HAEE HELLENIC ASSOCIATION for ENERGY ECONOMICS
WWW.HAEE.GR

Existing user? Login

17th IAEE European Energy Conference

Athens, September 21 - 24, 2022

The Future of Global Energy Systems

ORGANIZED BY:

IAEE International Association for ENERGY ECONOMICS

HAEE WWW.HAEE.GR HELLENIC ASSOCIATION for ENERGY ECONOMICS

TECHNISCHE UNIVERSITÄT WIEN

UPSCALING THE POTENTIAL OF ENERGY COMMUNITIES TO EUROPEAN LEVEL

Theresia Perger, Sebastian Zwickl-Bernhard, Hans Auer
TU Wien
Energy Economics Group (EEG)
IAEE International Conference Athens, 21.09.-24.09.2022
perger@eeg.tuwien.ac.at

This project has received funding from the European Unions Horizon 2020 research and innovation program under grant agreement No. 835896

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]

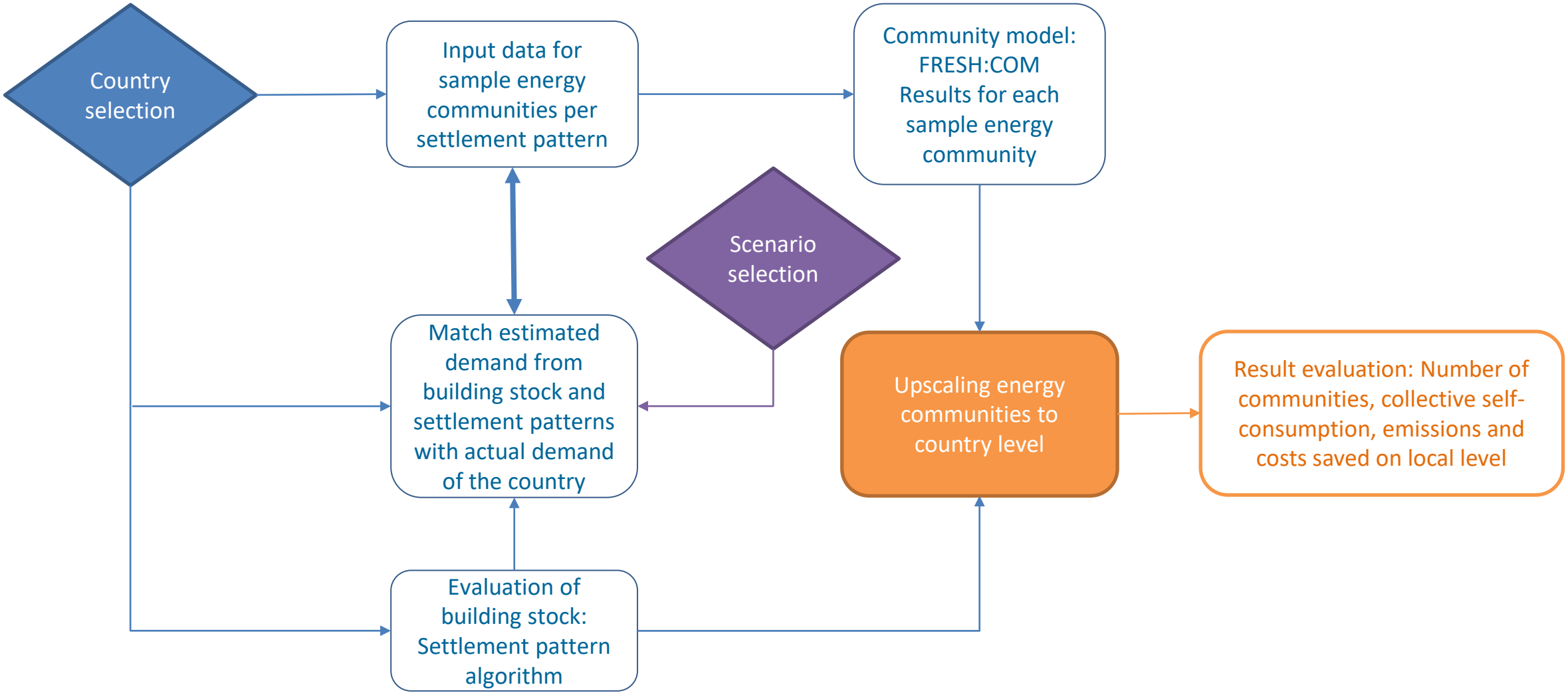
[1] T. Perger et al., PV sharing in local communities: Peer-to-peer trading under consideration of the prosumers’ willingness-to-pay, Sustainable Cities and Society, Volume 66, 2021, https://doi.org/10.1016/j.scs.2020.102634.
[2] Perger T and Auer H. Dynamic participation in local energy communities 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
  - Norway
  - England
- Quantitative upscaling of the local energy community potential is conducted for Europe as a whole

