

PREVENTION OF OVERHEATING RISK: ASSESSMENT OF A BUILDING PROJECT WITH LIGHTWEIGHT CONSTRUCTION IN AUSTRIA

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ABSTRACT

This contribution reports on an ongoing research effort within the project Sim4DLG to reduce the energy and resource use in the building sector via design optimisation of life cycle oriented buildings in Austria. To reduce the heating demand and overheating risk in the cold and warm seasons, a simulation-supported optimisation strategy was pursued in addition to the concurrently computed mandatory Austrian energy performance certificate. This approach is applied to different building types, which are to be constructed within the project Life Cycle Habitation. Apart from the heating demand of the buildings, the indoor environment in view of the indoor temperatures was specifically examined to avoid overheating risk and to increase the thermal comfort for the occupants. Furthermore, the potential for preventing summertime overheating was explored according to the requirements of the Austrian standards. This includes an evaluation of simplified calculation method results, computed operative temperature during the course of the day as well as a comparison of the outcome with the findings of parametric simulations. The results suggest that properly dimensioned building parameters of residential buildings with lightweight constructions and low U-value building elements can improve the thermal comfort for the occupants and fulfil the requirements of the Austrian standards for indoor environment conditions.

INTRODUCTION

The building sector is with 10 % one of the largest perpetrators of CO₂ emissions in Austria [1]. To encounter this the study “Simulationsunterstützte Designoptimierung Lebenszyklus orientierter Gebäude” (Sim4DLG) aims at reducing the energy consumption through a design optimisation of life cycle-oriented buildings by using dynamic simulations in addition to the mandatory Austrian energy performance certificate (AEPC) [2]. This part of the study is carried out in the framework of the European Union (EU) Life project “Life Cycle Habitation” (LCH), which targets the demonstration of innovative building concepts that significantly reduce CO₂ emissions, mitigate climate change and contain a minimum of grey energy over their entire life cycle to make energy-efficient settlements the standard of tomorrow in line with the EU 2020 objectives [3]. To this end, a highly resource and energy-efficient building complex is being built in the region of Böheimkirchen, Lower Austria. The case study project includes six living units and a community area as well as two single-family houses, which will be realised based on energy-efficient building solutions (passive house components, improved household appliances, thermal insulation etc.) and on the maximum utilisation of regional renewable

resources for building materials to reach a lower energy demand. The building compound will be designed as a two-story lightweight non-load bearing straw bale construction in style of the neighbouring award-winning S-House (see Figure 1). The low U-value building elements with its comparable low area-related mass capable of heat storage (exterior wall=0.09 W/(m²K) and 32.12 kg/m²; roof =0.07 W/(m²K) and 35.56 kg/m²; floor=0.09 W/(m²K) and 24.64 kg/m²; partition wall=0.11 W/(m²K) and 13.22 kg/m²) are combined with triple layer windows (U_g=0.47 W/(m²K); U_f=0.91 W/(m²K); g-value=0.52).



Figure 1. Design of the buildings (left), floor plan Top 4 GF and Top 6 UF (right).

In a prior project phase, the dimensions of the external fixed shading elements were optimised regarding the two performance indicators (PI) heating demand and overheating, since the buildings are designed for passive cooling only and are not planned to have any air conditioning systems. And because these two key PI may evolve in opposing directions, a parametric optimisation approach with EnergyPlus (EP) was used [4]. For the concurrently calculated mandatory AEPC the software GEQ by Zehentmayer is used [5]. The simulation models were defined based on standard assumptions and calibrated according to calculation methods of the AEPC with a standard heating set point of 20 °C and a fixed air change rate (ACR) of 0.4 h⁻¹. According to the design of the buildings typical activities varying from sleeping (80 W/person) to housecleaning (300 W/person) in accordance with the ASHRAE standard were assumed for the occupants. The living units are designed for up to 4 persons, which are working or employed persons, since professionals are covering with 4.26 of 8.79 million the largest group in Austria in 2017 [6]. With the overall goal of achieving a reference climate heating demand (HWB_RK) of maximum 15.0 kWh/m²a for the atrium-style buildings and 10.0 kWh/m²a for the building compound according to the AEPC, models with large south-facing windows (for high solar gains) and large overhangs (to prevent overheating) are proposed in general. Resulting in suggested models with location climate heating demands (HWB_SK) of 11.7 kWh/m²a for the building compound and values of 17.0 and 16.9 kWh/m²a for atrium-style buildings [7].

