TAF The Atmospheric Fund

Lessons from a Heat Pump Retrofit at Walpole Ave

A TAF CASE STUDY

TAF The Atmospheric Fund

About The Atmospheric Fund

The Atmospheric Fund (TAF) is a regional climate agency that invests in low-carbon solutions for the Greater Toronto and Hamilton Area and helps scale them up for broad implementation. TAF is supported by dedicated endowment funds provided by the City of Toronto (1991), the Province of Ontario (2016), and the Government of Canada (2020).

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CMHC SCHL

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Canada

Executive Summary

To advance climate action and reduce carbon emissions in the Greater Toronto and Hamilton Area (GTHA), The Atmospheric Fund (TAF) is focused on scaling up the adoption of deep energy retrofits (defined here as savings of 40 per cent or more) in multi-family buildings. Deep retrofits offer multiple benefits to communities including carbon reduction, cost savings, and health and comfort improvements.

66 Walpole Avenue is a townhouse complex located in Toronto's east end. The nine townhouse blocks have 120 suites in total, ranging in size from one- to three-bedrooms. Space heating is provided by electric baseboards around the perimeter of each suite. The site consumes approximately 1,663,400 kWh of electricity, amounting to $302,000 a year.

To demonstrate the viability of retrofits focused on electric heat pumps, TAF installed and monitored eight cold climate air-source heat pumps (CC-ASHPs) at 66 Walpole Avenue as a pilot project. This case study summarizes the pilot project specifics, results, and learnings.

Suites

- 8 retrofitted
- 8 baseline

Technology

- Air source heat pump
  + remotes
  + thermostats

Key outcomes at 66 Walpole Ave

- **80% satisfaction with winter indoor temperatures**
- **Average electricity heating savings = 36%**

Key recommendation

Resident engagement, education, and controls are key to realizing expected savings when upgrading to ASHPs.

Content

66 Walpole Avenue Townhouse Complex

TAF and Toronto Community Housing go deeper with building energy retrofits

TAF and Toronto Community Housing (TCHC) have a have a long established partnership, and have been working together on energy efficiency retrofits since 2006. See TAF.ca/publications for other case studies featuring these projects.

66 Walpole Avenue

Built in 1987, 66 Walpole Avenue is a townhouse complex located in Toronto's east end. The nine townhouse blocks have a gross building area of 13,444 m^2. In total there are 120 suites, ranging in size from one- to three-bedrooms. There is also a common laundry room, a parking garage, a storage room and an office on site. All suites are sub-metered, and residents pay their own electricity bills; common area and exterior electricity is paid for by TCHC. There is no natural gas used on site. While electricity is already a cleaner fuel source than natural gas, demonstrating the benefits of heat pump technology in electrically heated buildings currently offers a stronger business case.

In a typical year, site-wide electricity consumption is approximately 1,663,400 kWh (140 kWh/m^2 or 13,862 kWh/suite), with a cost of $302,000. Annual electricity consumption at the site is responsible for 83 tonnes CO_2eq emissions.

Electric baseboard heating, switch operated ventilation

Space heating for each suite is provided by multiple electric baseboard radiators, the majority of which are controlled by a single wall-mounted thermostat within a given room. Some baseboards are controlled individually by a built-in thermostat on the baseboard itself. This is often the case for auxiliary baseboards in areas such as entryways or storage rooms. The common areas (office and storage room) are also heated by electric baseboards.

There is no cooling provided on site, however many residents have installed their own cooling through window-mounted or portable air conditioners. In some cases, these units remain in the windows year-round.

Ventilation is provided to each suite through local bathroom exhaust fans, which are switch operated. Some residents have installed their own laundry machines and dryers in their suites, particularly if they have basement suites. Upon inspection we found that the majority of these were properly vented to the exterior. The common room laundry is vented through a single exhaust fan, which runs continuously. Parking garage ventilation is provided by a single exhaust fan controlled by a timer.

Addressing challenges: high electricity bills, poor thermal comfort

A key resident concern was high electricity bills, which could cause a financial burden. Moreover, the existing baseboard heating system was inefficient (relative to modern ASHP systems) and had poor controls that lacked sensitivity. Many residents resorted to using space heaters as a cost saving measure. Residents in basement units also expressed concerns about high humidity, particularly in the summer.

Pilot Project Design

TIMELINE

September 2017
Pilot participants recruited

April 2018
Systems installed

August 2018
Survey completed

May 2019
Pilot phase completed

June 2019
Full project design began

In September of 2017, TAF began recruiting resident volunteers at 66 Walpole to participate in the pilot project. In total, we recruited 16 residents for study participation. Of these, eight two-bedroom units were included as baseline suites. Four one-bedroom units and four two-bedroom units were included for heat pump installation. The eight heat pump systems were installed and commissioned by April 2018, however due to resident changeover, only seven were included in the pilot study.

There are a number of challenges to consider when retrofitting with heat pumps, particularly the location of the outdoor condenser unit and the necessary line runs. For the pilot project TAF focused on recruiting residents from ground floor units, where it would be easiest to install condensers with less complicated line runs.

The retrofitted suites have Mitsubishi M-series cold-climate ductless multi-split systems (maximum capacities between 22,000 – 28,600 BTU/h) with two to three indoor heads serving each suite—one in the main living area and one in each bedroom. To ensure the heat pumps would carry the full heating load, we disabled existing electric baseboards at the circuit panel but remain in place.

