

Synthetic Reference Energy Community Load Profiles for Artificial Case Studies

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Abstract

This data descriptor presents CINES-REC-CITY, an open synthetic dataset providing high-resolution load profiles for energy community research. The dataset represents a typical German urban district with 70 apartments across eight multi-family buildings, including diverse socioeconomic characteristics. Three main components are provided at 15 min resolution for a full year: non-controllable residential electricity consumption for all apartments, charging profiles for 17 battery electric vehicles with trip information, and heat pump operation data for both variable-speed and hysteresis-controlled ground-source systems. All profiles were generated using validated bottom-up stochastic simulation models accounting for realistic user behavior, mobility patterns, and thermal building physics. The modular structure allows for selective combination of components, enabling investigation of different technology penetration scenarios. The dataset serves as a reference benchmark for reproducible research, allowing for direct comparison of optimization approaches, business models, and control strategies using identical underlying consumption patterns. It is suitable for techno-economic analysis, algorithm development for flexible load control, and grid impact assessment. All data is provided in CSV format with weather data for consistent extensions.

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1. Summary

The increasing integration of distributed energy resources into residential areas has created demand for standardized datasets enabling reproducible research on energy community concepts. This data descriptor presents CINES-REC-CITY (Cluster of Excellence Integrated Energy Systems—Renewable Energy Community CITY), an open synthetic

dataset providing high-resolution load profiles for a representative German urban neighborhood. The dataset serves as a reference benchmark, allowing researchers to test different optimization approaches, business models, and control strategies using identical underlying consumption patterns, and thereby facilitating direct comparison of results.

CINES-REC-CITY represents a typical urban district comprising 70 apartments distributed across eight multi-family buildings with diverse socioeconomic characteristics including families, pensioners, students, and workers with various employment patterns. The dataset provides three main components at 15 min resolution for a full year (2023, Munich weather conditions): non-controllable residential electricity consumption for all apartments, charging profiles for 17 battery electric vehicles (BEVs) including workplace charging, and heat pump (HP) operation data for both variable-speed and hysteresis-controlled ground-source systems. All power values are provided in kW.

The profiles were generated using validated bottom-up stochastic simulation models. Residential loads employ probability distributions for socioeconomic user groups to determine appliance stocks and activity patterns [1]. BEV usage follows Markov chain-based trip generation [2], while thermal demands utilize a 5R1C building model accounting for internal gains, solar radiation, and ventilation [3]. HP operation is simulated with detailed thermal storage models [4]. Building characteristics follow TABULA standards for German construction (2002–2016) with a 1000 m² gross floor area per building [5].

The modular dataset structure allows for selective combination of components. Users can work with base residential loads alone (CINES-REC-CITY), add BEV (CINES-REC-CITY-EV), include HP (CINES-REC-CITY-HPvar or -HPHyst), or combine all elements. This flexibility enables investigation of different technology penetration scenarios. Weather data is included for consistent photovoltaic (PV) generation modeling if needed.

The dataset is suitable for techno-economic analysis of energy communities, algorithm development for flexible load control, and grid impact assessment and could also be applied in studies on electric vehicle flexibility utilization with similar study designs as in [6]. It is explicitly not intended for behavioral studies, as profiles are synthetically generated. While based on German characteristics, the data can be applied to comparable European contexts with similar climate, building standards, and socioeconomic patterns. All files are provided in CSV format.

2. Data Description

2.1. Dataset Overview

The CINES-REC-CITY dataset comprises time-series data for a synthetic urban energy community with 70 residential apartments across 8 multi-family buildings. All power flow data is provided at 15 min resolution for a complete year with power values in kW. The dataset structure is modular, consisting of building load profiles (non-controllable residential electricity), BEV profiles (charging behavior and trip information for 17 BEV), HP profiles (thermal demands and operation data for both variable-speed and hysteresis-controlled variants), and weather data (ERA5 reanalysis for Munich 2023 [7]). Components can be selectively combined based on research needs.

2.2. Existing Datasets

Before presenting the dataset introduced in this paper, this section provides an overview of similar datasets currently available. The most relevant dataset regarding energy communities is provided in [8]. It contains measured electrical data from 250 households across Europe, including PV, batteries, and BEVs, but lacks heat pump data and does not include multi-family buildings.

Another detailed dataset is described in [9] and provided at [10]. It includes measured data at a 1 min resolution for the year 2020, also including PV-battery systems, but no BEV or heat pump data. An electrical load profile dataset named WPuQ, comprising 38 households measured in a small village in Lower Saxony, Germany, is described in [11] and available at [12]. This dataset may be of interest to anyone looking for single-family house profiles. It also includes separate data for heat pumps but no PV, battery, or BEV data. A set of 74 min-based electrical profiles derived from measured data is available at [13]. It consists solely of overall household loads, with no separate data for HP or BEV. Synthetic end-use-specific electrical household load profiles for four weather years across 29 European countries are provided in [14]. An alternative synthetic dataset of 500 hourly single-family household water-to-water heat pump load profiles, based on the weather profile of Karlsruhe, Germany, in 2021, can be found at [15].

Reviewing the existing datasets, none currently include a combined representation of BEVs, HP, and residential loads for multi-apartment buildings, which represents a notable gap given the growing relevance of these load types in residential energy systems. While this combination could, in principle, be approximated by supplementing existing datasets with synthetic data generated by the tools referenced in Sections 3.1–3.4, such an approach requires additional effort and methodological choices that may introduce inconsistencies. The dataset presented in the following chapters directly addresses this gap by providing this combination in a single, ready-to-use resource. Furthermore, it is easy to handle and sufficiently adaptable to be combined with any of the listed datasets or extended with additional load generators, making it a flexible foundation for a broad range of research applications.

2.3. Scenario Naming Convention

To facilitate clear communication and comparison across studies, a systematic naming convention is employed for different dataset configurations:

- CINES-REC-CITY: Base scenario with only residential apartment loads.
- CINES-REC-CITY-EV: Base scenario plus BEV charging profiles.
- CINES-REC-CITY-HPvar: Base scenario plus variable-speed HP profiles.
- CINES-REC-CITY-HPhyst: Base scenario plus hysteresis-controlled HP profiles.
- CINES-REC-CITY-EV-HPvar: Combined scenario with BEVs and variable-speed HP.
- CINES-REC-CITY-EV-HPhyst: Combined scenario with BEVs and hysteresis-controlled HP.

For example, a study investigating optimal control strategies for flexible loads including BEVs and variable-speed HP would reference “CINES-REC-CITY-EV-HPvar” to clearly indicate which dataset components were utilized.

2.4. Building Characteristics, Energy Consumption, and Load Patterns

The district consists of 8 multi-family buildings with common thermal characteristics: 1000 m² gross floor area over three floors, insulation standards from TABULA data for German buildings (2002–2016), and heating set-point of 21 °C with 4 °C nighttime reduction (22:00–06:00).

2.4.1. Annual Energy Demands

Table 1 summarizes the annual thermal energy demands for each building:

Table 1. Annual heating and domestic hot water demand for the 8 buildings in CINES-REC-CITY.

