The Atmospheric Fund

Retrofitting Arleta Manor

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 Arleta Manor retrofits 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.

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.

Executive Summary

Through the TowerWise program, The Atmospheric Fund (TAF) undertakes energy retrofits, targeting significant energy and carbon emission reductions across the multi-unit residential building sector. By demonstrating the business case and the environmental and social benefits of retrofits, TAF is helping to accelerate the scaling up of retrofits across the Greater Toronto and Hamilton Area.

From 2015-2018, TAF partnered with Toronto Community Housing Corporation (TCH) to undertake retrofits in seven buildings on three sites ('the portfolio'). This case study looks at one of those sites, Arleta Manor. Arleta Manor is a two-building seniors residential complex in North York constructed in 1972 containing 372 apartments.

To support the implementation of comprehensive energy retrofits and address the lack of access to capital for building owners, TAF created an innovative, non-debt financing instrument called the Energy Savings Performance Agreement (ESPA™). Retrofits across the portfolio were financed through an ESPA™.

The retrofit conservation measures targeted all resource types at Arleta Manor:

Gas

- Condensing boilers
- Gas absorption heat pumps
- In-suite smart thermostats
- Make-up air units with heat recovery and duct cleaning

Electricity

- LED lighting retrofit (interior/exterior)
- Occupancy sensors
- Variable frequency drive on cold water booster pumps
- Efficient heating motors

Water

- Ultra-low flow toilets

Key outcomes at Arleta Manor

- **30 per cent reduction** in carbon emissions
- **Higher than projected** utility cost savings
- **Significantly improved** indoor environmental quality

Key recommendation

Take a holistic view of an energy efficiency retrofit, integrating multiple measures and ensuring residents are engaged and building owners are active participants in the project.

Content

Arleta Manor Retrofit

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

As part of the TowerWise program, The Atmospheric Fund (TAF) and Toronto Community Housing Corporation (TCH) partnered to undertake a series of comprehensive energy retrofits in seven multi-unit residential buildings (MURBs) situated across three sites. The buildings chosen represent common MURB archetypes (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 prior to the retrofit, including poor thermal control, under-ventilation, and high energy consumption. This case study focuses on two of the seven TCH buildings that were retrofitted, at 7 and 11 Arleta Avenue (Arleta Manor).

Between 2015 and 2018, TAF retrofitted Arleta Manor in North York in order to improve the building's utility performance and indoor environmental quality, to reduce carbon emissions, and to bring down future maintenance and operating costs.

Arleta Manor was constructed in 1972. It is owned and operated by TCH and home for hundreds of seniors on low incomes. The two four-storey buildings have a gross floor area of 16,260m^2 and contain 372 studio and one-bedroom apartments.

Arleta Manor: pressurized corridor ventilation, hydronic baseboards

The Arleta Manor buildings have a concrete structure with original brick cladding and single-pane windows with aluminum frames, usually in a fixed-window over horizontal slider configuration.

The buildings share a central basement mechanical plant which provides heating and domestic hot water (DHW) for the site. The original boiler plant consisted of two 4.4 MMBTU/h Unilux boilers that provided both DHW and space heating. Hydronic baseboards are located in all units; however, prior to the retrofit there were no in-suite heating controls. Fresh air was provided by three make-up air units per building through a corridor-pressurized system. The buildings do not have any central cooling; TAF has estimated that 59 per cent of residents have purchased either window-mounted or externally ducted portable units. Common area lighting consisted of T8 fluorescent fixtures (either in 2x17W or 1x32W configurations), while exterior lighting was high-pressure sodium or metal-halide mounted fixtures ranging from 70W to 400W.

Overall, the buildings had a pre-retrofit energy use intensity of 284 ekWh/m^2, which is very close to the average for a MURB in Toronto[1]. See Appendix B for further pre-retrofit building information.

Energy and resident comfort challenges needed to be addressed

Pre-retrofit monitoring and analysis identified a number of energy and indoor environmental quality (IEQ) challenges that were harming building efficiency and resident comfort. First, the buildings were uncomfortably warm year-round, even during the winter, and a majority of residents reported opening their windows regularly during the heating season. Second, both the supply and exhaust ventilation systems were exchanging far less air than their rated capacity and code standards, and duct work was visibly contaminated and leaked[i]. Finally, the existing boiler plant was operating at only 54 per cent efficiency, on average, while providing much more heat than required. These findings were used to prioritize and optimize the retrofit measures.

[i] Supply and exhaust rates were 45% and 25% below ASHRAE 62.1 guidelines, respectively.

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**

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 project delivery 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 were jointly selected as a project delivery partner by TAF and TCH through a competitive procurement process.

Multiple resource conservation measures undertaken

Through the IPD process, 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 improving the indoor environment, while simultaneously addressing capital renewal or end of life issues:

- Installation of two gas absorption heat pumps (GAHPs) as part of a combination system with indirect heated DHW storage tanks and high-efficiency boilers
- Installation of two 5:1 modulating condensing boilers to provide heat and supplementary hot water, with original boilers kept for backup
- Installation of in-suite smart thermostats and radiator control valves to address overheating concerns
- Installation of new heating motor
- Replacement of existing multiple make-up air units with one air handling unit (AHU) per building, also tying in central bathroom exhausts. Both AHUs are equipped with heat recovery wheels and variable-frequency drives (VFD) and can cool ventilated air during the summer
- Replacement of lighting in mechanical rooms, stairs, lobby, and common areas with LED bulbs and motion sensor installation in mechanical rooms, garbage rooms, and infrequently used common areas; exterior lighting which consisted of high intensity discharge (HID) fixtures was replaced with integral LED fixtures
- Replacement of existing 6L toilets with 3L flapperless models

Not all RCMs considered by the project team were implemented, as Table 1 outlines.

RCM	Reason for Exclusion
Building envelope repairs and window replacement	High capital cost measures, disruption to tenants.
Refrigerator replacement	Evaluation of existing ENERGY STAR® certified refrigerators revealed good performance that did not merit replacement.
Washing machine replacement	Existing machines are rented and expected savings would likely not be substantial given review of machines on site.
Low-emissivity coating on windows	Significant expense that could not be justified given the poor state of the existing windows.
Solar DHW pre-heat	Payback on this RCM was greater than 30 years.
Radiator replacement	High capital cost of equipment that is still fully functioning.
Radiator heat reflector panels	Site surveys revealed that most units already have reflector panels installed.

Table 1: RCMs evaluated but not installed

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

- Heating valve replacement with three-way valves, optimized to provide adequate flow to all zones of the three buildings
- Shutoff valve for toilets
- Removal of decommissioned old boilers
- Exit sign replacement

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 indoor environmental quality (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 between five to 15 per cent of the residents before and after the retrofits.

Project financials

For a detailed breakdown of RCM construction costs and expected savings, see Appendix C and Appendix D. Appendix F summarizes the equipment details.

Project Financials	Value
Total project cost [ii]	$1,912,482
Total incentives	$109,276
Net cost	$1,803,206
Projected annual utility savings	$111,513

Table 2: Project financials

Projected cost savings and carbon emission reductions from the RCMs can be seen in Figure 1. The circle size reflects the full capital cost including design, equipment, installation, and commissioning.

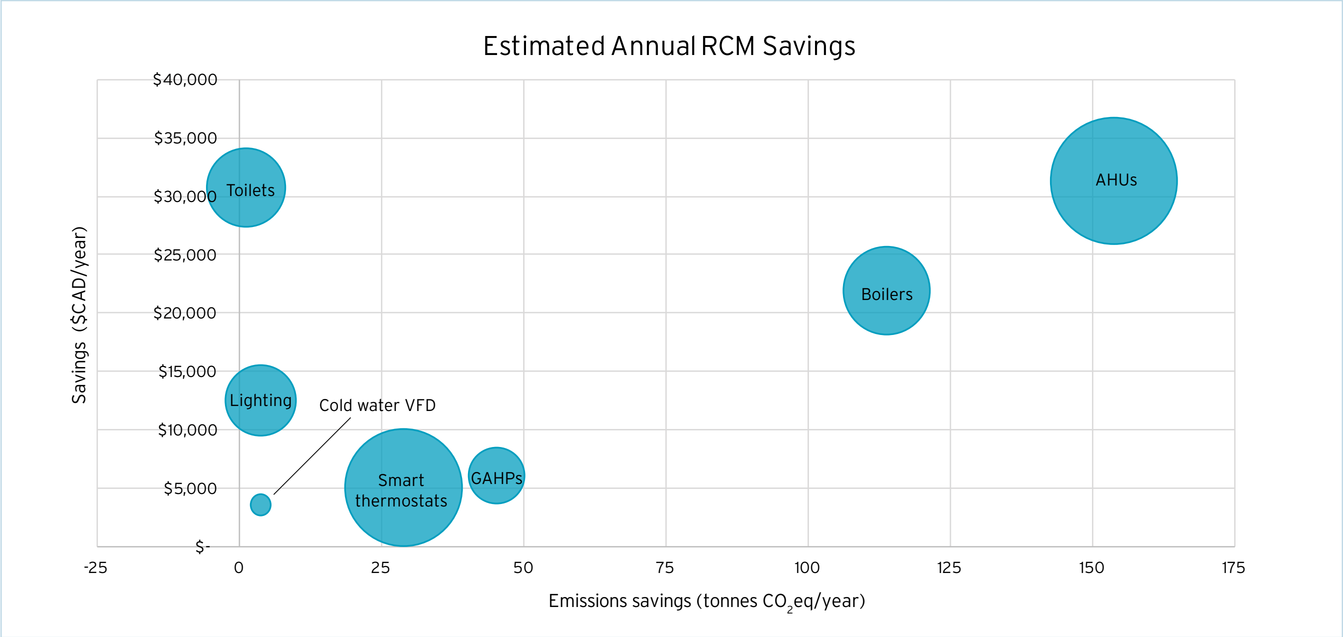


Figure 1: Estimated annual cost savings and emission reductions for each RCM implemented.

