OPTIMISATION OF CLIMATE ROBUST BUILDINGS UNDER SUMMER CONDITIONS WITH "PRIMERO-COMFORT" SIMULATION SOFTWARE INCLUDING DETAILED USER BEHAVIOR AND COMFORT EXPECTANCE

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Abstract

In this paper the possibilities for avoiding active air conditioning by all means of the room itself (window size, glazing, shading system, natural ventilation, furniture), artificial light and control strategy of these systems are investigated. A very important component of the system is the user with his ability to adapt to changing conditions in his surrounding and with his possibilities to manipulate the window, the shading system, the light switch etc.

All these aspects interact together. It is necessary to optimize them simultaneously. But real planning often separates them into single sections. Simulation tools also handle normally only one or a few aspects, we know for example the thermal simulation or the daylight simulation.

Primero-Comfort (2009) is a simulation tool based on energy+, what is able to consider thermal simulation as well as daylight simulation as well as user behaviour in regard to the probability of window openings. The resulting thermal comfort is rated by an adaptive comfort model, the dutch ISSO 74 (2004).

This allows to design office rooms more realistic. And it shows that an optimized solution has to include the interactions of all mentioned aspects.

Investigations with Primero-Comfort for a moderate European climate (Hamburg) show that a very good comfort can be reached only by passive means of building design also for hot summer weather just like the summer in the year 2003. The keys for such hot-summer-robust-buildings are night ventilation with height difference, heat protection glazing and good shading system, reduced internal heat gains for artificial light by accepting a threshold of 300 lx of daylight as comfortable and a reduced window size oriented on daylighting and the view out of the window.

1. Simulation Model and PC-program

All the simulations were made with the beta release of Primero-Comfort (2009). The following screen shots demonstrate well the specifications of the program in input, simulation and results.

We regard a south oriented, standard office room 3.95 (width) x 5.93 (depth) x 2.70 (height) with 2 (big) desks 0.8 x 2.0 m, in depth between 0.4 and 2.4 m. The internal heat gains are for office equipment 42 Wh/m² d and for persons 30 Wh/m² d, the artificial light has a maximum power of 14 W/m².

Figure 1 Intensity of internal heat gains and time profile of use for a standard group office (Primero-Comfort Screenshot).

With the simulations we try to investigate the possibilities and limits of only passive methods (i.e. no air conditioning) for reaching a good comfort under summer conditions. The comfort will be evaluated with an adaptive comfort model, the Dutch ISSO 74 (2004).

