THERMAL COMFORT ANALYSES IN CLASSROOMS

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ABSTRACT

Thermal comfort in classrooms seems to be the most important parameter in the sensation of pupils, for both warm and cold season. It could be more important than IAQ (CO_2-concentration) or daylight-conditions of the classroom. Focus in schools will be the comfort conditions of transition and summer period which increases importance due to all-day and summer schools, changing climate conditions and technical equipment of pupils and teaching.

KEYWORDS
Investigations and simulations of the ERACOBUILD-project “school*vent*cool” could show that in the middle European climate classrooms are at high risk for overheating, not only during summer time, also during transition period. It is believed that the high temperatures decrease the ability to concentrate during lessons and is as important as the IAQ in classrooms.

INTRODUCTION

As there is very low energy demand for heating in high performance modernized and new passive house standard school (and similar) buildings the importance shifts towards the cooling demand of these buildings. First of all this is significant for buildings where technical equipment is the main factor for internal heat gains like schools and office buildings.

On that point, following Figure 1 shows the measured average hourly room temperatures of a school building which was retrofitted to passive house standard. On the x-axis the outside temperatures and on the y-axis the room temperatures were plotted.
There are a large number of hours with high room temperatures outside the defined comfort zone (red mark). Overheating is therefore a present issue. Passive cooling concepts have to include measures like “intelligent” shading systems to avoid this overheating.

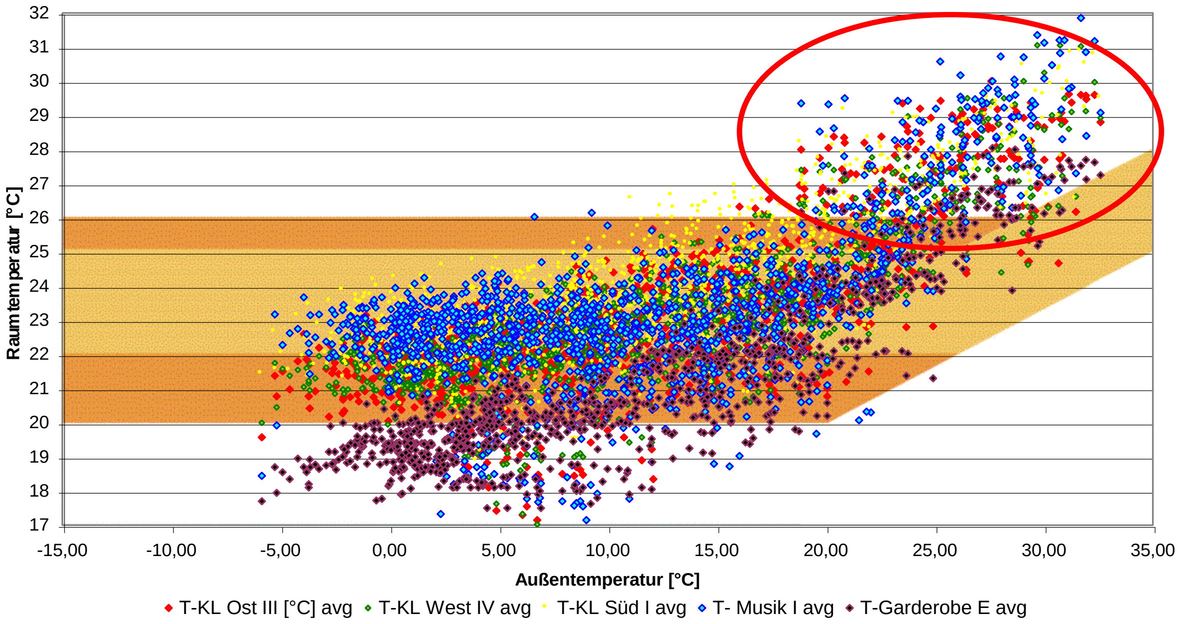

Figure 1: Temperatures in five different sections of an Austrian school building renovated to passive house standard (Source: AEE INTEC)

The existing school building stock is mostly equipped with big window areas without acceptable thermal and shading standards. High performance renovation and high new building standards lead to well insulated and airtight building envelope coupled with good indoor air quality (IAQ) like passive house standard offers and normally equipped with outside shading. But is this enough to ensure good summer comfort?

