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ANALYSIS OF ACTUAL INDOOR CLIMATE PARAMETERS OF A SUPERMARKET IN TERMS OF ENERGY EFFICIENCY

Abstract: *This article presents the analysis of the actual indoor climate parameters of an existing supermarket, which influence the energy consumption of the building's HVAC systems. The study is performed using the data of the Building Management System (BMS) of the analyzed supermarket. The functionality of HVAC systems' equipment, control solutions, actual thermal comfort, and air quality parameters were assessed during the study. The study found that improper control strategies of the air temperature supplied by the central ventilation system resulted in higher energy consumption to ensure the thermal comfort of the premises.*

Keywords: *actual indoor climate parameters, supermarket, energy efficiency, indoor air quality, thermal comfort*

Introduction

The increased requirements of building tightness go together with increased attention to indoor air quality (Kempton et al. 2022). The study (Du et al. 2020) shows that customers' satisfaction will improve when the indoor air quality is better in shopping malls. Commercial buildings such as shopping centres usually use BMS (Building management system) to ensure comfort indoor air parameters. However, scientists (Loomans et al. 2020; Džiugaitė-Tumėnienė et al. 2021) indicated that actual indoor parameters often do not match BMS data. Życzyńska et al. (2022) and Hauashdh et al. (2022) affirm that technical systems should be managed appropriately, and their performance parameters should be controlled.

Forming new and optimizing existing traditional design solutions for the engineering systems of commercial buildings, it is necessary to evaluate the influence of the functioning and management of indoor climate systems of operating shopping centres on their energy consumption intensity.

The main problems of high energy consumption intensity are the insufficient number of data and control parameters recorded by BMS in the existing objects, the problematic separation of the effect of technological equipment on energy consumption and the indoor climate of the premises, the too complicated connection between the building's indoor climate conditions and energy consumption.

Methodology

The goal of the paper is to determine the main indoor climate parameters of the premises of the existing supermarket, which influence the energy consumption of the building's HVAC systems. The authors assessed the functionality of HVAC system equipment and control solutions, the actual thermal comfort, air quality parameters, and ventilation intensity of the analyzed supermarket. The functionality and efficiency of HVAC systems are evaluated according to these aspects: 1) actual energy

efficiency of the existing HVAC equipment; 2) Is the capacity of the installed heating/cooling equipment sufficient?; 3) Are the indoor climate parameters ensured (actual temperature, relative humidity, CO_2) in winter/summer?; 4) Is the current control of the HVAC equipment effective?; 5) HVAC control complexity level (manual/automatic/mixed).

Results

Analysis and evaluation of the actual indoor climate data of the investigated supermarket determine the main parameters that influence the energy consumption of the building's HVAC systems.