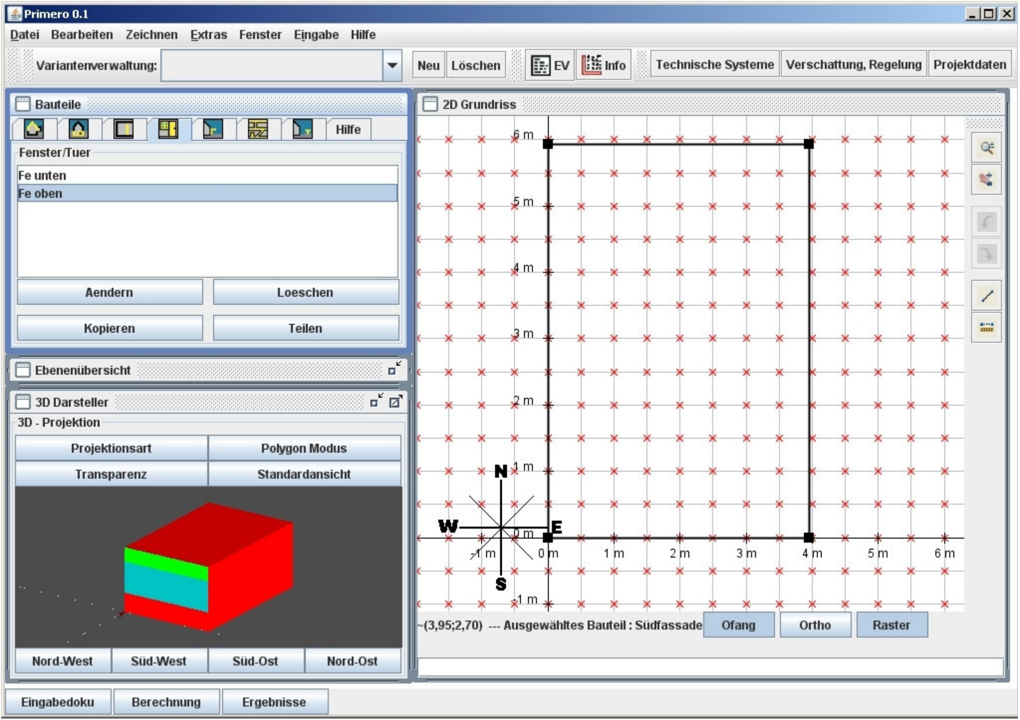

Figure 2 Reference room with two windows with different control strategy of shading (lower part cut off, upper part horizontal), main user interface of Primero-Comfort.

Construction, façade, shading system, artificial light and their control systems are assumed as optimal for avoiding overheating in summer: Ceiling and floor are massive with floating floor (wood), interior walls are assumed as light, the external wall as massive, insulated outside. The façade has a parapet; the window is shaded by a louvre blind. For a maximum of daylight (and a minimum of artificial light and internal heat) when activated, the control system of the blind is shared in 2.1 m height: lower part cut off, upper part horizontal. The illuminance level for lighting is set to 500 lx, if daylight is not sufficient, artificial light is dimmed to this value.

Parameters of the simulations are:

- The width of the window (from 40 to 100% of the area above the parapet)
- The type of glazing (sun g=0.33 or heat protection g=0.60)
- The depth of reference point for lighting (light sensor for daylight)
- The climate data: All simulations for Hamburg, but with standard climate / hot summer of 2003
- The type of natural Ventilation: Only by windows / cross ventilation / ventilation with height difference >= 4m, inside / outside working hours.

2. Simulated Strategies for Natural Ventilation and Lighting

2.1 Natural ventilation

The probability of window opening is in correlation with outside temperature (Pfafferot 2002). Everybody has the whish to open a window, but if this would be too uncomfortable because of too deep temperatures outside (let's say 5℃), the window remains closed. With increasing temperature the probability increases too. At about 18 to 20℃ we reach the maximum air change by natural ventilation – the windows are open.

This user behaviour can be reproduced in Primero-Comfort.

The kind of natural ventilation may differ during the period of use and outside of it, depending e.g. on the possibilities of a natural night ventilation (protection against weather and burglary). We differentiate between ventilation only by windows / cross ventilation / a ventilation over a height difference of >= 4m with resulting maximum air changes of 1, 2 and 3 resp. (because of higher temperature differences during night time between 22 and 6 o'clock multiplied by 1.5).