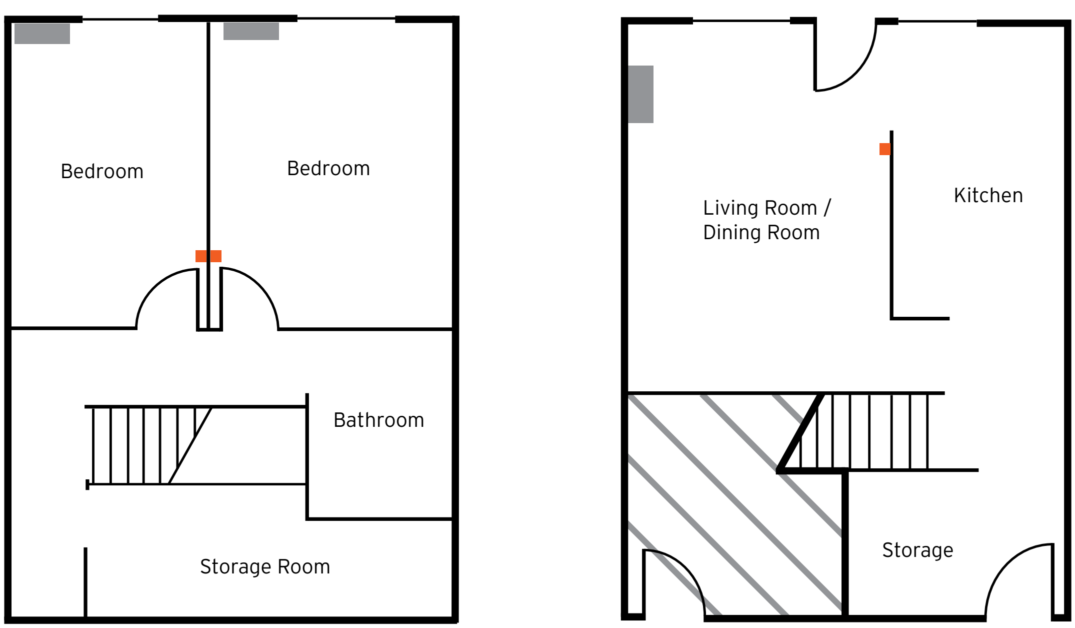

Figure 1. Typical floorplan, grey rectangle indicates indoor header position, orange square indicates thermostat position.

Figure 2: Outdoor compressor unit of heat pump

Exploring control options: remote controls and thermostats

To explore different system control options, five of the eight heat pumps were controlled with one standard hand-held remote per suite, while the remaining three were controlled with Mitsubishi's MRCH1 wireless thermostat.

In the wireless thermostat configuration, there was one wireless thermostat per heat pump head for a total of three thermostats per suite. The wireless thermostats allowed the building owner to have greater operational control through specific programming, such as setting upper and lower temperature limits. Moreover, there was less of a concern that a wall-mounted thermostat could become lost at resident turnover. However, wireless thermostats came at an added price premium of $525 per suite, whereas hand-held remotes were already supplied by default.

Both remote controls and wireless thermostats were battery operated and would need to be changed every two years (depending on the type of battery and use). For this reason, the project team opted for wired thermostats in the full roll-out of this project.

Equipment Type	Model Number	Quantity	Location
Outdoor compressor	MXZ-3C24NAHZ	1	Mounted to exterior wall.
Indoor head	MSZ-GE06NA	2	Bedrooms
Indoor head	MSZ-GE12NA	1	Living room/dining room
Wireless remote	N/A	1	Per suite
Wireless thermostat	N/A	3	Per indoor head.

Note: suites either have a wireless remote or a wireless thermostat, depending on their configuration.

Table 1: Components of typical installation in a two-bedroom suite

Monitoring approaches

Robust monitoring is a key component of all TAF retrofit pilot projects. We monitored electricity consumed for space conditioning for both the baseline and heat pump suites in 15-minute intervals using Accuenergy Acuvim II energy meters. It is important to have electricity metering installed by a qualified electrician who is familiar with metering equipment (preferably with the equipment specified), and to commission the meters soon after installation to ensure accurate data is being collected. In this pilot study, some initial data was lost due to incorrectly configured meters. Fortunately, we identified the issue early in the pilot and it did not affect TAF's performance analysis; once properly configured, the system-level metering was integral to the study.

Interior and exterior conditions were also key parameters in this study. For exterior temperatures, TAF relied on data from the weather station at the Toronto International Airport. Interior temperature and relative humidity were monitored by HOBO MX1101 Bluetooth Data Loggers. Bluetooth connectivity allowed TAF staff to collect data without entering resident suites. Monitoring electricity consumption data along with indoor temperature and relative humidity allowed us to model suite level trends. More details about the monitoring equipment used can be found in Appendix B.

Figure 3: Electricity metering.

Resident survey

Beyond the roughly 235,000 quantitative datapoints collected, the pilot study also captured resident perceptions of their pre-retrofit indoor environment, particularly around thermal comfort. TAF administered a survey to both groups of residents in the pilot, with a more detailed survey for residents with heat pumps installed. Survey work was completed in summer 2018; a total of 12 residents participated, six with heat pumps and six baseline suites. A copy of the survey questions can be found in Appendix C.

Indoor Environmental Quality

Maintaining comfort, even in cold winters

Toronto's climate requires more heating than cooling, averaging approximately 3,620 heating degree days (HDD)[i] during the heating season, which TAF defines as September 15 through May 31, in-line with local by-laws[1]. Average low temperature in January, historically the coldest month of the year in Toronto, is -7C.

80%

of residents satisfied with winter temperatures

Thermal comfort issues were exacerbated by envelope weaknesses across the site. Although some insulation and air sealing improvements were undertaken in 2014, the original single-pane windows created comfort and heat loss issues. Pre-retrofit, 50 per cent of residents surveyed felt too cold in their suites in winter. Moreover, heating costs were an issue for many residents, and some residents chose not to use their baseboards in order to save money. In these cases, residents often purchased space heaters and heated only one room at a time. Post-retrofit saw an increase in thermal comfort, with 80 per cent of residents feeling satisfied with their winter temperatures.

