The Atmospheric Fund

Retrofitting Trethewey Tedder Apartments

A TOWERWISE 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) and the Province of Ontario (2016).

Visit taf.ca for more information

THE ATMOSPHERIC FUND

75 Elizabeth Street
Toronto, ON M5G 1P4

Acknowledgments

The phase of TowerWise which included the Trethewey Tedder Apartments retrofit work described in this report was made possible by financial contributions from the Federation of Canadian Municipalities, Toronto Community Housing Corporation, Enbridge Gas Distribution, Union Gas Limited and ecobee.

FCM Federation of Canadian Municipalities / Fédération canadienne des municipalités

Toronto Community Housing

Enbridge Life Takes Energy™

uniongas An Enbridge Company

ecobee

The views expressed here are those of The Atmospheric Fund and do not necessarily reflect the views of the City of Toronto, the Province of Ontario, or any of our project funders or partners.

Ontario

Toronto

Executive Summary

Through the TowerWise program, The Atmospheric Fund accelerates retrofits targeting significant energy and carbon emission reductions across the multi-unit residential building sector. From 2015-2018, TAF partnered with Toronto Community Housing Corporation to undertake retrofits in seven buildings on three sites ('the portfolio'). This case study looks at one of those sites, Trethewey Tedder Apartments, comprised of two 1970s-era highrise buildings with a joint total of 369 apartments.

Energy efficiency retrofits at Trethewey Tedder Apartments were financed through an Energy Savings Performance Agreement (ESPA™), an innovative non-debt financing instrument created by TAF to support retrofits.

Using an integrated design and project delivery process, the project team developed a package of measures. These measures aim to achieve major reductions in utility costs and carbon emissions, while enhancing resident comfort and wellbeing.

The results demonstrate that energy retrofits can provide a compelling return on investment while enhancing comfort, reducing environmental impacts, and generating green jobs.

The retrofit conservation measures targeted all resource types:

Gas

- New condensing boilers
- Recommissioned boilers
- In-suite smart thermostats
- New air handling units and duct cleaning

Electricity

- LED lighting retrofit (interior, exterior, garage)
- Occupancy sensors
- Variable frequency drives on heating pumps

Water

- Ultra-low flow 3L toilets

Key outcomes at Trethewey Tedder Apartments

- **Higher than projected cost savings**
- **Higher than projected emissions reductions**
- **Overheating in shoulder seasons decreased by 22 per cent**

Key recommendation

Undertake regular maintenance, as it increases savings. Maintenance helps improve system performance, which lowers utility costs and can extend the life of the system.

Content

Trethewey Tedder Apartments Retrofit

TAF and Toronto Community Housing partner in multi-site retrofit project

Under the TowerWise program, The Atmospheric Fund (TAF) and Toronto Community Housing Corporation (TCH) partnered to undertake a series of building retrofits in seven multi-unit residential buildings (MURBs) situated across three sites. The buildings chosen represent common MURB archetypes (ranging from 4-19 storeys in height) with typical central heating, hot water, and ventilation systems. Similar to many other MURBs of this vintage, these buildings experienced a number of operational challenges like poor thermal control, under-ventilation, and high energy consumption.

This case study focuses on two of the seven TCH buildings that were retrofitted, the Trethewey Tedder Apartments located at 710 and 720 Trethewey Drive. TAF retrofitted the two towers between 2015 and 2018 in order to improve the site's utility performance and indoor environmental quality (IEQ), reduce carbon emissions, and bring down future maintenance and operating costs.

Spotlight on local job creation

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

buildingup.ca

Constructed in 1974, 710 Trethewey is 19 storeys and contains 165 apartments while 720 Trethewey is 18 storeys and contains 204 apartments. Both buildings contain one-, two- and three-bedroom apartments and primarily house families.

Trethewey Tedder Apartments: highrise residential, separate heating plants

The two buildings are concrete construction with original brick cladding. The windows are aluminum frame with single panes, with a mix of operable (horizontal slider) and inoperable windows.

Each building is serviced by a separate heating plant, and residents did not have individual control over temperatures in their apartment. 710 Trethewey's heating plant had been retrofitted within the last five years. Two 1 MMBTU/h boilers and one 2 MMBTU/h boiler had been installed, with two 2 hp pumps that supply the heating water to the building's hydronic baseboards. Two 1.5 MMBTU/h boilers supply domestic hot water (DHW), through heat exchangers located in the penthouse and basement. These boilers remain post-retrofit, but have been recommissioned. At 720 Trethewey there were four 2 MMBTU/h boilers, installed in parallel. These boilers supplied both the hot water for the hydronic baseboards, as well as the DHW (through heat exchangers in the penthouse and basement) via two 5 hp pumps. These original boilers were about 12 years old.

Make-up air units (MAUs) equipped with variable frequency drives (VFDs) on the fan motors supplied 100 per cent fresh air to the units via a pressurized corridor system. 710 Trethewey was supplied by two 16,780 CFM units and 720 Trethewey was supplied by one 16,780 CFM unit. Through a pre-retrofit ventilation survey the project team determined that the ventilation system was operating well below its maximum efficiency.

The building does not have any central cooling, but TAF estimates that approximately 76 per cent of residents have purchased either window-mounted or externally ducted portable units.

Common area lighting consisted of T8 fixtures (typically 1x32W), and the underground parking garage was lit by 100W HPS fixtures. Moreover, a number of parking garage fixtures were burnt out, leaving some areas inadequately lit.

For a complete pre-retrofit building summary, see Appendix B.

Energy and IEQ challenges needed to be addressed

To help inform the design process and prioritize specific measures, TAF undertook a comprehensive pre-retrofit monitoring program. This included measuring the performance of the existing boilers as well as undertaking an IEQ monitoring program. We monitored seven per cent of units at 710 Trethewey and five per cent of units at 720 Trethewey, and surveyed 16 per cent of the residents before and after the retrofits.

Overheating during the winter and shoulder seasons (spring and fall) was a significant source of discomfort pre-retrofit, with interior temperatures over 26°C nearly 70 per cent of the time. Between eight and 17 per cent of residents reported their apartments were too hot in the winter, and 85 per cent reported opening windows during the winter. This is a common challenge for buildings of this type, as stack effect creates a temperature differential between the lower and upper floors that is difficult to compensate for.

Pre-retrofit site EUI:

301.7 ekWh/m²

PORTFOLIO-WIDE GOALS

- **30%** **reduction** of carbon emissions
- **20%** **savings** in utility costs
- **Improve indoor environmental quality**
- **Minimize maintenance and operating costs**
- **Address capital renewal and deferred maintenance**

TIMELINE

December 2014
ESPA signed with TCH

February 2015
Pre-retrofit IEQ monitoring and surveys

July 2015
Start of integrated project delivery

December 2016
RCM installations substantially completed

January-February 2017
Start-up commissioning and initial optimization

March 2017
Start of ESPA performance period

February 2018
Post-retrofit IEQ monitoring ends and surveys undertaken

February 2027
End of ESPA performance period

Energy and Water Conservation Measures

Project approach: integrated project delivery

This retrofit project was implemented using an integrated project delivery (IPD) approach. IPD is an innovative approach that facilitates deep collaboration and partnership between key project stakeholders through all project phases, from preliminary design through to commissioning and performance monitoring. The key project partners were TAF, TCH, and Ecosystem; the latter was jointly selected as a project delivery partner by TAF and TCH through a competitive procurement process.

