

Smart Thermostats

TECHNOLOGY ASSESSMENT AND FIELD TEST
FINDINGS IN MULTI-UNIT RESIDENTIAL BUILDINGS





ACKNOWLEDGMENTS

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The views expressed here are those of The Atmospheric Fund and do not necessarily reflect the views the City of Toronto or the Province of Ontario.





About The Atmospheric Fund (TAF)

Founded in 1991, The Atmospheric Fund (TAF) invests in urban climate solutions in the Greater Toronto and Hamilton Area to reduce carbon emissions and air pollution. TAF is supported by dedicated endowment funds provided by the City of Toronto (1991) and the Province of Ontario (2016).

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Executive Summary

This report examines lessons learned from the installation of in-suite smart thermostats in four 1970s-built multi-unit residential buildings (MURBs) in Toronto. The smart thermostat installations are part of the larger TowerWise program, through which TAF is undertaking comprehensive energy retrofits in MURBs across the greater Toronto and Hamilton area. The TowerWise program aims to demonstrate the potential to dramatically reduce energy-use and carbon emissions while reducing operating costs and improving indoor environmental quality.

While smart thermostats have achieved remarkable market growth in the single-family home sector, they have not been widely deployed or tested in the MURB sector. In this report, we discuss the impacts of the in-suite smart thermostats on energy efficiency and resident comfort at the four pilot sites, the challenges of adapting this technology to MURBs, and the scale-up potential for this technology within Ontario's existing building stock. The carbon emission reductions achieved as well as the potential reductions from a smart thermostat scale-up across the MURB market are also provided. A summary of the key findings is provided below:

Energy Performance

Installing in-suite smart thermostats resulted in

8.8-11.8%

space heating savings per year

55,700m³

of natural gas was saved at the pilot sites over one year, reducing emissions at the sites by 105 tonnes CO₂eq.

Comfort



The in-suite thermostats helped reduce exposure to extreme heat ($\geq 28^{\circ}\text{C}$) by

35%

in the shoulder seasons

54%

in the winter

Resident Experience



65%

of residents were either **satisfied or very satisfied** with their smart thermostat.



Resident education on thermostat use and energy saving tips are key to a successful smart thermostat retrofit.

Scale Up Potential

- Installing smart thermostats across the estimated 1.18M gas-heated apartment units in Ontario could result in 165-219 million m³ of annual natural gas savings.
- Smart thermostat retrofits could result in 310,000-412,000 tonnes CO₂eq reductions annually.

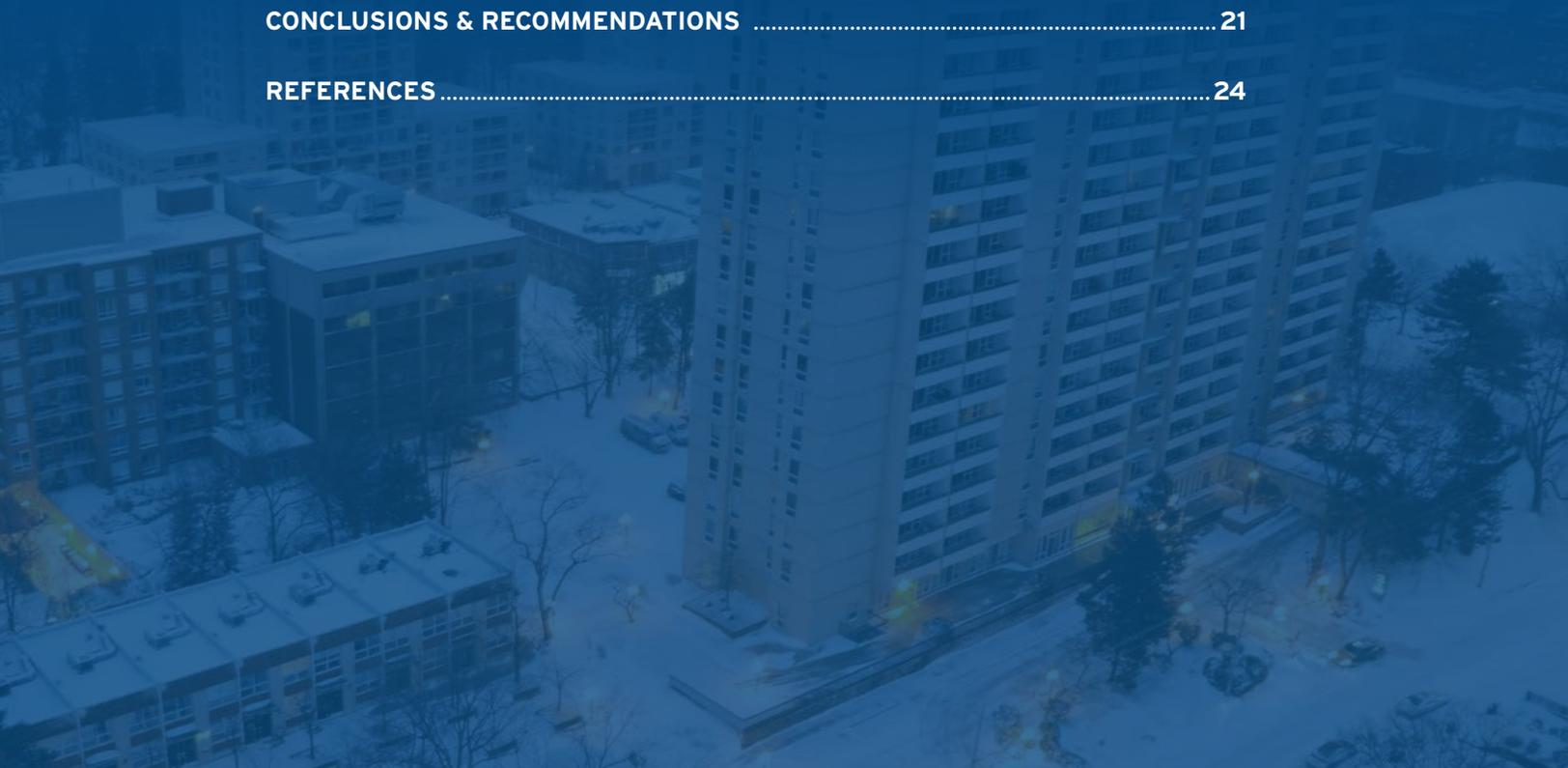


Recommendations

- Utilities:** provide incentives for MURB owners and operators, and promote the benefits of in-suite smart thermostats, particularly as part of larger energy efficiency retrofits featuring boiler and/or heating pump upgrades.
- Smart thermostat manufacturers:** provide centralized control through online portals for building operators, ability to wirelessly connect to radiator control valves, and control of multiple zones through one thermostat.
- Building Owners/Operators:** approach retrofits holistically by considering smart thermostats as part of larger HVAC retrofit projects. Resident engagement can also offer important insight to help inform retrofit plans, and build resident support.