TAF and TCHC sought to resolve these issues with the air source heat pump retrofit. Digital controls (wall-mounted thermostats or remote controls) allowed residents to heat their home to the specific temperature desired. With a separate control for each indoor heat pump head, the apartments were essentially zoned, which allowed residents to lower the temperature of unoccupied spaces in order to save energy and costs.

After the first year of use, the majority of residents found the heat pump system "significantly better" than the electric baseboards. Heating season monitoring revealed that the heat pumps were able to maintain consistently warm interior conditions even when outdoor temperatures reached -25°C.

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i Based on base-18°C heating degree days.

Providing summer cooling

As extreme heat days in Toronto grow in frequency and severity due to climate change, bringing efficient cooling systems into the spaces where we live and work becomes increasingly important. A recent Ontario study has linked exposure to sustained indoor temperatures over 26°C to significant increases in mortality and morbidity, yet such temperatures are common in older multi-residential buildings. Recognizing the potential to address this through an energy efficiency retrofit, TAF and TCHC felt that introduction of cooling for residents was another key goal of this pilot project.

97%
of residents satisfied with summer temperatures.

According to survey results, 70 per cent of residents found it to be too hot in their suites in the summer, particularly in the living room and kitchen which are typically located at the ground level. Post-retrofit, 97 per cent of residents expressed satisfaction with their summer temperatures. The majority of residents surveyed did use window AC units on a daily basis, and yet were still uncomfortable. This speaks to how ineffective window ACs can be, often with high energy consumption and little improvement in thermal comfort.

Additionally, TAF observed that most residents were only able to install window AC units on the main level, conditioning the living room and kitchen but not the bedrooms. Residents often described the basement bedrooms as being too humid, which also led to discomfort. With a heat pump head in each bedroom and the main floor living space, residents now had increased access to efficient (and effective) cooling and dehumidification.

Electricity Consumption

While improving resident comfort was a major component of this study, understanding the potential for heat pump retrofits to reduce energy consumption and costs were important goals. This section discusses the energy savings seen over the course of one heating season. As the suites previously relied only on resident-owned fans and window air conditioners (or in some cases had no cooling at all), the project team did not expect to see significant energy savings during the summer period as the heat pumps expanded (or introduced) cooling capacity to the suites.

Based upon weather-normalized hydro bill analysis, Figure 4 shows electricity savings by season, during the first year of monitoring. TAF was unable to establish a clear trend between the suites, with some units seeing savings as high as 24 per cent in the winter, but others seeing no savings or a slight increase in consumption. Average yearly heating energy savings range between -7 per cent and 17 per cent across the retrofitted suites.

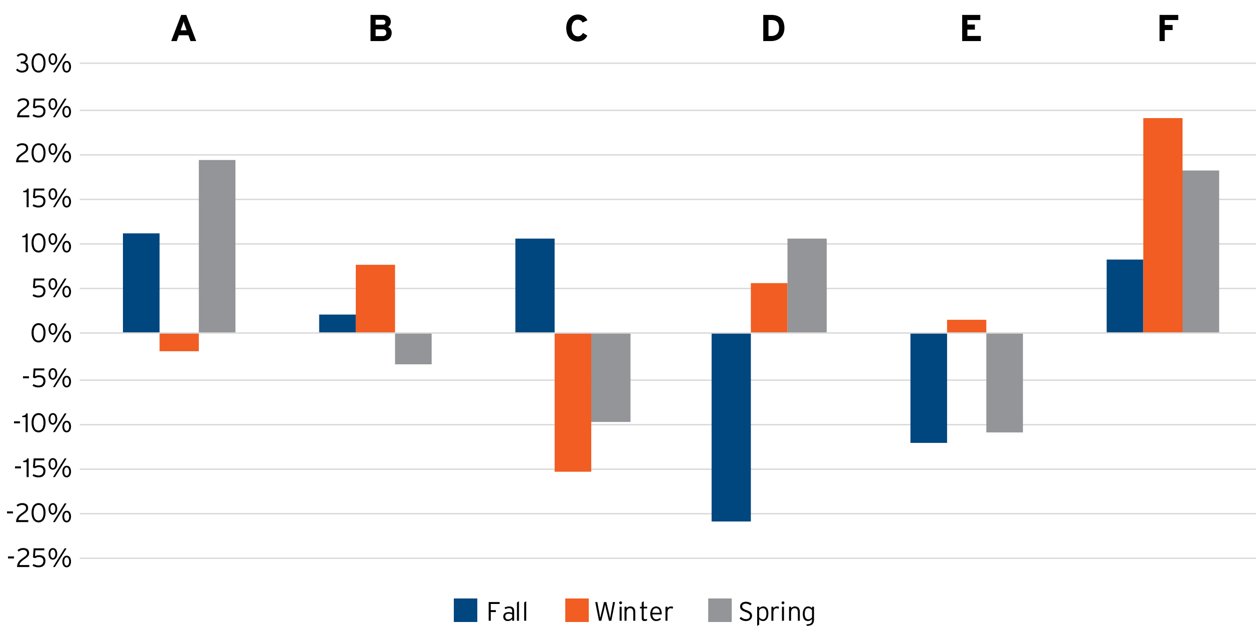

Figure 4: Electricity savings in per cent by season, by suite.

One of the limitations of this study was that pre-retrofit metering data for the heat pump units was unreliable due to issues with the original electrical meters, which had to be replaced. In order to get a different perspective on heat pump performance that accounted for resident behaviour, TAF developed a regression model based on baseline suite data. The baseline suite model was then used to benchmark the heat pump suites' performance. While benchmarking heat pump consumption against baseline suite consumption is less desirable than benchmarking to pre-retrofit data from the same suite, it can provide a reasonable basis for comparison when pre-retrofit data is unavailable.

