

Figure 2 Specific primary energy consumption and CO₂-emissions of 3 analyzed buildings in Karlsruhe-Rintheim.

performance gap. The influence of the occupants in buildings with complex, sophisticated system technology often leads to increased energy consumption. Thus, another project has been funded (2012 to 2015) called “The impact of the rebound effect on the refurbishment of the existing building stock”. An intensive monitoring has been installed in the three above mentioned buildings with different variants.

In this case, measured data with respect to temperature and humidity are shown for building 3 with three entrances and the different flats (Figure 3). The data stem from one winter month (February 2013). The average temperature (Celsius) of the flat is shown top left, average humidity is shown top right. The values down left show the percentage of the duration of an open window (based on the total hours of the month) and the values down right show the CO₂ concentration as criteria of air quality. The value in the middle of the cells show heating energy consumption in kWh/m². Orange tones stand for a high and blue tones for a low consumption.

There are some explanations for the results in building R3, for example the location of a flat (inside or outside oriented) or the orientation towards north and south. Not least the behavior of the tenants, their acceptance or handling of newly implemented technologies (e.g. air heating) make a difference. Further analyses suggest that the user-specific heating behavior of neighboring housing units and the associated heat displacement within a building can have a large influence on the heating energy consumption of a single flat. Thus, the project team intervened with some measures: interviews with tenants, information events at the beginning of the heating period and accompanying surveys. In the course of these measures, the tenants were taught the correct use of the heating and ventilation system as well as the basic principles of an appropriate ventilation behavior.

Case 2: School Campus—Detmold

The school campus in Detmold consists of three buildings from the late 1950s, retrofitted between 2010 and 2015 accommodating around 3,600 students. The buildings of the

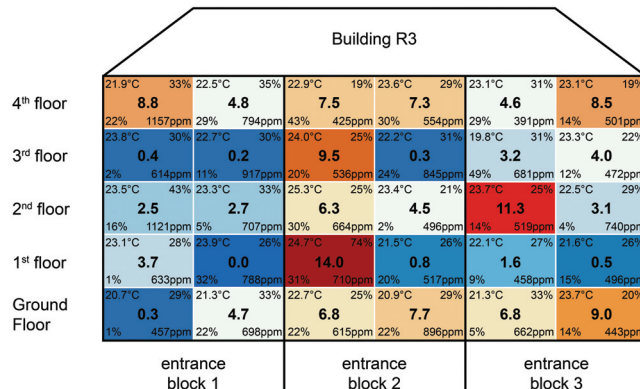


Figure 3 Chromatic representation of 30 flats in building R3: the colored boxes represent one flat each with their monthly averages measured in February 2013; orange tones stand for a high and blue tones for a low specific heating energy consumption (Source: illustration based on Calì et al., 2016, p.81)

two vocational colleges (Berufskolleg), the “Felix-Fechenbach-Berufskolleg” with two buildings and the “Dietrich-Bonhoeffer-Berufskolleg” with one building were thoroughly renovated. The aim was to achieve a significant improvement in energy efficiency and to improve the quality of the school stay in terms of high comfort for students and teachers. With an energy related surface of 9,373 m² (104,730 ft²) and a high energy demand of 272.3 kWh/m² (86 MBTU/ft²) per year, the goal of a plus energy campus was challenging. However, the measured consumption after retrofit was 42.2 kWh/m² (13 MBTU/ft²) in 2016, reaching even a lower value than calculated. An intensive monitoring of energy consumption, indoor environmental quality (IEQ) and user satisfaction is still ongoing.

The heating energy consumption of 42.2 kWh/m²a (13 MBTU/ft²) of the Felix-Fechenbach college and the Dietrich-Bonhoeffer college in Detmold, which is supplied by district heating, fits very well to the numbers calculated in advance (Figure 5). Domestic hot water consumption however is clearly above the calculated value at 23.5 kWh/m²a (6.3 MBTU/ft²). The upgrading of the previously uninsulated domestic hot water network and the shutdown of irrelevant areas are still being implemented. The high consumption is due to the fact that two oversized circulation pumps have to send the domestic hot water through old pipes over almost the entire campus. Therefore, they need high flow rates due to the large thermal losses in order to minimize the drop in temperature of the domestic hot water in order to ensure the necessary hygiene. For lighting and ventilation, no separate measurements are available.

The original energy target of the Felix-Fechenbach- und Dietrich-Bonhoeffer-Berufskolleg in Detmold was a plus energy standard considering the primary energy demand for

