Development of a new decision tool for Sustainable COOLing Systems (CORNET SCOOLS)

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Key Innovations

- Decision support tool for sustainable cooling systems
- Assessment of summer comfort in dwellings
- Cooling loads room per room

Practical Implications

- The uncertainty about climate projections complicate summer comfort evaluations.
- There exist many methods to assess summer comfort, it is always a good idea to store the (hourly) operative temperatures so that other calculations can be done in post-processing
- Be sure to implement a realistic control algorithm when comparing passive and active cooling systems

Introduction

Due to climate change and increasing frequency of heat waves, cooling in residential buildings gains importance. The most common way of cooling in buildings is active cooling with the use of 'split units' or central air-conditioning systems, using an electric compressor and standard refrigerant. However, these systems have a relative high energy consumption, and the European parliament has called a phasedown for many of the refrigerants. Sustainable cooling systems can therefore be a superior alternative for conventional systems. These systems are however not often applied due to a lack of real performance data and guidelines for the correct selection and dimensioning. This problem is addressed by the CORNET SCoolS.

Methods

An accessible decision support tool for cooling systems, like in Figure 1, can give insight in the applicability of sustainable cooling systems. After the selection of a limited number of descriptive input parameters on the left of the screen, the main graph gives an indication of the energy consumption (height of the bars) and an assessment of the comfort level (color of the bars) for different cooling systems. Another graph (not on the figure) gives the specific cooling load for each room.

To enable such a user-friendly approach, the tool is conceived as a window to an underlying database with simulation results. A parameter study has been undertaken by simulating 5 different building types, variated by insulation level, thermal capacity, window percentage and orientation of the building. Internal heat gains are imposed based on a Dutch method developed by Witkamp et al. (2019).

For these building variants, an assessment was made of the performance of different cooling systems and emitters, optionally combined with passive cooling strategies. More precisely, systems with free geo-cooling coupled with floor cooling, fan coils or cooling coils (in the ventilation supply air), as well as indirect adiabatic cooling systems are considered and compared with a classic air conditioning system. Concerning the passive strategies, solar shading devices and intensive ventilation or less intensive night cooling by opening of windows can be applied. The occupant behavior with respect to the control of solar shading and window opening supposed to follow logical rules and could be assumed automated as well.

For all these cases energy consumption and temperature exceeding hours on an annual basis were calculated using TRNSYS17 simulations, with a room-by-room approach. Unfortunately, there is no standard method to assess summer comfort with respect to residential buildings. Based on literature review, a.o. IEA (2018), EN16798 (2019), ISO 7730 (2005), and given the scope of the simulations, it was quite straightforward to express the comfort range in terms of operative temperature (instead of PMV) and based on the individual room temperature (instead of a mean building temperature) and room occupancy. However, a decision had to be made about the maximum allowed temperatures and whether to use an adaptive comfort model or not.

Furthermore, comfort models are always somewhat defined with respect to the used climatic data. For this project, a new climate file has been constructed based on a selection of the most severe heat waves of the recent 10 years (2010-2019) using the official weather station data of Belgium in Uccle. This could seem a bit extreme, but the authors found a good overlap with the very recently constructed 2040-2060 weather files in the framework of Annex80 Task A (IEA 2020).

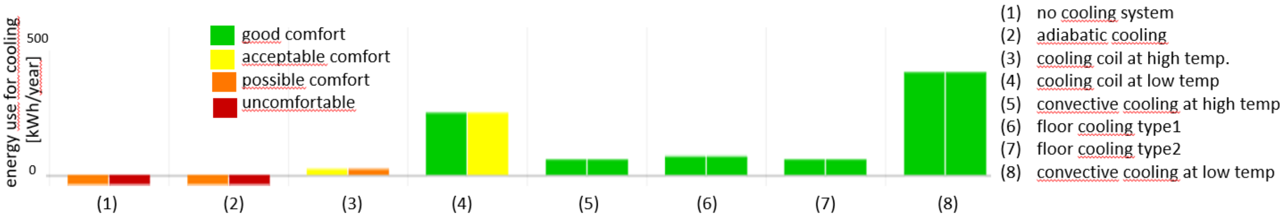

Figure 1: decision support tool for cooling systems

Results

Figure 1 shows the results within the decision tool of a terraced dwelling with massive construction, insulation according to the current standard, and at the most critical orientation (W-E). Outside solar protection and window opening (ventilative cooling) are applied. Apparently, most of the cooling systems, except for the adiabatic one and the cooling coil at higher regime temperatures, provide acceptable or good comfort. The 3 systems based on free geocooling reach a good comfort (system 5-7 on X-axis) and a low energy consumption compared to the airconditioning system (rightmost on the graph).

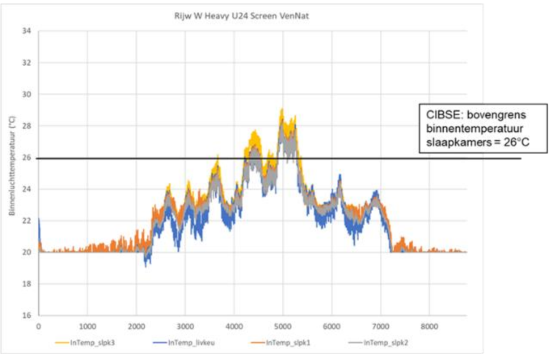

Figure 2: operative temperatures and CIBSE criterion

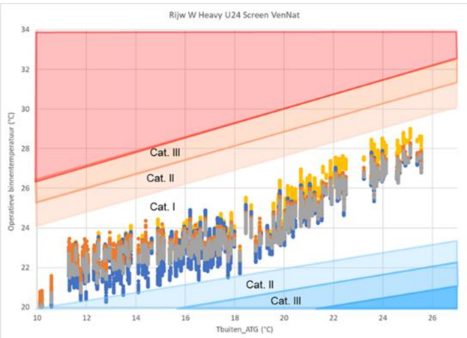

Figure 3: operative temperatures and ATG criterion

Figure 2 compares the operative temperatures for this building case with the passive cooling strategies but without an extra cooling system, to the CIBSE (2018) comfort criterion. With maximum allowed temperatures of 28°C in the living areas and 26°C in sleeping rooms, this would result in respectively 30 and 230 exceeding hours, and thus a rather bad result in the sleeping rooms.

On the other hand, if we would use an adaptive criterion like the ATG from EN16798, the allowed indoor temperatures highly depend on the long-term average outside temperature, resulting in a perfect comfort for the same simulated case during the heat waves (see Figure 3).

Conclusions

A new decision tool has been made to compare different (sustainable) cooling systems and passive cooling strategies in dwellings. To make it future proof, a new (extreme) climatic data file was constructed. However, the selection of the comfort criteria showed to be difficult.

If adaptive temperature boundaries are used, as is allowed and described in EN16798-1 (2019) for free running buildings, the impact of heat waves is somewhat tempered as the temperature criteria go up as well. However, it is not certain if this can be applied straightforward to residential cases. The authors chose to add the absolute comfort criteria of CIBSE Guide A (2015) and the following comfort classes were determined based on the exceeding hours: good (<33h), acceptable (<100h), possible (< 250h), uncomfortable.

In general, the simulations show that a lot of sustainable cooling systems, although their lower specific power, can provide good comfort in most of the residential buildings, provided that passive cooling strategies are applied. Without any cooling system this will become difficult.

References

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IEA EBC (2020). Annex 80 Resilient Cooling

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