A Parametric Study: Impact of Thermal Mass on Summer Overheating for Residential Buildings in Germany

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Abstract

Rising average temperatures and the increasing frequency of heatwaves as a result of climate change make effective passive measures for indoor overheating mitigation urgently needed. This paper evaluates the future thermal performance of 2,880 building variants, focusing on material- and design-related parameters, using climate data sets intended to represent future conditions. The study shows that future climate datasets (TRY-45) for all three summer climate regions in Germany only represent current summer conditions, emphasizing the need for additional climate data to simulate future scenarios. Based on the parametric simulation outputs, the statistical analysis suggests that window-to-floor ratio, sun shading, and thermal mass of exterior walls have the greatest impact on overheating hours in residential buildings. The assessment of a reduced set of variants, that comply with both thermal and visual comfort, indicates that façade configurations with medium- and high bulk density materials offer a larger degree of design freedom for window sizing than lightweight configurations.

Keywords: parametric simulation, thermal mass, overheating hours, thermal comfort, visual comfort

1. Introduction

High temperature anomalies are getting more severe and occurring more often. This problem has become even more acute in the last years with constant new record braking-temperatures registered worldwide. Recently, the global average surface temperature surpassed in 1.48 °C the 1850-1900 reference value (Copernicus, 2024). With this, the past nine years have been the warmest on record globally (Umweltbundesamt, 2024).

Global warming can be largely attributed the emission of greenhouse gases, where the building sector plays a major role (Levermore G, 2008). Despite existing pacts to limit global warming, such as the Paris Agreement, it is likely that the threshold of 1.5 °C above preindustrial levels will be surpassed by 2030, rather than by 2100 as initially intended. This rapid trend implies irreversible effects on ecosystems and further acceleration of climate change (Armstrong McKay, D. I. et al., 2022).

Europe exhibits temperatures that are rising twice as fast as the global average since the 1980s (EEA, 2024). More frequent and intense heat extremes are taking place in Germany, where the number of Summer Days with a maximum temperature of at least 25 °C has more than doubled since the 1950s, while the number of Hot Days with a maximum temperature of at least 30 °C has nearly tripled. (DWD, 2024)

Recurring elevated outdoor temperatures lead to more frequent high indoor temperatures, causing thermal discomfort. Furthermore, high indoor temperatures can trigger cardiovascular health problems, as well as cognitive impairments, among other issues (Cicci et al., 2022; Khan et al., 2021). The use of air conditioning is a countermeasure; however, they rely on energy-intensive systems typically powered by fossil resources, which generate additional CO_2 emissions and further exacerbate the problem. Passive design strategies are a better approach to mitigate indoor overheating. The German standard DIN 4108-2establishes a general framework with minimum requirements for summer heat protection promotes such passive strategies and measures. These measures aim to prevent high room temperatures during the summer in buildings without mechanical cooling.

This research explores a set of passive measures for residential buildings and evaluates their effectiveness in improving thermal comfort. In addition, for a selected future scenario, daylighting conditions are evaluated to establish minimum window-to-floor ratio values. The assessment of both, thermal and visual comfort reveals

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dependencies between external wall types and window ratio. The study aims to address the following research questions: What passive design strategies in Central Europe are effective in reducing overheating in residential buildings? Which of the construction types offer advantages regarding flexible window sizing configurations?

2. Methodology

To reach the formulated objective, a parametric study was set up using dynamic building simulations at a detailed room level. The parametric study assessed a total of 2,880 variants and it is performed using TRNLizard (Transsolar Software Engineering, 2017), which allows automated input parameter variations for thermal simulations with TRNSYS via additional scripts. The evaluation of all performed simulations was rated using automated scripts with statistical functions.

Each simulated variant is assessed according to the thermal comfort band for operative room temperature defined by DIN EN 16798-1 and the number of overtemperature hours (OTH [Kh a^{-1}]). Consequently, results of OTH lead to corresponding exceedance frequencies (EF [%]) during occupancy or usage time. Since the study focuses only on residential buildings without mechanical cooling, we use the adaptive comfort band within Category II as a realistic framework for the assessment.

The study is divided into three analysis stages, each building upon previous results. First, Test Reference Years (TRY) datasets from the German Weather Service (DWD) are compared against measured weather data for all three summer climate regions. This comparison is intended to verify the suitability of TRY datasets for subsequent investigations. In the second stage, a parametric study is conducted, and its results are statistically rated to identify the most effective passive measures. In the third stage, certain combinations of measures are selected to compare them according to their thermal- and visual comfort performance. Plotting the results for both comfort categories elucidates the degree of design freedom enabled by each configuration.

3. Modeling and Simulation

3.1. Climate Analysis (Stage One)

Using future weather data in thermal building simulations is essential due to the long lifespan of buildings, typically 50 to 100 years, during which significant climate changes are expected. Considering future conditions ensures that currently built spaces will remain comfortable and energy-efficient in the future (Cellura et al., 2018). Moreover, future climatic conditions will greatly impact heating and cooling demands. Studies, such as those by Cellura et al. (2018) indicate that while heating energy demand will decrease, cooling energy demand will increase drastically.

