The Journal of Open Source Software

Districtgenerator: Generating building-specific load profiles for residential districts.

Sarah Henn [1], **Joel David Schölzel** [1], **Tobias Beckhölter** [1], **Carla Wüller** [1], **Rawad Hamze** [1], **and Dirk Müller** [1]

1 Institute for Energy Efficient Buildings and Indoor Climate, RWTH Aachen University

DOI: 10.21105/joss.07657

Software

- Review
- Repository
- Archive

Editor: Adam R. Jensen

Reviewers:

- @jtock
- @snjsomnath

Submitted: 21 June 2024
Published: 14 July 2025

Summary

The `Districtgenerator` Python tool enables an automated generation of time-resolved load profiles for residential districts. The profiles generated for each building within the district are the demands for electricity, space heating demand, domestic hot water, and the occupancy profiles. Additionally, a heating load calculation is carried out for each building. The `Districtgenerator` is conceptualized using a minimum amount of input data. Thus, the tool is valuable for researchers and planners to obtain information needed, for example, for the energy system or energy management system design during the early planning phase of a new district.

Statement of need

An essential part of mitigating global warming is reducing the carbon footprint of the building sector, especially considering the growing world population and the trend towards urbanization (International Energy Agency, 2021). The `Districtgenerator` tool offers knowledge, shows synergy potentials, and supports scalability regarding building and district solutions.

- **Knowledge** of energy demands is fundamental for the proper design and operation of any energy system. With the integration of distributed energy resources (DER), district energy systems and building energy systems become more complex. The energy supply from highly variable generators and user-dependent consumption need to be aligned. Thus, detailed time-resolved profiles of energy generation and demand are required for a successful and future-oriented energy system design and operation.
- **Synergy** potentials between buildings of different usage structures can be exploited through joint concepts. While joint heating concepts, such as local heating networks, have been the focus of research for a long time, joint electricity concepts have only recently emerged. For example, the European Union proposed and introduced the concept of energy communities (European Parliament, 2018, 2019). According to the Renewable Energy Directive (European Parliament, 2018), a district can also form an energy community where energy is shared or traded Peer-to-Peer. By this, district concepts can lead to financial benefits for consumers and prosumers. Moreover, it is expected that self-consumption increases, peaks are evened out, and the superordinate grid might be decongested. (Bose et al., 2021)
- **Scalability** is a key issue for a resource-efficient transformation of the energy system, especially as numerous existing districts will have to be retrofitted and newly equipped in the next few years (International Energy Agency, 2021). The `Districtgenerator` enables its users to easily gain information about districts in order to identify promising concepts and conduct comparative evaluations. By using representative building types, data for representative districts is created. Thus, the data applies to a wide range of

The Journal of Open Source Software

residential districts and can be included in guidelines or representative examples.

Also existing tools facilitate during the strategic and preliminary planning phases the identification of measures that support the detailed planning and subsequent implementation of sustainable and sector-coupling energy systems in neighborhoods. However, the models and calculation methods of the time series are often not transparent. For stakeholders such as investors, urban planners, property owners, or municipalities with limited resources, the complexity of these tools can be a barrier. Their user-friendliness is low, leading to potentially time-intensive applications. Furthermore, utilizing them may require specialized knowledge in energy planning, modeling, and data analysis, thus restricting access for less experienced users (Schölzel et al., 2024).

Functional principle

The minimum input data required is the number of buildings and basic information about each building, namely the building type, year of construction, retrofit level, and net floor area. The district size can be configured freely and there are no limitation on the number of buildings used. The default file format for the building information is CSV due to its cross-platform compatibility and ease of use. Optionally, the site of the district, the time resolution of the profiles, and the test reference year (TRY) for weather data (Bundesinstitut für Bau-, Stadt- und Raumforschung, 2020; *Klimaberatungsmodul*, 2023) can be modified. There are 16 choosable sites, which refer to the representative locations of the German climate zones. For every site, the user is able to select between warm, cold and normal TRYs. Moreover, TRYs are available for 2015 and 2045, reflecting either current or future weather conditions.

