Retrofitting Perth Avenue Housing Co-operative

A TOWERWISE CASE STUDY

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).

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Acknowledgments

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Executive Summary

Through the TowerWise program, the Atmospheric Fund (TAF) undertakes energy efficiency 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.

Built in 1987, Perth Avenue Housing Co-operative is an eight-storey tower with 102 one-, two- and three-bedroom homes. Between 2014 and 2016, TAF undertook retrofits on the building.

To support the implementation of comprehensive energy efficiency 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^{TM}). Retrofits at Perth Co-op were financed through an ESPA^{TM}.

The retrofit conservation measures targeted all resource types at Perth Co-op:

Gas

- Condensing boiler and mixing valve

Electricity

- Programmable thermostats and new electric baseboards
- Variable frequency drive upgrades for make-up air units
- Domestic cold water booster pump with variable speed drive
- LED lighting upgrades

Water

- Low-flow toilets, shower-heads, and aerators

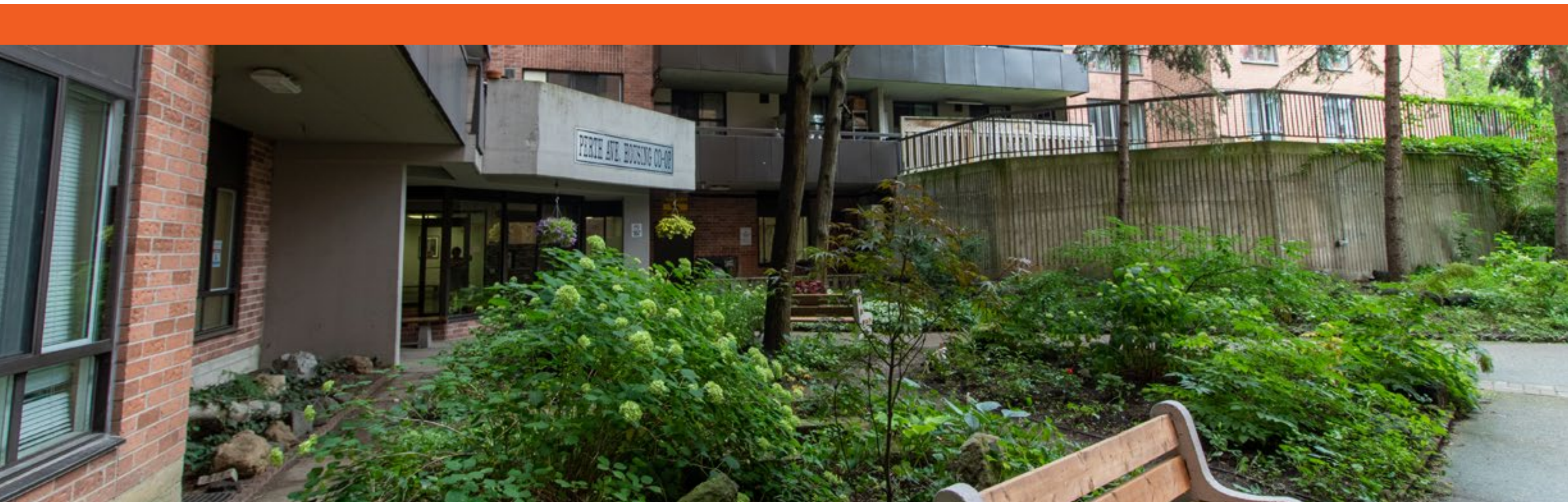
Key outcomes at Perth Co-op

- ☑ **$84,000 annual cost savings**
- ☑ **103 tonnes annual carbon emissions reductions**
- ☑ **3.7-year simple payback**
- ☑ **36 per cent decrease in EUI**

Key recommendation

Understand resident needs including accessibility. By including questions around resident needs as part of the preliminary audit, the project team can ensure early in the design process that these needs will be met.

Content



Perth Avenue Housing Co-operative Retrofit

High energy and water bills spurred co-op to seek retrofits

High energy and water bills together with aging equipment spurred Perth Avenue Housing Co-operative towards action. In 2013, the co-op reached out to Finn Projects, expressing their interest in undertaking energy efficiency retrofits. By September 2014, energy and investment grade audits were completed, outlining a series of retrofit recommendations for the building. Finn Projects then collaborated with The Atmospheric Fund (TAF) to present an Energy Savings Performance Agreement (ESPA™) solution for the project, which was signed in December 2014.

Electrically heated post-war building

Perth Co-op is a complex that includes an eight-storey tower and a four-storey attachment with 102 one-, two- and three-bedroom suites. The building was constructed in 1987 and has a gross floor area of just over 12,000m^2. The electric baseboards that provide heat to the units were tied to non-programmable thermostats, with integral controls in the suite bedrooms. The common areas were heated either by electric baseboards controlled by non-programmable thermostats or by force-flow electric heaters. The building has one level of underground parking, which is not heated.

The building does not have central cooling, but approximately 50 per cent of residents use window air conditioning units and the main lobby was cooled with a one-ton AC unit. Domestic hot water (DHW) was provided by two gas fired boilers rated at 750 MBTU/hr and 600 MBTU/hr. The latter boiler appeared to be original to the building. Detailed building information is provided in Appendix B.

Prior to any retrofits, the building had annual utility costs of approximately $209,000 and an energy use intensity (EUI) of approximately 173.5 ekWh/m^3. The analysis contained in this case study is based on two years of post-retrofit performance monitoring, between March 2016 and February 2018.

PROJECT 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

2013
Perth Co-op approaches TAF with interest in ESPA™

September 2014
Energy and investment grade audits completed

December 2014
ESPA™ signed

March 2015 - February 2015
RCM equipment installed

March 2016 - February 2018
Utility consumption monitoring

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.

TAF, Finn Projects, and Perth Co-op worked together to determine the most effective resource conservation measures (RCMs) that could be implemented. Focus was placed on improving the DHW system efficiency and modulation capacity, reducing over-ventilation of the common area hallways during low-use periods, adding programmable thermostats to baseboard heaters, and providing central control systems for the heating and fresh air equipment.

Construction began in March 2015, with the majority of RCMs completed by December 2015. Substantial completion was reached in February 2016. Post-retrofit utility consumption monitoring began in March 2016 and ended in February 2018.

Multiple resource conservation measures undertaken

Detailed information about RCMs is provided in Appendix C, but in brief the retrofit involved:

- Replacing the lead DHW boiler with a condensing model
- Replacing the domestic cold water (DCW) booster pump and adding a variable speed drive
- Installing variable frequency drives (VFDs) in both make-up air units (MAUs)
- Installing programmable thermostats
- Installing a metering and control system
- Installing LED-equivalent fixtures and replacing existing fluorescent lamps with reduced wattage T8 fixtures
- Installing occupancy sensors in garbage and laundry rooms
- Installing low-flow aerators and toilets
- Replacing weatherstripping of entry and exterior doors
- Installing a water flow management device to eliminate excess water pressure and turbulence through the main water meter
- Replacing the lobby air conditioning unit with a split variable refrigerant flow (VRF) system
- Conducting resident training and education regarding energy efficiency and water conservation best practices

Based on the outlined RCMs, the projected annual carbon emission reduction was 75 tonnes, representing a 23 per cent reduction.