TAF The Atmospheric Fund   Toronto Community Housing   ecosystem

Multiple resource conservation measures undertaken

TAF, TCH, and Ecosystem worked together to determine which resource conservation measures (RCMs) would meet the ambitious project goals. The retrofit approach focused on grouping shorter and longer payback measures that target resource consumption or improve the indoor environment, while simultaneously addressing capital renewal or replacement.

After a thorough evaluation of the possible RCMs and a number of design charrettes, the following measures were implemented:

- Two boilers at 720 Trethewey were replaced with two modulating condensing boilers; all existing boilers were recommissioned
- The lights in corridors, stairwells, the lobby, and mechanical rooms were replaced with LED lamps; motion-sensor LED lighting retrofits were undertaken in garbage rooms and underground parking area
- In-suite smart thermostats and radiator control valves were installed to address overheating concerns
- 6L toilets were replaced with 3L flapperless models
- All MAUs were replaced, and flexible seals and fire dampers were replaced or reset. VFDs were introduced
- Heating network VFDs were introduced
- Radiator reflector panels were installed and radiators were cleaned

Not all RCMs considered by the project team were implemented. A list of those measures considered but ultimately not included can be found in Table 1. Most of these RCMs did not provide sufficient cost savings to justify their capital expense.

RCM	Reason for Exclusion
Micro CHP	Budgetary considerations and difficulty adding many emergency power connections to units
Building envelope repairs and window replacement	High capital cost measure, disruption to residents
Refrigerator replacement	Evaluation of existing Energy Star certified refrigerators revealed good performance that did not merit replacement
Washing machine replacement	Existing machines are rented
Low-emissivity coating on windows	Significant expense that could not be justified given the state of the existing windows
Solar DHW pre-heat	Payback on this RCM was greater than 30 years

Table 1: RCMs evaluated but not installed

As part of TCH's capital renewal priorities, the following supplemental measures were implemented:

- A hot water mixing valve was installed to ensure that water delivered to the faucets is below 49°C
- The existing supply and exhaust ductwork was cleaned
- Heating valve bypass was introduced
- A preventative maintenance program was established for boilers and MAUs during first year post-retrofit
- A CHP feasibility study was conducted to determine opportunities to implement this technology

Comprehensive monitoring

In support of TAF's broader research and demonstration objectives, as well as to support retrofit design, the project team undertook a comprehensive monitoring program that went well beyond typical measurement and verification (M&V). This included instrumentation of heating and hot water systems as well as an IEQ monitoring program, both of which captured a year of pre-retrofit data in addition to post-retrofit outcomes. The IEQ element included air quality and thermal comfort monitoring in five per cent of apartments, testing of the ventilation system, and surveying approximately 16 per cent of the residents before and after the retrofits.

Project financials

Construction costs, incentives, and projected utility cost savings from the RCMs are shown in Table 2. For a detailed breakdown of RCM construction costs and expected savings, see Appendices C and D. Appendix E provides a summary of equipment details.

Approximately 359 tCO_2eq of emissions[ii] reductions were expected annually, which is a 20 per cent reduction over the site's pre-retrofit annual emissions. Projected cost savings and carbon emission reductions from TAF-funded RCMs can be seen in Figure 1. The circle size reflects the full capital cost including design, equipment, installation, and commissioning. This project implemented a variety of measures with a range in paybacks resulting in maximizing utility cost and carbon emission reductions. Note that the carbon emission savings of the lighting retrofits are somewhat limited by the increase in gas heating energy consumption due to using fixtures that generate very little heat. The lighting retrofits also account for the greatest annual cost savings. In contrast, the new condensing boilers have similar capital costs to the lighting retrofit, but have a smaller impact on utility cost savings and the most significant impact on emission reductions.

Project Financials	Value
Total project cost[i]	$1,638,745
Total incentives	$103,861
Net cost	$1,534,884
Projected annual cost savings	$190,083

Table 2: Project financials

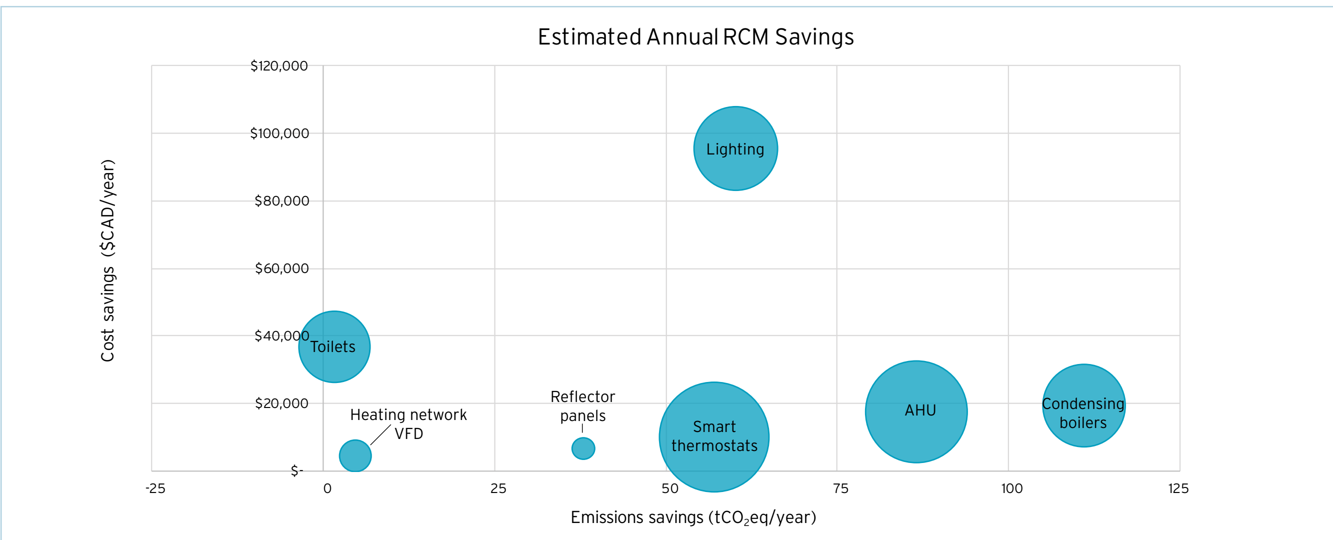


Figure 1. Estimated annual cost savings and emission reductions for each RCM implemented

Project financing: ESPA™

TAF financed the project through an Energy Savings Performance Agreement (ESPA™). This is a non-debt agreement where energy savings are used to cover the retrofit capital costs (the structure of the ESPA™ is illustrated in Appendix A).

