Zukunft Bau

KURZBERICHT: SWD – 10.08.18.7-15.58

Title

Development of methods for the collection and evaluation of user satisfaction, building performance, and interaction between residential buildings and residents

Abstract

In most cases, the evaluation of buildings relies on a one-sided calculation of building physical values. In very few cases are the predictions made in the planning phase subsequently verified by monitoring and/or surveying residents to determine their satisfaction with the performance of a building. User-satisfaction can be used as an indicator of the acceptance of a building (Voss, K.; Herkel, S.; et al, 2016).

Project

Goal

In the „research project for the development of methods for the collection and evaluation of user satisfaction, building performance, and interaction between residential buildings and residents“, a tool is developed which generates a simple and precise evaluation of the user data as well as the measured physical values in the building. A comparison of the two data groups can then be used in practice for evaluating a building.

For this purpose, existing tools and different methods of describing and forecasting the user comfort were used in parallel to collect target values from the planning in three dimensions - the building characteristics, the indoor climate, and the user comfort - and to compare them with their actual values during operation. In addition, the three dimensions were then linked and compared with each other.

To evaluate and compare the residential buildings, an online-based tool was developed which allows the multi-dimensional recording of the user experience with the building and its indoor climate simultaneously. First, the platform captures the physical comfort parameters of the buildings by recording the indoor climate by means of measuring stations. Second, residents are asked to complete online questionnaires four times over a period of twelve months so that the measured values can be matched to the subjective data from the surveys. A total of 100 housing units were outfitted with this software for evaluation during the monitoring time.

Procedure

Due to the large amount of data that could be collected through physical measurements and surveys, certain parameters were chosen in advance for investigation and monitoring. Reducing the number of measurement parameters was appropriate to provide meaningful observation of the buildings. The following parameters that are relevant for comfort and well-being in housing were recorded, including physical and psychological indicators:

- Thermal comfort
    - Room temperature (summer and winter)
- Indoor air quality
    - Humidity
    - CO_2 concentration

        - Ventilation (natural or mechanical)

  - General housing satisfaction
  - Perceived options for action

In addition, factors relevant for the building performance were recorded and measured. This includes:

  - Outdoor weather data

The above parameters are analyzed in the following three dimensions of building performance:

1. Building characterics
2. Building physical values and the resulting indoor climate
3. User comfort

Target values in the form of EnEV verifications, simulations, building physics calculations, and legal requirements were used for each dimension. The actual values were ascertained through measurements or through surveys of the users.

The physical and climatic dimension is based on the parameters assumed in the planning phase and measured in the operating phase in inhabited rooms by NETATMO devices. These devices continuously collect (in 15 minute intervals) indoor air temperature $T_{i,NETATMO}$ [°C], relative humidity $RH_{i,NETATMO}$ [%], and CO_2 content of indoor air $CO_{2i,NETATMO}$ [ppm]. In addition, climate data from external sources was used for the locations of the buildings that were monitored and from this data the outside air temperature was recorded.

The monitoring occurred in 19 buildings that were used for the project. The physical parameters recorded as above were done in these buildings. In the next step, the indoor climate data was evaluated and correlated with the results from the user surveys.

Selection of the investigated buildings

The 100 residential units that were monitored during the project were found in 19 different buildings of different construction ages and energy standards. Of the 19 buildings used, 4 of them were refurbished and the other 15 were newly constructed. The renovated buildings were built between the years 1955 and 1977. Except for one building, they were renovated to the updated Energy Saving Ordinance (EnEV) between 2000 and 2015. The new buildings were built between 2003 and 2015.

Conclusion

Recording, comparing, and evaluating the three dimensions – planning, physical measurement, and surveys – for the residential units was a methodological challenge. This study also highlighted the difficulties with comprehensive data collection. Therefore, it made sense to narrow the research question to a more limited scope.

