Representative electrical load profiles of residential buildings in Germany with a temporal resolution of one second

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Abstract

Precise and representative electrical load profiles of households are an essential basis for a variety of scientific research questions in the field of energy supply and storage. Firstly, this document describes the data basis and preparation of a freely available dataset of highly temporal resolved and representative load profiles. Finally, the data is visualized and its representative status for single family households in Germany is proven.

Keywords: *load profiles, measurements, energy-related simulation, energy management*

1 Introduction

There is a variety of conventional and renewable technologies available for realizing the energy supply of single family households. Concerning system sizing issues and the determination of energetic performance, detailed simulations based on time series of the generation and consumption are necessary. The household´s electricity consumption in its seasonal and average daily variability is often crucial for the simulation results [1]–[3]. Furthermore, it is obvious that a higher temporal resolution of the data can lead to more reliable or more exact results. This report introduces a freely available synthesized dataset which contains phase resolved yearly load profiles of the active and reactive power of 74 German single family households with a temporal resolution of 1 s.

2 Data base

The subsequently introduced load profiles are based on two different measurement campaigns. Firstly, data of the measured active power that was accumulated over three phases was taken into account. The data was measured in a 15-minute resolution within the framework of the field test “Moderne Energiesparsysteme im Haushalt” by the “Institut für ZunkunftsEnergieSysteme” (IZES) in the years 2008 through 2011 using smart meters in 497 households (IZES dataset) [4]. Secondly, highly temporally resolved load data that was recorded by the Vienna University of Technology (TU Wien) in the research project “ADRES-Concept” was used. The measurements were carried out in 30 different Austrian households during a winter week as well as during a summer week with a temporal resolution of 1 s and contain information about the three-phase active and reactive power (ADRES dataset) [5].

3 Methodology

From 497 available measurements of the IZES dataset, 74 load profiles were chosen that contained less than one day of summed up data gaps for the year 2010 in the record. All of the chosen datasets come from a single grid operator, therefore the households are located in immediate proximity to each other. Occurring gaps in the measurements were replaced with measured data from the same time frame of the respective day of the previous week. The load profiles with their resolution of 15 minutes define the yearly and daily course of the electrical load and form the basis for the synthesis toward load profiles with a 1 s resolution. Since the measured data for the quarter-hourly used energy in Wh is only available as integers without decimal places, equally distributed decimal places in the range of ±0.5 Wh have been added.

For the further synthesis of the highly resolved yearly load profiles, a data pool of 604,786 time series with a 1 s resolution was initially created from the ADRES dataset by shifting a 15-minute time frame by 1 minute. For each household load profile of the IZES dataset, a 1 s time series whose amount of energy came closest to the 15-minute measurement was taken from the data pool for each time step. The original 15-minute measurement was then replaced by the selected 1 s time series of the phase resolved active and reactive power.

In order to prevent the accumulation of individual time series of the data pool, the synthesized load profiles were changed again. Determined by a random number in the range of ±450 s, each day of the year was shifted again for each of the 74 load profiles. The missing measurements at the beginning or end of a respective day were filled with the measurements that were cut off by the shift.

Due to the higher temporal resolution, the synthesized load profile depicts the characteristic dynamic response of household load curves with distinct load peaks much better. At the same time, the individual daily course of the various household load profiles from the IZES dataset persists and is enhanced by the fluctuating load behavior of switching consumers. Therefore, through the utilization of this load profile synthesis, load profiles with a low temporal resolution can be converted into highly temporally resolved load profiles with typical load fluctuations.

4 Visualization

In order to facilitate the work with the data and to enable quick access to essential information, the characteristic properties of the dataset are described in the following.

4.1 Exemplary Day

Figure 1 shows the original data resolved at 15 minutes of the active power on 3rd of January for load profile No. 1 as well as the 1-s load profile of the active and reactive power and the power factor. It can be clearly seen that the synthesized load in the household fluctuates strongly and therefore frequently exceeds or undercuts the 15-minute average. These fluctuations realistically depict the electrical consumption of a household and present a difficult challenge for many control tasks.

