A NINE-STEP FRAMEWORK TO ASSESS THE IMPACTS OF ENERGY COMMUNITY ROLL-OUT ON A LARGE SCALE

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KONTEXT

- *Clean Energy for all Europeans Package* of 2019
  → Renewable Energy Directive
  → Electricity Market Directive

- Guidelines for Renewable Energy Communities and Citizen Energy Communities
  → transposition into national law within 1-2 years

- Austria pioneer in the transposition of the EU regulations regarding energy communities (ECs)
  → mid 2021 → *Renewable Energies Expansion Act*

- Lack of experience with these novel concepts
  → question reagarding impact in case of large-scale roll-out

→ **Development of a framework to assess the impact of the large-scale roll-out of ECs**

FRAMEWORK TO ASSESS THE IMPACTS OF ENERGY COMMUNITY ROLL-OUT (I)

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Step 1 – Number of buildings per type at a future point in time

- Information regarding the current building stock of the region of investigation
  - Certain granularity beneficial for realistic estimation
  - E.g. number of buildings per building type
  - In Austria provided by statistical institute:
    → number of buildings for SFHs, small MABs (3-10 units), large MABs (>= 11 units)

- Estimate future building stock
  - Numbers of current buildings in combination with
  - Expected building stock development

FRAMEWORK TO ASSESS THE IMPACTS OF ENERGY COMMUNITY ROLL-OUT (II)

Step 2 – Number of buildings categorised by rooftilt

- Two major roof-types:
  - Tilted roof
  - Flat roof
- Different building types → different percentages of tilted or flat roofs
- such data for the Austrian case not available, but for Germany available (similarity of the building stock)

Für den Fall Österreichs:

Building type	SFHs	Small MABs	Large MABs
Building number (to date)	1,727,129	175,910	70,940
Share TR	95 %	92 %	75 %
Share FR	5 %	8 %	25 %
Number buildings with TR (to date)	1,640,773	161,837	53,205
Number buildings with FR (to date)	86,356	14,073	17,735
Building number (future)	1,849,755	188,399	75,977
Number buildings with TR (future)	1,757,268	173,327	56,983
Number buildings with FR (future)	92,487	15,072	18,994
Total number of buildings (future)		2,114,131	

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Step 3 – Determining the theoretical and actually usable rooftop area

- Estimation for PV-based ECs (rooftop PV installation)
- Average rooftop areas of the diffent building types
- From theoretical rooftop area to actually usable rooftop area
  - Construction restrictions (e.g. chimneys, technical equipment on roofs etc.)
  - Shading (neighbouring buildings, trees, etc.)
  - Historical restriction (historic preservations)
  - Self-Shading of PV modules (in case of flat roofs)

Theoretical average rooftop area:

Building type	Tilted roofs	Flat roofs
Single-family buildings	$129\,m^2$	$112\,m^2$
Small multi-apartment buildings	$210\,m^2$	$158\,m^2$
Large multi-apartment buildings	$272\,m^2$	$206\,m^2$

Actually usable rooftop area (for PV installation):

Building type	Tilted roofs	Flat roofs
Single-family buildings	$88.2\,m^2$	$25.7\,m^2$
Small multi-apartment buildings	$143.6\,m^2$	$36.3\,m^2$
Large multi-apartment buildings	$186.0\,m^2$	$47.3\,m^2$

$$A_{usable} = A_{theor} * (1-\mu_1) * (1-\mu_2) *..* (1-\mu_n)$$

FRAMEWORK TO ASSESS THE IMPACTS OF ENERGY COMMUNITY ROLL-OUT (IV)

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Step 4 – Theoretical maximum and realistically installable PV capacity

- Maximum installable PV capacity
  - Based on actually usable rooftop area
  - In combination with specifics of a PV module (e.g. 1,5m^2; 0,3kW$_p$)

Building type	Tilted roofs	Flat roofs
Single-family buildings	17.6 kW$_p$	5.1 kW$_p$
Small multi-apartment buildings	28.7 kW$_p$	7.3 kW$_p$
Large multi-apartment buildings	37.2 kW$_p$	9.5 kW$_p$

- Realistically installable PV capacity (depending on irradiation, financial means, etc.)

