BEHAVE 2020
6th European Conference on Behaviour and Energy Efficiency
Copenhagen, 21-23 October 2020

THE SPECTRUM OF RESIDENTIAL COOLING DEMAND – MODELED DEMAND VERSUS OCCUPANTS' REAL-LIFE NEEDS

J. Mittermüller[1]* and F. Banihashemi[2]

1: Lokale Passung – Sozialstruktur und Umweltanpassung
Institute of Sociology
Ludwig-Maximilians-University (LMU) Munich
Konradstr. 6, 80801 Munich
e-mail: julia.mittermueller@soziologie.uni-muenchen.de, web: https://www.lokale-passung.de

2: Institute of Energy Efficient and Sustainable Design and Building
Department of Architecture and the Department of Civil, Geo and Environmental Engineering
Technical University of Munich
Arcisstr. 21 80333 Munich
e-mail: farzan.banihashemi@tum.de, web: https://www.bgu.tum.de/enpb

Keywords: cooling energy demand, indoor thermal comfort, occupant behaviour, mixed-methods approach, simulation, energy sufficiency

1. Introduction

The heat waves of the past two decades have pushed climate adaptation and mitigation of heat stress in the building sector up the political and public agenda also in regions with temperate climates, like Western Europe. The average number of Cooling Degree Days (CDD) in temperate regions like Germany have doubled within the last 50 years [1], and cooling energy demand is predicted to multiply. Building standards define certain temperature thresholds above which a building is considered "overheated" and needs cooling. The residential cooling energy demand is, thus, directly related to the number of hours in which indoor temperatures exceed this critical numerical threshold. What this understanding of 'cooling demand' does not consider, though, is the actual need for active cooling experienced by the occupants themselves. Thermal comfort models of the occupants exist but the majority of these models include neither occupants' activity patterns, nor sociodemographic and psychological factors [2].

We suppose there is a substantial difference between the predicted cooling demand and the cooling demand perceived by the actual users due to the following two crucial factors: 1.) There is a huge intra- and inter-individual variance regarding thermal perception and thermal preferences [3], [4]. 2.) People are not passive recipients of thermal stimuli as chamber experiments often suggest, in contrast, they can react with a variety of adaptive actions, such as modifying clothing levels, adjusting blinds, or even adapting their expectations of comfort [5].

Considering these aspects, the actual demand for active cooling from the residents' perspective may well be much lower or higher than the calculated cooling demand. Depending on individual thermal preferences, occupancy schedules, and people's everyday practices (i.e. adaptive behaviour but also practices, which increase internal heat gains), we claim there could be a substantial energy-saving potential while maintaining thermal comfort. In this interdisciplinary mixed-methods study, we seek to quantify this potential by comparing the predicted cooling demand based on thermal comfort simulations of residential buildings in Munich, Germany, with the perceived cooling demand based on the residents' thermal comfort levels stated in our survey.

2. Methodology

Energy consumption in buildings can be investigated in a top-down or bottom-up approach [6]. While the top-down approach focuses on macroeconomic factors, the bottom-up approach depends on socio-demographic, household and energy behaviour characteristics and data [6]. In order to make policies on a district level with the focus on the occupant, the bottom-up approach should be implemented [7]. The present study introduces a bottom-up methodology and combines household-survey and thermal building simulation results in order to identify

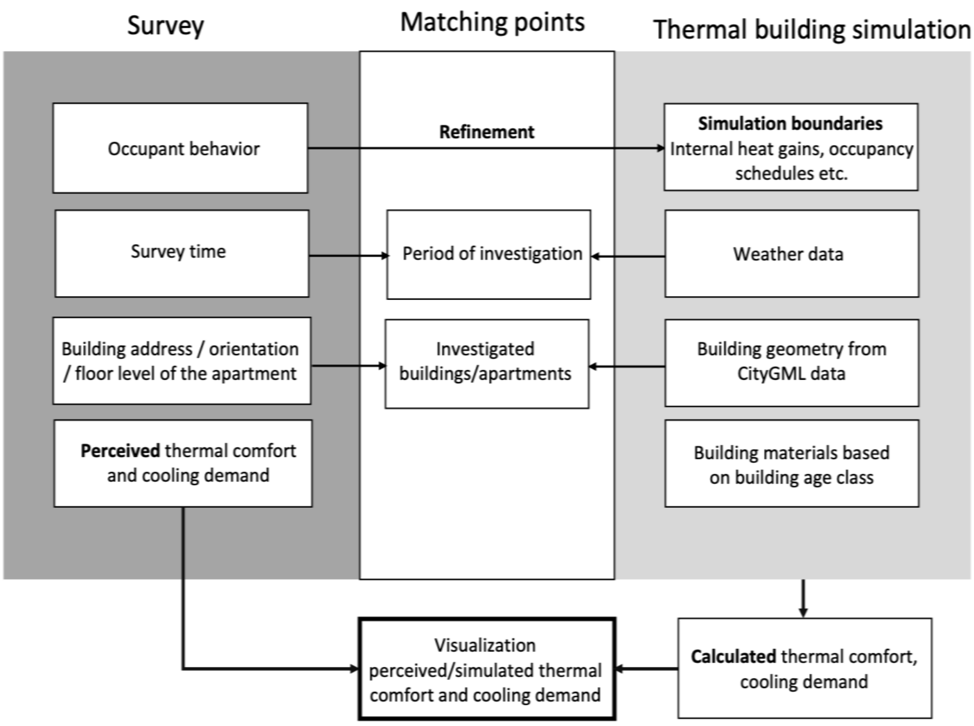


Figure 1. Mixed methods approach merging household survey data (resident's thermal comfort and cooling demand) with simulation results (calculated thermal comfort and cooling demand).