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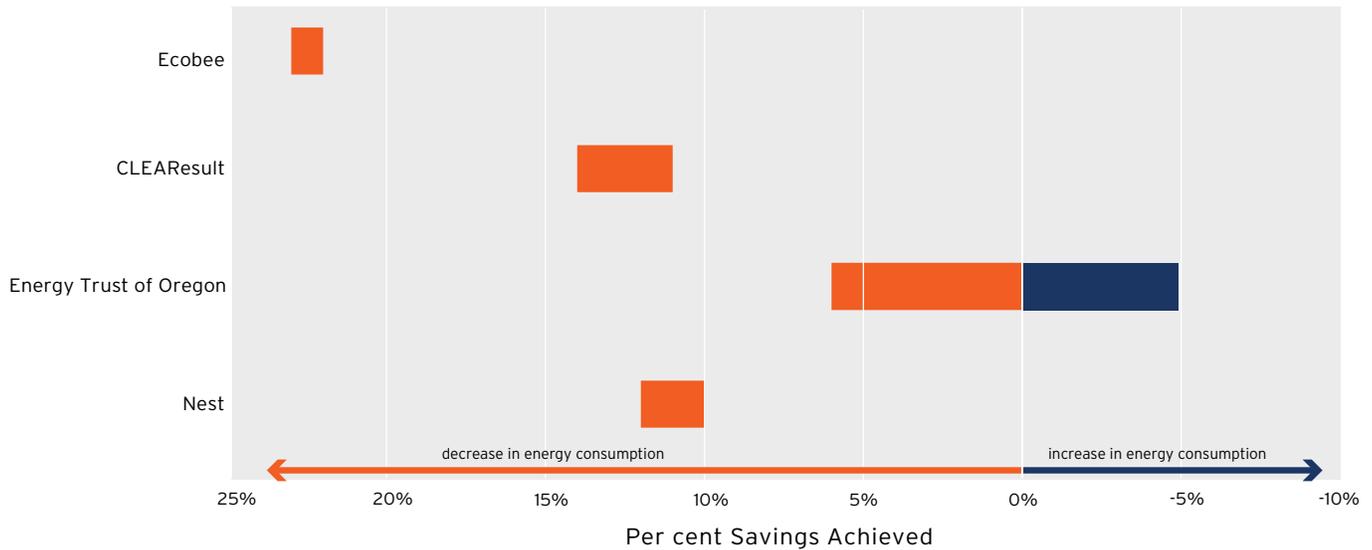
Introduction

Space heating in multi-residential buildings (MURBs) accounts for an estimated 3.5 megatonnes of annual emissions in Ontario. While high-efficiency heating equipment, such as condensing boilers, can reduce this substantially, it is just one piece of the puzzle. Smart heating controls also have a key role to play in decarbonizing the MURB sector. In-suite smart thermostats have the potential for rapid adoption, as has already been seen in the single-family homes sector, because they are relatively inexpensive to implement and can provide improved thermal comfort in addition to reducing utility costs.

Smart thermostats have achieved rapid market growth in recent years, helping to reduce energy bills and improve comfort. Studies have shown smart thermostats can save between 6-23 per cent of energy bills, mostly in single-family residential settings¹⁴. The range in savings depends on occupant behaviour including set points, use of scheduling functions, and actual time spent within the space. In some cases, studies showed no significant savings – one study even revealed a five per cent increase in energy use after smart thermostats were installed⁵. Figure 1 shows a comparison of savings achieved by several North American smart thermostat studies.



Figure 1. Changes in energy consumption based on existing smart thermostat literature. The ecobee study examined ecobee models in North America (23% savings); the CLEARResult study examined the Nest and ecobee3 (11% - 14% savings); Energy Trust of Oregon study examined both Nest (6% savings) and Lyric (5% increase energy use) thermostats; and Nest Labs study examined Nest thermostats (10% - 12% savings).



Currently a number of conservation programs exist that encourage the adoption of smart thermostat technology in single-family residential homes; however, the same opportunities do not exist for multi-unit residential building (MURB) tenants and owners. This project is intended to demonstrate the suitability of smart thermostats for MURBs, with the aim of unlocking significant potential for carbon emissions reductions, energy cost savings, and comfort improvements.

Pilot Study

As part of the TowerWise program, TAF undertakes major energy retrofits and indoor environmental quality improvements in demonstration sites across the greater Toronto and Hamilton area. In 2015, four of these buildings were selected to receive smart thermostats to complement a range of comprehensive retrofit measures including major heating system upgrades. The project team installed over 700 ecobee E3 smart thermostats across the four buildings. Ecobee donated the thermostats and associated room sensors.

In these four buildings, as in the majority of older MURBs, the suites are heated by hydronic baseboard radiators and there were no existing in-suite heating controls available. The lack of in-suite heating controls result in sub-optimal comfort and the widespread use of windows to regulate temperatures during the heating season. The smart thermostat installation was intended to improve comfort and energy performance by providing residents with more control over their unit temperatures. Table 1 summarizes the general characteristics of the pilot sites.

Table 1. General building characteristics

Building	Year of construction	Number of Storeys	Number of Units	Resident Demographic
Building A	1972	4	201	Seniors Bachelor Units
Building B	1972	4	171	
Building C	1974	19	165	Predominantly families 1-3 bedroom units
Building D	1974	18	202	

Upgrading the existing heating systems was a major component of the retrofit to improve energy efficiency and combat overheating. Although outdoor temperature reset controllers operated the original boiler systems at all sites, this type of control can lead to overheating because it does not monitor indoor temperatures, determining how much heat is needed solely on the basis of the outdoor temperature. Furthermore, the control system at buildings A and B was often by-passed, and boilers were switched into manual mode. This caused further overheating within the buildings.

The project team installed two new condensing boilers to service building A and B’s combined space heating and domestic hot water (DHW) system as well as introducing two gas absorption heat pumps (GAHP). The team also recommissioned the five-year-old condensing boiler at building C; two new condensing boilers were also installed at building D—one dedicated to space heating and one dedicated to DHW. Building D only uses the remaining two boilers during periods of extreme cold. Table 2 summarizes the pre-and-post retrofit heating systems:

Table 2. Overview of pre-and-post heating and domestic hot water systems.