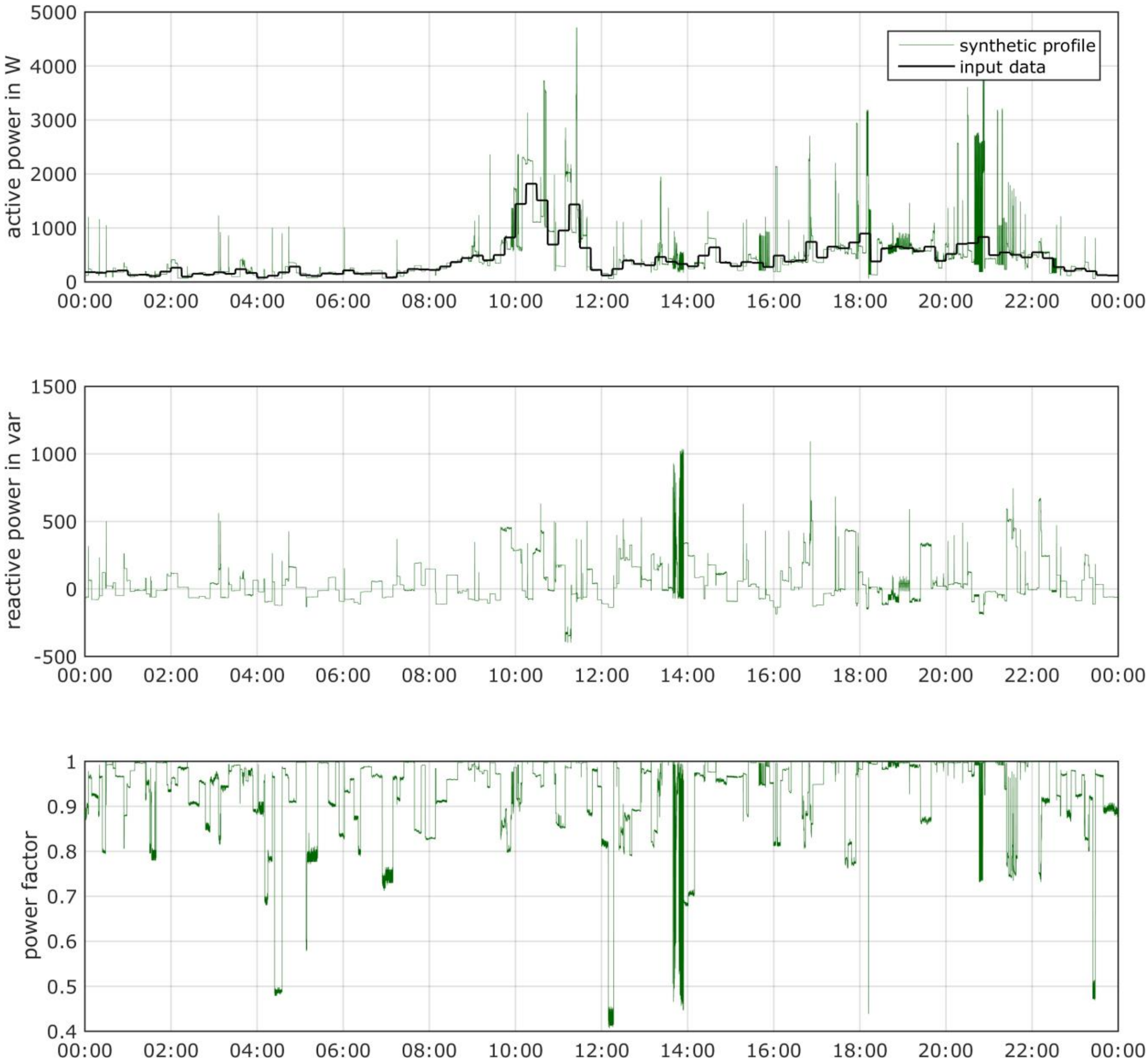


Figure 1 Exemplary daily course of the active power, reactive power and of the power factor.

Strong fluctuations of the active power that seem extensively green in the figure are often kitchen appliances, such as stove tops. Induction hobs, as well as ceramic glass cooktops show an oscillating behavior within a time range of a few seconds.