A comparison of the buildings with each other along with a cross-analysis of the simulated or planned building performance was not possible. This was due to the lack of comparable data. The diversity of results in individual cases do not allow generalization – this requires a larger number of cases.

Key Information

Kurztitel: Well-being and building monitoring in high-efficiency buildings

Research / Project Management:
Technical University of Braunschweig, Institute for Building Services and Energy Design, Department of Architecture, Civil Engineering, and Environmental Science – Thomas Wilken und Caroline Fafflok

University of Stuttgart, Institute for Lightweight Structures and Conceptual Design – Dr. Dirk Schwede

DGJ Architektur GmbH – V. Prof. Hans Drexler

Berliner Institut für Sozialforschung GmbH – Dr. Eva Schulze und Karoline Dietel

Humboldt University of Berlin, GeSK, Survey Research & Evaluation – Prof. Dr. Bernd Wegener und Moritz Fedkenheuer

Beibob Medienfreunde – Tobias Lode

AktivPlus e.V. – Hélène Bangert

Total cost: 213.997 €
Federal subsidy: 149.797 €

Project duration: 18 Months

FIGURES:

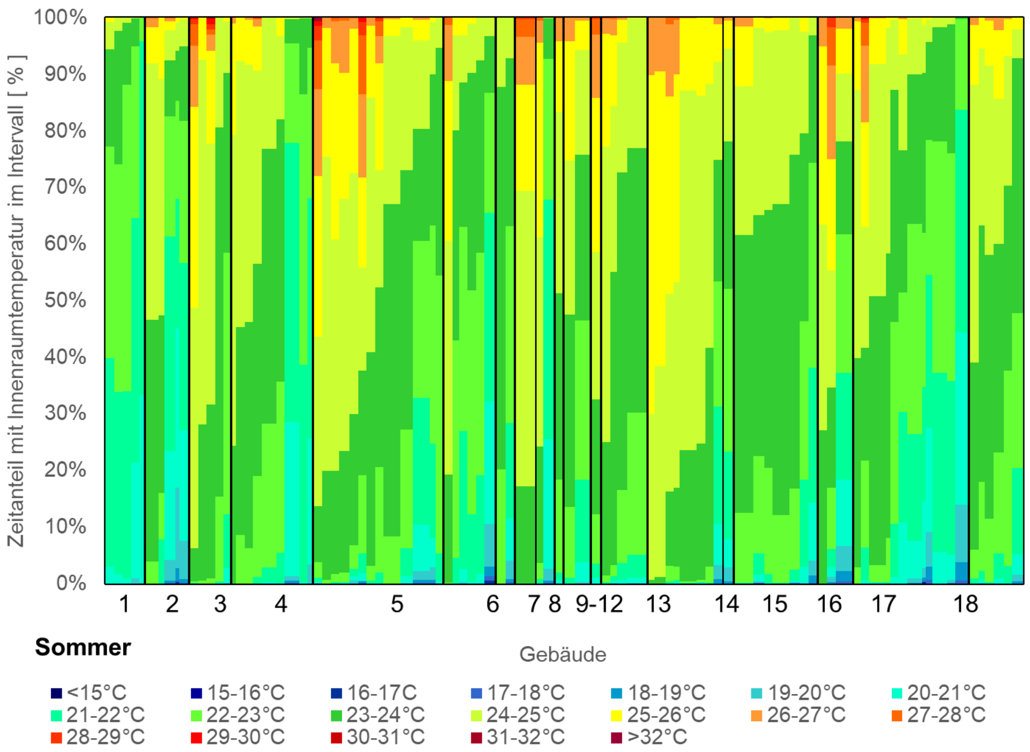

Figure 1:
Description:
Percentage of measured indoor air temperatures in the living room in 1°C temperature intervals between 15°C and 32°C, shown for each of the participating apartments in each of the 19 buildings during the summer (01.06.2016 - 31.08.2016)