Building	Pre-Retrofit	Post-Retrofit
Buildings A & B	Two Unilux 4,400 MBTU/h boilers for space heating and domestic hot water (DHW).	Two Viessmann Vitocrossal 200 CM2-246 condensing boilers, 1,756 MBTU/h total capacity. Two gas absorption heat pumps Robur GAHP-A, total capacity 250 MBTU/h.
Building C	Two 1,000 MBTU/h boilers and one 2,000 MBTU/h boiler for space heating. Two 1,500 MBTU/h for DHW. This site had been retrofitted within the past 5 years.	Existing 2,000 MBTU/h condensing boiler was recommissioned.
Building D	Four 2,000 MBTU/h boilers for space heating and DHW.	Two Viessmann Vitocrossal 200 CM2-400 (total capacity 2,890 MBTU/h) and two 2,000 MBTU/h original boilers.

In addition to the above upgrades, the project team also installed variable speed circulation pumps at all sites. This measure saves energy in-and-of-itself, but is also integral to the successful integration of smart thermostats with hydronic radiant heating. The in-suite thermostats control heat by closing off valves when set points are exceeded. In this context, variable speed pumps are necessary to maintain proper pressure within the hydronic system and mitigate the risk of possible leaks.

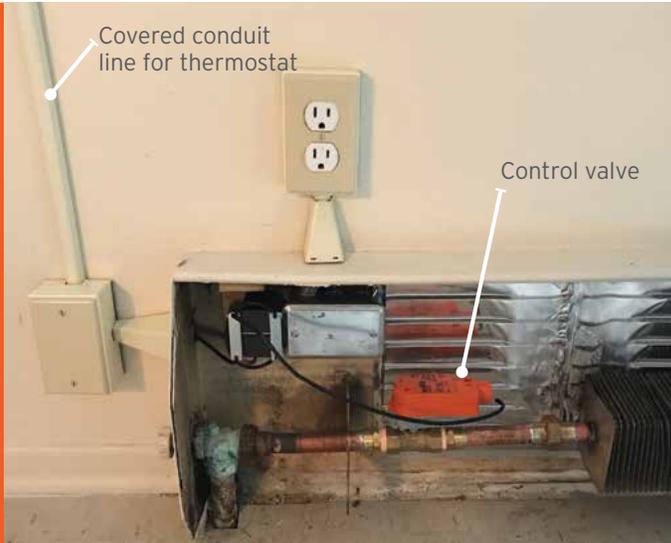
In order to track pre-and-post retrofit differences in thermal comfort and other conditions, TAF installed indoor temperature and humidity sensors in six per cent of units across the four buildings prior to the retrofit. Resident surveys were also conducted pre-and-post retrofit, capturing 10-16 per cent of the population in each building. A more in-depth analysis of the survey data can be found in the Pre-And-Post Retrofit Survey Analysis report⁶. The data collected revealed extreme overheating problems at all buildings, especially during the shoulder seasons (spring and fall). At buildings A and B, average pre-retrofit shoulder season temperature was 28°C, while the average winter temperature was 27°C. Average temperatures were 26°C and 27°C during the entire heating season in buildings C and D, respectively. Resident surveys also showed that 22 per cent of occupants reported overheating in the winter. A majority of residents (56 per cent) also reported opening their windows on a daily basis during the pre-retrofit winter.

TAF’s analysis revealed that the primary cause for these high indoor temperatures during the winter were the existing oversized boilers combined with the simple outdoor temperature reset control systems. The combination of these factors led to the heating systems simply providing much more heat than was needed, leaving residents with no option but to open windows to maintain comfort. The installation of the in-suite thermostats aimed to correct this problem, which was making it very difficult to maintain reasonable indoor temperatures during the heating season and resulting in a considerable amount of wasted energy.

IN-SUITE THERMOSTAT DETAILS

An upgraded building automation system controls the temperature set point of a central hydronic heating loop based on the outdoor air temperature. The upgraded boiler plants provide heat to the loop to maintain the set point, and the water is circulated to baseboard radiators, which are located along the perimeter of units. Generally, there is one radiator in the living room, one in the washroom, and one in each bedroom. Though the in-suite thermostat devices can control cooling equipment, there is no central cooling system at any of the pilot sites, so this study focuses only on the heating configuration.

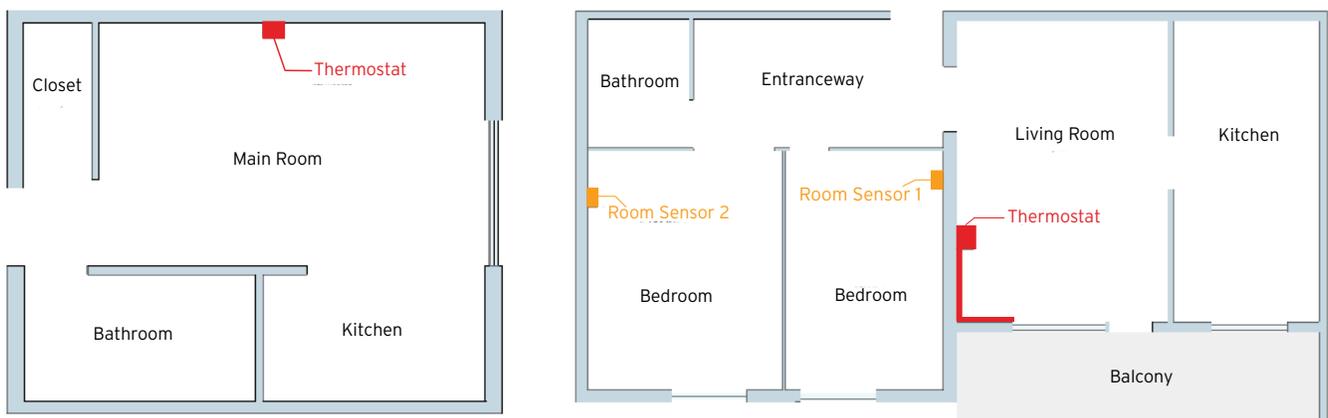
Figure 2. Typical control valve installation.



Single lines branch from the central heating loop to serve each unit, and the project team installed control valves in each apartment to allow unit-by-unit control. All radiators in a given unit feed from the same pipe; therefore, only one control valve per unit is needed. As shown in Figure 2, the control valve assembly features a 2-position actuator, powered directly from the thermostat. The valve limits the flow of warm water through the radiators based on the signal sent by the smart thermostat, by either fully opening or fully closing the valve.

The room sensors are installed in each bedroom (see Figure 3) to ensure that the temperature used to control the thermostatic valves is based on the entire unit. In each unit, the temperatures between the thermostat location and room sensors are averaged to determine the overall unit temperature, which signals the use of heat.

Figure 3. Typical thermostat and room sensor configuration for a sample bachelor unit (left) and sample two bedroom unit (right).