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

RCM	Reason for Exclusion
Rooftop solar panels	Not financially feasible due to changes to the incentives offered through the Ontario Power Authority's Feed-In Tariff program
Solar wall	Impractical due to the high amount of glazing in the building envelope, which would require covering residents' windows
High-efficiency motors	Not financially feasible due to the size of the existing motors and the cost of replacing them. Run time too low for high-efficiency motors to be cost effective

Table 1: RCMs not installed

Project Financials	Value
Total project cost	$473,400
Total incentives	$157,800
Net cost	$315,600
Projected utility cost savings	$43,850

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.

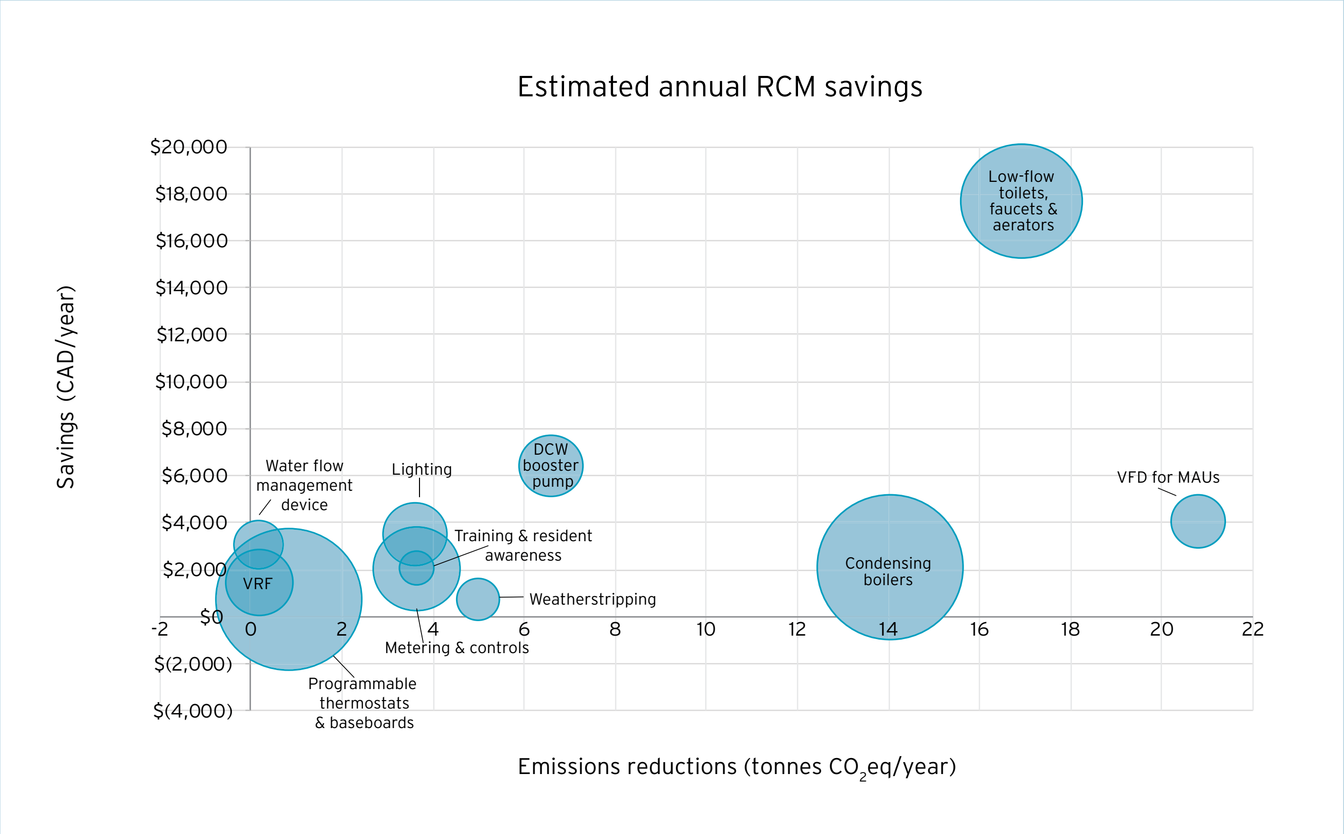


Figure 1: Estimated annual RCM savings, carbon emissions reductions, and measure costs

A number of measures across all three utilities were implemented to reach the project's goals. Some of these measures have impacts on multiple utilities; for example, measures that reduce DHW use will result in both water and gas savings.

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). As part of the ESPA™, 90 per cent of the expected utility cost savings were guaranteed through an insurance product available from Energi of Canada. There was also an opportunity to take advantage of available utility incentives for some of the upgrades via the agreement. Post-retrofit cost savings are shared between TAF and Perth Co-op for a period of 10 years, based on the ESPA™ agreement. After the 10-year agreement concludes, 100 per cent of the cost savings are transferred to the co-op.

Energy Monitoring

Utility meters for electricity (Toronto Hydro), natural gas (Enbridge Gas), and water (City of Toronto) were used to monitor whole building energy and water consumption. In addition, a real-time metering system was installed to collect electrical, gas, and water readings from those utility meters as well as electricity consumption of the MAUs and DCW booster pumps. Further to the utility meters, one gas meter was installed on the gas line to the new condensing boiler and another meter was installed on the gas line to the existing boiler. Flow meters were installed on both boilers as well as on the DCW line feeding the two boilers. Temperature sensors were installed on either side of the boilers to monitor the supply and return temperatures. Table 3 summarizes the building sub-metering points.

Metering Point	Resource Metered	Metering Interval
Whole building	Natural gas, electricity, water flow	1-minute
MAU 1	Electricity	1-minute
MAU 2	Electricity	1-minute
DCW booster pump	Electricity	1-minute
DCW booster pump	Water flow	15-second
Condensing boiler	Natural gas	15-second
Return water for condensing boiler	Water flow	15-second
Supply and return water for condensing boiler	Temperature	15-second
Existing boiler	Natural gas	15-second
Existing boiler return water	Water flow	15-second
Existing boiler supply and return water	Temperature	15-second

Table 3: Metering parameters

Project Energy, Water, and Carbon Emission Performance

This section presents the post-retrofit utility savings and emissions reductions related to the various RCMs implemented. Given the meters in place and the timing of the installations, it was possible to evaluate the individual performance of the DCW pump, MAUs, and low-flow fixtures.The boiler performance and operating efficiencies were also evaluated separately and are described in this section.

When examining utility savings, it's important to consider both cost savings and emissions reductions. Figure 2 below provides a visual comparison, illustrating that the RCMs which provide the most cost savings may not generate sufficient emissions reductions to meet the project's carbon reduction goals — hence the balanced approach used. For example, reducing natural gas use may not save a huge amount on gas bills but will greatly reduce carbon emissions; adding in water efficiency measures greatly increases cost savings and the business case for the retrofit.