In the present ERACOBUILD-project "school*vent*cool", the Austrian partner AEE INTEC investigates the different reasons for and the amount of overheating in existing and high performance renovated schools and solutions for protection from heat and glare during the warm season. There are made calculations (PHPP, iDbuild, TRNSYS,…), measurements and interviews, analysing classroom comfort conditions before and after shading solutions, and before and after renovation, including the use of daylight. The comfort situation of the pupils is a central point in all evaluations and solutions.

THE INVESTIGATED SCHOOL BUILDING

All results of the calculations and the interviews shown on the following pages are an outcome of the detailed investigation of the vocational school Gleinstätten. Here is some information about the investigated school (see Table 1):

Parameter	Value
Years of construction	1974 – 1977
Numbers of floors	Basement and 3 floors
Number of classrooms	10
GFA (school building)	6.253 m²
Energy performance (calculated)	100 kWh/m²a
Heating supply	Central heating system fed by biomass-solar thermal district heating
Ventilation	Natural ventilation by windows

Table 1: Characteristic values of the existing school building (Source: AEE INTEC)

Figure 2: Views of the existing school building in Gleinstätten/Austria (Source: AEE INTEC)

Figure 3 shows the ground plan of the school with the investigated classrooms (marked in colour). Classroom E007 is mainly oriented to the north, classroom E004 to the west and classroom E001 to the south. The selection of these three rooms enables also information of all other classrooms in this storey because (nearly) all orientations are depicted by these three rooms. In the existing building classroom E007 is used as a computer room.

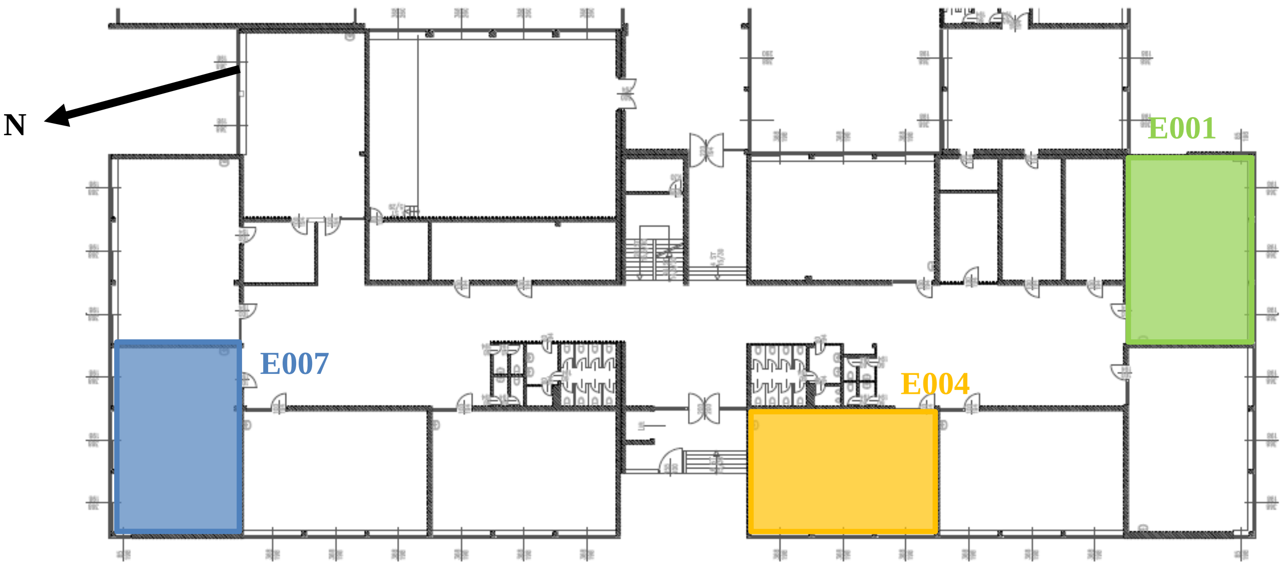

Figure 3: Ground plan of the existing school building with the three investigated rooms (marks) (Source: LIG)

The calculations of the school building were performed for the existing building and the retrofitted building whereas for the retrofitted building assumptions were made concerning the insulation of the building parts, the mechanical ventilation with heat recovery and other measures based on the passive house standard.