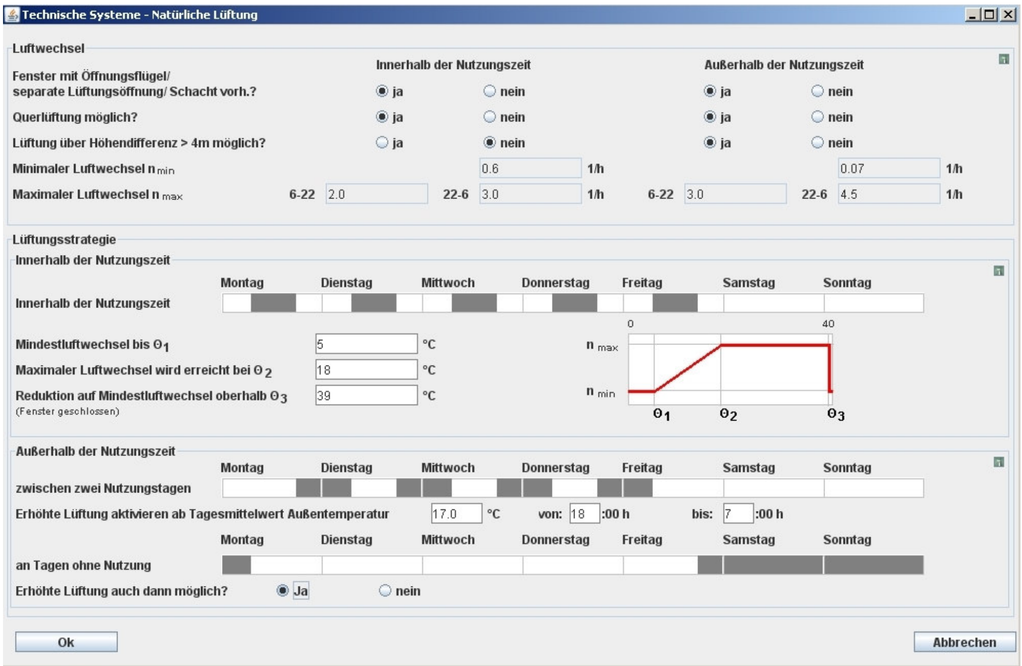

Figure 3 *Parameters for natural ventilation. Set outside temperatures for minimum and maximum air change, type of ventilation (only by windows / cross ventilation / ventilation with height difference >= 4m) and control strategie for natural ventilation inside and outside hours of use (Primero-Comfort screenshot).*

Increased natural ventilation outside the period of use is activated above a set temperature of daily mean value of outside temperature (16 to 17°C, this was deduced as good compromise between overheating by to less night ventilation and heating demand by to much night ventilation).

2.2 Reference Point of Light Sensor

In accordance to EN 12464 an illuminance of 500 lx should be reached at the whole desk area. This leads to a position of the light sensor at the end of a (big) desk at a depth of 2.4m.

But this assumption is very conservative, because it neglects the higher value of daylight in comparison to artificial light. It is known that 300 lx of daylight are felt as very comfortable for office work – there is no need for additional 200 lx of artificial light.

Because of that, an “I like daylight” situation can be assumed too. This could be realised e.g. by two different ways with similar results:

a) A reference point for daylight near to the window. If there are 300 lx daylight in the centre of the desk (where the user is sitting), than the sensor nearer to the window receives 500 lx - no artificial light! Only if daylight in the centre of the desk falls below 300 lx, artificial light is given additionally. With additional simulations for both cloudy (shading system is open) and clear sky with sun (shading system is closed) was found out, that this is fulfilled with a position of the light sensor in a depth of about 0.9m.

b) The reference point remains at 2.4 m, but the sensor is set to 300 lx. Every user has an individual working place illumination of 200 lx and may decide what he wants.

3. Evaluation of Comfort in Summer with an Adaptive Comfort Model – Dutch ISSO 74

In naturally ventilated buildings users can adapt to the surrounding conditions. They feel well with operative temperatures increasing with outside temperatures. Comfort temperature is significiantly higher than in buildings with AC, see van der Linden (2006).

ISSO 74 (2004) differs between three comfort ranges:

- Class A: More than 90% satisfied (for high expectance)
- Class B: More than 80% satisfied (standard for new buildings)
- Class C: More than 65% satisfied (standard for renovated buildings)