4.2 Analysis: Annual Energy Consumption

The annual electricity consumption of the examined load profiles are between 1.4 and 8.6 MWh with a mean value of 4.7 MWh (Figure 2). Under consideration of several current studies, this approximately corresponds with the electricity consumption of a 4-person household [6, p. 28]. The various consumptions are roughly normally distributed. Furthermore, it is apparent that the consumptions are equally distributed throughout the three phases.

The reactive power usage averages over all load profiles at 2.91 Mvarh/a (Figure 3). It is predominantly inductive (2.15 Mvarh/a), so that the capacitive reactive energy represents only a small amount (0.76 Mvarh/a).

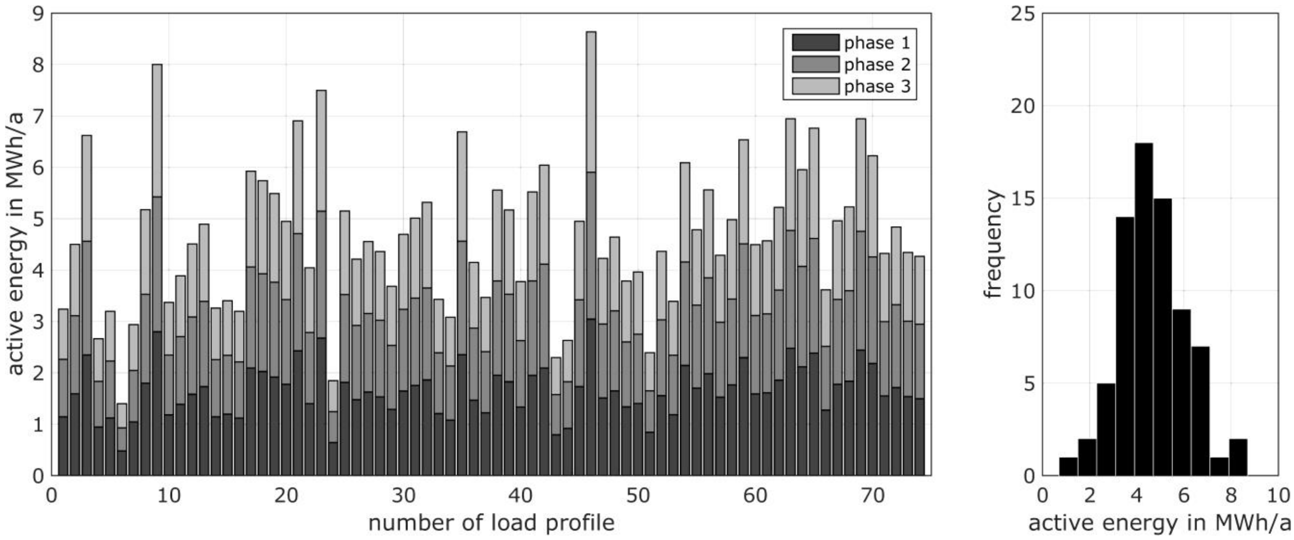


Figure 2 Phase resolved sum of the active energy of the 74 load profiles and the corresponding histogram.

