

# UPSCALING THE POTENTIAL OF ENERGY COMMUNITIES TO COUNTRY-LEVEL



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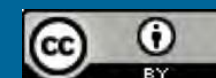
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# Motivation and Scope

## Case study 2 “Behavior of communities of actors” in Horizon 2020 project openENTRANCE

- Communities of actors are energy communities:
  - Voluntary participation and consideration of individual willingness-to-pay
  - Low entry barriers: No closed systems, but part of the distribution network
  - Trading and sharing of locally generated energy within a certain framework: E.g. with a local electricity/energy market, here as Peer-to-Peer Trading
  - Dynamic phase-in and phase-out of members
- Previous work on CS 2:
  - Energy community model FRESH:COM [1]
  - Dynamic participation in energy communities [2]

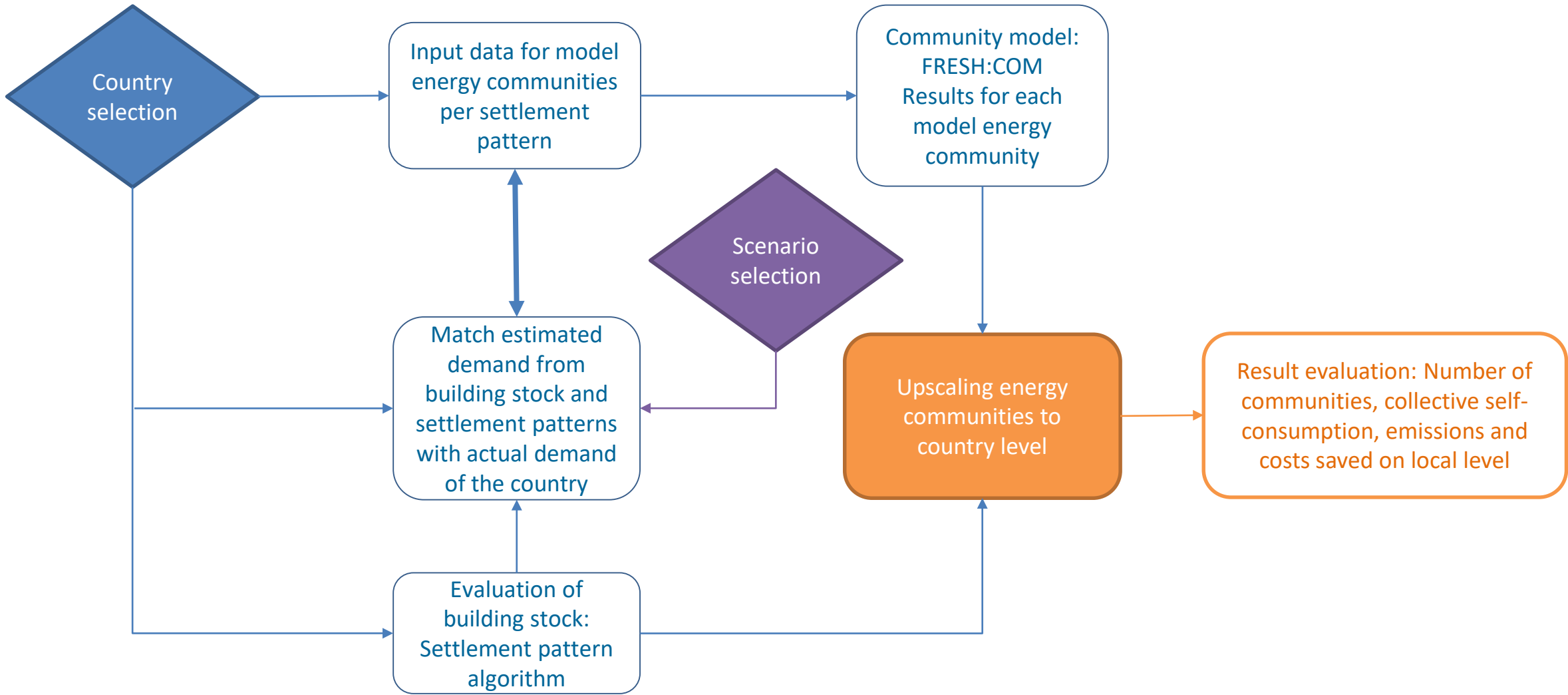
[1] T. Perger et al., PV sharing in local communities: Peer-to-peer trading under consideration of the prosumers' willingness-to-pay, Sustainable Cities and Society, Volume 66, 2021, <https://doi.org/10.1016/j.scs.2020.102634>.

