Retrofitting R.J. Smith Apartments

A TOWERWISE CASE STUDY

TAF The Atmospheric Fund

About The Atmospheric Fund

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

Visit taf.ca for more information

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Ontario Toronto

Executive Summary

Through the TowerWise program, The Atmospheric Fund accelerates retrofits targeting significant energy and carbon emission reductions across the multi-unit residential building sector. 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 to undertake retrofits in seven buildings on three sites ('the portfolio'). This case study is looking at one of those sites, R.J. Smith Apartments. The buildings were constructed in 1965 in Etobicoke; 101 and 121 Kendleton Drive are identical seven-storey buildings of predominantly studio suites and 111 Kendleton is an 11-storey building with some multi-bedroom suites, primarily home to seniors. In total there are 471 suites at R.J. Smith Apartments, with a total gross building area of 25,950 m^2.

To support the implementation of a variety of resource conservation measures targeting all fuel types 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™). Energy retrofits at R.J. Smith Apartments (101, 111, and 121 Kendleton) were financed through the ESPA™.

The retrofit conservation measures targeted all resource types:

Gas

- New condensing boilers
- Existing domestic hot water boiler recommissioning

Electricity

- LED lighting retrofit (interior, exterior)
- Occupancy sensors
- Variable frequency drives on domestic cold water booster pump

Water

- Ultra-low flow 3L toilets

Key outcomes at R.J. Smith Apartments

- **$123,957** annual cost savings
- **212 tCO_2eq** emissions reductions
- **7.1 year** simple payback and **9.2 per cent** IRR over 10 years.

Key recommendation

Integrate multiple measures. Integration across utilities enhances savings, improves financial performance, and reduces risk of underperformance.

Content

R.J. SMITH APARTMENTS RETROFIT 5

ENERGY AND WATER CONSERVATION MEASURES 8

ENERGY AND IEQ MONITORING 11

PROJECT ENERGY, WATER, AND CARBON PERFORMANCE 12

- Total Resource Savings 12
  - Electricity 13
  - Natural Gas 13
  - Water 14
- Individual Measure Performance 15
  - Condensing Boilers 15
  - Domestic Hot Water Recommissioning 16
  - Lighting 16
  - Ultra-Low Flow Toilets 17
  - Duct Cleaning 17
  - Supplemental Equipment 17

FINANCIAL PERFORMANCE 18

RECOMMENDATIONS 19

APPENDICES 21

REFERENCES 31

R.J. Smith Apartments 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) with typical central heating, hot water, and ventilation systems. Similar to many other MURBs of this vintage, these buildings experienced a number of operational challenges like poor thermal control, under-ventilation, and high energy consumption. This case study focuses on three of the seven TCH buildings that were retrofitted, at 101, 111, and 121 Kendleton Drive in Etobicoke (R.J. Smith Apartments).

TAF retrofitted R.J. Smith Apartments between 2015 and 2018 in order to improve the site's utility performance and indoor environmental quality (IEQ), reduce carbon emissions, and bring down future maintenance and operating costs.

Spotlight on local job creation

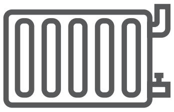
We worked with Building Up on this project. Building Up connects housing providers with skilled labourers from the local community to improve Toronto's environmental efficiency and affordable housing stock, and create a real pathway for individuals experiencing barriers to enter apprenticeships and careers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

buildingup.ca

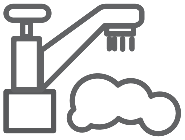
Built in 1965, 101 and 121 Kendleton are twin seven-storey buildings with studio suites, while 111 Kendleton is an 11-storey building and includes some multi-bedroom units; it is predominantly home to seniors. In total there are 471 suites across the three buildings, for a gross building area of 25,950 m^2.

R.J. Smith Apartments: centralized systems, concrete construction

The apartment buildings are concrete construction with original brick cladding. The windows are aluminum frame with single panes, and each suite has storm doors that lead out to a balcony, or a patio in the case of first-floor suites.



Before the retrofit, two 9.8 MMBH boilers, located in the basement of 121 Kendleton, provided heat to all three of the buildings. Seven pumps ranging from 1.5 to 5 hp circulated the hot water through two zones at each of the three buildings. The boilers and pumps were started manually at the beginning of each heating season, running 24 hours a day until the heating season was over.