[ii] Includes TCH's contribution of $248,655 towards capital renewal and deferred maintenance work.

This project implemented a variety of measures with a range in paybacks resulting in maximizing utility cost savings and carbon emission reductions. Note that lighting improvements result in less carbon emission reduction than the associated electricity savings would indicate, because the reductions are partly offset by increases in gas consumption due to using fixtures that generate very little waste heat. In contrast, although the AHUs were the most capital-intensive RCM, they resulted in the greatest annual cost savings and emission reductions while significantly improving IEQ for residents.

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).

Energy and IEQ Monitoring

TAF and the project team put in place a comprehensive monitoring regime to track project outcomes and facilitate supplemental research on the effectiveness of key RCMs in achieving energy savings and IEQ improvements. In addition to monitoring whole-building utility consumption, the team monitored many of the key energy systems in isolation to track system-level performance. Table 3 summarizes key energy metering points at the site, while the International Performance Measurement and Verification Protocol (IPMVP) approaches used for measurement can be found in Appendix E.

The heating system has been designed so that the high-efficiency GAHPs pre-heat cold water that is further warmed by the boilers and sent on to the DHW storage tank. In this configuration, the boilers provide supplemental heating for DHW year-round, and all space heating for both buildings during heating season. Appendix H presents a diagram of the configuration of the boiler system, and the associated monitoring points.

Metering Point	Resource Metered	Interval
Whole building	Natural gas, electricity, water	Daily and hourly (water, gas) Daily (electricity)
GAHP	Natural gas Electricity	1-Minute 15-Minute
GAHP supply / return	Temperature	1-Minute
GAHP return	Water flow	1-Minute
Glycol pump	Electricity	15-Minute
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
Cold water VFD pump	Electricity	15-Minute
AHUs	Electricity	15-Minute

Table 3: Arleta Manor energy-related metering points

IEQ monitoring was undertaken in six per cent of units at 7 Arleta, and four per cent of units at 11 Arleta. Table 4 summarizes IEQ monitoring parameters. Appendix G shows a list of the specific monitoring equipment used.

Metering Point	Resource Metered	Interval
Individual suites	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: Arleta Manor IEQ-related metering points

Project Energy, Water, and Carbon Performance

This section details the energy, water and carbon emissions performance of the RCMs during the first 12 months of operation, March 2017 – February 2018. Performance is described in two parts: total resource (building-wide) savings and individual measure performance.

Cost savings and emissions reductions are also broken down by resource. Figure 2 provides an overview of the projected emissions reductions and costs savings for the first year of operation, highlighting that the more significant emissions reductions are often found in the cheaper utilities, yet are still of equal importance.

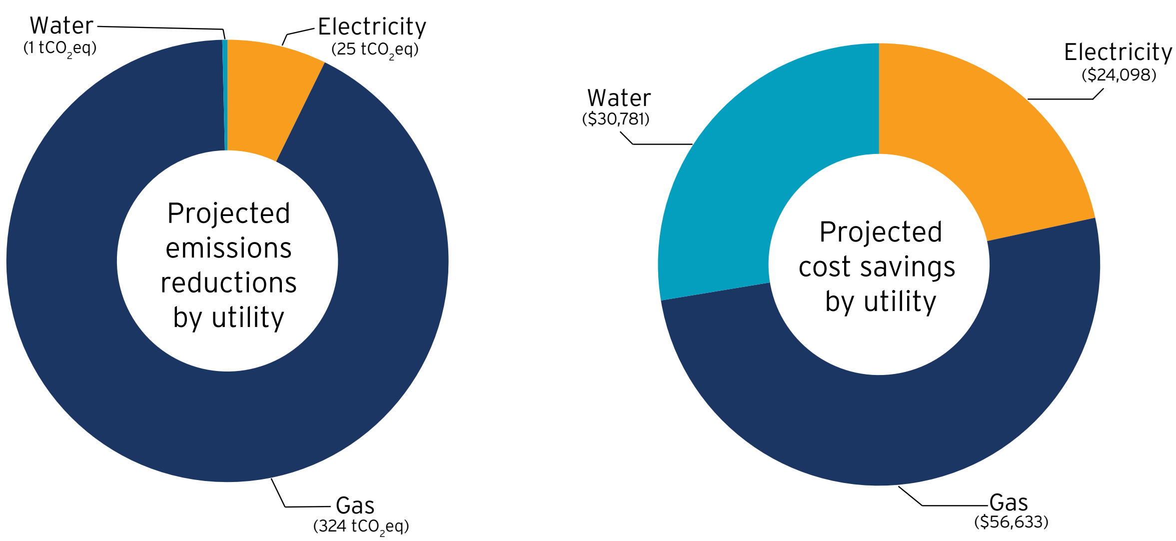


Figure 2: Projected emissions reductions and cost savings for the first year of post-retrofit operation at the site

TOTAL RESOURCE SAVINGS

In the first year the project saved $135,000, exceeding projected cost savings by 21 per cent. Despite not meeting the projected savings targets for all three resources the project was still able to meet its cost-savings projections since the multi-resource approach allowed for water savings that exceeded projections by 118 per cent to offset natural gas savings that were 33 per cent below projections.

Importantly, the project reduced carbon emissions by 248 tonnes CO_2eq, a 30 per cent reduction in emissions at the site and equivalent to the emissions from burning over 120 tonnes of coal.[2] Although first-year emissions reductions were significant, they were lower than the 351 tonnes of CO_2eq projected due to the shortfall in natural gas savings. Natural gas consumption is responsible for the vast majority of Arleta Manor's carbon emissions (nearly 75 per cent prior to the retrofit). This performance gap is further explained below.

Electricity

Electricity savings for the first year were 173,300 kWh, 13 per cent of total pre-retrofit electricity consumption. Electricity savings exceeded targets by eight per cent, largely due to the performance of the cold-water booster pumps and the highly efficient AHUs. The VFD cold-water booster pumps were able to run at reduced speed and pressure, resulting in less electricity consumed by the cold water system. The AHU fan speeds (and electricity consumption) required to meet code ventilation requirements has been less than expected, likely as a result of reduced friction from the thorough duct-cleaning performed as part of the ventilation system upgrade. LED lighting retrofits were responsible for most of the expected electricity savings, which also improved the indoor environment by providing better lighting levels and distribution. **In total, electricity measures reduced emissions over the year by 27.6 tCO_2eq.**