RESULTS

Calculations

Figure 4 shows the assorted room temperatures of classroom E001 (large south façade) plotted to the hours of the school year in %. In this case the calculation was performed with the internal gains of 18 pupils and one computer in the classroom.

The analysis of this figure shows that in the existing building the room temperature is about 88 hours (or just above 5% of the total school year) higher than 26°C. In the retrofitted building the room temperature is about 242 hours (or 14.5% of the total school year) above this limit. This is equal to the 2.75-fold of the value of the existing building! Another calculation (with hybrid ventilation, 18 pupils, each pupil equipped with a computer) resulted in even 637 hours (or 38.2% of the total school year) higher 26°C.

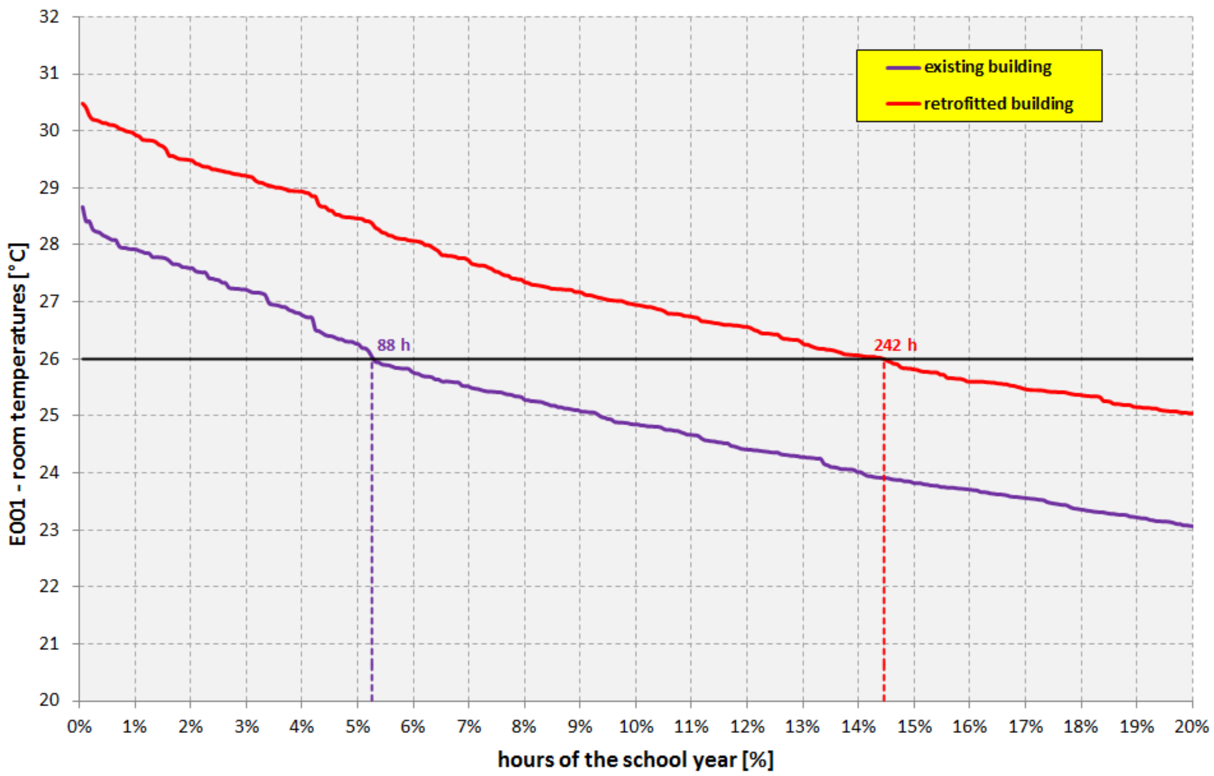

Figure 4: Sorted room temperatures for room E001 – comparison of existing and retrofitted building (Source: AEE INTEC)

In another calculation the influence on the high room temperatures was investigated. Figure 5 shows four different scenarios. Case 1 (red bars) represents the retrofitted building with 18 resp. 11 pupils inside the classroom, an automatic control of the shading and mechanical ventilation (including one calculation with an additional night ventilation). Case 2 (blue bars) represents case 1 plus the assumption that every pupil is equipped with a computer. The comparison of this two scenarios shows that the technical equipment (in this case computers) has more influence on the overheating in the classroom than the number of pupils inside.
This statement can confirmed by the comparison of the cases 3 (green bars) and 4 (orange bars). These two scenarios also represent the retrofitted building with 18 resp. 11 pupils inside the classroom and an automatic control of the shading but in this time executed with an optimized hybrid ventilation. With an increased number of computers in case 4 the school

days with temperatures above 26°C in the classroom also increase (from 51 to 86 and from 47 to 68) more than they do because of the higher number of pupils in the classroom.