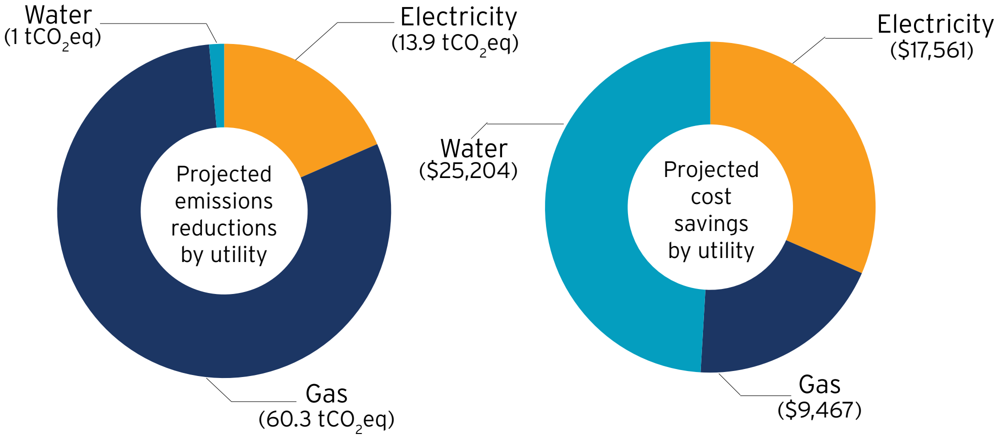


Figure 2: Projected emissions reductions and cost savings for the first year of post-retrofit operation at the site

TOTAL RESOURCE SAVINGS

Resource savings were higher than projected for all three resources in the first and second year of monitoring. The most significant savings were seen in water use, followed by electricity, and then natural gas. Gas and water savings decreased slightly in Year 2, while electricity savings increased from Year 1 to Year 2.

Overall, the average annual utility cost savings were $81,300. Savings exceeded projections by 61 per cent in the first year and 54 per cent in the second year. Based on Year 1 and Year 2 performance, the installed RCMs reduced the building's total EUI by approximately 36 per cent. A full table of the reported parameters including the emission factors used can be found in Appendix E.

Electricity

Electricity savings in the first two years averaged $22,074 a year, with an **average annual carbon reduction of 20 tCO_2eq**. This electricity use reduction resulted in an average of 119,609 kWh, or 24 per cent savings over the adjusted baseline. These savings are a culmination of numerous measures including DCW booster pump replacement, lighting retrofits and MAU upgrades.

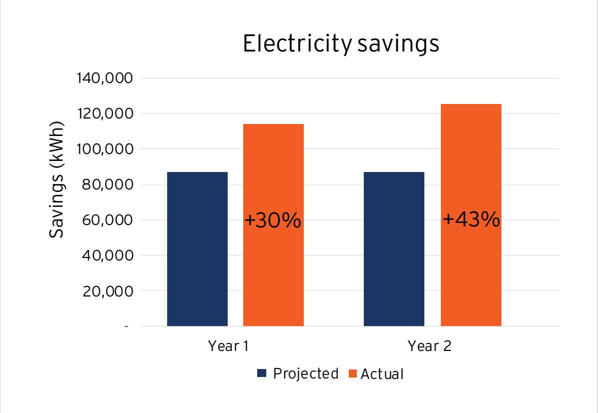


Figure 3: Projected and actual electricity savings for Year 1 and Year 2

	Utility Savings (kWh)	Cost Savings	Emissions Reductions (tCO_2eq)
Year 1	113,963	$23,023	18.38
Year 2	125,254	$21,124	21.90
Average	119,609	$22,074	20.14

Table 5: Electricity savings

Natural Gas

Natural gas savings represented the vast majority of carbon emissions reductions, with **average reductions of 79.4 tCO_2eq per year.** Due to the low utility cost for natural gas, these measures resulted in the smallest cost savings, averaged at only $12,416 annually. Natural gas savings can largely be attributed to the boiler and MAU retrofits. There was also a derivative effect of lower DHW usage (resulting from low-flow showerheads and aerators), which contributed slightly to natural gas savings.

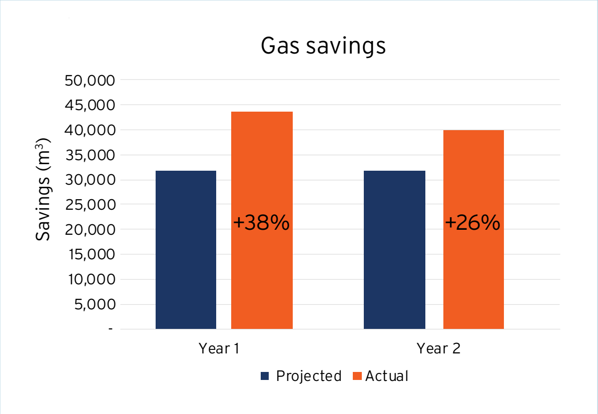


Figure 4: Projected and actual natural gas savings for Year 1 and Year 2

	Utility Savings (m^3)	Cost Savings	Emissions Reductions (tCO_2eq)
Year 1	43,722	$12,986	83.03
Year 2	39,903	$11,846	75.78
Average	41,813	$12,416	79.40

Table 6: Gas savings

Water

Water savings significantly exceeded projections in the two years of post-retrofit monitoring. These measures saved an average of 13,166 m^3 of water, 45 per cent of the building's annual consumption. This may be in part due to reductions in water leakage from toilet flapper valves that were not included in the projections. Water measures also resulted in the largest cost savings, exceeding projections by an average of 82 per cent per year. Water savings contributed minimally to emissions reductions, with an **average of 1.97 tCO$_2$eq of reductions annually**.

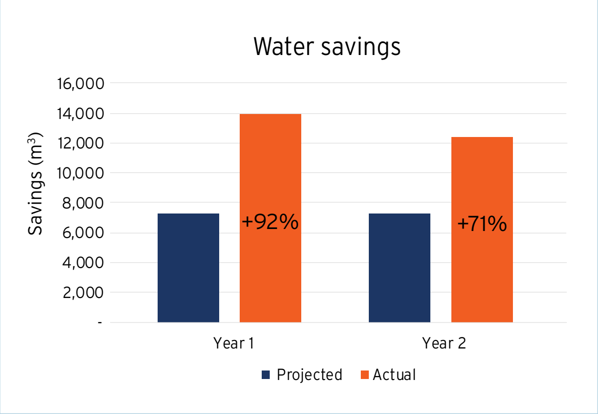


Figure 5: Projected and actual water savings for Year 1 and Year 2

	Utility Savings (m^3)	Cost Savings ($)	Emissions Reductions (tCO$_2$eq)
Year 1	13,901	$48,308	2.09
Year 2	12,431	$45,375	1.86
Average	13,166	$16,485	1.97

Table 7: Water savings

INDIVIDUAL MEASURE DESCRIPTION AND PERFORMANCE

Domestic Cold Water Booster Pumps

Prior to the retrofit, the operation of the existing booster pumps for the DCW required improvement; both pumps ran continuously when a drop in water pressure occurred, even though the pumps were designed to allow two stages based on pressure needs. The existing booster pumps were replaced with a more efficient variable speed drive model supplemented with a cushion tank as a pressurized storage buffer. The cushion tank allows the pumps to turn off completely during low-flow periods, while the variable speeds allow the pumps to use less energy to supply intermittent demands.