TAF created the regression model using the electricity and indoor temperature data aggregated from the occupied baseline suites (one suite was unoccupied for most of the monitoring period); the resulting r^2 for this model was 0.6358. This model was used to project daily hypothetical baseboard consumption for the retrofitted heat pump suites. Figure 5 shows the savings generated by heat pump systems over the projected baseboard consumption.

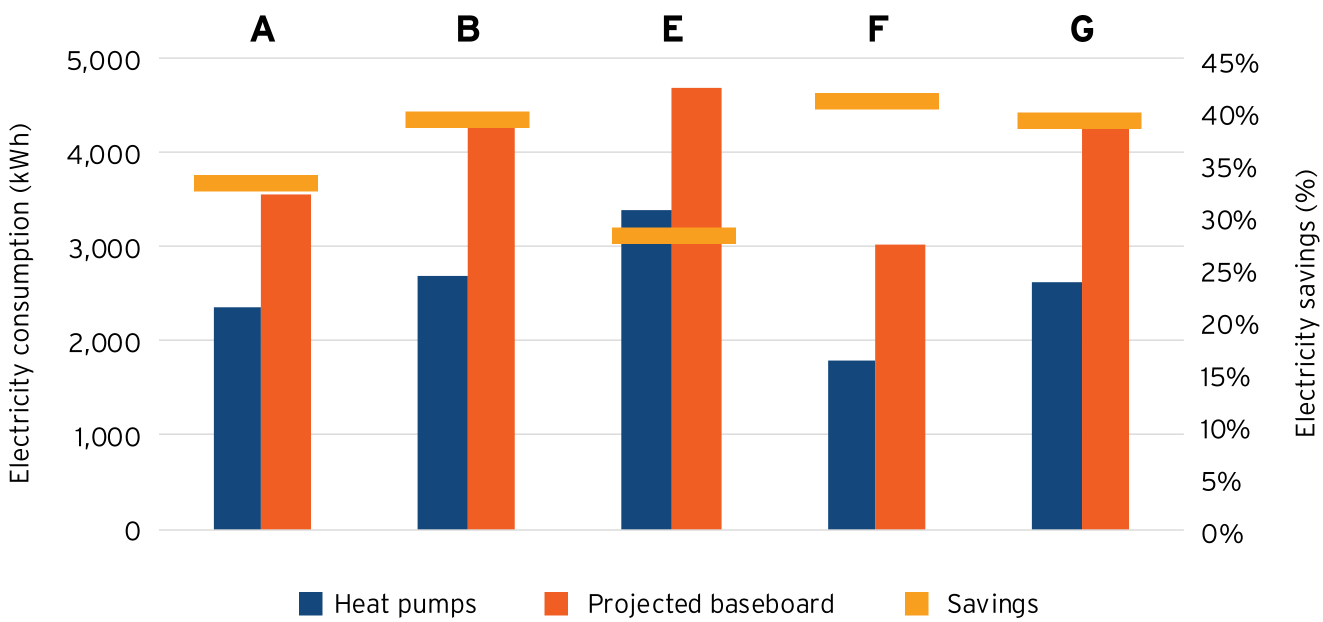

Figure 5: Electricity consumption and associated savings compared to baseboard heaters between January 16th and May 15th 2019

When compared to the modelled baseboard projections, the retrofitted suites saved between 28–41 per cent of heating electricity on average. This was below TAF's expectations but in-line with other cold-climate heat pump retrofit studies.[2]

Resident Education, Behaviour, and Controls

TAF's initial findings revealed that further investigation into the system's performance was needed. To rule out the possibility of mechanical or operational issues, the original contractors evaluated the heat pumps at the end of the 2018/2019 heating season by the contractors who did the installation. All heat pumps were found to be in good working order, with the exception of one system with a low refrigerant pressure reading. A subsequent warm-weather assessment of this system found no refrigerant issues, just a valve in need of tightening.

With mechanical and operational issues ruled out, the team turned their attention towards resident education, behaviour, and controls. TAF believed that human behavior and a lack of thermostat limits led to increased indoor temperatures and eroded savings. A comparison of interior temperatures of the baseboard and heat pump suites for the 2018-2019 heating season revealed a pattern of higher interior air temperatures for the heat pump suites, with average temperatures 1.4°C higher in heat pump units (Figure 6).

