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Davidsson, Henrik; Kowshik Chowdary , Sunkavalli ; Gentile, Niko; Berggren, Björn; Kanters, Jouri

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PO Box 117
221 00 Lund
+46 46-222 00 00

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Energy use of buildings in relation to occupancy rates

H Davidsson¹, S K Chowdary¹, N Gentile¹, B Berggren¹ and J Kanters¹

¹ Energy and Building Design, Department of Architecture and the Built Environment, Lund University, P.O. Box 118, SE-221 00, Lund, Sweden

henrik.davidsson@ebd.lth.se

Abstract. This paper presents basic data of the energy demand for district heating and plug loads logged by a building management system of an energy-efficient academic building located in Lund, Sweden. The data refers to the years 2019 and 2020 when occupancy varied significantly due to the Corona pandemic. The data shows that the building energy demand adapts poorly to fluctuating occupancy rates. With a possible increase of smart working in the future, building codes should account for more fluctuating occupancy rates in the modelling of the energy demand of buildings.

1. Introduction

Buildings accounts for a significant share of the global energy use and has led to the European Union setting targets for buildings' energy use towards a net-zero energy balance [1]. Research has shown that 56 % of the total energy is used during non-occupancy hours and, on average, 23 % of the energy is used during weekends [2]. In commercial buildings, 40 % to 60 % of the energy can be saved through different occupancy strategies [3]. However, buildings are intrinsically designed for regular and high-occupancy rates and building codes seem to be biased towards this too [4].

The current Corona pandemic offers the opportunity to observe how the energy demand of buildings responds to unexpected fluctuations in occupancy rates. In this short paper, basic logged data of energy demand and occupancy for an energy-efficient academic building located in Lund, Sweden is presented.

2. Method

The investigation concerns the building hosting the Department of Architecture and Built Environment at Lund University in Lund, Sweden. The building, constructed in 1965 and designed by Klas Anshelm, is a five-storey brick building connected to a district heating system.



Figure 1. The A-building in Lund, Sweden. Photo, Kennet Ruona.



The first three storeys host studios and larger classrooms. Ventilation and the lighting in all rooms is controlled by a presence sensors. The upper two storeys consist of roughly 70 individual offices, six meeting rooms, and a lunch room. The building has been recently renovated in 2011 and equipped with an advanced Building Management System (BMS) and has received a LEED classification. The BMS performs sensing, logging, control, and actuation of a variety of building services.

The energy use for domestic hot water, electricity use, and building occupancy rates were retrieved from the logged data of the BMS, which uses the following sensors:

- District heating– Kamstrup SVM F4, compliance E1434, accuracy $\pm 2\%$
- Electricity – ABB DAM 13000, compliance IEC 62053-21 Cl 2 and IEC 62053-23 Cl 2
- Presence – Panasonic AMN 3211 PIR, installed in the ventilation units

The presence data are measured as the percentage of sensors in the building that was triggered by movement within the sensors' view. Since one person can trigger more than one sensor by moving in the building, the exact number of people in the building remains unknown. However, the presence statistics provides an indication of the occupancy rate of the building. As separate energy meters were available, the data reported in this investigation includes only energy demand for district heating for the whole building – accounting for both heating and domestic hot water - and the electricity use for plug loads and lighting. The latter includes, for example, office and corridor lighting, emergency lighting, office equipment and the like, but it does not include electricity for pumps, fans or elevators.

Data were available for the period May 2019 to November 2020 due to limited memory of the BMS logging system. Data were averaged to daily values to reduce fluctuations in the presented data. Only standard office hours were analysed (8:00 to 17:00, weekends excluded).

Data were grouped in two-month series, as occupancy rates in this academic building are more homogenous, e.g. lecturing and teaching in May-June, holidays in July-August, etc.

Simple coefficients of determination (R^2) were calculated to check the goodness of fit between the independent variable (occupancy rates) and the two dependent variables (energy demands for district heating and for plug loads).