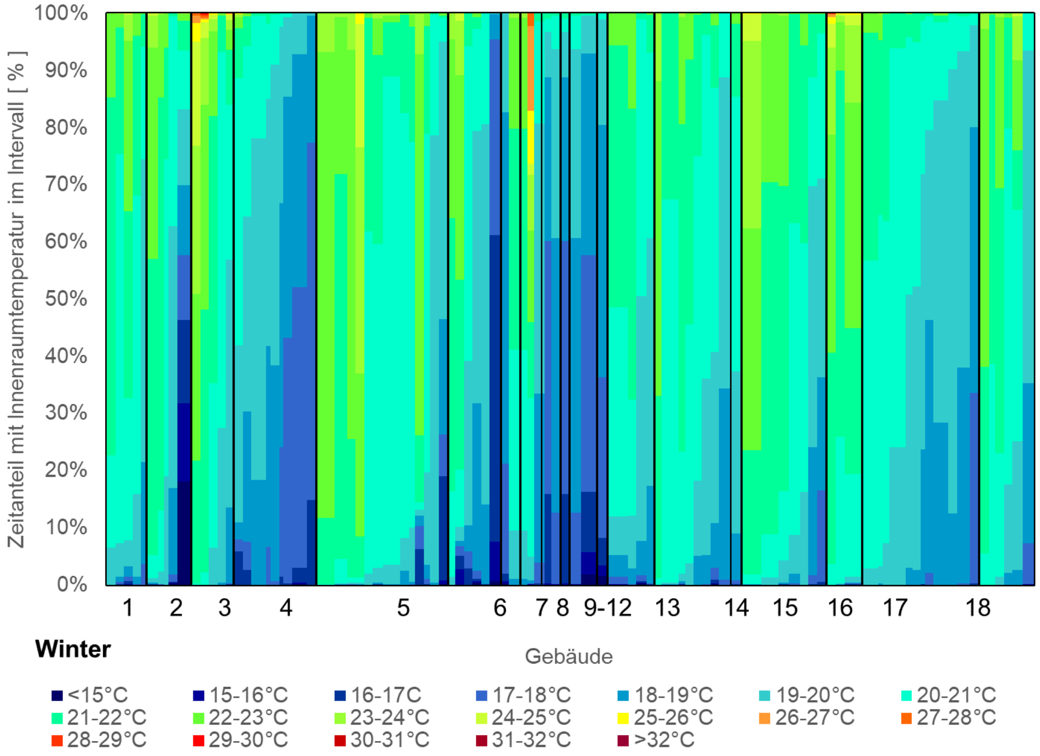

Figure 2:
Description:
Percentage of measured indoor air temperatures in the living room in 1°C temperature intervals between 15°C and 32°C, shown for each of the participating apartments in each of the 19 buildings during the winter (01.12.2016 - 28.02.2017)