Building	Heating Demand [kWh/a]	Domestic Hot Water Demand [kWh/a]
1	26,158	10,070
2	27,760	4806
3	27,319	5729
4	27,133	6120
5	26,760	6027
6	27,480	4845
7	26,729	5301
8	26,554	5586

2.4.2. Building Compositions and Electrical Consumption

Each building has a unique socioeconomic composition reflecting realistic urban diversity. The following tables (Tables 2–9) provide detailed apartment-level information for all 8 buildings.

Table 2. Building 1 composition and annual electrical energy consumption. Characterized by: high load, many residents present during day, and many BEVs.

Apartment	Residents	Socioeconomics	Apartment Load [kWh/a]	BEV Load [kWh/a]	BEV Present
1	4	Family 2 children	3603	2652	Yes
2	4	Family 2 children	2530	2346	Yes
3	3	Family 1 child	2844	1873	Yes
4	3	Family 1 child	2895	1809	Yes
5	2	Pensioners	1942	-	No
6	2	Full-time teleworker	1856	-	No
7	2	Full-time teleworker	2163	-	No
8	1	Part-time office worker	1166	-	No
Sum	21	-	19,000	8680	4
Optional Add-On		System Control	Electric Load [kWh/a]	Thermal Load [kWh/a]	
HP		Variable-speed (var)	12,182	41,447	
		Hysteresis-contr. (hyst)	15,345	41,230	

Table 3. Building 2 composition and annual electrical energy consumption. Characterized by: low load, only singles, and no BEVs.

Apartment	Residents	Socioeconomics	Apartment Load [kWh/a]	BEV Load [kWh/a]	BEV Present
1	1	Pensioner	1308	-	No
2	1	Pensioner	1404	-	No
3	1	Pensioner	1138	-	No
4	1	Student	981	-	No
5	1	Student	1395	-	No
6	1	Part-time office worker	1408	-	No
7	1	Part-time office worker	1171	-	No
8	1	Part-time teleworker	996	-	No
9	1	Part-time teleworker	1198	-	No
Sum	9	-	11,000	0	0
Optional Add-On		System Control	Electric Load [kWh/a]	Thermal Load [kWh/a]	
HP		Variable-speed (var)	11,274	37,318	
		Hysteresis-contr. (hyst)	14,223	37,094	

Table 4. Building 3 composition and annual electrical energy consumption. Characterized by: medium load, people working in offices, and average BEVs.

Apartment	Residents	Socioeconomics	Apartment Load [kWh/a]	BEV Load [kWh/a]	BEV Present
1	2	Full-time office worker	1988	2086 ¹	Yes
2	2	Full-time office worker	2202	1754 ²	Yes
3	2	Full-time office worker	2091	-	No
4	1	Part-time office worker	1327	-	No
5	1	Part-time office worker	1592	-	No
6	1	Part-time office worker	1147	-	No
7	1	Full-time office worker	1378	-	No
8	1	Full-time office worker	1190	-	No
9	1	Full-time office worker	1085	-	No
Sum	12	-	14,000	3840	2
Optional Add-On		System Control	Electric Load [kWh/a]	Thermal Load [kWh/a]	
HP		Variable-speed (var)	11,396	37,894	
		Hysteresis-contr. (hyst)	14,350	37,674	

¹ and ² BEVs for office workers also charge at work. Additional workplace charging: Apartment 1 = 17 kWh/a; Apartment 2 = 1079 kWh/a.

Table 5. Building 4 composition and annual electrical energy consumption. Characterized by: mixture of socioeconomics and average BEVs.

Apartment	Residents	Socioeconomics	Apartment Load [kWh/a]	BEV Load [kWh/a]	BEV Present
1	3	Family 1 child	2121	1623	Yes
2	2	Pensioners	2821	2234	Yes
3	2	Full-time office worker	2328	-	No
4	2	Full-time teleworker	1875	-	No
5	1	Student	1421	-	No
6	1	Part-time office worker	1082	-	No
7	1	Full-time teleworker	1347	-	No
8	1	Full-time office worker	1005	-	No
Sum	13	-	14,000	3857	2
Optional Add-On		System Control	Electric Load [kWh/a]	Thermal Load [kWh/a]	
HP		Variable-speed (var)	11,451	38,115	
		Hysteresis-contr. (hyst)	14,410	37,930	

Table 6. Building 5 composition and annual electrical energy consumption. Characterized by: mixture of socioeconomics and average BEVs.

Apartment	Residents	Socioeconomics	Apartment Load [kWh/a]	BEV Load [kWh/a]	BEV Present
1	3	Family 1 child	2833	1406	Yes
2	2	Pensioners	1594	1983	Yes
3	1	Pensioner	1631	1488	Yes
4	2	Full-time teleworker	2135	-	No
5	2	Full-time office worker	2123	-	No
6	1	Student	1316	-	No
7	1	Full-time teleworker	1204	-	No
8	1	Full-time office worker	1165	-	No
Sum	13	-	14,000	4877	3
Optional Add-On		System Control	Electric Load [kWh/a]	Thermal Load [kWh/a]	
HP		Variable-speed (var)	11,312	37,695	
		Hysteresis-contr. (hyst)	14,237	37,471	

Table 7. Building 6 composition and annual electrical energy consumption. Characterized by: pensioners (mostly single) with large apartments and average BEVs.

Apartment	Residents	Socioeconomics	Apartment Load [kWh/a]	BEV Load [kWh/a]	BEV Present
1	2	Pensioners	1733	-	No
2	1	Pensioner	1514	1289	Yes
3	1	Pensioner	1500	817	Yes
4	1	Pensioner	1573	697	Yes
5	1	Pensioner	1732	-	No
6	1	Pensioner	1552	-	No
7	1	Pensioner	1397	-	No
Sum	8	-	11,000	2803	3
Optional Add-On		System Control	Electric Load [kWh/a]	Thermal Load [kWh/a]	
HP		Variable-speed (var) Hysteresis-contr. (hyst)	11,199 14,155	37,075 36,850	

Table 8. Building 7 composition and annual electrical energy consumption. Characterized by: high share of single student flats and only one BEV.

Apartment	Residents	Socioeconomics	Apartment Load [kWh/a]	BEV Load [kWh/a]	BEV Present
1	2	Full-time teleworker	2948	-	No
2	1	Student	1010	863	Yes
3	1	Student	876	-	No
4	1	Student	1021	-	No
5	1	Student	1160	-	No
6	1	Student	903	-	No
7	1	Student	905	-	No
8	1	Part-time office worker	1103	-	No
9	1	Full-time teleworker	1398	-	No
10	1	Full-time teleworker	1416	-	No
11	1	Full-time office worker	1260	-	No
Sum	12	-	14,000	863	1
Optional Add-On		System Control	Electric Load [kWh/a]	Thermal Load [kWh/a]	
HP		Variable-speed (var) Hysteresis-contr. (hyst)	11,110 13,986	36,853 36,635	

Table 9. Building 8 composition and annual electrical energy consumption. Characterized by: mix of teleworkers and office workers and average BEVs.