[2] Perger T and Auer H. Dynamic participation in local energy communities with peer-to-peer trading [version 1; peer review: 1 approved]. Open Research Europe 2022, 2:5 (<https://doi.org/10.12688/openreseurope.14332.1>)

# Motivation and Scope

## Case study 2 “Behavior of communities of actors” in Horizon 2020 project openENTRANCE

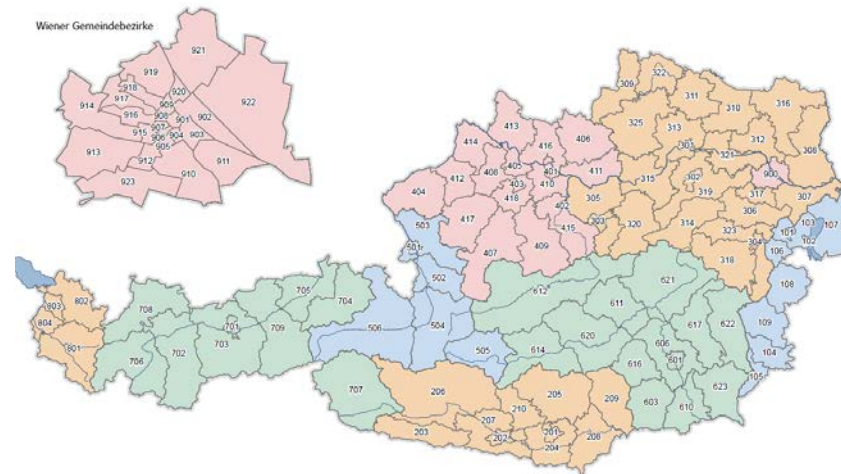
- Upscaling the potential of energy communities for different European countries based on building stock, PV potential, electricity consumption
- Reference countries:
  - Austria
  - Greece
  - Spain
  - Others (not shown here)
- Quantitative upscaling of the local energy community potential is conducted for Europe as a whole



# Austria

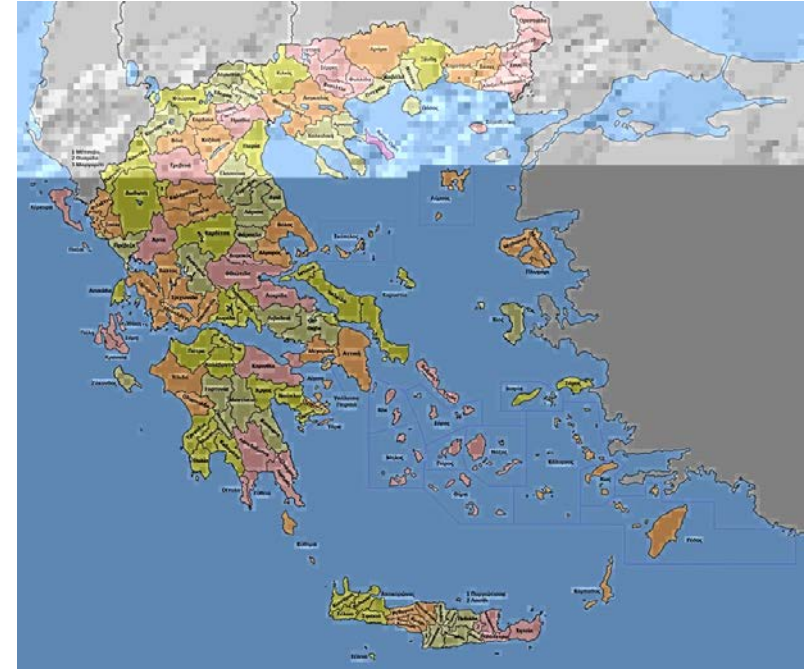
About the Austrian building and household data (census 2011):

- Almost 9 Mio. inhabitants
- Household electricity demand in total 15222 GWh in Austria
- Average electricity demand (2016) of a
  - Single house: 5175 kWh/a
  - Apartment: 2000 kWh/a
- 121 political districts



About the Greek building and household data (census 2011):

- 11.1 Mio. inhabitants
- Over 3 Mio. buildings for residential use, about 6.4 Mio. dwellings
- Average electricity demand per household is 4152 kWh/a (2019)
- Percentage of occupied dwellings average over the whole country: 64%
  - Varying from 14-84% depending on municipality
  - Secondary and vacation homes are excluded
- 326 municipalities (spatial level: LAU)





# Spain

About the Spanish building and household data (census 2011):

- 47 Mio. inhabitants
- Over 3 Mio. buildings for residential use, about 18 Mio. dwellings
- Household electricity demand in total 60 TWh
- Average electricity demand per household is 3318 kWh/a
- Percentage of occupied dwellings average over the whole country: 72%
  - Secondary and vacation homes are excluded
- 52 regions (spatial level: NUTS 3)



# Settlement patterns

## Characteristics of the different settlement patterns [3]:

### 1. City areas (high population density)

- Large apartment buildings
  - Aggregation of tenants' load profiles
  - Possibly with different types of businesses in the buildings (shops on the first floor, offices, ...)
  - Limited rooftop area for PV systems

### 2. Town areas (medium density)

- Mostly small apartment buildings
- Limited rooftop area for PV systems
- Some businesses included (e.g., shops, bakery, ...)