During the installation, ecobee, Building Up, and TAF staff members taught residents how to use their thermostat and its various functions, as summarized in Table 3. The project team also programmed the thermostats with a temperature range that maximized the energy savings while providing a comfortable and reasonable indoor environment. Upper temperature limit is set to 24°C (26°C in cases of medical concerns), while the lower temperature limit is set to 17.5°C. While the temperature limits are passcode protected, residents can freely adjust their unit temperature within these limits.

Spotlight on Local Jobs

Building Up connects housing providers with skilled labourers from the local community to improve Toronto's environmental efficiency, affordable housing stock, and create a real pathway for individuals experiencing barriers to enter apprenticeships and careers in the trades.



Table 3. Types of features communicated to residents.

Building	Resident Demographics	Main Features Communicated
Buildings A & B	Seniors	<ul style="list-style-type: none"> • Adjusting temperature
Buildings C & D	Families (including children and youth)	<ul style="list-style-type: none"> • Adjusting temperature • Connecting device to Wi-Fi network • Setting schedules • Using the phone app for remote control



ENERGY PERFORMANCE

TAF examined energy performance of the pilot sites over the pre-and-post-retrofit heating season. The project team calculated the impacts of the boiler and air handling unit upgrades, combined with the installation of the new thermostats, and found 33 per cent total gas savings at buildings A and B, and 19 per cent total gas savings at buildings C and D. The project had a total carbon emissions reduction of 671 tonnes CO₂eq per annum across the four buildings.



The older boilers at the four buildings had been providing significantly more heat than necessary. Pre-retrofit, boiler output at buildings A and B exceeded the actual heating demand by as much as 43 per centⁱ. Mechanical retrofits reduced the maximum heating output of the boilers from 4,400 MBTU to 3,762 MBTU. Through the heating plant retrofits, the project team redesigned the boiler output to be closely aligned with the actual heating needs of the building, exceeding actual heating demand by a maximum of 10 per cent.

The project team achieved similar results at buildings C and D, where the original boilers exceeded the actual heating demand by as much as 32 per cent. At building C, the total capacity did not change. At building D, total capacity of the heating and domestic hot water system was reduced from 8,000 MBTU/h to 6,890 MBTU/h, ensuring actual heating capacity does not exceed demand by more than 12 per cent.

Further analysis was needed to isolate the impact of the smart thermostat measure from the other retrofit measures. In order to do this, TAF did the following:

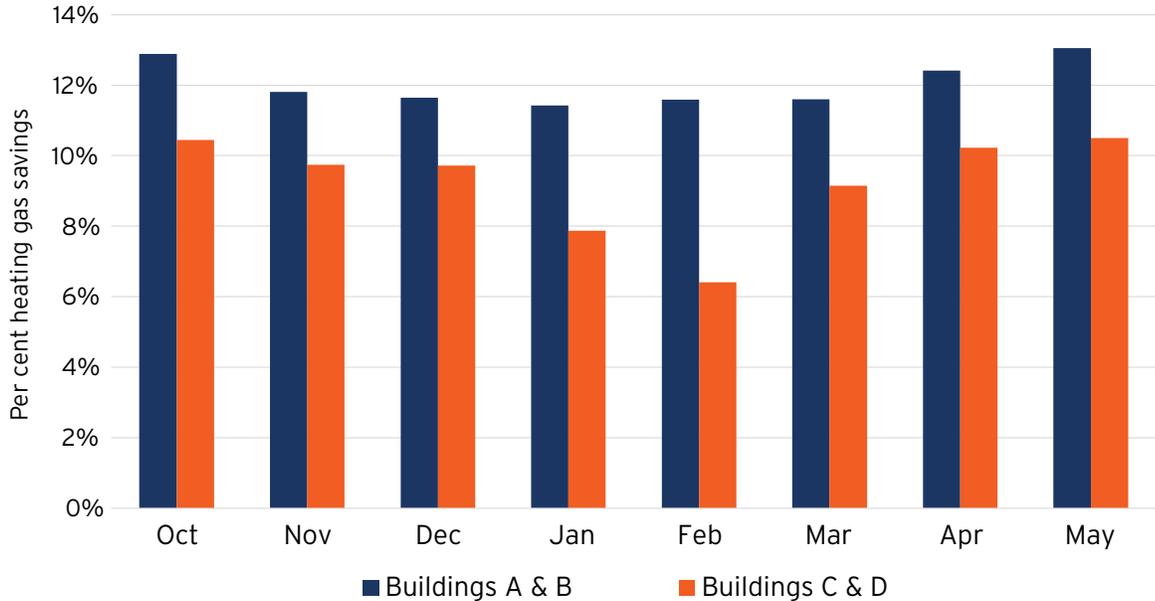
- 1 Used energy models** to calculate monthly pre-retrofit heating gas consumption with and without the thermostats in place. The difference in results represents savings directly attributable to the thermostats and was used to calculate monthly gas heating savings ratios for each site. These ratios represent the percentage of heating gas (by month) that would have been saved with the introduction of the thermostats in isolation.
- 2 Calculated the estimated space heating savings** for the in-suite smart thermostats by applying the savings ratios to the actual heating gas consumption for the first year of post-retrofit occupancy.ⁱⁱ

ⁱAs outdoor temperature increased, so did the percentage difference between the buildings' heating demand and heating output. This is because the original boilers had difficulties "ramping down" when exterior temperatures rose.

ⁱⁱThis methodology results in an optimistic estimate of post-retrofit thermostat savings, as the savings ratio is calculated on pre-retrofit conditions with high levels of overheating. Post-retrofit, the installation of correctly-sized boilers with the ability to modulate helped to reduce overheating, which would also reduce the savings directly attributable to the thermostats.

This methodology resulted in an estimate of thermostat savings of 11.8 per cent of space heating gas at buildings A and B, and a 8.8 per cent savings at buildings C and D. Savings are slightly higher during the shoulder season for both sites, and this pattern is especially strong at buildings C and D, which had less pre-retrofit overheating and therefore lower thermostat savings overall. Figure 4 shows the monthly savings over an entire heating season.

Figure 4. Monthly natural gas space heating savings stemming from smart thermostats.



Pre-retrofit, the heating system was working near capacity for most of the heating season, even when exterior temperatures were mild. Post-retrofit, the in-suite controls and the condensing boilers scaled down the amount of heat provided. Over one heating season, the reduction in heating gas attributed to the in-suite thermostats was 16,200 m³ at buildings A and B, and 39,500 m³ at buildings C and D. This equates to annual carbon emissions reductions of 30 and 74 tonnes CO₂eq respectively from the thermostat measure, cumulatively accounting for 16 per cent of emissions reductions across all sites.

