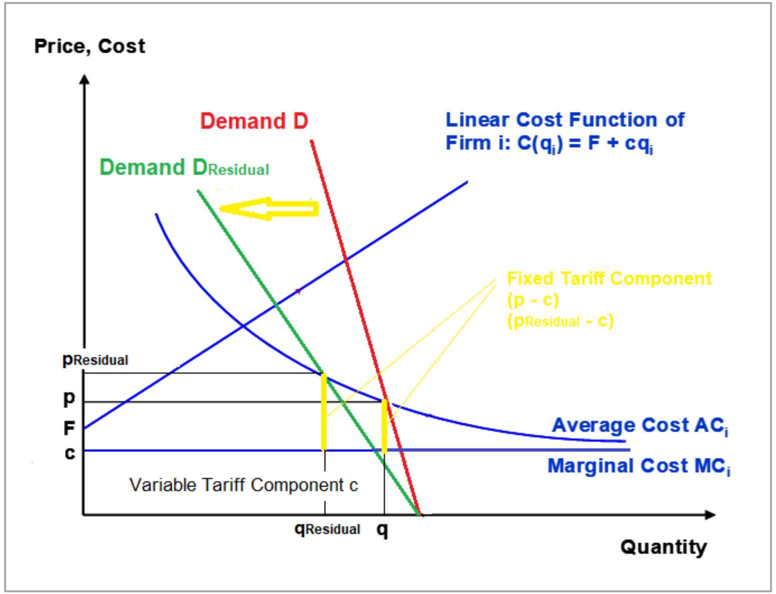
Definition of a Natural Monopoly (Grid):