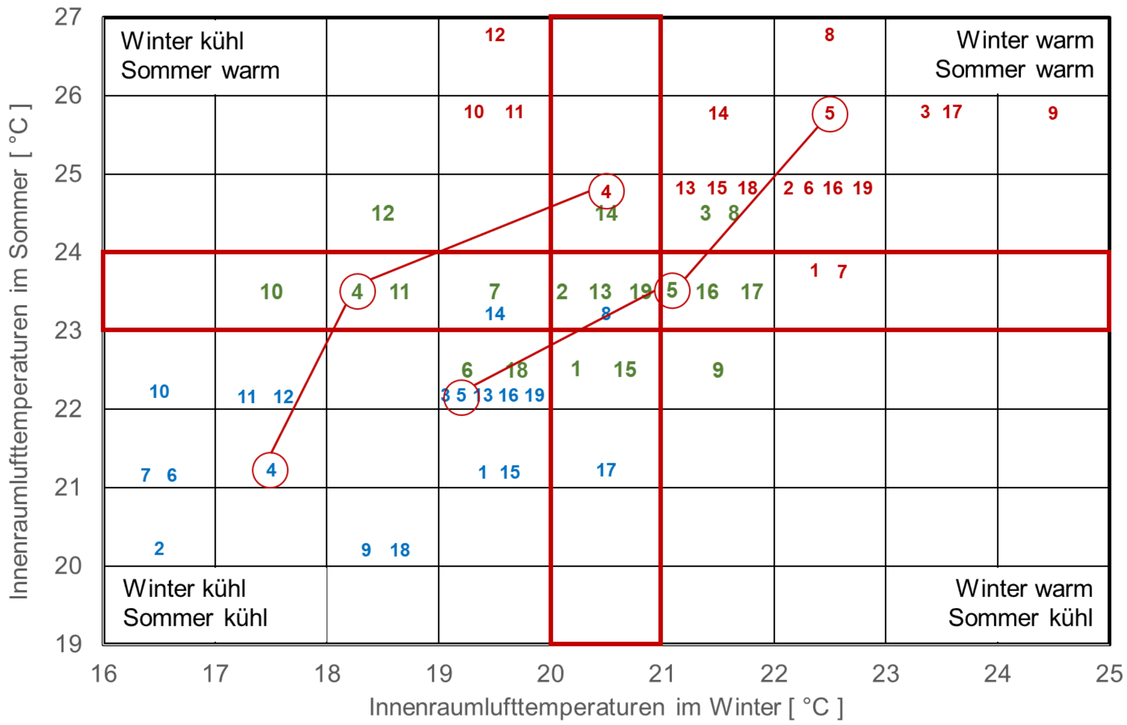

Figure 3:
Description:
Classification of the indoor air temperatures in the living room of the 19 examined buildings during the summer (01.06.2016 - 31.08.2016) and the winter (01.12.2016 - 28.02.2017), 10% percentile, median (green) and 90% percentile of room air temperatures, blue: winter cool/summer cool, red: winter warm/summer warm. Buildings 4 and 5 are marked.