[i] Includes TCH's contribution of $120,596 towards capital renewal and deferred maintenance work. Also includes the cost for radiator cleaning.

[ii] Equivalent to the emissions from 38.7 average-sized homes over the course of a year.

Energy and IEQ Monitoring

In addition to utility data monitoring post-retrofit, TAF and the project team designed and installed monitoring systems that would provide one-minute intervals of data for the condensing boilers' operation as well as 15-minute intervals for electricity consumption of the MAUs and pumps. Table 3 summarizes key metering points at the site. Appendix F shows a list of the specific equipment used.

Metering Point	Resource Metered	Interval
Whole building	Natural gas, electricity, water	Daily
Condensing boilers	Natural gas	1-Minute
Condensing boiler supply / return	Temperature	1-Minute
Condensing boiler return	Water flow	1-Minute
DHW and heating pumps	Electricity	15-Minute
Heat exchanger supply / return	Temperature	1-Minute
Heat exchanger return	Water flow	1-Minute
Colder water VFD pump	Electricity	15-Minute
MAUs	Electricity	15-Minute

Table 3: Trethewey Tedder Apartments metering points

IEQ monitoring was undertaken in seven per cent of units at 710 Trethewey, and five per cent of units at 720 Trethewey. Table 4 summarizes IEQ monitoring parameters. Appendix G shows a list of the specific monitoring equipment used.

Metering Point	Resource Metered	Interval
Individual apartments	Temperature, mean radiant temperature, relative humidity, carbon dioxide	15-Minute
Rooftop CO_2 sensor	Exterior carbon dioxide	15-Minute
Rooftop weather station	Temperature, relative humidity	1-Minute

Table 4: Trethewey Tedder IEQ-related metering points

Project Energy, Water, and Carbon Emission Performance

This section details the energy and carbon emissions performance of the RCMs during the first full year of operation, March 2017-February 2018. Performance is described in two parts: total (building-wide) savings and individual measure performance.

Figure 2 shows the projected cost savings and carbon emission reductions by utility and highlights the contrast between utility price and potential for emissions reduction. A look at the projected emission reductions and cost savings by resource reveals that while water savings can result in substantial cost savings, the emission reductions are minimal. In contrast, the majority of the project's emission reductions come from reducing natural gas consumption, which provides a relatively small amount of cost savings due to low natural gas prices. This underscores the importance of comprehensive multi-measure retrofits where the measures combine to reduce both costs and emissions.

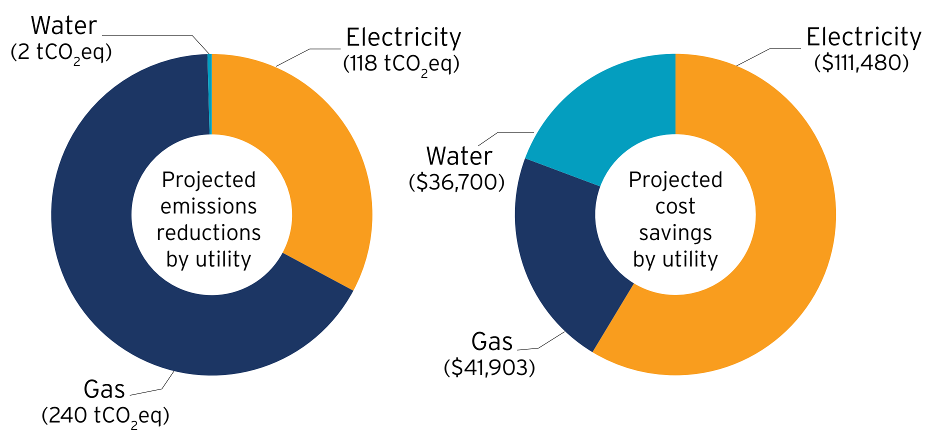


Figure 2: Projected emissions reductions and cost savings, by utility, for the first year of post-retrofit operation at this site. See Appendix D for emissions factors.

TOTAL RESOURCE SAVINGS

First-year cost savings exceeded predictions across all three utilities: electricity, natural gas, and water. In terms of utility costs, the project saved $242,997 over the course of the first year, exceeding the predicted cost savings by 28 per cent. The project also reduced carbon emissions by 429 tCO_2eq within the first year, a 24 per cent reduction of the site's annual emissions. This exceeds the original projections of 359 tCO_2eq and site goal of 20 per cent reduction in emissions.[iii]

[iii] Note that the portfolio-wide emissions reduction goal for the project was 30 per cent, with a 20 per cent reduction goal for each of the three sites in the portfolio.

Electricity

Electricity savings were slightly above projections, with site wide consumption reduced by 800,985 kWh, or 24 per cent. The better-than-expected savings can be attributed to the introduction of heating network VFDs, which reduced pumping energy needed during off-peak times. Also, upgrading to highly efficient MAUs with VFDs allowed the team to schedule the fan use based on a targeted occupancy schedule. Duct cleaning may have also played a part in the MAUs outperforming their original targets. **Electricity measures reduced emissions by 127 tCO_2eq in the first year.**

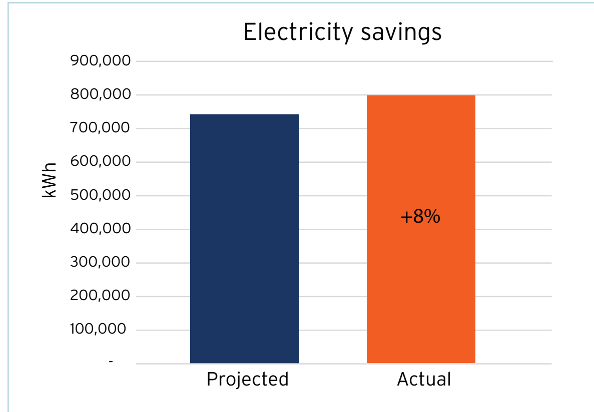


Figure 3: Projected and actual electricity savings

Natural Gas

The introduction of natural gas-related RCMs resulted in significant gas savings of 157,446 m^3, exceeding projections by 25 per cent. These savings represent a 24 per cent reduction of the site's annual gas consumption. During the summer months when hot water is only needed for the DHW system, the efficient condensing boilers are able to satisfy demand on their own, leading to year-round gas savings. During the shoulder seasons when outdoor temperatures may be warm but space heating is still needed, the heating system is optimized to run only one condensing boiler which results in further savings. **In total, gas measures provided 299 tCO_2eq of emissions reductions in the first year of post-retrofit operation.**

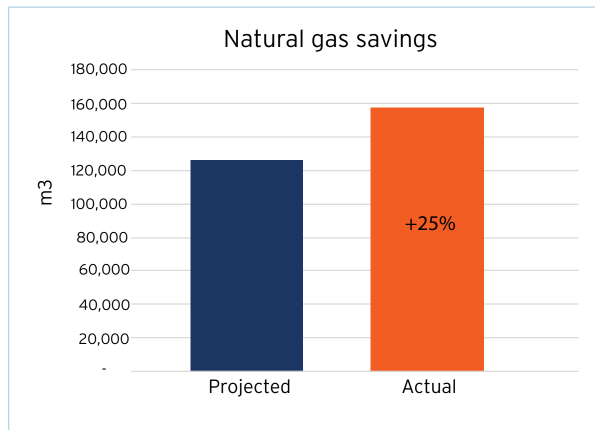


Figure 4: Projected and actual gas savings

Water

Within the first year 18,767 m^3 of water was saved, an 80 per cent increase over projected savings and 20 per cent of the site's annual water usage. The project team assumed that 7.5 per cent of the original toilets were leaking or running continuously at a rate of 0.1 gallons per minute, and reductions in post-retrofit nighttime water consumption confirm that leaks were an issue. Actual water savings suggest that the leakage rate was significantly higher than originally estimated.