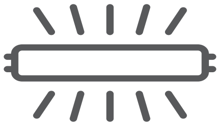


Domestic hot water (DHW) is produced locally in the penthouse mechanical room of each building by a pair of 600 MBH boilers. At the beginning of this project the DHW boilers at 101 and 121 Kendleton were approximately two years old, and in good condition. In contrast, the DHW boilers at 111 Kendleton were 10-12 years old and site staff noted a number of issues with them, such as flame failure.

Typical of most buildings of this vintage, R.J. Smith Apartments are ventilated through a pressurized corridor system, with 100 per cent fresh air make-up air units feeding into the hallways. Ventilation surveys found that the ventilation systems were operating well below their maximum efficiency. At 101 and 121 Kendleton, the make-up air units are equipped with gas burners for pre-heating, whereas at 111 Kendleton the make-up air units are capable of both heating and cooling. Each suite is exhausted through a vent in the bathroom; there is no kitchen exhaust.

Pre-retrofit site EUI:

318.0 ekWh/m^2



At 101 and 121 Kendleton, 1x32W T8 and 1x40W T12 fixtures made up the corridor lighting. At the suite level, the kitchen is lit by two fluorescent one-lamp fixtures, 40 per cent of which are T12, which are being switched to T8 as replacements are needed. The rest of the suite is lit by 9W CFL fixtures. At 111 Kendleton corridor lighting was provided by 2x13W CFL fixtures while the suites contain 9W CFLs. The lighting levels at 111 Kendleton were well above code.

Overall, the building had a pre-retrofit energy use intensity of 318.0 ekWh/m^2, which is close to that of a typical MURB in Ontario.[1]

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

Energy and IEQ challenges needed to be addressed

As discussed above, there were numerous energy challenges across the site, like non-modulating, non-condensing boilers; no in-suite heating controls, which led to residents opening their windows even in winter; and inefficient lighting and ventilation systems.

Not only did overheating at the buildings result in wasted energy, it also created poor thermal comfort for residents. Average pre-retrofit interior temperatures were 26.0-26.8°C in the shoulder seasons (spring and fall), which is when the majority of overheating was concentrated. Shoulder season temperatures were above 26°C for 62 per cent of the time pre-retrofit; this decreased to 44 per cent of the time post-retrofit. This monitoring aligns with over-heating concerns that residents had expressed on the pre-retrofit resident survey. As extended exposure to high temperatures has been shown to influence mortality and morbidity rates[2], reducing over-heating has real human health benefits. Addressing this challenge became a priority of the 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

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

TAF The Atmospheric Fund   Toronto Community Housing   ecosystem

Multiple resource conservation measures undertaken

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 resources consumption or improving the indoor environment, while simultaneously addressing capital renewal or end of life replacement.

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

- Replacement of existing heating boilers with condensing boilers
- DHW boiler recommissioning
- Lighting replacements in corridors, stairwells, lobby, and mechanical rooms. Motion sensor LED lighting retrofits in garbage rooms and basement storage area
- Replacement of 6L toilets with 3L flapperless models
- Cold water VFD to reduce pumping energy

In addition, installation of a chimney lining was required to properly exhaust the new condensing boilers. For equipment details, refer to Appendix F.

Not all RCMs considered by the project team were implemented, as Table 1 outlines. Most of these RCMs did not provide enough cost savings to justify their capital expense.

RCM	Reason for Exclusion
Thermostatic valves	Budgetary constraints
Radiator replacement	Budgetary constraints
Building envelope repairs and window replacement	High capital cost measure, disruption to residents
Washing machine replacement	Existing machines are rented
Low emissivity window film	Significant expense that could not be justified given the state of the existing windows
Solar cold-water preheat	Payback on this RCM was greater than 30 years

Table 1: RCMs evaluated but not installed

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

- Heating valve replacement with three-way valves, optimized to provide adequate flow to all zones of the three buildings
- Shut-off 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 and 15 per cent of the residents before and after the retrofits.

