Generic Input Generation for Residential District Energy System Models from Open Data for Germany

21-22 September 2021 | K. KNOSALA, N. PFLUGRADT, L. KOTZUR, D. STOLTEN

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IEK-3: Techno-Economic Systems Analysis

Bottom-up Modeling at IEK-3: Techno-economic Systems Analysis[1]

International
Global, European

National
Germany …

Regional
City, District,
industrial site, …

Local
Building, technical
component, …

Temporal

- Demand and generation time series
- Storage design (from daily to seasonal storage)

Spatial

- Transmission infrastructure
- Placement recommendations

Sectoral

- Sector-coupling opportunities

Some of our open-source contributions[2]:

- Framework for Integrated Energy System Assessment (FINE)
- Time Series Aggregation Module (TSAM)
- Load Profile Generator (LPG)
- Renewable Energy Simulation Toolkit (RESKit)
- Geospatial Land Availability for Energy Systems (GLAES)

[1] https://www.fz-juelich.de/iek/iek-3/

[2] https://github.com/FZJ-IEK3-VSA

Parametrization in District Energy Systems Modeling

State of the art

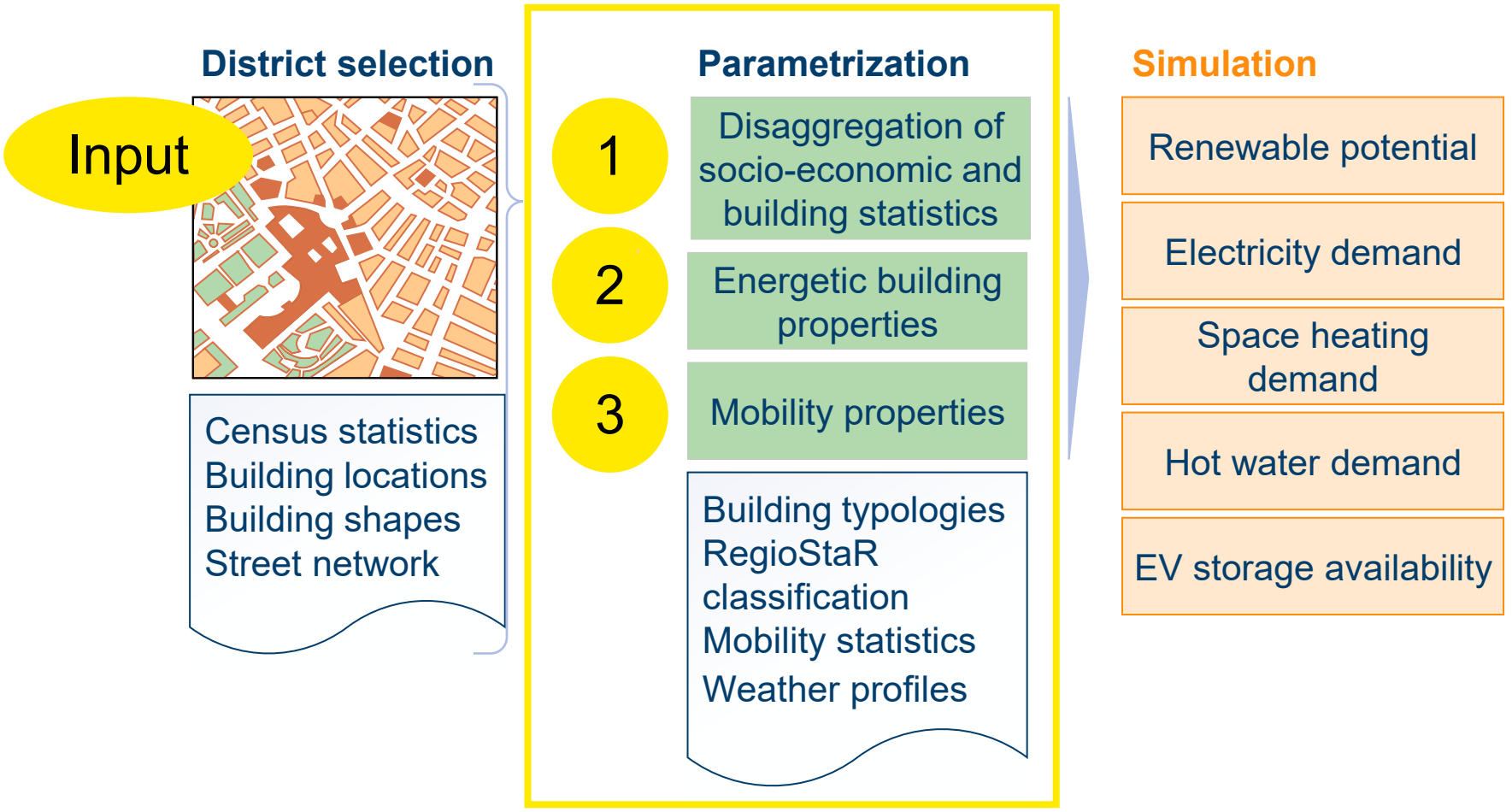
- Absence of adequate detailed building level data for whole Germany[1,4]
- Laborious data collection and classification (e.g., building age by visual survey[1,2])
- Significant modelling errors when the archetype buildings are not tailored to the studied location[1,4]
- Household details missing for energy systems analysis at building/district level[3,] use of synthetic populations[5]