The new toilets have performed well and save three litres of water with each flush. In addition, their flapperless design will prevent the type of leakage seen in the old pre-retrofit toilets. **Although water measures represent the highest cost savings, the related emissions reductions were quite low, at 2.8 tCO_2eq in the first post-retrofit year.**

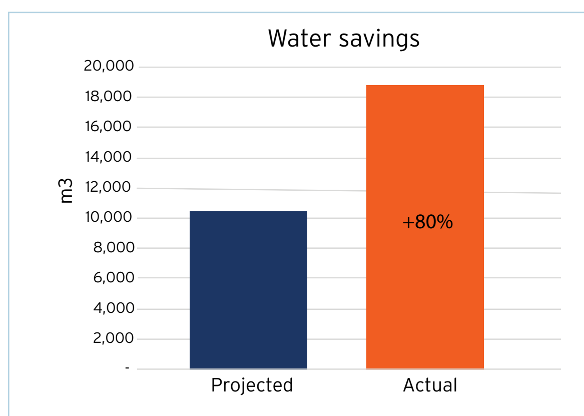


Figure 5: Projected and actual water savings

INDIVIDUAL MEASURE PERFORMANCE

Condensing Boilers

At 720 Trethewey Drive, two of the existing boilers were removed and replaced with two Viessmann Vitocrossal 200 CM2-400 condensing boilers that work together to provide all DHW and most of the space heating load for the building. One of the boilers satisfies DHW demand year round and provides additional heat to support the second boiler, which is dedicated to space heating, when DHW demand is low (like at night). Two of the original boilers remain for periods of extreme cold and to provide redundancy.

In addition to the installation of the new boilers at 720 Trethewey, all boilers retained within the two buildings including the newer existing boilers at 710 Trethewey Drive were recommissioned. This included adjusting the temperature curves in the boiler room, reducing the temperatures required at warmer outdoor temperatures so that only the necessary amount of heat is supplied to the building. This tuning cannot be done all at once, but instead should happen gradually after the initial installation period has finished, so as to prevent a shock to the residents. At 720 Trethewey one of the boilers was set as a dedicated DHW boiler so that the other boilers could be shut off when it was no longer heating season. And at 710 Trethewey the DHW boiler temperatures were reduced.

Furthermore, the controls across the two buildings were optimized. The control system was sequenced so that the condensing boilers received the coldest water first, increasing the time they spent in condensing mode. The boilers at 720 were sequenced to minimize the time that the system would be relying on the remaining inefficient boilers.

Smart Thermostats and Control Valves

The combination of oversized boilers with little ability to modulate and no in-suite temperature controls resulted in excessive overheating during the winter and shoulder seasons. In order to address the overheating issue while saving energy and providing residents with greater control of their indoor environment, the project team installed ecobee3 smart thermostats and radiator control valves in each apartment. Additional temperature sensors were also installed in each bedroom, which helped to even out temperatures across the apartment. The control valves were installed in-line with the radiators and include a two-position actuator controlled by a signal from the thermostats. When the thermostat setpoint is reached, the control valves shut down flow through the radiators. Residents are able to change the setpoint as desired, up to a maximum of 24°C, which was programmed into the thermostats; and can use features such as scheduling to reduce setpoints while away. Residents could also use an app on their smartphone to control system settings remotely.

TAF estimates that the smart thermostats saved 8.8 per cent of the natural gas normally used for heating over the course of a year. Monthly thermostat savings percentages over a full heating season can be seen in Figure 6. Note that it is difficult to allocate savings contributions between the smart thermostats and the heating plant upgrades, as the measures interact and work together to generate savings. TAF estimated thermostat savings by modelling the amount of energy saved with just the introduction of in-suite controls that limit temperatures to 24°C — this represents the maximum amount of heating energy savings that could be attributed to the thermostats.

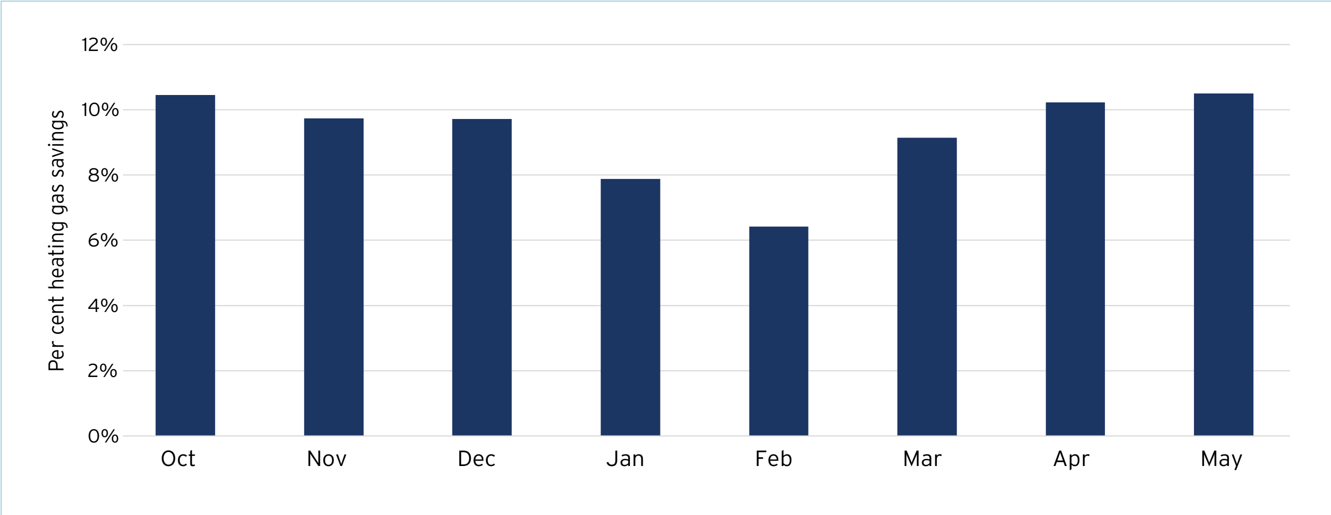


Figure 6: Modelled smart thermostat heating season gas savings

The thermostats contributed greatly to improved thermal comfort for residents. Overheating, which TAF defines as time spent above 26°C, is common in buildings like the Trethewey Tedder Apartments. In-suite monitoring of 23 units revealed average pre-retrofit indoor air temperatures of 27°C in the shoulder seasons, and the units maintained temperatures above 26°C 66 per cent of the time. Not only did these high temperatures result in discomfort, they also led to significant wasted energy, as 85 per cent of residents reported opening their windows in winter. Overheating decreased by 22 per cent post-retrofit, and winter window opening decreased by 20 per cent.