This contribution presents an ongoing research effort of the project Sim4DLG addressing the design optimisation of the buildings regarding the reduction of the energy consumption and an increase of the thermal comfort in the cold and warm seasons. Therefore, not only possibilities for a low heating demand of the building were investigated but also prevention of overheating in summertime as well as the approval of the suggested building models according to the requirements of the Austrian standards.

METHODOLOGY

In the software GEQ for the mandatory AEPC, the calculation methods in accordance with the Austrian standard ÖNORM B 8110-3 (rel. 2012) [8] to avoid the overheating risk are included. The requirements of this standard for an overheating prevention in summertime have to be fulfilled according to the prior released OIB Guideline 6 (2011) [9]. The examination of the suitability of the residential buildings can be done either by calculation of the operative temperature over the day or due to the simplified verification method. For the application of both methods the following essential conditions must be met. First, the average daily temperature of the outdoor environment needs to be not above 23 °C and second, the windows of the investigated area need to be operable for night-time ventilation.

In the first method, the operative temperature is used as assessment parameter, which is defined by the arithmetic mean value of the indoor air temperature and the average surface temperature dependent on the outdoor temperature for a repeating period of 24 h. The date used for this calculation is the 15th of July. In case the operative indoor temperature is not exceeding 27 °C the risk of overheating is considered to be avoided. In addition, for sleeping environments the minimum value of the daily operative temperature also needs to be within 25 °C for times between 10 pm and 6 am. In the second method, the simplified calculation method, the heat storage capacity of the building elements and the minimum required ventilation rate for each room is set in relation to the exposure surface. The suitability of the room for summertime is approved, if the heat storage capacity of the exposure surface is above the required threshold-value of the standard.

In the updated OIB Guideline 6 (2015) [10] it is even stated that the simplified calculation method is sufficient for residential buildings in Austria and as a consequence, applied to the majority of buildings to approve the prevention of overheating in summertime. Nonetheless, an absolute planning certainty is not given for this simplified calculation approach [11]. The latest version of the OIB Guideline 6 (2019) [12] therefore quotes in contrary, without any direct reference to the ÖNORM B 8110-3 standard, that overheating in summertime for residential building is avoided, if the operative temperature in the examined spaces is not exceeding the location depending daily mean value of the standard outside temperature ($T_{NAT,13}$) for a periodically repeating outdoor climate by $1/3 * T_{NAT,13} + 21.8$ °C. While the latest version of the Austrian standard ÖNORM B 8110-3 (rel. 2018) [13] includes only the simulation method for the calculation of the operative temperature over the day for approval of the suitability regarding prevention of overheating in summertime.

Both methods are applied to the prototype buildings and compared regarding the computed results with EP, but the focus for comparison is therefore on the simulation of the operative temperature and not on the simplified method because of the adaptations in the recently released guidelines. Three living units are selected for a further assessment in specific. These are Top 2, Top 4 and Top 6, covering the town house style unit as well as one apartment in the ground floor (GF) and one in the upper floor (UF). Top 2 has a total net living area of 106.7 m² on both floors and 8 thermal zones (see Figure 2). These are an entrance hall (EH), a living-kitchen area (LK) and a cloakroom (WC) in the GF as well as a hallway (HW), three bedrooms (Bed1, Bed2, Bed3), and a bathroom (Bath) in the UF, while the smaller living units Top 4 and 6 consist of an EH, a storage room (SR), a bathroom, a LK and a bedroom with a net living area of 55 m² each (see Figure 1).