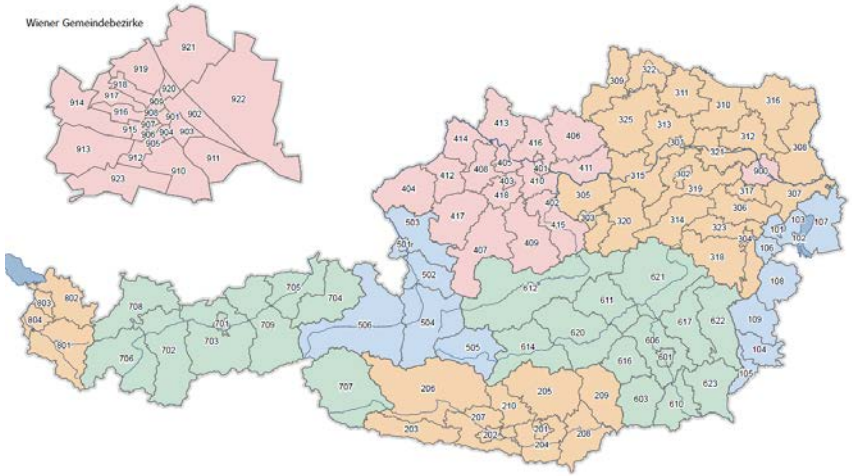
Methodology overview



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: 5625 kWh/a
  - Apartment: 2261 kWh/a
- 121 political districts



Greece

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

[3] Bernadette Fina, Hans Auer, Werner Friedl, Cost-optimal economic potential of shared rooftop PV in energy communities: Evidence from Austria, Renewable Energy, Volume 152, 2020, DOI: https://doi.org/10.1016/j.renene.2020.01.031

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

[3] Bernadette Fina, Hans Auer, Werner Friedl, Cost-optimal economic potential of shared rooftop PV in energy communities: Evidence from Austria, Renewable Energy, Volume 152, 2020, DOI: https://doi.org/10.1016/j.renene.2020.01.031

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:

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

- 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

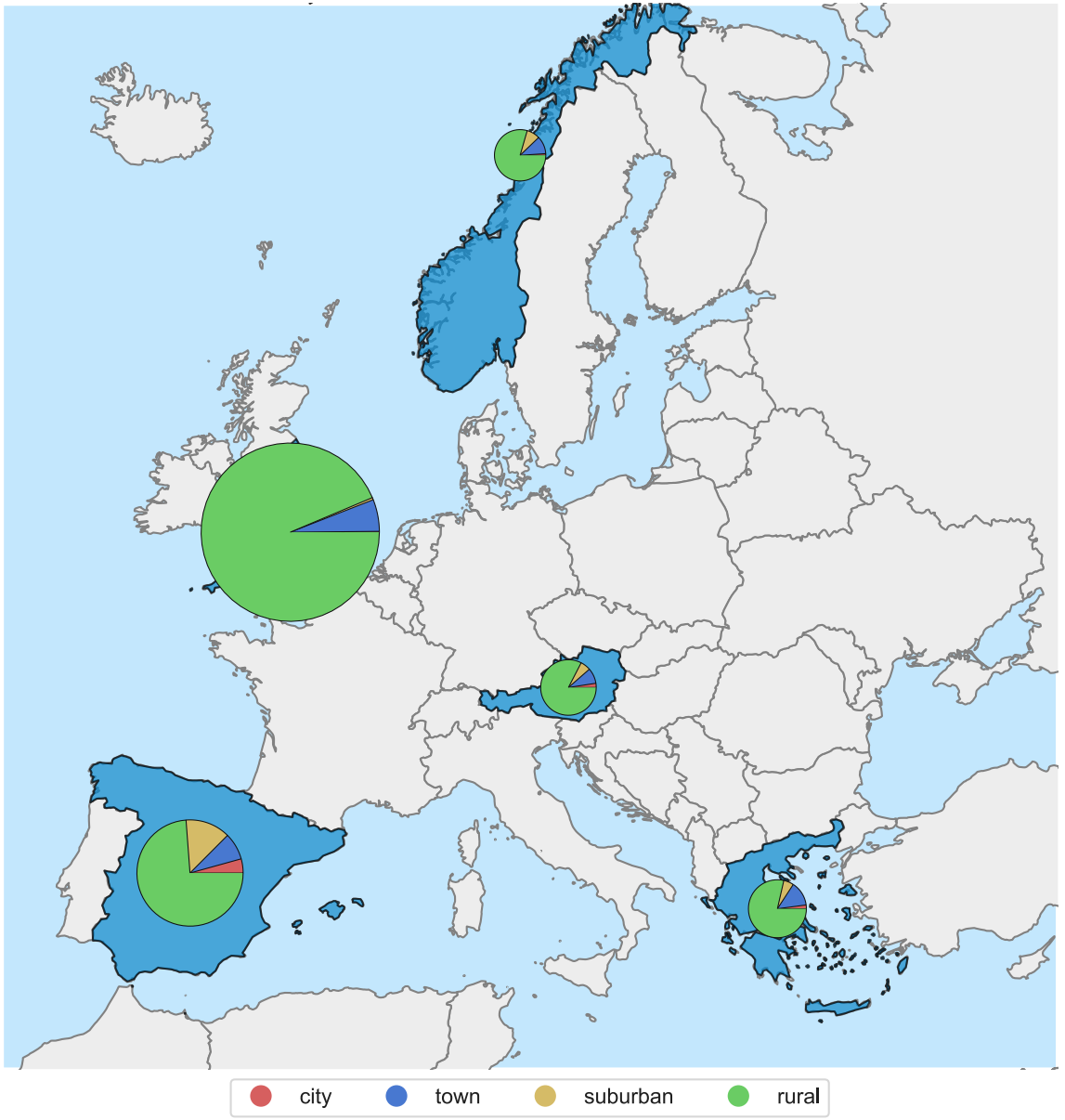
How to define each settlement pattern's energy community:

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

	Austria	Greece	Norway	Spain	England
avg. Demand per household (kWh/a)	3848	4125	16000	3318	3582
avg. Demand per single house (kWh/a)	5652	5678	20830	5401	4108
avg. Demand per flat (kWh/a)	2261	2271	8332	2160	1643
Avg. Number of dwelling per single house	1.2	1.4	1.1	1.1	1
Avg. Number of dwelling per small apartment building	5.5	4	1.8	6.2	3.6
Avg. Number of dwelling per large apartment building	18.7	12	15.5	18	20

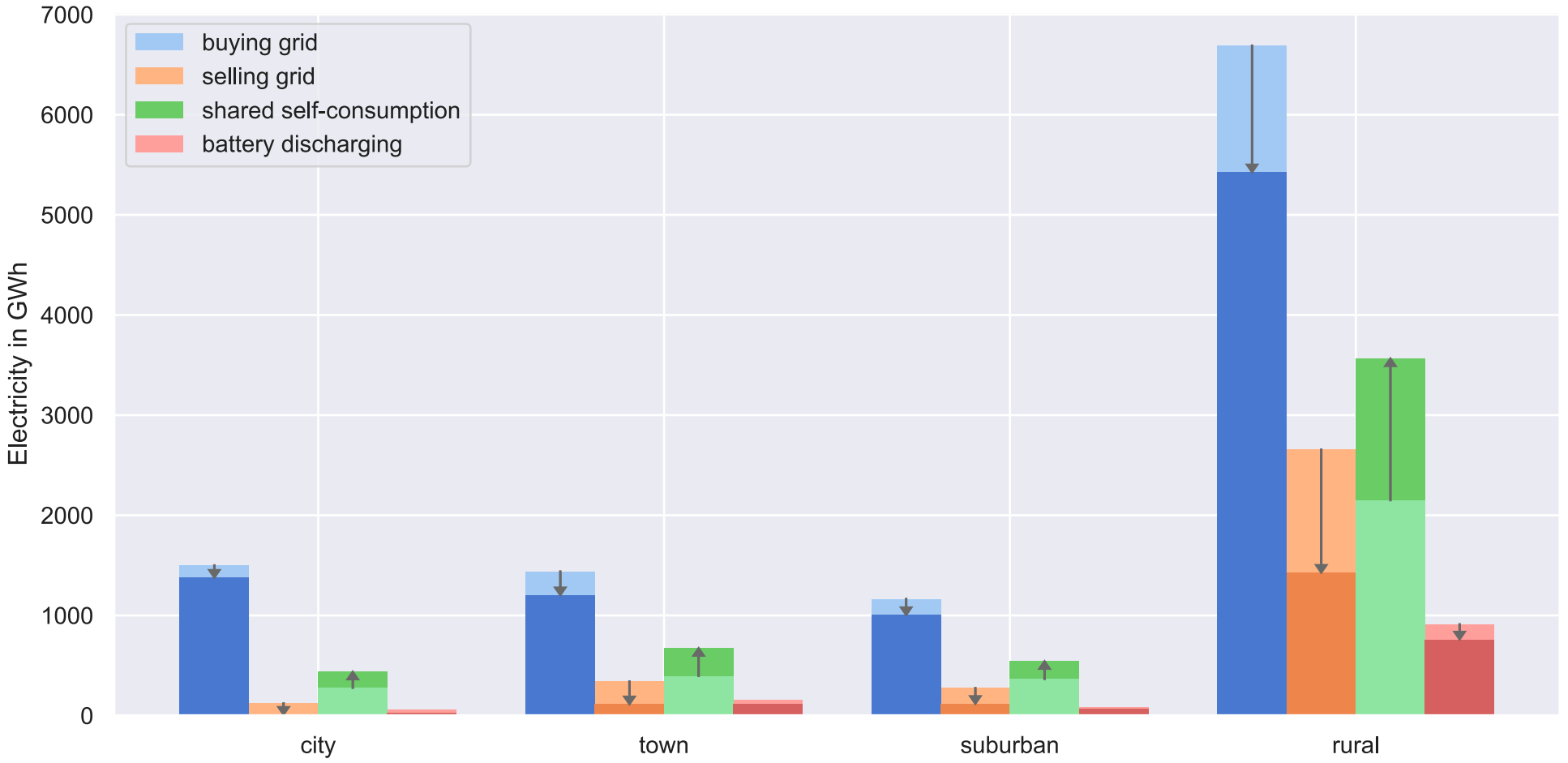
- Each prosumer is assigned a different annual electricity demand using normal distribution
- PV systems:
  - Peak capacities installed: 3-15 kWpeak
- Battery storage systems:
  - Storage capacities: 3-8 kWh
- Some members are consumers only