Figure 5 also shows the "reduction potential" of an optimized ventilation system. By the implementation of a hybrid ventilation system the school days with room temperatures above 26°C can be reduced from 67 to 51 resp. 64 to 47 school days per year. An additional night ventilation can even reduce the school days with room temperatures above 26°C from 67 to 11 days per year.

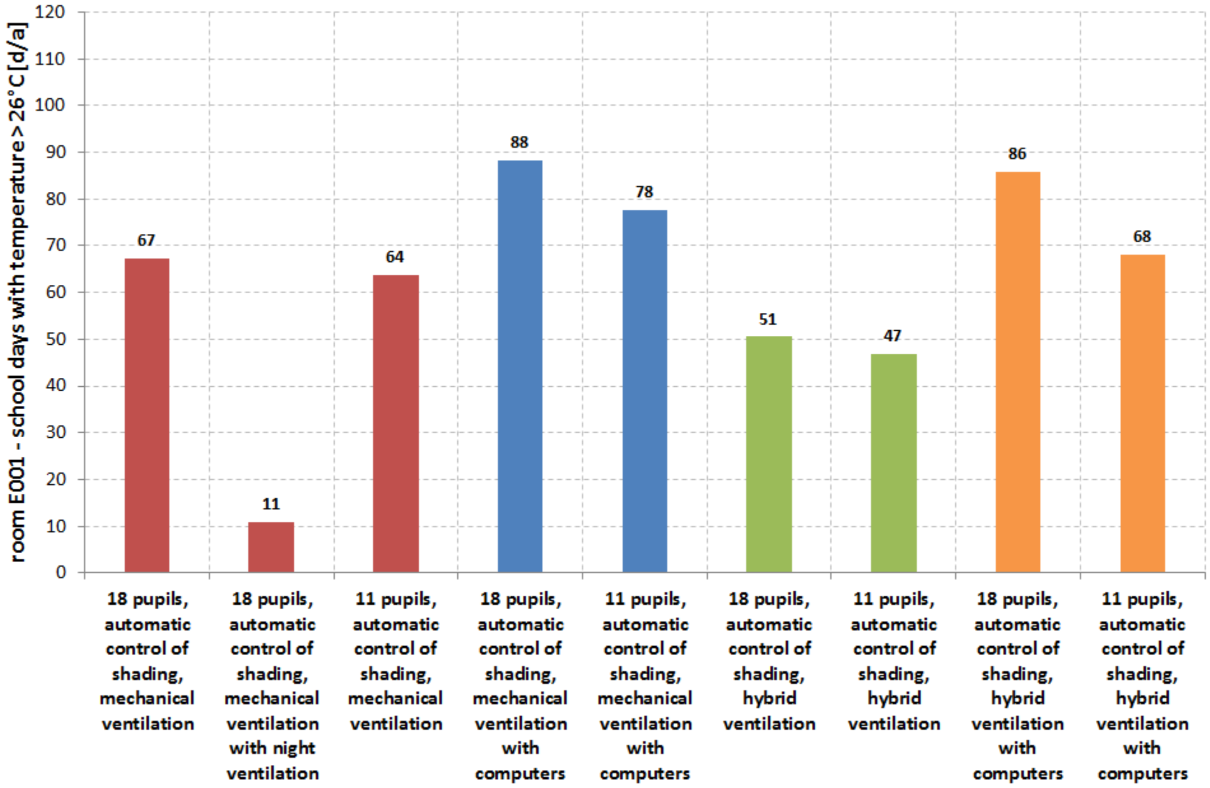

Figure 5: Influence on the overheating in classrooms – comparison of different varieties of the retrofitted building (Source: AEE INTEC)

Besides the room temperature other comfort parameters in the classroom have to be regarded as well. Pooled can this comfort parameters for instance in the characteristic value of the air quality according to EN 15251. This value was evaluated for the three classrooms, both existing and retrofitted building.