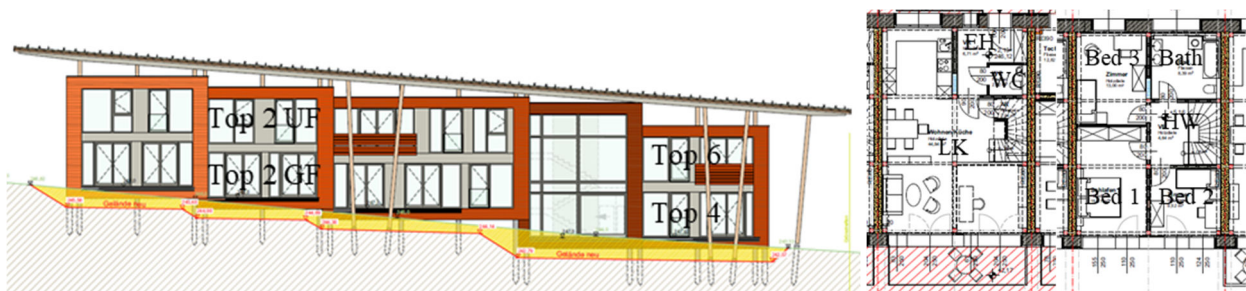


Figure 2. South view of the building compound (left), floor plan Top 2 GF and Top 2 UF (right).

Relevant for the approval regarding prevention of overheating in summertime according to the AEPC are all thermal zones containing transparent surfaces. For these spaces the minimum required settings, in specific time controlled exterior shades for the individual windows, are applied in a first step for the building model in GEQ necessary for approval of the simulation method. These settings are then applied to the suggested EP building model and compared with the findings of GEQ including an assessment of the outdoor air temperatures. The results are displayed in the following section.

RESULTS AND DISCUSSION

To fulfil the requirements of the Austrian standards for the suggested building models additional measures are necessary for individual thermal zones. The approval can be achieved by use of time controlled external

shading devices. An overview for the areas to be examined, the individual windows and the required operation time is provided in the following Table 1. The results show that especially for the south-oriented windows an additional shading is needed to achieve an adequate thermal comfort in summertime for the occupants. Also the east-oriented windows of Top 4 and 6 are showing some differences, while the windows in the UF are shaded by the extended roof, an additional mechanical shading is required for the ones in the GF.

Table 1. Minimum required approval settings in GEQ for prevention of overheating in summertime.

Building	Compound Top 2												
Thermal zone	TZ9 LK					TZ11 EH	TZ12 Bed1		TZ13 Bed2		TZ14 Bed3		TZ15 Bath
Window	GF N3	GF S5	GF S6	GF S7	GF S8	GF N4	UF S5	UF S6	UF S7	UF S8	UF N4	UF N5	
Orientation	N	S	S	S	S	N	S	S	S	S	N	N	
Exterior shades [time]	-	11-15	11-15	11-15	11-15	-	11-16	11-16	11-16	11-16	-	-	
Building	Compound Top 4												
Thermal zone	TZ29 Bed				TZ30 LK					TZ31 SR		TZ33 Bath	
Window	GF S16		GF S17	GF N12	GF E1	GF E2	GF S18	GF S19	GF S20	GF N10		GF N11	
Orientation	S	S	N	E	E	S	S	S	N	N			
Exterior shades [time]	11-15	11-15	-	08-16	08-16	09-17	09-17	09-17	-	-			
Building	Compound Top 6												
Thermal zone	TZ34 Bed				TZ35 LK					TZ36 SR		TZ38 Bath	
Window	UF S16	UF S17	UF N14	UF E1	UF E2	UF S18	UF S19	UF S20	UF N10		UF N11		
Orientation	S	S	N	E	E	S	S	S	N		N		
Exterior shades [time]	11-16	11-16	-	-	-	10-16	10-16	10-16	-		-		

In the next step the climate conditions of the different software, in specific the outdoor air temperatures, are examined for a unified comparison. In contrary to the AEPC for which the repeating outdoor air temperature of the 15th of July is used for the simulation, the climate data used for the location of Böheimkirchen with EP is showing in comparable cold day with low temperatures and therefore not representative. Instead, the average hourly temperatures for July are considered (see Figure 3).