Results reference countries



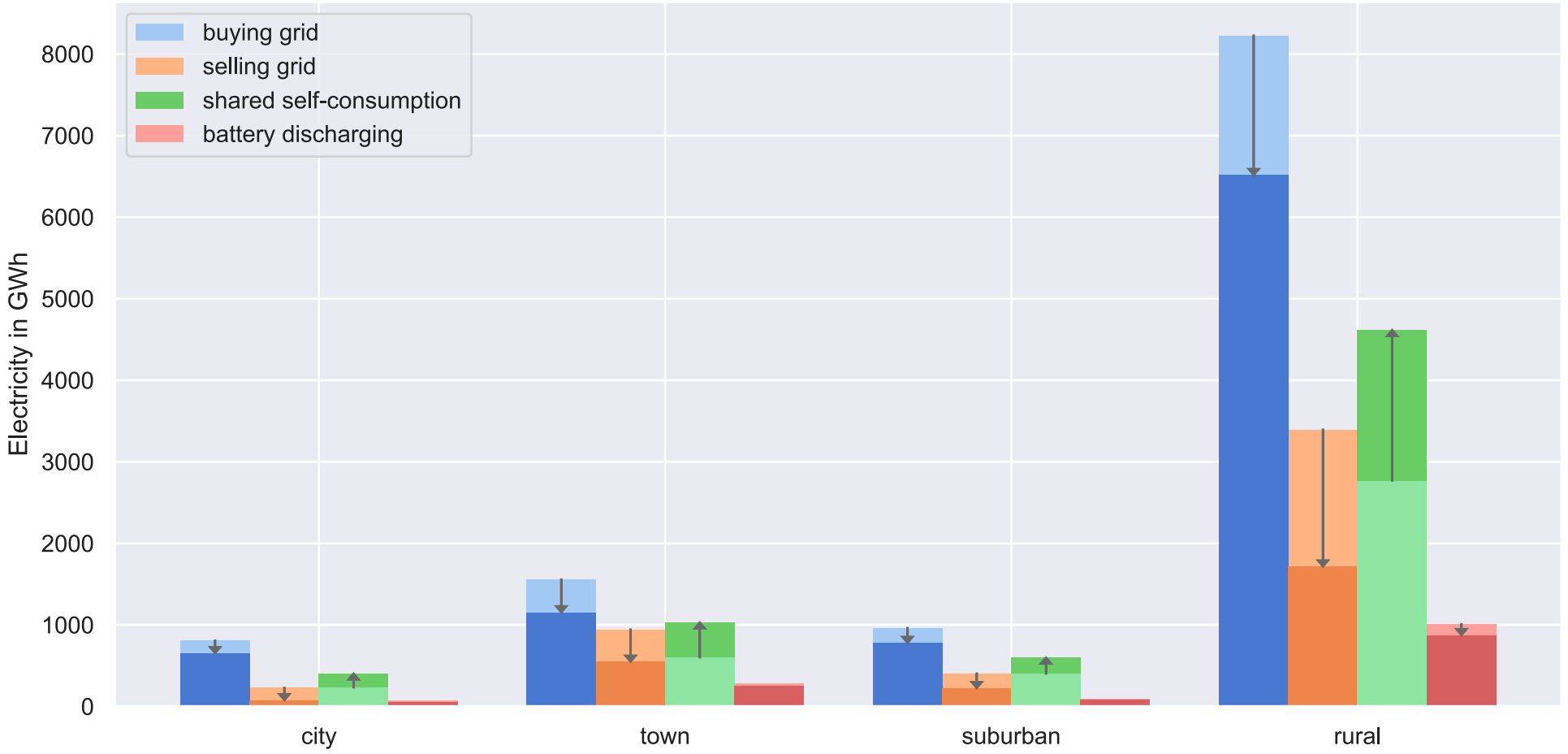
Results Austria

Impact of ECs on grid purchases, grid feed-in, shared self-consumption, and battery operation: Austria



