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Whole year evaluation of thermal comfort using international standards EN16798-1 and TR16798-2

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Abstract: There is an increasing interest in evaluating the indoor environment on a yearly basis. The technical report (TR16798-2) to EN16798-1 recommend criteria for thermal comfort evaluation based on heating and cooling seasons, but do not give clear indications of how to manage the transition between them. This study used dynamic simulations to evaluate the thermal comfort level and energy use when the heating-cooling seasons are defined either by a pre-fixed date, by identifying the periods with energy requirements for heating-cooling or by considering prevailing outdoor conditions. The results show that a better thermal comfort level was obtained when the heating-cooling seasons were defined by using prevailing outdoor conditions, without a significantly higher energy use compared to the other two cases. Including a transition period between seasons where only heating is available was observed to optimize both energy use and thermal comfort. The study also evaluated the thermal comfort level in buildings with and without air-conditioning systems using categories of indoor environment and a yearly thermal comfort score. The results showed that the latter yielded to similar conclusions when assessing the annual thermal comfort but in a much simpler manner than using indoor environmental categories.

Keywords: Thermal comfort, heating, cooling, performance evaluation.

1. Introduction

Indoor environmental quality (IEQ) is becoming an increasingly important concern, along-side energy consumption, for both new and existing buildings. Building energy performance, even for buildings utilising multiple disparate fuel sources, is generally expressed as a single annual value, either as primary energy (kWh/m^2/yr.) or carbon intensity (kgCO_2/yr.). As a consequence, in order to compare energy performance with the corresponding indoor environmental performance, there is a need to also express the indoor environmental performance on a yearly basis, referring both to each separate environmental factor (thermal comfort, air quality, light and noise) and to a combination of these factors.

If the indoor environmental criteria in existing standards have to be met 100% of occupied periods, the amount of heating, cooling and/or ventilation capacity of any HVAC installation would be significantly increased. Economic and/or environmental considerations lead to a more pragmatic position of allowing the indoor environmental conditions to exceed the recommended ranges for a limited time: this can be verified both by computer simulations (design stage) and by the field monitoring (post-occupancy phase). This paper will focus on the issues related to perform a whole year evaluation of the performance of HVAC systems, under a range of climatic conditions and operational scenarios. The aim is to evaluate the consequences, in terms of annual energy use and thermal comfort, when the heating-cooling seasons are defined based on a pre-defined date; based on previously identified periods when the energy requirements for heating or cooling are higher; or based on prevailing outdoor temperature conditions. The transition period between heating-cooling seasons will be also analysed, considering cases with and without heating or cooling available during that period. This paper also aims to compare methods to evaluate thermal comfort on a yearly basis, considering buildings with and without air-conditioning systems.

2. Issues with Thermal Comfort Evaluation Methods in Current Standards

The main issues that will be analysed in the present paper is whole year evaluation method for thermal comfort and how to define heating (winter) and cooling (summer) season, especially focused on definitions and guidance provided in EN16798-1. To illustrate and analyse the issues, a dynamic simulation of the thermal comfort and energy use in an example office building will be used.

2.1. Thermal comfort evaluation methods

Both the Adaptive method (ACM) (De Dear & Brager 1998) and the PMV-PPD method (Fanger 1970) for mechanical heated and cooled buildings, use categories are to define input parameters for design of buildings and systems, as well as for input to energy calculations. However, the intent is not that the buildings must always be operated within one category. Instead the distribution of time in the different categories during a year (or another time interval) can be used to express the long-term performance. For example, even if a system is designed for Cat. II, it may operate a significant part of the year in Cat I. According to Khovalyg et al. 2020, standards like EN 16798-1 give acceptable exceedance hours to allow for variations under real weather conditions compared to the simulation results using weather data files and to avoid the design of oversized HVAC systems. The required operative temperature categories for sedentary office work are shown in Table 1. For the adapted approach, the criteria for the operative temperature categories are taken from Figure B.1. in EN16798-1.

Table 1: Temperature ranges consider for the four categories of indoor environment defined for offices in EN 16798-1. Air velocity is assumed below 0.1 m/s and the relative humidity is 40% for heating seasons and 60% for cooling seasons.

Category	Temperature range for heating seasons, °C (1.0 clo)	Temperature range for cooling seasons, °C (0.5 clo)
I	21.0 - 23.0	23.5 - 25.5
II	20.0 - 24.0	23.0 - 26.0
III	19.0 - 25.0	22.0 - 27.0
IV	17.0 - 25.0	21.0 - 28.0

2.2. Definition of heating (winter) and cooling (summer) season.

For the PMV-PPD method for mechanically conditioned buildings the comfort requirements are divided in heating and cooling season with an assumed clothing change. The definition of heating-cooling season can be made in different ways:

- Based on date
- Based on outdoor temperature
- Based on calculated needs by dynamic building simulations

In the standards, it is recommended to define heating season (winter) at running mean outside temperatures below 10 °C. Cooling (summer) season is defined at running mean outdoor temperatures higher than 15 °C. It is assumed that in the heating season it is not possible to use mechanical cooling and vice-versa for the cooling season. However, it is a question whether heating-cooling should be assumed in the transition period between winter and summer, one of the focus areas for this paper. Using the adapted method, the thermal comfort requirements for the heating season (below 10 °C running mean outdoor temperature) are the same as for mechanical conditioned buildings.

3. Method

To study the issues outlined above dynamic building simulations was used for a typical office building in four different geographical areas Edinburg, Copenhagen, Zurich and Palermo.

3.1. Boundary building conditions

The model corresponded to a module of an office building, originally developed by Olesen and Dossi (2004). The building was composed of two identical offices with a floor area of 19.8 m² (length/height/width = 5.5/2.8/3.6 m) and a corridor section with a floor area of 8.6 m² (length/height/width = 2.4/2.8/3.6 m) between them. Each office had one 10 m² external wall with a window area of 5 m² (height/width = 1.65/3 m). One of the external walls was facing south and the other one facing north. All the internal walls of the building model were assumed adiabatic, except for the walls in between the corridor and the offices. The thermo-physical properties of the building components are shown in Table 2. Windows were equipped with automatically controlled solar shading devices. For incident radiations higher than 100 W/m² on the external glazing, internal blinds were drawn. When the internal blinds were active, the transmittance was multiplied with a factor of 0.09 and the solar gain was multiplied with a factor of 0.14.

