Overheating assessment of energy renovations

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In many post-occupancy studies of renovated houses elevated temperatures have been documented. This article presents in which situations overheating need to be addressed and which renovation measures are causing this need. The analysis contains representative houses from central and north Europe. Both dynamic and static overheating assessment criteria are used.

Keywords: renovation, overheating occurrence, single family house, nZEB, adaptive comfort.

Introduction

The greatest share of the European building stock (EU-27) is residential buildings and the majority of them are single-family houses [1]. The current target of the European Council is to have the majority of the existing stock be renovated until the middle of the century. More and deeper renovations (nZEB) are expected in the coming decades.

Energy renovations mainly concern the colder conditions in winter. However, in many comfort studies of energy renovated buildings and nZEB, elevated temperatures have been documented not only during the summer period but also during the transition months, even in Central and North Europe [2]. For the designers, builders and occupants of these areas overheating is an unknown challenge until recently. Moreover, cooling demand calculations are based on simplified monthly methods, averaging the need both in time and space. High temperatures for long periods cause serious impacts to the indoor environmental quality [3]. This article summarizes ongoing scientific work [4].

Case studies

This analysis involves investigation of four representative houses (1960's, 70's and 80's), of U.K. (London city); Denmark (Copenhagen); Austria (Vienna) and South France (Marseille, H3 climatic zone of France). The stock of these countries equates with one third of the European Union building stock [1]. Two out of the four case studies are real buildings extracted from the

TABULA project (Denmark, France, **Figure 1**) and the other two cases are the result of deep statistical analyses (energy certificates; [4]).

Table 1 presents the thermal and technical characteristics of the cases. The case studies represent typical heavy-weight constructions [4]. For the investigation of the overheating risk at room level two bedrooms (6.3 m² of net floor area) facing the south and west orientations (SW bedroom) and the north and east orientations (NE bedroom) were developed.

The applied renovation measures are divided into 2 categories:

- elements (improve of the efficiency) and systems (mechanical ventilation, shading systems)

and have been analyzed in three phases:

- base case; deep renovation (regulation) and nZEB renovation

The renovation in every phase is conducted in steps:

- replacement of windows; improvement of the ceiling; improvement of the external walls; improvement of the floor and improvement of the airtightness

The improvements of the efficiency of the elements is conducted and simulated externally (graphite EPS for the walls, mineral wool for the ceiling and high compressive strength XPS boards for the floor elements).

Figure 1. Examined case studies for Denmark (top) and South France (bottom).

System measures refer to new mechanical ventilation systems (higher capabilities) and shading systems as a package with the new windows.

Three different shading systems have been analyzed:
1. Internal venetian blinds with high reflectivity (0.8);
2. External slat blinds with high reflectivity (0.8) and
3. Fixed pergolas-awnings (0.5m projected)

Table 1. Technical and thermal characteristics of case studies and different renovation phases.

a/a	Period	U_{wall} (W/m²K)	$U_{ceiling}$ (W/m²K)	U_{floor} (W/m²K)	U_{window}, g (W/m²K), -	Infiltration n_{50} (ACH/h)	Storey	Net floor area (m²)
Austria (After 1960)								
Base Case		1.20	0.55	1.35	3.0, 0.67	3.0	2	144.4
Deep Renovation		0.27	0.15	0.30	1.2, 0.6	1.5		
nZEB Renovation		0.15	0.15	0.15	0.8, 0.5	0.6		
Denmark (1973–1978)								
Base Case		0.45	0.45	0.35	2.7, 0.76	5.0	1	116.2
Deep Renovation		0.20	0.15	0.12	1.65, 0.7	1.6		
nZEB Renovation		0.20	0.15	0.12	1.2, 0.6	0.8		
France (1982–1989)								
Base Case		1.00	0.60	1.00	4.6, 0.9	5.0	1	94.2
Deep Renovation		0.43	0.22	0.43	1.5, 0.7	1.4		
nZEB Renovation		0.15	0.15	0.15	0.8, 0.5	0.6		
U.K. (Before 1978)								
Base Case		2.25	0.85	1.35	3.2, 0.8	8.0	2 (semi-detached)	60.3
Deep Renovation		0.30	0.18	0.20	1.6, 0.7	4.0		
nZEB Renovation		0.15	0.15	0.15	0.8, 0.5	0.6		

The movable shadings systems are applied during the non-occupied hours. The mechanical ventilation system increase constantly the ventilation airflow rate from the basic value (0.5 ACH/hr for indoor air quality reasons) to 1.5 ACH/hr in two steps (all day application). The case studies were simulated without mechanical cooling systems. The profile and internal loads reflects a 5-member working family [4].