The average space heating energy saved over the first post-retrofit heating season was below the 23 per cent found in the ecobee case study, however estimated monthly savings were as high as 13 per cent⁷. The average savings achieved in this pilot project are also comparable to the savings achieved by studies with Nest and Lyric thermostats, which reported 6-12 per cent savings in gas-heated homes on average⁸. As the existing literature on smart thermostats does not yet include multi-unit residential buildings, an exact comparison to multi-residential buildings cannot be made.

16%

 emissions reductions
 across all sites

COMFORT

In addition to the space heating and carbon emission savings, the in-suite thermostats also improved thermal comfort for residents. One of the main goals of introducing this technology was to curb overheating issues seen during the winter and shoulder seasons. Table 4 shows the average interior temperatures, pre-and-post retrofit, by season and by site.

Table 4. Average indoor air temperature by season and by site.

Building	Average Pre-Retrofit (2015 - 2016)			Average Post-Retrofit (2017 - 2018)		
	Fall	Winter	Spring	Fall	Winter	Spring
Buildings A & B	28.2°C	27.7°C	27.5°C	26.7°C	25.8°C	27.2°C
Buildings C & D	26.6°C	26.4°C	27.0°C	27.4°C	25.5°C	26.5°C

Based on the pre-retrofit monitoring, overheating was a persistent problem at both sites. This was also reflected in the pre-retrofit resident surveys, where 29 per cent of residents in buildings A and B and 11 per cent of residents in buildings C and D felt that overheating was an issue during the winter. It is notable that the average temperatures post-retrofit significantly exceed the maximum set point on the thermostats; however, this may be due to a number of factors. After the thermostat closes the control valves the radiators continue emitting heat until they cool down to ambient temperatures, thus the system has a tendency to overshoot the set point. Additionally, TAF discovered a number of thermostats had setpoints which were configured incorrectly, potentially allowing for temperatures above 26°C. TAF continues to work on resolving this issue.

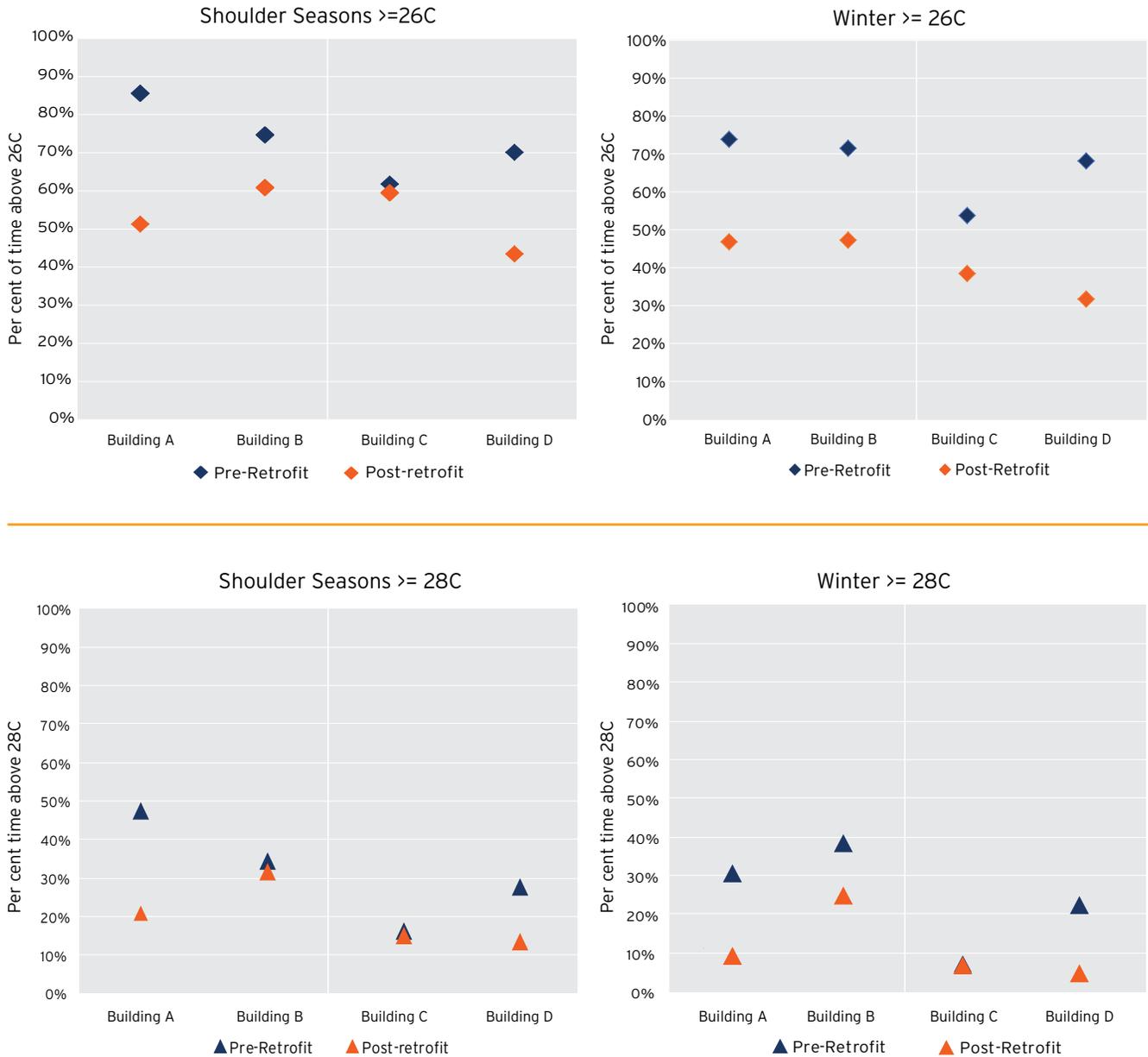
Reductions in over-heating are particularly salient not just from a thermal comfort perspective, but also from the perspective of human health, as studies have shown that sustained exposure to high temperatures can have impacts on mortality and morbidity⁹. As over-heating was prevalent across all case study buildings, and nighttime cooling also had little effect on reducing interior temperatures, discomfort was an issue throughout the entire day. In order to understand the extent of overheating in these buildings, TAF examined the amount of time spent $\geq 26^{\circ}\text{C}$ and $\geq 28^{\circ}\text{C}$ pre-and-post retrofit.

Pre-retrofit temperatures were $\geq 26^{\circ}\text{C}$ for 3156 hours over the six shoulder months, on average across the four buildings. This decreased by 25 per cent post-retrofit to 2360 hours. Similarly, temperatures at the four buildings were $\geq 26^{\circ}\text{C}$ for 1448 hours in winter pre-retrofit, decreasing by 39 per cent post-retrofit to only 883 hours.