Table 2: Characteristics of the building components of the simulation model

Component	Material	Thickness (mm)	Density (kg/m3)	Heat conductivity (W/mK)	Specific Heat (Wh/kg K)	Emissivity, (-)
Opaque component						
Floor/ceiling	Floor coating	5	1100	0.18	0.26	0.95
	Concrete	150	2300	1.7	0.24	
	Air gap	500	1.2	2.8	0.28	
	Ceiling panels	20	970	0.22	0.3	
Outside wall	Plaster	8	1000	0.7	0.28	0.82
	Insulation	80	40	0.04	0.42	
	Sand lime brick	240	1200	0.56	0.28	
	Plaster	15	1200	0.35	0.28	
Internal wall	Plaster	15	1200	0.35	0.28	0.82
	Sand lime brick	115	1800	0.99	0.28	0.93
Glazing component						
Windows	Heat transfer coefficient for the frame, W/m2 K					2.1
	Heat transfer coefficient for the glazing, W/m2 K					1.1
	Overall heat transfer coefficient, W/m2 K					1.4
	Solar heat gain coefficient, -.					0.58

3.2. Simulated weather conditions

For each location, a 3-day running mean outdoor air temperature was calculated from January to December according to equation (1), defined in EN 16798-1.

$$T_{rm} = \frac{1}{(1+\alpha+\alpha^2)} \cdot (T_{ed-1} + \alpha \cdot T_{ed-2} + \alpha^2 \cdot T_{ed-3}) \quad (1)$$

where T_{rm} is the daily running mean outdoor temperature for a specific day; T_{ed-1}, $T_{ed-2}$and T_{ed-3} represent the daily mean outdoor air temperatures from the previous three days and α is a constant with the value 0.8 (recommended in EN 16798-1).

In Figures 1 to 4 it is shown the running mean outdoor air temperature as well as the lower criteria for operative temperature during the heating season (Trm<10°C) and the upper criteria for operative temperature during the heating season (T_{rm}>15°C).

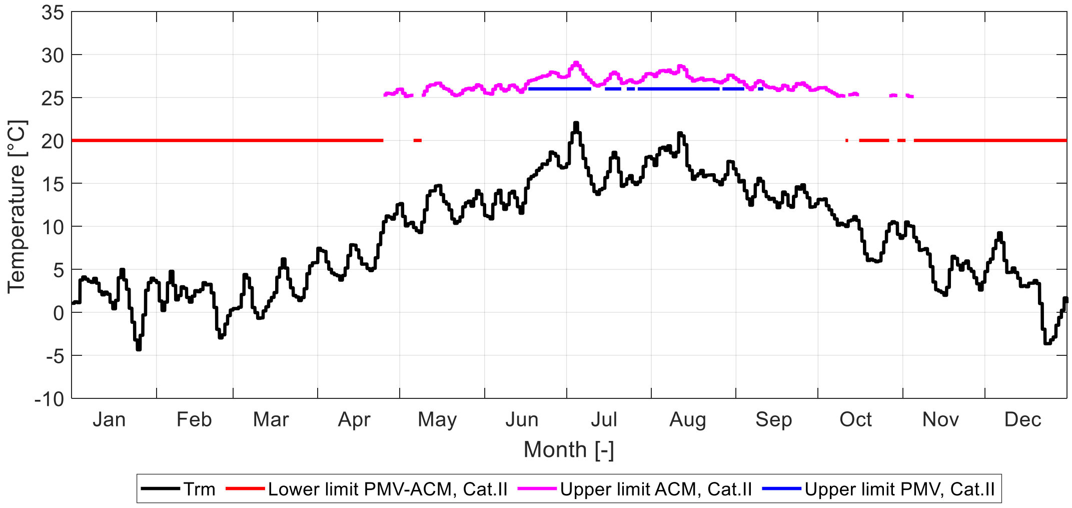

Figure 1: Daily running mean outdoor temperature (T_{rm}) as well as upper and lower limits for the PMV-PPD method and the ACM method for Category II, EN 16798-1 in Copenhagen.

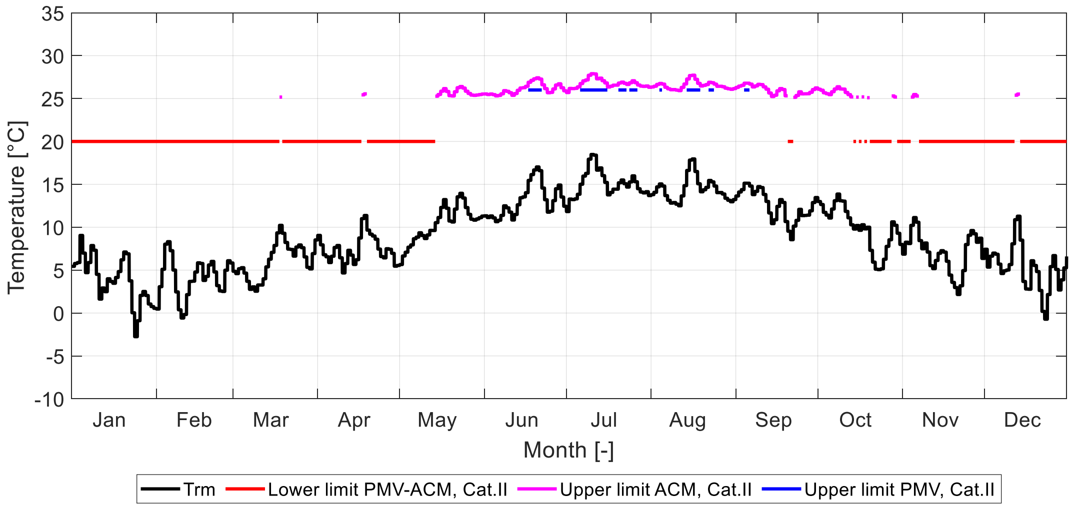

Figure 2: Daily running mean outdoor temperature (T_{rm}) as well as upper and lower limits for the PMV-PPD method and the ACM method for Category II, EN 16798-1 in Edinburgh.