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

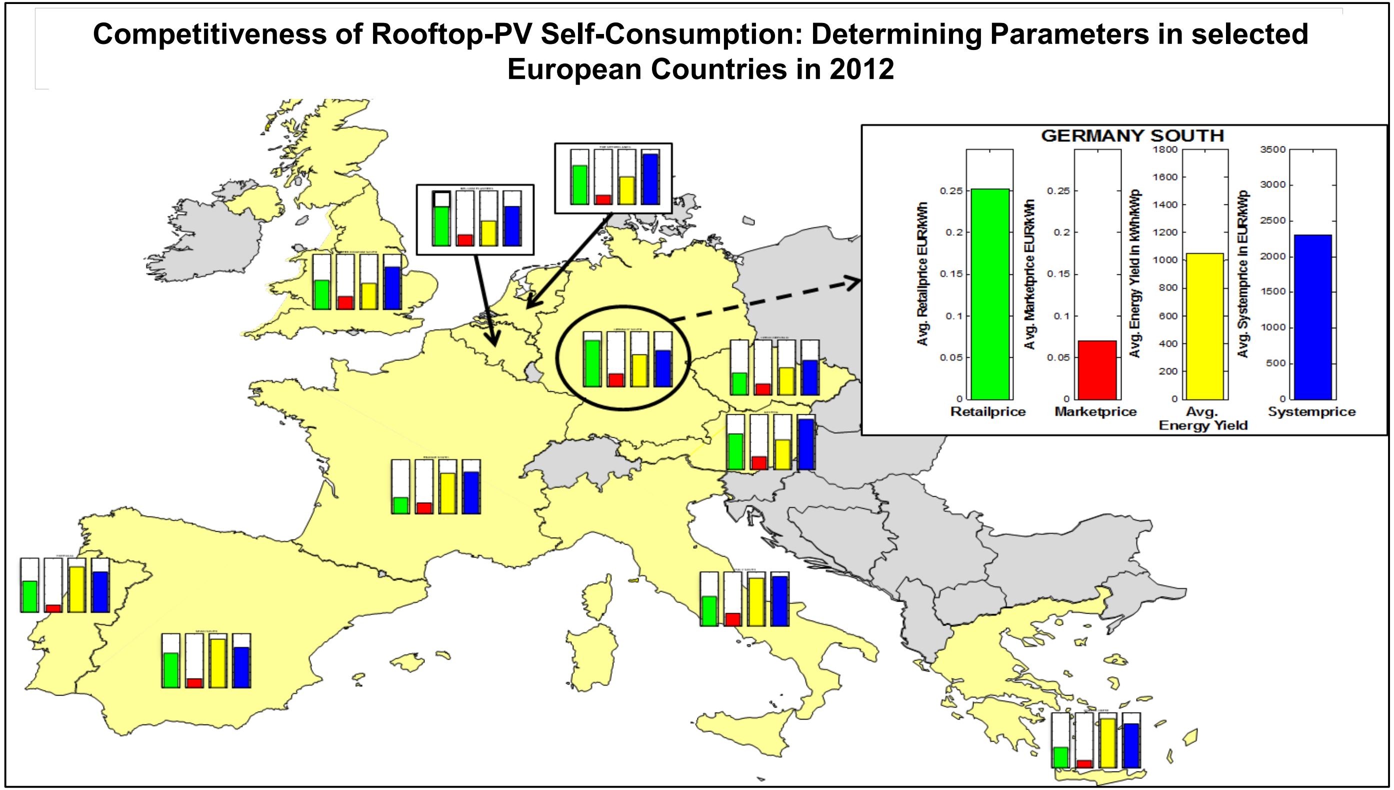


PV Self-consumption & Energy Communities lead to more elastic electricity demand:

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



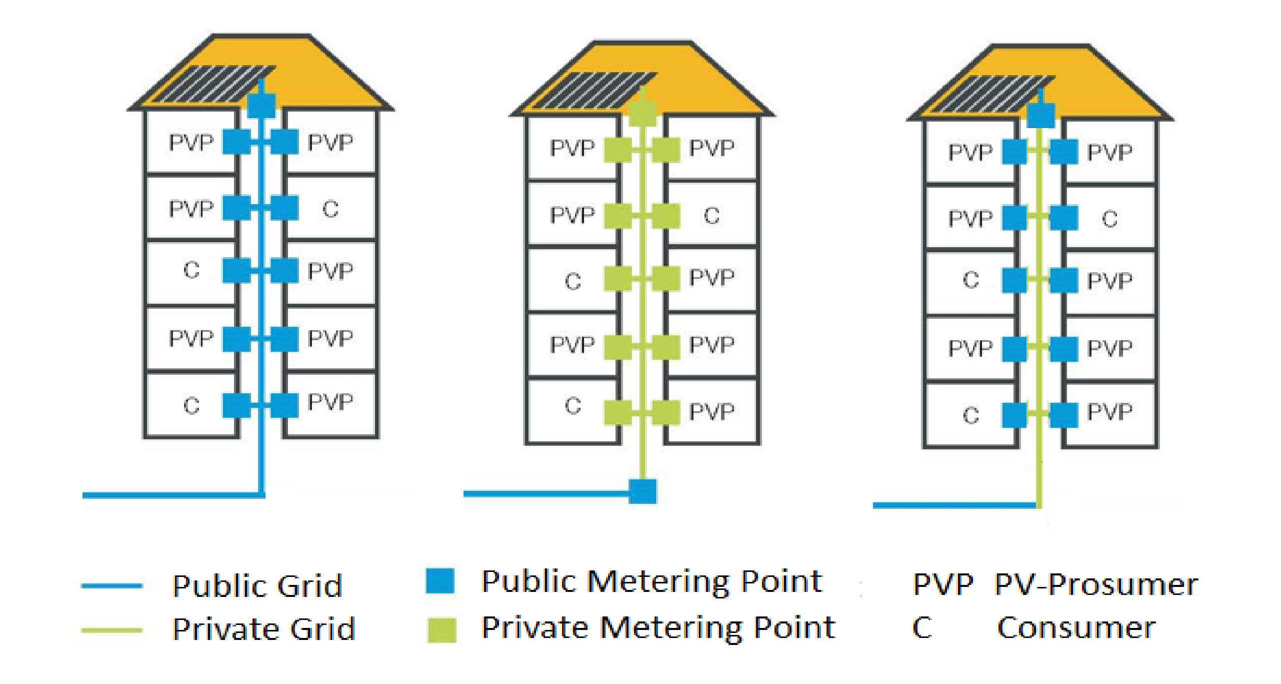
Start of Rooftop-PV „Parity“ in Single-Family Houses in 2012