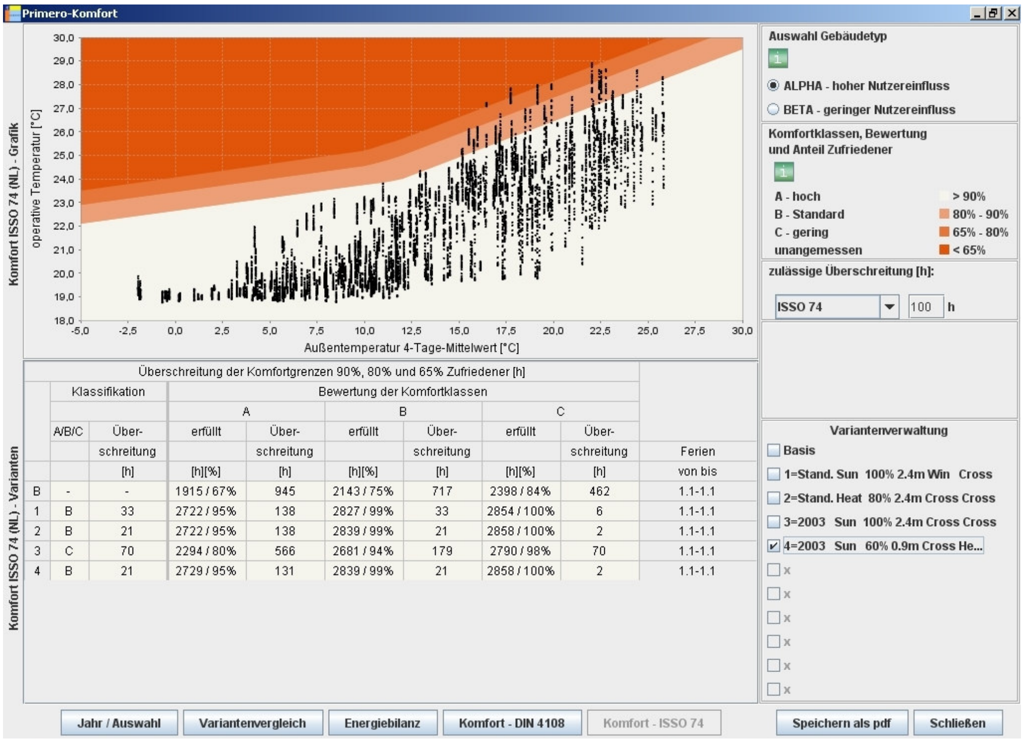

Figure 4 Evaluation of comfort by ISSO 74 (2004) for a simulated summer period. Every point corresponds to one hour of the period of use. The Comfort classes A, B and C are marked in different red colours (Primero-Comfort screenshot).

From a puristic point of view an exceeding of just one hour leads to the next lower class. Practice shows, that this would lead to comfort class insufficient very often. That's why a moderate exceeding of the limits should be allowed. We assume here an amount of 100 h during the period of use (this is about 10% of working time during summer).

Thus, classification results in classes A, B, C or insufficient with a supplement regarding to the number of exceeding hours, like A (75) or B (23) or C (46) and so on. For our investigations the recommendation for new buildings, comfort Class B is the target, of course. This is in accordance with a high comfort.

4. Results

With the parameters listed in chapters 1 and 2 more than 20 simulations were realised. We show here the main results, e.g. good combinations of equipment and control systems.

4.1 Standard Weather

All equipments without ventilation outside the period of use will result in insufficient comfort. Thus, the first principle is: Create a building that allows (cross) ventilation outside the period of use! This requires overflow openings inside the building and openings in the façade which are safe against weather and burglary.

If there is a sun protection glazing, 100% of window size is possible; for the period of use ventilation just by the windows is sufficient (this could be an advantage, because overflow openings can be linked with acoustic problems from other offices).

With heat protection glazing the solar transmittance is much higher, of course. But this can be compensated with a cross ventilation also during the period of use and a smaller window of 80% size – with nearly no reduction in daylight autonomy because of the higher light transmission of this glazing!

In both cases the ventilation outside the period of use should be activated at mean daily temperatures above 17°C.