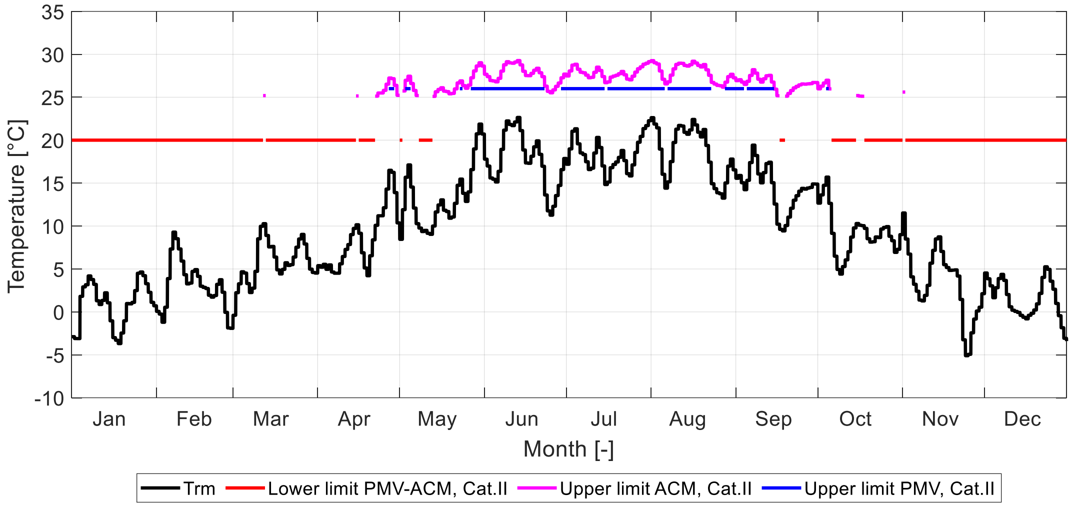

Figure 3: Daily running mean outdoor temperature (T_{rm}) as well as upper and lower limits for the PMV-PPD method and the ACM method for Category II, EN 16798-1 in Zurich.

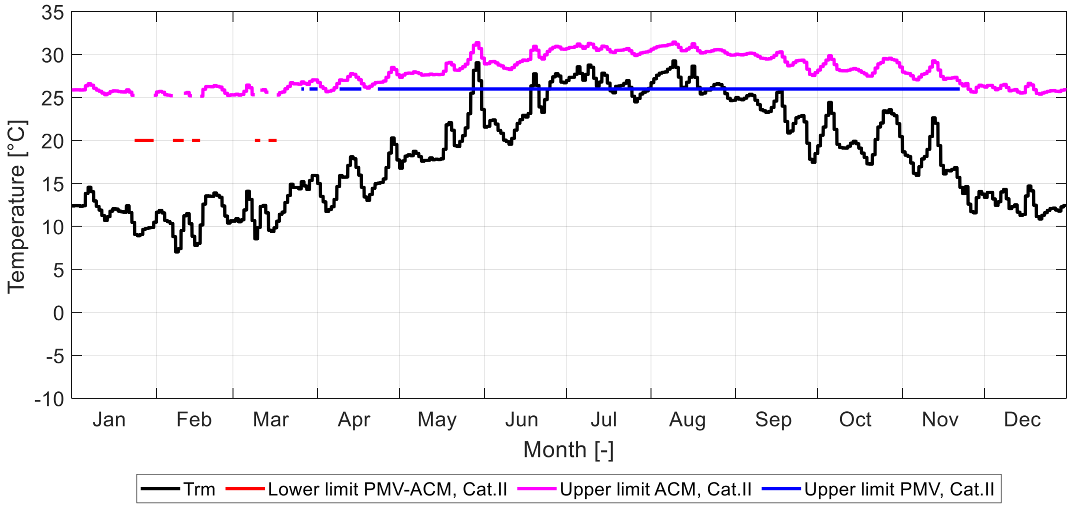

Figure 4: Daily running mean outdoor temperature (T_{rm}) as well as upper and lower limits for the PMV-PPD method and the ACM method for Category II, EN 16798-1 in Palermo.

3.3. Boundary system conditions and internal heat gains

As internal heat gains, each office had 2 occupants with a metabolic rate of 1.2 met, which were estimated to produce 238 W (12 W/m²). The occupancy level was based on the schedule defined in EN 16798-1 for single offices, where occupants are present only during weekdays from 08:00 to 13:00 and from 14:00 to 17:00. The equipment on each office corresponded to two computers and one printer, which altogether produced 350 W (17.7 W/m²). Ceiling lighting accounted for 50 W (2.5 W/m²), with a convective fraction of 50%. The schedules for the equipment and lighting were the same as for the occupants. The internal heat gains in the corridor corresponded only to a 100 W (11.6 W/m²) ceiling light, which had the same schedule as occupants in the offices.

The building was equipped with an all-air system, where a central air-handling unit (AHU) provided both heating and cooling to all zones. The supply temperature was proportionally controlled in the AHU between 16°C to 34°C based on the outdoor air temperatures between 22°C to -12°C respectively. The office rooms were equipped with a Variable Air Volume (VAV) system, where the air flow was controlled based on operative temperature, with a minimum supply airflow of 1.4 [L/sm²] (1.8 ACH) and maximum supply airflow of 10 [L/sm²] (13 ACH). The ventilation system in the corridor was controlled by a Constant Air Volume (CAV) control, with a constant airflow of 0.5 [L/sm²] (0.6 ACH). The operation time of the all-air system was continuous from 08:00 to 17:00 for all zones.

3.4. Cases considered for the evaluation

In order to analyse the implications of the seasonal operation of heating and cooling on thermal comfort and energy use, seven cases were considered in the evaluation: cases A, B, C, D, E and F. In case A, the change between the heating and cooling seasons is given by a fixed date. The change between the heating and cooling seasons was considered to occur on the 1st of April and the opposite change occurred on the 1st of October, without transition periods between seasons. In case B, the seasons were based on prevailing outdoor temperature levels. The heating season was defined as the period with T_{rm} below 10°C, the cooling season as the period with T_{rm} above 15°C and the transition between seasons occurred when T_{rm} was between 10°C and 15°C. In case C, the seasons were defined based on a fixed date obtained from building dynamic simulations, without considering a transition period between seasons. The simulations to define the duration of the heating and cooling seasons were based on the same boundary conditions mentioned in Section 3.1, 3.2 and 3.3, using as set points 20.5°C and 25.5°C for heating and cooling respectively. The period when the energy use for cooling was observed to overpass the period when heating was used was defined as the cooling period, without applying any specific guidelines for its definition. The same approach was used to define the heating period. An additional case was added to analyse the yearly performance of a building without any mechanical cooling systems installed, named case D. The heating season was considered as the period where the running mean outdoor temperature was below 10°C, as presented in EN 16798-1. However, the cooling season and transition period where not considered in case D, as no mechanical cooling was applied during the year. Finally, two additional cases were added in the analysis to evaluate the effects on thermal comfort when heating and/or cooling is available during transition period between seasons. Those cases are: only heating was applied during the transition period (case E) and neither heating nor cooling were available within that period (case F). A summary of the cases is presented in Table 3.