To verify whether the future weather data provided by the German Weather Service (DWD) is suitable for our study, test reference years for the present (TRY-15) and future (TRY-45) were compared with measured weather data for the respective locations.

The impacts of climate change vary regionally. Vukadinovic et al. (2020) and Cellura et al. (2018) highlight that urban areas may be more affected by summer overheating than rural regions. The urban heat island effect causes cities to have higher temperatures and longer heat periods. The study of Vukadinovic et al. (2020) also shows that the differences in Gh26 values (excess temperature degree-hours over 26 °C) are so significant that a differential consideration of the summer climate regions is necessary. When considering summer thermal protection in Germany, the standard DIN 4108-2 distinguishes between three different summer climate regions. Table 1 shows representative locations commonly used.

Tab. 1: Summer Climate Regions

Summer climate region		Indoor temperature ref. value	Location
A	cool	25 °C	Rostock
B	temperate	26 °C	Potsdam
C	warm	27 °C	Mannheim

3.2. Parametric Analysis (Stage Two)

The study starts with the "small multi-family building" by Klauß and Maas (2010) as reference for the studied space because of its comprehensive inclusion of various building types and frequent use in other studies (Doleski, 2020; Schlitzberger et al., 2017). The model building was slightly adapted, and the two critical rooms shown in Figure 4 were chosen to perform the simulation.

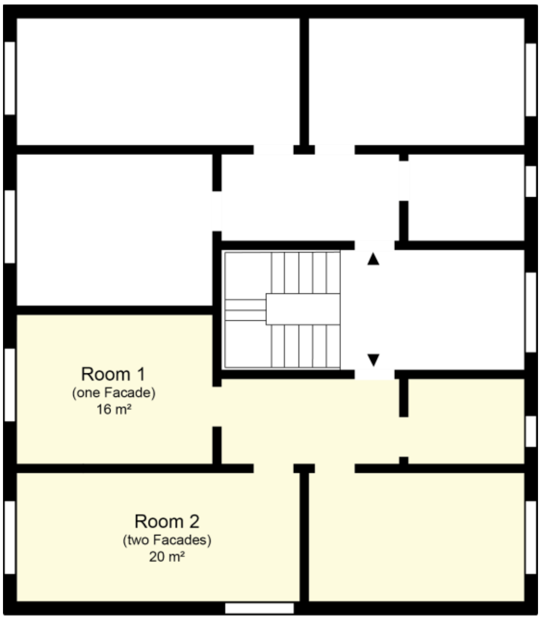


Fig. 4: Floor plan of the modified model building (own illustration based on Schlitzberger et al. (2017))

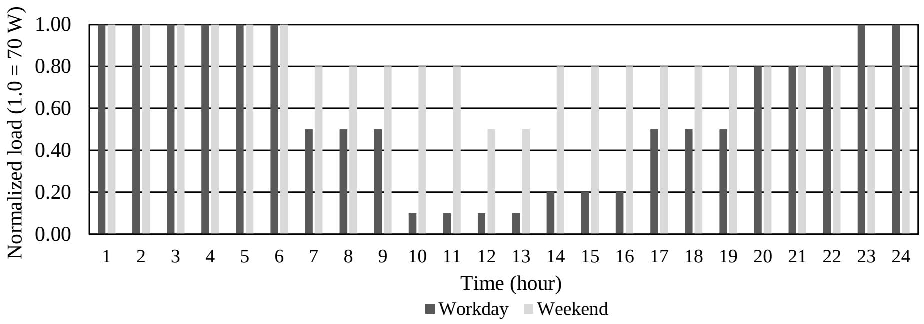
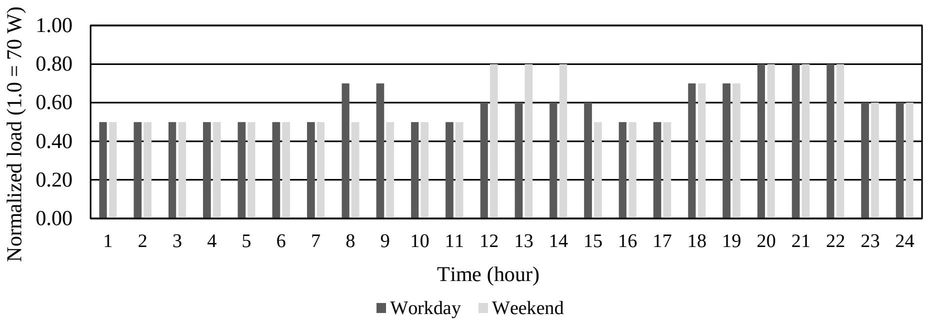
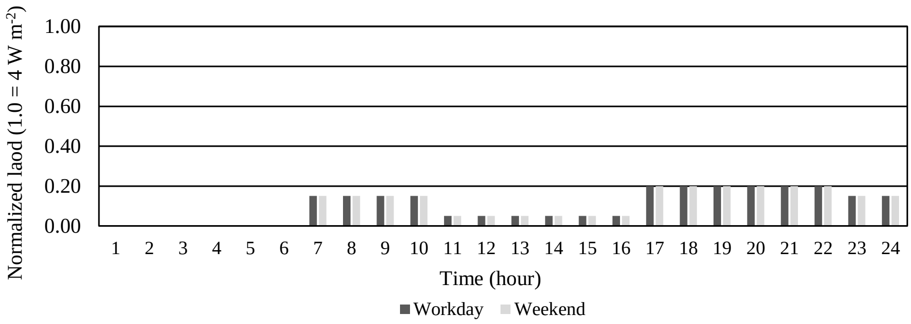
Table 2 summarizes the general boundary conditions to perform the thermal simulation. These values are based on established German standards, specifically DIN 4108-2:2013-02 and DIN V 18599-10:2018-09.