Table 1 Good combinations of window size, system of natural ventilation and position of reference point for daylight, standard weather

Window size above parapet [%]	Glazing type	Ventilation in period of use	Ventilation outside period of use	Depth of reference point light	Evaluation of comfort (ISSO 74)	Daylight autonomy [% of working hours]
100	sun protection	windows only	cross ventilation	2.4 m	B (33)	58
80	heat protection	cross ventilation	cross ventilation	2.4 m	B (21)	57

4.2 Hot Summer Weather (2003)

The summer of the year 2003 is hold as a century summer; the temperature level is about 4 degrees higher than in standard weather resulting in higher indoor temperatures and worse comfort classes.

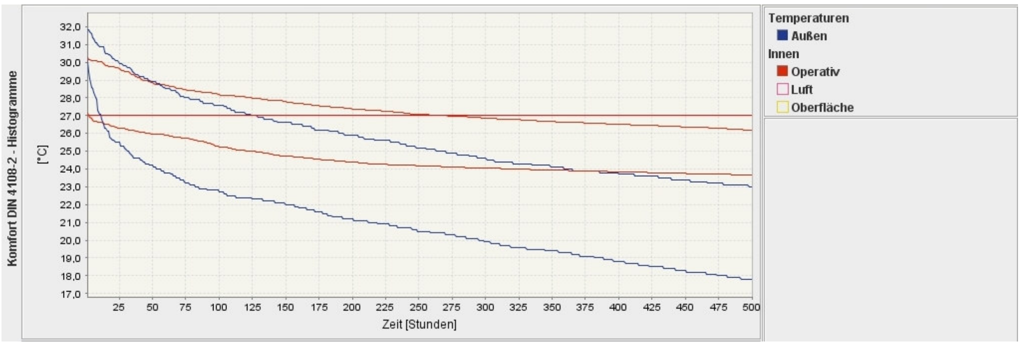

Figure 5 Histogram (number of hours with temperature above a certain value) of temperatures outside (blue lines) and resulting operative temperature inside for the same room (red lines), (Primero-Comfort screenshot).

Is it possible to compensate this extreme weather conditions only by passive means in spite of this leading to a good comfort and daylight autonomy? This is a central question for the future – if the answer is no, we would be forced to install AC in each office building!

The simulations give reason to the hope that the answer could be yes, but only if we regard all the aspects simultaneously together and if our buildings allow to do so.

Again ventilation outside the period of use is a first key, of course. Here, ventilation with a height difference outside the period of use would be very helpful (or alternatively mechanical ventilation). And the second key is to use heat protection glazing. But also then comfort is changing to the worse to class C – for new buildings insufficient.

So, the third key may be to think about the too strong requirements of EN 12464 and to allow 300 lx of daylight without additional artificial light.