Table 3: Characteristics of the cases considered in the evaluation, showing how the seasons were defined and whether heating and/or cooling was present in each season. HA: Only heating was available; CA: Only cooling was available; NHC: neither heating nor cooling were available.

Case	Season definition	Heating season (winter)	Cooling season (summer)	Transition period
A	Fixed date, defined arbitrarily	HA	CA	Not considered
B	Based on T_{rm}	HA	CA	HA and CA
C	Fixed date, based on simulations	HA	CA	Not considered
D	Based on T_{rm}	HA	Not considered	Not considered
E	Based on T_{rm}	HA	CA	HA
F	Based on T_{rm}	HA	CA	NHC

4. Results

4.1. Analysis of heating and cooling seasons

The results in Figures 5, 6, 7 and 8 show that the operative temperature differed for the three cases A, B and C for the south room in each location. In Copenhagen, Edinburgh and Zurich, the lowest temperature levels were observed for case A, when the seasons were defined based on an arbitrary date. In that case, the heating season finished too early, leaving a period within April, May and September without heating supply. In Palermo, the operative temperature reached the highest values for case A, right after the beginning of the heating season. The case when the seasons were defined based on outdoor temperatures (case B) and building simulations (case C) showed operative temperature values between 20°C and 26°C for all the locations.

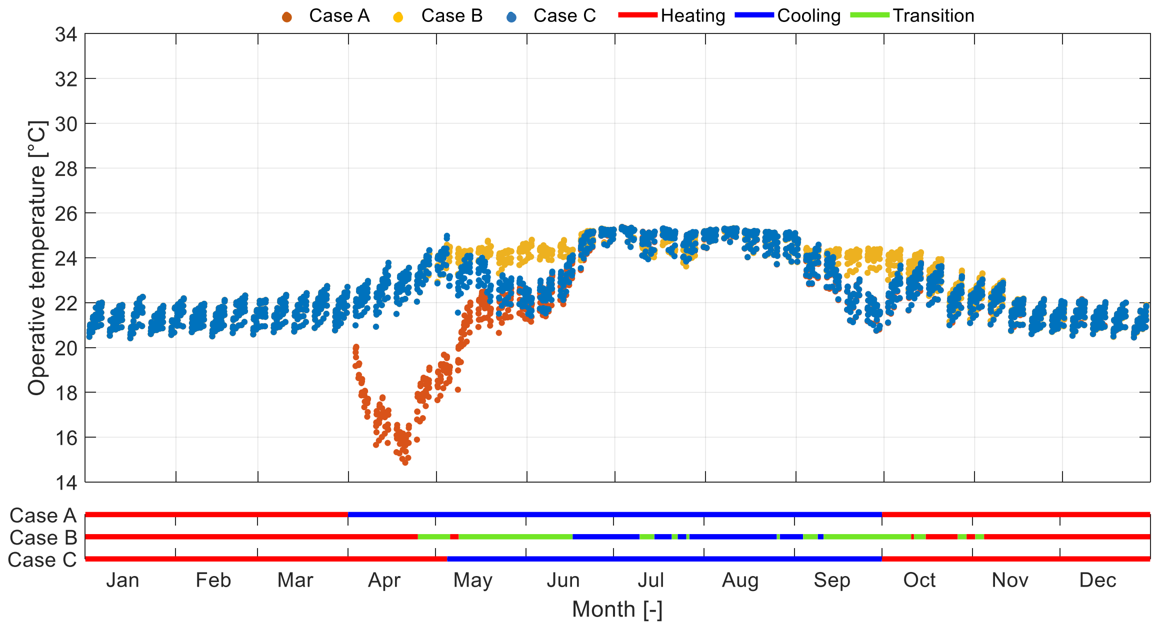

Figure 5: Operative temperatures obtained from the south room in Copenhagen for the cases A, B and C, during occupied hours

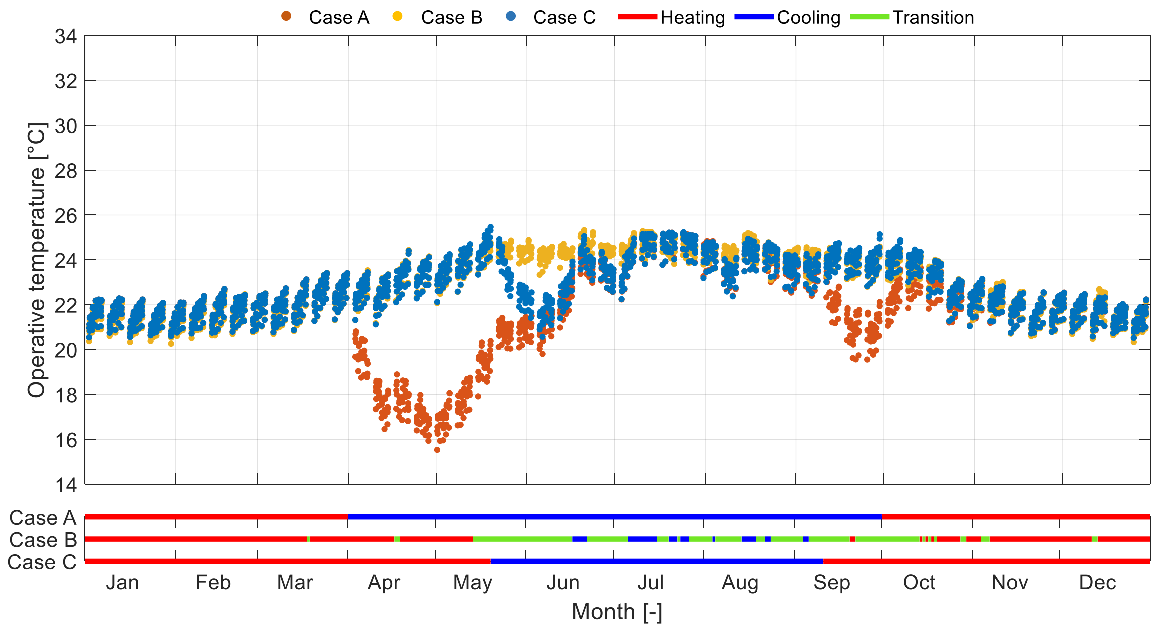

Figure 6: Operative temperatures obtained from the south room in Edinburgh for the cases A, B and C, during occupied hours