Tab. 2: Boundary Conditions for Thermal Simulation

Boundary Condition	Value
Room set temperature	20 °C $\leq \theta_i \leq$ 25 °C
Night setback	$\Delta\theta_{i,NS}$ = 4 K
Annual usage days	365 d a^{-1}
Daily heating operating time	6 a.m. – 11 p.m.
Base air exchange rate	n = 0,5 h^{-1}
Increased day/night air exchange rate	n = 3 h^{-1} and n = 5 h^{-1} (depending on occupancy schedule)
Sun protection control based on threshold irradiance I_{lim}	NE, NW: $I_{lim} \geq$ 200 W m^{-2} Other orientations: $I_{lim} \geq$ 300 W m^{-2}
Active cooling	None
Ventilation unit	None

DIN 4108-2, defines that for thermal simulations, all internal heat loads caused by occupants, electronic devices, and artificial lighting are combined into a continuous load of 100 Wh m^{-2} d^{-1} or about 4.16 W m^{-2}. Since we chose a more detailed approach, values and profiles for each internal heat source are based on Annex C of DIN EN 16798-1. The following table summarizes the implemented occupancy schedules.

Tab. 3: Day Profiles for each Internal Heat Load

Internal Heat Load	**Schedule**
Occupants	
Electronic equipment	
Light	

A minimum air exchange rate of 0.5 h^{-1} was defined as a baseline. In addition, elevated air exchange rates can be expected when windows are opened. In this case, an increased value up to 3.0 h^{-1} was defined for a standard room (openable window in one facade) and up to 5.0 h^{-1} for a corner room (openable windows in two facades). We assumed no automated window opening system in residential buildings; therefore, windows are only opened during occupancy, i.e. from midnight to 8 a.m. and from 6 p.m. to midnight. Window opening only occurs when the indoor air temperature exceeds 23 °C and is higher than the outdoor air temperature (DIN 4108-2:2013-02).

The total number of simulations is derived from building variations, namely: exterior wall types, slab types, room types, ceiling heights, room orientations, window-to-floor ratio, and shading types. The variant matrix is shown in Table 4.

Tab. 4: Variant matrix

<table>
<tr><th>Parameter</th><th colspan="7">Levels</th><th>Total</th></tr>
<tr><td>Room type</td><td colspan="4">One facade</td><td colspan="3">Two facades</td><td>2</td></tr>
<tr><td>Sun shading</td><td colspan="4">No shading</td><td colspan="3">Ext. shading</td><td>2</td></tr>
<tr><td>Location</td><td colspan="2">Rostock</td><td colspan="3">Potsdam</td><td colspan="2">Mannheim</td><td>3</td></tr>
<tr><td>Room height</td><td colspan="2">2.4 m</td><td colspan="3">2.8 m</td><td colspan="2">3.2 m</td><td>3</td></tr>
<tr><td>Orientation</td><td colspan="4">NO</td><td colspan="3">SW</td><td>2</td></tr>
<tr><td>Window-to-floor ratio</td><td>0.12</td><td>0.18</td><td colspan="2">0.25</td><td colspan="2">0.30</td><td>0.34</td><td>5</td></tr>
<tr><td>Exterior wall</td><td>AW0
(timber)</td><td colspan="2">AW1
(ρ = 600 kg m^{-3})
Insulating Brick</td><td colspan="3">AW2
(ρ = 1200 kg m^{-3})
Perforated Brick</td><td>AW3
(ρ = 1800 kg m^{-3})
Sand-Lime Brick</td><td>4</td></tr>
<tr><td>Slab</td><td colspan="4">Timber</td><td colspan="3">Concrete</td><td>2</td></tr>
<tr><td></td><td colspan="7"></td><td>2880</td></tr>
</table>

The façade serves as the primary interface between outdoor and indoor conditions. Therefore, most of the studied parameters are related to the building envelope. The size of the window is a relevant parameter in our research. Hereby the size of the window is defined as the window area ratio relative to the usable floor area, or short “window-to-floor ratio”.

The variation in exterior wall types focuses on different bulk densities. Additionally, room-enclosing elements (interior walls) are categorized into two groups (Table A2) and assigned based on the material type used in the façade. An overview of these components, including their material properties, is provided in Table A1 and Table A2 in the Appendix. Four different exterior wall constructions with low to high bulk densities were examined. The bulk density values, as indicated in kg m^{-3}, are grouped into bulk density classes (BDC) for simplification:

- AW0: Timber frame construction
- AW1: Insulating brick with a BDC of 0.6
- AW2: Perforated brick with a BDC of 1.2
- AW3: Sand-Lime brick with a BDC of 1.8

Variants AW2 and AW3 are constructed as double-leaf exterior walls. The outer leaf, made of an insulating brick (e.g., Poroton-WDF-180), functions similarly to an external thermal insulation composite system (ETICS), while the inner load-bearing wall leaf with a bulk density class of 1.2 or 1.8 acts as a thermal storage layer.