The residents of the Trethewey Tedder Apartments were pleased with the ecobee3 smart thermostats. During TAF's post-retrofit survey, 62 per cent of residents interviewed at the two buildings indicated they are either "satisfied" or "very satisfied" with these new in-suite controls. It is also important to note that the success of this measure relied on residents knowing how to use the thermostats. While technological uptake at the site was straightforward, there can be challenges when introducing new technology. Fortunately, with adequate resident engagement, these challenges can be overcome.

Make-Up Air Units

720 Trethewey's fresh air was supplied by a 100 per cent fresh air MAU located on the roof, and a pressurized corridor ventilation system. 710 Trethewey was ventilated in the same manner but with two MAUs instead of one. Exhaust air is returned outdoors through bathroom fans in each suite, which vent directly through the exterior wall.

Pre-retrofit ventilation analysis revealed that fresh air supply at the site was being provided at 50 per cent below ASHRAE 62.1 requirements. This was largely due to one of the rooftop units at 710 Trethewey not operating for an unknown amount of time prior to the retrofit project.

All three MAUs have been replaced and connected to VFDs. The VFDs control the fan speeds of the MAUs in order to deliver the appropriate volume of air based on a set occupancy schedule. Supply air will be at 100 per cent during times of high occupancy and high activity, such as the evening when tenants are at home cooking. During periods of low occupancy, fan speeds decrease to reduce energy consumption while still meeting ventilation requirements. Although the previous MAUs were also equipped with VFDs, they were previously not programmed with a schedule, leading to the units running at 100 per cent at all times.

Lighting

In both buildings, the 1x32W T8 wrap fixtures in the corridors, lobby, and stairs were retrofitted with LED tubes. These LED lamps were designed to match the lumen output of the existing lamps so that light levels were maintained. Motions sensors were also installed in garbage rooms to minimize energy when not occupied. Exterior lighting, including fixtures mounted on the building, on poles, or within canopies were also replaced with LED equivalents with increased uniformity to provide a brighter, safer space.

The parking garage was originally fitted with 100W HPS fixtures, many with cracked or burnt-out lenses. These were replaced with new LED lamps and vapour-tight fixtures to reduce the effects of aging on the product. Three out of every four fixtures were fitted with motion sensors to further reduce energy consumption while still ensuring visibility and safety. This portion of the RCM almost didn't go ahead as initial projections did not show a strong business case. But in the end, post-retrofit analysis revealed a simple payback of only 1.2 years. In total, 285 occupancy sensors were installed, saving approximately $9,705 per year.

This RCM had a number of benefits, including significant reductions in electricity consumption and utility costs, as well as improved IEQ through improved lighting quality. The new fixtures have a higher colour temperature and colour rendering index, adding to the perceived sense of brightness and ability to accurately see colour. Maintenance is also reduced as the new lamps have a 15-year life expectancy.

LED fixtures use energy far more efficiently than their fluorescent predecessors and generate far less heat as a result. The project team had to account for this small reduction in internal gains when estimating natural gas savings, resulting in a 26,354 m^3 increase in gas use.

Ultra-Low Flow Toilets

The project team proposed replacing the original 6L (six liter per flush) toilets with Hennessy & Hinchcliffe's Proficiency ultra-low flow 3L/flush toilets. In order to test for pressure and plugging issues, the team installed 30 new toilets across both buildings as a pilot. The pilot ran successfully for 2-3 months. As no major issues were revealed, the team was comfortable that the new toilets would perform well at the site and replaced the original 6L toilets in all units, along with several seized shut-off valves.

20%

reduction in site water use

The ultra-low flow toilets provide water savings in multiple ways. Not only was flushing water consumption halved based on the toilet specifications, but many of the original toilets wasted water through leaks and running issues. The toilet replacement also saved electricity by reducing the amount of energy used by the domestic cold water pumps.

Duct Cleaning

As mentioned, a pre-retrofit ventilation analysis revealed that ventilation systems at the two buildings were operating well below maximum efficiency. These issues were already set to be taken care of by TCH outside the scope of this retrofit project. TCH replaced the MAU and performed duct cleaning of both the main hallway ducts and the smaller ducts which serve as the exhaust for each apartment.

The benefits of preventative maintenance such as duct cleaning are often overlooked; however, this can both reduce wasted energy and improve resident health and comfort. TAF recommends incorporating duct cleaning into a building's regular maintenance plan.

Radiator Reflector Panels and Cleaning

At the Trethewey Tedder Apartments the hydronic baseboard radiators that provide heat to the units are located in the kitchen, living room, and each bedroom – against the exterior walls, just below the windows. The installation of heat-reflecting aluminum coated plastic panels between the radiators and walls helped to prevent radiation heat loss through the exterior envelope. The panels are expected to last for the life of the radiator.

The impacts of radiator cleaning associated with this measure are not to be overlooked. Years of accumulated dust buildup reduced the heat exchange surface of the radiators, thus degrading the efficiency of the radiators. The cleaning helped improve radiator performance, allowing heat to enter the space more easily and respond more quickly to changes in outdoor temperatures. Overall, this measure contributed to a significant portion of the projected gas savings at the two buildings.

Space Heating Circulation Pumps

The project team installed VFDs on one of the existing heating pumps at 720 Trethewey, and on the two new heating pumps installed at 710 Trethewey. These pumps help modulate and reduce the flow of the heating network during times of lower demand, thus reducing the amount of electricity used by the motors. Using the outdoor temperature, they are able to determine the right time to ramp down the system. The VFDs also created lower return water temperatures for the condensing boilers, allowing them to operate in condensing mode more often.

In addition to increased pumping efficiency, introducing VFDs was necessary with the installation of in-suite smart thermostats. The newly installed in-suite radiator valves close off the flow of water when suites reach their set temperature, thus increasing system pressure. Without VFDs on the pumps, the system could not adjust to these varying pressure changes and could result in leaks.

In the first year of operation, heating pump VFDs saved 27,270 kWh, slightly below their projected savings of 29,618 kWh.

Financial Performance

Actual savings performance in the first year of post-retrofit operations exceeded projections by 28 per cent, largely due to the higher than projected water and gas savings. Actual savings were $242,997, exceeding projected cost savings by $52,914. Savings targets were exceeded in all three resources: electricity savings exceeded projections by 8 per cent, gas savings exceeded projections by 25 per cent, and water savings exceeded projections by 80 per cent.

Table 5 highlights the financial performance of the Trethewey Tedder Apartments and the larger project portfolio, consisting of three different sites.