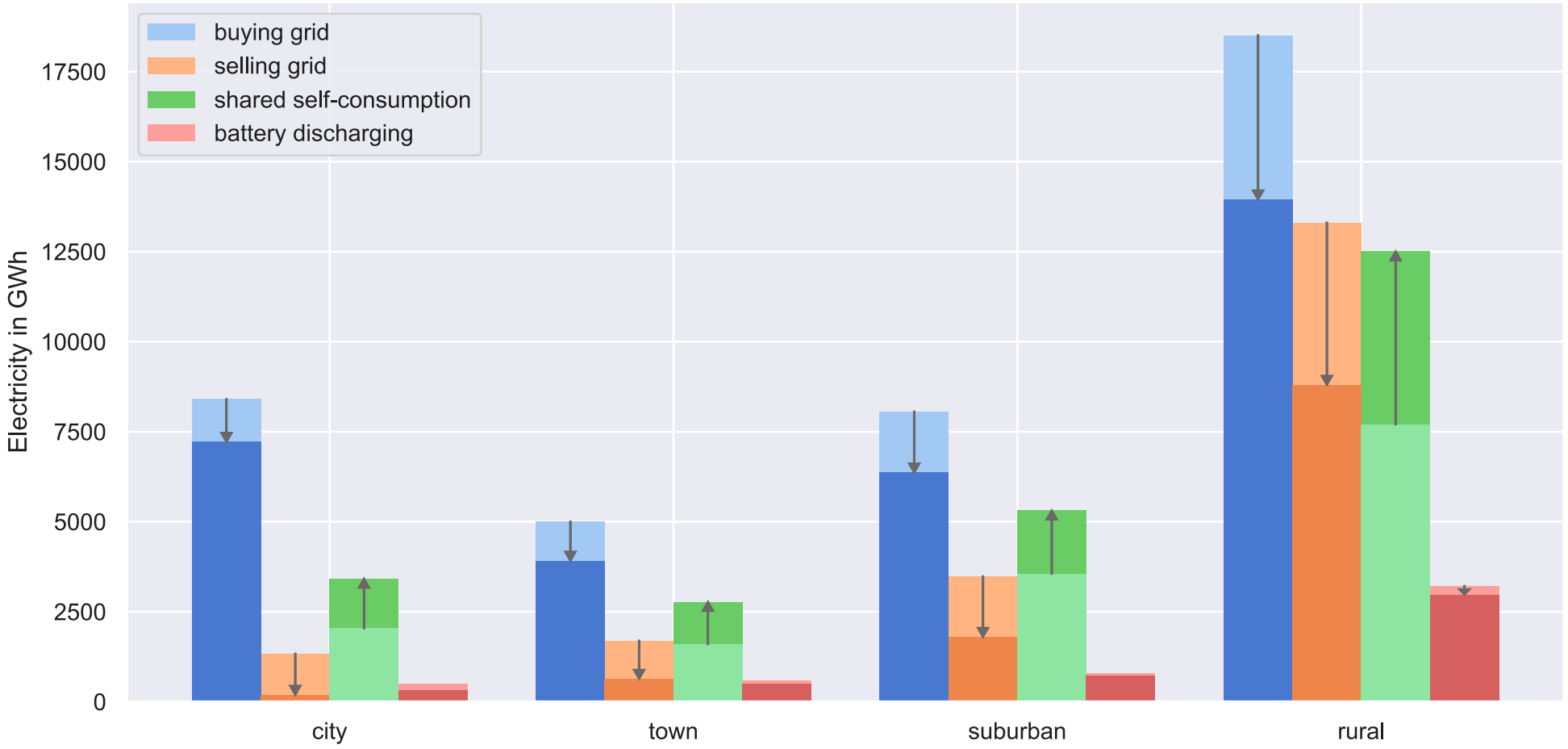
Results Greece

Impact of ECs on grid purchases, grid feed-in, shared self-consumption, and battery operation: Greece