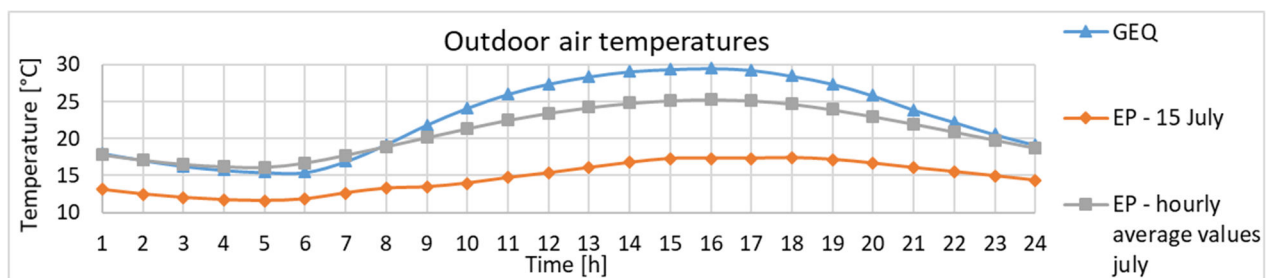


Figure 3. Comparison of the outdoor air temperatures.

For the assessment of the results in EP, the required external shades and operation times (see Table 1) are applied to the building model together with a natural ventilation during night. According to the Austrian standards, the windows have to be kept open, if the outdoor air temperature is below the indoor temperatures between 22 pm and 6 am. This is applicable for all examined spaces. During all other times a specific hygienic air flow volume of 1.411 m³/m²h is applied.

The results are displayed in Figure 4 for Top 2, in Figure 5 for Top 4 and in Figure 6 for Top 6. Same like for the outdoor air temperatures also the hourly average indoor temperatures of the individual thermal zones for July in EP are considered for comparison with the results of GEQ.

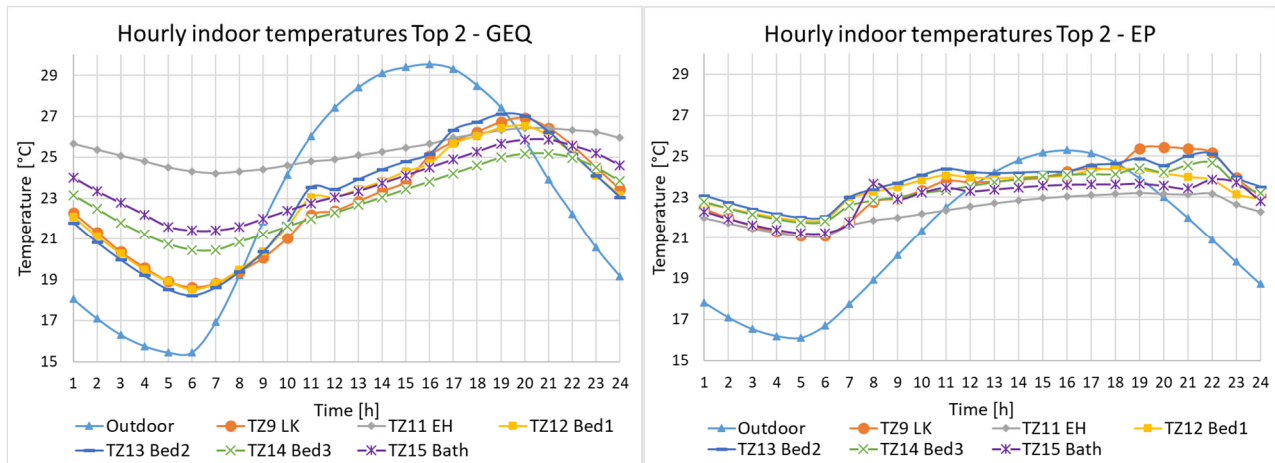


Figure 4. Indoor temperatures of Top 2 for GEQ and EP.