Project financials

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

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

Project Financials	Value
Total project cost [i]	$1,511,785
Total incentives	$119,515
Net cost	$1,392,270
Projected annual utility savings	$116,111

Table 2: Project financials

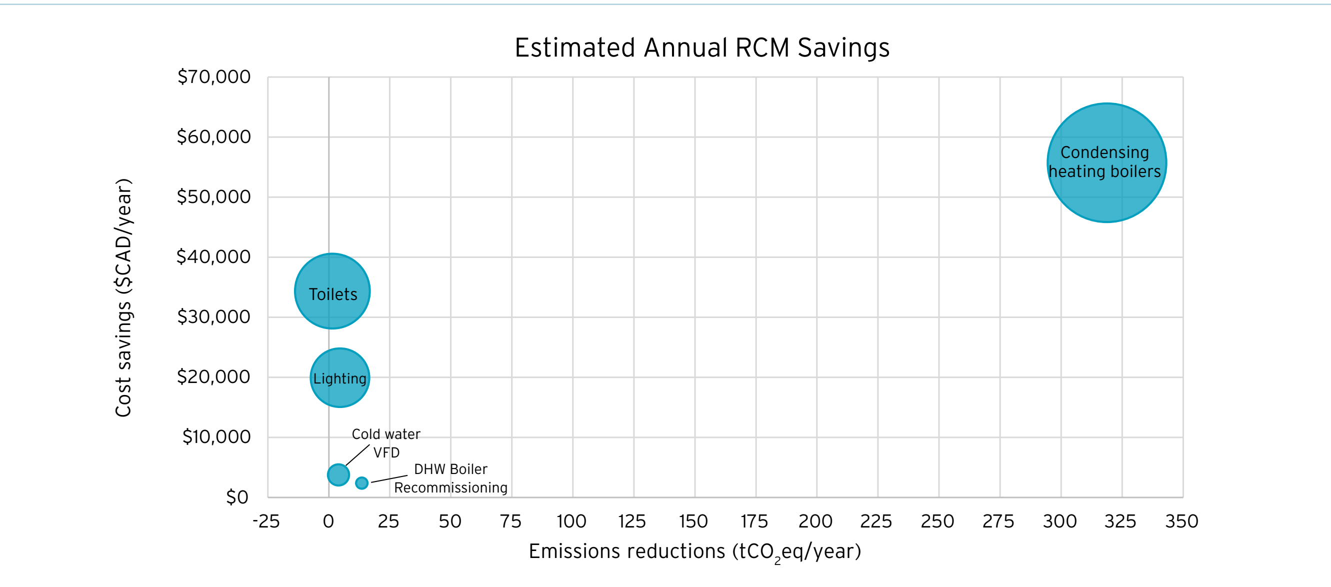


Figure 1. Estimated annual cost savings and emission reductions for each RCM implemented.

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 very little carbon emission reductions because the low-carbon electricity savings do not offset the increase in gas consumption due to using fixtures that generate very little heat.

Project financing: ESPA™

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

[i] Includes TCH's contribution of $506,052 towards capital renewal and deferred maintenance work.

Energy and IEQ Monitoring

TAF and the project team undertook a comprehensive monitoring program that went well beyond typical Measurement and Verification (M&V) 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. This included instrumentation of heating and hot water systems as well as an IEQ monitoring program, both of which captured a year of pre-retrofit data in addition to post-retrofit outcomes. 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.

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

Table 3: R.J. Smith Apartments metering points

The IEQ element included air quality and thermal comfort monitoring, testing of the ventilation system, and pre-and-post retrofit surveys with up to 15 per cent of residents. IEQ monitoring was undertaken in 29 units at the site – six per cent of units at 101 Kendleton, five per cent of units at 111 Kendleton, and seven per cent of units at 121 Kendleton. Table 4 summarizes IEQ monitoring parameters. Appendix G shows a list of the specific monitoring equipment used, while Appendix H presents the monitoring layout of the heating plant.

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: Kendleton Drive IEQ-related metering points

Project Energy, Water, and Carbon Performance

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

It is valuable to consider resources savings not only from a cost perspective, but in terms of carbon emissions reductions as well. A look at the projected emissions reductions and cost savings by resource, as shown in Figure 2, reveals that while water efficiency results in substantial cost savings, the emissions reductions are minimal. In contrast, the majority of emission reductions come from natural gas savings.