In the research two widely applied indices for the assessment of the overheating indoors is been used. The first index measures the percentage of the occupied hours with operative temperatures higher than the upper bound of the adaptive comfort temperature (Category II; [5]). The second index measures the percentage of occupied hours with operative temperatures above fixed thresholds, 26°C for bedrooms (also building) and 28°C for living room (static method; [6]).

Results and discussion

The way to building energy efficiency, through elements improvements and without passive or active cooling measures, leads to the increase of the overheating risk indoors. Both methods and all cases show similar peaks and valleys and critical renovation measures (**Figure 2**). The renovation measures for ceiling and external walls (variants 2, 3 and 7; French case) of both renovation phases slightly decrease or increase (neutral effect) the discomfort conditions indoors (**Figure 2**). The g value coefficient of solar gains seems to be the critical parameter, as far as the decreasing of these indices (variants 1 and 6). Additional floor insulation and improvements of the airtightness (variants 4, 5, 8 and 9) of both renovation phases increase overheating hours for both indices. Floor insulation seems to be the most critical renovation measure, in terms of overheating occurrence. Similar conclusion regard the overheating indoors for all the cases may be extruded. Elements' improvements increase also average and maximum indoor temperatures and extend the overheating period (**Figure 3**). For the Austrian and Danish houses the period with overheating incidents starts in May and finishes in October (nZEB renovation).

The static method always shows higher overheating values compared with the dynamic one for every renovation measure, room and case study (similar only in U.K. case). Moreover, rooms facing the northwest orientation overheated less compared with others (SE orientation) for both methods and renovation phases.

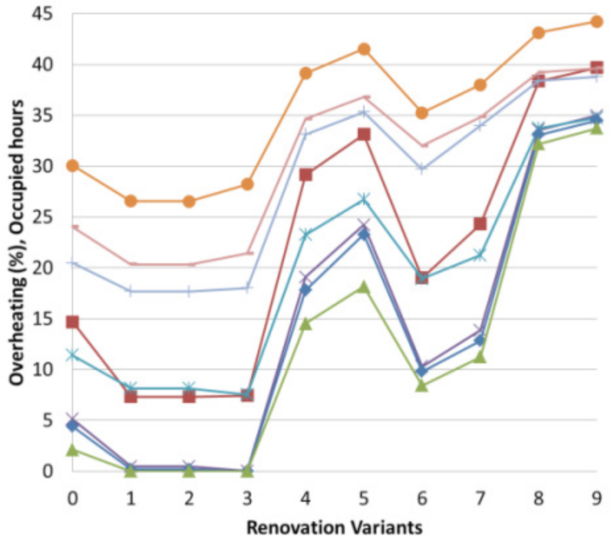

Figure 2. Percentage of overheating hours (measured only for occupied hours) for different renovation variants (Table 2) in room level for both methods of assessment, for the southern French case study.

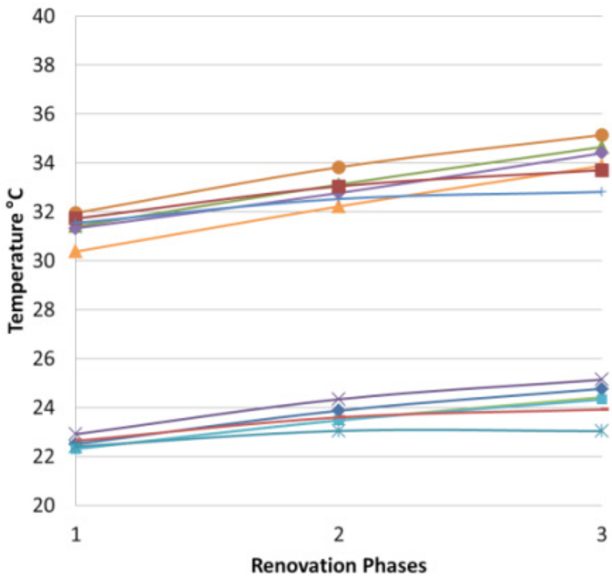

Figure 3. Yearly average and maximum building temperatures for southern French case study for different renovation phases (initial; deep and nZEB) and different systems-measures.