In addition, the massive timber slab appears to gain greater relevance in the near future and is therefore contemplated in our study. As a viable alternative to components with CO_2-intensive production processes, the massive timber slab offers both ecological and economic advantages (Abed et al., 2022) compared to the standard reinforced concrete slab, which is also analyzed in our study.

3.3. Degree of Design Freedom (Stage Three)

Each parameter combination in the given matrix yields a different result regarding overheating hours. The implementation of certain measures enables thermal comfort without compromising the degree of flexibility in design-related parameters. Based on the results of the previous section (stage two), the passive measures with the most influence on heat mitigation are further analyzed by plotting their occurrence of overheating hours. These results show parameter configurations that enable extended design flexibility while complying with thermal and visual comfort requirements.

In order to filter the 2,880 variants and establish a reduced set of relevant scenarios, the following assumptions are considered:

- The political commitment to achieve decarbonization goals in Germany is expected to increase the market relevance of timber products. Therefore, mass timber slabs are likely to replace a significant portion of the currently dominant reinforced concrete.
- A room height of 2.8 m is considered representative of both currently built and future residential spaces.
- Although sun protection in glazed surfaces plays a major role in mitigating indoor overheating, this section (stage three) focuses only on results with a g_{tot} = 0.6 (total energy transmittance value). Sun-protective glazing is excluded from the study as it reduces solar gains during winter and significantly limits daylight conditions during the same period. Manually operated external shading is a common configuration in current projects, however, a correct and consistent operation (user-dependent) cannot be guaranteed. This leads to several user behavior scenarios that are beyond the scope of this study.

To establish threshold values for both thermal and visual comfort, we refer to the standards outlined in German regulations. The selected metric to assess summer thermal comfort is the “Frequency of Excess Temperature” also known as Over Temperature Hours (OTH), whereas visual comfort is evaluated using the Daylight Factor (DF).

The term "frequency of excess temperature" encompasses all hours during which the adaptive comfort ranges are exceeded. A certain number of overheating hours should not compromise human thermal comfort and are therefore tolerated. Values of 3 % (equivalent to 259 hours per year) and 5 % (equivalent to 432 hours per year) during the occupancy period in residential buildings are considered acceptable thresholds established in DIN EN 15251, the preceding norm to DIN EN 16798-1. These thresholds have been also used in building certification systems such as DGNB (2018).

The German standards catalog offers well-defined daylight thresholds for office and other working spaces; however, such thresholds are not established for residential spaces. This study uses recommendations in DIN EN 17037 based on calculations under a covered sky with a diffuse horizontal illuminance of approximately 14,000 lux (DIN EN 17037, 2019). An appropriate level of illumination is achieved when DF exceeds 2 % on a horizontal plane at a height of 0.85 m above the floor over at least 50 % of the room area, and DF is also above 0.7 % for more than 95 % of the room area. These values approximately correspond to illuminance levels of 300 lux and 100 lux, respectively, and when fulfilling both conditions, the space is considered well-lit.

4. Results and Discussion

4.1. Climate Analysis (Stage One)

Besides average dry-bulb temperatures, the DWD defines other indicators such as “Climatological Reference Day” (*Klimatologischer Kenntag* in German). A "Climatological Reference Day" refers to a day on which a specific threshold of a climatic parameter is met or exceeded. Summer Days, Hot Days, and Tropical Nights are suitable for summer climate assessment. A Summer Day is defined by a maximum temperature of at least 25.0 °C, while a Hot Day is characterized by a maximum temperature of at least 30.0 °C. Conversely, Tropical Nights are defined by a minimum temperature that does not fall below 20.0 °C (Deutscher Wetterdienst, 2023).

Figure 5 shows the annual values for average temperatures, Hot Days, and Tropical Nights. The orange columns represent the average measured data from 2016 to 2021, whereas the blue columns display values from the Test Reference Year (TRY) datasets: TRY-15 (light blue) and TRY-45 (dark blue). The locations of the weather stations correspond to the locations of the TRY datasets, enabling a direct comparison between measured and reference data.

The results indicate that the TRY-15 datasets do not accurately reflect current climatic conditions. In contrast, the TRY-45 datasets provide a more accurate representation of all climate regions, particularly in terms of the above-mentioned Climatological Reference Day categories. Since our focus is on future climate projections and the German Weather Service does not provide datasets beyond TRY-45, we selected the dataset RCP 4.5 2080 (Representative Concentration Pathway, a moderate climate scenario for the year 2080, defined by the IPCC) retrieved from Meteonorm as a representative weather dataset for future climate conditions.