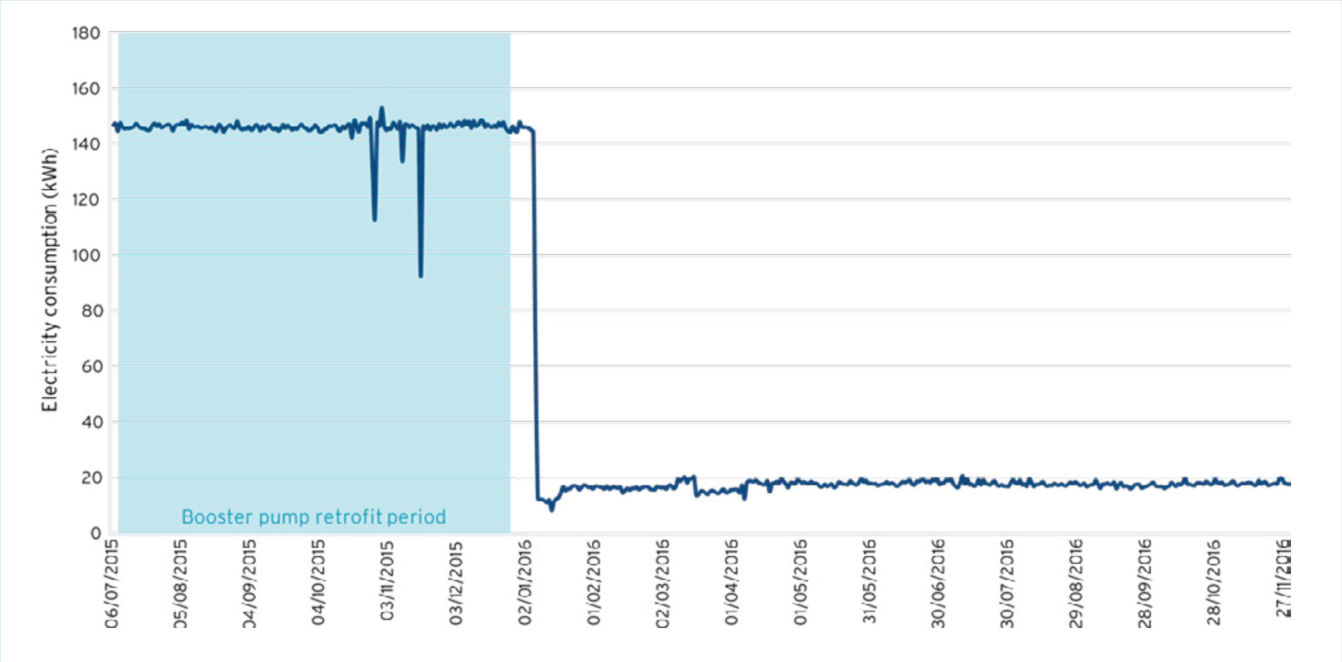


Figure 6: Daily booster pump electrical consumption

Figure 6 shows an immediate reduction in the electrical consumption after the measure installation date of December 31, 2015. The booster pump's daily electricity consumption dropped approximately 88 per cent. The booster pumps were decommissioned in two stages. The first booster pump was turned off, causing daily consumption to drop from 250 kWh to 150 kWh. The VFD was installed in the first week of January, which triggered a second drop from 150kWh to 18kWh. This RCM resulted in a total of 48,011 kWh savings between March and November 2016 when compared to the pre-retrofit period.

Make-Up Air Units

Fresh air is provided to the building through two 3,450 CFM MAUs, with a 1.5 hp fan motor. Prior to retrofits, the two MAUs supplied a constant quantity of air regardless of indoor conditions. The units were approximately 1.5 years old at the start of this project, and in otherwise good condition, so there was no need to replace them. Instead, VFDs were installed on MAUs to vary the amount of fresh air supplied from a pre-set schedule. Figure 8 shows the daily electrical consumption of the MAUs before, during, and after the retrofit period. Work began on July 1, 2015 and was completed on December 31, 2015. The energy consumption averages decreased from 48 kWh per MAU per day to 11 kWh per MAU per day once the VFDs were commissioned in February.

Figure 7: MAU on the roof

The total electricity savings associated with the MAU retrofit, calculated as the difference of consumption between the pre-retrofit period (March-November 2015) and the post-retrofit period (March-November 2016), were approximately 20,033 kWh per year; more than twice the projected electricity savings (see Appendix D).

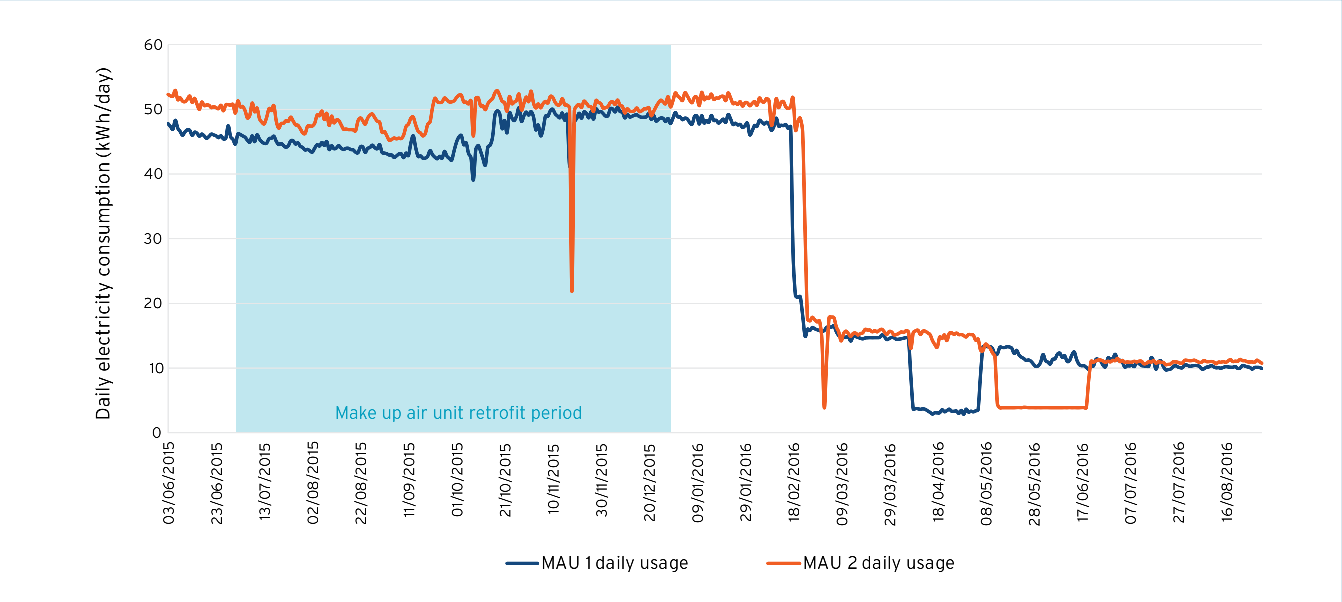


Figure 8: Daily MAU electrical consumption

In addition to reducing energy consumption, introducing VFDs can also reduce the amount of natural gas needed for conditioning the supply air in the winter months. The control improvements made to the MAUs are estimated to save approximately 50 m^3 of natural gas per day in the heating season.

Low-Flow Water Fixtures

New toilets, low-flow faucet aerators, and low-flow showerheads were installed to reduce water consumption in the building. First, existing six-litres-per-flush toilets were replaced with new toilets that consume only three litres per flush. Next, faucets were retrofitted with aerators, reducing the rated flows from 7.6 litres-per-minute to 5.7 litres-per-minute in the kitchen faucets and 3.8 litres-per-minute in the washrooms. Finally, 9.5-litres-per-minute showerheads were replaced with 5.7-litres-per-minute showerheads.