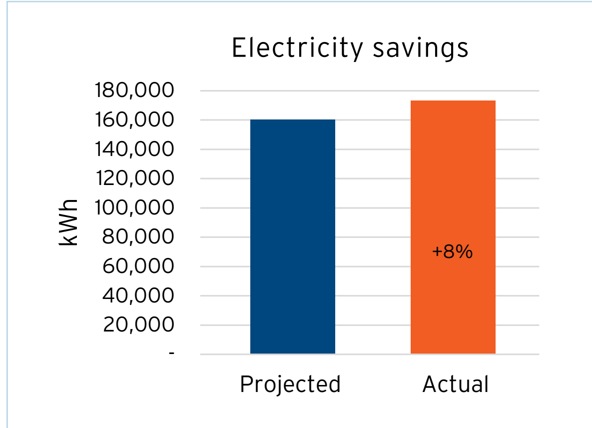


Figure 3: Year 1 electricity savings were 8% higher than projected

Natural Gas

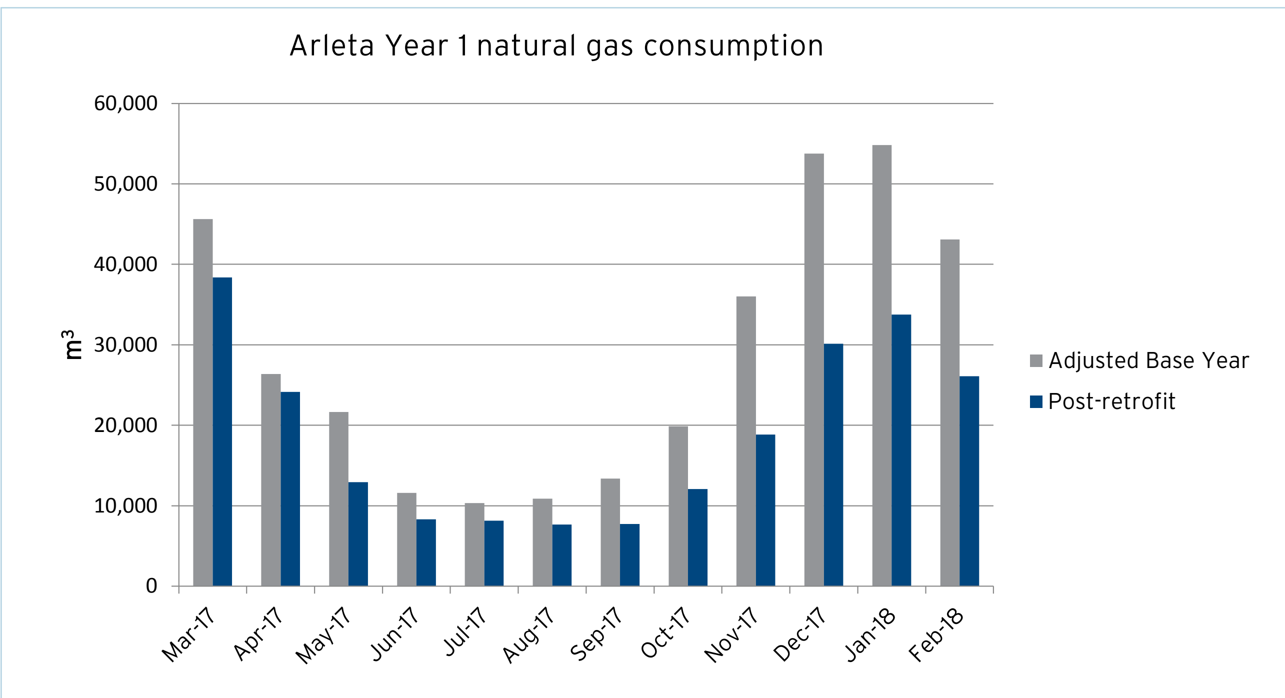


Figure 4: Monthly actual natural gas consumption versus adjusted base year consumption for the first year of RCM operation

The project achieved natural gas savings at Arleta through four RCMs: installation of new AHUs on each building, installation of new condensing boilers, installation of GAHPs, and installation of in-suite smart thermostats. These RCMs saved 114,681 m^3 of natural gas in the first year, which is 35.8 per cent of total pre-retrofit consumption for the entire building. **Gas measures reduced emissions over the year at the site by 217.8 tCO_2eq.** Figure 4 shows the monthly natural gas consumption during the first year of post-retrofit operation compared to the weather-normalized baseline.

Although the project achieved natural gas savings of 35.8 per cent from the pre-retrofit baseline, this was 33 per cent below expected savings. Reasons for this difference include:

- An undersized heat-exchanger was replaced midway through the first year of post-retrofit operation in order to increase heat transfer from the GAHPs to the DHW system.
- Although the GAHPs are reaching their expected efficiencies and the project team has optimized controls in order to minimize water temperatures returning to the GAHPs, operational temperature limits have prevented full utilization of the GAHPs to this point.
- In late December, the old and inefficient backup boilers were turned on in error, and remained on in high capacity for over two weeks. This prevented the condensing boilers and GAHPs from operating normally. Operational maintenance protocols have been improved to ensure this does not occur in the future.

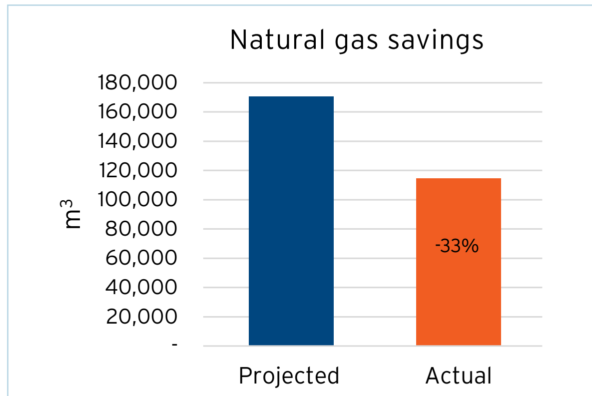


Figure 5: Natural gas savings in Year 1 were lower than projected

By addressing these issues and continuing to closely monitor system performance, TAF expects to see improved gas savings going forward. However, without significant changes to the existing DHW system, high loop temperatures will impair GAHP utilization and prevent the project from reaching 100 per cent of target savings.

Water

Water savings of 19,033 m^3 in the first year represents a reduction of 45 per cent. Water savings significantly exceeded projections (by 118 per cent), in part due to greater than expected leaks from the original toilets. The project team assumed that 7.5 per cent of the 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. However, actual water savings suggest 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, the flapperless design will prevent the type of leakage seen in the old pre-retrofit toilets. **Water measures reduced emissions over the year by 2.9 tCO_2eq.**

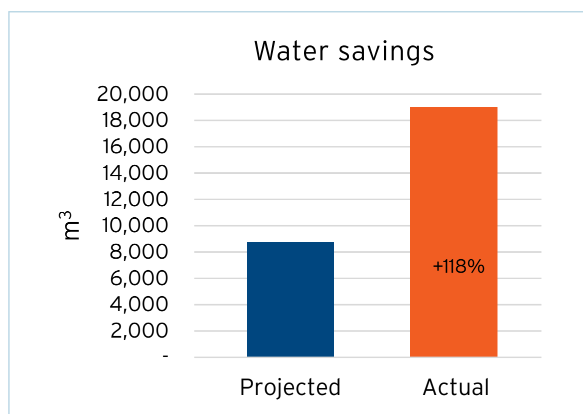


Figure 6: Projected and actual water savings

INDIVIDUAL MEASURE PERFORMANCE

Gas Absorption Heat Pumps

Two GAHP units were installed to supply DHW in concert with new condensing boilers. This was the first demonstration of GAHP technology for multi-residential DHW heating in the Canadian climate, and was incorporated into the project to evaluate the potential of this technology in a cold climate. Like conventional electric air-sourced heat pumps (ASHPs), GAHPs leverage a refrigeration cycle to draw heat from the surrounding air. However, they use gas combustion to drive the process instead of electricity, although a small amount of electricity is used to move fluids through the system (see page 19 for a fuller explanation). Figure 7 shows the installed GAHP models.

Figure 7: Two Robur GAHP units installed at Arleta Manor

Pre-retrofit modelling of the DHW system revealed that two GAHPs could satisfy 58 per cent of Arleta Manor's overall DHW needs while increasing the overall efficiency of the DHW system to 110 per cent. The GAHPs were installed at ground-level just outside the boiler room, which minimized the amount of glycol piping exposed to outside temperatures while avoiding any acoustic impacts to residents (the noise generated by these GAHPs is just slightly higher than a modern window air conditioner). Figure 8 shows the modelled output for a sample week.

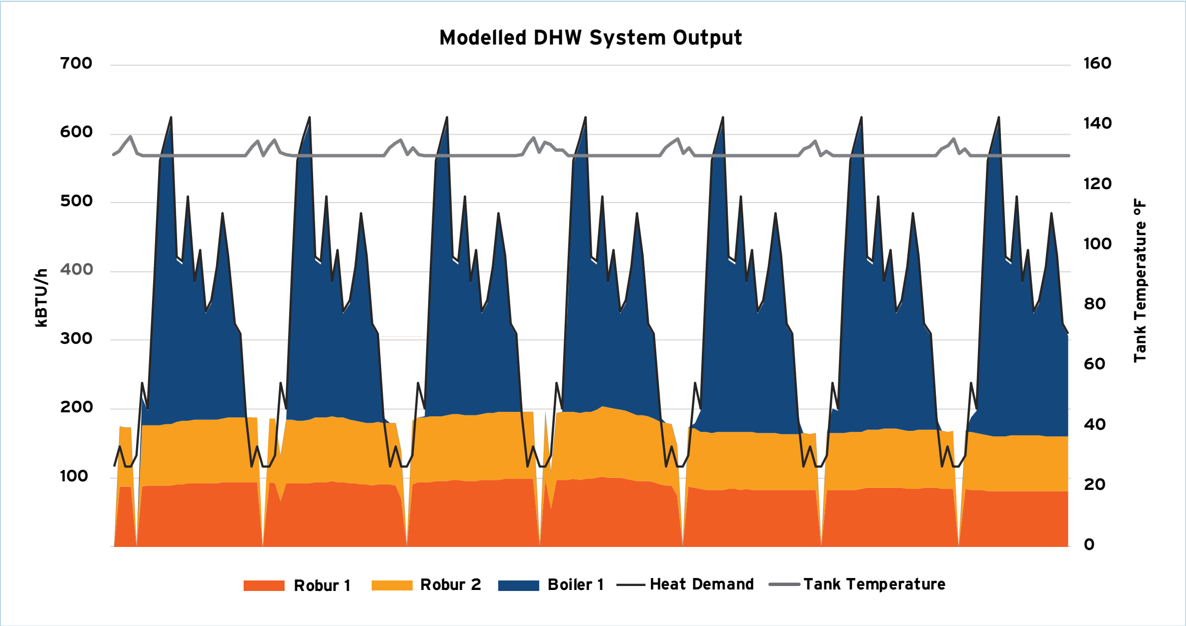


Figure 8: Modelling output for two GAHPs and condensing boiler for a week in January 2015. Modelling done for TAF by Ecosystem.[3]

The project team settled on a design where the GAHPs would supply base domestic water heating, with the condensing boilers providing any additional heating required to bring water temperatures up to the DHW storage tank's setpoint of 54°C. The GAHPs preheat cold water entering (or cool water returning from) the DHW system, which is fed to the condensing boiler's heat exchanger for further heating (if necessary) before entering the storage tank. This design works well when DHW demand and cold-water return volumes are high. However, when demand is low the heating loop temperatures become too high for the GAHPs to operate; per the manufacturer's specifications and TAF experience at this site, return temperatures to the GAHPs must be below 50°C. As a result, in periods of low DHW demand the condensing boilers provide most of the DHW energy and actual utilization did not match modelled utilization.