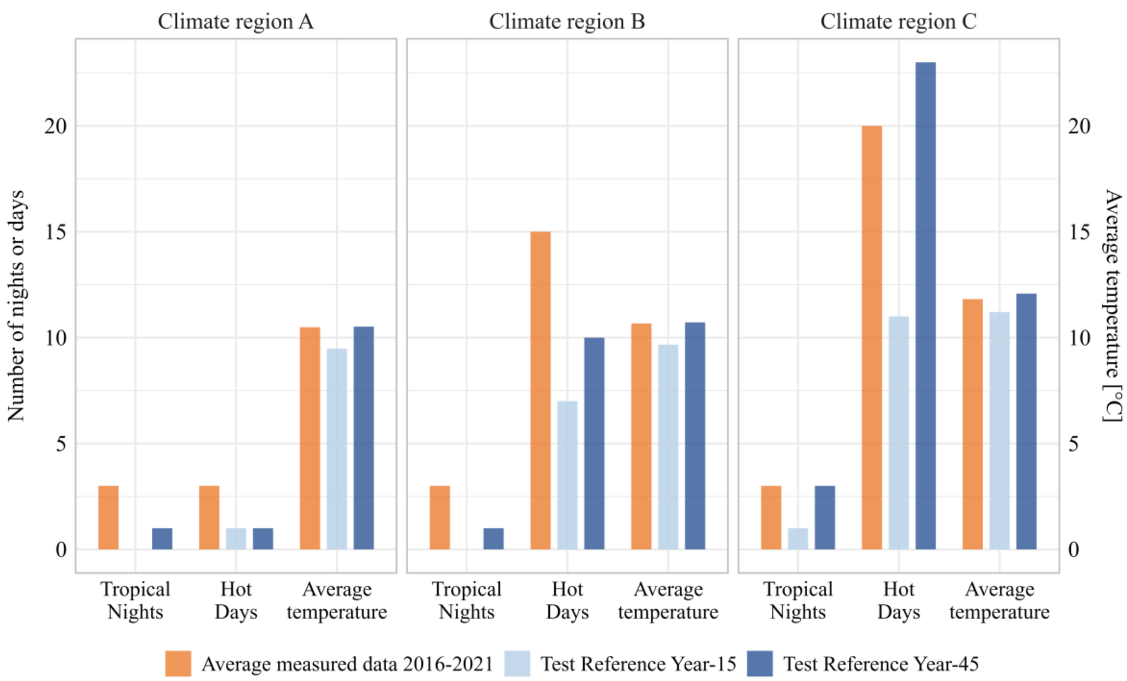


Fig. 5: Climatological reference days: Comparison between measured data and available reference data (TRY)

4.2. Parametric Analysis (Stage Two)

To identify which parameter has the most significant impact on overheating hours, we employed the Spearman correlation coefficient to determine the effect size, given its suitability for non-parametric and ordinal data. This method allows us to effectively measure the strength and direction of the association between each parameter and overheating hours. Figure 6 depicts the correlation coefficient between the analyzed parameters and overheating hours. Focusing on the strength of the effect, we considered the absolute values of the correlation coefficients, making it easier to compare the magnitudes of the relationships, as the direction of the correlation does not play a significant role in this analysis. According to Cohen's (1992) guidelines for interpreting effect sizes, the correlation coefficients are categorized as follows: small (0.1 to < 0.3), medium (0.3 to < 0.5), and large (≥ 0.5).

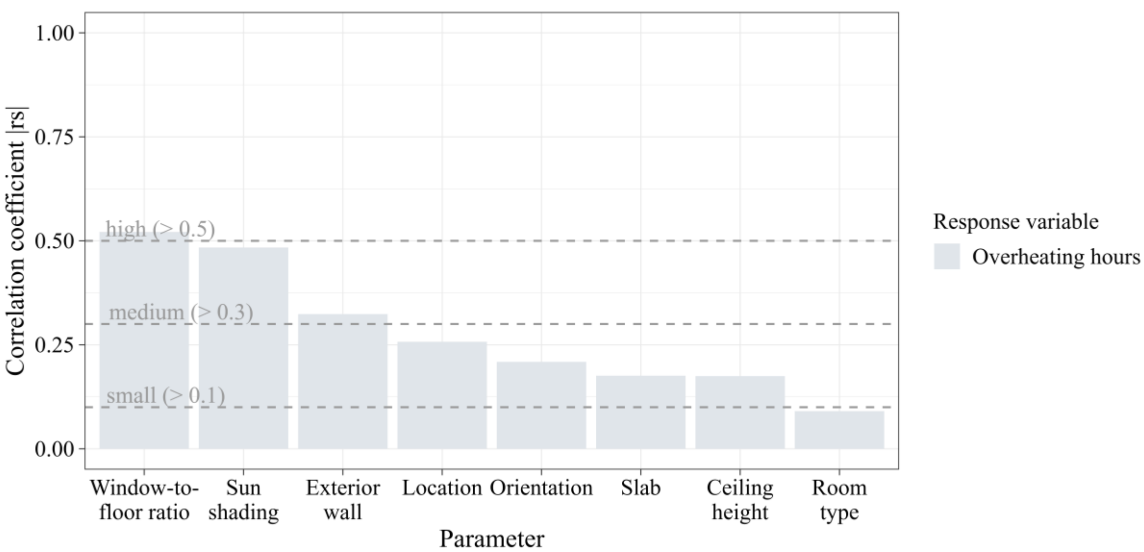


Fig. 6: Comparison of the effect size (correlation coefficient) of the analyzed passive strategies

Here, it can be observed that the window-to-floor area ratio, the sun shading, and the exterior wall have the greatest influence on the overheating hours. In contrast, the room type (room with one façade or with two facades) has the smallest influence. Surprisingly, when the timber frame structure is excluded from the statistical analysis, the influence of the exterior wall shifts from being the third most significant factor to the least significant. This suggests that medium- and high-density exterior wall constructions yield similar results in terms of overheating hours.