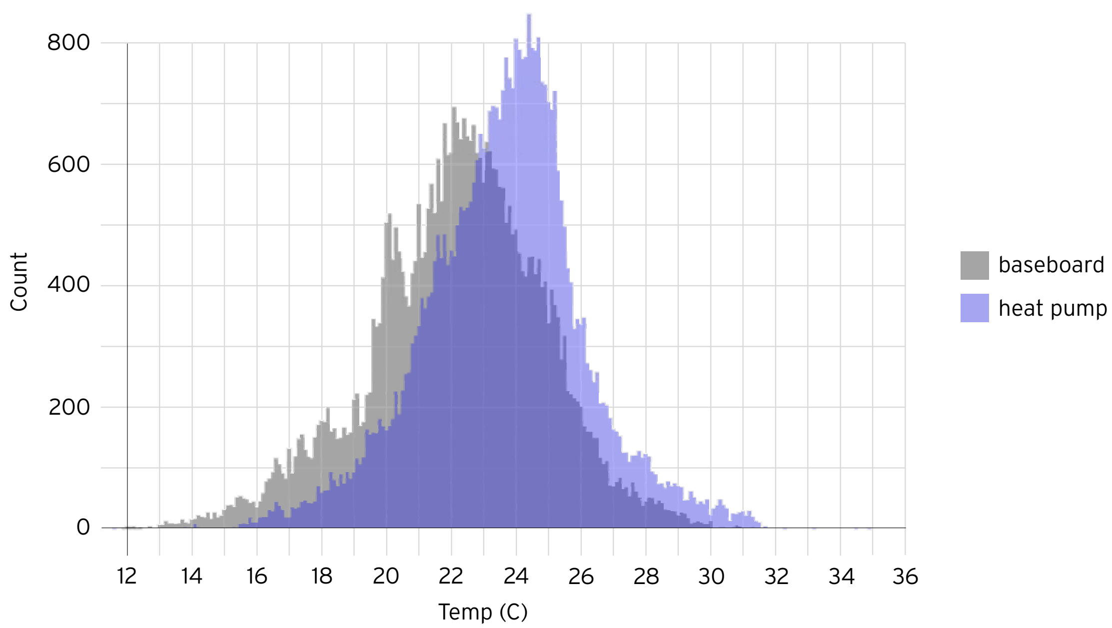

Figure 6: Histogram of average hourly interior temperatures of baseboard (grey) and heat pump (blue) units for the 2018/2019 heating season (September 15th 2018 – May 15th 2019) The heat pump units are maintaining higher temperatures on average.

There were three potential causes of these indoor temperature differences. The first of these was comfort. Moving from a radiant baseboard system to a low-temperature forced air system affects comfort in two key ways: it reduces mean radiant temperature (MRT) and increases airflow. One or both factors could result in residents maintaining higher interior air temperatures to feel as comfortable as they had with the pre-retrofit radiant systems. In addition, baseboards had been installed below windows to help mitigate comfort issues related to cold and drafty windows. With the baseboards disabled, the old single-pane windows may have an outsized impact on comfort, requiring residents to maintain higher interior temperatures to stay comfortable. Fortunately, the windows are scheduled to be replaced within the next two years as part of this step-wise retrofit.

Some residents also disclosed that they were afraid to use their electric baseboards because of the cost of electricity and fire concerns. It was possible that residents with heat pumps were simply heating their spaces more (and were more comfortable) once those concerns were alleviated.

The post-retrofit increase in interior temperatures may also be due to the so-called "rebound effect" associated with the installation of high-efficiency equipment. Prior to the retrofit, we informed residents about the efficiency of the new heat pumps and their potential for significant electricity and cost savings. This may have led to residents maintaining higher temperatures with the belief that it would not significantly impact their utility costs. Using the pre-retrofit data available, TAF examined pre-and-post retrofit interior temperatures of three of the heat pump suites as shown in Figure 7.

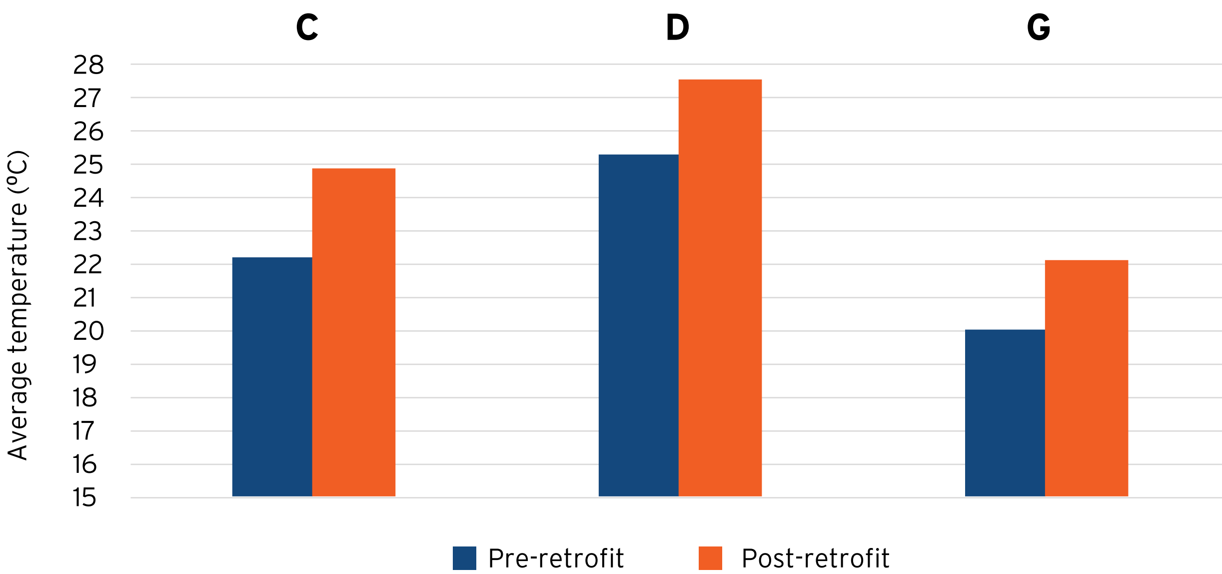

Figure 7: Pre-retrofit (November 2017 – January 2018) and post-retrofit (November 2018 – February 2019) average interior temperatures.

It was clear that not only were heat pump suites maintaining higher temperatures than their baseboard counterparts, they were also maintaining higher temperatures than they had been pre-retrofit. Whether this was due to residents adjusting to the new type of heating system or due to the rebound effect or both, maintaining increased interior temperatures was likely the reason that utility savings did not meet TAF's expectations.

In order to improve savings for the full roll out of this project, TAF and TCHC have developed improved user education materials and training. We updated the educational materials to highlight the relationship between temperature settings and expected savings, and suggested a heating range between 20°C to 22°C. Additional suggestions on how residents could operate their system to maximize both comfort and savings were included in the revised materials and training.