Efficiency of the GAHPs did meet TAF's expectations and was in line with the manufacturer's stated performance curve. Daily average coefficient of performance (COP, which considers gas and electricity consumption of the units) between March 2018 and February 2019 was 1.12, with a higher average daily COP value of 1.20 over the warmer months of May – September 2018. As with electric ASHPs, warmer ambient temperatures make it easier to extract heat from the air, resulting in higher operational efficiencies. Although GAHP efficiencies did decline with cold temperatures, efficiency never fell below that of a typical atmospheric boiler, and exceeded condensing boiler performance in ambient temperatures above -13°C.

Based on detailed analysis of GAHP operation over the course of a year, TAF found that the heat pumps saved over 10,000 m^3 of natural gas and 19 tonnes of carbon emissions when compared to the efficiency of the pre-retrofit DHW system.

Time Period	Natural Gas	Carbon Emissions
March 2018 – February 2019	10,195 (m^3)	19.19 (tCO_2eq)

Table 5: Natural gas and carbon emission reductions associated with GAHP operation

Operation of the GAHPs saves gas and reduces carbon emissions since it offsets heating that would otherwise be done by the less efficient condensing boilers. Figure 9 highlights emissions differences between the GAHPs installed at Arleta Manor and condensing boilers of various efficiencies, which represent typical boiler efficiencies that TAF has seen in existing buildings.

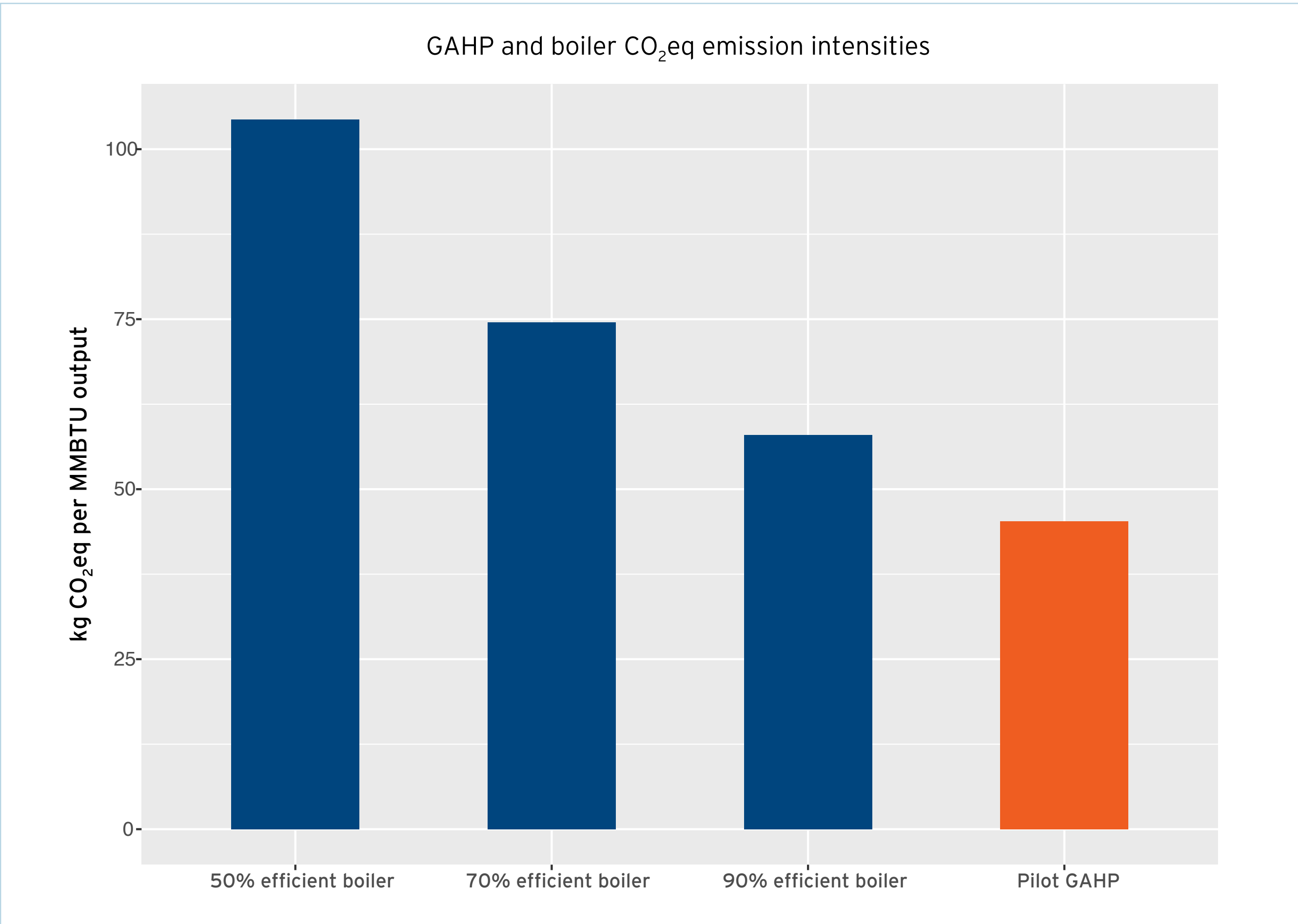
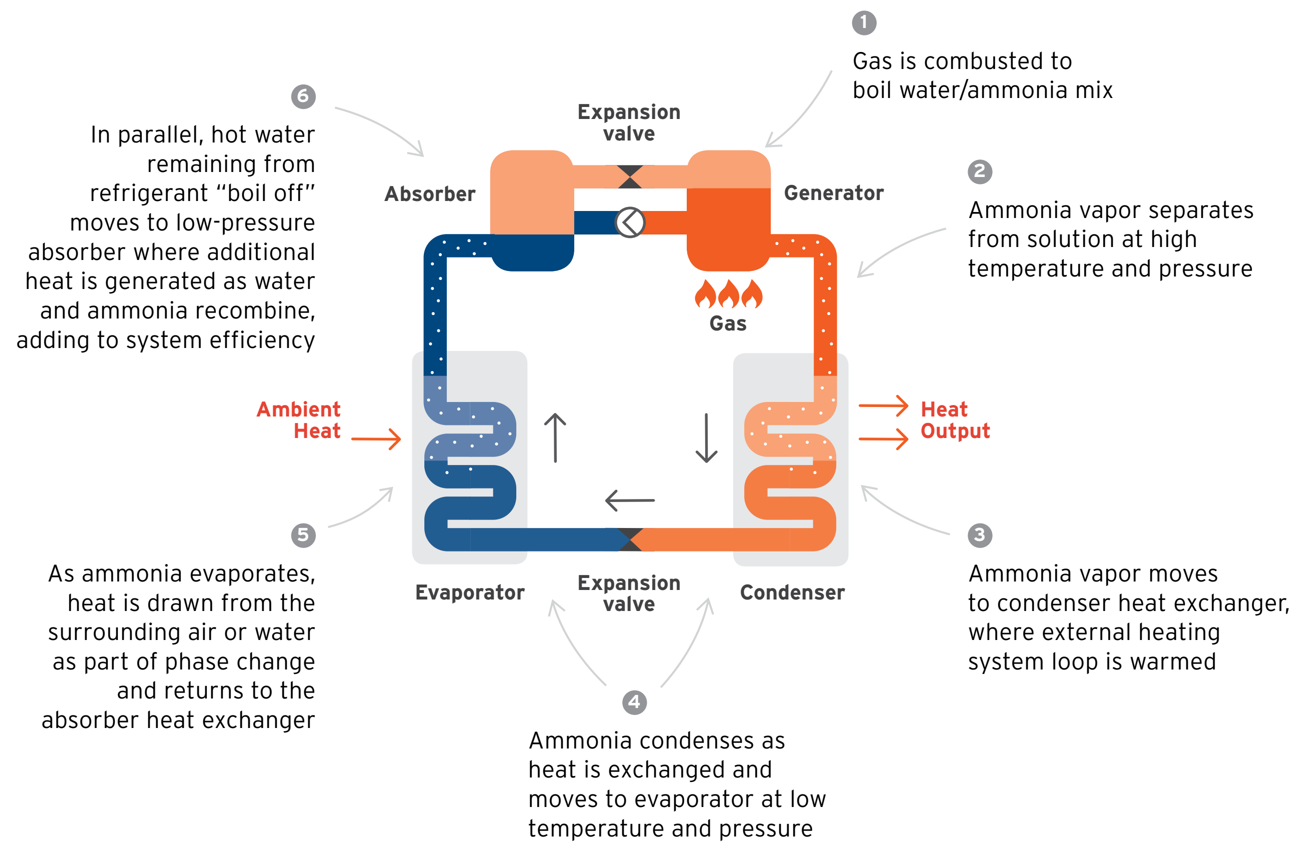


Figure 9: Carbon emission intensities of various gas hydronic heating systems based on an emissions factor of 1899 gCO_2eq/m^3 [4]

HOW ABSORPTION HEAT PUMPS WORK[5]

GAHPs and electric heat pumps both leverage a refrigeration cycle to draw energy from air, ground, or water to provide highly efficient heating and/or cooling to buildings.However, there are three significant differences between these technologies:

1. GAHPs use gas combustion to drive an absorption refrigeration cycle, whereas conventional heat pumps use electricity to drive a vapour compression refrigeration cycle.
2. An ammonia-water solution is commonly used as the working fluid in GAHPs instead of the Hydrofluorocarbons (HFCs) used in conventional electric heat pumps.
3. GAHPs are highly efficient, but less so than their electric counterparts.