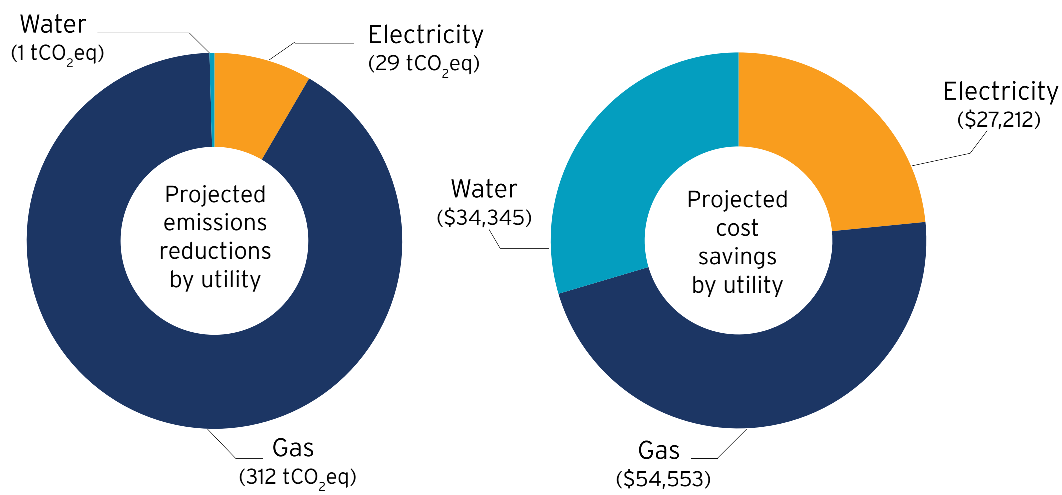


Figure 2: Projected emissions reductions and cost savings for the first year of post-retrofit operation at the site. See Appendix D for emissions factors.

TOTAL RESOURCE SAVINGS

In the first year of post-retrofit operation, the project saved $123,957 in utility costs, exceeding projections by six per cent. Although the cost savings target was exceeded, not all resource savings met their projections. The greatest savings were seen in water, followed by electricity, both of which exceeded projections. This helped offset the lower than expected gas savings.

The retrofits at R.J. Smith Apartments illustrate how underperformance on one resource type is often offset by better than anticipated performance on another. Balancing retrofits across multiple resources and multiple measures helps to produce a sound business case and reduces the risk of underperformance.

Collectively, retrofits across the three utilities resulted in carbon emissions reductions of 212 tCO_2eq within the first year. Although this is below the projected emissions reductions of 341 tCO_2eq, with continuous commissioning the project team expects to see significantly improved emissions reductions in the future.

Electricity

Electricity-related RCMs saved 216,150 kWh of electricity, representing 19 per cent of the site's annual consumption. First-year electricity savings exceeded targets by 19 per cent, largely due to the cold water booster VFD performing better than expected. The pump almost always runs at 30 per cent speed, the minimum allowable flow. By dynamically accounting for pressure requirements, the pump is able to run at reduced speeds while providing adequate pressure for even the highest apartments, reducing electricity consumption. **Electricity savings resulted in 34 tCO_2eq of reductions within the first year.**

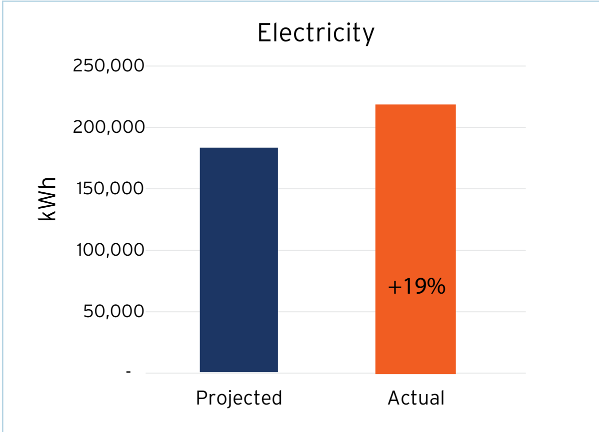


Figure 3: Projected and actual electricity savings

Natural Gas

Natural gas-related RCMs saved 97,882 m^3 of natural gas in the first year, or 14 per cent of the site's annual natural gas consumption. However, these savings are 40 per cent lower than projected; there are a number of reasons for this:

- In spring, the project team discovered that a setting on one of the heating boilers was causing a high minimum temperature for the heating loop, even when outdoor temperatures were warm. This has since been resolved
- An earlier than normal winter resulted in increased temperatures on the reset curve of the heating boilers
- The boilers encountered some connectivity issues with the building automation system (BAS) system, resulting in the heating plant operating less efficiently than projected
- On multiple occasions, external contractors switched the boilers into manual mode, further compromising savings

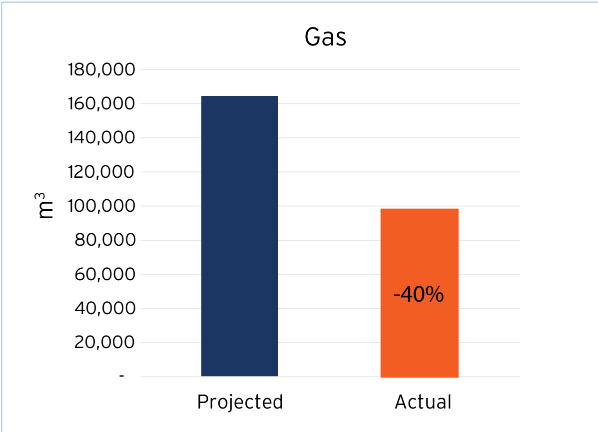


Figure 4: Projected and actual gas savings

The project team continues to work to resolve these issues, and an improvement in savings is expected in future years. **Natural gas savings reduced carbon emissions by 186 tCO_2eq in the first year.**

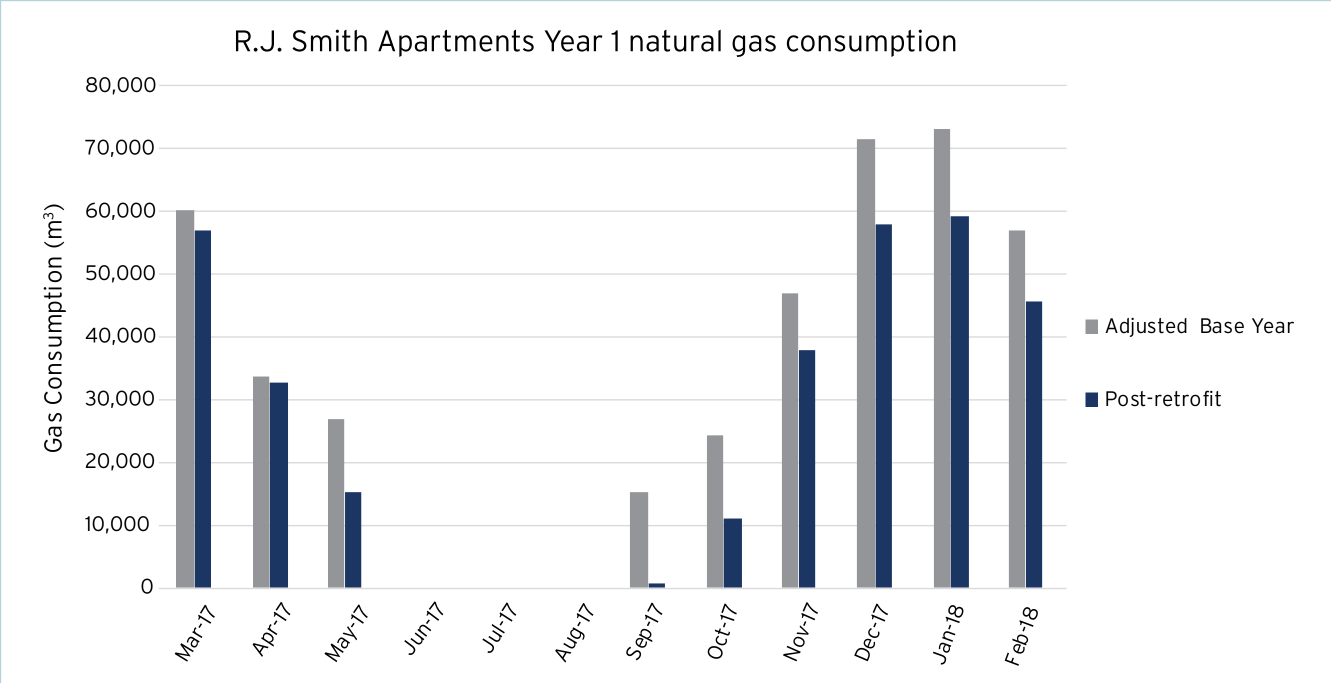


Figure 5: Year 1 gas consumption at R.J. Smith apartments. Adjusted base year represents modelled gas consumption without RCMs, versus actual post-retrofit consumption.