Source: EEG PV Parity Model Mithras (2012)

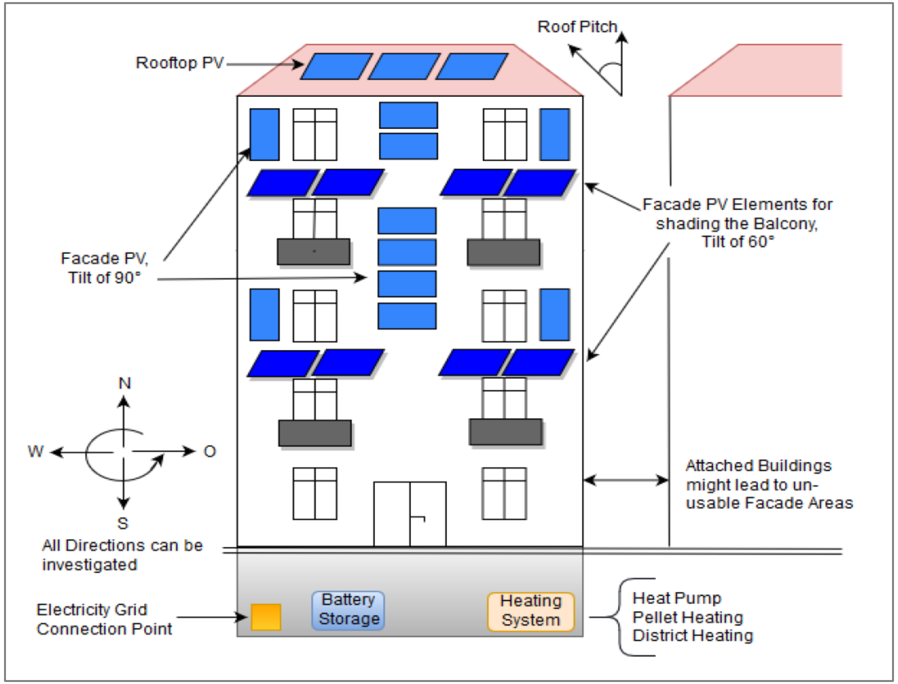
PV-Sharing Concepts in Multi-Apartment Buildings (1/4)

Possible Boundaries (simplified) between Public and Private Grid as well as Metering Points (w/o common areas like undergeround carpark)



Source: *H2020 EU-Project PVP4Grid, www.pvp4grid.eu*

BAPV / BIPV Sharing Models in Multi-Apartment Buildings



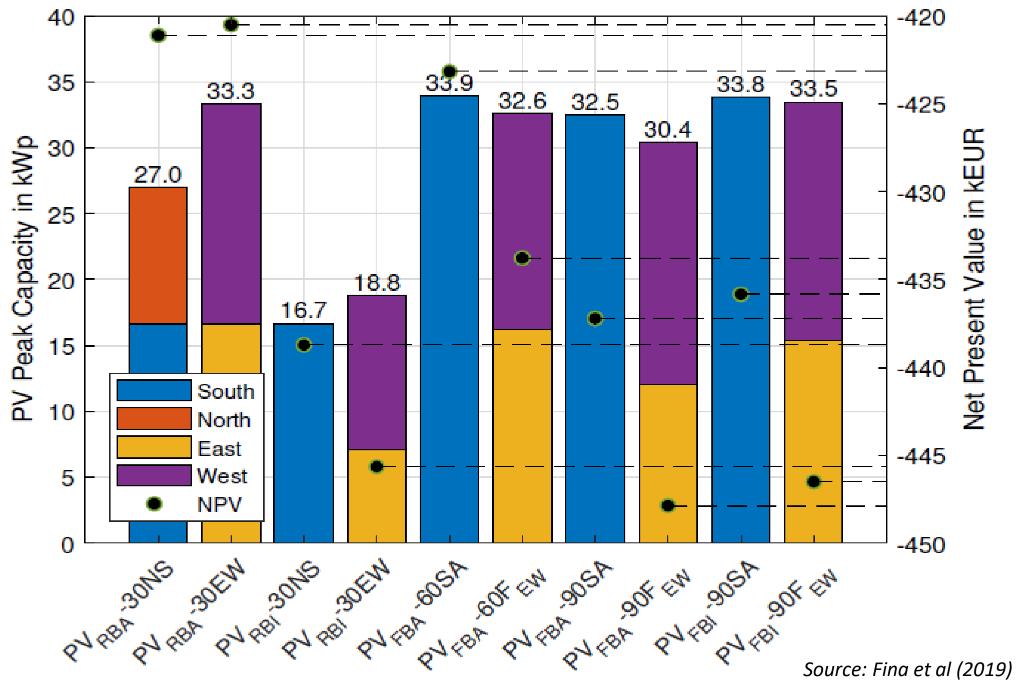
<u>Optimization Model (determining optimal Technology Capacities, Net Present Value):</u>