Research goals

- Automated precise description of **building typology** (including construction year)
- Per **rooftop surface area and orientation** for renewable generation simulation
- **Socio-economic household attributes** (e.g. family composition, commuting distances)
- **Scalable** workflow based on **open data** and open software for energy system analysis

[1] I. De Jaeger, G. Reynders, C. Callebaut, und D. Saelens, „A building clustering approach for urban energy simulations“, Energy and Buildings, Bd. 208, S. 109671, Feb. 2020, doi: 10.1016/j.enbuild.2019.109671.
[2] R. Braun, V. Weiler, M. Zirak, L. Dobisch, V. Coors, und U. Eicker, „Using 3D CityGML Models for Building Simulation Applications at District Level“, 2018 IEEE International Conference on Engineering, Technology and Innovation (ICE/ITMC), 2018, doi: 10.1109/ICE.2018.8436355.
[3] M. Schwanebeck, M. Krüger, und R. Duttmann, „Improving GIS-Based Heat Demand Modelling and Mapping for Residential Buildings with Census Data Sets at Regional and Sub-Regional Scales“, Energies, Bd. 14, Nr. 4, Art. Nr. 4, Jan. 2021, doi: 10.3390/en14041029.
[4] O. M. Garbasevschi u. a., „Spatial factors influencing building age prediction and implications for urban residential energy modelling“, Computers, Environment and Urban Systems, Bd. 88, S. 101637, Juli 2021, doi: 10.1016/j.compenvurbsys.2021.101637.
[5] S. Thorve, S. Swarup, A. Marathe, Y. Chungbaek, E. K. Nordberg, und M. V. Marathe, „SIMULATING RESIDENTIAL ENERGY DEMAND IN URBAN AND RURAL AREAS“, in 2018 Winter Simulation Conference (WSC), Dez. 2018, S. 548–559. doi: 10.1109/WSC.2018.8632203.

Per Building Parametrization for Regional Energy System Simulation



Automated parametrization for profile generation of realistic residential districts for **any** region in Germany

Combining Open Datasets

Input

Geo-Data from Federal States[1]

- Official building address coordinates, 3D geometries (cityGML), parcel footprints

Open Street Data (Open Street Maps[2])

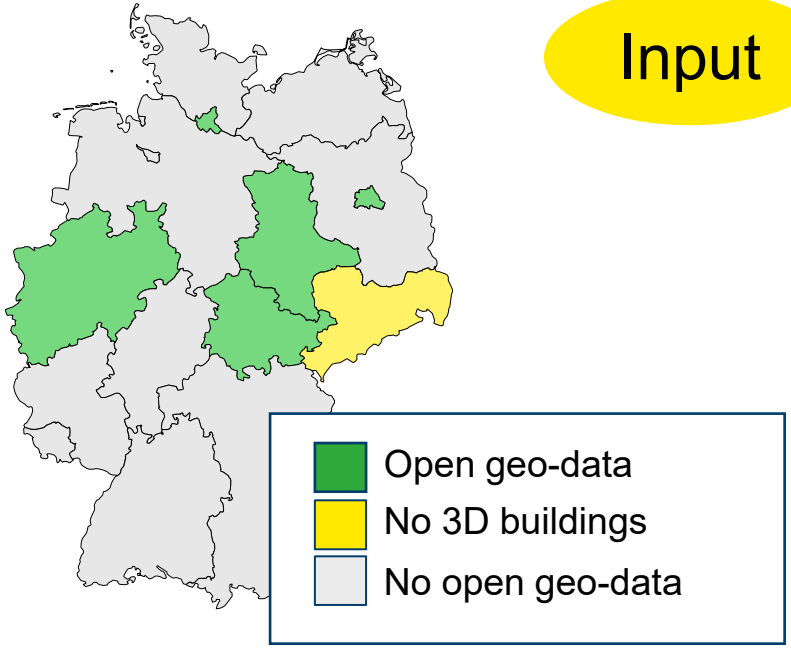
Weather Data (SARAH[3], TRY2015[4])