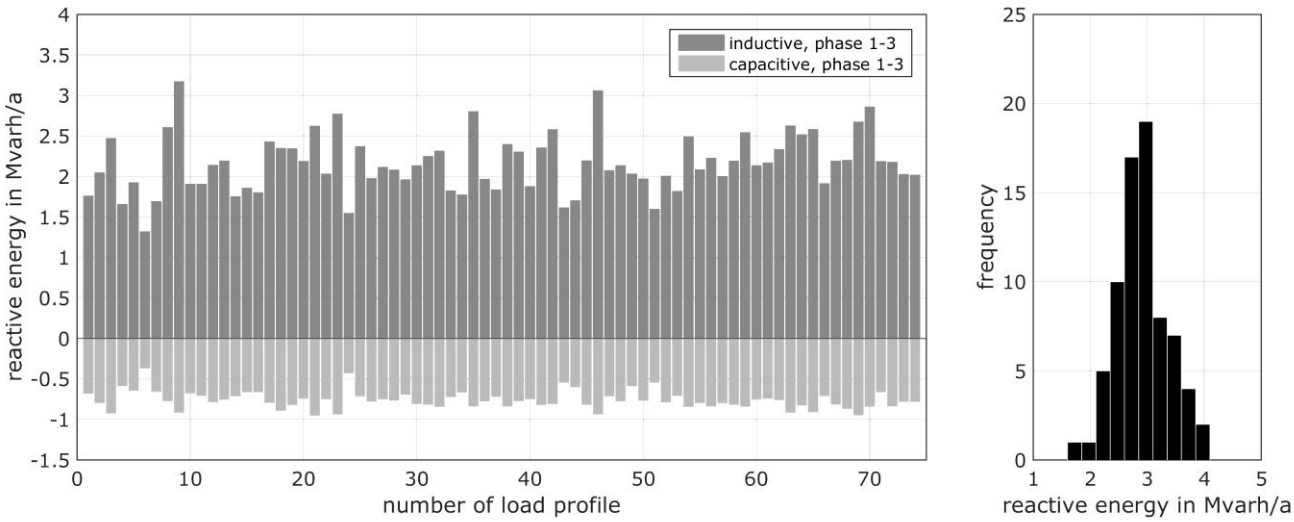
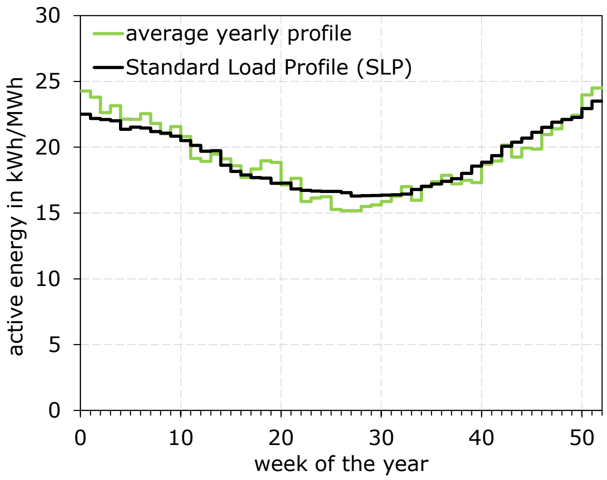


Figure 3 Phase-balanced sum of the reactive energy of the 74 load profiles and the corresponding histogram.

4.3 Analysis: Representability based on the Standard Load Profile

In order to be able to make universally valid statements about energy systems in single family households, it has to be ensured that the available data is a representative selection. Hence, for the validation, the average of the 74 chosen load profiles is compared with the standard load profile (SLP) for households. For this, data from Stromnetz Berlin GmbH for the year 2010 was taken into account [7]. For the seasonal course, Figure 4 (left) shows a good accordance between the measured data with the standard load profile. While the weekly electricity demand varies between 20 and 25 kWh per MWh annual consumption in the winter months, less than 20 kWh/MWh are consumed in typical summer weeks. Within the measured data, the summer and autumn holidays are more apparent than within the standard load profile due to lower consumption. The electricity consumption is slightly higher in the first and last weeks of the year.

The comparison of the daily mean course of the load, depicted in Figure 4 (right), is virtually identical to the standard load profile in many ways. Altogether, the dynamic of the synthesized profiles - characterized by a lower electricity demand at night and by a higher electricity demand in the evenings – is slightly more distinct compared to the standard load profile.



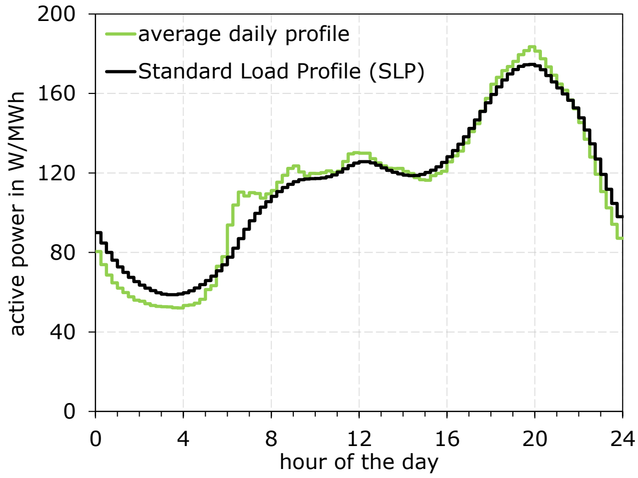


Figure 4 Comparison of the seasonal (left) and daily (right) course of the specific average load of the 74 load profiles with the standard load profile. *(For the purpose of a better depiction, the average daily profile of the 1-second load profiles was converted into 15-min average values in the right figure)*