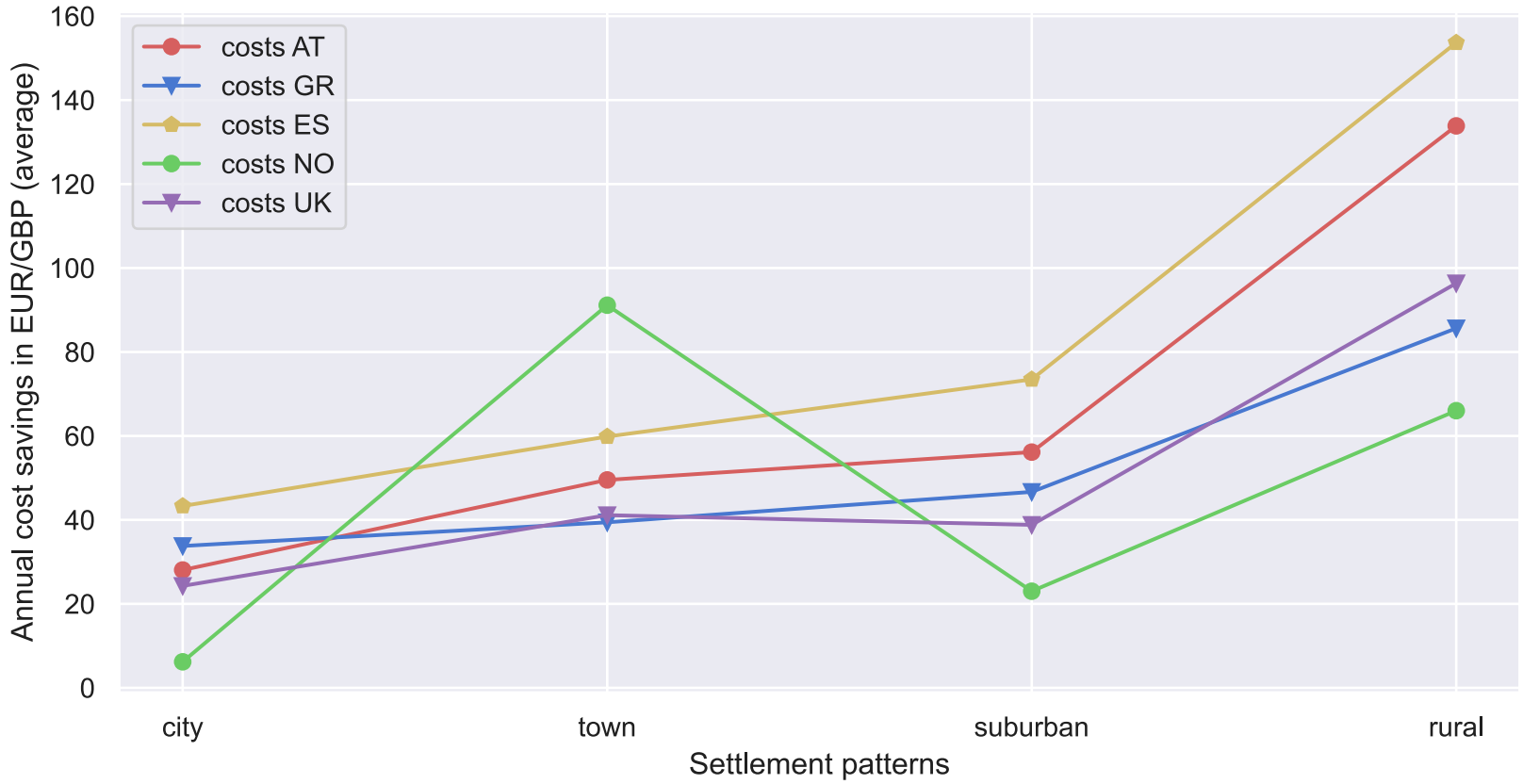
Results Spain

Impact of ECs on grid purchases, grid feed-in, shared self-consumption, and battery operation: Spain