Building Typologies and Material Databases

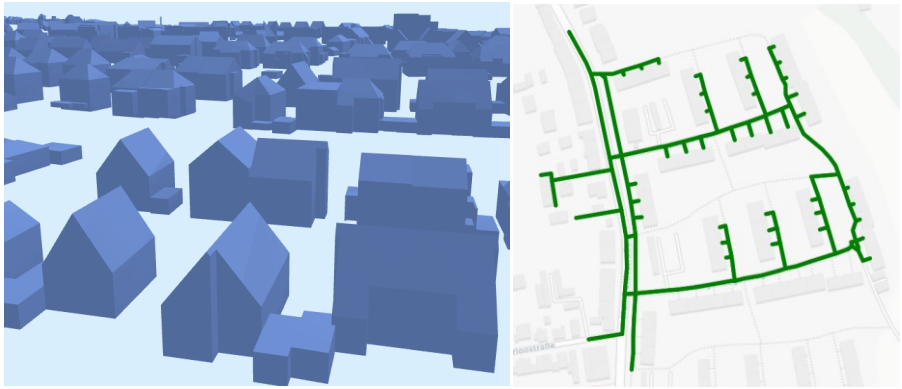
- Heat transfer coefficients from TABULA[5]

Statistical Data from Census[6]

- Information contains: Building age, number of households, residents age etc.
- Resolution 100m x 100m (13 M tiles)
- Hold every 10 years (next planned for 2022)



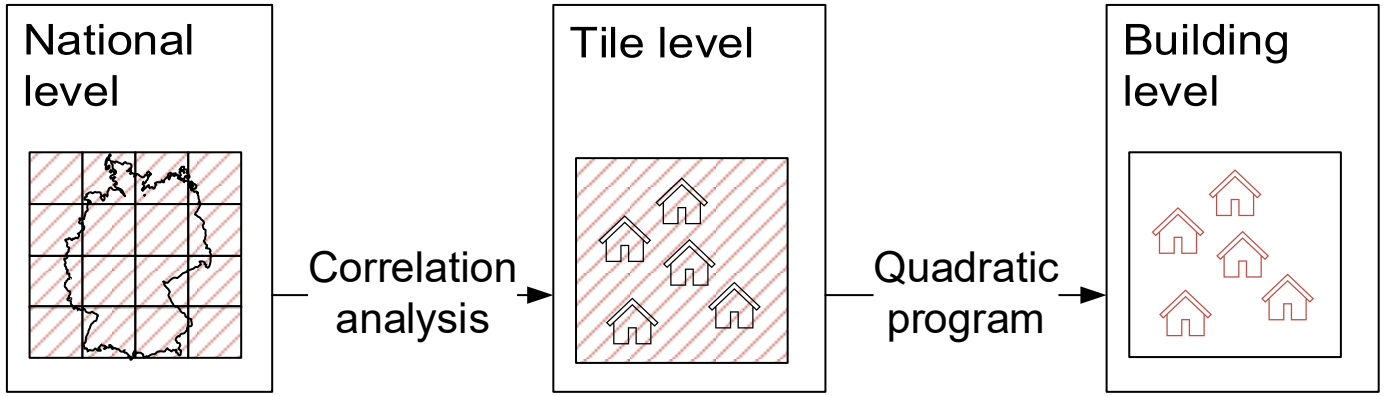
Availability of open geo-data on buildings in German federal states



3D building geometries (left) and OSM street network (right)

[1] https://gdz.bkg.bund.de/ [2] https://www.openstreetmap.org
[3] DOI:10.5676/EUM_SAF_CM/SARAH/V002
[4] https://www.dwd.de/DE/leistungen/testreferenzjahre/
[5] https://episcope.eu/ [6] https://www.zensus2011.de/