Condensing Boilers

The two existing oversized 4.4 MMBTU/h boilers were left in place as backups, while two new Viessmann Vitocrossal 200 CM2-246 condensing boilers (with a combined input of 1.756 MMBTU/h, approximately 40 per cent of pre-retrofit capacity) were installed to meet space heating and supplemental DHW needs for both buildings. The existing boilers can run at either low or full capacity but have no ability to modulate between these two ranges. Overheating was a significant problem pre-retrofit, but the new appropriately sized condensing boilers are able to modulate between 20 and 100 per cent of their rating capacity.

The new systems are providing adequate heat while using far less energy, and are able to operate at efficiencies in excess of 90 per cent – a significant improvement over the original boilers that wasted nearly 50 per cent of the gas they consumed.

Condensing boiler efficiency is affected by return water temperatures, with higher efficiencies expected at lower water temperatures. In particular, return water temperatures at or below 54.4°C allow the boilers to extract latent heat by condensing water vapour in the exhaust gasses – heat energy that would otherwise be lost to the atmosphere. Maximizing the efficiency of condensing boilers requires return temperatures below the condensing point. Figure 10 plots the percentage of time the new Viessmann boilers at Arleta Manor were operating below the condensing point, along with daily average return temperatures, against the average outdoor temperature. This figure shows that outdoor temperature has a significant impact on the boilers' ability to run in condensing mode; colder outdoor temperatures necessitates supplying heating water at higher temperatures in order to provide adequate heat to the building and DHW system, which leads to higher return temperatures for the boiler. Based on TAF's monitoring, it's clear that the boilers are operating at their most efficient (i.e. more likely to condense) when outdoor temperatures are 5°C and above.

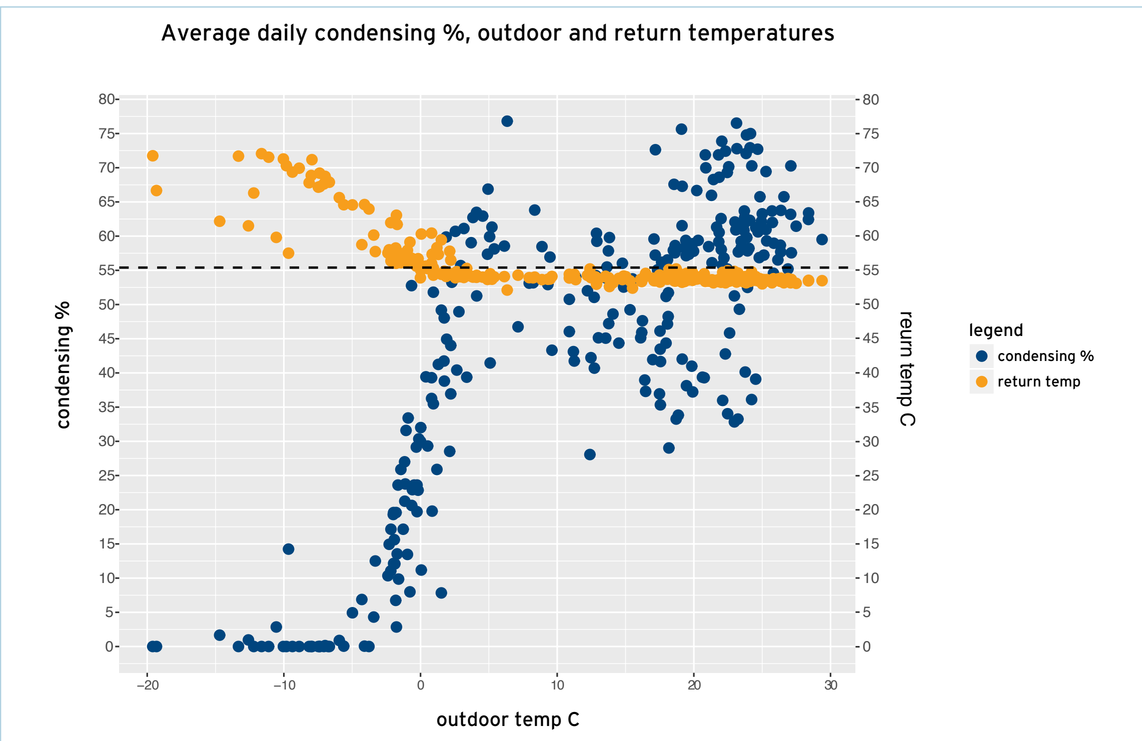


Figure 10: Daily condensing percentage and average return temperatures plotted against average outdoor temperatures (January – September 2018).

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 prior to the retrofit. In order to address this issue while saving energy and providing residents with greater control of their indoor environment, the project team installed ENERGY STAR® certified ecobee3 smart thermostats and control valves in each unit. 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 smart thermostats.

11.8%

Reduction in natural gas used for heating

TAF estimates that the smart thermostats saved approximately 11.8 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 11. Note that it is difficult to attribute natural gas savings between the appropriately sized boilers and the thermostats. 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 natural gas savings that could be attributed to the thermostats at the site.

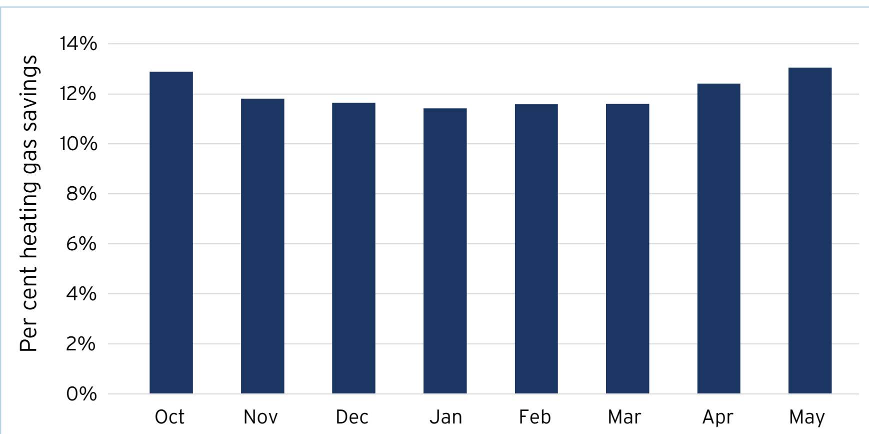


Figure 11: Monthly thermostat savings as a percentage of heating energy

The thermostats contributed to improved winter thermal comfort for residents. Pre-retrofit monitoring of 21 units revealed average winter indoor temperatures of 27°C, with slightly higher average temperatures in the fall and spring (27.5°C and 27.8°C respectively). Not only did overheating cause resident discomfort, but it wasted significant energy; 95 per cent of residents surveyed reported opening windows in the winter prior to the retrofit. With the installation of the new boilers and in-suite thermostat controls, perceived overheating decreased by 79 per cent in the winter, reported window opening decreased by 33 per cent, and average indoor winter temperatures dropped by over a degree to 25.8°C. Not only has overheating improved (quantitatively and qualitatively) with the introduction of the in-suite smart thermostats, but residents also reported a 41 per cent drop in portable heater use at the site while TAF's in-suite monitoring revealed that indoor temperatures never dropped below 22.5°C.

The seniors living at Arleta Manor were pleased with the smart thermostats. During TAF's post-retrofit survey, 67 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. An extensive resident engagement strategy aimed specifically at the seniors demographic was implemented at Arleta Manor.

Air Handling Units

A pre-retrofit ventilation analysis revealed that both Arleta buildings were under-ventilated; the existing systems were supplying fresh air at volumes 45 per cent below the ASHRAE 62.1 standard. This led to air quality and odour issues for residents. TAF's pre-retrofit survey found that almost 50 per cent of residents were affected by odours from their neighbours on a daily basis.

Figure 12: Newly installed air handling unit

The multiple make-up air units that supplied fresh air pre-retrofit were replaced with one dedicated AHU per building. All of the building supply and exhaust flows were re-routed to these new AHUs, which use heat recovery ventilation (HRV) to extract energy from exhaust air, which greatly reduces ventilation heating demand. The AHUs are able to heat and cool ventilation air (although cooling is limited by a lack of insulated ductwork and associated potential for condensation), and are equipped with variable frequency drives that modulate fan speeds in order to efficiently provide the appropriate amount of ventilation air. Ventilation ducts were cleaned as part of this measure, which removed significant amounts of dust and dirt and improved ventilation air quality and flow. Fresh air volumes now meet the ASRHAE 62.1 standard, and TAF's post-retrofit survey revealed a 31 per cent reduction in reported issues of odour from neighbouring apartments. Residents were also asked if they experienced fatigue, tiredness, headaches, irritated eyes, dry throat, or dry skin. Reports of residents experiencing five or more symptoms decreased by 38 per cent.

Although the new ventilation system was the most expensive RCM implemented, it provided numerous benefits: improved IEQ, reduced electricity consumption (from the VFD and duct cleaning), reduced natural gas consumption (due to the HRV) and reduced maintenance requirements through consolidation of the 16 individual fresh air units and exhaust fans into two dedicated AHUs. The AHUs ran more efficiently than expected in Year 1, likely due to the extensive duct and vent cleaning that was done as part of this measure. Figure 13 provides a before and after view of a typical exhaust vent located in a resident's bathroom.