A key goal of the design phase of the full project was to identify improved controls that provided the ability to limit temperature settings; the design team specified wall mounted thermostats as opposed to remotes. These thermostats allowed the building owner to specify upper and lower limits and password-protect these settings. By introducing temperature limits, the project team hopes to maintain comfort as well as energy savings.

Lessons Learned

This pilot project was a first for TAF, and it allowed us to understand not only the opportunities and challenges of air source heat pumps in retrofits, but also the business case for deep energy retrofits in electrically heated buildings. The pilot project generated many important lessons for TAF and TCHC, which have been incorporated into the full roll-out of the retrofit at 66 Walpole as well as other future projects.

Key lessons from the pilot project include:

- **Cold climate air source heat pumps (CC-ASHPs) can supply 100 per cent of space heating needs.** Prior to the retrofit residents often complained about feeling too cold in their space. TAF's pilot project has shown that CC-ASHPs can provide and maintain comfortable indoor temperatures even when external temperatures dip as low as -25°C.
- **Access to cooling has valuable comfort and health benefits.** Prior to the retrofit, residents cited summer heat and humidity as two of their largest concerns. When switching to a heat pump system, residents not only have more efficient heating, but additional access to cooling and dehumidification as well. Access to cooling is becoming an increasingly important issue; implementing efficient cooling systems now will prepare buildings for the climate of the future.
- **It is important to commission and verify accuracy of all electrical monitoring equipment early in the project.** Ensure that all devices are properly configured and collecting correct data. Valuable data was lost early on in this pilot project due to incorrectly configured monitoring equipment.
- **It is important to tailor resident education to avoid rebound effect.** When presented with a new, more efficient system it is important to convey that savings are directly tied to appropriate temperature settings is important. Work with residents to advise them of how the new system may feel different (forced air versus radiant heat) and how it can be operated efficiently to save costs.
- **Controls with limits can enhance savings.** Another way to ensure appropriate temperatures are maintained is to invest in controls with password protected limits. This allows the building operator to ensure that adequate heat and cooling can be provided, within reason, and helps discourage the rebound effect.

The heat pump pilot demonstrated that the multi-split systems can maintain comfortable conditions through a cold Toronto winter. The pilot also underscored the heating efficiency of the new multi-split systems; TAF's analysis clearly showed that the heat pumps used significantly less energy than electric baseboards to provide the same interior temperatures. The lower than expected utility savings, although disappointing, can be attributed to temperature settings due to the rebound effect and/or residents' perceptions of comfort. TAF is confident that these issues will be addressed in the full retrofit through resident engagement and enhanced heat pump controls.

Appendix A: Pre-Retrofit Building Characteristics

Gross Floor Area	127,400 ft^2
Year Constructed	1987
Building Form	9 blocks, 3 stories typical
Cladding	EIFS and brick
Parking	Above grade
Number of suites	120; 29 1-bedroom suites, 74 2-bedroom suites, and 17 3-bedroom suites, a laundry room, superintendent office, and meeting room.
Occupancy Type	Townhouses are a mix of 1-bedroom, 2-bedroom and 3-bedroom suites, with shared laundry available on site. All suites are sub-metered for electricity.
Heating	Suites are heated by baseboard electric heaters, which are original to the building.
Cooling	Some residents have installed window or unitary A/C systems.
Ventilation	There is no centralized ventilation. Code-required unit ventilation is provided by local washroom exhaust fans.
Hot Water	Domestic Hot water is provided by electric hot water tanks located in each suite.

Appendix B: Metering Equipment

Equipment Manufacturer	Equipment Model	Location	Purpose	Data interval
Accuenergy	Acuvim IIR-M-333-P1	In-suite electrical panel	Energy data logger	15 mins
	AcuMesh-L-900	In-suite electrical panel	Mesh network transceiver	$6,400
	AcuLink 710	Office	Central data collection hub	$4,050
ONSET	HOBO MX 1101	Living room	Temperature and humidity data logger	15 mins

Appendix C: Survey Questions

Survey

1. How long have you lived in this unit? [Q1]

a) Less than 6 months [1]
b) 6 to 12 months [2]
c) 1 to 2 years [3]
d) More than 2 years [4]

2. How many people live full-time in this unit?

Young children (age 0-5) [Q2R1]	**Children** (age 6-12) [Q2R2]	**Teenagers** (age 13-17) [Q2R3]	**Adults** (age 18-64) [Q2R4]	**Seniors** (65+)[Q2R5]

**3. Are there any pets living in this unit?
If yes, what kind of animals and how many?**

Cats [0-10]	**Dogs** [0-10]	**Birds** [0-10]	**Aquarium** [0-10]	**Mammals** [0-10]	**Reptiles** [0-10]

4. How many people are likely to be in the unit during weekdays?

Time of day	**Young children** (age 0-5)	**Children** (age 6-12)	**Teenagers** (age 13-17)	**Adults** (age 18-64)	**Seniors** (65+)
Morning (8 am – 12pm) [Q4R1]					
Lunchtime (12pm – 1pm) [Q4R2]					
Afternoon (1pm – 5pm) [Q4R3]					

5. **Have you or anyone else who lives in your unit had any of the following symptoms during the <u>last three months</u>?**