Financial Category	Trethewey Tedder Apartments		Portfolio (all three sites)[iv]	
	Original Projection	Actual Performance	Original Projection	Actual Performance
Year 1 savings	$190,083	$242,997	$417,707	$501,990
Net present value (NPV)[v]	$1,989,540	$2,847,367	$5,021,603	$6,830,223
Internal rate of return (IRR)	14.2%	18.3%	12.4%	14.9%
IRR (10 year)	7.1%	12.5%	3.5%	7.2%
Simple payback (years)	8	6.2	9.4	7.9
Return on investment (ROI)[vi]	263%	364%	286%	364%

Table 5: Site and portfolio financial performance[vii, viii]

iv The three TCH sites that make up the portfolio are Arleta Manor, R.J. Smith Apartments and Trethewey Tedder Apartments.

v Discount rate of 4%, utility cost inflation rate of 3%.

vi Based on average project lifetime.

vii Excludes TCH's contribution of $120,596 towards capital renewal and deferred maintenance work.

viii The financial metrics presented above illustrate the underlying economics of the project and do not take the ESPA financing structure into account. Under the ESPA funding model, savings are shared between project partners, but this is excluded in the above analysis in order to make the findings simpler and more generalizable for the reader.

Recommendations

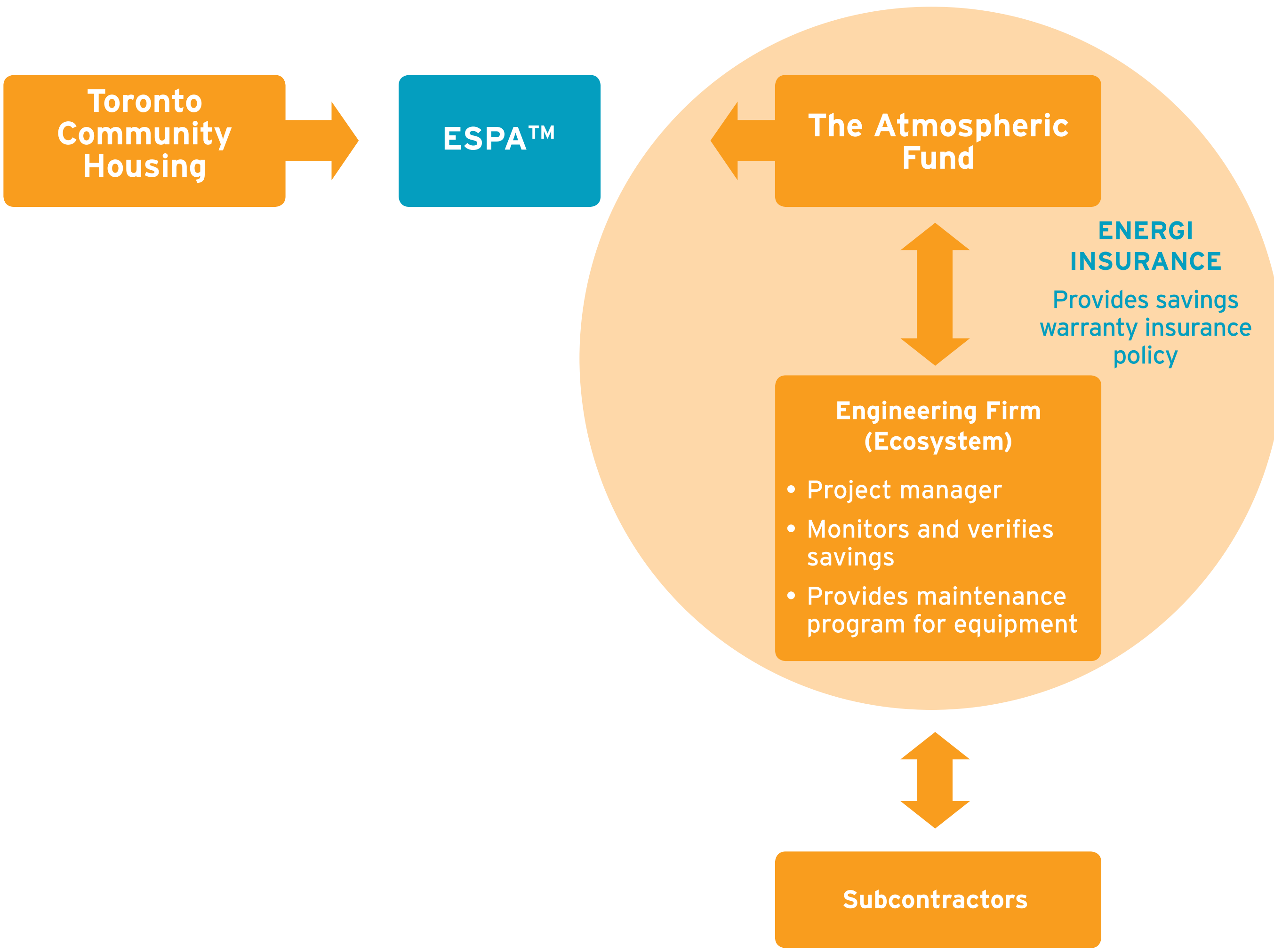
At the Trethewey Tedder Apartments the project team saw better-than-projected savings across all three utilities: gas, electricity, and water. The RCMs reduced utility costs and carbon emissions while also improving residents' thermal comfort and indoor air quality. As part of the larger portfolio, the gains seen at the Trethewey Tedder Apartments offset shortcomings at other sites, helping to balance the project portfolio and resulting in a very successful project overall.

Based on TAF's experience with the Trethewey Tedder Apartments and other large-scale retrofit projects, the following are some best practice recommendations that can be applied to projects in the future:

- **Integrate multiple measures.** Integration across all utilities enhances savings, improves financial performance, and reduces risk of underperformance. In this project the water measures provided the highest cost savings, yet water savings may not be typically considered as part of a building 'energy' retrofit. Using this opportunity to make improvements across all three utilities greatly improved the business case.
- **Site control and coordination is essential.** This provides an opportunity to undertake measures in parallel, which can reduce mobilization costs and allow money saved to be reallocated to address other energy saving or capital renewal priorities.
- **Building owners must actively participate.** Active participation by the building owner/operator is required to ensure good project outcomes. This participation is especially important during the design and planning stages, where retrofit options are evaluated and where there is an opportunity to maximize the expected outcomes.
- **Communicate with residents.** Communication is integral to retrofit success. Retrofitting an occupied building comes with challenges but these can be addressed through clear communication about the project, highlighting the benefits and impacts that residents can expect. For the Trethewey Tedder project this was done by holding 'town hall' meetings as well as through posters, handouts, and notices providing easy-to-understand information on the retrofit work and its benefits for residents. Written materials were translated into the most commonly spoken languages in the community to make information more accessible to residents with English as a second language.
- **Engage residents prior to installing new technology.** The successful implementation of smart thermostats requires engaging with residents prior to installation in order to identify potential implementation challenges and help determine the best retrofit engagement strategy. This strategy should focus on helping residents properly use the devices (behaviours that can save energy) and explaining benefits the resident will see as a result of the overall retrofit project.