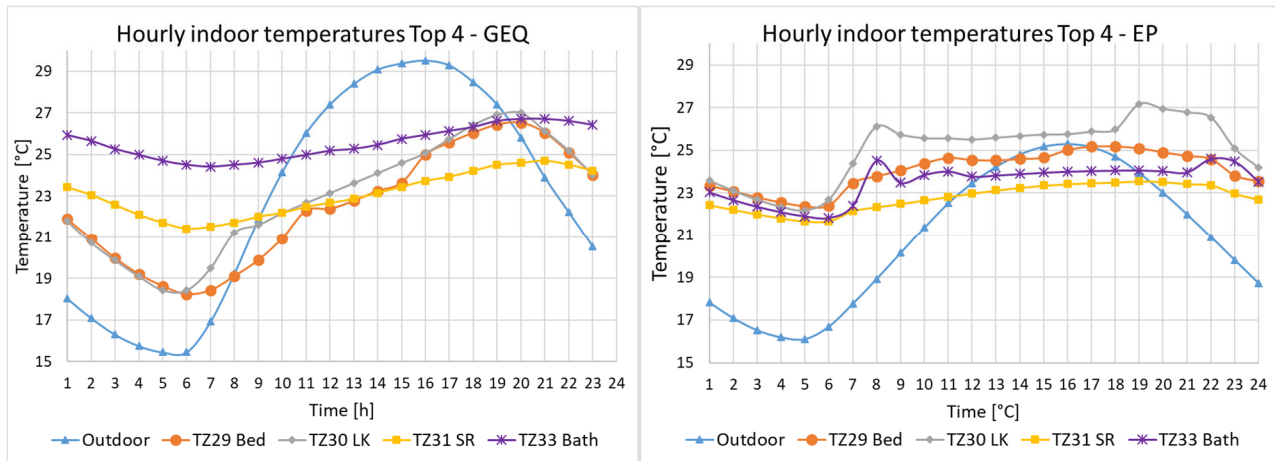


Figure 5. Indoor temperatures of Top 4 for GEQ and EP.

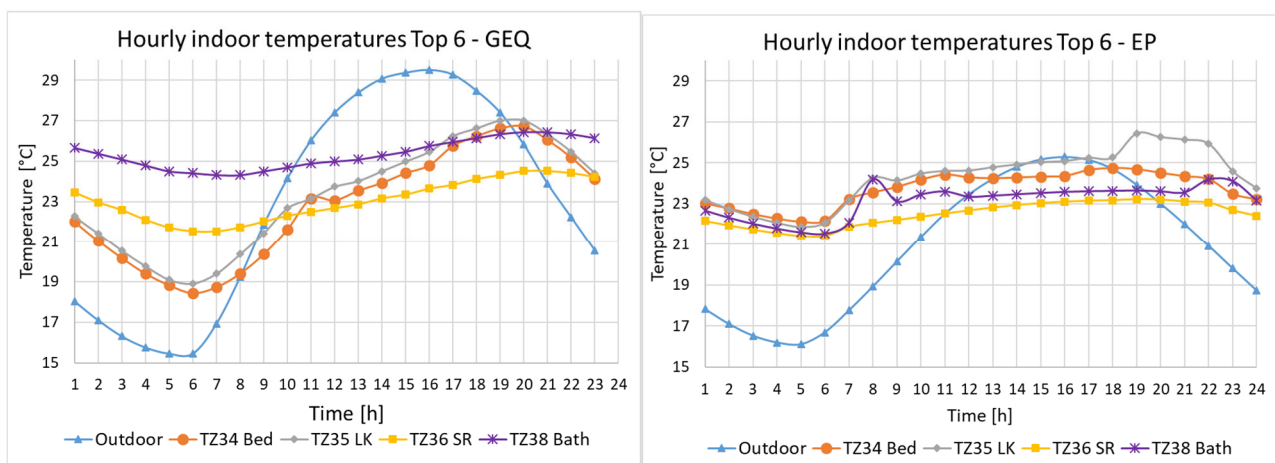


Figure 6. Indoor temperatures of Top 6 for GEQ and EP.