TAF saw significant reductions in the amount of time spent at extreme temperatures of $\geq 28^{\circ}\text{C}$. Pre-retrofit shoulder season temperatures were $\geq 28^{\circ}\text{C}$ for 453 hours on average. Post-retrofit, the suites spent a total of 293 hours above that threshold, a 35 per cent decrease. Excessive temperatures were further reduced in the

winter. Pre-retrofit winter temperatures were $\geq 28^{\circ}\text{C}$ for 177 hours, which decreased by 54 per cent post-retrofit to only 81 hours. While there are still some days where indoor air temperatures are outside of the comfort zone, there is a general reduction in overheating post-retrofit.

Figure 5. Per cent of time units spent above 26°C (top) and above 28°C (bottom) pre-and-post retrofit.

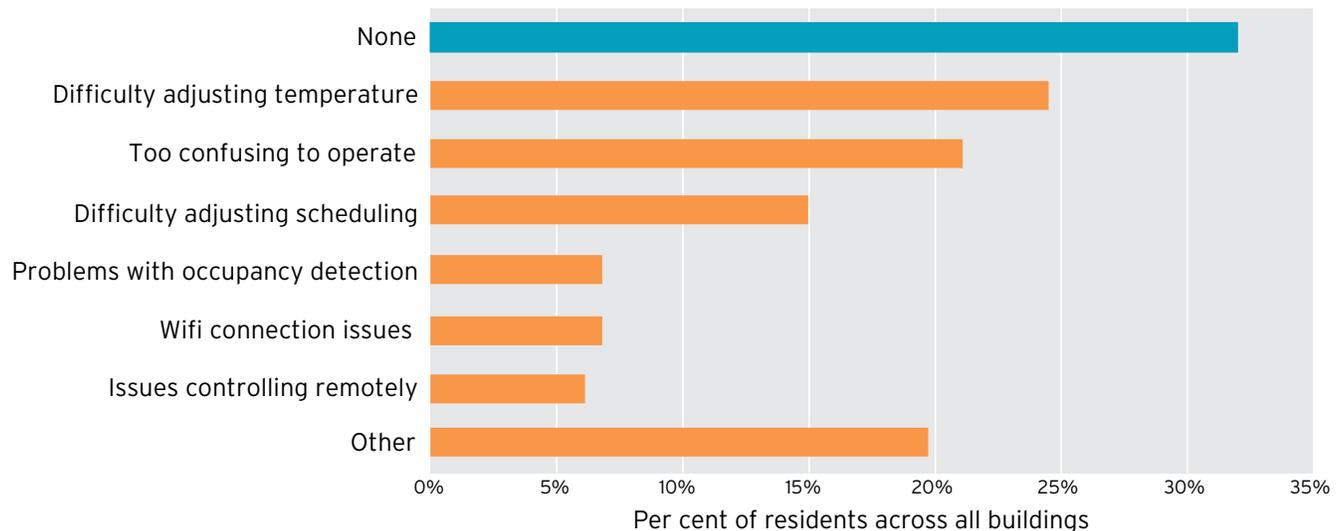


RESIDENT FEEDBACK

To understand how residents are reacting to the in-suite thermostats, TAF conducted a series of post-retrofit surveys focusing on how the smart thermostats are perceived. These surveys captured feedback from 16 per cent of residents across the four sites.

Figure 6 lists the types of difficulties residents experienced with the smart thermostats and the percentage of residents experiencing those difficulties. Residents' concerns did not vary much between the four buildings, with the exception of building C and D where more residents found it difficult to adjust the scheduling. Based on interactions with residents over the past year, TAF has found that very few residents in building A and B actually use the scheduling function as they spend the majority of the time in their units. Consequently, TAF does not recommend programming schedules for senior populations, a recommendation which is echoed in other smart thermostat studies¹⁰.

Figure 6. Difficulties using thermostat as reported by residents.



TAF's findings are consistent with similar smart thermostat case studies, where adjusting temperature and adjusting scheduling accounted for most of the difficulties described by users¹¹.

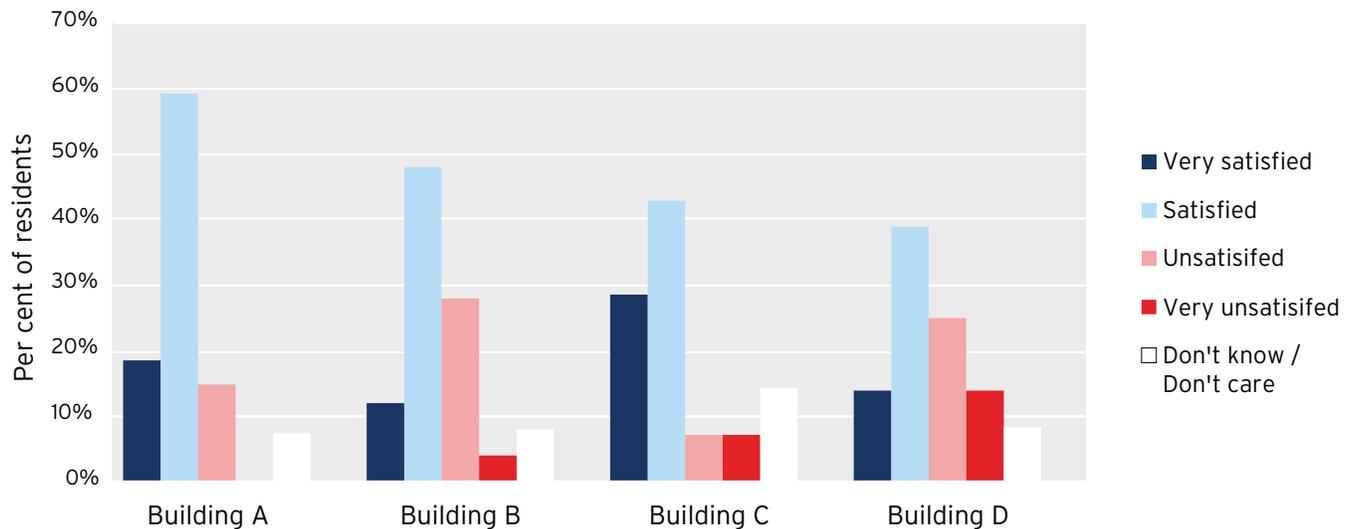
As discussed above, buildings A and B are predominantly home to seniors, who may not be familiar with using a technology with a touch screen. This poses a unique challenge when implementing any type of new technology, as the learning curve can be higher than expected. Language barriers posed another challenge. Although the thermostat interface is only in English, the project team translated additional educational materials into Spanish (the most commonly spoken language at the sites), and all materials focused heavily on images rather than text for simplicity.