- **Actively consider IEQ goals.** There is potential to significantly improve resident health and comfort in tandem with retrofit measures. Key IEQ challenges identified at this site (overheating and under-ventilation) were clearly related to outdated and poorly performing energy systems. Achieving IEQ improvements requires taking active consideration of IEQ at the design stage.
- **Challenge assumptions.** Challenging assumptions and re-evaluating building systems, loads, and operating requirements is critically important. A key finding from this project (and others) is that existing building mechanical systems are often oversized significantly, in some cases as high as 50-70 per cent. In particular, oversized heating boilers with little or no ability to modulate can regularly exceed a building's heating demand, resulting in wasted energy and overheating of living areas. Replacing old, inefficient systems provides an opportunity to downsize oversized systems while re-evaluating operating temperatures and pressures. This approach of right-sizing retrofits has been implemented successfully at numerous sites, and has led to reductions in energy consumption and improved resident comfort.
- **Continuous commissioning is critical.** Commissioning and ongoing optimization is critical in ensuring systems are operating as designed. However, properly commissioning and optimizing systems requires a stable and functioning building automation system (BAS). While it is important to ensure that new systems are properly working (start-up commissioning), ongoing commissioning and optimization is critical to long-term project success and savings.
- **Regular maintenance increases savings.** Maintenance measures such as duct and radiator cleaning should not be overlooked. Regular maintenance helps to improve system performance, thereby lowering utility costs associated with inefficient operation, and can also extend the life of the system. Moreover, tenants may also see improvements in their IEQ such as less odour transfer or better thermal comfort.
- **Consistently track and monitor changes.** Excellence in operation and maintenance requires standardization, consistent tracking and monitoring, and use of qualified personnel. This can help ensure that controls are not overridden, systems are not switched into manual mode, and sub-optimal system operation is avoided. Although emergences may require short-term repairs, proper tracking of maintenance calls and issues can ensure that short-term modifications do not lead to long-term degradations in system performance and operation.
- **Invest in building-wide internet connectivity.** To get the full value of smart building components, such as smart thermostats, requires building-wide internet connectivity. This would allow building operators to obtain real-time temperature data from the smart thermostats, and to make bulk adjustments to programming remotely through platforms such as ecobee's SmartBuildings.

Appendix A: ESPA™ Structure



Appendix B: Pre-Retrofit Building Information

Building Type	Social housing MURB Predominantly families
Name & Address	Trethewey Tedder Apartments 710 and 720 Trethewey Drive Toronto, Ontario
Year of Construction	1974
Major Renovations	Boiler upgrades at 710 within the past five years.
Number of Floors	18 and 19
Parking Levels	One, underground
Apartments	369 apartments, 1-3 bedrooms
Gross Floor Area	33,019 m^2
Heating	Hydronic baseboards located in every room of the apartment (except bathrooms). 720 Trethewey space heating is provided by one of two Viessman Vitocrossal 200 CM2-400 boilers; two existing boilers remain as backups. Heating boilers at 710 are new within past five years and were recommissioned as part of this project.
Cooling	No central cooling; residents can purchase/install their own window-mounted or externally ducted portable air conditioners.
Domestic Hot Water	One of the two Viessman Vitocrossal 200 CM2-400 boilers at 720 meets the DHW demand. DHW boilers at 710 were recommissioned.
Ventilation	Three MAUs (one at 720, two at 710), 100 per cent fresh air. One of the units at 710 has not been functioning for an unknown amount of time. Design flow rate is 26,980 cfm for each building (both operating 50% below ASHRAE 62.1). Each unit has its own bathroom exhaust fan and individual vent, venting directly to outside through the exterior wall on each floor. Air heating supplied by gas burners in each air handler.
Miscellaneous Equipment/ Facilities	Pool located outdoors. Recreation rooms on the ground floor of both buildings. Laundry rooms.

Appendix C: RCM Costs

Resource Conservation Measures	Gross Cost[ix]	Incentives[x]	Net Cost	Projected Annual Savings	Estimated Asset Lifetime[xi]
Two condensing boilers	$260,186	$21,117	$239,069	$19,400	25
In-suite smart thermostat and radiator control valves	$449,923	$0	$449,923	$9,994	13
Reflector panels	$18,146	$0	$18,146	$6,639	-
MAUs	$385,398	$0	$385,398	$17,414	25
LED lighting, interior and exterior common areas	$260,819	$54,988	$205,831	$95,483	18
New 3L toilets	$191,240	$0	$191,240	$36,701	30
Heating network VFD	$39,299	$2,827	$36,472	$4,452	15
Total	**$1,605,010**	**$78,932**	**$1,501,149**	**$190,083**	**-**
Simple payback			8 years		
NPV			$1,989,540		
IRR			14.2%		

Capital Renewal Measures	Net Cost[xii]
New hot water mixing valve	$31,664
Heating valve bypass	$6,703
Duct cleaning of supply and exhaust fans & MAU cooling	$48,187
Preventative maintenance program (Year 1 post-retrofit)	$9,245
Boiler troubleshooting	$4,501
CHP feasibility study	$20,296
Total	**$120,596**

[ix] Includes design, construction documents, management, construction, commissioning, & M&V plan fees.
[x] Audit incentives ($24,929) are not included. Total measure & audit incentives is $103,861.
[xi] Calculated based on weighted average between lifetime of individual asset components and their costs.
[xii] Incentives are not applicable to measures that address capital renewal or differed maintenance.

Appendix D: Projected RCM Savings

Resource Conservation Measures	Projected Annual Savings Electricity (kWh)	Natural Gas (m^3)	Water (m^3)	Carbon Emissions (tCO_2e)
Two new condensing boilers	0	58,450	0	111
Radiator reflector panels	0	20,004	0	38
In-suite smart thermostat and radiator control valves	0	30,113	0	57
Replace existing MAUs with one per building, equipped with heat recovery and VFD	18,617	44,038	0	87
LED lighting, interior and exterior common areas	693,480	-26,354	0	60
New 3L toilets	0	0	10,429	2
Heating network VFD	29,618	0	0	5
Total	**741,715**	**126,251**	**10,429**	**359**

Emissions Factors[1]	
Electricity	159 gCO_2eq/kWh
Natural gas	1899 gCO_2eq/m^3
Water	150 gCO_2eq/m^3

Appendix E: IPMVP Approaches

RCM	Primary M&V Approach per IPMVP	Supplemental Performance Monitoring
Condensing boilers	Option C – Gas	Option B – Gas and thermal
Smart thermostats	Option C – Gas	
Reflector panels	Option C - Gas	
MAU	Option A – Electricity Option C – Gas	
Lighting	Option A – Electricity	
Toilets	Option C – Water	
Heating network VFD	Option A – Electricity	

Appendix F: Equipment Details

Equipment	Manufacturer	Quantity	Description
Air handling unit	Engineered Air	3	One DG180-0 and two DJE60-0
Boilers	Vitocrossal	2	Vitocrossal 200 CM2 400
DHW mixing valve	Honeywell	2	Honeywell DHW mixing valve, one MX-130 and one MX-131
Lighting tubes	Osram	1,770	Substitube 15 W LED lighting tubes
Light poles	Cooper	33	PRV Prevail
Low flow toilets	Hennessey & Hinchcliffe	381	3L/flush low flow toilet
Heating network VFD	Armstrong	2	Armstrong IVS-102
Reflector panels	NoviTherm	1,364	Aluminum reflector panel
Thermostats	ecobee	365	ecobee3 smart thermostats

Appendix G: Monitoring Details

In addition to the monitoring sensors installed below, the project team monitored electricity consumption of the MAU and new VFD pumps installed as part of the boiler room retrofit.