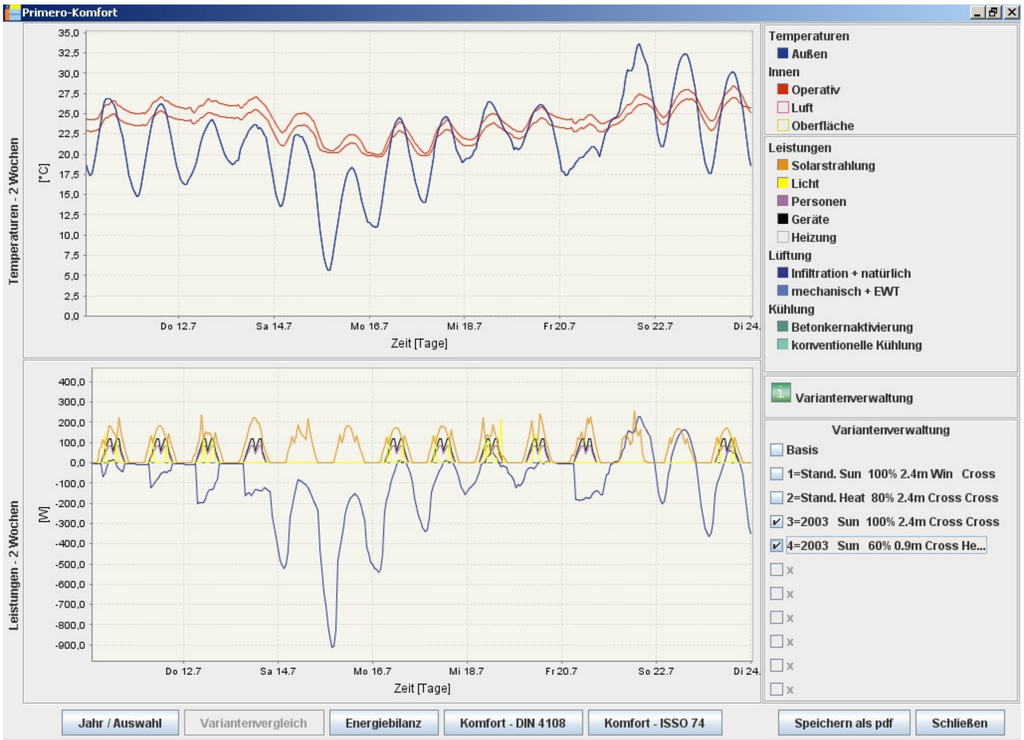

Figure 6 Comparison of operative temperature and energy fluxes for 2 different control strategies for artificial light (reference point in 2.4 / 0.9m depth), hot summer weather (2003). Note that for reference point 0.9m there is in the whole period of 14 days no artificial light contrary reference point 2.4m (yellow lines), this is the reason for the different operative temperatures! (Primero-Comfort screenshot).

With the “I like daylight” strategy a window size of 60% would be sufficient (leading to less solar transmission) to reach a daylight autonomy of 80% and a comfort class of B (21)!

Table 2 Good combinations of window size, system of natural ventilation and position of reference point for daylight, hot summer weather (2003)

Window size above parapet [%]	Glazing type	Ventilation in period of use	Ventilation outside period of use	Depth of reference point light	Evaluation of comfort (ISSO 74)	Daylight autonomy [% of working hours]
100	sun protection	cross ventilation	cross ventilation	2.4 m	C (70)	58
60	sun protection	cross ventilation	height difference	0.9 m	B (21)	80

In both cases the ventilation outside the period of use should be activated at mean daily temperatures above 17℃.

5. Conclusions

The results shown here should be stabilised with expanded simulations and measurements.

But we hope that the tendency given here will be shown as solid. It is almost a bit astonishing - there seem to be chances to meet a good thermal user comfort under summer conditions also for hot summer weather. But this requires coordination of all aspects influencing comfort.

Instead of the method cooling to 18 degrees in summer and heating to 26 degrees in winter we should think back to our human behaviour and use adaptive qualities of people. What temperature is really felt as most comfortable? This is described in adaptive comfort models that should be used for valuation of achieved comfort.

We should remember that it is a simple method of adaptation to comfort to add or reduce clothing. If it is possible to work without a jacket in summer the felt comfort temperature is 1 to 2 degrees higher and the building has much better chances to deliver this. A weakened or no dress code is a simple measure of sustainability.

Of course the building itself has to allow that the user has the possibility of personal manipulation of windows, shading system, artificial light etc. Only with this pre-condition human adaptation can be realized. A building with a sealed façade, central air conditioning, automatically activated shading system don’t allow the adaptation of the users according to their wishes and brakes contact with outdoor climate.

The higher quality of daylight in comparison with artificial light should be taken into account again. Pre-condition is that the user has the possibility to switch on and off artificial light by himself (e.g. with a basic central artificial light of 300 lx and an individual working place light). This increases the number of daylight hours, reduces hours with artificial light and internal heat gains.

Supplementary aspects are a good shading system, sun protection glazing and a window size what is sufficient for daylighting and the view out of the window instead of a glass front.

In short – we should give men back into the centre of contemplation. We should leave the way of believing only on the abilities of the technical equipment and bring it back to that what it is. Just an auxiliary component if the users operating with windows, shading system, light switch and the building alone can’t deliver comfort.

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