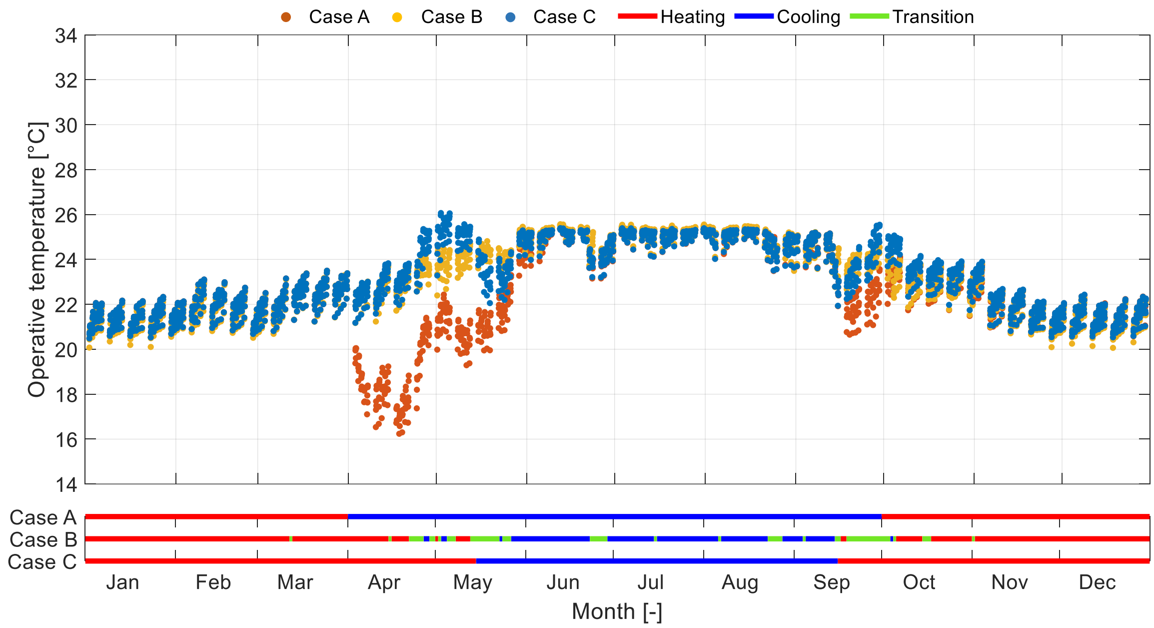

Figure 7: Operative temperatures obtained from the south room in Zurich for the cases A, B and C, during occupied hours

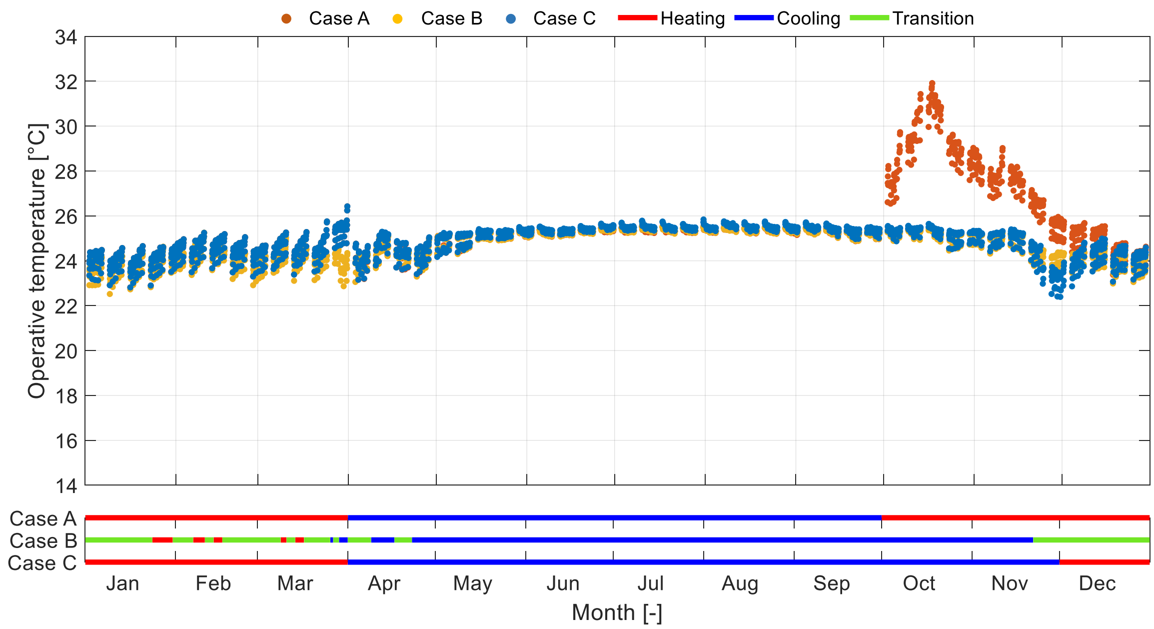

Figure 8: Operative temperatures obtained from the south room in Palermo for the cases A, B and C, during occupied hours

4.2. Thermal comfort evaluation

Figure 9 shows how the operative temperatures during time of occupancy from each studied case were distributed into the four categories of indoor environment presented in EN 16798-1, Table B.5. The limits defined for heating and cooling season were applied for the assessment of cases A and C. For case B, additional limits between heating and cooling seasons were added to account for the transition period between seasons, considering 0.75 clo, 1.2 met and 50% relative humidity. The percentage of occupied hours inside Cat. I was the highest in case B for all four locations (CPH-Copenhagen, ED-Edinburgh, ZH-Zurich, PA-Palermo). The period outside all categories was near zero for case B in all locations. The results show that when the heating and cooling seasons are defined based on a date (cases A and C), the thermal comfort level of the building is lower than when they are defined based on outdoor temperature levels (case B). The lowest thermal comfort was observed when the change between seasons occurred on a date determined arbitrarily (case A). The thermal comfort is improved when the date for changing from heating to cooling is based on the local climate and estimated based on a building simulation (case C).