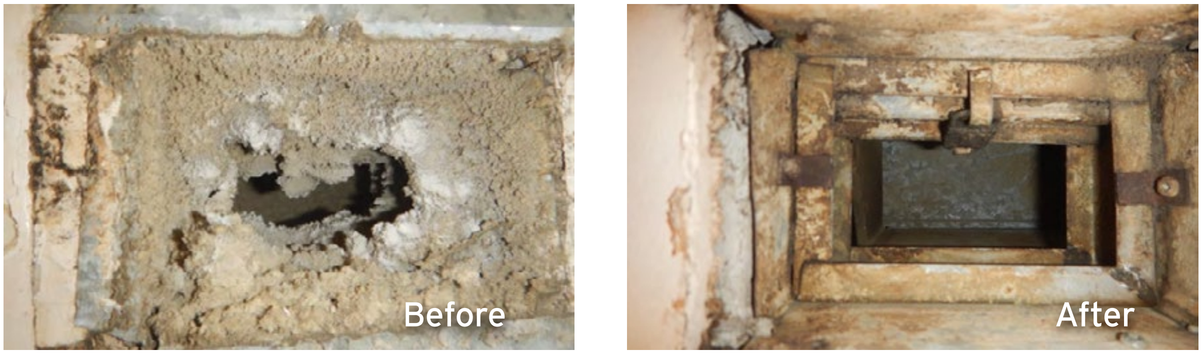


Figure 13: Bathroom exhaust vent pre-retrofit (left); bathroom exhaust vent post-retrofit cleaning (right)

The project team utilized the new AHUs' cooling ability to reduce summertime hallway temperatures. Although the amount of cooling that can be provided is limited by condensation concerns, qualitative feedback from building staff and residents has been positive. TAF's post-retrofit monitoring revealed:

- Hallway temperatures rarely exceeded 26°C, even on very warm days where outside temperatures were higher than 27°C.
- During hot summer days, hallway temperatures remained cooler than exterior temperatures through most of the day (from 12pm).
- During periods of extreme heat, average hallway temperatures remained 1.7°C cooler than exterior temperatures in the summer of 2017, and 2°C lower in the summer of 2018.

Although the hallways were not monitored prior to the retrofits, these measurements indicate that the hallways are providing a buffer to extreme outdoor temperatures. The fact that some residents have been observed opening their doors in the summer to take advantage of cool hallway air is an indication that this is an improvement over pre-retrofit conditions.

Providing hallway cooling is no guarantee of significant in-suite cooling due to the difficulty of circulating air into units via undercut doors. However, it does appear that hallway cooling is providing some suite-level improvements to residents at Arleta Manor. Summertime in-suite temperature monitoring over multiple years revealed that post-retrofit indoor temperatures were up to 2.3°C cooler during periods of high outdoor temperatures.

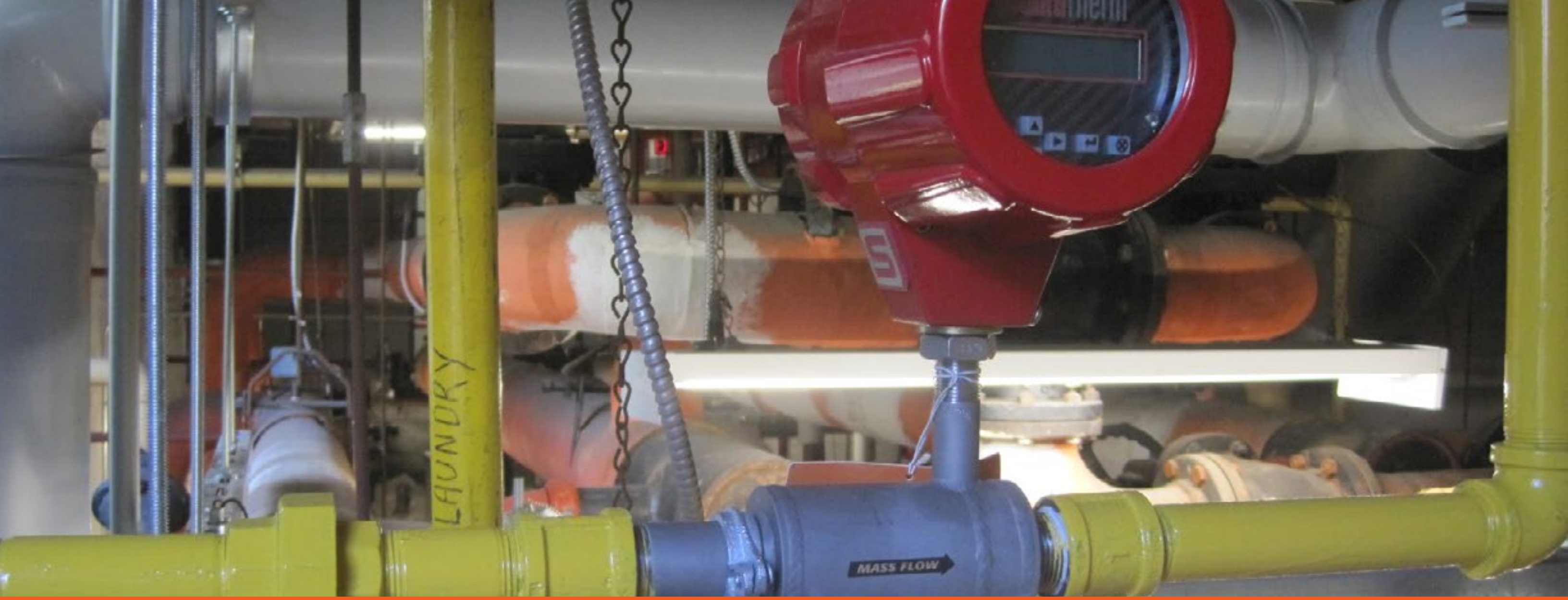
Lighting

All fluorescent lighting fixtures in the lobby, stairs, hallways, mechanical rooms, and common area were retrofitted with LED lamps that maintain existing lighting levels while improving visual comfort; the new lamps have a higher colour rendering index (CRI) and provide illumination that more closely resembles natural light. Motion sensors were also installed in the laundry rooms and garbage rooms in order to minimize lighting energy in these intermittently used areas.

Existing high-intensity discharge (HID) fixtures installed in the exterior were replaced with LED fixtures. The new exterior lighting design meets code, saves electricity, and provides increased lighting uniformity.

The lighting retrofit provided numerous benefits, including significant reductions in electricity consumption and utility costs; improved IEQ due to less variable and higher quality light; and reduced maintenance due to the 15-year life expectancy of the new LED bulbs.

The 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 loss of heat when estimating natural gas savings, resulting in a slight reduction in gas savings (approximately 6,100 m^3).



Ultra-Low Flow Toilets

The project team proposed replacing the original 6L/flush (six litres per flush) toilets with Hennessy & Hinchcliffe's Proficiency ultra-low flow 3 L/flush toilets. In order to test for pressure and plugging issues, the team installed the measure in 30 units across both buildings as a pilot. The pilot ran for two to three months and did not reveal any plumbing issues or resident complaints. Comfortable that the new toilets would perform well at the site, the team replaced the original 6L toilets in all units, along with several seized shut-off valves.

26%

Reduction in site water use

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

Supplemental Equipment

The project team installed a VFD on one of the primary cold-water booster pumps. These pumps are located in the basement boiler room and increase pressure to the cold-water distribution system throughout the buildings. Prior to the installation of the VFD, the system was over-pressurized and wasted electricity. In the first year of operation, the VFD saved 25,880 kWh and $3,900 in utility costs.

While the configuration of the radiators did not allow for the introduction of VFDs, there was still opportunity to improve the system by upgrading the existing standard efficiency motors. One of the large motors used to move space-heating water to both buildings was replaced with a Siemens premium efficiency model. The new motor reduces electricity consumption while maintaining performance of the existing heating system.

TCH also requested the installation of a DHW mixing valve in the boiler room at 7 Arleta. This was an asset renewal measure that was not intended to reduce energy consumption; the valve ensures hot water delivered to residents does not exceed the building code temperature specification of 49°C.

Financial Performance

Actual cost savings performance in the first year of post-retrofit operation exceeded projections by 21 per cent, primarily due to greater than expected water savings. The project saved $135,036 in utility costs in the first year, exceeding projected cost savings by $23,500. TAF expects to continue to exceed projected costs savings, especially as more work is done to improve natural gas savings at the site.

Table 6 highlights the financial performance of the Arleta site and the larger project that includes two additional sites. Financial performance for Arleta Manor should be seen within the context of the overall project; although the simple payback is greater than 10 years at this site and the 10-year return is not positive, the overall project is a good financial investment within a 10-year timeframe. In addition, Arleta Manor on its own has a positive rate of return (8.2 per cent) over the expected lifetime of the project (in this case, 26 years based on the average life expectancy of the RCMs installed).