Figure 6 shows the results of the calculation of the air quality according to EN 15251 of room E001. Thereby the number of pupils, the solar shading and the ventilation of the building was varied. The best result was achieved by the scenario with more pupils, no shading and with mechanical ventilation (green bar). The results show in general that the two scenarios with no shading devices (green and purple bar) achieve the best values (30% resp. 25% in class I of EN 15251).

The further analysis shows that the hybrid ventilation system performs worse than the scenarios with mechanical ventilation systems. The use of a hybrid ventilation system reduces the characteristic value of the air quality in this case from 23% in class I to 16%.
Astonishingly the number of pupils in the classroom has no influence on the air quality in this calculation.

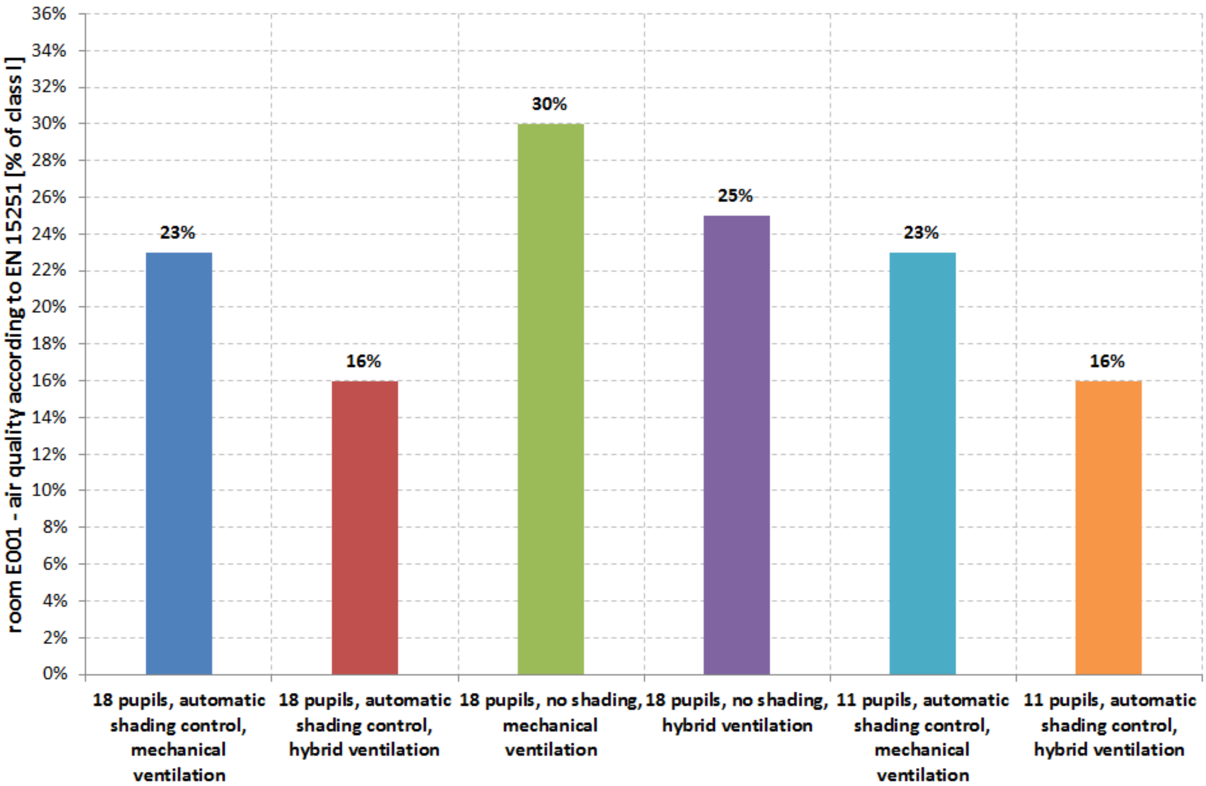

Figure 6: Air Quality in room E001 - comparison of different varieties of the retrofitted building (Source: AEE INTEC)

For the visual comfort and the health of the pupils the daylight use is of importance. For different scenarios the percentage of possible daylight use and the resulting primary energy demand for the lighting was calculated. For the simulation the illumination was set to 500 lux in the middle of the classroom. Again all three classrooms were investigated and analysed. Figure 7 shows the results of room E001. The blue bars characterize the existing building scenarios, the green bars the retrofitted building scenarios.