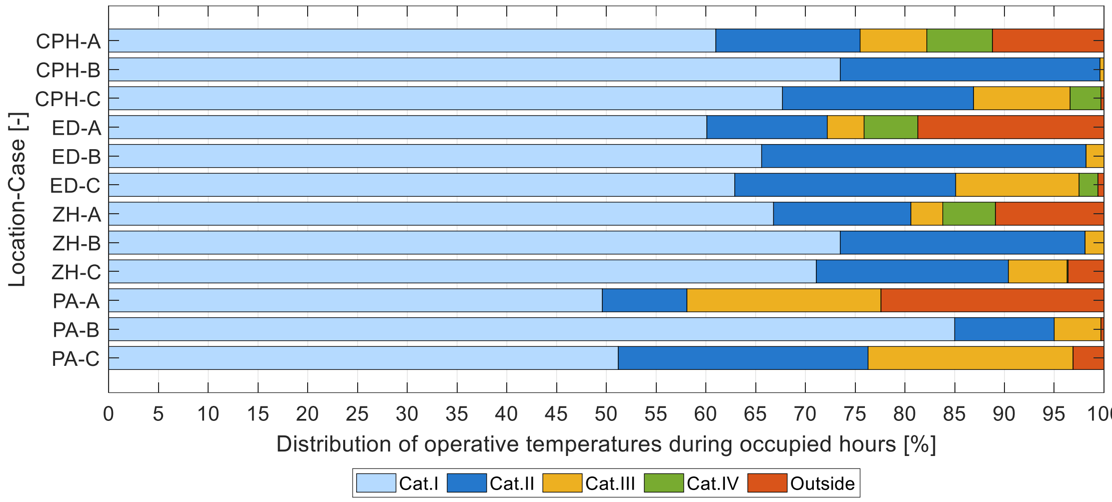

Figure 9: Distribution of the operative temperatures from the south room in the IEQ categories from EN 16798-1 during occupied hours, evaluated based on heating, cooling seasons for cases A and C and adding the transition period between seasons for the evaluation of case B.

The Adaptive Comfort Method (ACM) was used to evaluate the thermal comfort in four additional simulations for each location, defined as case D. In this case, only mechanical heating was used, which was only available during the heating season. Figure 10 shows how the operative temperatures were distributed during the year in the three categories defined for the ACM defined in EN 16798-1. For Palermo, the number of hours with operative temperatures outside all categories was negligible. Locations with colder average outdoor temperatures such as Copenhagen, Edinburgh and Zurich showed less hours inside all categories, compared to the simulation for Palermo.

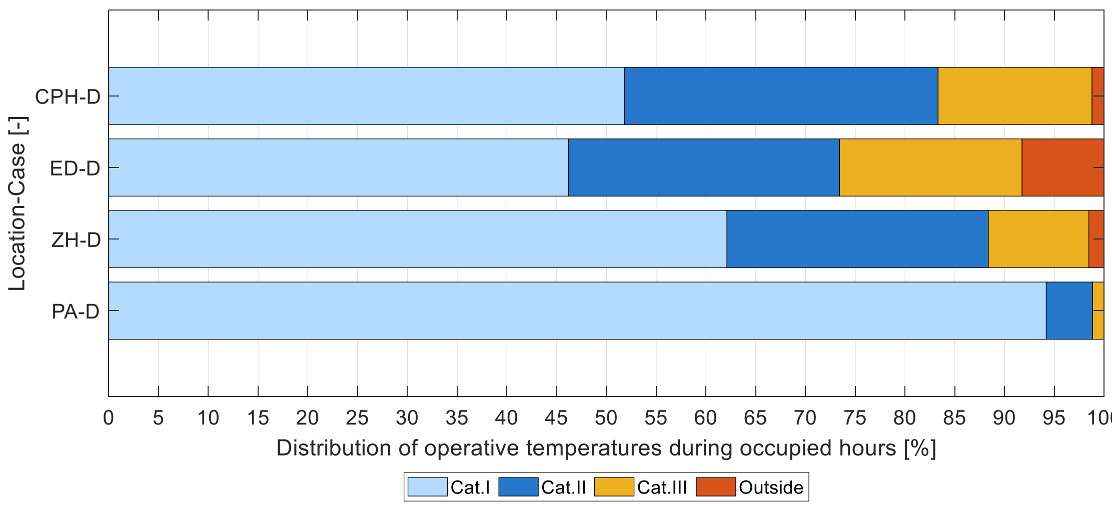

Figure 10: Distribution of the operative temperatures from the south room in the IEQ categories from EN 16798-1 during occupied hours.

The energy performance of a building is expressed with one number in kWh/m^2. To compare thermal comfort for different heating-cooling concepts and for expressing comfort with a single value, the yearly thermal comfort score (TCS) was introduced. This value was calculated based on the percentage of occupied hours (Figure 9 and 10) inside the categories of indoor environmental quality defined in EN 16798-1. The score assigned weighted values for % time spent in each category, and provides a single value from 1 (Best) to 5 (Worst) as an overall assessment of a zone or a building in each case. Equation (2) was used for the calculation of the weighted score for cases A, B and C.

$$TCS = \%Cat.I * 1 + (\%Cat.II - \%Cat.I) * 2 + (\%Cat.III - \%Cat.II) * 3 + (\%Cat.IV - \%Cat.III) * 4 + \%outside * 5 \quad (2)$$

The percentages inside each category (%Cat.I, %Cat.II, %Cat.II, %Cat.IV and %outside) correspond to the results showed in Figure 9.

For case D, the approach to calculate the weighted score was different, since the adaptive comfort method (ACM) accounts only for three IEQ categories. The yearly thermal comfort score for case D (TCS_{ACM}) was calculated using the ACM categories and percentage of time outside them as shown in equation (3).

$$TCS_{ACM} = \%Cat.I * 1 + (\%Cat.II - \%Cat.I) * 2 + (\%Cat.III - \%Cat.II) * 3 + \%outside * 5 \quad (3)$$

The highest TCS from cases A, B and C was obtained for case A, whereas the lowest value was observed for case B, as presented in Table 4. This is in agreement with the results from Figure 9, since the yearly thermal comfort score represents a weighted score of the IEQ categories based on the PMV-PPD method. For case D, the highest TCS was observed from the simulation in Zurich, where the number of occupied hours outside all categories was higher than for the other locations (see Figure 10). The highest TCS was observed in case D for Palermo.

Table 4: Yearly thermal comfort score (TCS) calculated for cases A, B, C and D. Higher score-lower comfort

Location	Copenhagen			Edinburgh			Zurich			Palermo		
Case	A	B	C	A	B	C	A	B	C	A	B	C
TCS	1.93	1.27	1.49	2.11	1.36	1.55	1.80	1.28	1.46	2.37	1.21	1.79
Case	D			D			D			D		
TCS,ACM	1.71			2.00			1.56			1.10		

The same approach to evaluate the category distribution for case B (see Figure 9), was used to calculate the percentage of time inside the four IEQ categories for cases E and F. That is to say, the percentage of hours inside each category was calculated for the heating season (clo=1, RH=40%), the cooling season (clo=0.5, RH=60%) and the transition period between them (clo=0.75, RH=60%). Figure 11 shows that the percentage of occupied hours with temperatures outside the IEQ categories was significantly higher when neither cooling nor heating were available during the transition period (case F), compared to the case only with heating (case E). For the latter case, the period inside Cat. II was approximately the same compared to case B in Palermo and 4% lower for Copenhagen (see Figure 9).

