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

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IEK-3: Techno-Economic Systems Analysis
Bottom-up Modeling at IEK-3: Techno-economic Systems Analysis

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:
- 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)

Parametrization in District Energy Systems Modeling

State of the art

▪ Absence of adequate detailed building level data for whole Germany\textsuperscript{1,4}

▪ Laborious data collection and classification (e.g., building age by visual survey\textsuperscript{1,2})

▪ Significant modelling errors when the archetype buildings are not tailored to the studied location\textsuperscript{1,4}

▪ Household details missing for energy systems analysis at building/district level\textsuperscript{3}, use of synthetic populations\textsuperscript{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


Per Building Parametrization for Regional Energy System Simulation

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

Input
- Census statistics
- Building locations
- Building shapes
- Street network

Parametrization
1. Disaggregation of socio-economic and building statistics
2. Energetic building properties
3. Mobility properties
   - Building typologies
   - RegioStaR classification
   - Mobility statistics
   - Weather profiles

Simulation
- Renewable potential
- Electricity demand
- Space heating demand
- Hot water demand
- EV storage availability
Combining Open Datasets

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)

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

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

3D building geometries (left) and OSM street network (right)
Disaggregation of Open Statistical Data from Census to Building Level

**National level** → **Correlation analysis** → **Tile level** → **Quadratic program** → **Building level**

Staggered attribution:
1. Buildings
2. Apartments and families
3. Persons

**Distribution MIQP* for per tile and statistic** (Building, Apartment, Person):
- **Goal function:**
  \[
  \min \sum \left( \text{Occurrences in statistic} - \text{Occurrences attributed} \right)^2 - \sum \text{Correlation factor}
  \]

- **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

[1] https://episcope.eu/
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)

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

Household Data
- 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
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
Thank you for your attention!

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