Building type	Tilted roofs	Flat roofs
Single-family buildings	4 kW$_p$	4 kW$_p$
Small multi-apartment buildings	28 kW$_p$	7 kW$_p$
Large multi-apartment buildings	37 kW$_p$	9 kW$_p$

- Small PV capacity on SFHs (relatively small load and comparably large rooftop areas for PV intallation)
- Maximum PV installation on MABs (large load and comparably small rooftop areas available)

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Step 5 (I) – Number of PV systems and distribution among building types (currently)

- Data regarding current number of PV systems
- „distribution“ of PV systems on the different building types
  → if data available in this granularity → perfect
  → if not → estimation necessary: e.g. „Distribution“ of PV systems equivalent to the share of the individual building types on the total building stock
- In Austria: 4/5 SFHs und 1/10 small and large MABs, respectively
- Therefore assuming: 4/5 of all PV systems on SFHs, 1/10 of PV systems on rooftops of small/large MABs, respectively
- Finally further sub-distribution of PV systems per building type to buildings with tilted and flat roofs
  → for example based on the shares of tilted and flat roofs on the three different building types (slide 5)

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Step 5 (II) – Number of PV systems and distribution among building types (future)

- Data regarding expansion plans of PV systems (f.e. to be found in general renewable expansion plans)
- For example in AT: 4 TWh additional expected PV generation until 2030 (→ approx. 4GW PV capacity additionally)
  → „Distribution" of these 4GW to different building types (see previous slide)
  → Further Sub-distribution to buildings with tilted and flat roofs per building type
- Knowledge about additional installable PV capacities per building type and roof type in comtination with
- Knowledge of Step 4 -- realistically installable PV capacitiy per building type and roof type
- → Enables to determine the additional number of PV systems

FRAMEWORK TO ASSESS THE IMPACTS OF ENERGY COMMUNITY ROLL-OUT (VII)

Step 5 (III) – Number of PV systems and distribution among building types

Building type	Tilted roofs	Flat roofs
Current status		
Single-family buildings	91,666	4,825
Small multi-apartment buildings	11,096	965
Large multi-apartment buildings	9,046	3,015
Additions until 2030		
Single-family buildings	760,000	40,000
Small multi-apartment buildings	13,143	4,571
Large multi-apartment buildings	8,108	11,111
Total in 2030 (current status plus additions until 2030)		
Single-family buildings	851,666	44,825
Small multi-apartment buildings	24,239	5,536
Large multi-apartment buildings	17,154	14,126

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Step 6 – Shares of buildings equipped with PV systems

dividing the number of buildings that are equipped with PV systems (the number of PV systems equals the number of buildings → one PV system -- one building) by the total number of buildings per type
→ shares of buildings per type that are equipped with a PV system

Building type	Tilted roofs	Flat roofs
In 2030		
Single-family buildings	48 %	48 %
Small multi-apartment buildings	14 %	37 %
Large multi-apartment buildings	30 %	74 %

FRAMEWORK TO ASSESS THE IMPACTS OF ENERGY COMMUNITY ROLL-OUT (IX)

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Step 7 – Definition of model energy communities

- Possibly typical energy communities (so-called model energy communities, for example based on settlement patterns, building types etc.
- In AT – based on three building types: three characteristic settlement patterns
  - Rural area (SFHs)
  - Town area (small MABs)
  - City area (large MABs)
- → Characteristics of such model energy communities per settlement pattern
  - Number of participating buildings
  - Diffusion of PV systems within the community (knowledge application from step 6 about the share of buildings equipped with PV systems)