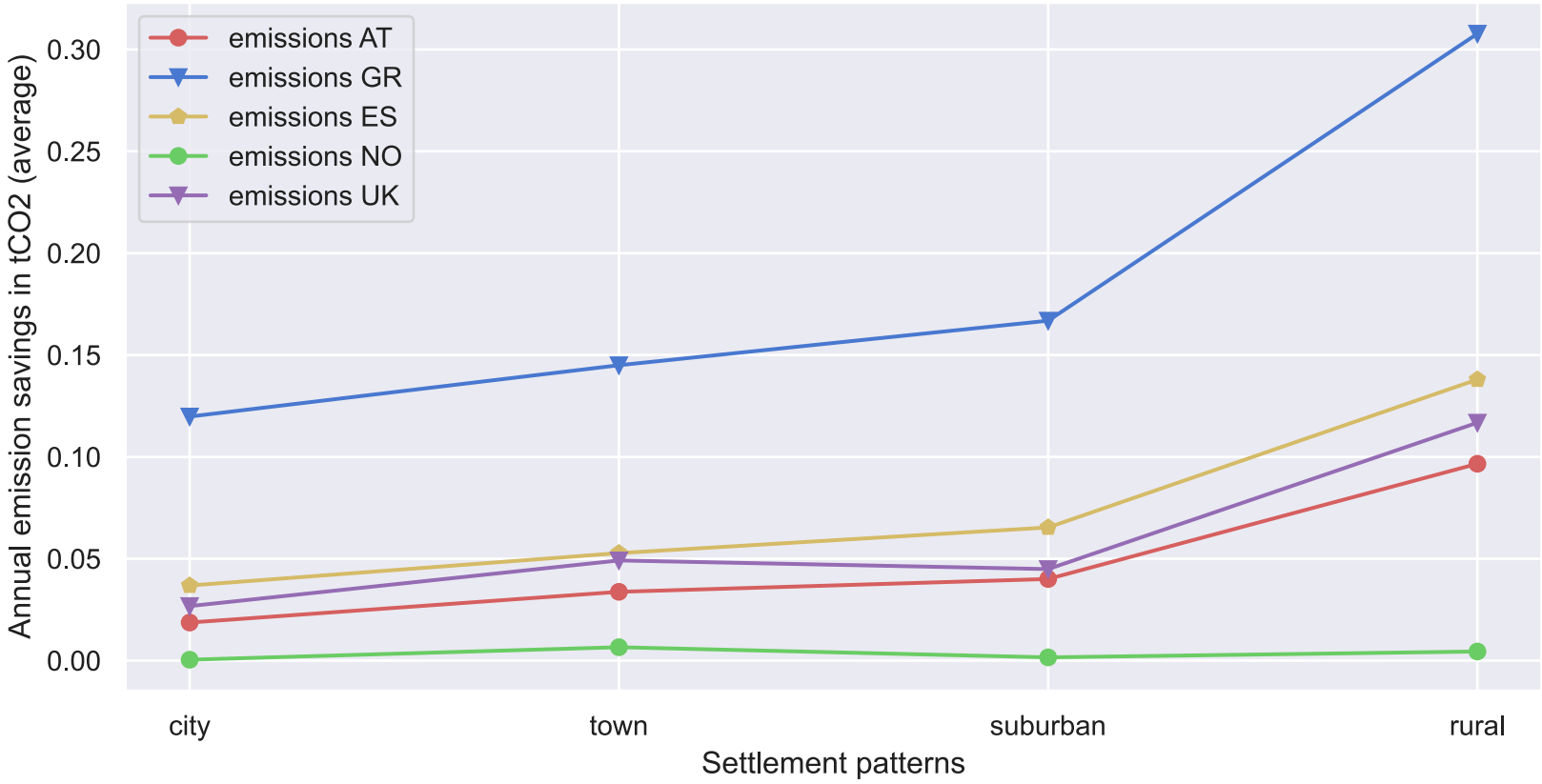
Results on prosumer level

Impact of ECs on individual costs:



Results on prosumer level

Impact of ECs on individual emissions:



Potential on European level

Estimation based on the reference countries:

- For each cluster of countries represented by one of the five reference countries, the number of energy communities is

$$EC_{cluster} = EC_{ref.country} \frac{population_{cluster}}{population_{ref.country}}.$$