Apartment	Residents	Socioeconomics	Apartment Load [kWh/a]	BEV Load [kWh/a]	BEV Present
1	2	Full-time teleworker	3326	-	No
2	2	Full-time office worker	1600	1259 ¹	Yes
3	1	Full-time teleworker	1241	-	No
4	1	Full-time teleworker	1365	-	No
5	1	Full-time teleworker	1275	-	No
6	1	Full-time teleworker	1366	-	No
7	1	Full-time office worker	1103	1064 ²	Yes
8	1	Full-time office worker	1249	-	No
9	1	Full-time office worker	1211	-	No
10	1	Full-time office worker	1264	-	No
Sum	12	-	15,000	2323	2
Optional Add-On		System Control	Electric Load [kWh/a]	Thermal Load [kWh/a]	
HP		Variable-speed (var) Hysteresis-contr. (hyst)	11,142 14,010	36,965 36,750	

¹ and ² BEV for office workers also charge at work. Additional workplace charging: Apartment 2 = 654 kWh/a; Apartment 7 = 428 kWh/a.

2.4.3. Seasonal and Day-Specific Load Patterns

Supplementing the tabular energy information from the previous section, the following Figures 1–8 provide an overview of seasonal and working day-/off-day-specific load patterns for the different buildings.

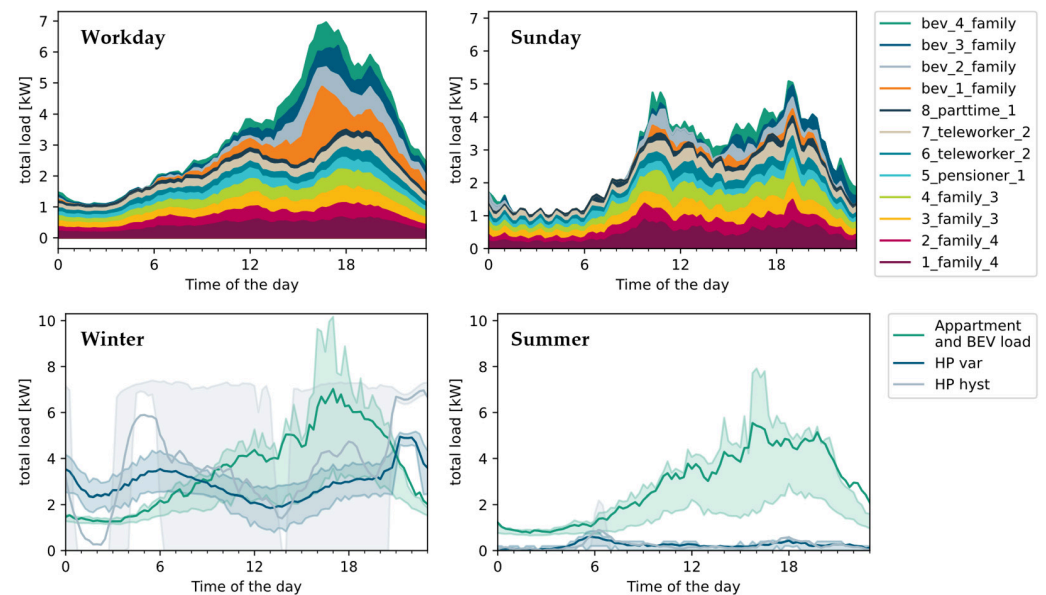


Figure 1. Mean day plots for building 1. **(Top):** Socioeconomic influence visualized by stacked mean day load plots for working days (**left**) and Sundays (**right**). **(Bottom):** Seasonal influence and heat pump operational behavior for mean winter days (**left**) and summer days (**right**); shaded areas represent the 0.25 and 0.75 data quantiles. (Note that Y-axis scale is different from the following figures).

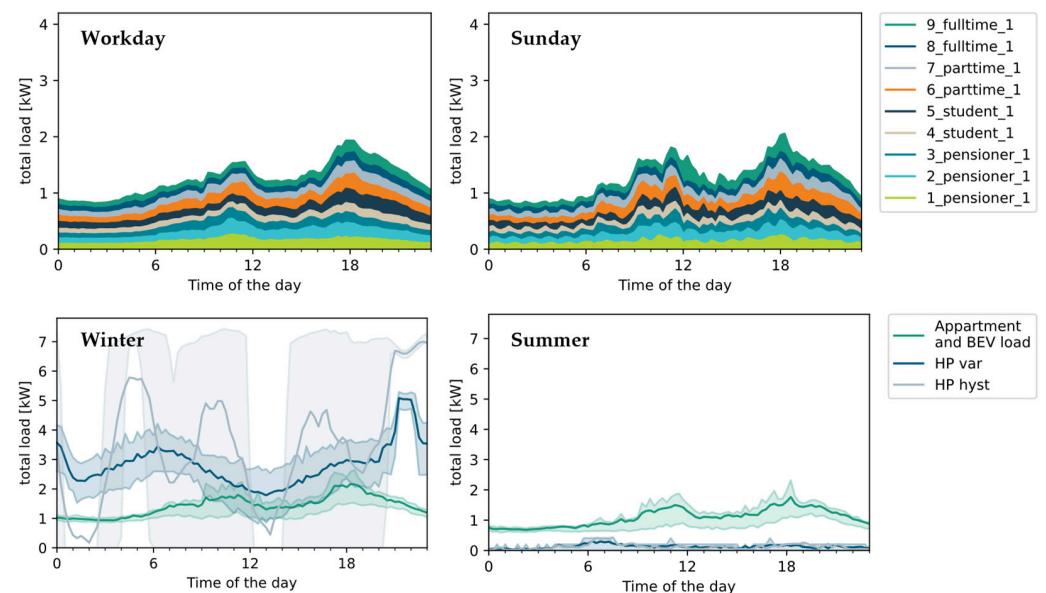


Figure 2. Mean day plots for building 2. **(Top):** Socioeconomic influence visualized by stacked mean day load plots for working days (**left**) and Sundays (**right**). **(Bottom):** Seasonal influence and heat pump operational behavior for mean winter days (**left**) and summer days (**right**); shaded areas represent the 0.25 and 0.75 data quantiles.