	Yes, every few days	**Yes,** few times per month	**No,** never	**If Yes**, is this symptoms related to a pre-existing illness?		
	[1]	[2]	[3]	**Yes [1]**	**No [2]**	**Don't know [3]**
Fatigue, tiredness, exhaustion [R1]	☐	☐	☐	☐	☐	☐
Headache [R2]	☐	☐	☐	☐	☐	☐
Itching, burning, irritation of eyes [R3]	☐	☐	☐	☐	☐	☐
Irritated, stuffy or runny nose [R4]	☐	☐	☐	☐	☐	☐
Hoarseness, dry throat [R5]	☐	☐	☐	☐	☐	☐
Cough [R6]	☐	☐	☐	☐	☐	☐
Dry or flushed skin on the face [R7]	☐	☐	☐	☐	☐	☐

6. **How many times during the last three months have you or anyone else who lives in your unit missed work or school due to illness?**

☐ none [1] ☐ 1 to 2 [2] ☐ N/A - not currently
☐ 3 to 5 [3] ☐ 6 or more [4] ☐ attending work/school [5]

7. **How many times during the last three months have you or anyone else who lives in your unit visited the hospital, a doctor or a walk-in clinic due to illness?**

☐ none [1] ☐ 1 to 2 [2]
☐ 3 to 5 [3] ☐ 6 or more [4]

8. **Do you weather strip or take measures to reduce odour or drafts in any of the following areas:**

☐ Exterior door [1] ☐ Windows [2] ☐ Other: ________________ [3] ☐ No weather stripping [0]

9. **Do you allow smoking in your unit? (Check one)**

☐ No [0] ☐ Sometimes [1] ☐ Yes [2]

10. **Typically, what time period(s) during the day is the bathroom used for showering or bathing? [0/1]**

☐ Morning (5am - 12pm (noon)) [Q10R1] ☐ Afternoon (12pm (noon) - 5pm) [Q10R2]
☐ Evening (5pm - 10pm) [Q10R3] ☐ Overnight (10pm - 5am) [Q10R4]

*[For residents which currently have a heat pump in their unit make sure to clarify that Questions 11-15 are asking about conditions **BEFORE the installation of these heat pumps**.]*

11. This question is about how comfortable you are [were] in different rooms of your unit.

	In the **SUMMER** months				In the **WINTER** months			
	Too cold [1]	Just right [2]	Too warm [3]	Don't know [4]	Too cold [1]	Just right [2]	Too warm [3]	Don't know [4]
In the kitchen [Q11R1]	☐	☐	☐	☐	☐	☐	☐	☐
In the living room [Q11R2]	☐	☐	☐	☐	☐	☐	☐	☐
In the main bedroom [Q11R3]	☐	☐	☐	☐	☐	☐	☐	☐
In the bathroom [Q11R4]	☐	☐	☐	☐	☐	☐	☐	☐
In the hallways [Q11R5]	☐	☐	☐	☐	☐	☐	☐	☐

12. Are [Were] you bothered by any of the following in your unit?

	In the **SUMMER** months			In the **WINTER** months		
	Yes, every day [1]	Yes, once or twice a week [2]	No, never [3]	Yes, every day [1]	Yes, once or twice a week [2]	No, never [3]
Your own cooking smells spreading in the unit [Q12R1]	☐	☐	☐	☐	☐	☐
Cooking smells from neighbours [Q12R2]	☐	☐	☐	☐	☐	☐
Tobacco smoke or other smells from neighbours [Q12R3]	☐	☐	☐	☐	☐	☐
Smells from outside, such as car exhaust fumes, barbecue smoke, industrial exhaust [Q12R4]	☐	☐	☐	☐	☐	☐
Dry air [Q12R5]	☐	☐	☐	☐	☐	☐
Humid air or moisture related discomfort [Q12R6]	☐	☐	☐	☐	☐	☐
Difficulties in drying laundry/ damp towels in the bathroom [Q12R7]	☐	☐	☐	☐	☐	☐
Condensation on the inside of windows [Q12R8]	☐	☐	☐	☐	☐	☐

13. How often do [did] you use a...

	In the **SUMMER** months					In the **WINTER** months				
	Every day [1]	Once or twice a week [2]	Never [3]	Don't know [4]	Don't have one [5]	Every day [1]	Once or twice a week [2]	Never [3]	Don't know [4]	Don't have one [5]
Portable heater [Q13R1]	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Window air-conditioning unit [Q13R2]	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Portable fan [Q13R3]	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Humidifier/ dehumidifier [Q13R4]	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Air cleaner/filter [Q13R5]	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Air freshener [Q13R6]	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Candles, incense, burn scented oils [Q13R7]	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

14. How often do [did] you open the...

	In the **SUMMER** months				In the **WINTER** months			
	Every day [1]	Once or twice a week [2]	Never [3]	Don't know [4]	Every day [1]	Once or twice a week [2]	Never [3]	Don't know [4]
Windows [Q14R1]	☐	☐	☐	☐	☐	☐	☐	☐
Window blinds or shades [Q14R2]	☐	☐	☐	☐	☐	☐	☐	☐
Front or back exterior doors [Q14R3]	☐	☐	☐	☐	☐	☐	☐	☐

15. Do [Did] you experience drafts or air flows in the...

	NO draft or air flow [0/1]	Draft or air flow at the:			
		Vents [0/1]	Windows [0/1]	Doors [0/1]	Don't know [0/1]
Kitchen [Q15R1]	☐	☐	☐	☐	☐
Living room [Q15R2]	☐	☐	☐	☐	☐
Main bedroom [Q15R3]	☐	☐	☐	☐	☐
Bathroom [Q15R4]	☐	☐	☐	☐	☐
Hallways [Q15R5]	☐	☐	☐	☐	☐

[Next question is ***ONLY*** *for residents which* ***DO NOT*** *have a heat pump. For residents with heat pumps, go directly to 'Heat Pump Related Questions' below].*

16. Do you have anything else to add concerning your unit or its indoor climate? *[Freeform response]*

Heat Pump Related Questions

The following questions are related to the heat pumps installed in your unit.