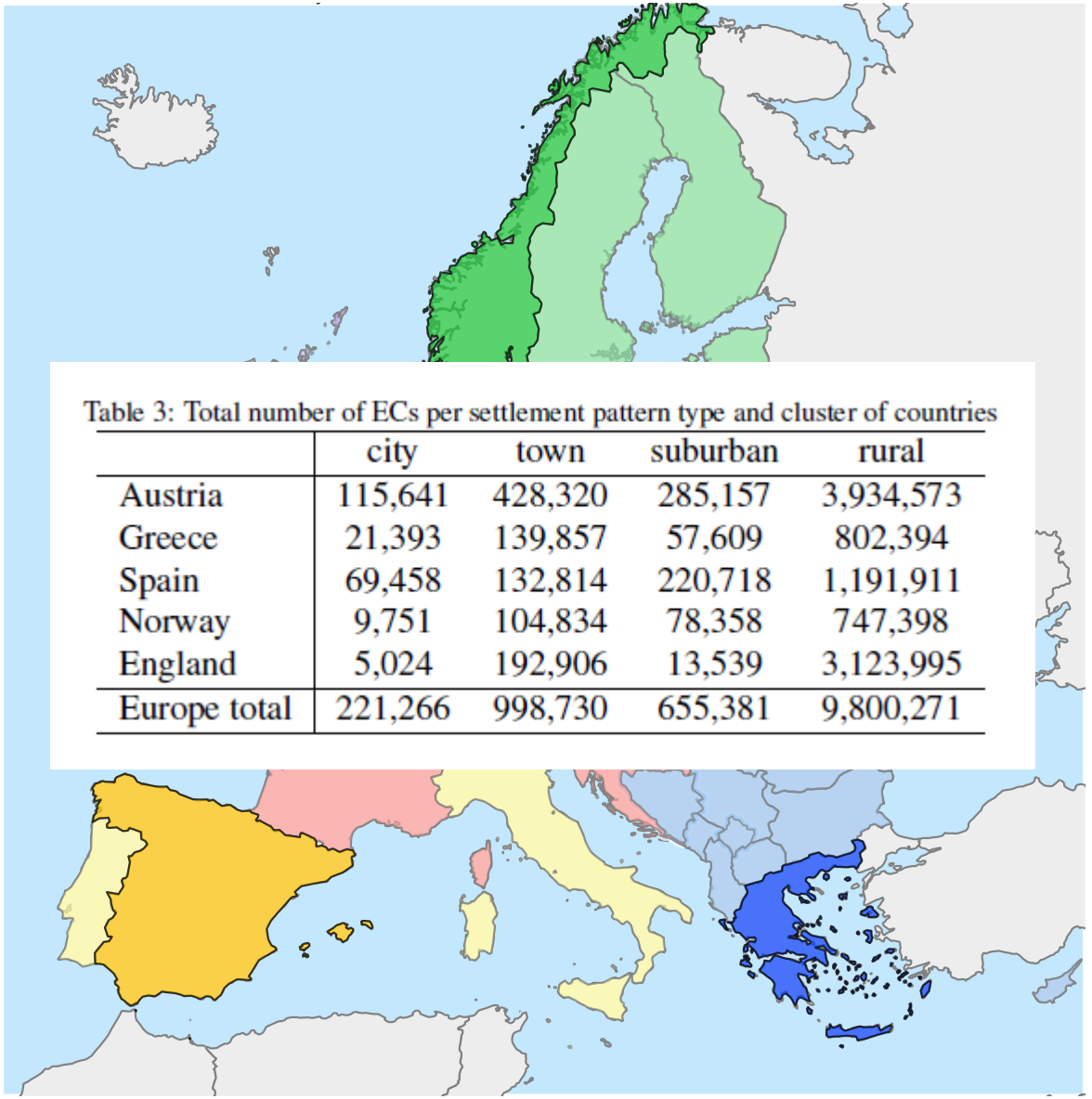


Table 3: Total number of ECs per settlement pattern type and cluster of countries

	city	town	suburban	rural
Austria	115,641	428,320	285,157	3,934,573
Greece	21,393	139,857	57,609	802,394
Spain	69,458	132,814	220,718	1,191,911
Norway	9,751	104,834	78,358	747,398
England	5,024	192,906	13,539	3,123,995
Europe total	221,266	998,730	655,381	9,800,271

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:

- See future development on GitHub + upcoming publications
  - https://github.com/tperger/ASCENDEMUS

TECHNISCHE UNIVERSITÄT WIEN

Energy Economics Group

Thank you for your attention!

https://github.com/tperger/ASCENDEMUS

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

open ENergy TRansition ANalyses for a low-Carbon Economy

https://openentrance.eu/

This project has received funding from the European Unions Horizon 2020 research and innovation program under grant agreement No. 835896