### 3. Suburban areas (low-to-medium density)

- Mix of apartment buildings and single family houses

### 4. Rural areas (low population density)

- Mostly single houses
- Sufficient rooftop area available



# Settlement patterns

From building stock to energy communities:

- Definition of energy communities per settlement pattern
  - City: 10 large apartment buildings (10 or more dwellings)
  - Town: 10 small apartment buildings (3-9 dwellings)
  - Suburban: 10 single houses (1-2 dwellings) + 2 large apartment buildings
  - Rural: 10 single houses
- Per district/region, the buildings are assigned to settlement patterns
  - number of energy communities per type and per region

# Energy community model FRESH:COM

About the (open-source) model:



- Linear optimization model FRESH:COM [4] maximizing the community welfare of a **local energy community by peer-to-peer trading**

- Community welfare:

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

- Allocation mechanism: Peer-to-peer trading under the consideration of each prosumer's *individual willingness-to-pay*:

$$wtp_{i,j,t} = p_t^{G_{in}} + w_j(1 - d_{i,j}) \cdot e_t.$$

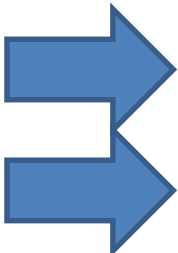
- Members: Private households and SMEs
  - Photovoltaic (PV) and Battery Energy Storage Systems(BESS)

[4] T. Perger, FRESH:COM, <https://github.com/tperger/FRESH-COM>

# Data and assumptions

How to define each settlement pattern’s energy community:

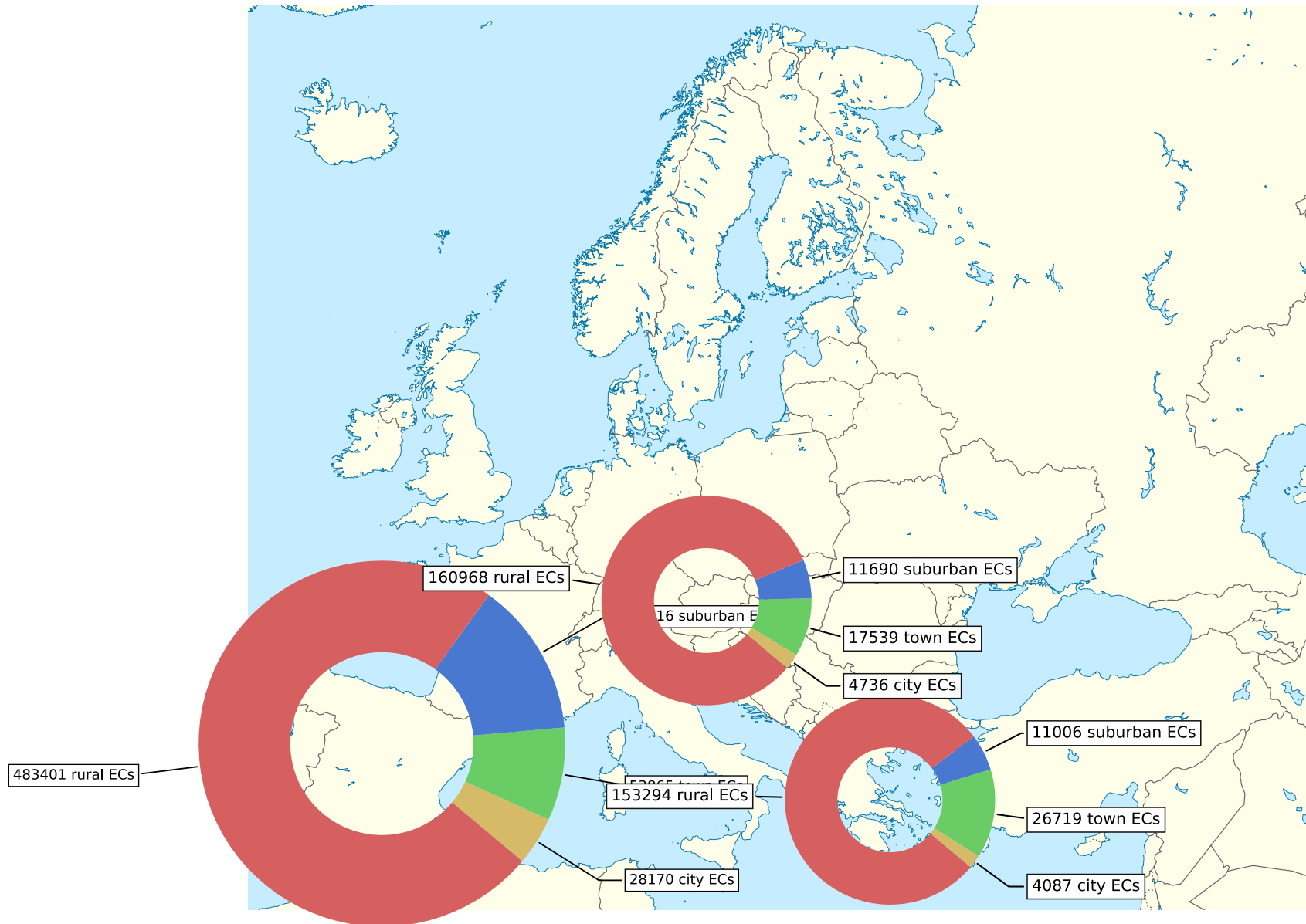
- Input data (normalized electricity demand and PV generation) from open-source tools
- Assignment of annual electricity demand per building:



	Austria	Greece	Spain
avg. Demand per household (kWh/a)	3486	4125	3318
avg. Demand per single house (kWh/a)	5175	5678	5401
avg. Demand per flat (kWh/a)	2000	2271	2160
Avg. Number of dwelling per single house	1.165	1.266	1.078
Avg. Number of dwelling per small apartment building	5.464	4.095	6.596
Avg. Number of dwelling per large apartment building	18.700	14	18

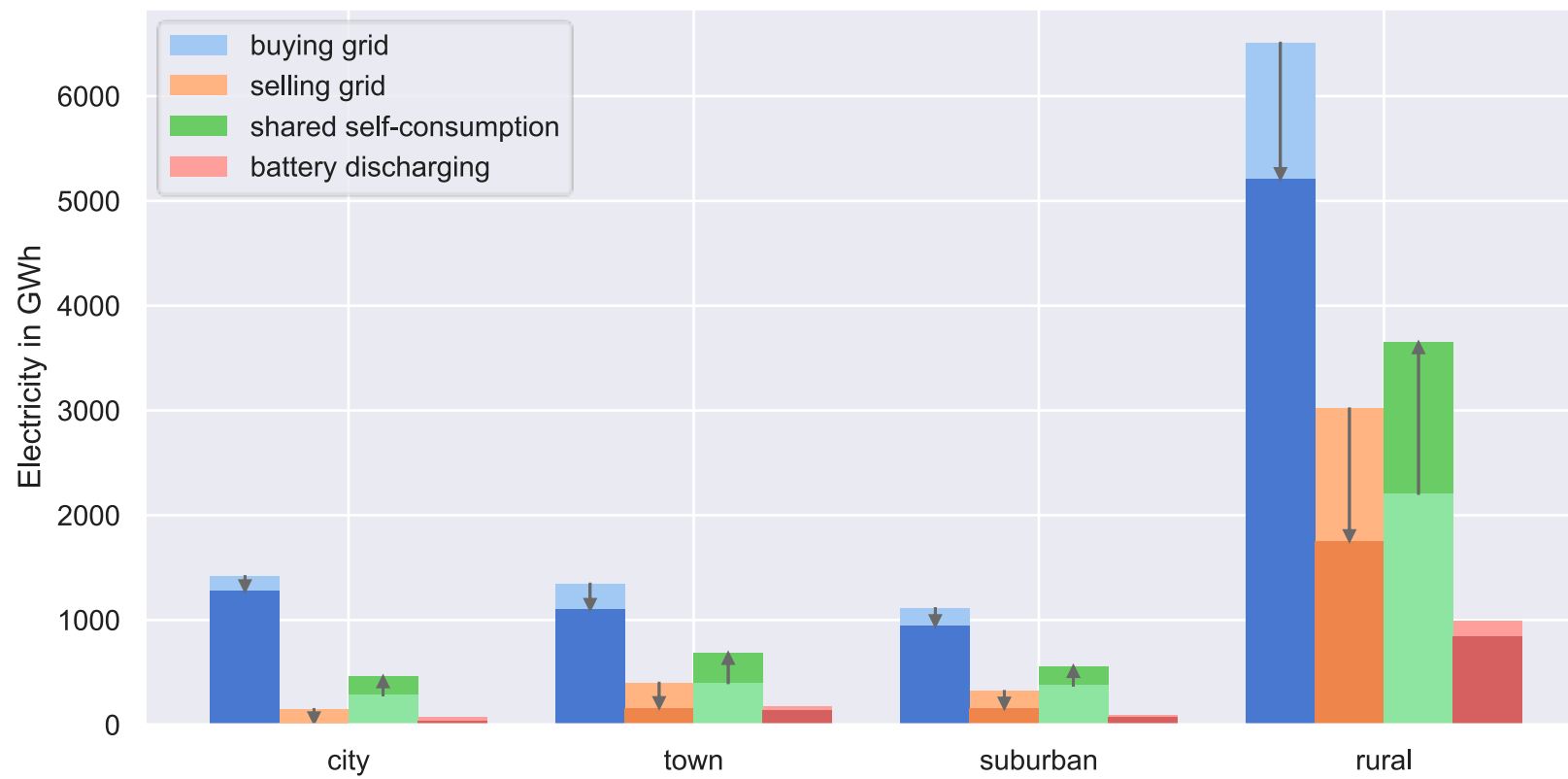
- Each prosumer is assigned a different annual electricity demand using normal distribution
- PV systems:
  - Peak capacities installed: 3-15 kW<sub>peak</sub>
- Battery storage systems:
  - Storage capacities: 3-8 kWh
- Some members are consumers only