The result of the calculation shows that the percentage of daylight use in the retrofitted building scenarios is fairly high while the existing building scenarios perform worse. This indicates that there is a lot of potential to optimise the daylight use in the retrofit. Coincident not only the daylight use can be increased, also the primary energy demand for the lighting in the classroom can be lowered with an optimized shading solution (automatic control) in the retrofit.

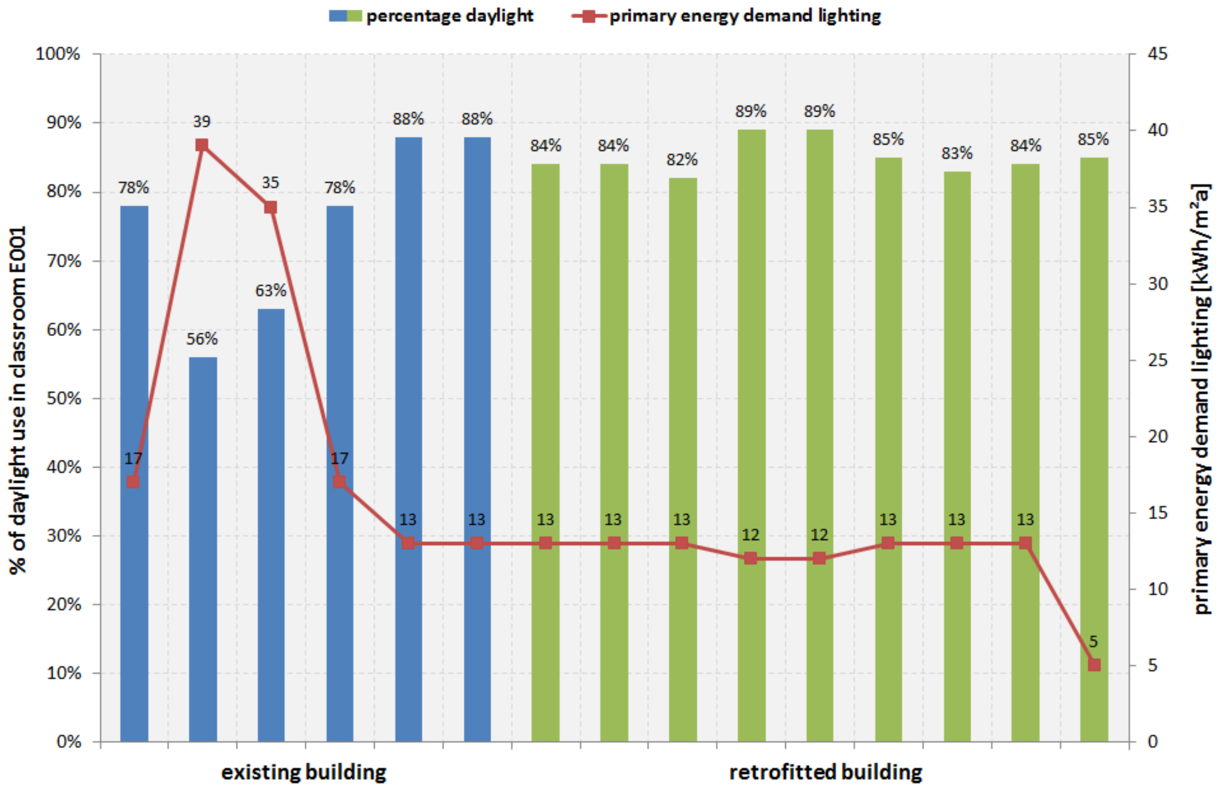

Figure 7: Daylight use and primary energy demand for lighting – comparison of different varieties of the existing and the retrofitted building (Source: AEE INTEC)

Interviews

73 pupils plus one teacher were asked in personal interviews to answer questions about the classroom comfort situation, written down in a specially developed questionnaire. Parameters like noise, IAQ, smell, temperatures, draught, interior design, acoustic and daylight conditions were asked to be assessed by the interviewee.

The interviews showed that pupils have the greatest sensation for the thermal situation in classrooms (cold and draught in winter, hot conditions in summer). Further results indicate that parameters like noise, IAQ, daylight conditions are much more linked to the special situation of the classrooms, individuals and their constitution. For example only 32% of the pupils perceive the smell in the classrooms as an annoying thing, but the amount of 79% of the pupils say, that the classrooms are too cold or too hot (see Figure 8).