All computed results show similar tendencies. Corresponding to the larger variation between day and night time outdoor temperatures of the location, which are caused by the used repeating temperature of the 15th of July, also the operative temperatures of the individual thermal zones show for GEQ a wider variation,

especially the spaces with large building openings, compared to temperatures of EP. The results with EP therefore are less effected by the varying day and night time temperature differences and show more constant values throughout the day. It is also important to mention that the operating temperatures of the indoor environments of both software are in average on the same temperature level, considering that the outdoor peak temperatures during the hottest period of the day, which are used for GEQ in accordance with Austrian standards, are up to 5 °C above the ones used for the calculation with EP. Furthermore, the simulation with EP was done for the period of the entire year, even if for the assessment for prevention of overheating in summer only the findings of July are used, to include the influence of warmer or cooler prior outdoor conditions and their effect on the indoor environment, which is not considered for GEQ. Due to the use of lightweight construction building elements the deviation in this case is in average 0.1 °C only. While in contrary also the occupants' behaviour in EP e.g. in case of the bathroom show bigger impacts on the indoor temperatures.

CONCLUSIONS

The presented study showed that an accurate design of shading elements can reduce indoor air temperatures, while maintaining a low heating demand. Furthermore, the requirements regarding prevention of overheating in summer according to the Austrian standards can be fulfilled for this lightweight building by accurate design of external fixed shading elements in combination with exterior mechanical shades and proper use of windows for passive cooling. The results of GEQ are in general confirmed by the findings of EP, if identical parameters for shading and ventilation are applied. Nevertheless, some deviations have to be considered for example that the indoor temperatures are less effected by the varying outdoor day and night time temperatures for EP.

In the next step, this assessment will be reapplied to the buildings' final design and data of the selected building products and elements. After the construction, a comprehensive building monitoring will be conducted during the initial occupancy phase to validate the simulated results.

REFERENCES

- [1] Environment Agency Austria (2016): Climate protection report REP-0582, Vienna, Austria.
- [2] Sim4DLG (2019): Information website, <https://www.ffg.at/dissertationen/ausschreibung2015>, FFG 853842, project is funded by the FFG and FTE.
- [3] LCH (2019): Project homepage, www.lch.grat.at, LIFE13 ENV/AT/000741, project is realised with the contribution of the LIFE financial instrument of the European Union.
- [4] EnergyPlus, U.S. Department of Energy's (DOE), <https://energyplus.net/>.
- [5] GEQ Zehentmayer Software GmbH, <https://www.geq.at/>.
- [6] Statistik Austria (2018): Erwerbstätige in Österreich bis 2017, Study 217682, Statista, Austria
- [7] S. Eikemeier, R. Wimmer and A. Mahdavi (2018): Simulation-Supported Design Optimization of Atrium Buildings with Passive Cooling in Austria, Smart Innovation, Systems and Technologies **131**, pg.21-31.
- [8] ON (2012): ÖNORM B 8110-3 - Thermal protection in building construction - Part 3: Prevention of summerly Overheating, release 2012-03-15, Austrian Standards, Austria.
- [9] OIB (2011): OIB Guideline 6 - Energy saving and heat insulation, OIB-330.6-094/11, Austrian Institute of Construction Engineering, Austria.
- [10] OIB (2015): OIB Guideline 6 - Energy saving and heat insulation, OIB-330.6-009/15, Austrian Institute of Construction Engineering, Austria.
- [11] J. Nackler (2017): Sommerlicher Wärmeschutz – Vergleich von berechnungsansätzen und Entwicklung eines Planungsinstrumentes für Entwurfsfindung und Nachweis, Dissertation, TU Vienna, Austria.
- [12] OIB (2019): OIB Guideline 6 - Energy saving and heat insulation, OIB-330.6-026/19, Austrian Institute of Construction Engineering, Austria.
- [13] ON (2018): ÖNORM B 8110-3 - Thermal protection in building construction - Part 3: Determination of the operating temperature in summer (Prevention of summerly overheating), release 2018-09-01, Austrian Standards, Austria.