General Information

The data and computational effort is not to be underestimated, when calculating with 1-second load profiles. When calculating with only one load profile, but with as representative results as possible, the following load profiles are recommended

- Load profile 31 with regard to a good compliance with the seasonal course of the SLP
- Load profile 17 with regard to a good compliance with the daily course of the SLP

4.4 Analysis: Daily and Seasonal Consumption

Regarding the energetic simulation of energy systems, in which it comes down to the simultaneity of generation and consumption, the seasonal and daily distribution of the electricity consumption plays an important role. For example, the load profiles can be characterized by the so-called noon-, summer- and night fraction (Figure 5):

- The noon fraction describes which portion of the daily electricity consumption of a load profile that was consumed until noon (12:00 o'clock CET) on an annual average. The smaller the value, the higher the electricity consumption in the evening and therefore for example an advantageous west-orientation of the PV system.
- The summer fraction describes which portion of the annual load consumption of a load profile is consumed in the six summer months. The smaller the value, the higher the relative portion of the electricity consumption in the winter months (i.e. through a heat pump).
- The night fraction describes which portion of the daily electricity consumption of a load profile is consumed between sunset and sunrise on an annual average. The smaller the value, the better the correlation between the PV generation and the consumption.

Figure 6 depicts the results of the three characterization methods for the 74 load profiles. The noon fraction averages to 39 %, the summer fraction to 45 % and the night fraction to 48 %.

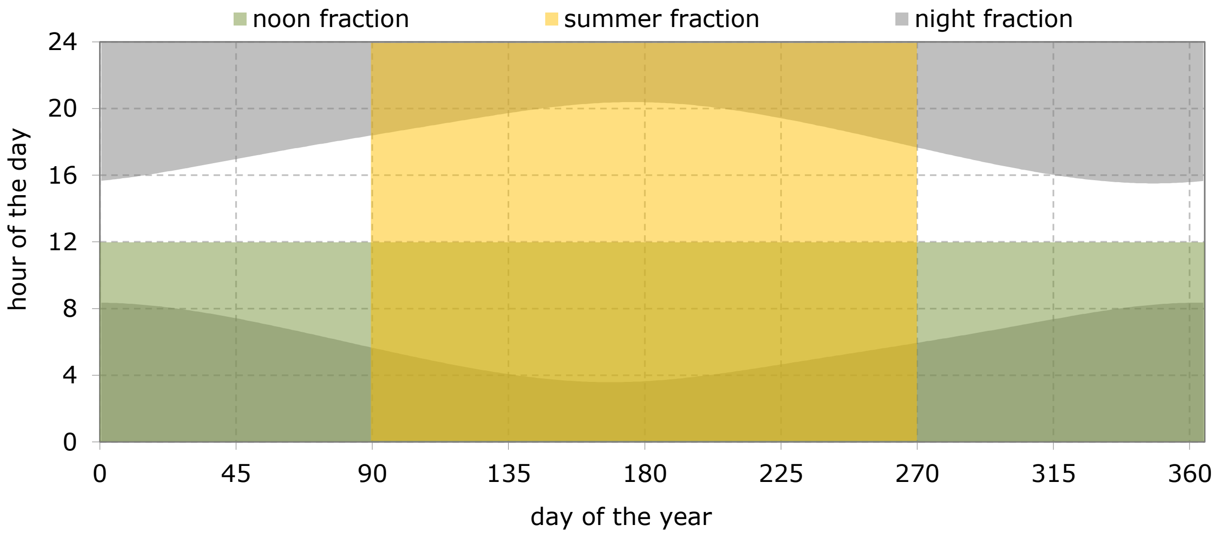


Figure 5 Qualitative depiction of the noon-, summer and night fraction of the electricity consumption.