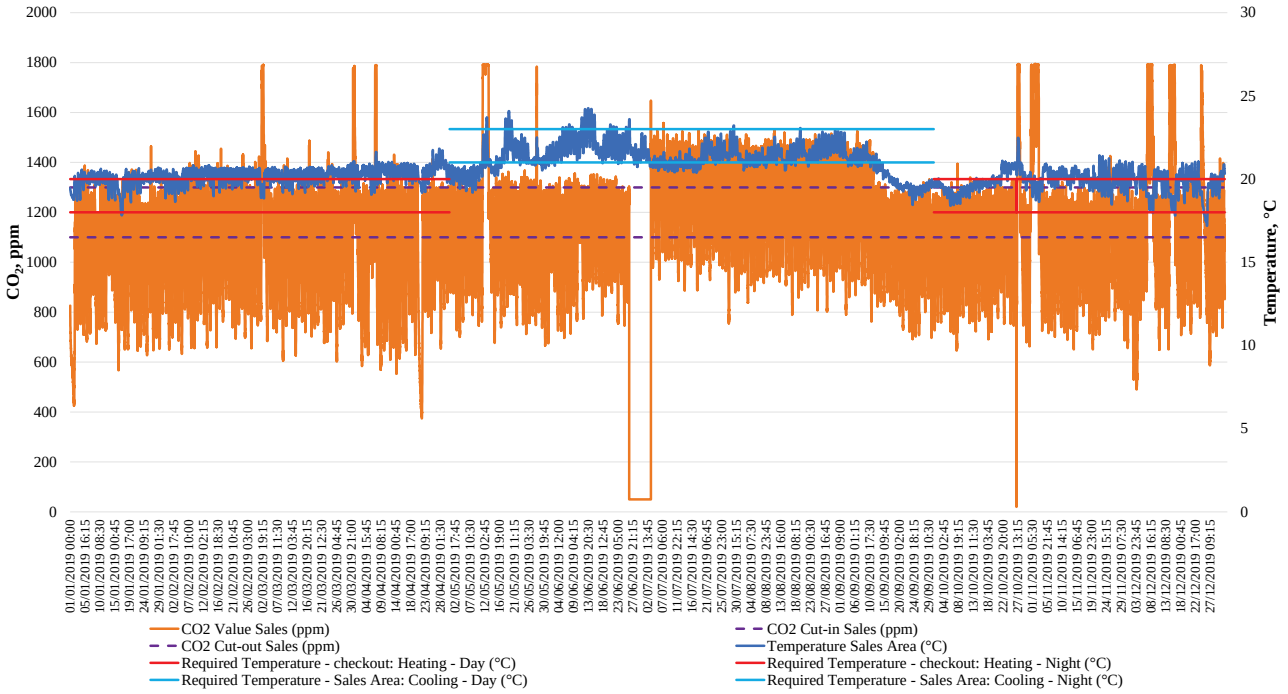

FIGURE 1. *The variation of air temperature and CO_2 concentration in the supermarket's sales area during the surveyed period*

As seen in Figure 1, the variation in air temperature and CO_2 concentration of the supermarket's sales area does not meet the limits of the Building Management System (BMS) settings. It means that the control of the central ventilation system is not based on the indoor climate parameters of the sales area.

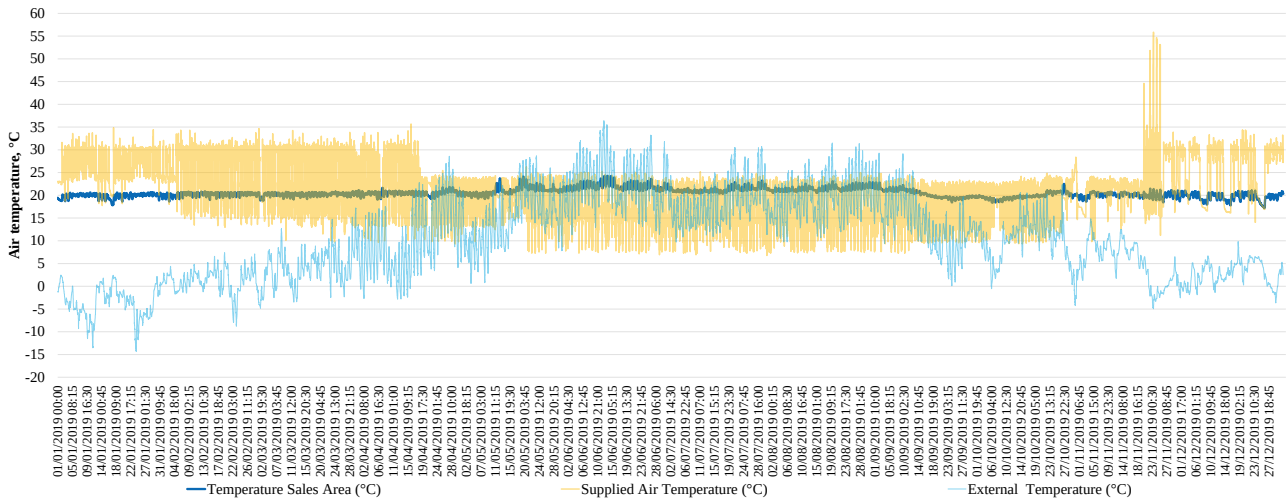

FIGURE 2. *Variation of indoor and supplied air temperatures of the sales area during the year*