- 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,…

Source: 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. https://doi.org/10.1016/j.enbuild.2019.02.034

PV-Sharing Concepts in Multi-Apartment Buildings (3/4)

Optimal PV System Size & Profitability of different Building Configurations

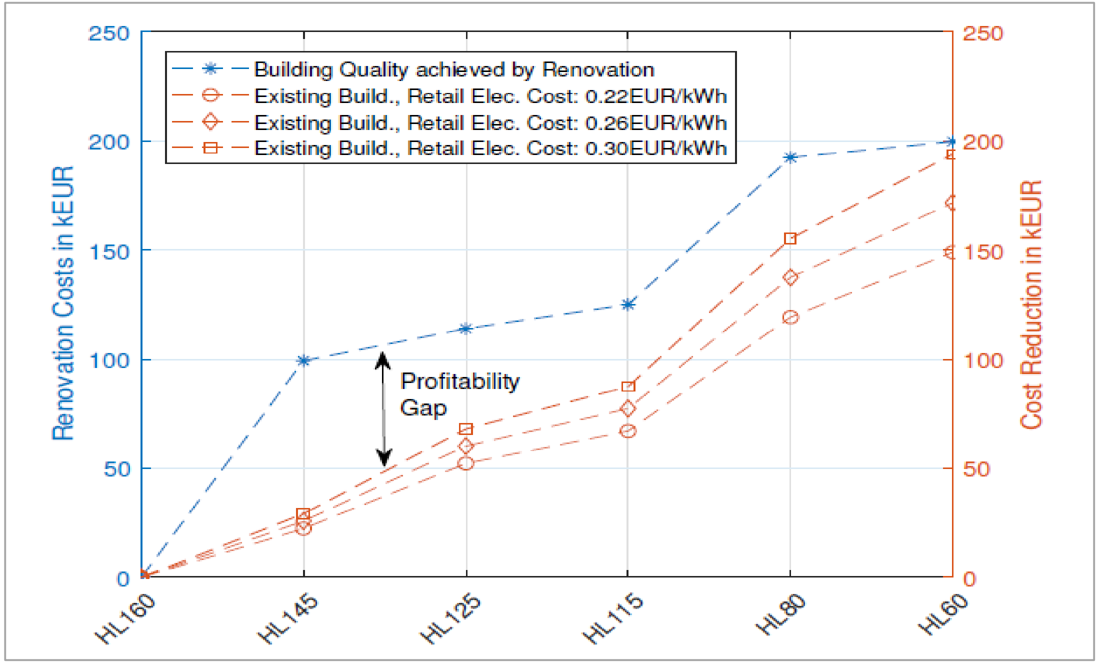


Source: Fina et al (2019)

Impact of building configutation and PV implementation concept on optimal PV system size and Net Present Value (NPV). Heat load: 145 kWh/m2/yr; Heating system: monovalent heat pump