The reduction in water consumption from the pre-retrofit average of approximately 81 m^3/day to 43 m^3/day can be observed in Figure 9. Actual water savings were higher than the projected annual savings of 5,170 m^3. Water savings were 7,121 m^3 for six months in 2015 and 12,697 m^3 in 2016.

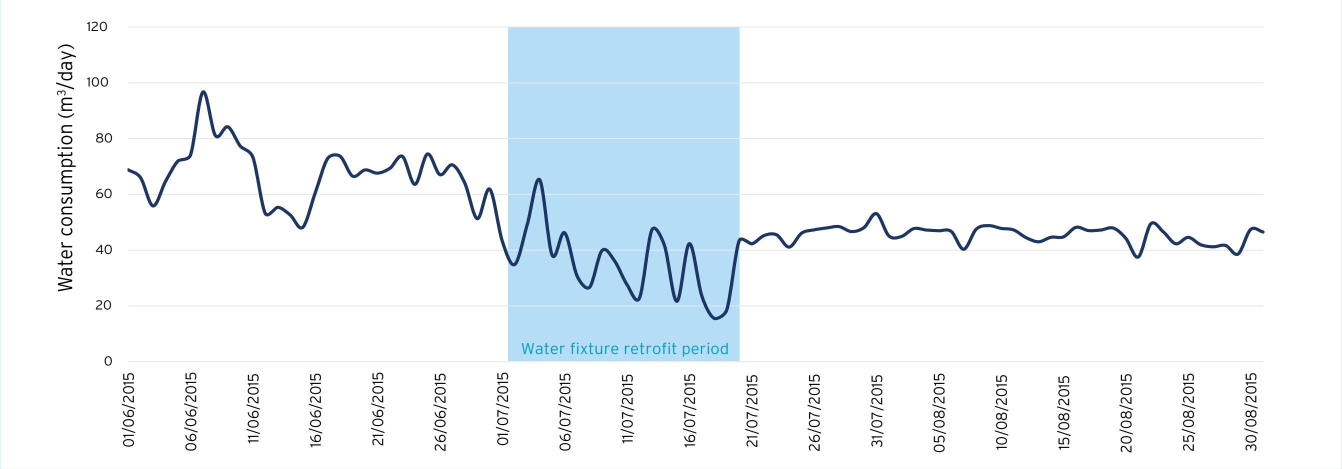


Figure 9: Daily average water consumption

The higher than expected savings are likely due to a reduction in water leakage. For instance, original estimates did not take into account the potential for savings stemming from reduced toilet leakage through the flapper valves. The significance of leakage savings may be estimated by analyzing hourly average water consumption when occupant usage is at a minimum. As shown in Figure 10, the average relative difference between the pre- and post-retrofit hourly water consumption was 21 per cent cumulatively; however the relative difference was 43 per cent during the lowest usage times of 2-5 a.m.

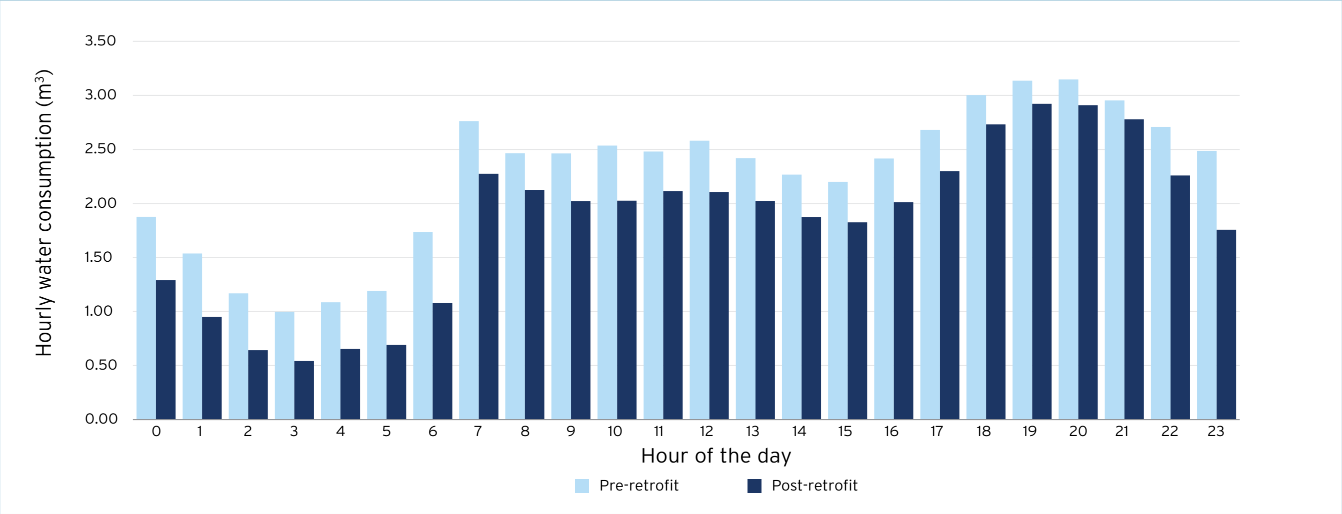


Figure 10: Hourly average water consumption[i]

In addition to water savings, water efficiency measures that target DHW use (in this case faucet aerators and low-flow shower heads) also reduce the natural gas required for meeting the DHW demand as well as the associated emissions. Reduced hot water consumption is estimated to save an additional 25m^3 of natural gas per day.

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[i] Pre-retrofit hourly consumption calculated from November 13, 2014 to July 2, 2015. Post-retrofit hourly consumption calculated from July 20, 2015 to December 1, 2016.

Condensing Boilers

Two natural gas boilers are used to heat the building's DHW and makeup air. The lead boiler was a Teledyne Laars with a maximum input of 600 MBTU/h, which was in poor condition and appeared to be original to the building. The secondary boiler was an RBI boiler with a 750 MBTU/h input capacity and was 5-10 years old at the start of the project.

During the retrofit, the existing lead boiler was replaced with a new high efficiency Laars Neotherm condensing boiler, while the secondary boiler remained. Boiler sizing analysis was performed to determine the optimal boiler size. A 750 MBTU/h boiler was selected as the size that would be able to accommodate demands the majority of the time, reducing the need to use the less efficient boiler.

Figure 11: A Laars Neotherm boiler (right) was installed as the primary boiler

The Laars Neotherm condensing boiler was installed as the primary boiler to heat water for the building's DHW needs as well as to heat intake air for the building. In addition, both boilers were modernized with updated control systems. A control panel was installed to adjust burner output, stage the boilers to optimize performance, and set a supply water setpoint based on the hot water storage tank temperature.

Prior to the retrofit, existing boilers were operating at low efficiencies within the 70-75 per cent range. The boiler upgrades were completed on February 29, 2016. The Laars Neotherm boiler has a rated thermal efficiency as high as 96.6 per cent and a 5 to 1 turndown ratio which will allow the boiler to respond efficiently to changes in heating demand.

Figure 12 shows natural gas consumption in 2015 and 2016. The average daily consumption decreased from 358 m^3 pre-retrofit to 234 m^3 post-retrofit.