17. Overall, how does your heat pump compare to your old heating system?

☐ Worse [1] Ð ☐ About the same [2] Ð ☐ Somewhat better [3] Ð ☐ Significantly better [4]

☐ Not sure [5]

17o. Do you have any additional comments? *[Interviewer note down free form answers.]*

18. Currently, how easy is it to control your heat pump unit in HEATING mode?

☐ Difficult [1] ☐ Somewhat difficult [2] ☐ Somewhat easy [3] ☐ Very easy [4] ☐ Not sure [5]

19. Since you've started using your heat pump in HEATING mode, have you found it [check applicable answer]:

☐ Easier to use over time [1] ☐ No change in ease of use over time [2]

☐ More difficult to use over time [3] ☐ Other [4]

18o. [note down response]

20. Currently, how easy is it to control your heat pump unit in COOLING mode?

☐ Difficult [1] ☐ Somewhat difficult [2] ☐ Somewhat easy [3] ☐ Very easy [4] ☐ Not sure [5]

21. Since you've started using your heat pump in COOLING mode, have you found it [check applicable answer]:

☐ Easier to use over time [1] ☐ No change in ease of use over time [2]

☐ More difficult to use over time [3] ☐ Other [4]

21o. *[note down response]*

22. How easy is it to switch your heat pump between heating and cooling modes?

☐ Difficult [1] ☐ Somewhat difficult [2] ☐ Somewhat easy [3] ☐ Very easy [4] ☐ Not sure [5]

*[The following questions are asking about conditions **AFTER the installation of these heat pumps**]*

23. This question is about how comfortable you are in different rooms of your unit.

	In the **SUMMER** months				In the **WINTER** months			
	Too cold [1]	Just right [2]	Too warm [3]	Don't know [4]	Too cold [1]	Just right [2]	Too warm [3]	Don't know [4]
In the kitchen [Q23R1]	☐	☐	☐	☐	☐	☐	☐	☐
In the living room [Q23R2]	☐	☐	☐	☐	☐	☐	☐	☐
In the main bedroom [Q23R3]	☐	☐	☐	☐	☐	☐	☐	☐
In the bathroom [Q23R4]	☐	☐	☐	☐	☐	☐	☐	☐
In the hallways [Q23R5]	☐	☐	☐	☐	☐	☐	☐	☐

24. Are you bothered by any of the following in your unit?

	In the **SUMMER** months			In the **WINTER** months		
	Yes, every day [1]	Yes, once or twice a week [2]	No, never [3]	Yes, every day [1]	Yes, once or twice a week [2]	No, never [3]
Your own cooking smells spreading in the unit [Q24R1]	☐	☐	☐	☐	☐	☐
Cooking smells from neighbours [Q24R2]	☐	☐	☐	☐	☐	☐
Tobacco smoke or other smells from neighbours [Q24R3]	☐	☐	☐	☐	☐	☐
Smells from outside, such as car exhaust fumes, barbecue smoke, industrial exhaust [Q24R4]	☐	☐	☐	☐	☐	☐
Dry air [Q24R5]	☐	☐	☐	☐	☐	☐
Humid air or moisture related discomfort [Q24R6]	☐	☐	☐	☐	☐	☐
Difficulties in drying laundry/ damp towels in the bathroom [Q24R7]	☐	☐	☐	☐	☐	☐
Condensation on the inside of windows [Q24R8]	☐	☐	☐	☐	☐	☐

25. How often do you use a...

	In the **SUMMER** months					In the **WINTER** months				
	Every day [1]	Once or twice a week [2]	Never [3]	Don't know [4]	Don't have one [5]	Every day [1]	Once or twice a week [2]	Never [3]	Don't know [4]	Don't have one [5]
Portable heater [Q25R1]	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Window air-conditioning unit [Q25R2]	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Portable fan [Q25R3]	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Humidifier/ dehumidifier [Q25R4]	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Air cleaner/filter [Q25R5]	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Air freshener [Q25R6]	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Candles, incense, burn scented oils [Q25R7]	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

26. How often do you open the...

	In the **SUMMER** months				In the **WINTER** months			
	Every day [1]	Once or twice a week [2]	Never [3]	Don't know [4]	Every day [1]	Once or twice a week [2]	Never [3]	Don't know [4]
Windows [Q26R1]	☐	☐	☐	☐	☐	☐	☐	☐
Window blinds or shades [Q26R2]	☐	☐	☐	☐	☐	☐	☐	☐
Front or back exterior doors [Q26R3]	☐	☐	☐	☐	☐	☐	☐	☐

27. Do you experience drafts or air flows in the…

	NO draft or air flow [0/1]	Draft or air flow at the:			
		Vents [0/1]	Windows [0/1]	Doors [0/1]	Don't know [0/1]
Kitchen [Q27R1]	☐	☐	☐	☐	☐
Living room [Q27R2]	☐	☐	☐	☐	☐
Main bedroom [Q27R3]	☐	☐	☐	☐	☐
Bathroom [Q27R4]	☐	☐	☐	☐	☐
Hallways [Q27R5]	☐	☐	☐	☐	☐

28. Do you have anything else to add concerning your experience with the heat pump?

References

[1] Toronto Municipal Code Chapter 629, Property Standards, City of Toronto, https://www.toronto.ca/legdocs/municode/1184_629.pdf

[2] Toronto and Region Conservation Authority (TRCA), "Assessment of Multi-split Ductless Air-source Heat Pump Retrofits in an Ontario Rowhouse: Heating and Cooling", January 2019, https://sustainabletechnologies.ca/home/heating-and-cooling/air-source-heat-pumps/mini-split-ashps-alternative-electric-heating-multi-unit-residential-buildings/

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