Energy Economics Group

Profitability of PV Sharing & Deep Building Renovation for varying CO_2-Prices

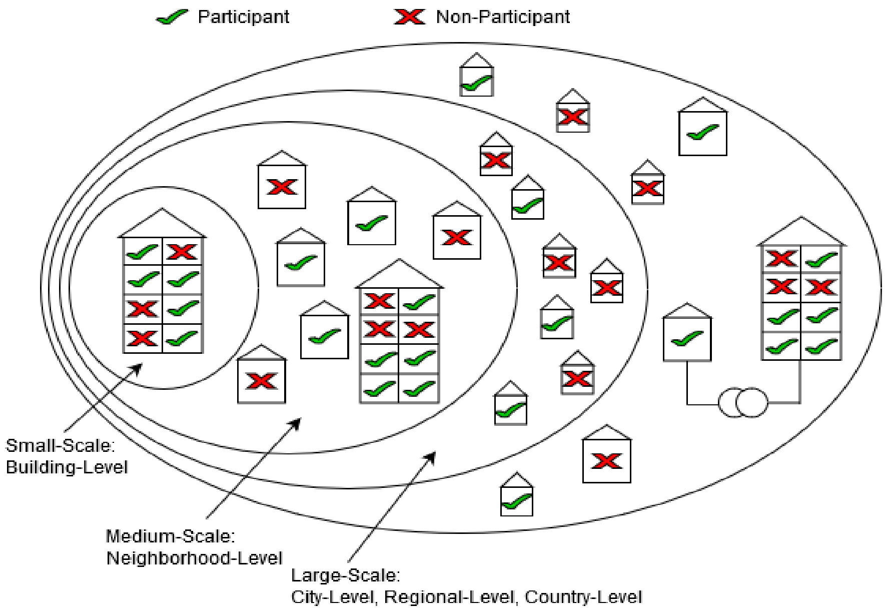


Source: Fina et al (2019)

Changes of profitability gap between renovation costs and cost reductions with increasing CO2 prices/ retail prices (80 €/tCO2, 160 €/tCO2). Heating system: monovalent heat pump.

PV-Sharing Concepts beyond Building-Level (1/4)

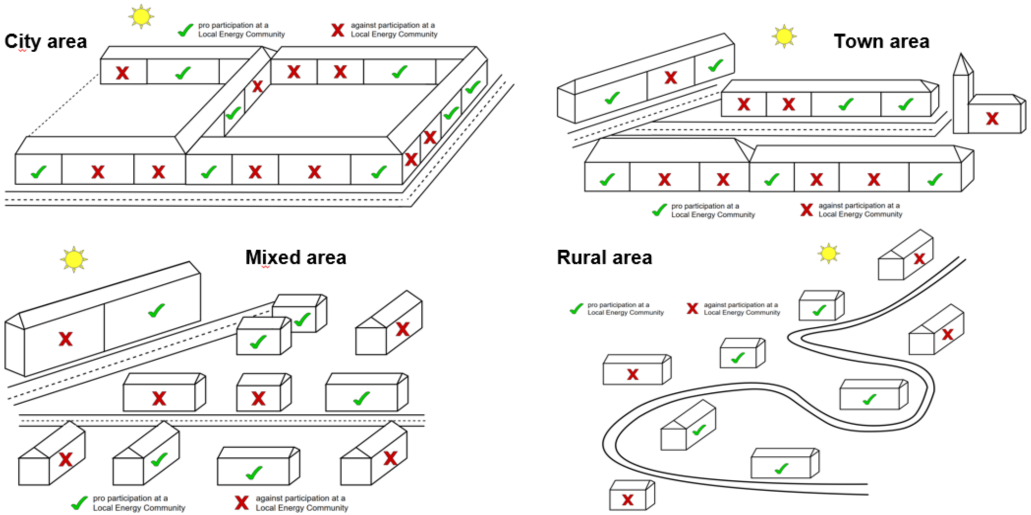
PV Sharing & Peer-to-Peer Trading in Energy Communities at different Geographical Borders

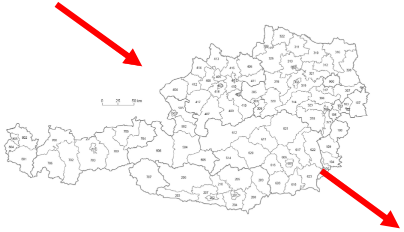


<u>Advantage of energy community compared to microgrid:</u> neither physical connectivity nor mandatory participation is expected; however, an energy community can also perfectly coincide with a microgrid