Financial Category	Arleta Manor		Portfolio (All three sites)[III]	
	Original Projection	Actual Performance	Original Projection	Actual Performance
Year 1 cost savings	$111,513	$135,036	$417,707	$501,990
Net present value (NPV)[IV]	$922,607	$1,445,139	$5,021,603	$6,830,223
Internal rate of return (IRR)	8.2%	10%	12.4%	14.9%
IRR (10 year)	-3.27%	-0.07%	3.5%	7.2%
Simple payback (years)	13.9	11.5	9.4	7.9
Return on investment (ROI)[V]	177%	235%	286%	364%

Table 6: Site and portfolio financial performance [VI, VII]

[III] The three TCH sites that make up the efficiency portfolio are Arleta Manor, R.J. Smith Apartments and Trethewey Tedder Apartments.
[IV] Discount rate of 4%, utility cost inflation rate of 3%.
[V] Based on average project lifetime.
[VI] Excludes TCH's contribution of $248,655 towards capital renewal and deferred maintenance work.
[VII] 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

It can be tempting to focus on the performance and benefits of individual RCMs or even on the performance of one site within a portfolio of retrofit projects, but a holistic view is required in order to ensure the success of large retrofit projects. IPD that incorporates a diverse array of project stakeholders is key. Through this type of delivery process, it is possible to simultaneously achieve energy and carbon emission reductions, improve thermal comfort and air quality, as well as address deferred maintenance items. Achieving all these objectives requires viewing both the forest and the trees — ensuring that individual measures are appropriate for the site and project while maintaining focus on the projects' overall financial, emission and energy goals.

Based on TAF's experience with large-scale retrofit projects at Arleta Manor and other MURBs, the following are some best practice recommendations that can be applied to future projects:

- **Integrate multiple measures.** Integration across utilities enhances resource and cost savings, improves financial performance, and reduces risk of underperformance. In this project the water savings represented 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 Arleta project, this was done by holding "town hall" meetings as well as simply providing more details on notices of entry which explained the work and benefits.
- **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, behaviors that can save energy, and 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 on 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.

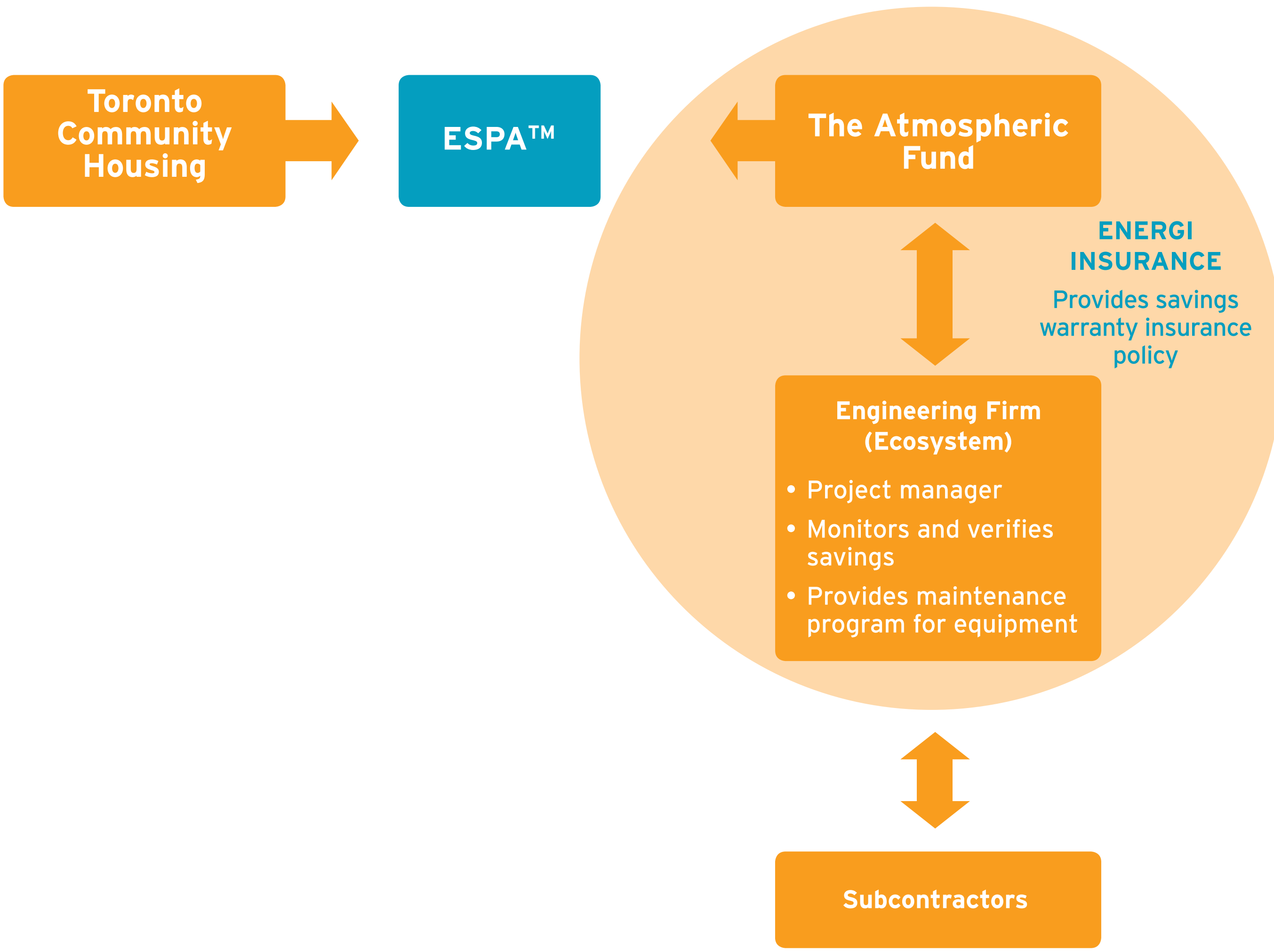
- **Challenge assumptions**. Challenging assumptions and re-evaluating building systems, loads, and operating requirements is critically important. A key finding from this project (and others) is that existing building mechanical systems are often significantly oversized; in this case the original boiler plant exceeded the buildings peak heating demands by a factor of 2.5. 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 (including Arleta Manor), and has led to reductions in capital costs and energy consumption and improved resident comfort.

- **Continuous commissioning is critical.** Commissioning and ongoing optimization ensures that systems are operating as designed. This 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 cannot be overlooked in order to achieve long-term project success. TAF expects that without continuous commissioning and optimization of the gas-conserving measures installed as part of this project, savings would erode over time. Continuous evaluation and optimization are key to long-term savings.

- **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 emergencies 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.

- **GAHPs improve efficiency but also add complexity.** Incorporating GAHPs into a boiler-based heating system requires careful analysis and consideration. TAF recommends investigating the separation of GAHP and boiler heating loops as much as possible in order to avoid high GAHP return temperatures that can adversely impact GAHP efficiency and utilization.

Appendix A: ESPA™ Structure



Appendix B: Pre-Retrofit Building Information

Building Type	Social housing Seniors residences
Address	Arleta Manor 7 - 11 Arleta Avenue Toronto, ON
Year of Construction	1972
Major Renovations	Fixing pinhole leaks in the DHW re-circulation loop.
Number of Floors	4
Parking Levels	None
Number/Type of Units	372 (studio and one bedroom)
Gross Floor Area	16,260 m^2
Heating	Two 4,400 MBTU/h boilers (also provide DHW). Two 7.5 hp heating loop pumps running at constant flow. Hydronic radiators in units – loop temperature set by mixing valve in mechanical room.
Cooling	No central cooling; residents can purchase/install their own window-mounted or externally ducted portable air conditioners. Common activity room is air-conditioned.
DHW	Two 4,400 MBTU/h boilers (also provide space heating). 3,200-gallon storage tank, 54.4°C set point temperature.
Ventilation	Three air handling units per building, 100% fresh air. 7 Arleta rated at 5,500 cfm, 11 Arleta rated at 4,800 cfm (both operating 45% below design flow). Central exhaust in bathrooms, six exhaust fans at 7 Arleta, four fans at 11 Arleta (operating at 35% below design flow). Air heating supplied by burners in each air handler.
Miscellaneous Equipment/Facilities	One activity room/common area Two laundry rooms

Appendix C: RCM Costs

Resource Conservation Measures	Gross Cost[VII]	Incentives[IX]	Net Cost	Projected Annual Cost Savings	Estimated Asset Lifetime[X]
Two condensing boilers	$244,721	$24,996	$219,725	$21,914	31
Two GAHPs	$100,841	$0	$100,840	$6,087	20
In-suite smart thermostat and radiator control valves	$431,305	$0	$431,305[XI]	$5,058	11
New heating motors	$5,360	$0	$5,360	$206	18
Replace existing AHUs with one per building, equipped with heat recovery and VFD	$511,472	$49,800	$461,672	$31,361	25
LED lighting interior/ exterior common areas	$157,947	$16,462	$141,486	$12,511	19
New 3L toilets	$198,751	$0	$198,750	$30,782	30
Cold water VFD	$13,430	$4,782	$8,649	$3,594	18
Total	**$1,663,827**	**$96,040**	**$1,567,787**	**$111,513**	**–**
Simple payback			13.9		
NPV			$909,371		
IRR			8.1%		

Capital Renewal Measures	Net Cost [XII]
New booster pump controls	$4,278
Exterior lighting pole replacement	$68,338
New hot water mixing valve	$19,187
Duct cleaning of supply and exhaust fans and AHU cooling	$154,039
Preventative maintenance program (Year 1 post-retrofit)	$2,813
Total	**$248,665**

[VIII] Includes design, construction documents, management, construction, commissioning, & M&V plan fees.
[IX] Audit incentives ($13,261.10) are not included. Total measure and audit incentives were $109,276.
[X] Calculated based on weighted average between lifetime of individual asset components and their costs.
[XI] Ecobee donated the smart thermostats to this project. The estimated market value of this donation ($79,980) is included in the total measure cost.
[XII] Incentives are not applicable to measures that address capital renewal or deferred maintenance.