Water

Significant water savings of 15,843 m^3 was achieved in the first post-retrofit year, a 22 per cent reduction over the site's annual consumption. Water savings were 62 per cent higher than expected due to a greater number of leaks than were foreseen. The project team assumed that 5 per cent of the original toilets were leaking or running continuously at a rate of 0.1 gallons per minute, and reductions in post-retrofit nighttime water consumption confirm that leaks were an issue. Actual water savings suggest that the leakage rate was significantly higher than originally estimated. The new toilets have performed well and save 3 litres of water with each flush. In addition, their flapperless design will prevent the type of leakage seen in the old pre-retrofit toilets. **Water savings reduced emissions 2.4 tCO_2eq in the first year.**

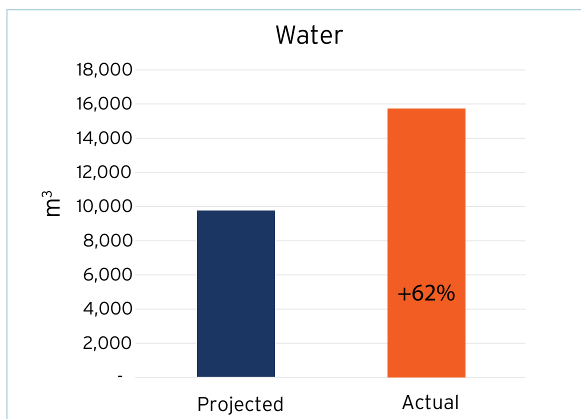


Figure 6: Projected and actual water savings

INDIVIDUAL MEASURE PERFORMANCE

Condensing Boilers

Three Viessmann Vitocrossal 300 condensing boilers replaced the existing 9.8 MMBH boilers at 121 Kendleton, providing space heating to the three buildings. These condensing boilers each have two individual burners that can turn down to 20 per cent capacity for a turndown ratio of 12:1 – compared to the 5:1 turndown ratio of the old boilers.

R.J. Smith Apartments experienced the least overheating of the three TCH sites involved in the overall portfolio, with average indoor air temperatures of 25.3°C in the winter. However, more overheating was seen in the shoulder seasons, fall and spring, where average temperatures reached 26.4°C and 26.5°C respectively. Not only does overheating cause discomfort to residents, it is a significant waste of energy. Pre-retrofit, 71 per cent of residents reported opening their windows in winter.

The new smaller boilers are correctly sized and can modulate to lower temperatures when the outdoor temperature is mild, which helped to reduce overheating. Time spent above 26°C dropped by 47 per cent in the shoulder seasons and 59 per cent in winter, on average.