Different Categories of Residential PV Energy Communities (2/4)

Representative Residential PV Energy Communities for typical Austrian Settlement Patterns*



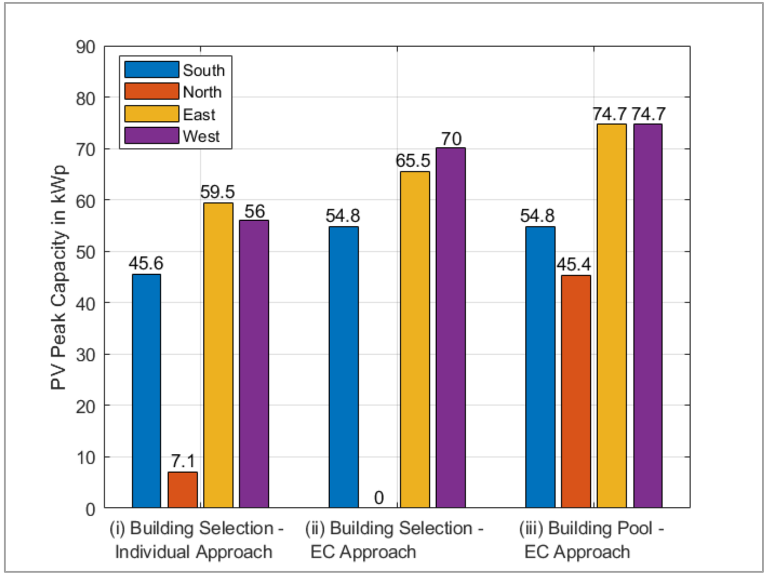


10-12 GW ?
(Austrian overall 2030 PV Target)

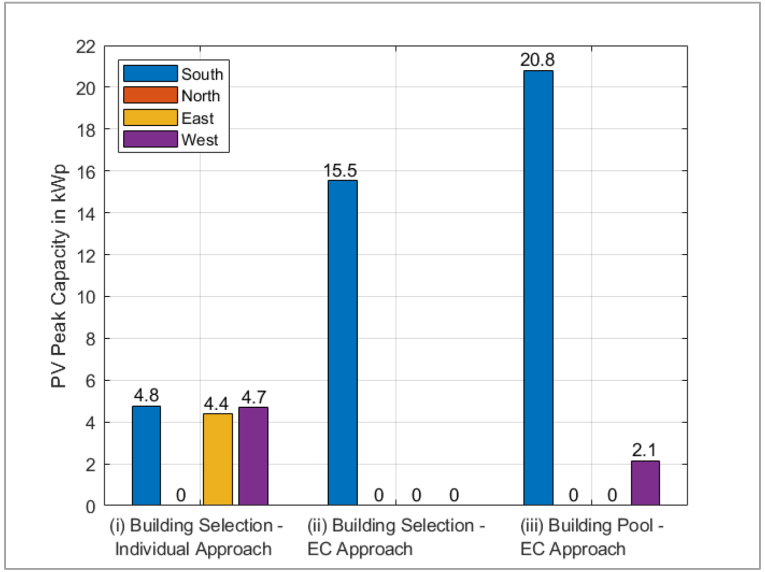
* Each EC consists of 10 buildings (only mixed area 12): City area: 10 MAB, Town area: 10 MAB, Rural area: 10 SFH, Mixed area: 10 SFH & 2 MAB

Cost-Optimal PV Capacities for varying PV Sharing Allocation (3/4)