TYPICAL AUSTRIAN SETTLEMENT PATTERNS

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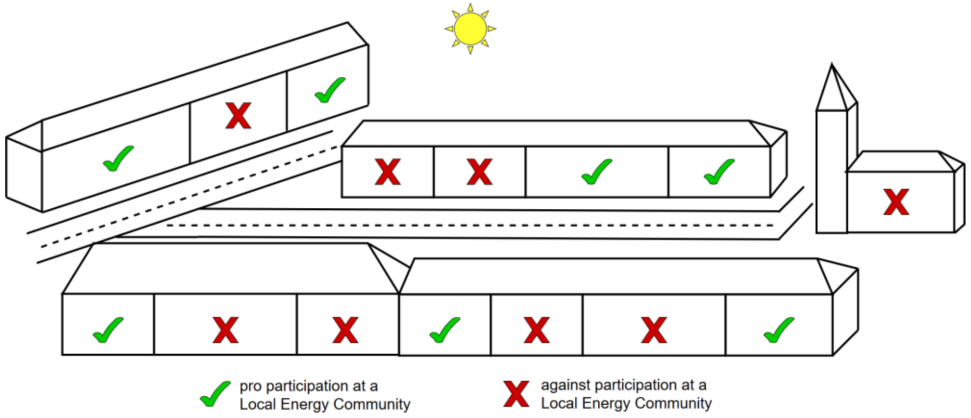
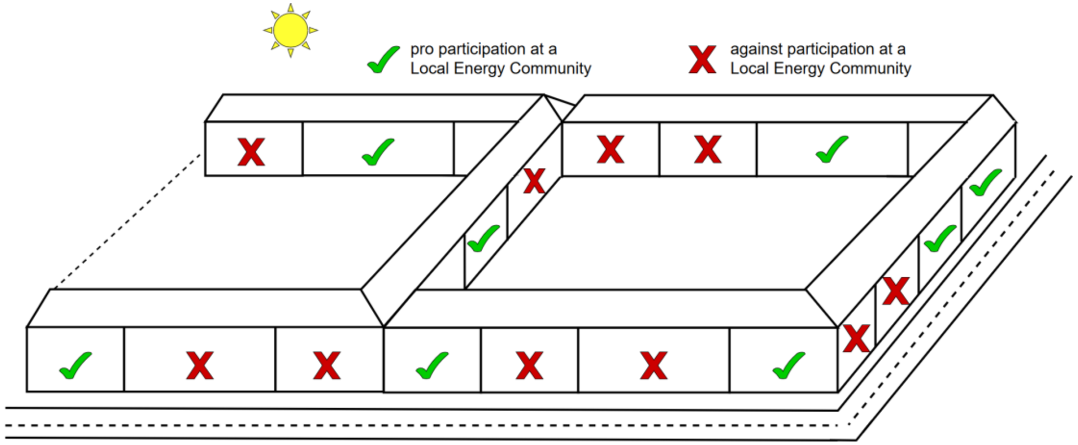
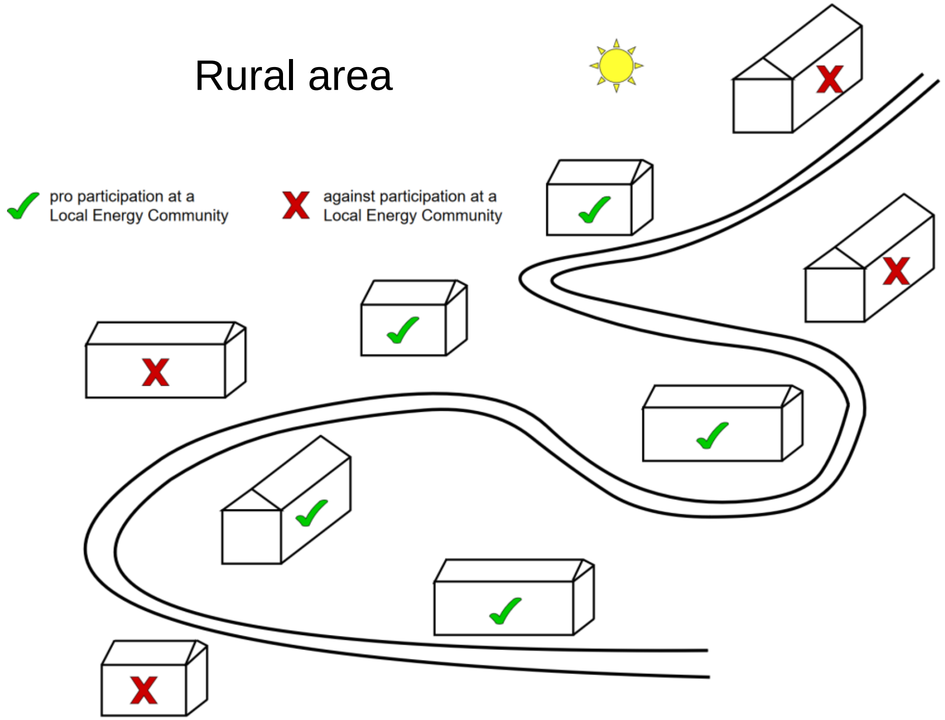
Town area