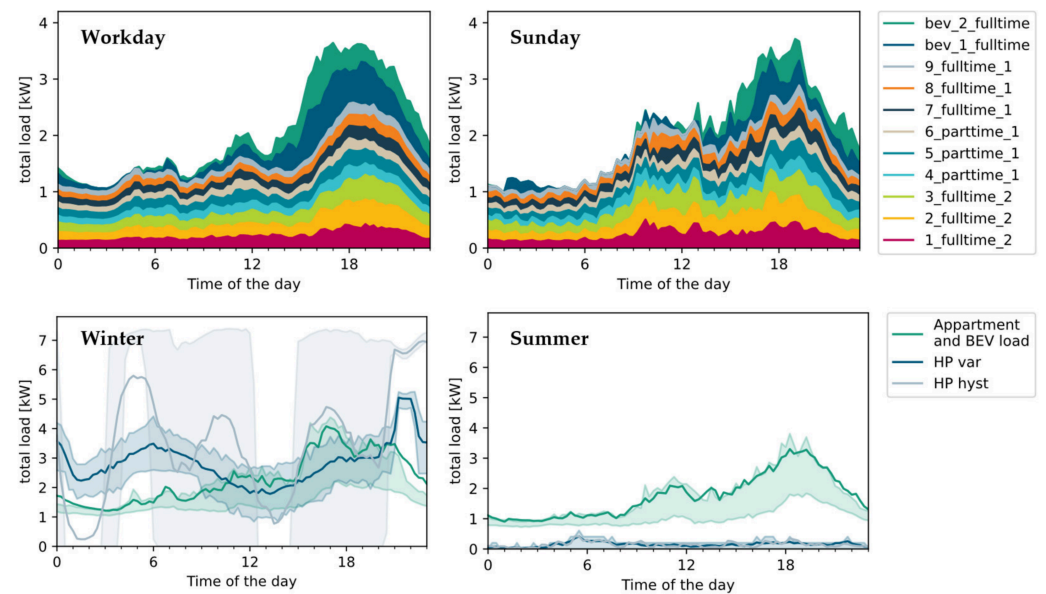


Figure 3. Mean day plots for building 3. (Top): Socioeconomic influence visualized by stacked mean day load plots for working days (left) and Sundays (right). (Bottom): Seasonal influence and heat pump operational behavior for mean winter days (left) and summer days (right); shaded areas represent the 0.25 and 0.75 data quantiles.

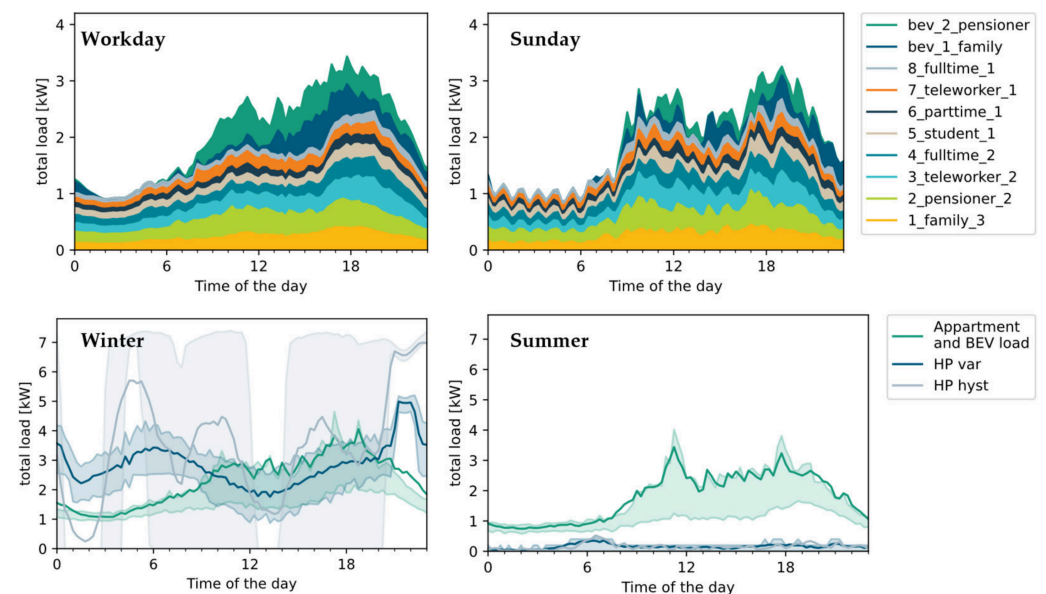


Figure 4. Mean day plots for building 4. (Top): Socioeconomic influence visualized by stacked mean day load plots for working days (left) and Sundays (right). (Bottom): Seasonal influence and heat pump operational behavior for mean winter days (left) and summer days (right); shaded areas represent the 0.25 and 0.75 data quantiles.

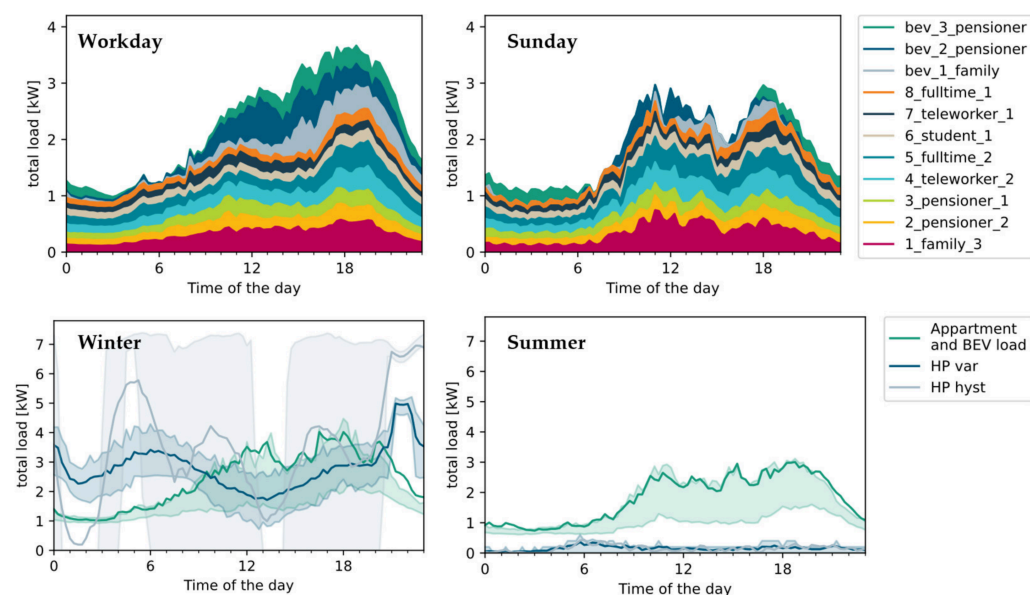


Figure 5. Mean day plots for building 5. (Top): Socioeconomic influence visualized by stacked mean day load plots for working days (left) and Sundays (right). (Bottom): Seasonal influence and heat pump operational behavior for mean winter days (left) and summer days (right); shaded areas represent the 0.25 and 0.75 data quantiles.