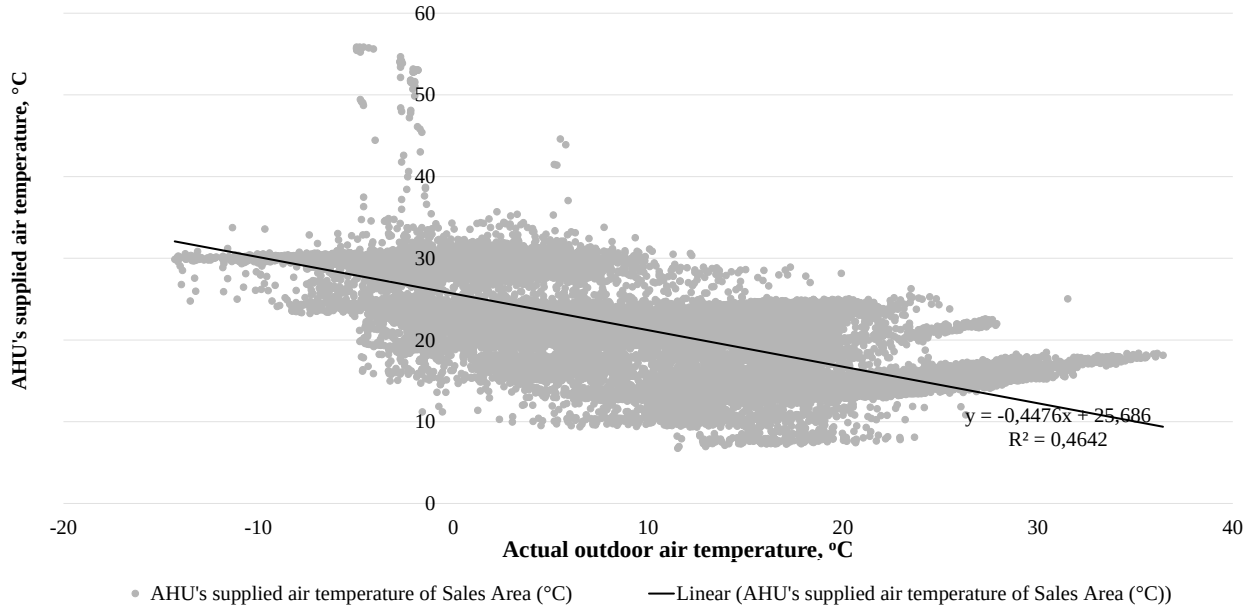

FIGURE 3. *AHU's supplied air temperature of the sales area during the year*

As seen in Figures 2 and 3, the sales area's indoor climate parameters analysis shows that the supplied air temperature during the winter (including March) usually varied in the range of [+29; +31]°C to ensure the required air temperature. During the spring, the supplied air temperature varied in the range of [+21; +24]°C. During the summer, the temperature of the air supplied during the supermarket's working hours varied in the range of [+13; +17]°C to cool the sales area, and during non-working hours [+22; +24]°C. During the autumn period, it varied in the range of [+20; +24]°C. However, in September, cooling of the sales area is still required, so the supplied air temperature is lowered in the range of [+13; +16]°C. The authors found that the supplied air temperature varies considerably (i.e. [+8; +33]°C) to ensure thermal comfort (from +17°C to +24°C) in the supermarket's sales area during the surveyed period of the year. Therefore, such a significant difference in the temperature of the supplied air indicates inappropriate control strategies of the central ventilation system.