The `Districtgenerator` tool integrates multiple open-source tools and databases. Figure 1 visualizes the dependencies of external tools and data with internal functions. The geometry and material properties of the buildings are determined based on the TEASER Python package (Remmen et al., 2018) with data from the TABULA WebTool (Loga et al., 2015). As the TABULA WebTool defines archetypal building properties for type, age class, and retrofit level, the districts generated by the `Districtgenerator` are composed of representative buildings, making them ideal for representative analyses or scalability studies. The DIN EN 12831-1:2017-09 (2017) contributes standard design temperatures for the selectable sites. Based on this standard, a heating load calculation is performed. The standard load for domestic hot water demand is determined using the unit dwelling method (DIN 4708-1:1994-04, 1994). A number of residents is choosen at random, but within pre-defined limits, attributed to each dwelling and serves as input data for the richardsonpy tool (Richardson et al., 2010) to calculate the time-resolved occupancy profiles. Furthermore, Stromspiegel (co2online, 2019) provides statistical data on annual electricity consumption in German households. Annual consumption is stochastically assigned to each building, upon which the time-resolved electricity profile is created using the stochastic profile generator richardsonpy again. The electricity and occupancy profiles serve as input for a time-resolved internal gain calculation. Additionally, the occupancy profiles are needed for domestic hot water profile generation, for which functions from the pyCity tool (Schiefelbein et al., 2019) are utilized. Finally, the static building data, as well as the time-resolved weather and internal gain data, are included in the space heating profile generation. These are computed by means of a 5R1C-substitution model according to DIN EN ISO 13790:2008-09 (2008), using the simplified hourly method.

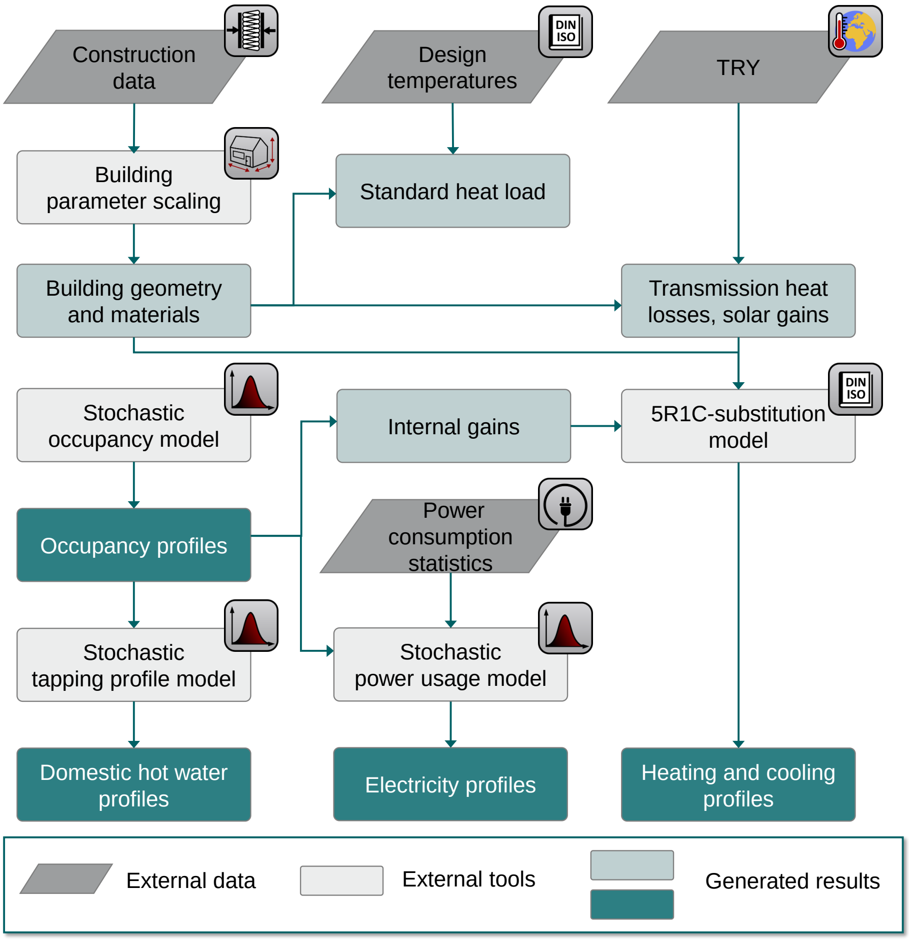

Figure 1: Usage of external tools and data sources to generate occupancy and demand profiles with the Districtgenerator.

All profiles generated can be saved in a customizable format, with CSV files output by default. The `Districtgenerator` also provides various plotting functions. The generated plots visualize the profiles and can show monthly energy consumption or stepwise data for user-defined periods of the year. For easy handling, a web-based graphical user interface is created.