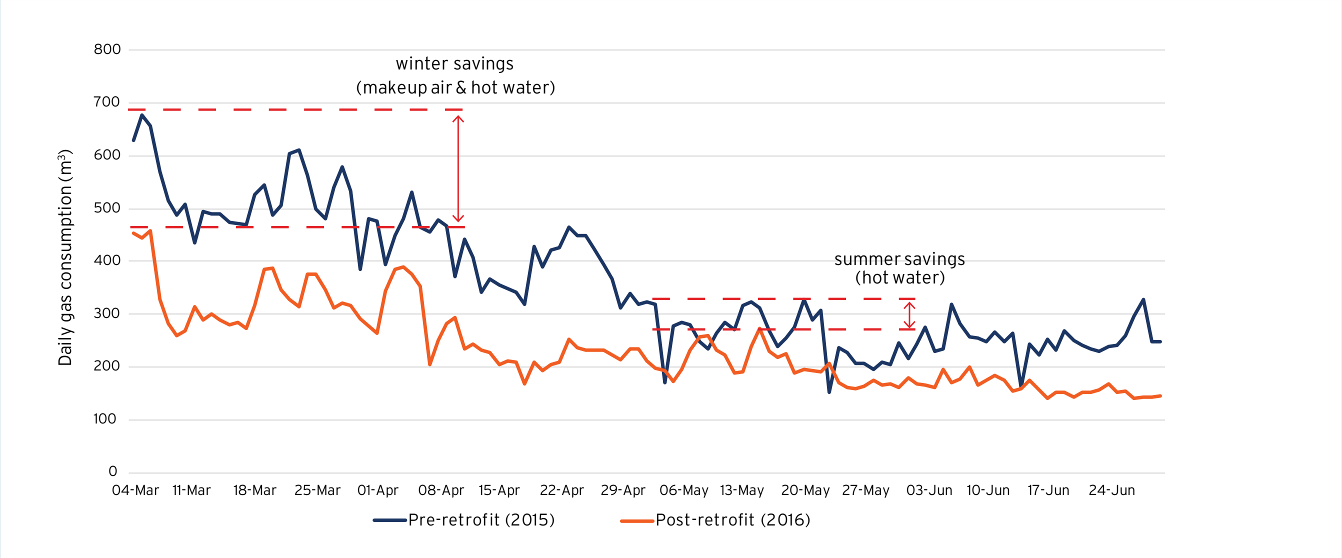


Figure 12: Daily natural gas consumption, pre- and post-retrofit from March to June

Natural gas savings varied by season: as expected gas consumption (and savings) was greater in the heating season when pre-heating make-up air was required. The installation of low-flow faucets and showerheads led to reduced gas consumption throughout the year.

Lighting

The common areas had a variety of CFL, incandescent and halogen lamps. These were converted to LED wherever possible. Other common area lighting included 4 ft. T12 linear fluorescent fixtures with magnetic ballasts, while hallway lighting consisted of 2 ft. T8 fluorescent fixtures with electronic ballasts. Magnetic ballasts were replaced with electronic ballasts, and all 4 ft. lamps were replaced with 25W T8 fixtures. In the garage, 32W T8 lamps with electronic ballasts provided the lighting. These were already controlled by occupancy sensors in certain zones, and therefore no changes were made.

Figure 13: Examples of exterior LED lighting

Programmable Thermostats and Baseboards

Prior to the retrofit, each apartment was electrically heated by a series of baseboard radiators. In the living room of each suite, the radiator was controlled by a non-programmable, wall-mounted thermostat whereas the bedrooms had integral thermostatic controls. Common areas were either heated by electric baseboards controlled by non-programmable thermostats, or by force-flow heaters with integral controls.

In order to reduce electricity consumption, the electric baseboards were replaced with newer electric baseboards and programmable thermostats, with a nighttime setback schedule. Though individual performance of this RCM was not measured, the project team estimates that this RCM combined with lighting retrofits resulted in an average of 15 per cent electricity savings in winter months.

Figure 14: New electric baseboard

Metering and Controls

Prior to the retrofit, there was no central system for controlling, tracking, and monitoring the various building systems. All major mechanical and terminal heating equipment were operated under individual controls. The project team proposed moving towards a centralized direct digital control system, which would allow for finer tuning of the various equipment's operation parameters and scheduling and would reduce the need for troubleshooting and maintenance time.

In order to provide an improved, centralized control system a number of upgrades were needed. These included new sensors which would allow the system to take control of the equipment; additional system architecture such as control panels, wiring, relays, and communication devices; a new workstation with expanded software and updated graphical user interface; and a web-based real-time monitoring system. In addition, the building operator needed to be trained to operate this new system.

Weatherstripping

While the building envelope was in decent condition, most common doors had either damaged or missing seals. Some doors were damaged and required replacement, as air infiltration through the envelope can have significant energy impacts through both heat loss and moisture infiltration.

Variable Refrigerant Flow System

Prior to the retrofit, the main entrance lobby was conditioned by a self-contained water-cooled air conditioning unit located in the ceiling space. The unit had an estimated capacity of one ton. In order to reduce the amount of electricity and water used for cooling this space, an air-cooled split variable refrigerant flow system was introduced.

Water Flow Management Device

Air bubbles found in the DCW piping can cause turbulent flow. As water meters record both the volume of water and the volume of air passing the meter, this can artificially inflate the recorded water consumption. A solution is to install a water flow management device, which creates backpressure through the water meter assembly in the main water line, thus eliminating excess water pressure and turbulence, resulting in more accurate readings.

This measure was projected to have an annual cost savings of $3,050, giving it a simple payback of only three years.

Training and Resident Awareness

Training both technical and non-technical building staff on the new energy efficiency features of their building is critical to realizing the anticipated savings. Training allows building operations staff to increase efficiencies, identify opportunities for energy-savings measures, and raise awareness of energy efficiency with the non-technical staff. Research shows that, when properly implemented, training and awareness can result in four to 20 per cent energy savings.[1]

In this case study, project engineer Finn Projects led the delivery of a resident awareness program focused on energy efficiency and water conservation, in addition to training the building staff. They took a two-pronged approach, employing in-person information sessions as well as displays and information packages. The information sessions included introduction to the energy efficiency measures implemented and their benefits, as well as tips on how residents can modify their behaviour to further reduce resource consumption. The displays and information packages focused on the key messaging and tips from the information sessions, and serve as reference for all residents, including new tenants.

A conservative estimate predicts training and resident awareness will reduce Perth Co-op’s annual energy costs by one per cent annually.

Financial Performance

Actual cost savings surpassed projections. The majority of these added cost savings were due to the greater than expected water savings from fixture and toilet replacements. The second largest factor in helping achieve the high savings was electricity.