TAF, ecobee, and building staff addressed these reported difficulties through resident education. This included information and drop in sessions where individuals could get one-on-one guidance. The team also informed residents about important topics such as the impact that window opening in winter has on heating and the importance of keeping spaces in front of the radiators free of furniture to improve heat flow through the unit. The project team found that resident education was a key to success in terms of achieving the expected space heating savings as well as ensuring residents can use the thermostats to improve their thermal comfort. In general, buildings C and D required fewer resident engagement events, as the population was more comfortable with this type of technology.

TAF also asked residents about their overall satisfaction with the in-suite smart thermostat. On average, 65 per cent of residents were either satisfied or very satisfied with their thermostat, as shown in Figure 7. Despite the steeper learning curve for residents at buildings A and B, a large majority were satisfied with their in-suite smart thermostats.

65%
of residents were either satisfied or very satisfied with their thermostat

Figure 7. Resident satisfaction with smart thermostats, by building.



SCALE-UP POTENTIAL

The majority of MURBs in Ontario share similar challenges as these pilot sites—old mechanical equipment with no turn-down capability, overheating, and lack of in-suite controls. As MURBs account for 56 per cent of Toronto’s existing housing stock there is a great opportunity to make significant impacts on building energy use by introducing in-suite smart thermostats¹².

There are an estimated 1.18 million gas-heated apartment units in Ontario¹³. Assuming an 8.8-11.8 per cent reduction of space heating energy, as shown in this study, smart thermostats could potentially save between 164-219 million m³ of natural gas across Ontario, per heating season. This would produce a per-unit savings of between 139m³-185m³ gas. Although the accuracy of this scale up is limited by the data currently available on Ontario’s building stock, and is based on the findings of only a handful of pilot buildings, it does highlight the potential improvements that can be made to similar buildings.

Moreover, this study did not cover the impacts that smart thermostats could have during the cooling season, as neither pilot site has central cooling. However, using thermostats to control cooling has been shown to reduce electricity by 14-16 per cent in single-family homes¹⁴.

Introducing in-suite smart thermostats can also have significant impacts on carbon emissions, with the potential for 310,000-412,000 tonnes of CO₂eq reductions. This is equivalent to taking as many as 87,473 passenger vehicles off the road annually¹⁵.

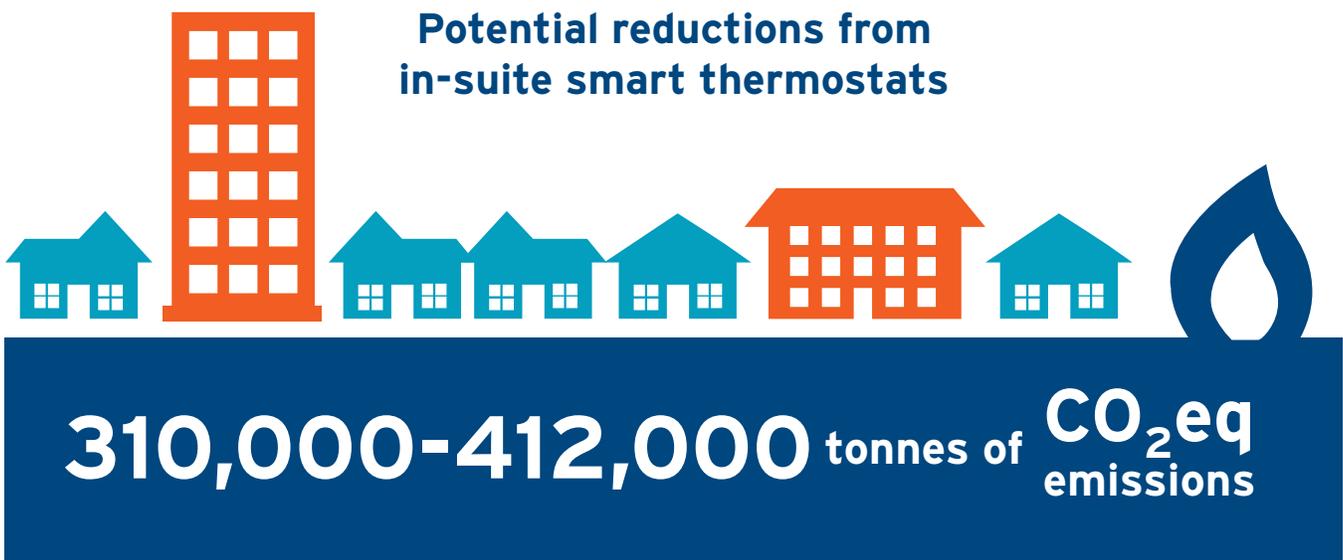


Table 5 lists the costs associated with the thermostat measure for each unit. The largest cost impact is the valve retrofit, which accounts for 70-75 per cent of the total costs in this pilot study. It should be noted that buildings with a different type of heating system (e.g. fancoil units, electric baseboards) may have much lower costs due to avoiding expense associated with installing valves.

Table 5. Installation components and costs.

Component	Cost
Thermostat + 1 room sensor	\$299
Additional room sensors	\$89
Valve retrofit installation work + materials	\$900
Conduit + associated labour	\$175

Given that the useful life of a smart thermostat is 20 years, the cost of the device as well as the required valve retrofit to install it cannot be paid back from the energy savings achieved over the device’s lifetime. To reduce capital expenditures associated with wiring the thermostats to the radiators, TAF recommends that smart thermostat manufacturers investigate wireless connection options for MURBs.

It is important to remember that the above calculations are based purely on the space heating savings. However, there are a number of co-benefits achieved that need to be carefully considered. One is the direct comfort benefit to residents, who now have more autonomy over their own thermal comfort. Another benefit is improved temperature regulation across units with multiple bedrooms.

As there will now be room sensors in each room, the smart thermostat will average the various room temperatures accordingly to ensure that the correct conditions are met in each room, not just the room in which the smart thermostat is located. Indoor environmental quality is about more than simply reducing resident complaints, as research shows that poor thermal comfort can lead to poor health¹⁶. Resident surveys also showed 58 per cent less reported absenteeism from work or school at buildings C and D after retrofits, indicating that resident health may have improved as a result of these endeavoursⁱⁱⁱ.

58%

 less reported absenteeism
 from work or school
 in buildings C & D

ⁱⁱⁱBuildings A & B are predominantly home to seniors who did not attend work/school, so only buildings C & D are reported here.

CONCLUSIONS & RECOMMENDATIONS

The pilot studies have revealed the potential for significant energy savings and carbon reductions from the introduction of in-suite smart thermostats in MURBs.