10 Multi-apartment buildings in city EC



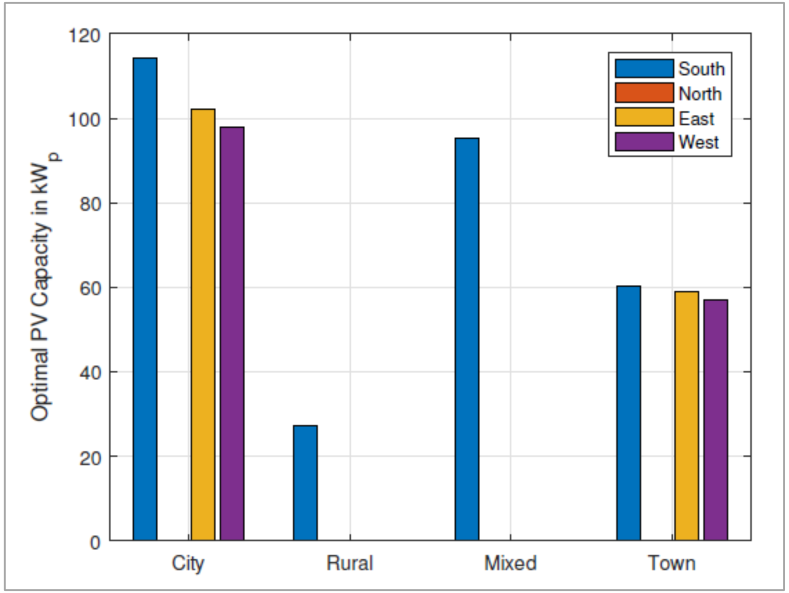
10 Single-family buildings in rural EC



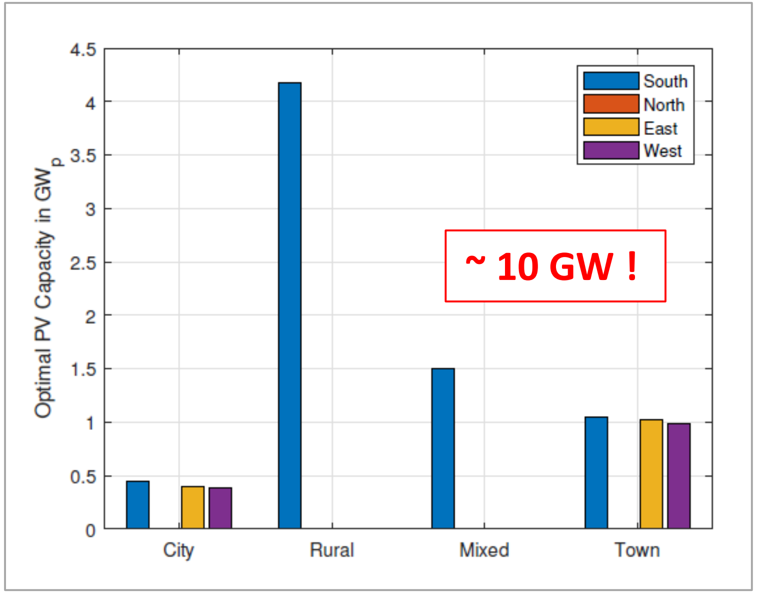
(i) Buildings in EC with feasible PV rooftops – individual PV self-consumption
(ii) Buildings in EC with feasible PV rooftops – optimal PV sharing among those with PV
(iii) All buildings in EC (also those without PV) – optimal PV sharing among all buildings in EC

Cost-Optimal Rooftop PV System Sizes (Capacities) for…

…individual ECs per Settlement Pattern



…Austria (upscaled on Country-level)



Concluding Remarks

- PV systems are household appliances with negative electricity demand
- Even more, PV can be the high-end technology in deep renovation of buildings
- „Energy democracy“ will take-off, supported by technology innovation & digitalization
- „Electricity autarky“ is NOT the goal, but exploitation of synergies via energy communities
- Legislative/regulatory barriers prevent rapid PV implementation in buildings
- Amendments in distribution grid regulation / tariff setting are urgently needed:
  - *Grid infrastructure capacities must be able to cope with the most challenging supply/ demand patterns during the year*
  - *Thus, much greater weighting of the fixed grid tariff component to ensure stable revenue streams for the distribution grid operator*
  - *Adding new dynamic grid tariff component sending correct price signals about current grid state*
- Lower variable grid tariff component has negative impact on profitability of PV self-consumption:
  - *Incentives for formation of suitable energy communities*
  - *An increasing CO_2 price is reflected in an increasing variable electricity tariff component again…*