Disaggregation of Open Statistical Data from Census to Building Level



Staggered attribution:

1. Buildings
2. Apartments and families
3. Persons

Distribution MIQP* for per tile and statistic (Building, Apartment, Person)**:**

- Goal function:

$$\textit{min} \sum_{\text{Attributes}} ((\text{Occurrences in statistic} - \text{Occurrences attributed})^2 - \sum_{\text{Attributes}} \text{Correlation factor})$$

- Logical Constraints e.g.:
  - "Set only one household per apartment."
  - Larger buildings have more apartments than smaller ones

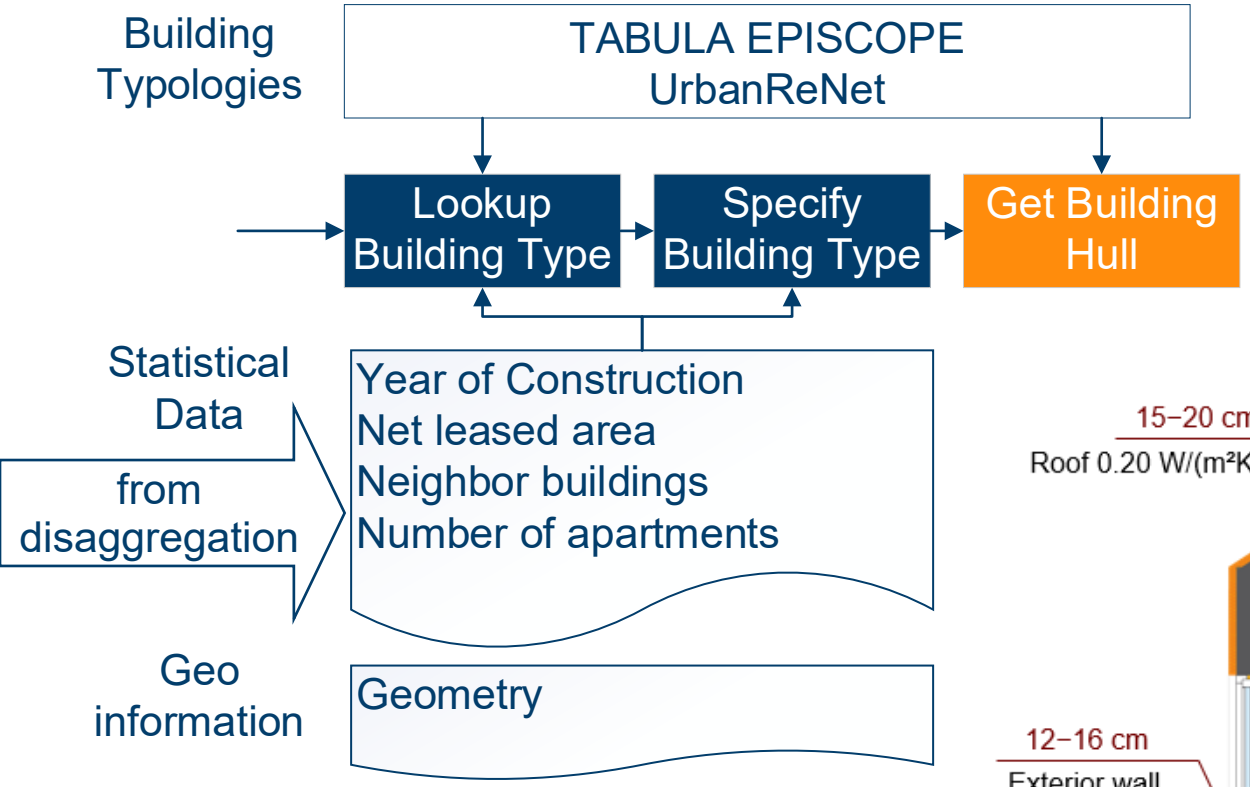
Problem sizes for 11 Buildings, mostly MFH 3-6

Apartments per Building:

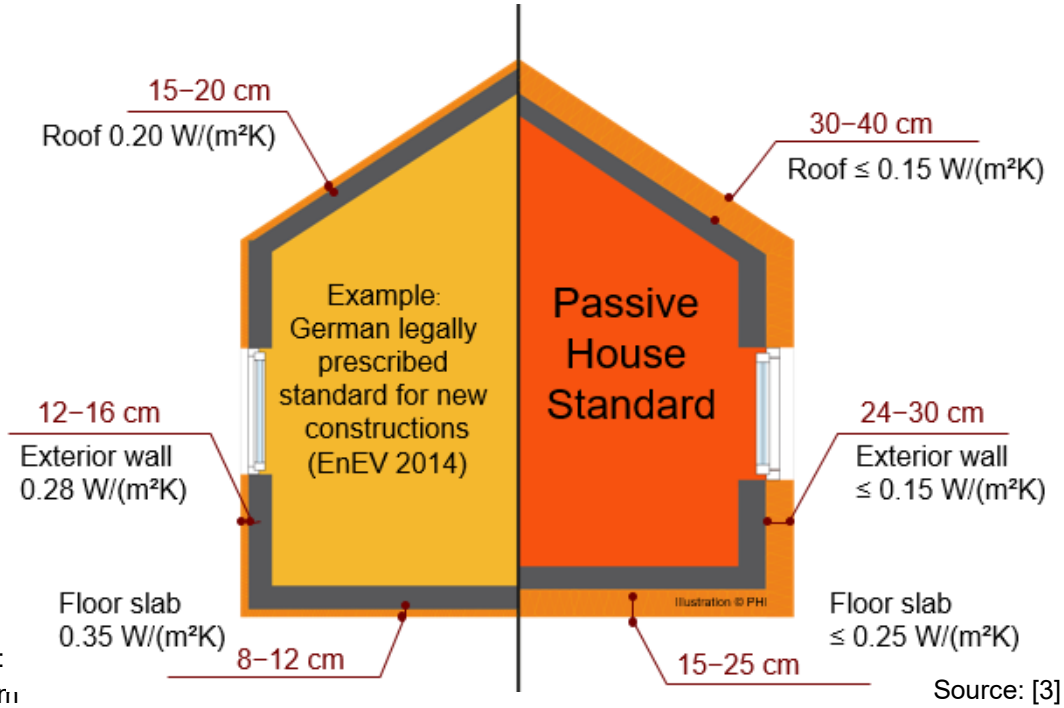
1. 2182 integer (2167 binary)
2. 16352 integer (16327 binary), 25 quadratic objective terms
3. 31268 integer (31252 binary), 15 quadratic objective terms

* Mixed Integer Quadratic Program

Building Parametrization – Define Building Hull



- Building Typologies are specified in
  - Construction age classification
  - Level of refurbishment
- Different renovation choices are reflected in building parametrization



Source: [3]

[1] https://episcope.eu/

[2] UrbanReNet, EnEff:Stadt - Verbundprojekt Netzoptimierung - Teilprojekt: Vernetzte regenerative Energiekonzepte im Siedlungs- und Landschaftsraum

[3] https://blog.passivehouse-international.org/ug-uf-uw-uwhat-an-intro-to-the-u-value-and-those-most-important-to-passive-house-design/

Mobility Parametrization – Mode Choices and Distances

Household Data

Household size (working adults, children)
Individual or multi-apartment building
Quality of public transport
Availability of car sharing

Statistical Data [1]

Survey:
“Mobility in Germany 2017” (MiG17)

