The Impact of a High-End Climate Change Scenario on the Energy Use of a Flemish Office Building

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Abstract
It is expected that the energy performance of buildings will be strongly influenced by climate change. In this paper, the energy use of a Flemish office building at the end of the 21st century is investigated for an RCP 8.5 climate change scenario. The building is evaluated for various locations in Flanders to investigate the location influence on the energy performance. Results show a decrease of the heating demand by approximately 15-18% and an increase of the cooling demand of approximately 57-80% depending on the location.

Key Innovations
- Evaluation of the expected future energy need for heating and cooling of a Flemish office building with high-resolution climate model data

Research Implications
Use of typical future weather data in building simulations and extreme weather data to evaluate the building robustness. Use of representative weather data for the location of your building (urban vs. rural).

Introduction
Various studies identified that the energy performance of buildings will be strongly affected by climate change, predicting a reduction of the heating demand and increase of the cooling demand (Berger et al. 2014; Isaac and van Vuuren 2009; Moazami et al. 2019; Ramon et al. 2020). To date, regional climate model (RCM) output is typically used as weather data for simulating the building performance in future (Berger et al., 2014; Moazami et al., 2019). Typically, these climate model data have a spatial resolution up to 12.5km and further parametrisation is needed to represent all physical processes such as deep convection. At a convection-permitting resolution (<4km), these processes can be solved explicitly (Prein et al. 2015). Consequently, an improved performance of predicting physical processes, daily cycles, urban effects and the climate change signal is obtained in comparison with RCMs (10-100 km spatial resolution) making them favourable for building energy simulations.

The use of RCM data in general, and convection-permitting climate model (CPM) data in particular, is rare in Belgian practice for building energy simulations. Further, evaluations of building performance towards the future in a Belgian context are not elaborated making use of climate model output in dynamic building simulations. This project evaluates the impact of an RCP 8.5 climate change scenario on the energy use for heating and cooling of a Flemish office building. Dynamic building energy simulations (BES) are executed with EnergyPlus using weather data from a CPM. In order to investigate the importance of the location, three locations in Flanders are analysed. As current BES typically use the weather file for Uccle (suburban context, 50.80°N 4.36°E) this location is included as reference base.

Methods
Case study
The BelOrta building is a two-story business as usual office building situated in a suburban region in Belgium designed by the architectural office ar-te and finished in 2014. The building has a net floor surface of 3000 m² equally distributed over the two floors. Further, there is an inner patio around which the office and meeting rooms are organized (Figure 1). The building has a concrete structure and is well insulated (average U-value of 0.42 W/(m²K)) and airtight (v50 of 3.5 m³/(hm²) measured by a blowerdoor test). The office spaces make use of a climatic ceiling. A condensing gas boiler (139 kW, efficiency of 97%) is used for space heating, while the cold is generated through a cooling machine (223kW, COP 3.57). The office spaces are equipped with a continuous hygienic ventilation. The ventilation system has a total supply volume of 12408m³/h and an extraction volume of 10670m³/h, heat recovery is foreseen (48 kW in summer mode, 151 kW in winter mode, total efficiency of 85%) The building has an E-level of 70. Internal gains are in line with EN 16798-1:2019.

Figure 1: BelOrta Office Building – Ground floor ©archipelago architects
Building Energy Simulation – EnergyPlus

A multizone simulation is executed with Energyplus v8.8. From the simulations results, the end energy use for heating and cooling is extracted. Further the thermal comfort is evaluated based on the operative temperatures in the zones and applying the cat. II limits of EN 16798-1:2019, meaning the operative temperature should stay below 26°C during occupancy. The model could not be calibrated due to lack of data. The results were, however, compared and found to be in line with literature.

Weather data

Based on the methodology of Nik (2016), a typical downscaled year (TDY) and an extreme warm year (EWY) have been extracted from an EC-Earth driven CPM for the Belgian domain for an RCP8.5 climate change scenario. The weather files are extracted for the recent past (1976-2004) and for the end of the 21st century (2070-2100). The spatial resolution of the model (i.e. 2.8 km) allows to extract weather files for Uccle (50.80°N 4.52°E), Sint-Katelijne Waver (i.e. the location of the building, abbreviated as SKW, 51.06°N 4.52°E), and Leuven (urban, 50.88°N 4.73°E). More information about the climate model can be found in Ramon et al. (2020).

Results

Figure 2 shows a clear reduction of the energy use for heating (gas) of 18% (i.e. 6.6 kWh/m²) for the TDY of Uccle, 16% (i.e. 5.5 kWh/m²) for TDY of SKW and of 20% (i.e. 7.1 kWh/m²) for the TDY of Leuven.

Figure 3 shows an increase in the energy use for cooling (electricity). The TDY for Uccle shows an increase of 120% (i.e. 4.7 kWh/m²) in future but is characterised by the lowest absolute cooling demand. The TDY for Leuven and SKW show respectively an increase of 94% (i.e. 4.5 kWh/m²) and 89% (i.e. 4.4 kWh/m²) in future. Results for the runs with EWY files show slightly higher absolute increases (between 5.8 and 6.1 kWh/m²), but relatively lower increases (between 66 and 71 %).

Important to note is that the differences for cooling between the various locations in the current climate are higher (up to 28%) than for the future climate (up to 10%)

Figure 3: Annual end-use consumption for cooling (electricity) (SKW: Sint-Katelijne-Waver)

for the TDY runs. For the EWY runs, this is the case in relative but not in absolute terms. Differences between locations were found to be higher by the end-use consumption for heating than for cooling similar as in the research of Berger et al. (2014). It is hence recommended to not only use the weather file of Uccle in BES, but to use weather file for the specific building location.

None of the simulations led to executed hours with operative temperature exceeding 26°C. It hence seems possible to guarantee thermal comfort in future with the current capacity of the cooling system.

Conclusion

In this research, a Flemish office building was evaluated using a Typical Downscaled Year and Extreme Warm Year for three locations in Belgium. A decrease in heating demand of up to 20% was found for the TDY. The energy use for cooling is estimated to increase up to 120% depending on the location. Differences between the various locations were found to decrease towards the future. Lastly, the cooling capacity installed today seems sufficient to guarantee future comfort, which is caused by the oversizing of the system for current cooling needs.

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References