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Reassessing Occupancy-Based Ventilation and IAQ in Homes

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SUMMARY

Most existing occupancy-based ventilation controls only ventilate if people are present. However, this approach ignores pollutants that are emitted when people are absent, such as formaldehyde from building materials and contents. Recognizing that pollutants are emitted when homes are vacant requires different approaches to occupancy-based ventilation system control, because occupants are exposed to high pollutant concentrations when they return home. In this study, we found that controlling for this additional pollutant exposure reduced the potential for energy savings from roughly 40% to less than 8% of ventilation energy.

KEYWORDS

Ventilation; controls; residential; energy; material emissions.

1 INTRODUCTION

Currently, occupancy-controlled ventilation in homes uses CO_2 or humidity to detect the presence of people. Ventilation systems are turned on when CO_2 or humidity exceeds set points, or the system is controlled to maintain some average concentration. This approach to ventilation is likely adequate for pollutants either emitted directly from occupants (odours, for example) or their activities (e.g., cleaning products). However, it does not account for pollutants emitted by building materials and contents (e.g., formaldehyde). This could have significant IAQ impacts when occupants are exposed to elevated levels of these additional pollutants – typically when first entering a home and for hours thereafter. In this study, we examined the effects of accounting for pollutant emissions during unoccupied times on the energy savings associated with occupancy-based ventilation controls.

2 METHODS

To assess occupant controlled ventilation strategies, we used the REGCAP combined heat and mass transport model that has been used in previous ventilation studies (e.g. Turner et al., 2014). The model performs minute-by-minute simulations that allow for calculation of peak exposures and the implementation of real-time ventilation controls. The analysis uses the concept of "Equivalence", where the annual average exposure for a time varying ventilation system is controlled to be the same as for a continuously operating system. In this study, we used the ventilation rates from ASHRAE 62.2 (ASHRAE, 2016) as the reference case, along with the relative exposure calculations from Appendix C of the standard, to calculate annual average exposure based on a continuously emitted pollutant. The smart controls use relative exposure and a 24-hour integrated relative dose as parameters, both of which are controlled to less than one over a 24-hour timeframe. The ventilation fan airflow is double that of the continuous reference case, and this larger fan is turned on when either the relative dose or relative exposure exceed one during occupied times, or when relative exposure is greater than 5 during unoccupied times (limiting peak exposures). Relative exposure is calculated during unoccupied times for control purposes, but it is averaged only during occupied periods to assess annual equivalency with a continuous fan. 24-hour integrated dose is calculated only during occupied periods. All simulations used a single-story, 200-m^2 home with three bedrooms, two bathrooms and four occupants. The homes are compliant with the energy and performance specifications of the U.S. DOE Zero Energy Ready Home program (U.S. Department of Energy, 2013), including an airtightness requirement of 3 ACH_{50} or less. All U.S. DOE climate zones were included. The unoccupied times were set to 8 am to 5 pm on weekdays and no unoccupied times on weekends (first shift), 9 pm to 6 am (third shift), and 8 am to 10 pm weekdays plus 10 am to noon and 6 to 8 pm on weekends (extended first shift).

3 RESULTS

Overall, the energy savings from the Occupancy-based smart ventilation controls were very low across U.S. DOE climate zones. For the 1st shift, energy use increased by 9 kWh (0.2% of ventilation energy increase). Savings were greater in the 3rd shift pattern (64 kWh/year, 2.9%), as well as in the extended 1st shift pattern with greater unoccupied time periods (248 kWh/year, 7.6%). Energy savings increased with climate heating demand and longer unoccupied time periods, though percent ventilation energy savings were fairly consistent across climate zones. The 3rd shift occupancy pattern had better performance, due to the thermal benefit of reducing the ventilation rate during the cold nighttime hours.

4 DISCUSSION

Savings were low, because much of the benefit of turning off the ventilation system during unoccupied time periods is offset when the smart controller over-ventilates to maintain equivalence with ASHRAE 62.2 during the recovery period after occupants return home. The common pattern was for the ventilation to be off for 9-hours, and then the fan airflow was doubled for roughly 6-hours in order to recover and maintain daily occupied exposure below one. Net-reduction in daily airflow was roughly 12%. This is distinguished from past demand controlled ventilation systems, where fans are simply turned off during unoccupied periods, resulting in daily airflow reductions of nearly 40% and roughly 40% increases in occupied exposure. Additionally, 1st shift occupancy patterns had reduced ventilation rates during mild daytime hours and increased ventilation during colder nighttime hours, with heating energy penalty or cooling benefit depending on the season. We found that energy savings for occupancy controls could be increased substantially by pre-venting the home 1-hour prior to occupancy, or by halving the pollutant emissions during unoccupied times.

5 CONCLUSIONS

This study shows that accounting for pollutants emitted from building materials and contents significantly reduces the potential energy savings of occupancy-based ventilation controls. Further study is needed to better establish the differences in pollutant emissions between occupied and unoccupied times in real homes to refine this analysis.

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