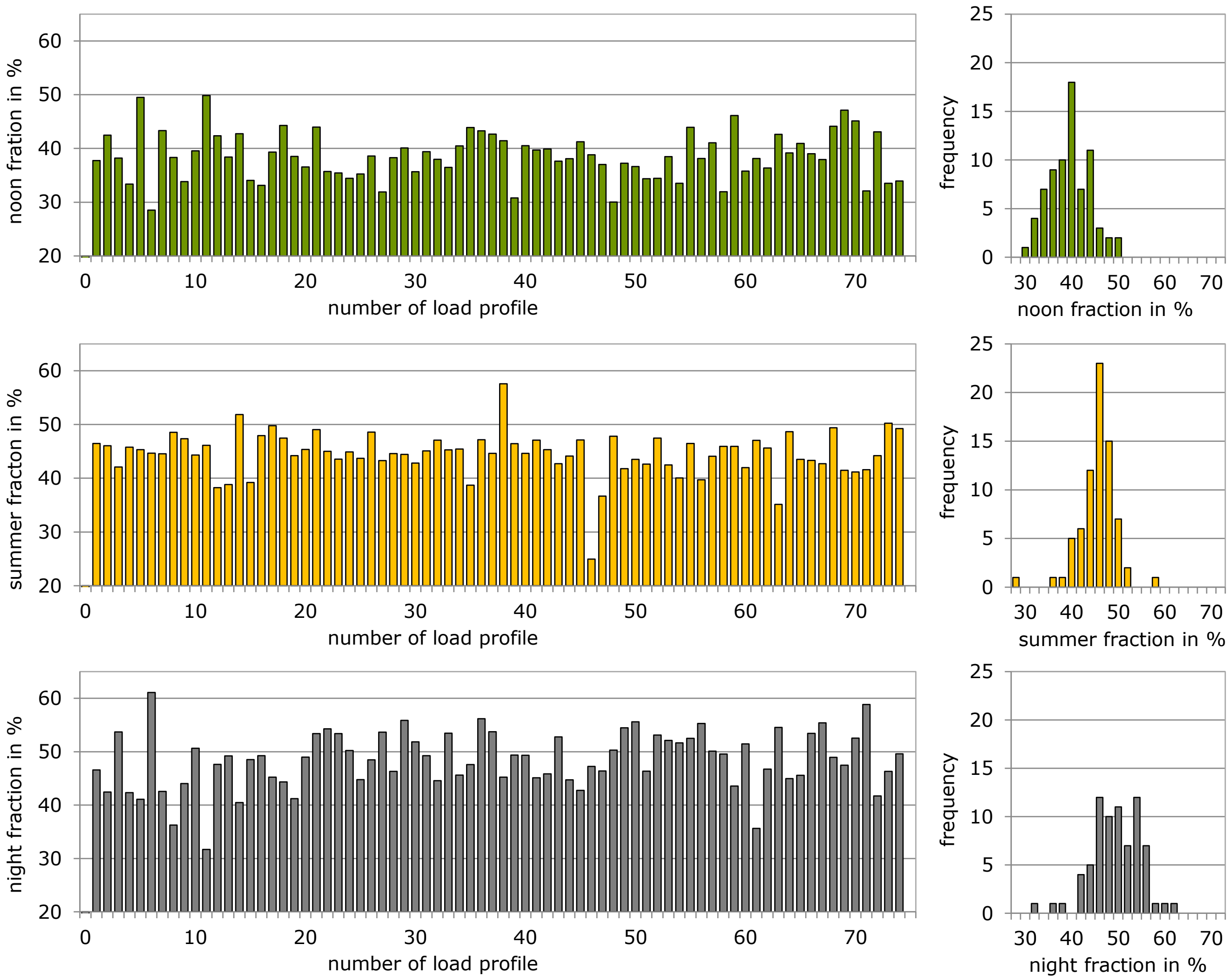


Figure 6 Noon-, summer- and night portions of the 74 load profiles and the corresponding histograms.

5 Download

If you are interested in the dataset, please follow this link:

https://pvspeicher.htw-berlin.de/veroeffentlichungen/daten/lastprofile/

You will receive a download link for the dataset, electively as compressed CSV files (approx. 5 GB compressed, 45 GB uncompressed) or in the MATLAB format (approx. 4 GB).

Please use the following citation when using the data:

Tjaden, T.; Bergner, J.; Weniger, J.; Quaschning, V.: "*Representative electrical load profiles of residential buildings in Germany with a temporal resolution of one second "*, Dataset, HTW Berlin – University of Applied Sciences, Berlin, 2015.

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7 References

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