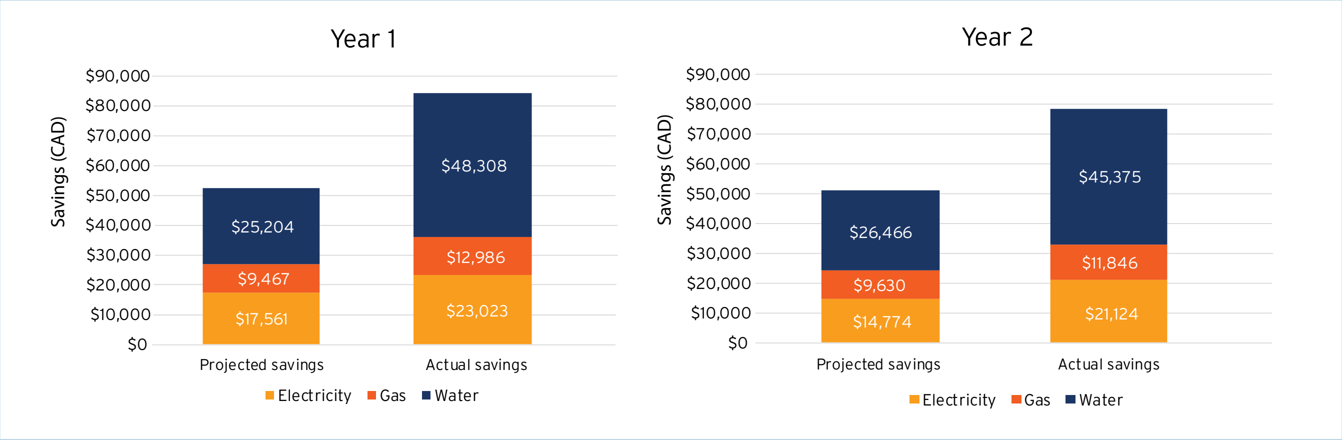


Figure 15: Cost savings by utility

Table 6 summarizes the resulting internal rate of return, return on investment, net present value and simple payback. Based on these parameters, the project has fared well financially.

Financial Summary		
	Projected	**Actual**
Year 1 cost savings	$43,850	$84,317
Net present value [ii]	$348,606	$961,569
Internal rate of return	15%	29%
Simple payback	7.2 years	3.7 years
Return on investment [iii]	202%	481%

Table 6: Summary of financial parameters[iv]

[ii] Discount rate of 4 per cent.

[iii] Based on average project lifetime

[iv] 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.

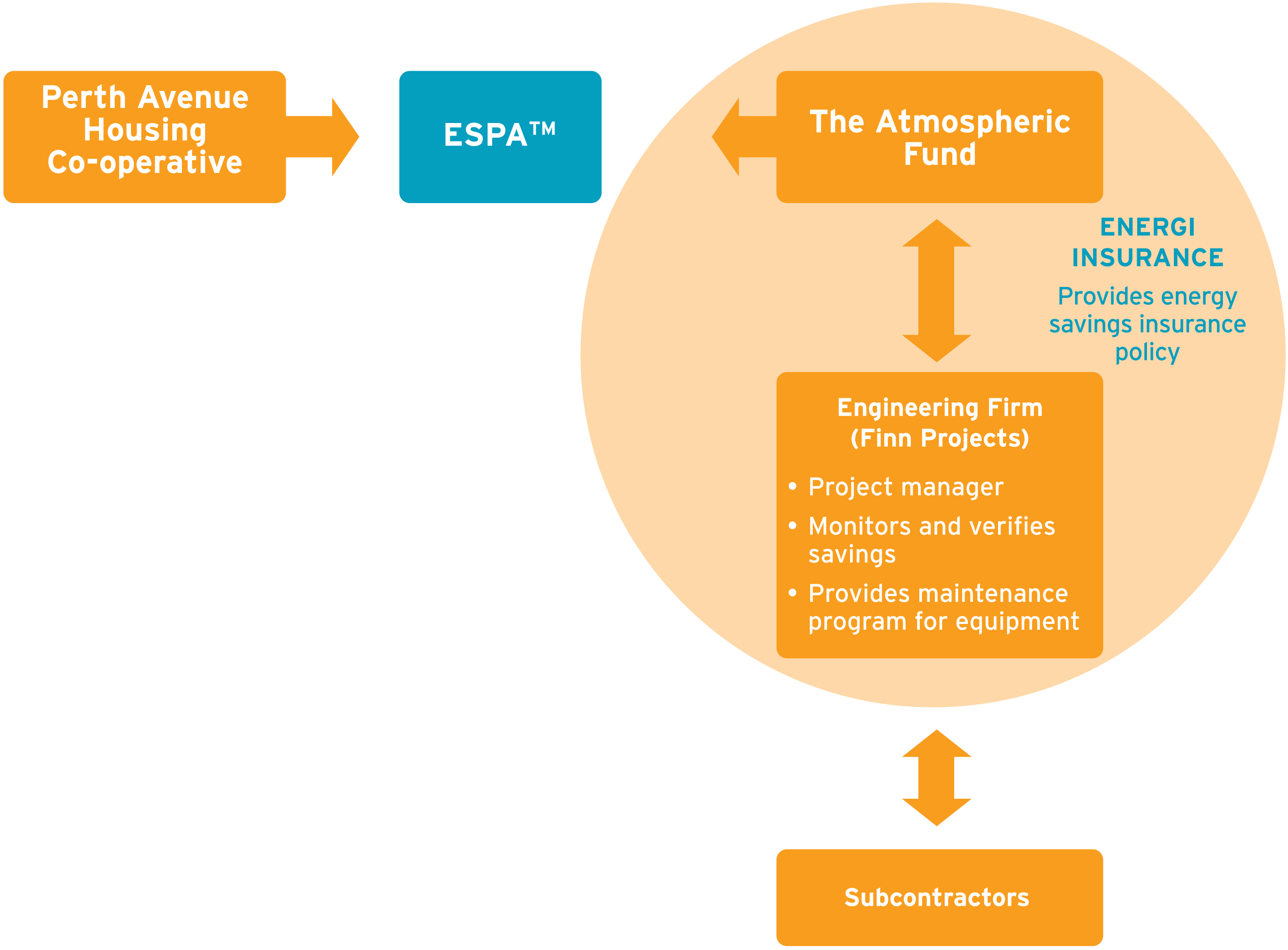
Recommendations

The retrofit of the Perth Avenue Housing Co-operative has exceeded expectations; two years of post-retrofit data reveal that RCMs are performing at or above projections. Based on TAF's experience with large-scale retrofit projects at Perth Co-op and other multi-residential sites, the following are some best practice recommendations that can be applied to projects in the future:

- **Integrate multiple measures.** Integration across utilities enhances savings, improves financial performance, and reduces risk of underperformance. In order to achieve emissions and cost savings reductions simultaneously, a balanced retrofit approach is needed.
- **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.
- **Sequence work accordingly.** Understanding how systems affect one another and sequencing work accordingly can help avoid duplication and unnecessary effort. For example, in order to conduct mechanical work in the building there were times that the building's water supply had to be shut down. When this happens the debris on the inner walls of the pipes (like calcium deposits) falls to the bottom of the pipe. When the water is turned back on, this debris flows through the pipes and can clog the aerators in the resident's suites. For this reason, old aerators should be replaced after the mechanical installations have been made.
- **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. Moreover, to get the best uptake of any new technologies, information sessions are necessary. On this project an information session was conducted with all residents at the end of substantial completion of the baseboard measure. However, upon reflection, the project team believes that educating residents prior to installation and then again once installation was completed would have improved residents' feeling of familiarity with the new system.
- **Understand resident needs including accessibility.** After the thermostat controls for the unit's baseboard heaters were installed, one resident with a visual impairment did not feel comfortable operating their new thermostat. Large coloured stickers have since been created to help with button identification. Knowledge of residents' additional needs before installation could have allowed the team to explore more options. By including questions around resident needs as part of the preliminary audit, the project team can address these needs earlier on in the design process.