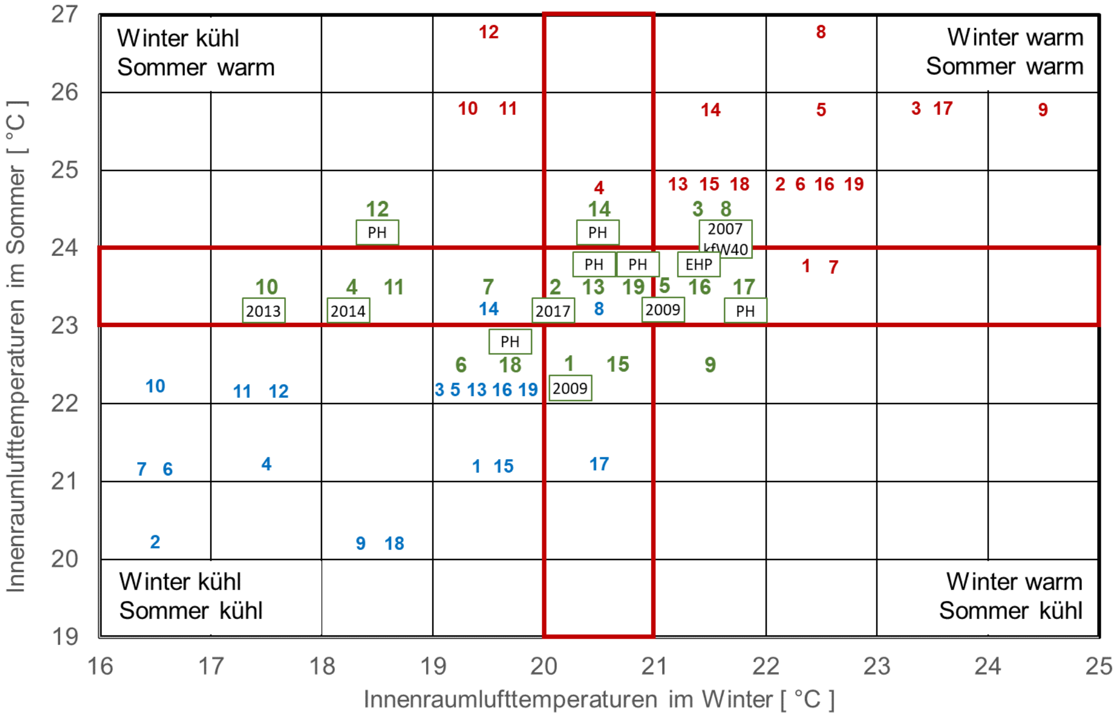

Figure 4:
Description:
As figure 3, with the additional information on the building energy standards of the buildings that were studied

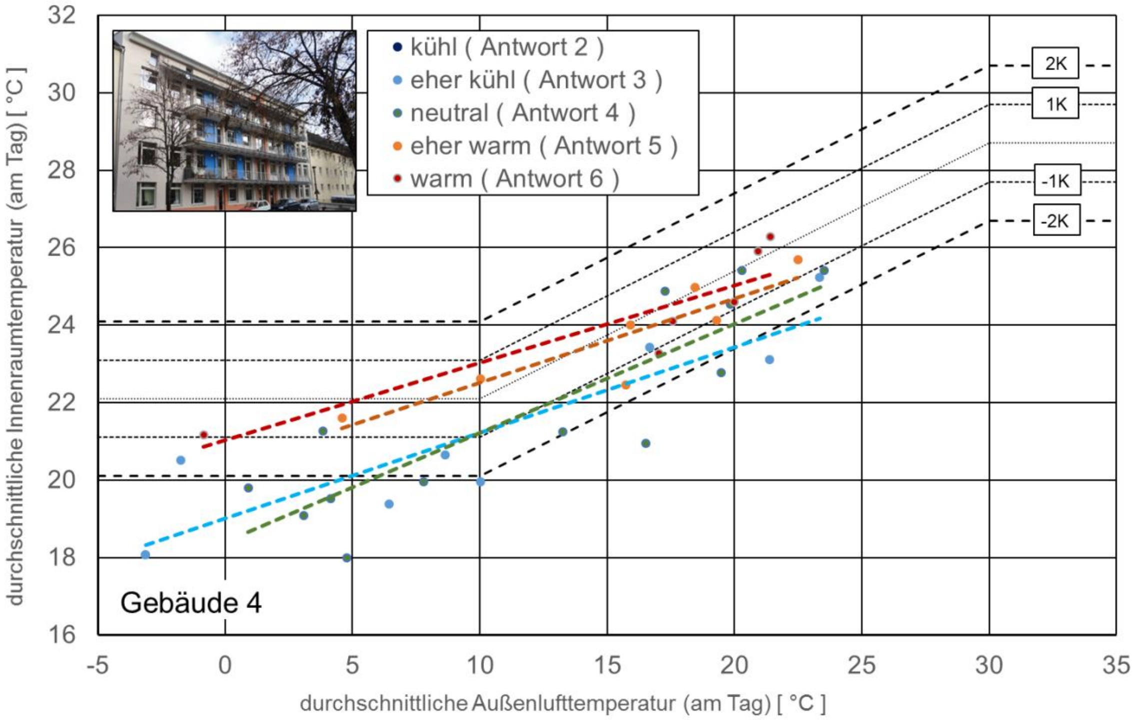

Figure 5:
Description:
Relationship between the perceived temperature in the living room (questionnaire question 5w) in relation to the average outdoor air temperature and the average indoor air temperature on the day of the survey. Grouped according to the temperature perception („warm“, „rather warm“, „neutral“, „rather cool“, „cool“, the groups „cool“ und „hot“ are not registered due to the small number of cases). The trend lines and arrangement shown are based on the adaptive comfort model for building 4.