Appendix D: 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	16,516	58,546	0	114
Two new GAHPs	-14,803	25,044	0	45
In-suite smart thermostat and radiator control valves	0	15,239	0	29
New heating motors	1,372	0	0	0.2
Replace existing AHUs with one per building, equipped with heat recovery and VFD	36,593	77,919	0	154
LED lighting interior/ exterior common areas	96,744	-6,116	0	4
New 3L toilets	0	0	8,747	1
Cold water VFD	23,911	0	0	4
Total	**160,333**	**170,632**	**8,747**	**351**

Emissions Factors[6]	
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
GAHP	Option A – Electricity Option C – Gas	Option B – Gas and thermal
Condensing boilers	Option C – Gas	Option B – Gas and thermal
Smart thermostats	Option C – Gas	
AHU	Option A – Electricity Option C – Gas	
Lighting	Option A – Electricity	
Toilets	Option C – Water	
Cold water VFD	Option A – Electricity	
Heating motor	Option A – Electricity	

Appendix F: Equipment Details

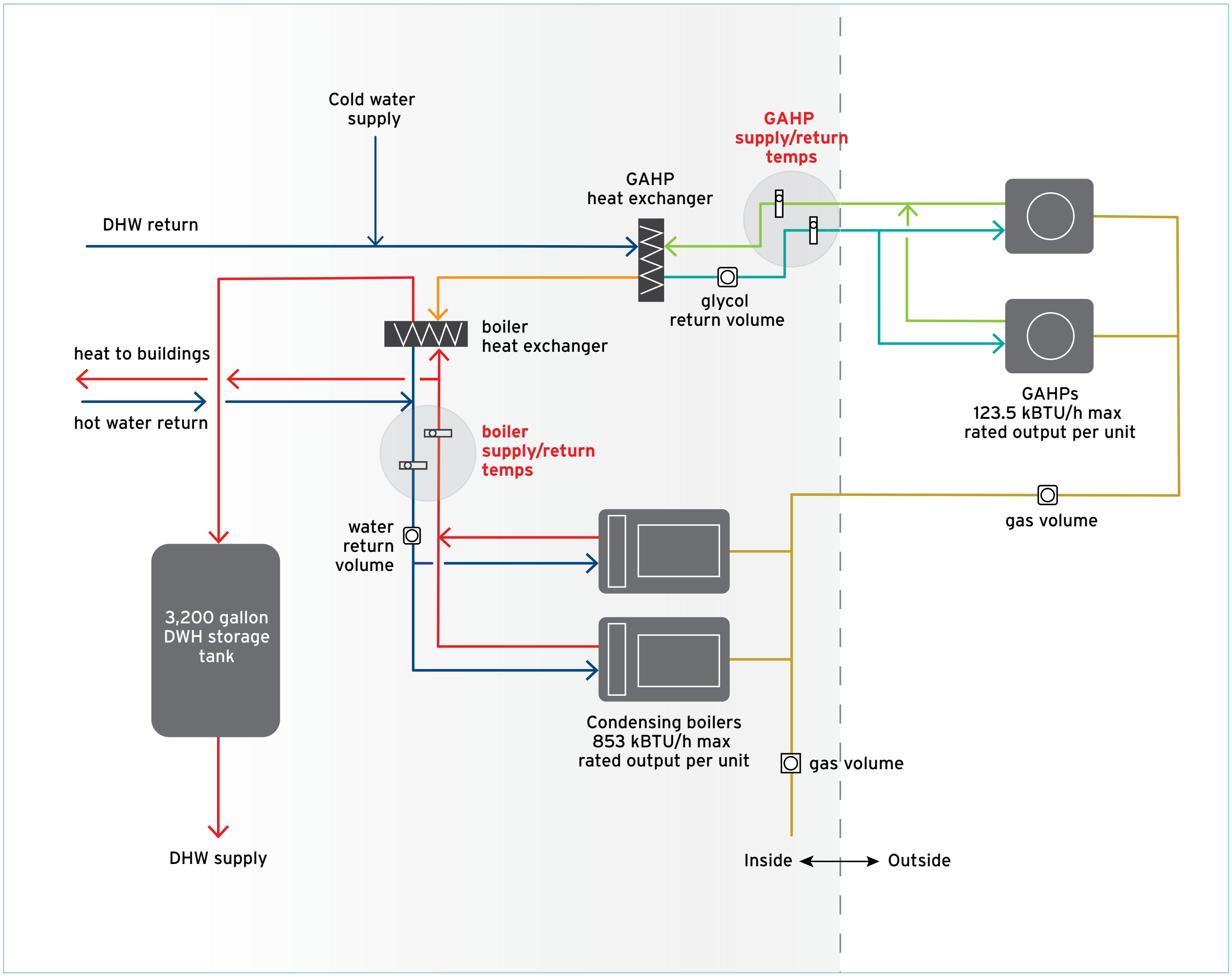
Equipment	Manufacturer	Quantity	Description
AHU	AAON	2	Equipped with heat exchanger and VFD, provides heating and cooling of incoming air
Heat exchanger	WTT	1	Brazed plate double wall
Boiler	Viessmann	2	Vitocrossal 200 1,756 MBTU/h total input capacity, 5:1 modulation ratio
DHW mixing valve	Honeywell	1	Enables the delivery of water to the faucets at 49°C
Lighting	CSC	4	Canopy lighting
	Cooper	28	Pole lighting
	Cooper	35	Wallpacks
	OSRAM	50	Ballasts
	Visioneering	232	Fixtures
	OSRAM	450	Light tubes, 15.5W LED
	Lutron	10	Occupancy sensors
Light poles	Eaton	17	4" square steel poles
Low flow toilets	Hennessey & Hinchcliffe	396	3L, flapperless technology in units and common areas
GAHPs	Robur	2	GAHP-A 250 MBTU/h total input capacity, 140°F max output temperature
Cold water VFD	ABB	1	ACH 550 model line
Thermostats	ecobee	372	E3 model with room sensors
Heating motor	Siemens	2	On-off control with electronic actuator, 370 GPM flow rate

Appendix G: Monitoring Details

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

Type	Manufacturer and Model	Location	Range		Operational Accuracy	
			Min	Max	At Min Flow	At Max Flow
Boiler room gas flow	Sierra, Quadra Therm 780i	Installed on gas line dedicated to boilers and GAHPs	0	5.4 m^3/h	± 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
GAHP gas flow	Sierra, Quadra Therm 780i	Installed on gas line dedicated to GAHPs	0	5.4 m^3/h	± 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, condensing boilers	Krohne Enviromag 2000 + IFC100 with PFA Teflon liner	Installed on water flow return to condensing boilers	4°C	85°C	± 0.3% of the measured value ± 1 mm/s	
Water/glycol flow	Krohne Enviromag 2000 + IFC100 with PFA Teflon liner	Installed on water flow return to GAHP	0	6.81 m^3/h	± 0.3% of the measured value ± 1 mm/s	
Temperature	WIKA, resistance temperature detector (RTD) TR10 PT100	GAHP heat exchanger supply GAHP heat exchanger return	0°C	80°C	Class A; ±(0.15 + 0.0020 * |t|)	
Temperature	Three-wire 100 Ohm RTD	Boiler supply Boiler return	0°C	80°C	0.18°C (0.1 sensor+ 0.15 transmitter)	
Temperature	Three-wire 100 Ohm RTD, PFA model for high temperatures	Supply from GAHP Return to GAHP	0°C	85°C	0.18°C (0.1 sensor+ 0.15 transmitter)	

Appendix H: Monitoring Layout



Appendix I: Arleta Manor Utility Savings Tables

	Annual Consumption			
Utility	**Baseline**	**Projected**	**Actual**	**Savings**
Electricity (kWh)	419,069	258,736	245,769	173,300
Gas (m^3)	347,372	191,979	232,690	114,681
Water (m^3)	55,033	46,286	36,000	19,033

References

[1] Binkley, Clarissa, Marianne F. Touchie, and Kim D. Pressnail, "Energy Consumption Trends of Multi-Unit Residential Buildings in the City of Toronto" (University of Toronto, 2012).

[2] Environmental Protection Agency, "Greenhouse Gas Equivalencies Calculator", https://www.epa.gov/energy/greenhouse-gas-equivalencies-calculator, accessed August 4, 2019

[3] Ecosystem, "Robur Savings Calculations" (internal modelling document)

[4] Ontario Ministry of the Environment and Climate Change, "Ontario Public Service Guidance Document for Quantifying Projected and Actual Greenhouse Gas Emission Reductions", June 30, 2017, http://www.grants.gov.on.ca/prodconsum/groups/grants_web_contents/documents/grants_web_contents/prdr017804.pdf

[5] The Atmospheric Fund, Gas Absorption Heat Pumps: Technology assessment and field test findings, 2018 https://taf.ca/publications/gas-absorption-heat-pumps/

[6] 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