3. Results

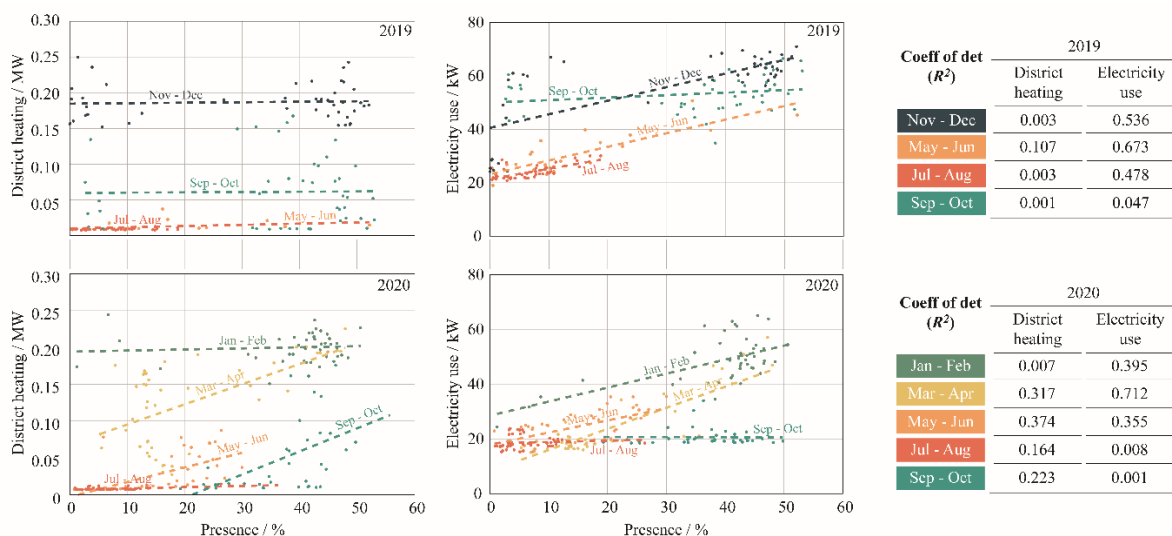


Figure 2. Coefficients of determination R^2 for occupancy and energy demand.

The main results are presented in Figure 2. As expected, the occupancy rates dropped dramatically around March 2020, when the Corona pandemic started to worsen in Europe and Sweden. As Sweden

did not experience a total lockdown, the lowest occupancy rates are observed for the summer breaks in both 2019 and 2020.

For any of the parameters the coefficient of determination is very low. While this was expected for the district heating, it was quite surprising for the electricity use. It should however be reminded that the electricity use also includes plug loads for common spaces, e.g. corridor lighting. Lighting in common spaces use predicted occupancy schedule (lighting is on between 8:00-17:00 working days), while office lighting is provided with an absence sensor. When occupancy is very low, between 0 % and 20 %, the electricity use is basically constant and as high as a third of peak use for 50 % of occupancy.

Absolute values of energy demand for district heating are largely linked to different weather conditions, rather than occupancy rates.

4. Discussion and conclusions

This building has been designed for a high energy performance. Its planning and design followed the Swedish building codes, which normally considers regular occupancy schedule. This resulted in a number of design choices for both heating and plug loads electricity. In this building, for example, efficient heating systems with high thermal inertia were selected over less efficient but demand-responsive ones. Lighting systems in common spaces were planned with large control zones and predefined schedules predicting occupancy, rather than with small control zones and real occupancy sensors. While this is possibly an optimal choice during regular operations, it becomes problematic with partial occupancy, as outlined by O'Brien & Gunay (2019) [4].

Even during regular operations, buildings are little occupied. In this case, the occupancy is only occasionally over 50%. Remote working is expected to increase during the post-pandemic, which implies even lower and more fluctuating occupancy of buildings.

In conclusions, it is suggested that strategies targeting to more buildings more adaptable to occupancy should be much more explored. In line with that, it is suggested that even building codes and regulations should start considering and rewarding the building adaptability to variable occupancy.

5. Future work

Data have been collected for several academic buildings in Sweden. Statistical analysis and simulations should provide a better understanding of: a) how existing energy-efficient buildings respond to unexpected fluctuations in occupancy and b) which design choices could make such buildings could be more occupancy-adaptable.

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