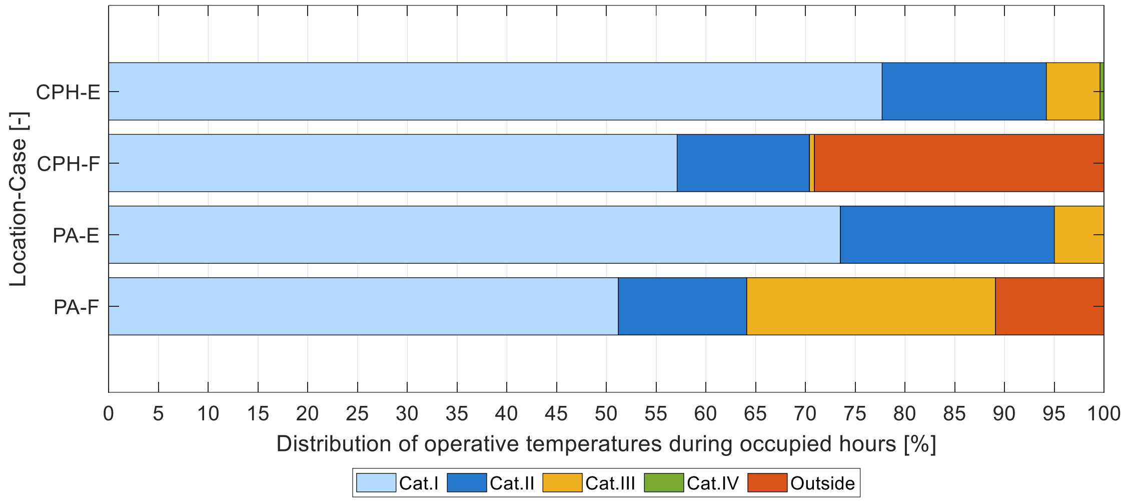

Figure 11: Distribution of the operative temperatures from the south room in the IEQ categories from EN 16798-1 during occupied hours, evaluated based on heating, cooling seasons and transition period. Two cases were considered for the transition period, where only heating was provided (case E) and neither cooling nor heating was available (case F).

The yearly thermal comfort score was calculated considering the distribution of operative temperatures presented in Figure 11, by applying equation (2). The results shown in Table 5 evidence that the overall thermal comfort level decreased significantly when neither heating nor cooling was available during the transition period, compared to the case only with heating applicable during that period. When comparing cases B and E, it was observed that the TCS for case B in Copenhagen was approximately the same for cases B and E. However, the TCS was higher for case B in Palermo. This suggests that allowing cooling during the transition period did not have an appreciable effect on the yearly thermal comfort level for Copenhagen, but it had a small improvement for Palermo.

Table 5: Yearly thermal comfort score (TCS)

Location	Copenhagen		Palermo	
Case	E	F	E	F
TCS	1.28	2.31	1.30	2.06

4.3. Energy evaluation

The results presented in Figure 12 show that case B had the highest level of energy used in each location. This was due to a greater energy use for heating in colder climates (Copenhagen, Edinburgh and Zurich) and for cooling in warmer climates (Palermo) compare to the other cases. When cooling (case E) or heating and cooling (case F) were not available during the transition period, the total energy use was lower than having both during that period. The lowest energy use in each location was from case D, as no cooling was considered along the year and no heating outside the heating period. The difference between the total energy use when changing the heating and cooling seasons based on a date defined arbitrary (case A) and grounded on building dynamic simulations (case B) was below 2 kWh/m² for cold climates (Copenhagen, Edinburgh, Zurich) and approximately 3 kWh/m² for warm climates (Palermo).

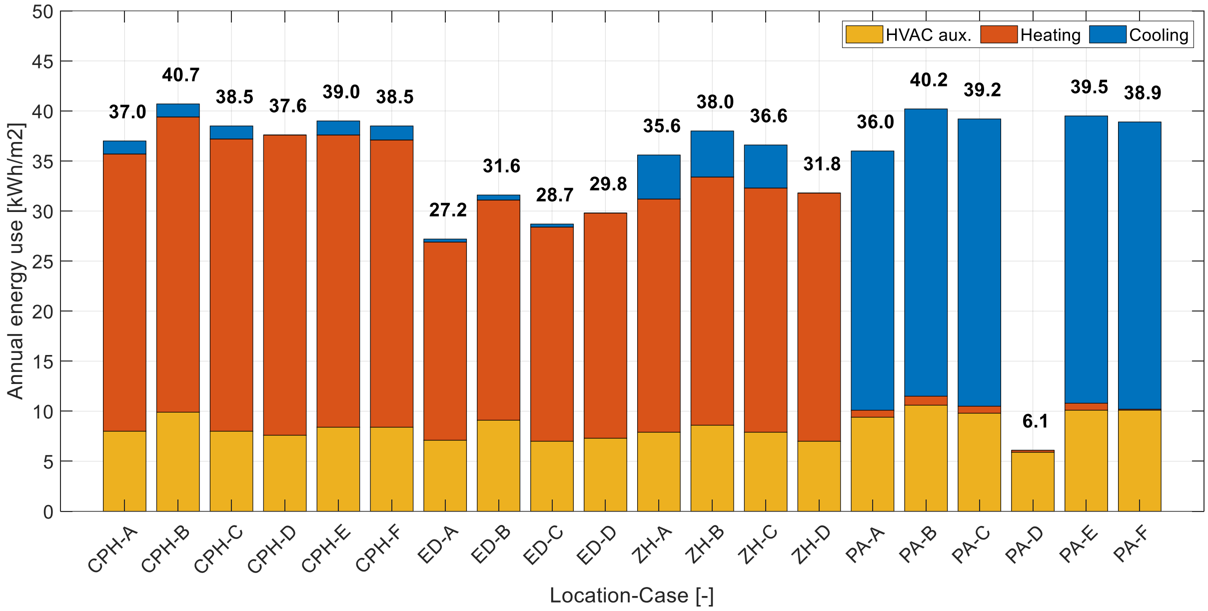

Figure 12: Annual energy use for each simulated case for heating, cooling and auxiliary energy used by the HVAC equipment (HVAC aux.).