possible strategies to improve the thermal comfort while at the same time reducing or even avoiding the energy demand for active cooling (see Figure 1).
We have selected three areas in the city of Munich, Germany, as study sites which cover the most typical types of city neighbourhoods in Germany and many other European cities to ensure transferability. These are usually characterized as follows:

1) Mainly older buildings in the city centre with high urban density and low green space

2) Mainly residential buildings from the 60's/70's at the outskirts with medium density due to compact or high rise building structure and large public green spaces

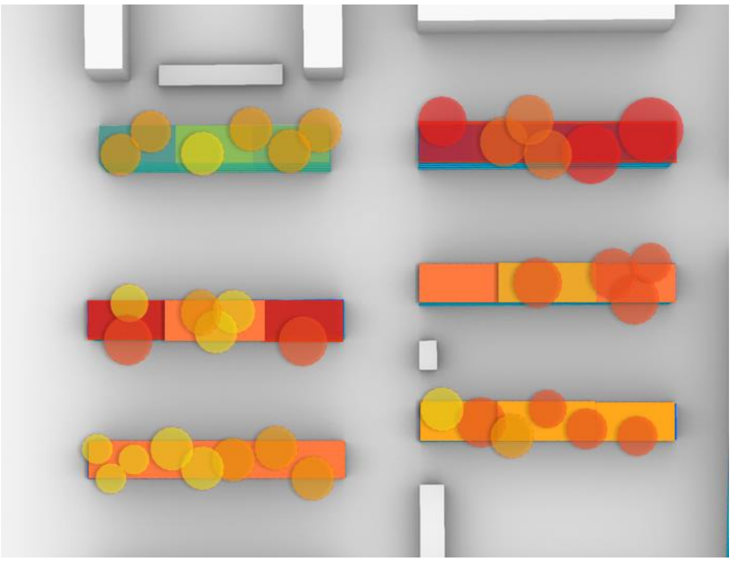
3) Mainly detached houses or small multi-family apartment buildings at the outskirts with low density and a large share of private green space

The urban energy simulation will be carried out with *urban modeling interface* (umi) [8]. The simulation model will be extracted out of the CityGML data and boundary conditions will be assigned according to the building age classes. The boundary conditions will be refined based on the survey outcomes. The survey, carried out in June/July 2020, assesses the perceived cooling demand, indoor thermal comfort, user behaviour, characteristics of the apartment, the individual person and the neighbourhood.

3. Results

At the moment of abstract submission, the research is still ongoing. Key highlights will include the visualization of the results which can be used by planners and policymakers as a decision-making tool (see Figure 2). The visualization uncovers the difference between the predicted and the perceived thermal comfort, thus, making visible the saving potential in cooling demand.

Figure 2. An example of a visualization with umi rendered in Rhinoceros. The colors of the buildings show the simulated



degree of overheating (cooling demand) based on DIN4108-2 building standards. The colors of the circles show the degree of overheating (cooling demand) perceived by the residents.

Additionally, the survey data will allow us to specify what it is that mainly causes this saving potential by examining how building physics, behaviour and individual thermal perception contribute to reduce or enhance indoor heat stress, thus influencing the perceived need for active cooling.

4. Conclusion

Our research can show how, in Germany, occupants are able to avoid active cooling and save energy while still experiencing thermal comfort. It is, thus, of great importance to support and enhance the range of energy-sufficient behaviors and attitudes in residents in order to prevent the spread of mechanical cooling as a new building standard. This visualization-tool contributes to this goal by quantifying the energy-saving potential and uncovering possible levers to provide energy-sufficient thermal comfort through architecture and urban planning by considering behavioural, psychological, and social aspects.

References

[1] F. Schröder, B. Gill, M. Güth, T. Teich, and A. Wolff, "Entwicklung saisonaler Raumtemperaturverteilungen von klassischen zu modernen Gebäudestandards - Sind Rebound-Effekte unvermeidbar?", *Bauphysik*, Vol. 40, pp. 151–160, (2018).

[2] E. R. Frederiks, K. Stenner, and E. V. Hobman, "Household energy use: Applying behavioural economics to understand consumer decision-making and behaviour". *Renewable and Sustainable Energy Reviews*, Vol. 41, (2015).

[3] M. Schweiker, G. M. Huebner, B. R. M. Kingma, R. Kramer, and H. Pallubinsky, "Drivers of diversity in human thermal perception – A review for holistic comfort models". *Temperature,* Vol. 5, pp. 308–342, (2018).

[4] R. F. Rupp, N. G. Vásquez, and R. Lamberts, "A review of human thermal comfort in the built environment", *Energy and Buildings*, Vol. 105, pp. 178–205, (2015).

[5] M. Nikolopoulou, and K. Steemers, "Thermal comfort and psychological adaptation as a guide for designing urban spaces", *Energy and Buildings*, Vol. 35, pp. 95–101, (2003).

[6] L. G. Swan, and V. I. Ugursal. "Modeling of end-use energy consumption in the residential sector: A review of modeling techniques". *Renewable and Sustainable Energy Reviews*, Vol. 13, 1819-1835, (2009).

[7] T. Zhang, P.-O. Siebers and U. Aickelin. "A three-dimensional model of residential energy consumer archetypes for local energy policy design in the UK". *Energy Policy*, Vol. 47, 102-110, (2012).

[8] C. F Reinhart, T. Dogan, J. A. Jakubiec, T. Rakha and A. Sang "umi – An urban simulation environment for building energy use, daylighting and walkability", *Building Simulation 2013*, Chambery, France, (2013).