Installing in-suite smart thermostats across these four multi-residential buildings resulted in 8.8 to 11.8 per cent of space heating savings per year. This equates to a 16,200 m³ reduction of natural gas at buildings A and B, and a 39,500 m³ reduction of natural gas at buildings C and D. The scale-up potential for the over 1.18M existing MURB units across Ontario is significant and could result in emissions reduction of 310,000-412,000 tonnes CO₂eq per year. The addition of these in-suite controls also provides a number of co-benefits: residents have greater autonomy over their home, leading to significant improvements in thermal comfort and reduced exposure to extreme temperatures that are known to affect human health and wellbeing. These co-benefits offset the high up-front cost of retrofitting smart thermostats into older hydronically heated MURBs.

Based on the experiences gathered through this multi-unit residential pilot study, TAF has developed a number of recommendations for three key stakeholder groups: utilities, thermostat manufacturers, and building owners/operators.

Utilities

Utility companies have a role to play in encouraging building owners to adopt energy efficiency technology such as smart thermostats by including them in their conservation programs. Cost can be a limiting factor for device installation in retrofit scenarios depending on the configuration and conditions of the existing heating system, despite the device itself having a relatively low cost. Providing incentives for smart thermostat retrofits within multi-unit residential buildings will encourage the adoption of this new technology.

This pilot study also shows that in-suite smart thermostats are most effective as part of larger, more comprehensive mechanical system retrofits in multi-unit residential buildings. At the pilot sites the thermostats combined with boiler and air handling unit upgrades created the largest impact (21-34 per cent total gas savings). The in-suite smart thermostats helped maximize the possible savings from the boiler upgrades because they helped to curb the difference between heating demand and heating supply. Installing variable frequency drives on the heating pumps is also critical to ensure that as various units close their radiator valves, the network pressure does not keep rising and potentially cause leaks in units. TAF recommends that, in the context of multi-unit residential buildings, in-suite smart thermostats be included in conservation programs. Depending on the existing heating system, there are a number of different opportunities for such programs to take shape, either as a standalone measure or as a combination with other planned heating system upgrades.

In addition to including smart thermostats in conservation programming, it is also important for utilities to work with other stakeholders, such as manufacturers, to ensure the incentives are widely promoted and that literature surrounding the devices and their savings potential reaches building owners, operators, and residents.

Pilot gas savings achieved by combining thermostats with boiler and air handling unit upgrades

21-34%

Smart Thermostat Manufacturers

In order to increase the scale-up potential for retrofitting older, multi-residential buildings with smart thermostats, we suggest a few technical changes. First, the thermostats within this survey were connected to the hydronic radiators via a covered conduit running from the thermostat to the valve. As most hydronic radiators are located at the building perimeter while the thermostat is better situated towards the interior (far away from direct solar radiation), developing a wireless system of connection would be ideal. This is preferred as it is both less expensive and more aesthetically pleasing. Integration with suite-based systems, such as air conditioners, is another key factor in the successful adoption of this technology.

Recommendations

- ➔ Developing a wireless system of connection
- ➔ Capability for smart thermostats to 'fail on'
- ➔ Ability to control multiple zones using one central thermostat
- ➔ Ability to make remote thermostat configuration changes

Another technical workaround that needed to be developed in order for the building owners to approve of the installation of this new technology was the ability for the smart thermostats to 'fail on'. It is essential that, in case of a device malfunction or other damage, building owners and tenants can be assured that the suites will continue to receive heat. At present, this either requires relays to be installed (at a significant extra cost) or the less costly work-around of forcing the thermostat into working in cooling mode when providing heat. In order to expand into the MURB market a proper technological solution to this needs to be developed.

Moreover, most thermostat technologies are not able to control multiple zones with one thermostat. In larger units, this often becomes a limiting factor, as there are multiple fan coil units or individual hydronic radiators to control. It may not be economically feasible to install an individual thermostat for every piece of conditioning equipment, so zoned controls using multiple sensors controlled by one thermostat interface would be ideal.

The ability to make changes to the in-suite smart thermostat through a central online portal would also help

building owners deal with any resident complaints more effectively^{iv}. For example, being able to adjust the current set point or the thermostat schedule from an online portal would allow building owners to troubleshoot problems quickly and remotely for residents who cannot make the changes themselves. Another important function would be the ability to adjust thermostat programming related to the return to base settings (the default was four hours in the devices in this study). The option to revert to a different base setting per season would be of value, for example, to building operators. In the case of a multi-unit residential building, any way to make changes without entering tenants' homes and disrupting their daily lives is preferred.

^{iv}Ecobee has recently introduced a SmartBuildings online platform that addresses many of suggestions TAF has outlined in this report, though it was not used during this case study.

Building Owners and Operators

With the introduction of in-suite smart thermostats, building owners and operators and tenants could see as much as 10 per cent savings on their energy bills. This is an important benefit, particularly in the realm of affordable housing. Reducing utility costs can help direct this money to other critical areas such as addressing deferred maintenance and further improving building operation. Moreover, ensuring that heating supply is better aligned with heating demand in order to reduce overheating not only benefits building owners from a cost-savings perspective, but also improves residents' thermal comfort, potentially reducing resident complaints.

Building owners and operators have an important role to play in ensuring that new energy-saving technologies such as smart thermostats are widely accepted. Based on this retrofit project, it is clear that prior to implementing any changes, gauging resident receptiveness and understanding possible challenges is key.

This study also shows that resident engagement can provide beneficial insights that can help inform building energy retrofits and smooth the process of implementation. Engagement can be done through formal and informal processes such as surveys, meetings, and conversations. Understanding residents' familiarity and comfort with technology, what languages to disseminate information in, and identifying any other potential hurdles early on in the process will make the uptake of new energy efficiency measures such as smart-thermostats smoother and can boost resident confidence in such upgrades. For example, in the case of thermostats that require Wi-Fi connections and/or smart phone apps, asking if residents have these resources readily available would be an important step. Residents who have experience with other smart devices will likely have a shorter learning curve when it comes to using this new technology.

Another important factor is to consider thermal comfort in a holistic manner. In many cases, residents do not understand the various ways in which their own behaviours can affect their thermal comfort. To reduce complaints and the need for repeat visits, it would be valuable to take extra time during thermostat installation to speak with residents about all aspects of thermal comfort. For example, residents may have large pieces of furniture or curtains blocking their radiators. They may also have different expectations of how quickly heat should be delivered, leading them to turn on supplementary heating devices which then affect the thermostat's ability to properly control temperature and undermine energy savings. Informing residents of how their actions affect their new thermostat is critical in maximizing the expected energy savings.



Reducing utility costs can help direct money to other critical areas such as addressing deferred maintenance and further improving building operation.

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