City area



Rural area



FRAMEWORK TO ASSESS THE IMPACTS OF ENERGY COMMUNITY ROLL-OUT (X)

Step 8 – Calculations with model energy communities

- Conducting calculations for individual model ECs as a basis for estimation of the large-scale impacts in case of roll-out
- For example: Using an optimisation model with the objective to calculate cost-optimal operation of an EC.

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Step 9 (I) – Estimating the large-scale impact of EC roll-out

- Participating building stock
  - Assumption that only a certain share of all buildings participate in an EC
  - Definition of a „Reduction-Factor“ based on possible Willingness-to-Participate (WTP)
    → Determine actual number of buildings that are assumed to participate in an EC
    → WTP at „community energy projects“ is estimated to be 1/3rd[1]
- Number of ECs
  - Determination through number of participating buildings and number of buildings per model energy community

$$No_{ECs} = No_{part\_build} / No_{build\_perEC}$$

- Upscaling
  - Multiplication of the number of resulting ECs per settlement pattern with results calculated for individual model Ecs (f.e. with using an optimisation model or else)

[1] B. J. Kalkbrenner, J. Roosen, Citizens' willingness to participate in local renewable energy projects: The role of community and trust in Germany, Energy Research & Social Science 13 (2016) 60-70. doi:10.1016/j.erss.2015.12.006.

FRAMEWORK TO ASSESS THE IMPACTS OF ENERGY COMMUNITY ROLL-OUT (XII)

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Step 9 (II) – Estimating the large-scale impact of EC roll-out

For the Austrian case:

	Rural area (SFHs)	Suburban area (sMABs)	City area (lMABs)
Total number	1,849,755	188,399	75,977
Reduced number	616,585	62,800	25,326
Number of ECs	41,106	4,187	1,688

Assumption: one model EC consists of 15 buildings each.

CASE STUDY

- Regional rural model EC
- 15 participating SFHs, load profiles between 3500 kWh and 7200 kWh.
- 7 SFHs equipped with PV (4kW$_p$ each, oriented south/east/west)
- Renewable Energy Community – subject to reduced grid tariffs in Austria

Optimisation of <u>one rural model EC</u> regarding cost-minimal operation:

- Annual savings through EC participation: 2578,96 €
- Annual amount of ‚shared' PV electricity between EC participants: 9659,08 kWh
- Annual monetary losses of distribution grid operators through reduced grid tariffs: 108,95 €

CASE STUDY

Based on conducted calculations in Austria: 41,106 rural ECs

Savings through participating at a rural model EC:

- Savings per EC: 2578,96 € (on average 171,9 € per participant)
- Total savings in case of large-scale roll-out: 106 Mio. €
- Knowledge regarding savings important for energy service providers

Impact on electricity suppliers' sales:

- Amount of PV electricity shared within one rural model EC: 9659,08 kWh
- Electricitiy suppliers would sell 397 GWh less
- Possible compensation of such losses through novel business models regarding services for ECs.

Impact on revenues of distribution grid operators:

- Monetary losses for distribution grid operators per rural model EC: 108,95 €
- 4,5 Mio. € less revenues due to large-scale roll-out of rural model ECs in Austria

Note: results only for rural areas in Austria, assuming a building participation of 1/3rd

Method and results based on:

B. Fina, C. Monsberger, H. Auer; *A framework to estimate the large-scale impacts of energy community roll-out*; Heliyon, CellPress, 2022 (currently under review)

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