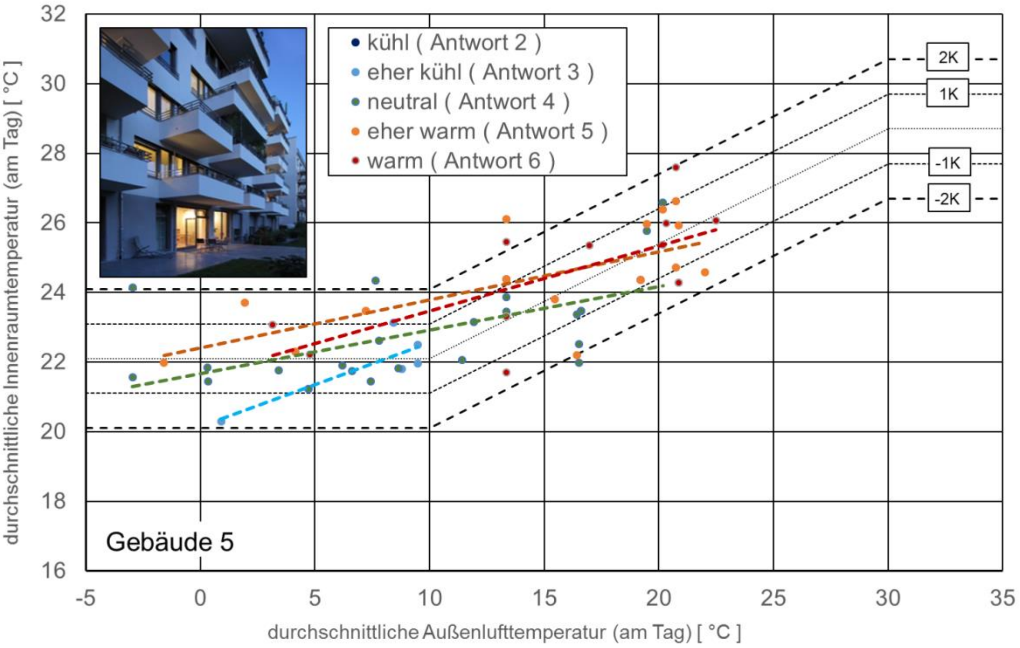

Figure 6:
Description:
Relationship between the perceived temperature in the living room (questionnaire question 5w) in relation to the average outdoor air temperature and the average indoor air temperature on the day of the survey. Grouped according to the temperature perception („warm“, „rather warm“, „neutral“, „rather cool“, „cool“, the groups „cool“ und „hot“ are not registered due to the small number of cases). The trend lines and arrangement shown are based on the adaptive comfort model for building 5.

Room temperature in Winter

In the desired area	=	*20-22°C*
Deviated	=	*Deviation by one °C*
Strongly divergent	=	*Further deviation*

Room temperature in Summer

In the desired area	=	*22-24°C*
Deviated	=	*Deviation by one °C*
Strongly divergent	=	*Further deviation*

CO_2-concentration

In the desired area	=	*Time with values >1000ppm: >5%*
Deviated	=	*Time with values >1000ppm: >10%*
Strongly divergent	=	*Time with values >1000ppm: >15%*

Figure 7: Table 1
Description:
Measured indoor climate values

Winter temperature performance, summer temperature performance, air quality

Positive	=	Q_1 >= 4
Rather positive	=	Q_1 < 4 AND Median >= 4
Neutral	=	Median >= 3 AND Median < 4
Rather negative	=	Q_1 > 2 AND Median < 3