Further development

There are further expansion stages planned for the `Districtgenerator` tool. Future versions will allow for technologies to be assigned to the individual buildings and including central generation units which can provide energy for an entire whole district. Based on that, firstly, the user will be given access to renewable energy generation data, such as photovoltaic generation and solar thermal heat generation, and to additional demands, such as electric vehicle charging demand. Secondly, a module for operation optimization will be added, with which the energy system under observation can be simulated and evaluated. Moreover, the open-source webtool EHDO will be integrated to provide optimization-based designing of energy hubs consisting of complex multi-energy systems (Wirtz et al., 2020).

Acknowledgements

We gratefully acknowledge the financial support by Federal Ministry for Economic Affairs and Climate Action (BMWK), promotional reference 03EWB003B.

References

Bose, S., Kremers, E., Mengelkamp, E. M., Eberbach, J., & Weinhardt, C. (2021). Reinforcement learning in local energy markets. *Energy Informatics*, *4*(1), 7. https://doi.org/10.1186/s42162-021-00141-z

Bundesinstitut für Bau-, Stadt- und Raumforschung. (2020). *Ortsgenaue testreferenzjahre (TRY) von deutschland für mittlere und extreme witterungsverhältnisse*. https://www.bbsr.bund.de/BBSR/DE/forschung/programme/zb/Auftragsforschung/5EnergieKlimaBauen/2013/testreferenzjahre/01-start.htm

co2online. (2019). *Stromspiegel für Deutschland*. https://www.stromspiegel.de/fileadmin/ssi/stromspiegel/Downloads/Stromspiegel-2019-web.pdf

DIN 4708-1:1994-04. (1994). *Central heat-water-installations; terms and calculation-basis* (p. 8). https://doi.org/10.31030/2480131

DIN EN 12831-1:2017-09. (2017). *Energy performance of buildings - Method for calculation of the design heat load - Part 1: Space heating load, Module M3-3; German version EN 12831-1:2017* (p. 101). https://doi.org/10.31030/2571775

DIN EN ISO 13790:2008-09. (2008). *Energy performance of buildings - calculation of energy use for space heating and cooling (ISO 13790:2008); German version EN ISO 13790:2008* (p. 185).

European Parliament. (2018). *Directive (EU) 2018/2001 of the European Parliament and of the Council of 11 December 2018 on the promotion of the use of energy from renewable sources* (Vol. 328). http://data.europa.eu/eli/dir/2018/2001/oj/eng

European Parliament. (2019). *Directive (EU) 2019/944 of the European Parliament and of the Council of 5 June 2019 on common rules for the internal market for electricity and amending Directive 2012/27/EU (recast) (Text with EEA relevance.)* (Vol. 158). http://data.europa.eu/eli/dir/2019/944/oj/eng

International Energy Agency. (2021). *Net Zero by 2050*. https://doi.org/10.1787/c8328405-en

Klimaberatungsmodul. (2023). Deutscher Wetterdienst. https://kunden.dwd.de/obt/

Loga, T., Stein, B., Diefenbach, N., & Born, R. (2015). *Deutsche Wohngebäudetypologie - Beispielhafte Maßnahmen zur Verbesserung der Energieeffizienz von typischen Wohngebäuden* (2. ed.). Institut Wohnen und Umwelt (IWU). ISBN: 978-3-941140-47-9

Remmen, P., Lauster, M., Mans, M., Fuchs, M., Osterhage, T., & Müller, D. (2018). TEASER: An open tool for urban energy modelling of building stocks. *Journal of Building Performance Simulation*, *11*(1), 84–98. https://doi.org/10.1080/19401493.2017.1283539

Richardson, I., Thomson, M., Infield, D., & Clifford, C. (2010). Domestic electricity use: A high-resolution energy demand model. *Energy and Buildings*, *42*(10), 1878–1887. https://doi.org/10.1016/j.enbuild.2010.05.023

Schiefelbein, J., Rudnick, J., Scholl, A., Remmen, P., Fuchs, M., & Müller, D. (2019). Automated urban energy system modeling and thermal building simulation based on OpenStreetMap data sets. *Building and Environment*, *149*, 630–639. https://doi.org/10.1016/j.buildenv.2018.12.025

Schölzel, J., Beckhölter, T., Henn, S., Wüller, C., Streblow, R., & Müller, D. (2024). *Dis-*

trictgenerator: A novel open-source webtool to generate building-specific load profiles and evaluate energy systems of residential districts. *4*. https://doi.org/10.52202/077185-0106

Wirtz, M., Remmen, P., & Müller, D. (2020). EHDO: A free and open-source webtool for designing and optimizing multi-energy systems based on MILP. *Computer Applications in Engineering Education*, *29*(5), 983–993. https://doi.org/10.1002/cae.22352