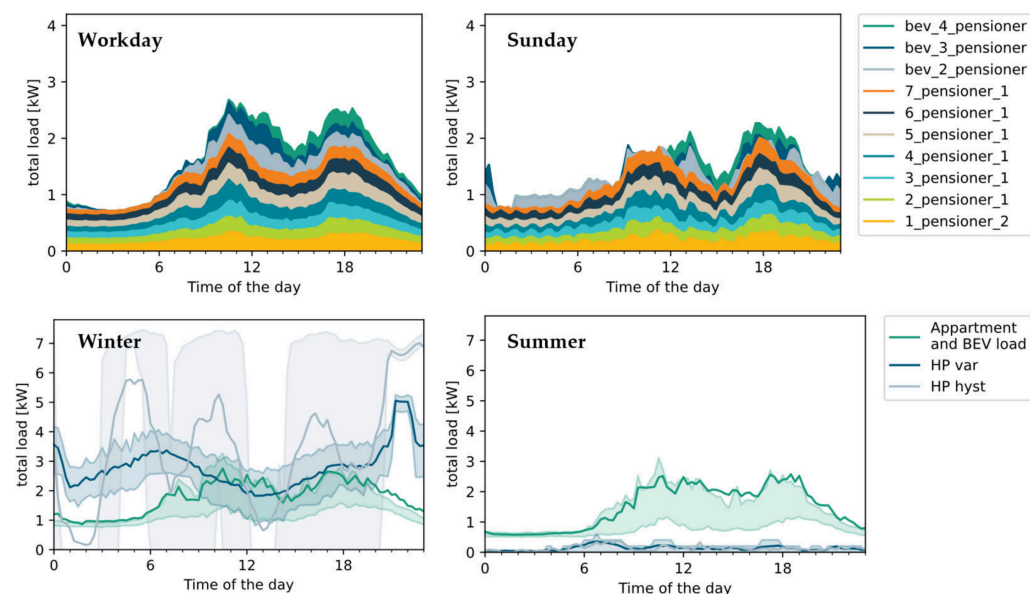


Figure 6. Mean day plots for building 6. (Top): Socioeconomic influence visualized by stacked mean day load plots for working days (left) and Sundays (right). (Bottom): Seasonal influence and heat pump operational behavior for mean winter days (left) and summer days (right); shaded areas represent the 0.25 and 0.75 data quantiles.

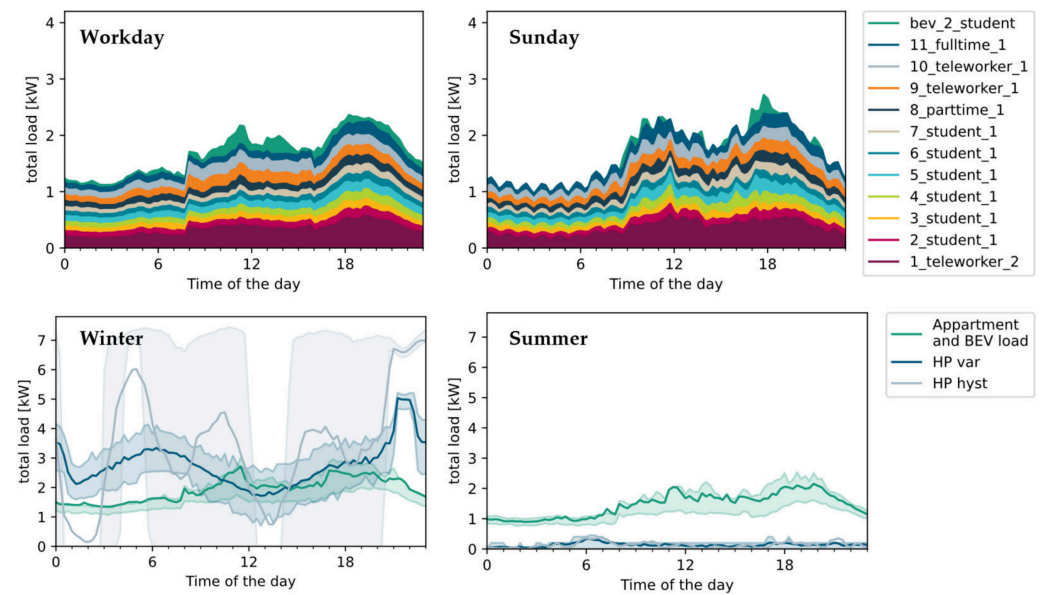


Figure 7. Mean day plots for building 7. **(Top):** Socioeconomic influence visualized by stacked mean day load plots for working days (**left**) and Sundays (**right**). **(Bottom):** Seasonal influence and heat pump operational behavior for mean winter days (**left**) and summer days (**right**); shaded areas represent the 0.25 and 0.75 data quantiles.

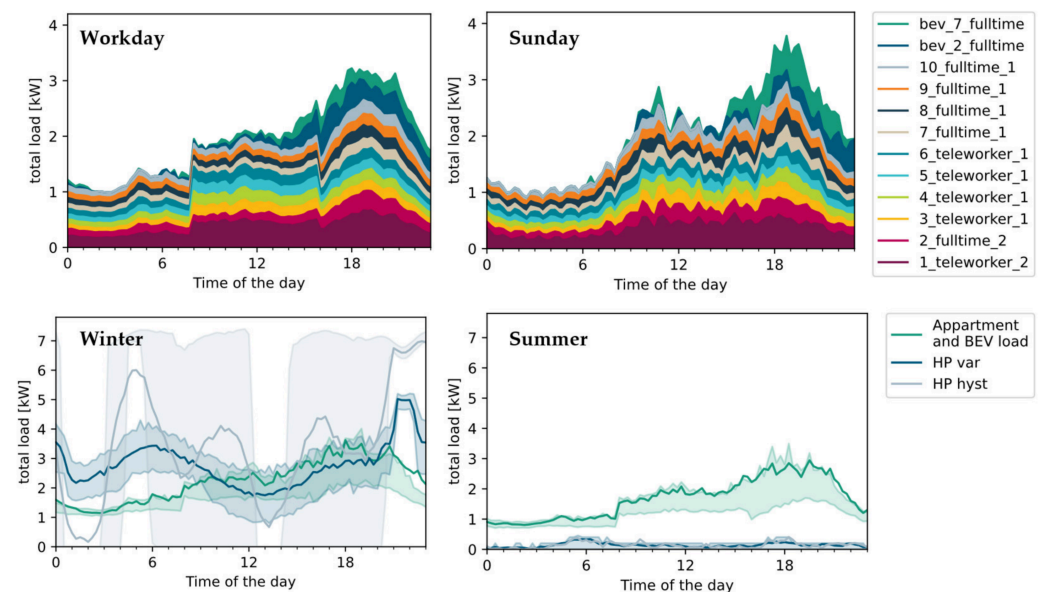


Figure 8. Mean day plots for building 8. **(Top):** Socioeconomic influence visualized by stacked mean day load plots for working days (**left**) and Sundays (**right**). **(Bottom):** Seasonal influence and heat pump operational behavior for mean winter days (**left**) and summer days (**right**); shaded areas represent the 0.25 and 0.75 data quantiles.

The different socioeconomic patterns are visualized by stacked mean day plots showing the average daily distribution of apartment load and BEV load. This is done for mean Sundays and mean working days for each building. Below these plots, the heat pump seasonality, the operational patterns of the two heat pump types, and the reference to the aggregated building and BEV load are shown. This is again presented using mean day plots, this time in an unstacked format but including the 0.25 and 0.75 data quantiles.

A clear difference between working days and off-days can be observed regarding load peaks. On working days, load peaks occur at 17:00 for all full-time working socioeconomic groups, while the load is low around noon (except for teleworkers). On Sundays, the

midday peak is similar to the peak in the late afternoon. Regarding seasonality, it can be observed that during winter, room heating leads to high heat pump usage, reaching dimensions comparable to all other electrical loads combined. Note that the power of the variable-speed heat pump only correlates with the outside temperature, which peaks in the early afternoon, and otherwise operates within a narrow operational band (shaded area). A hysteresis-controlled heat pump continuously turns on and off and therefore exhibits a significantly larger power variation, which also correlates with outside temperature. A nighttime temperature reduction of 4 °C between 22:00 and 06:00 can also be observed, during which heat pump power drops but is partially compensated by the decrease in outside temperature at around 02:00. During the summer, the heat pump only needs to supply domestic hot water, resulting in low power consumption with a peak in the morning hours when simultaneous demand for hot water is highest.