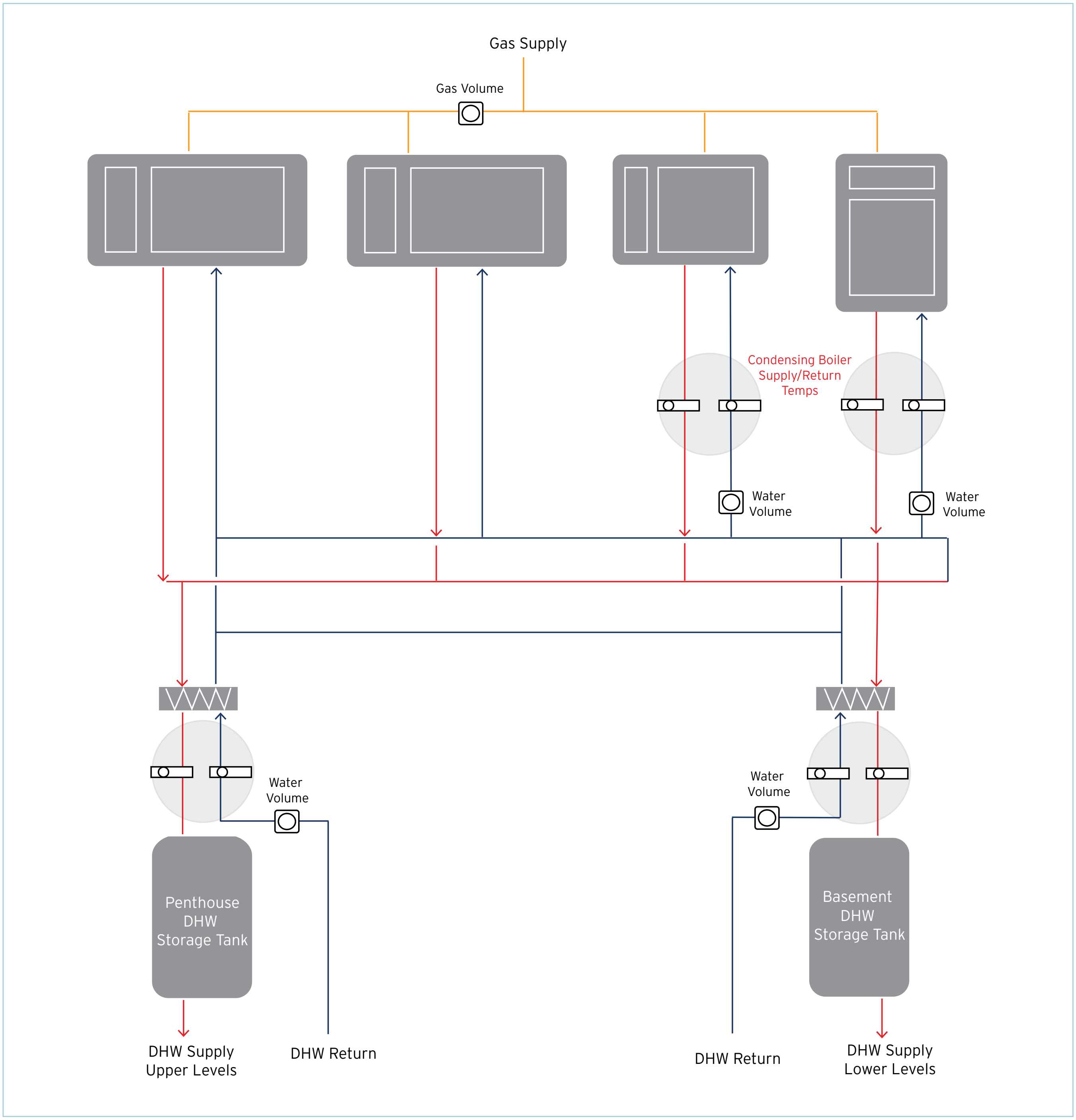
710 Trethewey

Type	Manufacturer and Model	Location	Range		Operational Accuracy	
			Min	Max	At Min Flow	At Max Flow
Gas, condensing boiler	Sierra, Quadra Therm 780i	Supply to condensing boilers	1 CFM	49.44 CFM	± 0.5% of reading plus 0.5% of full scale below 50% of full scale flow	± 0.5% of reading above 50% of the full scale flow
Water flow, DHW boilers	Waterflux 3100	Supply to condensing boilers	0 gal/min	130 gal/min	-	-
Temperature	Three-wire 100 Ohm RTD	Boiler supply	0°C	80°C	0.18°C (0.1 sensor + 0.15 transmitter)	
		Boiler return				

720 Trethewey

Type	Manufacturer and Model	Location	Range		Operational Accuracy	
			Min	Max	At Min Flow	At Max Flow
Gas, condensing boiler	Sierra, Quadra Therm 780i	Supply to condensing boilers	1 CFM	49.44 CFM	± 0.5% of reading plus 0.5% of full scale below 50% of full scale flow	± 0.5% of reading above 50% of the full scale flow
Water flow, DHW boilers	Waterflux 3100	Supply to condensing boilers	0 gal/min	130 gal/min	-	-
Temperature	Three-wire 100 Ohm RTD	Boiler supply	0°C	80°C	0.18°C (0.1 sensor + 0.15 transmitter)	
		Boiler return				

Appendix H: Monitoring Layout



Appendix I: M&V Utility Savings

Utility	Annual Consumption: M&V Baseline[xiii]	Annual Consumption: Projected	Annual Consumption: Actual	Actual Savings
Electricity (kWh)	1,086,956	345,241	285,971	800,985
Gas (m^3)	824,385	728,247	666,939	157,446
Water (m^3)	91,278	82,940	72,520	18,767

[xiii] M&V utility figures only include resource consumption associated with measures that were implemented.

References

[1] The Atmospheric Fund, "TAF Carbon Emissions Quantification Methodology", March 2018, https://taf.ca/wp-content/uploads/2018/04/TAF_Guide_Carbon_Emissions_Quantification_Methodology_2018-03-20.pdf

TAF The Atmospheric Fund

taf.ca | **THE ATMOSPHERIC FUND** | 75 Elizabeth Street, Toronto, ON M5G 1P4