# Results Austria, Greece, Spain



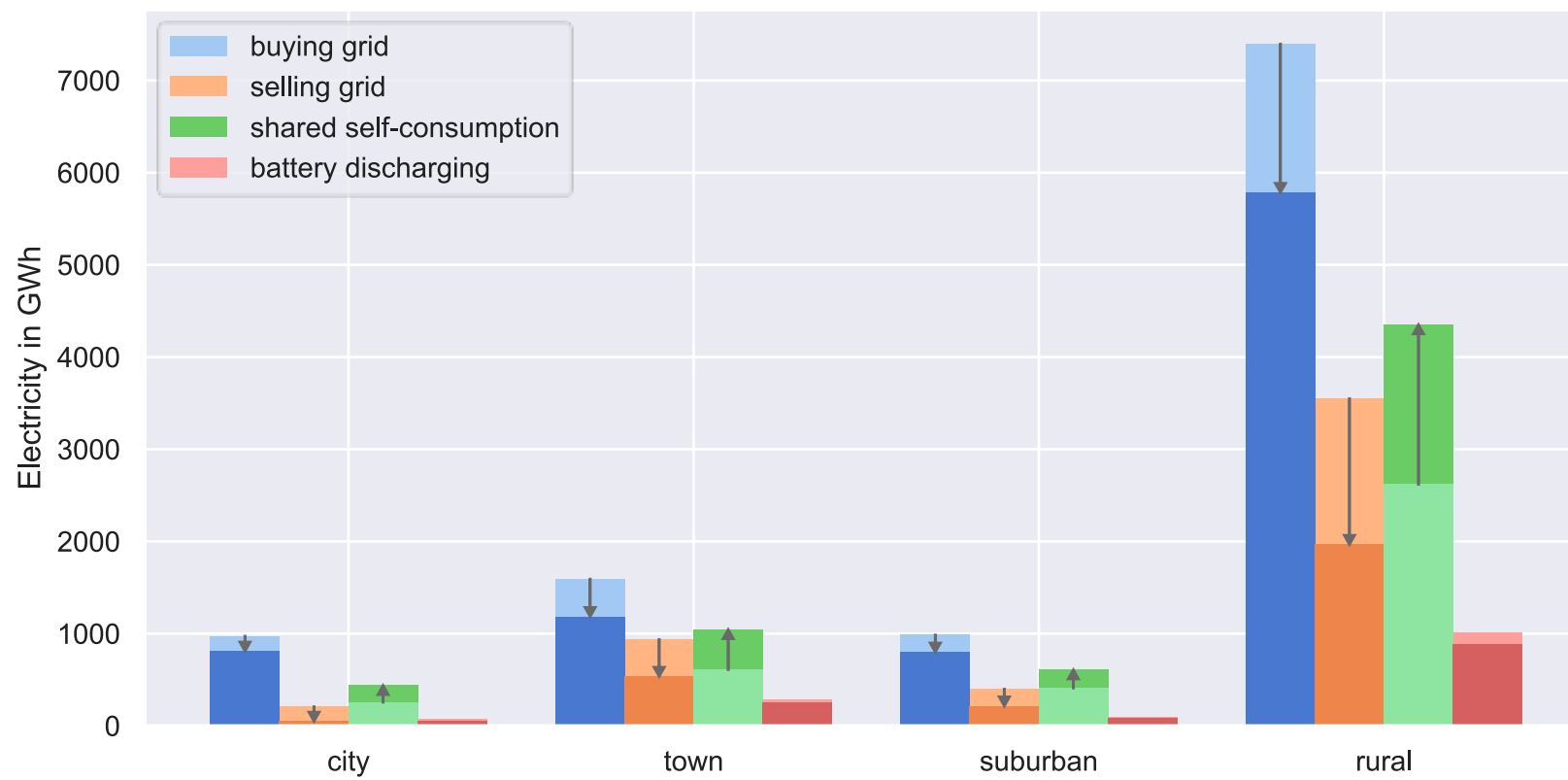
# Results Austria

Impact of ECs on grid purchases, grid feed-in, shared self-consumption, and battery operation: [Austria](#)