2.5. File Structure and Naming Conventions

The dataset follows a hierarchical folder structure designed for intuitive navigation and modular composition of different scenario configurations. Figure 9 illustrates the complete data organization.

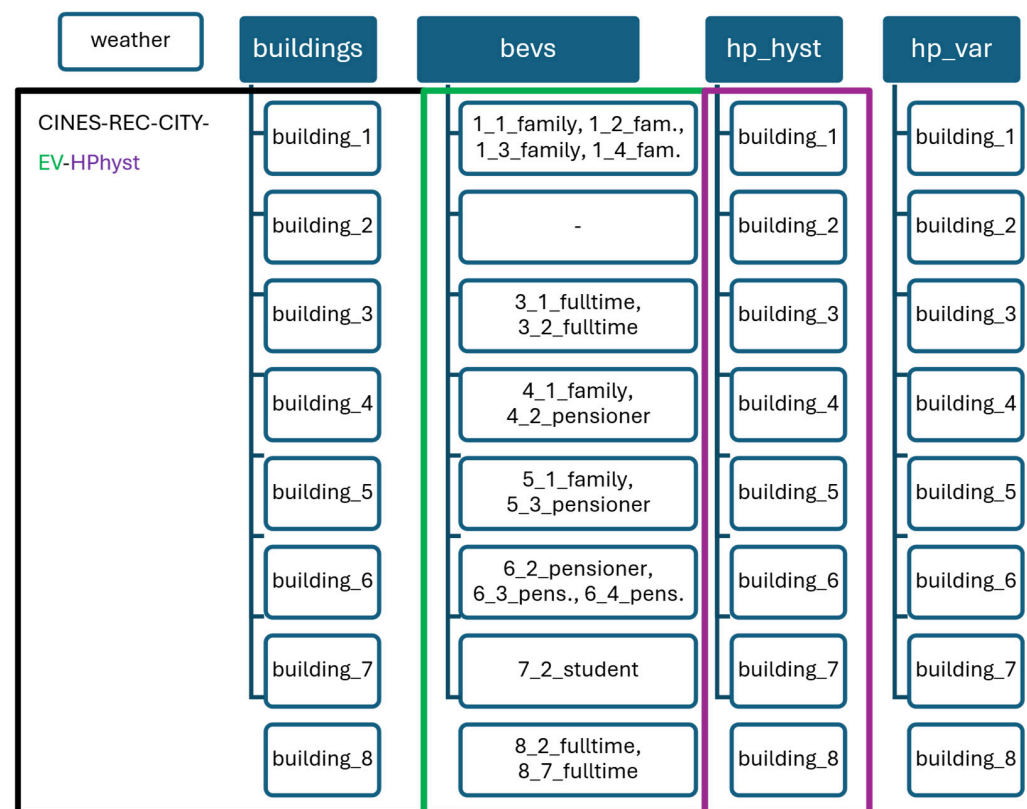


Figure 9. Dataset folder structure showing the modular organization of building loads, BEV profiles, and HP data. Colored boxes indicate how different components can be combined for specific scenario configurations (e.g., CINES-REC-CITY-EV-HPvar combines building data with BEV and variable-speed HP files).

The top level contains four main folders and one weather data file:

- buildings/: Contains 8 CSV files (building_1.csv through building_8.csv) with apartment-level residential electricity consumption profiles.
- bevs/: Contains 17 CSV files with BEV charging profiles and trip information.
- hp_var/: Contains 8 CSV files with variable-speed HP operation data.
- hp_hyst/: Contains 8 CSV files with hysteresis-controlled HP operation data.

- weather.csv: ERA5 weather data for Munich, 2023.

2.5.1. Building File Naming Convention

Building files are numbered 1 to 8 (building_1.csv through building_8.csv). Column names follow the structure: apartment number, socioeconomic factor, and number of residents, separated by underscores. For example, the column 2_family_4 represents apartment 2 with a family household of 4 residents. Socioeconomic categories include family, pensioner or pensioners, student, full time (further specified as office or telework), and part time.

2.5.2. BEV File Naming Convention

BEV files in the bevs/ folder are named using building number, apartment number, and socioeconomic factor, separated by underscores (e.g., 1_2_family.csv). Each BEV has three associated files. The base file contains time-series charging power with columns for Unix timestamp, trip identifier, home charging power, and workplace charging power. A trip information file provides detailed data including departure and arrival times, destinations, distances, and energy consumption. A flexibility file contains battery state-of-charge and control-relevant data for implementing custom control schemes. The extensive column description for the flexibility file can be found within the files as comment lines starting with a # above the tabular data. The method used for modeling flexibility is described in [6]. Note that workplace charging power contains non-zero values only for full-time office workers with workplace charging access.

2.5.3. HP File Naming Convention

HP files are organized in hp_var/ and hp_hyst/ folders and named according to building number (e.g., building_1.csv). Each file contains columns for heating demand, domestic hot water demand, thermal power output, electrical power consumption, domestic hot water storage temperature, heating storage temperature, and ambient air temperature, with power values in kW and temperatures in °C.

2.6. Data Format and Reading Instructions

All CSV files use semicolon separators, period decimal delimiters, 15 min time resolution, and UTF-8 encoding. Lines beginning with the hash symbol contain metadata. The datetime index follows ISO 8601 [16] format (YYYY-MM-DD HH:MM:SS±HH:MM) with Central European Time offset. A Unix timestamp column provides epoch time in seconds. Original load profiles were scaled using building-specific factors (Table 10) to achieve rounded 1000 kWh annual consumption increments.

Table 10. Scaling factors applied to residential apartment loads to achieve rounded annual building consumption values.

Building	Scaling Factor
1	0.97632
2	1.03304
3	1.01434
4	0.97273
5	1.00550
6	1.01499
7	1.02466
8	0.98912

A Python 3.14.5 reading example is provided in Box 1.

Box 1. Python 3.14.5 reading example to read in comma separated files.

```
import pandas as pd
df = pd.read_csv('path/to/file.csv', comment = '#', sep = ';',
                decimal = '.', index_col = 0)
# Optional: use Unix timestamp index
df.index = pd.to_datetime(df['unixtimestamp'], unit = 's', utc = True)
```

3. Methods

The CINES-REC-CITY dataset was generated using validated bottom-up stochastic simulation models for three main components: residential electricity consumption, BEV charging patterns, and HP operation profiles. In the following subchapters, the model methodologies are briefly explained, while for a more detailed description, references are made to the separate publications accompanying each model. The information on input required for the models is given in the Appendix A. At the end of each section, alternative tools are listed along with a brief description of their functionality.