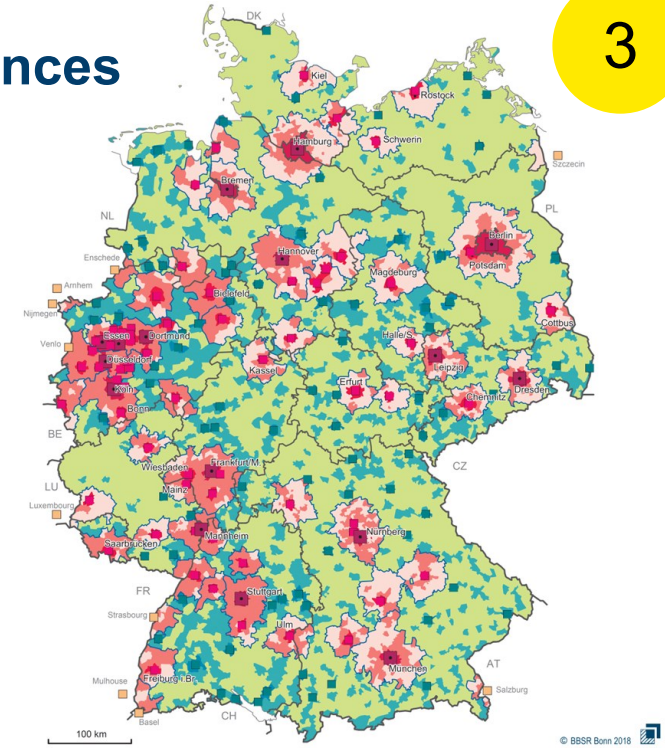
Weibull distribution

Trip distance

MO|DE.behave [3]

Mode choice

Number of cars per household



RegioStaR 7 – Regional typologies

Urban regions
- Metropolis
- Regiopolis, Large city
- Medium-sized town, Urban area
- Small town, Village area

Rural regions
- Central cities
- Medium-sized town, Urban area
- Small town, village area

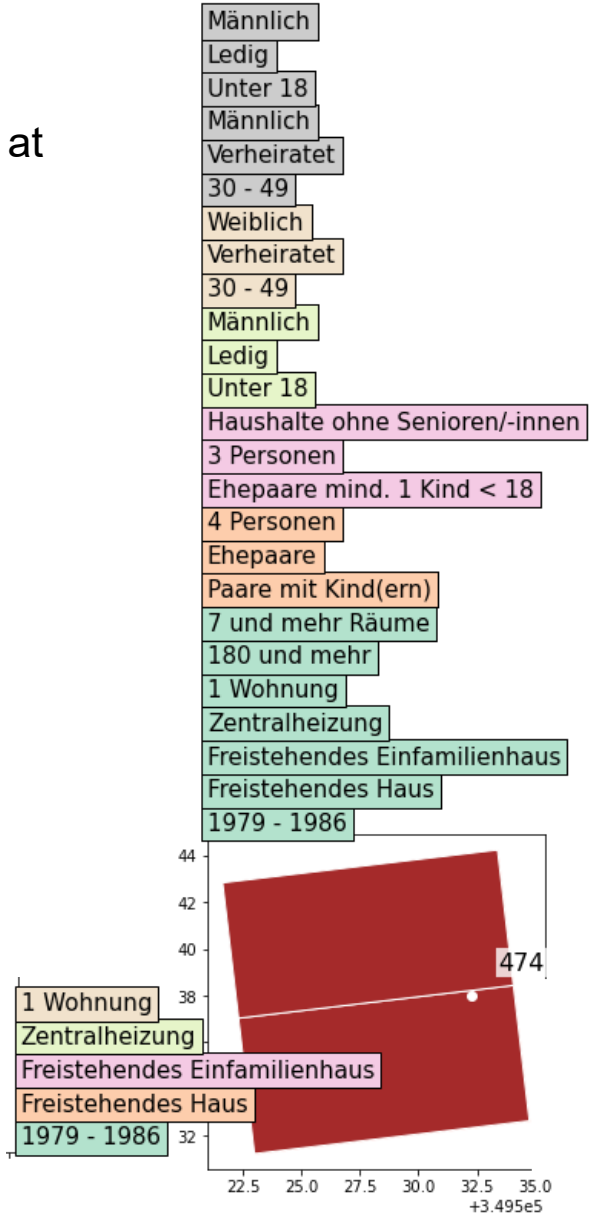
[1] Weibull Distribution deducted from:
infas, DLR, IVT, infas 360 (2018): Mobility in Germany (on behalf of BMVI)
[2] RegioStaR (2020): BMVI
[3] Internal model for travel behavior, based upon discrete choice methods

Conclusion

- Comprehensive data workflow for bottom-up energy systems analysis at household level without manual data acquisition for resident, building and mobility data
- Allows for simulation of demand and generation profiles from single building to national scale
  - Resident activity simulation and mobility demands per household[1]
  - Building hull heat transfer[2]
  - Solar potential simulation per rooftop[3]

Outlook

- Open-source tool for the generation of district energy system models
- Nation-wide data sets on energy demand at building resolution



[1] https://github.com/FZJ-IEK3-VSA/LoadProfileGenerator
[2] https://github.com/FZJ-IEK3-VSA/tsib
[3] https://github.com/FZJ-IEK3-VSA/RESKit

Thank you for your attention!

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