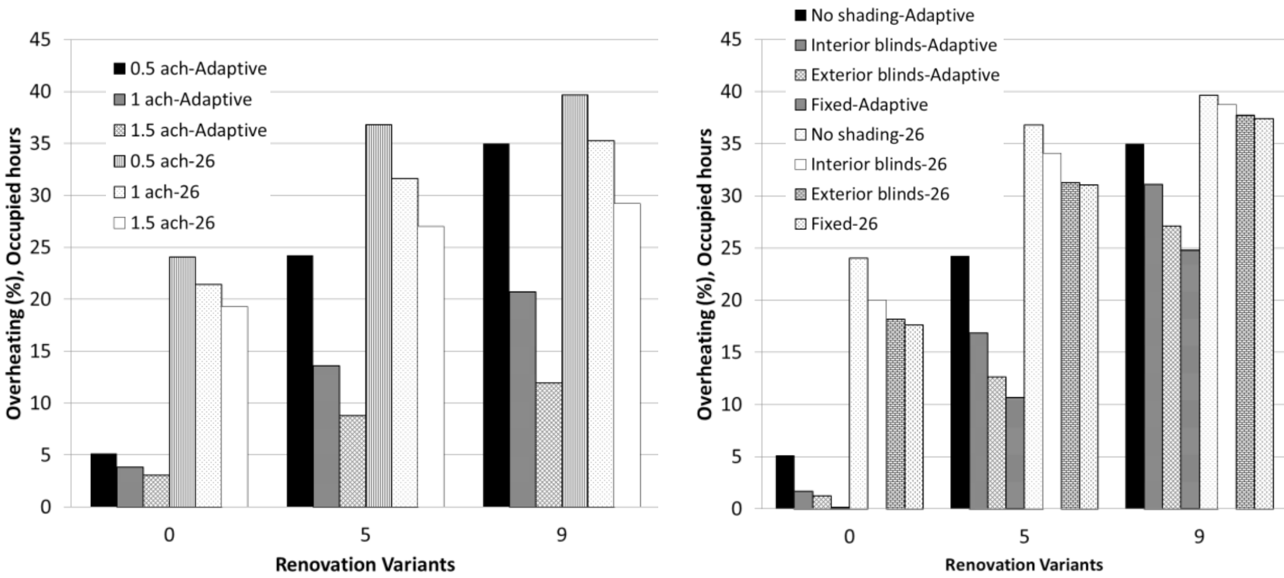

Figure 4. Percentage of overheating hours (measured only for occupied hours) for different renovation variants (Table 2), methods, ventilation rates and shading systems, for the southern French case study.

System improvements are actually antagonistic measures and decrease the overheating risk indoors. The most effective measure, compare to the others, is the increase of the ventilation rates (1.5 ACH/hr) for every case study and renovation phase (**Figure 4**). As far as the shading analysis goes, the shading systems are not very effective for the French case (**Figure 4**). The use of fixed systems or external movable blinds decreases the indices approximately 50% and the internal blinds approximately 25% (Danish case; not presented). **Figure 3** presents the yearly average and maximum building temperatures for both systems and in all renovation phases. Finally, there is an important decrease of the overheating period after the application of these improvements for every case study and renovation phase.

Conclusion

In terms of overheating, the most critical renovation measures are the insulation of the floor and the increase of the airtightness. The contribution of diminishing the g value of the window glazing is positive. Neutral contributions cause the energy improvements of the walls and/or ceiling. Total elements improvements result also an extension of the overheating period and higher average and maximum temperatures indoors. The increase of the ventilation rates of the mechanical systems, close to 1.5 ACH/h, may contribute significantly to the decreasing of the overheating discomfort. The external shading systems may decrease the discomfort effectively, especially to the northern countries. ■

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