More Than a Gadget:

The Role of Smart Thermostats in High-Rise Residential Building Diagnostics & HVAC Control

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Smart home technology is experiencing high adoption rates throughout North America. These smart technologies often provide improved user-device interfaces and offer new opportunities to manage building operation. Smart thermostats are one of the most common smart home devices and have demonstrated energy conservation benefits in single-family homes. However, their applications in high-rise residential buildings have yet to be fully explored.

The findings of a one-year case study that took place in two contemporary condominium buildings in downtown Toronto offer some interesting insights. Let's take a closer look at the case study, the operational challenges faced in HVAC systems in these buildings, and the energy and indoor environment management opportunities presented by smart thermostats. While the study buildings aren't necessarily representative of contemporary high-rise residential buildings in general, the HVAC systems installed in the buildings are typical among buildings of this type. As such, at a high-level, similar shortcomings, opportunities, and limitations may be present in other buildings of this type and warrant consideration.

CASE STUDY SUMMARY

In the case study, field data was collected from two highly glazed contemporary condominium buildings (Buildings A and B) located in the City of Toronto, Ontario, both equipped with pressurized corridor ventilation systems. In-suite space conditioning was provided via two-pipe fan coil units (FCUs) in Building A and via water-loop heat pump units in Building B.

Suite-level data collection took place in 54 suites across the two study buildings, in which pre-existing, non-programmable thermostats were replaced with ecobee3 smart thermostats. The research team remotely collected thermostat data and altered thermostat control methods for a 14-month monitoring period.

Central building HVAC system operation was also monitored in both buildings for a 14-month period. Data were collected on equipment electricity consumption (e.g., chiller, pumps, cooling towers, etc.), boiler natural gas consumption, and thermal energy output (e.g., flow rate and change in temperature for the main building water loop) to determine central space conditioning plant energy use and operating efficiency over the study period.

HVAC OPERATION CHALLENGES

Two key shortcomings were identified with respect to the study buildings' HVAC systems. The first is related to the operation


Electrical submetering installed in one of the study buildings.


A rooftop weather station installed at one of the study buildings.

of the pressurized corridor ventilation systems in the buildings. Short in-suite HVAC runtimes and frequent over-conditioning of suites were common in the study buildings, both of which appeared to be driven by over-conditioning of corridor ventilation air.

Shifting conditioning load from building common areas (e.g., through decreased conditioning of corridor ventilation air) to suite-level HVAC systems would allow individual suite HVAC systems to be more responsive to demand and only provide conditioned air where and when it's needed, saving energy and improving occupant comfort.

Over-conditioning is believed to occur, in part, due to unbalanced air duct systems in the buildings. Building staff noted that while they tried to move corridor ventilation dampers back to the same position they were in prior to cleaning, there are no markings present to indicate where dampers should be returned to, which likely results in the gradual unbalancing of air duct systems in the building. Additionally, adjustments to ventilation air supply temperatures, driven by occupant complaints of thermal discomfort in hallway areas, is likely a contributing factor.

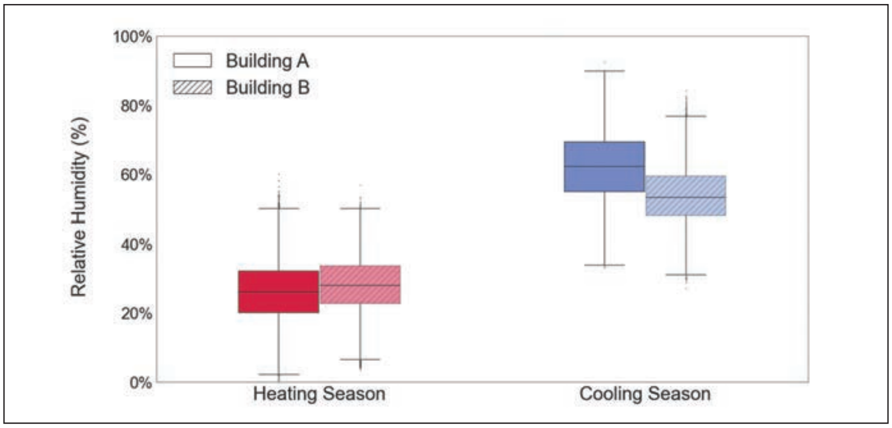
The second shortcoming is related to indoor air humidity levels in the study buildings. High humidity levels were present during the cooling season in both study buildings (average relative humidity of 65 per cent in Building A and 54 per cent in Building B), which may reduce indoor air quality and interior finish life spans. As climate change continues, this issue will be exacerbated, as cooling season outdoor dew point temperatures rise.

Additional dehumidification of indoor air is needed. This can be accomplished through different avenues, including increasing in-suite HVAC runtime (e.g., through reducing the provision of conditioned hallway air), increasing dehumidification at the make-up air unit level (e.g., through reducing air temperature setpoints or adding dehumidification systems), and / or providing dehumidification at the suite-level.

SMART THERMOSTAT DIAGNOSTIC AND CONTROLS OPPORTUNITIES

While advanced HVAC controls are the most common feature associated with smart thermostat use, in the region's minimally instrumented high-rise residential buildings, the opportunities to affordably collect data from building suites are arguably more valuable for energy and environment management. In-suite smart thermostat use allows the collection of HVAC operation and indoor condition data from all building suites, which can be used by property and energy managers to identify opportunities for building recommissioning. For example, smart thermostat data can be used to identify over- and under-conditioning issues, to develop targeted energy management outreach programs for individual suites based on analysis of their temperature setpoints and schedules, or to identify high-risk areas for mould growth based on indoor humidity levels.

Nevertheless, energy management opportunities from advanced HVAC controls opportunities shouldn't be discounted. For example, in the studied buildings, occupancy-based control was found to reduce HVAC system runtime during the cooling season by 5.9 per cent (+/- 46 per cent), on average. The absolute energy savings from occupancy-based control in the buildings, however, were limited by pre-existing short terminal HVAC runtimes in the studied suites (average of 12 minutes per hour in cooling season and five minutes per hour in heating season). As such, upgrading in-suite controls is unlikely to reduce overall building energy use substantially unless re-commissioning building HVAC systems, especially corridor ventilation systems, is completed first.



In-suite relative humidity measurements in Buildings A (n_{suite} = 26) and B (n_{suite} = 28).

ESTIMATING PRIMARY ENERGY IMPACTS OF RETROFITS

As our high-rise residential building stock ages, retrofits of building envelope systems are becoming more prevalent. Lowering building space cooling demand was shown to have diminishing effects on chiller plant electricity use for larger building demand reductions. To maximize the relative impact of retrofits on space cooling electricity use, the first 10 to 20 per cent of building space cooling thermal demand reductions are the most important. While these types of major retrofits may be far off for contemporary high-rise residential buildings, similar effects are likely to be observed in older buildings with chiller plants, which may be undergoing major retrofits in the near future.

PLANNING FOR THE FUTURE

In Toronto (and Ontario, more broadly), climate change is expected to have a significant impact on space cooling electricity demand. Based on 2040 weather projections[1] and central plant modelling in Building A, primary cooling plant electricity use is expected to increase by 21 per cent in the next 20 years. While the exact change in electricity demand will vary between different buildings and realized climate change outcomes, in general, a non-trivial change is expected and will represent significant increases in building operating cost, which building owners, operators, and energy management practitioners must start planning for. ■

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