4.3. Degree of Design Freedom (Stage Three)

Building on the previous findings, this section focuses on the overheating hours for the four studied exterior wall types in relation to increasing window area ratios. The 5 % OTH threshold in combination with a minimum threshold for daylighting indicates different degrees of flexibility in facade design.

Figure 7 shows two scenarios with performance differences in wall types. Solid lines represent the results for a room with a concrete slab and one façade opening, located in climate region C. Dashed lines correspond to results with the same setup, except for the slab being built in massive timber.

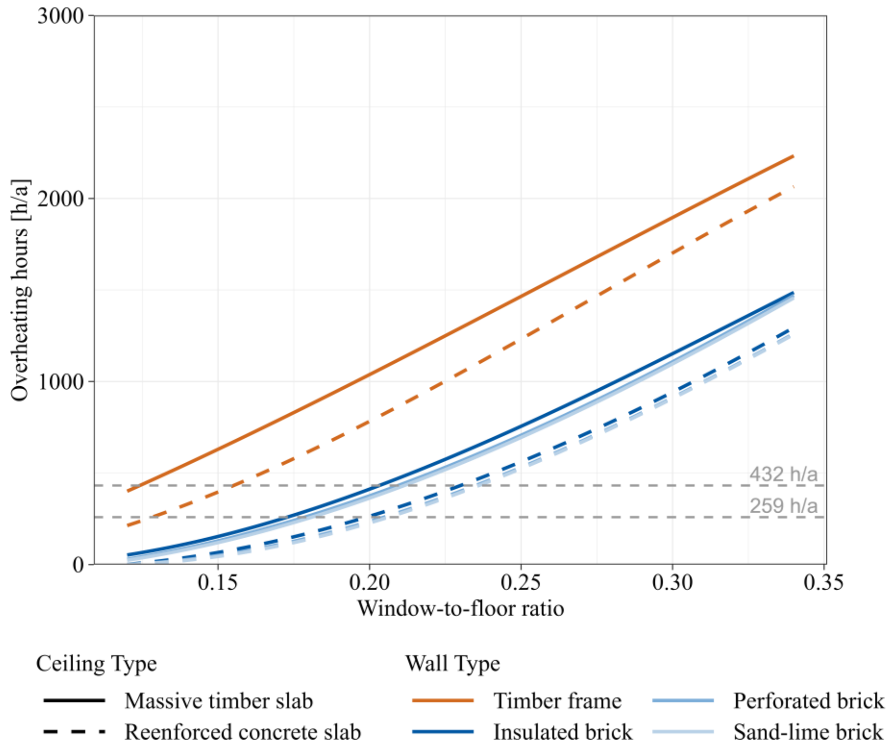


Fig. 7: Overheating hours with increasing window-to-floor ratio for reference room

The overlapping lines for Perforated- and Sand-lime brick suggest that there are no significant performance differences for exterior walls with bulk densities between 1200 kg m^{-3} and 1800 kg m^{-3}. Lightweight constructions may cause overheating issues in the future, even with a low window-to-floor ratio of approximately 16 %. Exterior walls with a bulk density of 600 kg m^{-3} reach this threshold at approximately 22.5 % window-to-floor ratio. In contrast, exterior walls with a bulk density above 1200 kg m^{-3} do not cause overheating issues as long as the window-to-floor area ratio remains below 23.5 %.

When the concrete slab is replaced with a mass timber slab, the suggested 5 % thermal threshold is reached at a window-to-floor ratio of 12.5 % for lightweight façade constructions, 20 % for exterior walls with a density of 600 kg m^{-3}, and 21 % for the other two categories.

Figures 8 and 9 depict the daylight factor results for window-to-floor area ratio of 12 % and 16 % respectively. The daylight recommendation (DF > 0.7 % for more than 95 % of the room) is achieved with a fenestration ratio of at least 15 %. To fulfill the second condition (DF > 2 % for more than 50 % of the room) the window-to-floor area ratio must be of at least 19.5 %. For this study we will take the first stated condition as the absolute minimum daylight requirement to be fulfilled.