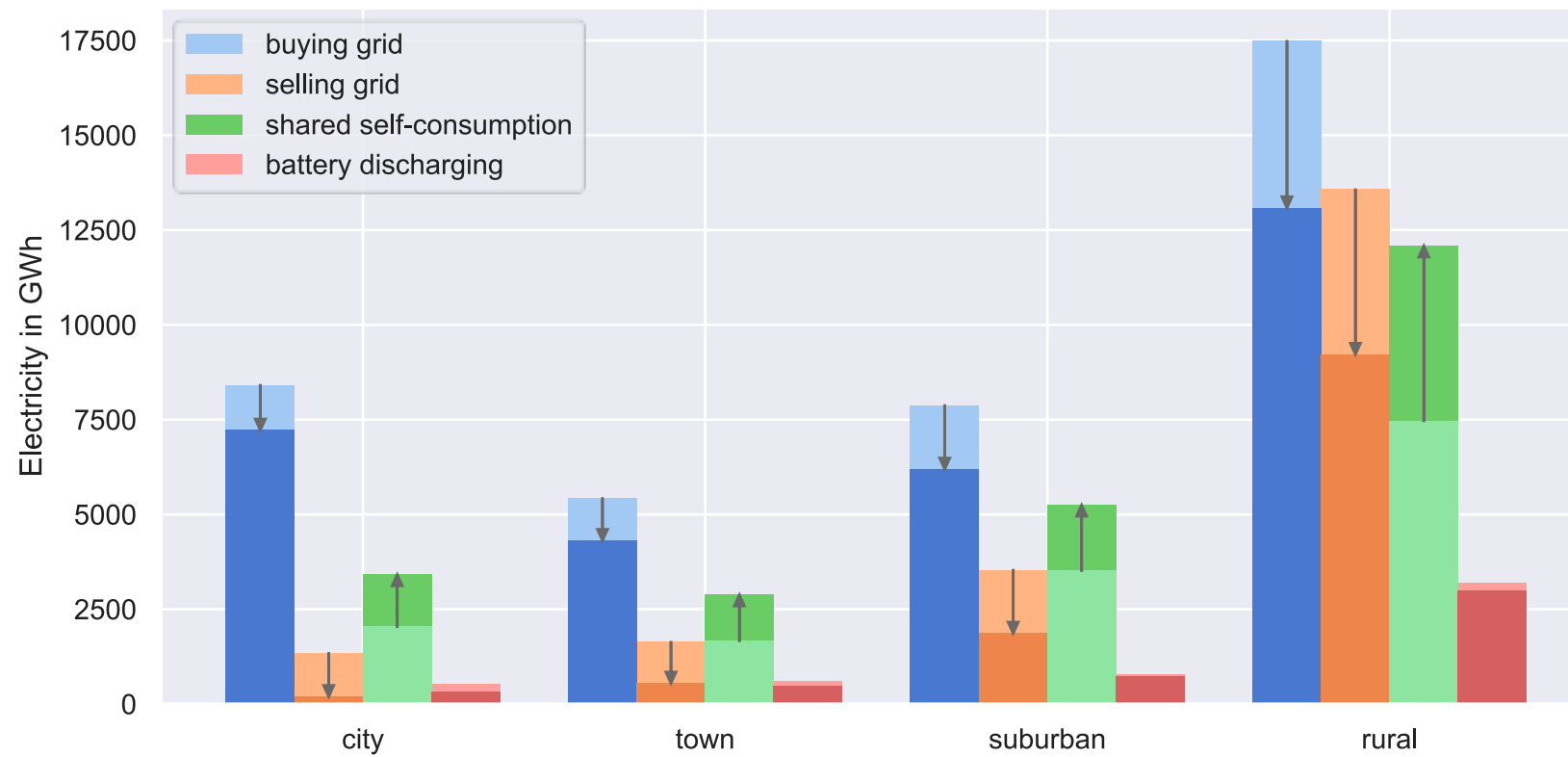


# Results Greece

Impact of ECs on grid purchases, grid feed-in, shared self-consumption, and battery operation: [Greece](#)