Negative = $Q_1 < 2$ *AND Median* < 3

Figure 8: Table 2
Description:
Subjective building performance

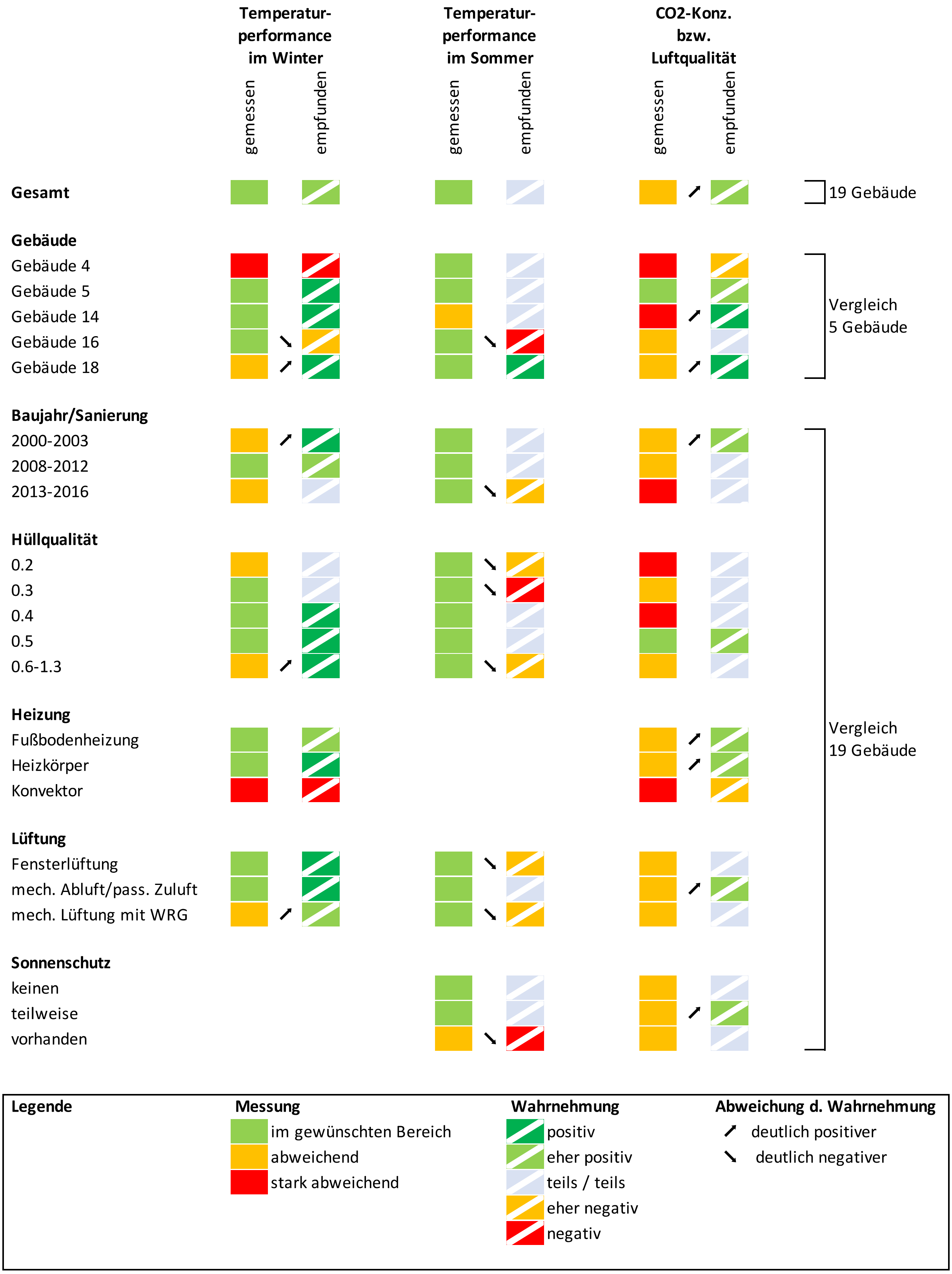

Figure 9: Table 3
Description:
Comparison of the buildings with each other