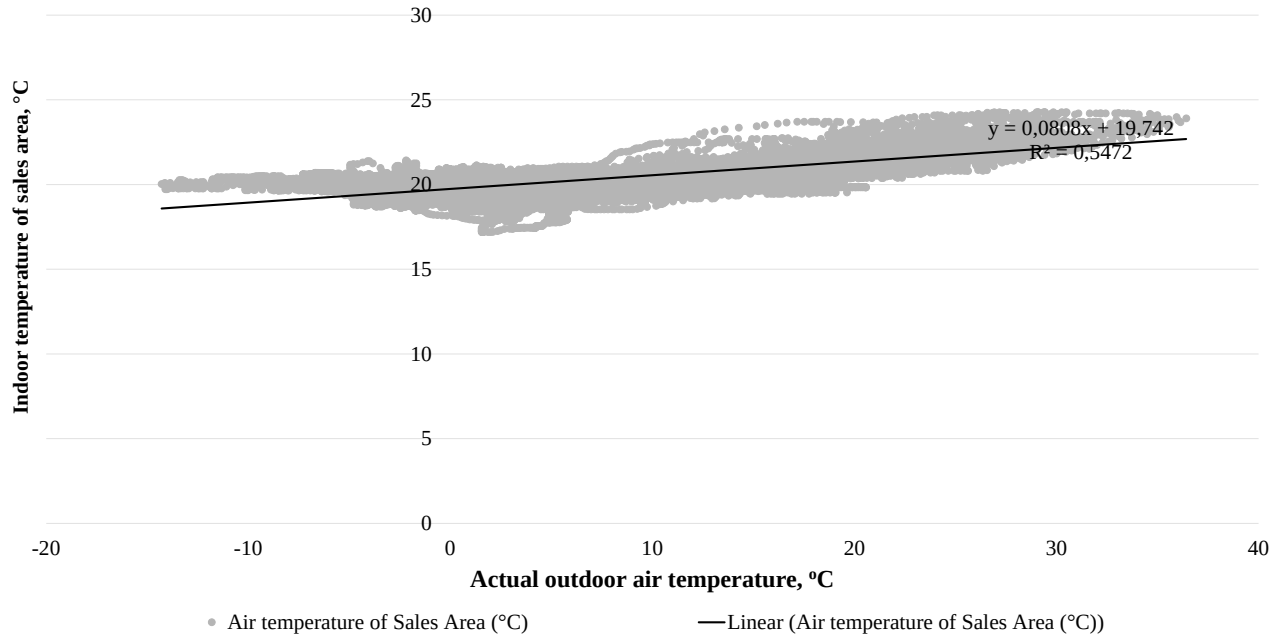

FIGURE 4. *Indoor temperature of the sales area during the year*

As seen in Figure 4, the sales area's indoor climate parameters analysis shows that the indoor temperature reaches +20°C during the winter. A slight decrease in temperature to +19°C indicates that the indoor air temperature does not decrease by more than one degree at night. During the spring period, the air temperature of the trading hall varied in the range of [+20; +21]°C. During the summer, the indoor air temperature mainly varied [+21; +23]°C range. However, as the outside air temperature rises, the indoor air temperature exceeds +24°C. The indoor temperature of the sales area varied in the range of [+20; +21]°C during the autumn period. When the outside air temperature is in the range of [0; +10]°C, the indoor temperature decreases up to +17°C.

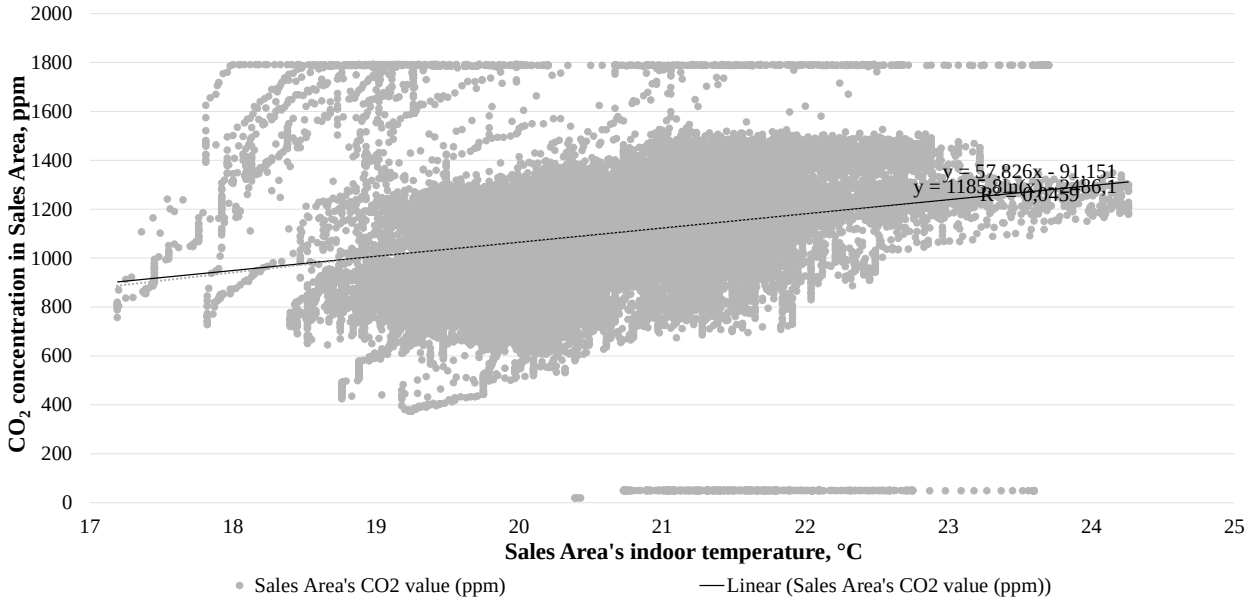

FIGURE 5. *CO_2 concentration (ppm) in the sales area during the year*

As seen in Figure 5, the central ventilation system of the sales area during the winter usually provided sufficient (from 950 ppm to 1150 ppm) and low (above 1350 ppm) air quality levels. During the spring and autumn periods, the CO_2 concentration usually varied in the range of [1134; 1294] ppm. The authors noticed that the air quality in the sales area was low during the most intensive work hours. During the summer, the CO_2 concentration usually changed in the range of [950; 1490] ppm. The authors noted that 11 stops (failures) of the ventilation system occurred per year. Most of the time, the proportion of outdoor air supplied to the trade hall is from 0% to 26% per year, resulting in sufficient or low air quality levels in the sales area of the supermarket.

Conclusions

The authors showed that the air temperature of the sales area of the supermarket is ensured during the analyzed period. The premises' thermal comfort is provided by higher energy consumption because of the central ventilation system's inappropriate control of the supplied air temperature. The authors indicated that the electricity consumption of the HVAC systems of the analyzed supermarket is the highest for the heating and cooling when heating/cooling coils (VRF type) of central ventilation system have been used to heat and cool the supplied air the whole year. In order to save energy, the Facility Manager runs the central ventilation system in partial or complete recirculation in winter and summer. Therefore, sufficient or low air quality levels are maintained in the sales area of the supermarket during working hours.

References

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