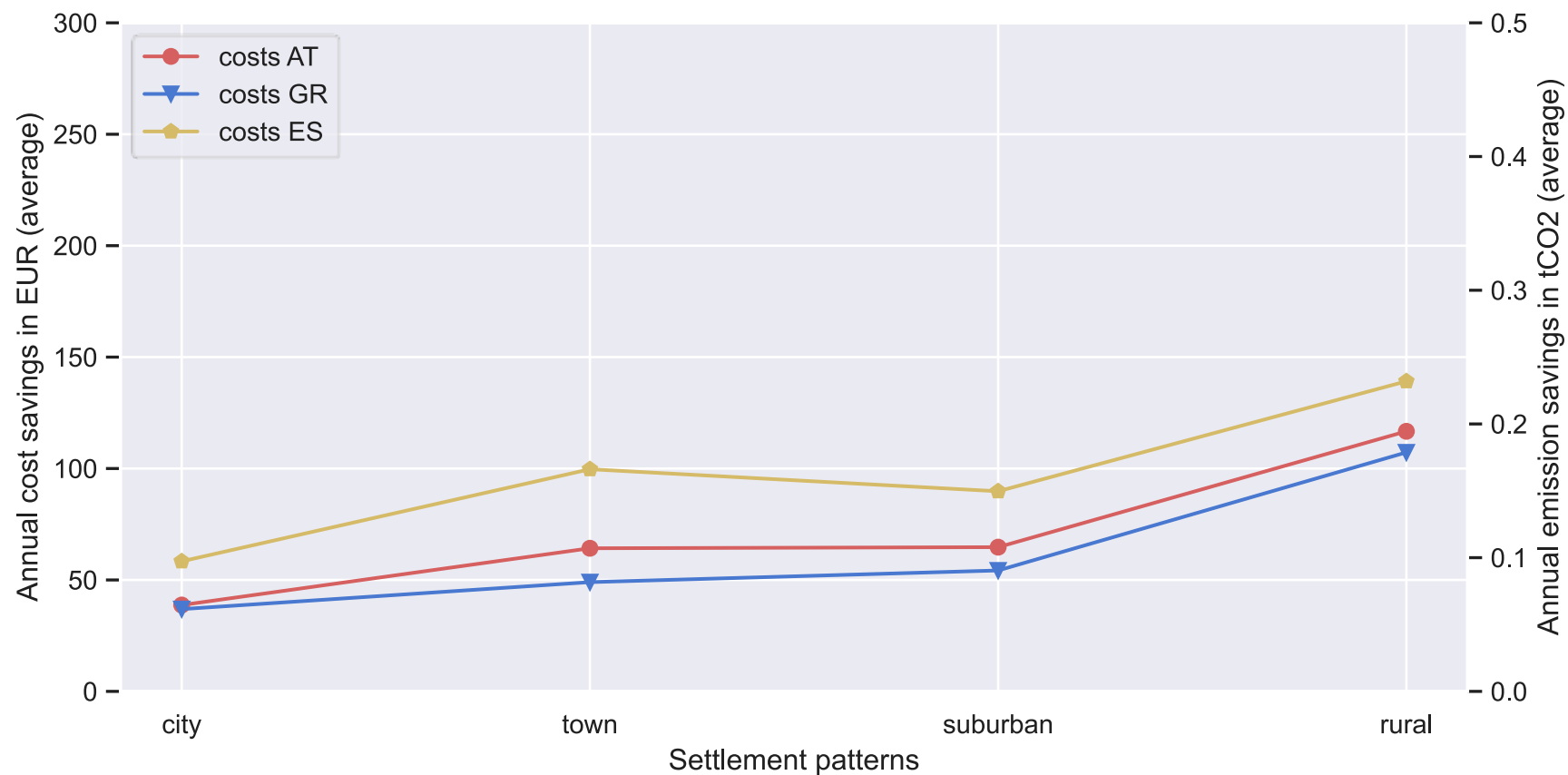
Impact of ECs on grid purchases, grid feed-in, shared self-consumption, and battery operation: [Spain](#)