- **Continuous commissioning is critical.** Commissioning and ongoing optimization is critical in ensuring 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 is critical to long-term project success and 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 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.

Appendix A: ESPA™ Structure



Perth Avenue Housing Co-operative

ESPA™

The Atmospheric Fund

ENERGI INSURANCE

Provides energy savings insurance policy

Engineering Firm (Finn Projects)

- Project manager
- Monitors and verifies savings
- Provides maintenance program for equipment

Subcontractors

Appendix B: Pre-Retrofit Building Information

Building Type	Co-operative
Name and Address	Perth Avenue Housing Co-operative 120 Perth Avenue Toronto, ON
Year of Construction	1987
Major Renovations	Two new MAUs in 2012
Number of Storeys	8 and 4
Parking Levels	1 underground, not heated
Number, Type of Units	102 (1, 2, and 3 bedrooms)
Gross Floor Area	~12,000 m^2
Heating	Residences electrically heated with baseboards, controlled by wall-mounted non-programmable thermostats (living rooms) or integral controls (bedrooms). Common areas heated with electric baseboards. Mechanical and utility rooms heated by electrical baseboard heaters and unit heaters (71 kW total load).
Cooling	No central cooling. Approximately half the apartments had window air conditioning units (estimated at 35 tons). Main lobby is cooled with one-ton self-contained water cooled air conditioning unit in the ceiling. Upper penthouse elevator machine room had a 1.5-ton DX fancoil unit.
Domestic Hot Water	Two gas fired DHW boilers, single 450-gallon horizontal storage tank. One boiler (750 MBTU/hr) was 10 years old while the second (600 MBTU/hr) was original to building. Two booster pumps rated at 200 gpm were run together (one had a 5 hp motor, the other had a 7.5 hp motor).
Ventilation	Two gas-fired MAUs on roof installed in December 2012. Each unit was rated at 3,450 CFM and operates continuously. Each apartment had individual kitchen and bathroom exhausts that are switch operated. Parking garage had a single propeller exhaust fan with a 1.5 hp motor.
Miscellaneous Equipment/ Facilities	Garage ventilated by single axial-type fan, no central controls; all heating and ventilation is self-contained.

Appendix C: RCM Costs

Resource Conservation Measures	Gross Cost[v]	Incentives	Net Cost	Projected Annual Savings	Asset Lifetime[vi]
Condensing boiler and mixing valve	$83,300	$2,950	$80,350	$2,100	25 years
DCW booster pump with VSD	$29,800	$14,900	$14,900	$6,400	15 years
Install VFD in MAUs	$25,700	$14,900	$10,800	$4,050	15 years
Programmable thermostats and electric baseboard upgrades	$159,400	$79,700	$79,700	$800	20 years
Metering and control system	$54,900	$27,450	$27,450	$2,050	16 years
Lighting upgrades	$30,800	$15,400	$15,400	$3,500	10 years
Low-flow aerators and toilets	$51,700	$1,300	$50,400	$17,650	15 years
Weatherstripping	$6,600	-	$6,600	$750	8 years
Main water meter valve	$9,000	-	$9,000	$3,050	20 years
Air-cooled split VRF system	$17,200	$500	$16,700	$1,450	15 years
Resident training and education	$5,000	$700	$4,300	$2,050	10 years
Total	**$473,400**	**$157,800**	**$315,600**	**$43,850**	**-**
Simple payback			7.2 years		
NPV			$348,606		
IRR			15%		

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[v] Excludes engineering and design fees.

[vi] Lifetime of asset is estimated by FINN Projects, Ecosystem, ASHRAE.

Appendix D: Projected RCM Savings

Resource Conservation Measures	Projected Annual Savings Electricity (kWh)	 Natural Gas (m^3)	 Water (m^3)	 Carbon Emissions (tCO_2e)
Condensing boiler and mixing valve	-	7,390	-	14
DCW booster pump with VSD	41,400	-	-	7
Install VFD in MAUs	7,250	10,340	-	21
Programmable thermostats and electric baseboard upgrades	5,200	-	-	1
Metering and control system	5,150	1,460	290	4
Lighting upgrades	22,550	-	-	4
Low-flow aerators and toilets	-	8,480	5,170	17
Weatherstripping	-	2,630	-	5
Main water meter valve	-	-	1,040	-
Air-cooled split VRF system	700	-	460	-
Resident training and education	5,150	1,460	290	4
Total	**87,000**	**31,760**	**7,250**	**75**

Emissions Factors[2]	
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
DCW booster pump	Option C - Electricity	
MAUs	Option A - Electricity Option C - Gas	
VRF System	Option C – Electricity Option C – Water	
Lighting	Option C - Electricity	
Condensing boilers	Option A - Gas	Option A - Gas
Low-flow toilets, faucets and aerators	Option C - Water	
Water flow management device	Option C - Water	
Programmable thermostats and baseboards	Option C - Electricity	

Appendix F: Equipment Details

Equipment	Manufacturer	Quantity	Description
Condensing DHW boiler	Laars	1	Neotherm
Heat pump	Mitsubishi	1	SEZ-KD18NA4 and SUZ-KA18NA
Electric baseboard radiators	Dimplex	436	350-2000W
Toilets	Proficiency		N7717 and N7717 SR
Showerheads	Niagara conservation	76 26	Handheld (N3210BFTP-PC-T) Fixed
Faucet aerators	Niagara conservation	108 102	Washroom (N3215BFTP-PC-T) Kitchen (N3210BFTP-PC-T)
Utility consumption monitor	Emmit	1	N/A
Boiler controls	Johnson controls	1	N/A
Water flow management device	H2 Minus O	1	N/A

Appendix G: Monitoring Details

Type	Manufacturer and Model	Range		Operational Accuracy	
		Min	Max	At Min Flow	At Max Flow
Condensing boiler gas flow	Sierra, Quadra Therm 780i	0	5.4m^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
Non-condensing boiler gas flow	Avensis Solution, FCI ST75V-2 Flow Meter	1.40 SCFM	559.27 SCFM	± 1% reading, ± 0.5% full scale	
Temperature sensor	3-wire 100 Ohm Platinum RTD Temperature Sensor	0°C	80°C	0.18C (0.12 sensor+ 0.152 transmitter)	
Water flow meter	Inline Krohne Magnetic Flow Meter				

Appendix H: Utility Savings

Year	Utility	Consumption			Actual Savings
		Baseline	Projected	Actual	
Year 1: March 2016 – February 2017	Electricity (kWh)	490,786	403,388	376,823	113,963
	Gas (m³)	129,536	97,775	85,814	43,722
	Water (m³)	29,453	22,202	15,552	13,901
Year 2: March 2017 – February 2018	Electricity (kWh)	500,351	412,953	375,097	125,254
	Gas (m³)	133,888	102,127	93,985	39,903
	Water (m³)	29,453	22,202	17,022	12,431

References

[1] National Resources Canada, "Energy Management Training Primer", 2016.
https://www.nrcan.gc.ca/sites/www.nrcan.gc.ca/files/oee/files/pdf/publications/commercial/EMT_Primer_en.pdf

[2] 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