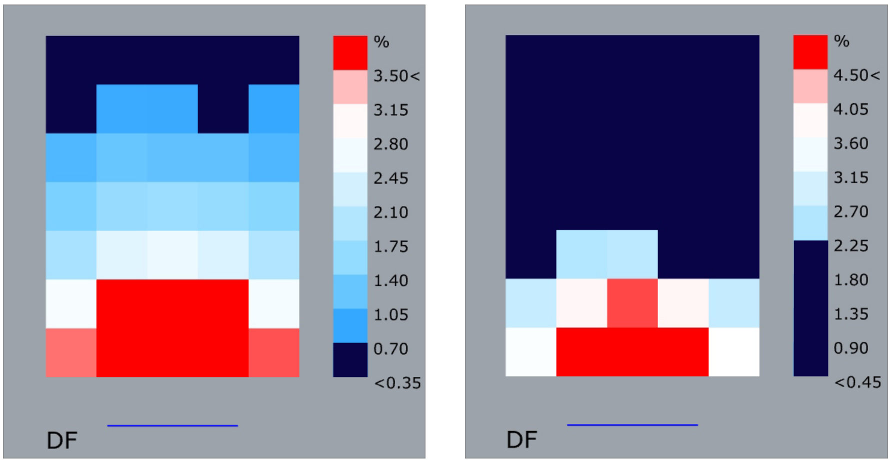


Fig. 8: Daylight performance with DF 0.7% (left) and DF 2% (right) for ref. room with window-to-floor area ratio of 12%

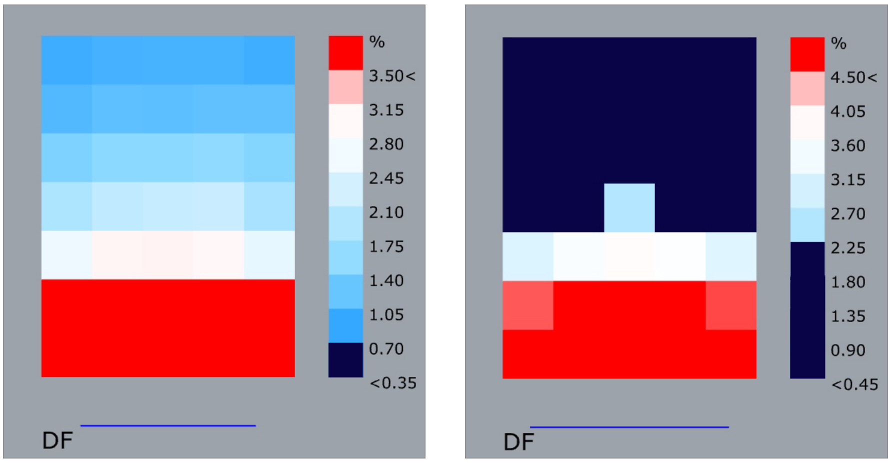


Fig. 9: Daylight performance with DF 0.7% (left) and DF 2% (right) for ref. room with window-to-floor area ratio of 16%

The combination of both (thermal and visual) thresholds defines the degree of design freedom for the planner in terms of flexibility in fenestration ratio, without limiting comfort either due to excessive overheating or the scarcity of natural light in the room. Figure 10 depicts the combination of the reference case with concrete slab presented at the beginning of this section. Evidently, in this case, the lightweight construction offers a reduced fenestration ratio scenario whereas walls with a bulk density of 600 kg m^{-3} and ≥ 1200 kg m^{-3} allow a larger fenestration ratio selection of 15 % and 22.5 %, respectively. In the case of mass timber slab implementation, the design freedom is restricted for all external wall types, mainly affecting results for the timber frame construction as shown in Figure 11.

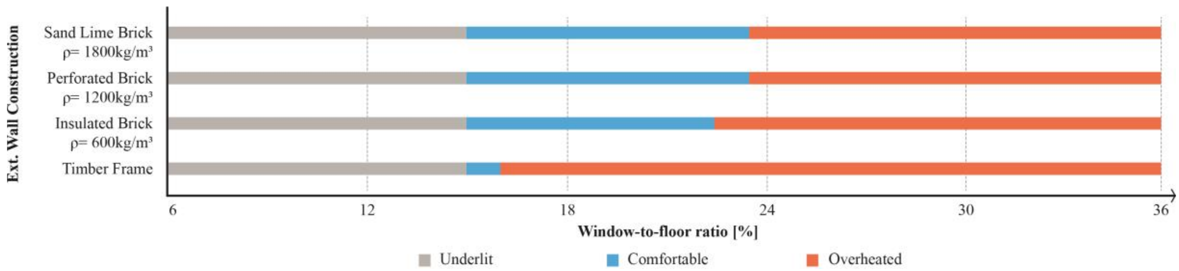


Fig. 10: Degree of Design Freedom by external wall type – Reinforced concrete slab

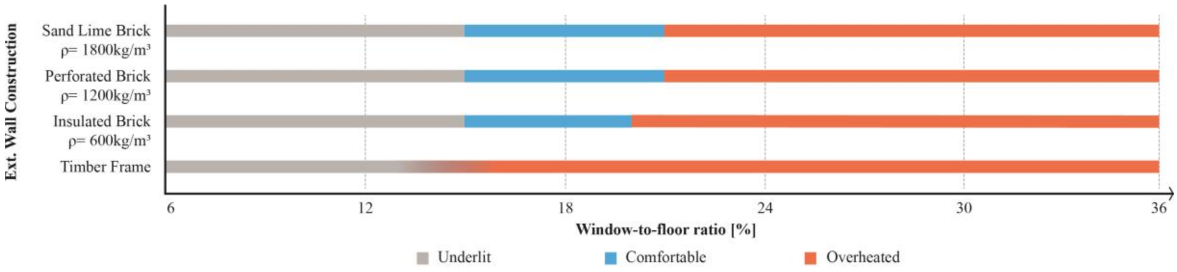


Fig. 11: Degree of Design Freedom by external wall construction type – Massive timber slab