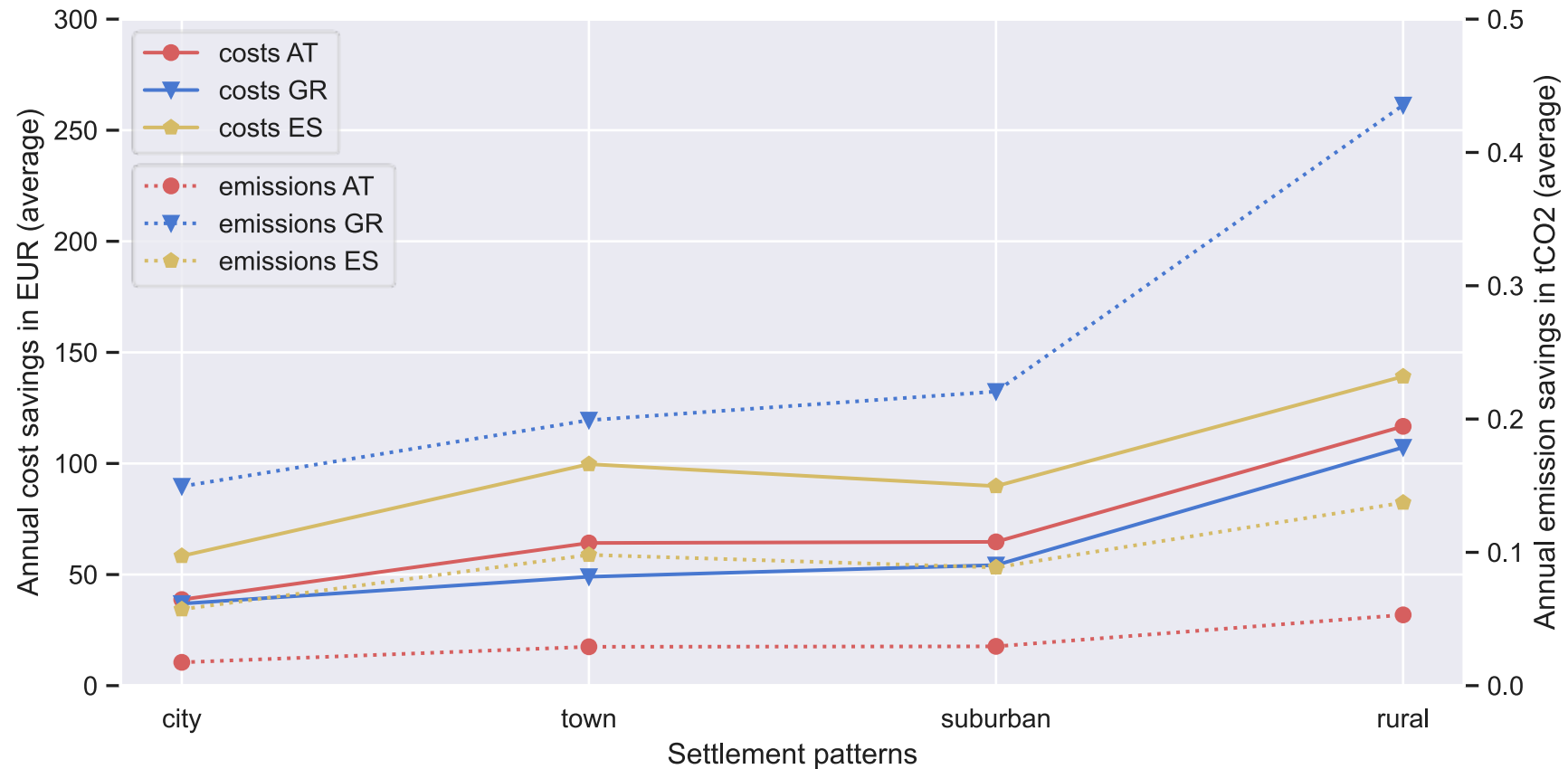


# Results on prosumer level

Impact of ECs on individual costs and emissions:



Impact of ECs on individual costs and emissions:



# Conclusions

Findings and limitations of this work:

- Evaluation of building stock crucial
- High special resolution is desirable
- Ideal case with 100% participation (in contrast to voluntary participation ... )
- Downscaling is possible, e.g. under consideration of settlement patterns and regions

Future outlook:

- Analysis of remaining reference countries
- Evaluation with the openENTRANCE scenarios for 2030/2050
- Further upscaling to European level
- See future development on GitHub + upcoming publications
  - <https://github.com/tperger/ASCENDEMUS>

# Thank you for your attention!

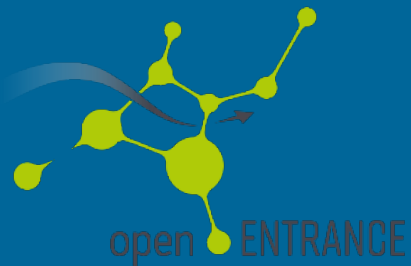
## GitHub

<https://github.com/tperger/ASCENDEMUS>

<https://github.com/tperger/FRESH-COM>

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Carbon Economy

<https://openentrance.eu/>



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