3.1. Residential Load Profile Generation

Residential electricity consumption profiles were generated using the bottom-up stochastic simulation approach described in [1]. The model operates at individual appliance level, classifying users into socioeconomic groups (families, pensioners, students, full-time workers, and part-time workers) with characteristic behavioral patterns. Probability distributions determine appliance stocks for each household, while device usage is triggered by stochastic activity patterns derived from time-use survey data accounting for weekday/weekend differences and seasonal variations. Individual load curves for each appliance are generated and summed up to create total household consumption, capturing realistic diversity both within and between buildings.

A very similar and open-source load profile generator is provided by the LoadProfile-Generator [17] developed by Forschungszentrum Jülich (Jülich, Germany), which calculates annual load profiles based on characteristic German behavioral patterns. Another profile generator named HEDGE developed by University of Oxford (Oxford, UK) is described in [18] and is available for download at [19]. It can also be used to create PV and BEV profiles based on UK data but only provides daily profiles. An alternative residential electrical load profile generator is available at [20]. The input consists of a load curve normalized to 1000 kWh, resulting in at least 1000 individual annual household profiles at a 15 min resolution.

3.2. Thermal Demand Modeling

Domestic hot water demand profiles are generated stochastically based on probability distributions for hygiene activities (showering, bathing, and hand washing) with frequency dependent on household size and socioeconomic characteristics. Activity timing reflects typical morning and evening routines.

Space heating demand is calculated using a thermal 5R1C building model that balances heat gains from electrical appliances, occupants, solar radiation through windows, and domestic hot water losses against transmission losses through the building envelope and ventilation losses. Building parameters are based on the TABULA database for German residential buildings constructed between 2002 and 2016. Each building has a 1000 m² gross floor area distributed over three floors with a target indoor temperature of 21 °C and 4 °C nighttime reduction (22:00–06:00). The model uses ERA5 weather data for Munich 2023 and calculates the required thermal power at each 15 min time step while accounting for thermal inertia. Details are provided in [3].

With the alternative load profile generator named LoadProfileGenerator [17] mentioned in Section 3.1, thermal profiles can be generated based on behavior patterns and a building heating model. A model following a very similar approach as was used in the space heating model for this dataset is given by tsib developed by Forschungszentrum Jülich (Jülich, Germany) available at [21]. A model dedicated to the heat load calculation and energy performance evaluation is given with the pyBuildingEnergy project developed by Eurac Research (Bolzano, Italy) and available at [22]. On a more detailed level, established tools dedicated to thermal demand simulation are available such as TRNSYS [23] developed by University of Wisconsin (Madison, WI, USA), Polysun [24] provided by Vela Solaris AG (Winterthur, Switzerland) or EnergyPlus [25] developed by NREL (Golden, CO, USA).

3.3. BEV Usage and Charging Profiles

BEV usage patterns and charging profiles were generated using the stochastic model described in [2]. A Markov chain approach generates trip sequences throughout the year with probabilities dependent on socioeconomic factors such as work schedule and household type. Trip purposes include commuting, shopping, leisure, and other activities with timing reflecting typical daily patterns. Energy consumption is calculated based on trip distance and vehicle efficiency. Charging occurs at home using 11 kW wallboxes and at workplaces for full-time office workers using 11 kW charging stations. The charging strategy assumes immediate plug-in upon arrival with uncontrolled charging at available power limited by the vehicle on-board charger and battery state-of-charge. Trip information files provide detailed data on departure times, destinations, distances, and energy consumption for flexibility analysis.

A user-friendly, web-based charge profile generator named ChargingProfileGenerator developed by ElaadNL (Arnhem, Netherlands) can be accessed at [26]. Users can select the vehicle type, charging power, and charge point location to generate annual time-series data for download. Another tool developed by SINTEF (Oslo, Norway) and NTNU (Trondheim, Norway) is described in [27], based on real-world data from Norway, providing weather-dependent annual hourly load profiles. An alternative open-source charge profile generator named CPGeM developed by TH Köln (Cologne, Germany) is explained in [28]. The author mentions that it is compatible with the LoadProfileGenerator referenced in Section 3.1.

3.4. HP System Modeling

HP operation was simulated using the model presented in [4] for ground-source HP with thermal storage systems. The configuration includes a ground-coupled heat exchanger and two thermal storage tanks: 300 L for domestic hot water (45–60 °C) and 800 L for space heating (35–55 °C). Variable-speed HPs use inverter-controlled compressors modulating thermal output continuously between 30% and 100% of nominal capacity with electrical power consumption adjusting according to part-load dependent coefficient of performance (COP). The control algorithm prioritizes domestic hot water demand followed by heating demand. Hysteresis-controlled HPs operate in on–off mode at fixed nominal thermal power, turning on when storage temperature drops below the lower threshold and off when reaching the upper threshold. Both variants are sized to cover peak heating demand with appropriate reserve. The COP is modeled quadratically based on the temperature difference between the heat source (constant ground temperature of 10 °C) and the heat sink (supply temperature), derived from a regression of the manufacturers' data. The full modeling approach is described in [4] (Section 2.1.4).

An alternative heat pump profile generator, named Heat Pump Ninja developed by KIT (Karlsruhe Germany), uses a k-means clustering approach on measured data and

is described in [29]. A heat pump modeling library for setting up heat pump profile generators is developed by Forschungszentrum Jülich (Jülich, Germany) provided by the hplib repository at [30].

3.5. Data Quality and Validation

The underlying simulation models have been validated in previous studies against measured data. Residential load profiles were validated against smart meter data from German households [1], BEV charging patterns compared with measured charging infrastructure data [2], thermal models validated against monitored building data [3], and HP models calibrated using field test data [4]. The synthetic nature ensures consistency, completeness, and absence of privacy concerns while maintaining realistic statistical properties and temporal correlations characteristic of German residential energy consumption. No data postprocessing was done apart from the scaling mentioned in Section 2.5; no data gaps needed to be filled, and no outliers were removed.

4. User Notes

This section provides practical guidance for researchers working with the CINES-REC-CITY dataset, including recommendations for scenario composition, data integration, and potential extensions.

4.1. Scenario Composition and Data Integration

The dataset supports flexible scenario composition through its modular structure. Researchers combine components by matching temporal indices (datetime or Unix timestamp columns present in all files) and summing power values. The naming convention clearly indicates which components are included: CINES-REC-CITY (residential loads only), CINES-REC-CITY-EV (with BEVs), CINES-REC-CITY-HPvar (with variable-speed HP), CINES-REC-CITY-HPhyst (with hysteresis-controlled HP), or combined scenarios such as CINES-REC-CITY-EV-HPvar.

Data can be analyzed at apartment level (individual profiles), building level (sum of apartments), or community level (sum of all buildings). Higher aggregation levels exhibit reduced volatility due to statistical smoothing effects.

4.2. HP Control Strategies

Two HP variants represent different technology types. Variable-speed systems (hp_var/) use inverter control, modulating thermal output continuously between 30 and 100% of nominal capacity. These enable advanced control algorithms and continuous optimization strategies. Hysteresis-controlled systems (hp_hyst/) operate in simple on-off mode, cycling between full power and zero based on storage temperature thresholds. These represent common installations without inverter control and are suitable for rule-based strategies. Both variants deliver identical thermal energy; differences appear in electrical consumption patterns and temperature trajectories.