5. Discussion

5.1. Definition of the heating-cooling period

The definition of heating (winter) and cooling (summer) period for mechanical cooled buildings has a significant influence in the overall comfort. Using the definition in EN16798-1 based on an outdoor running mean temperature of 10 °C and 15 °C seems to work well under all four climatic zones. To optimize the date for the change based on a pre-simulation will not give much improvement in the comfort (see Figure 9). It is however still an open question how the systems should be operated in the transition period. Should both heating and cooling be available or only heating or cooling? The running mean outdoor temperature will fluctuate and there will be days where it goes below 10 °C after it has passed 10 °C the first time. In reality, it is not likely that during the cooling period heating will be available and cooling will be applied during the period of the year when heating is normally used. Therefore, it is a difficult task to suggest consistent guidelines to define a transition season that is not intermittent in time and accounts for the seasonal variations of the outdoor climate. Again, it does not make sense to have both heating and cooling available in the transition period. A concept could be to have heating available in the spring until 15 °C running mean is reached the first time and again in fall when 10 °C running mean is reached the first time. This is supported by the results in figure 9 and Figure 11. Figure 11 show that providing heating during the transition period (Case E) provide about better comfort than Case F, with no heating and cooling in the transition period. The figures also show that the comfort with case E is very similar to case B, where heating and cooling is available in the transition period. This is also confirmed by comparing the Thermal Comfort Scores in Table 4 and 5.

The distribution of the energy use in the four cities (Figure 12) were, as expected, different between the four cities. In Edinburgh, Copenhagen and Zurich, the energy for heating was dominating while in Palermo it was for cooling. The energy use in all locations was larger for case B, where heating and cooling were considered during the transition period. The difference between the energy use between that case and case E, when only heating was as available in the transition period, was moderate (4% lower for Copenhagen and 2 % lower for Palermo). The reduction of the energy use when heating was not available (case F) compared to the case when it was available during the transition period was even lower (1% for Copenhagen and Palermo).

5.2. Yearly thermal comfort evaluation

The thermal comfort has been evaluated by looking at the temperature distribution in the different Categories as seen in Figure 9. It can still be difficult to compare the thermal comfort between the three cities and for the three definitions of heating and cooling season. Therefore, a method to combine the values into one number by a weighing factor for each category is shown in equations 2 and 3. In all cases A with a fixed date for switching between heating-cooling has the least comfort. For Edinburgh, Copenhagen and Zurich the difference between Cases B and C is very small; but for Palermo case B is significant better. The yearly thermal comfort score (TCS) gives an overall assessment of the thermal comfort in a building, therefore is not capable of analysing slight differences between temperature distribution in categories. For instance, when comparing the distribution of operative temperatures from Copenhagen and Palermo for case B (Figure 9), in the first case the period with temperatures above Cat.II was nearly zero, whereas for the second was approximately 5% of the occupied hours. However, the TCS is lower (better) for the second case than for the first one. This example demonstrates the penalty of using a single index to represent the yearly thermal comfort score.

Figure 11 shows the results with different concepts for the transition period regarding heating and cooling. When only heating was considered during that period, the yearly thermal comfort score estimated with the proposed methodology was approximately the same compared to the case when cooling was also available in that period. However, TCS increased significantly (40-80%) when heating was not available in the transition period, indicating a much poorer performance in terms of thermal comfort.

For buildings where the Adaptive approach can be applied to characterize the thermal comfort level, the cooling season does not exist as no mechanical cooling is available. The question is however when heating should be available. Only the period where the running mean is below 10°C? or until 15°C?. In the present simulation study, only heating for running mean outdoor temperatures below 10°C was assumed. The results showed that the operative temperatures for the simulation in Palermo had higher percentages inside the limits from the ACM, compared to the other locations (see Figure 10). The limits for the ACM from Palermo could be applied for a longer fraction of the year as presented in Figure 4. This suggests that, outside the heating period, the ACM limits can be used to evaluate the thermal comfort level in buildings without mechanical cooling, but the overall thermal comfort will be better in cases with warmer climates. It should be noted that in the current study the ventilation level was not increased for the adapted method, which could possibly provide more cooling during periods where outside temperature were lower than room temperature.

5.3. Suggested revision of the standards

The applicability of the temperature ranges considered for the indoor environmental categories defined in EN 16798-1 depends on the definition of the heating and cooling seasons. This study demonstrated that the definition of the period of the year when heating and cooling is available has a significant influence on thermal comfort and energy use. The definition of the heating and cooling seasons based on a running mean outside temperature of 10 and 15 seems to work well for the different climatic zones studied. However, the authors recommend that Guideline TR 16798-2, should provide more specific design guidance regarding the transition period. Should this period be evaluated using the adapted method as it seems cooling is not needed or should it be evaluated, as done in this paper, by using a clo-value of 0.75 clo? The standard defines three categories of indoor environment for the Adaptive method, when mechanical cooling is not available, and four categories for the PMV-PPD method. It is recommended to include an index that summarizes the overall comfort level described by the IEQ categories, which allows to compare in a simple manner scenario with different boundary conditions.

6. Conclusions

This study aimed to analyse how the heating and cooling seasons can be defined throughout a year, such that the thermal comfort level is adequate, and the energy use is minimized. The evaluation was performed by analysing the results from the dynamic simulation model of an office building for four locations: Copenhagen, Edinburgh, Zurich and Palermo. Defining the heating-cooling seasons based on outdoor temperature conditions with a transition period between them showed a better thermal comfort level compared to their characterization based on a date defined arbitrary or from dynamic simulations. No significant benefits in terms of thermal comfort and energy use were observed when operating the transition period with mechanical cooling available.

It was also the aim of the study to evaluate and compare different methods to analyse the thermal comfort level of a building throughout a year. The approaches recommended in EN 16798-1 and the technical TR16798-2 were used to assess the thermal comfort level by looking at the distribution of room temperatures in the different categories of indoor environment, based on the results from building dynamic simulations. The analysis was carried out in buildings with air-conditioning systems, where temperature limits of the comfort zone are calculated from the PMV-PPD method and buildings without air-conditioning, where the Adaptive Comfort model is used to define the limits of the comfort zone. A methodology to calculate an overall yearly thermal comfort score based on the IEQ categories of indoor environment, was also applied to evaluate the thermal comfort in buildings with and without air-conditioning. The results from the thermal comfort score allowed to have a simpler overview of the thermal comfort level from each simulation, compare to the categorization of thermal comfort.

7. References

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