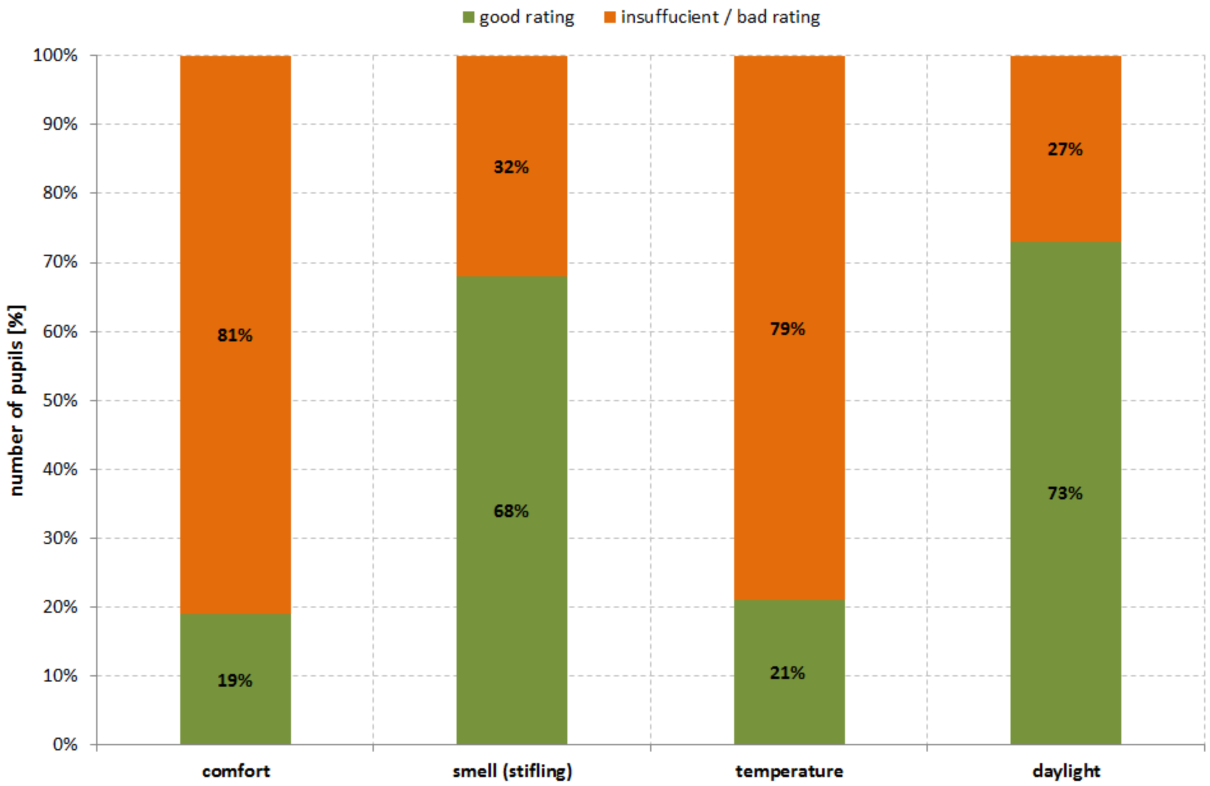

Figure 8: Simplified illustration of the results regarding the interviews about comfort sensation with the pupils and the teacher (Source: AEE INTEC)

CONCLUSION

Within the program "building of tomorrow" a lot of big-volume passive houses and down to lowest energy consumption renovated buildings were implemented and scientifically analysed, most of them by AEE INTEC. One of the results was the fact that a number of very energy efficient buildings exceeded thermal summer comfort (temperatures, relative humidity) limits in a quantity which was not expected [1]. In two more Austrian research projects there were found indications for the assumption that classrooms in schools built to nearly zero energy standard are at high risk for overheating, not only during summer time, and due to the high indoor temperatures the ability to concentrate during lessons decreases [2][3]. Analyses of the project "school*vent*cool" again could show that overheating is a serious problem and to be recognised in the very early planning stage of a nearly zero energy building. Suitable thermal comfort for pupils and teachers without active cooling is only possible with a range of passive cooling measures like outside shading and night ventilation in middle European climate.

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