4.3. Dataset Extensions

PV generation is not included, but the provided weather file contains all necessary meteorological data (irradiance components, temperature, and wind speed) for PV simulation using tools like pvlib. Stationary battery storage is excluded because operation depends entirely on user-defined control strategies; researchers should implement battery models according to their specific requirements. While household appliances like washing machines are included in residential profiles, they are modeled as non-controllable. Researchers interested in appliance-level demand response can contact the authors for device-disaggregated profiles.

4.4. Citation and Reproducibility

When using this dataset, researchers should cite it using the provided DOI and specify the exact scenario configuration (e.g., “CINES-REC-CITY-EV-HPvar”). All modifications including aggregation levels, time period selections, and preprocessing steps should be documented. Control strategies applied to flexible assets must be described to ensure reproducibility.

4.5. Appropriate Use and Limitations

The dataset is designed for techno-economic studies of energy community concepts, algorithm development and testing for flexible load control, comparative analysis of different strategies, and grid impact assessment. It is not appropriate for behavioral or sociological studies (synthetically generated), precise forecasting of specific real locations (represents typical rather than specific case), studies dedicated to single-family houses, or applications in climate zones significantly different from Central Europe.

While the dataset represents a realistic urban neighborhood with typical diversity in household types and consumption patterns, real case studies will vary in building characteristics, socioeconomic distributions, and technology adoption rates. In addition, all profile generators used to create the dataset are based on German behavioral studies, and especially the heat pump profiles will differ significantly for locations outside Central Europe—which is why they are set as an optional add-on. Results should be interpreted as indicative of potential benefits rather than precise predictions for specific locations. The primary value lies in enabling controlled comparisons between different approaches using identical underlying data.

Author Contributions: Conceptualization, A.S.; methodology, A.S., E.T., F.L. and P.S.; software, A.S.; validation, P.S. and F.L.; formal analysis, A.S.; resources, A.S., F.L. and P.S.; data curation, A.S.; writing—original draft preparation, A.S.; writing—review and editing, P.H. and A.S.; visualization, A.S.; project administration, A.S.; funding acquisition, A.S. All authors have read and agreed to the published version of the manuscript.

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Institutional Review Board Statement: Not applicable. This study did not involve humans or animals. All data presented is synthetically generated using validated simulation models.

Informed Consent Statement: Not applicable. This study did not involve human subjects. All profiles are synthetic and do not represent real individuals or households.

Data Availability Statement: Building typology data for Germany is available from the TAB-ULA/EPISCOPE project and can be accessed at <https://episcopes.eu/building-typology/country/de/> (accessed on 20 August 2025). Weather data was obtained from the ERA5 reanalysis dataset and can be accessed at <https://www.ecmwf.int/en/forecasts/datasets/reanalysis-datasets/era5> (accessed on 20 August 2025). The CINES-REC-CITY dataset described in this article is publicly available at Fordatis and can be accessed without registration at <http://dx.doi.org/10.24406/fordatis/408> (accessed on 2 October 2025). The dataset is released under the Creative Commons Attribution 4.0 International License (CC BY 4.0), allowing for free use, distribution, and modification with appropriate attribution. All files are provided in CSV format as described in Section 2.5. Users are encouraged to cite this data descriptor when using the dataset in publications.

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explanation document into the structured format of a scientific data descriptor paper. The authors have reviewed and edited the output and take full responsibility for the content of this publication.

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Abbreviations

The following abbreviations are used in this manuscript:

Abbreviation	Meaning
5RIC	Five Resistances One Capacitance Thermal Building Model
BEV	Battery Electric Vehicle
CINES	Cluster of Excellence Integrated Energy Systems
COP	Coefficient of Performance
DHW	Domestic Hot Water
ERA5	European Reanalysis 5 (weather dataset)
HP	Heat Pump
HTG	Heating
hyst	Hysteresis-controlled
PV	Photovoltaic
REC	Renewable Energy Community
TABULA	Typology Approach for Building Stock Energy Assessment
var	Variable-speed

Appendix A. Input Required for Reproducing the Dataset

Appendix A.1. Input Parameters for Reproducing the Electrical and Thermal Household Data

With the following information, the profiles for room heating, domestic hot water, and household appliance electricity consumption can be recreated by providing this file to the synPRO profile generator. Note that the publicly available online interface [31] can also be used for recreation; however, additional information on other components may need to be provided, as the tool is continuously being extended. Nevertheless, the core functionality remains the same, so any additional loads will appear in new files or columns and can simply be deleted by the researcher.

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Appendix A.2. Input Parameters for Reproducing the BEV Profiles

To create the BEV profiles used (including flexibility and trip information files), the following table provides information on car type, household type, and income level, which are user-specific parameters. Note that for this study, no new BEV profiles were created; instead, they were handpicked from a previously generated and publicly shared database available at [32].

The following parameters are identical for all BEV profiles:

emob_hh_place_of_residence = City, emob_hh_number_of_ev = 1, emob_ev_main_user_use_frequency = sampling, emob_ev_model = opel (for medium or low) tesla (for high or veryhigh), emob_ev_p_nominal_home_kw = 11, emob_ev_p_nominal_work_kw = 11, emob_ev_p_nominal_pop_kw = 11, emob_ev_p_nominal_other_kw = 11, emob_ev_connecting_neutrality_soc_home = 100, emob_ev_connecting_neutrality_soc_work = 100 (for 3.1, 3.2, 8.2 and 8.7) 0 (for all others), emob_ev_connecting_neutrality_soc_pop = 0, emob_ev_connecting_neutrality_soc_other = 0, emob_ev_connecting_sensitivity = 1, emob_ev_charging_energy_strategy = 1.

Table A1. BEV-specific parameter values (note that ‘veryhigh’ is written without a space or hyphen, as this reflects the exact parameter name used).

Building and Car Number	emob_hh_type	emob_hh_economic_status
1.1	2A1mCu14	high
1.2	2A1mCu14	medium
1.3	2A1mCu14	high
1.4	2A1mCu14	medium
3.1	2Ay3060	high
3.2	2Ay3060	veryhigh
4.1	2A1mCu14	high
4.2	1A60p	low
5.1	2A1mCu14	medium
5.2	1A60p	medium
5.3	1A60p	low
6.2	1A60p	medium
6.3	1A60p	low
6.4	1A60p	low
7.2	1A1830	veryhigh
8.2	2Ay3060	medium
8.7	2Ay3060	veryhigh

Appendix A.3. Input Parameters for Reproducing the HP Profiles

To create the HP profiles, the thermal output from the synPRO household simulation is required, as this output serves as the input time series for HP generation. They can be recreated as described in the opening chapter of the Appendix. Alternatively, the thermal data—including domestic hot water (DHW) profiles and heating (HTG) profiles—are also provided at [33]. Furthermore, information on whether the heat pump is variable-speed or hysteresis-controlled must be specified, along with the HP type, which is ground-source in this study. Finally, the storage sizes need to be defined: 300 L for domestic hot water (45–60 °C) and 800 L for space heating (35–55 °C).

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