5. Conclusion and Outlook

Within the current and future dynamics of climate change, the summer thermal performance of buildings is becoming increasingly important and is expected to play an even greater role in the future. This study investigated the effectiveness of passive design strategies for summer heat protection in terms of thermal comfort using suitable climate data sets for the future. Following multiple simulated scenarios, evidence was provided that in the future summer heat protection can be achieved within the adaptive comfort range of DIN EN 16798-1 without mechanical cooling. However, this is achievable only with specific passive measure configurations and applying a 5 % Frequency of Exceedance threshold.

The statistical analysis shows that the most effective passive measures, considering minimal energy demand, include reduced window-to-floor area ratio, sun shading, and the mass of the external wall. Nevertheless, thermal storage mass can also be achieved through mass in internal components or through phase change materials. The thermal and visual comfort analysis for specific configurations of thermal mass in relation to window-to-floor ratio indicates that medium- to high-bulk-density facade constructions offer greater design flexibility compared to lightweight solutions. This applies within a contextual scenario where external shading is either not implemented or not properly operated by users.

Although mass in exterior wall constructions offer an advantage in terms of design flexibility for the façade, the decarbonization goals imply a further evaluation of the studied construction types. Environmental aspects (e.g. Global Warming Potential (GWP) or recyclability) have to be also assess and included in upcoming studies.

The analysis of 2,880 simulated variants suggests that, without additional passive cooling measures, lightweight constructions with massive timber slabs and correspondingly low proportions of embodied energy may soon require effective sun protection measures or additional thermal storage to avoid active cooling during summer. Construction elements made of materials with a bulk density of approximately 900 kg m^{-3} or higher provide more leeway regarding additional measures to prevent overheating. However, with respect to improving summer heat protection, no significant differences or further enhancements are observed beyond a bulk density of 1200 kg m^{-3}.

Future research should address relevant aspects beyond the scope of this study. First, although natural ventilation was considered in the assessment, different natural night ventilation scenarios would yield a variety of results relevant to expanding the findings of this study. Second, despite the limited emphasis on natural daylighting in residential buildings, remote work practices have increased over the past four years since the onset of the COVID-19 pandemic and are likely to remain a staple of modern working culture. Therefore, a more detailed daylight study is necessary to establish thresholds for residential buildings. Third, sun shading is an effective strategy for mitigating heat. However, a realistic representation of its operation in residential buildings is challenging and requires an in-depth analysis of user behavior. Building on the current findings, future studies should address these challenges.

6. Acknowledgments

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Appendix

Tab. A1: Exterior wall constructions

	Material	Thickness [m]	Thermal conductivity [W m^{-1} K^{-1}]	Bulk density [kg m^{-3}]	Specific heat capacity [J kg^{-1} K^{-1})]	U-value [W m^{-2} K^{-1}]
AW0						0.18
	Larch wood external wall cladding	0.024	0.155	600	1600	
	Spruce wood battens offset (30/50; 30/80) - ventilation	0.030	0.120	450	1600	
	Fibreboard (MFD)	0.015	0.140	600	1700	
	Construction timber	0.22	0.12	600	1100	
	Mineral wool	0.22	0.04	33	1030	
	Vapour barrier	-	-	1000	-	
	Gypsum fibre board	0.015	0.32	1000	1003	
AW1						0.17
	Lime cement plaster	0.02	0.87	1800	1000	
	Thermal insulation brick	0.425	0.075	600	1000	
	Gypsum plaster	0.01	0.7	1400	1000	
AW2						0.25
	Lime cement plaster	0.02	0.87	1800	1000	
	Poroton-WDF-180	0.18	0.055	400	1000	
	Hollow brick 1.2	0.24	0.5	1200	1000	
	Gypsum plaster	0.01	0.7	1400	1000	
AW3						0.27
	Lime cement plaster	0.02	0.87	1800	1000	
	Poroton-WDF-180	0.18	0.055	400	1000	
	Calcium silicate brick	0.175	1	1800	1000	
	Gypsum plaster	0.01	0.7	1400	1000	

Tab. A2: Interior wall constructions

	Material	Thickness [m]	Thermal conductivity [W m^{-1} K^{-1}]	Bulk density [kg m^{-3}]	Specific heat capacity [J kg^{-1} K^{-1})]
IW0					
	Gypsum plasterboard	0.0125	0.25	800	1050
	Gypsum plasterboard	0.0125	0.25	800	1050
	Construction timber (60/100) with wood fiber insulation	0.01	0.039	45	1600
	Gypsum plasterboard	0.0125	0.25	800	1050
	Gypsum plasterboard	0.0125	0.25	800	1050
IW1					
	Gypsum plaster	0.01	0.7	1400	1000
	Hollow brick	0.175	0.58	1400	1000
	Gypsum plaster	0.01	0.7	1400	1000