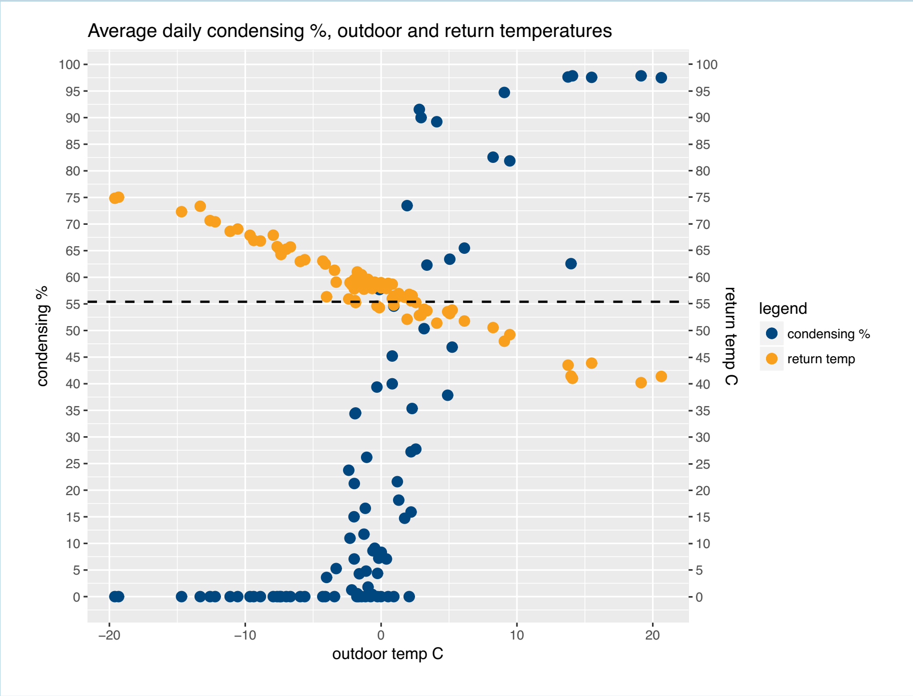


Figure 7 plots the percentage of time the new Viessmann boilers at Kendleton were operating below the condensing point, along with daily average return temperatures, against the average outdoor temperature. This figure shows that outdoor temperature has a significant impact on the boilers' efficiency; colder outdoor temperatures necessitate supplying higher temperature water in order to provide adequate heat to the building, which leads to higher return temperatures for the boiler. Maximizing the efficiency of a condensing boiler requires

Figure 7: Daily condensing percentage and average return temperatures plotted against average outdoor temperatures (October 2017–May 2018).

maintaining return temperatures below the condensing point. Based on TAF's monitoring, it's clear that the boilers are operating at their most efficient when outdoor temperatures are 2°C and above.

In addition to the installation of the new boilers, it was discovered that the existing exhaust chimney for the space heating system had only an unlined masonry interior, and therefore was not up to modern code. The project team retrofitted the existing chimney with a metal liner to resolve this.

Domestic Hot Water Recommissioning

The DHW boilers at 101 and 121 Kendleton were relatively new, having been replaced within two years prior to this project. However, investigation by the project team revealed that the boilers at 101 Kendleton were not working as efficiently as they should have been. This was due to an error in the piping configuration at 101 Kendleton, where incoming domestic cold water (DCW) was mixing with the hot supply water, rather than the boiler return water. In the correct configuration this DCW would lower the temperature of the return line, which allows the boilers to operate more efficiently. The piping was reconfigured to alleviate this issue.

Lighting

At 101 and 121 Kendleton, the T8 and T12 fluorescent fixtures in the mechanical rooms, corridors, and stairways were replaced with Osram SubstiTUBE 12W LED fixtures. In the case of the T8 bulbs, there was no need to replace the ballasts to fit the new LED fixtures; however, fixtures with T12 tubes had ballasts replaced with an Osram QHE T8 ballast. At 111 Kendleton, 26W CFL bulbs used in corridors were replaced with compatible LED 4-pin replacements. The lighting retrofit also included introducing motion sensors in the 121 and 111 Kendleton garbage chute rooms, 111 laundry rooms, and various basement storage rooms. Suite lighting was not considered under this measure; however, exit signs were replaced as an asset renewal measure.

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

LED fixtures use energy far more efficiently than their fluorescent predecessors and generate far less heat as a result. The project team accounted for this small loss of heat when estimating natural gas savings, resulting in a natural gas use increase of 10,623 m^3 per year.

Ultra-Low Flow Toilets

The project team proposed replacing the original 6L (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 40 new toilets across both buildings as a pilot. The pilot ran for three months and received no complaints during that time. As no major issues were revealed, the team was comfortable that the new toilets would perform well at the site and replaced the original 6L toilets in all units, along with several seized shut-off valves.

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

22%

Reduction in site water use

Duct Cleaning

As mentioned, a pre-retrofit ventilation analysis revealed that ventilation systems at the R.J. Smith Apartments were operating well below their maximum efficiency. As well, one of the make-up air units at 121 Kendleton had been off due to a malfunctioning gas burner, making it unable to pre-heat the air. These issues were already set to be taken care of by TCH outside the scope of this retrofit project. TCH replaced the make-up air unit and performed duct cleaning.

The benefits of preventative maintenance such as duct cleaning are often overlooked, even though it can reduce wasted energy and improve resident health and comfort.

Supplemental Equipment

The project team installed a variable frequency drive (VFD) on one of the main DCW booster pumps, alongside a temperature sensor on the DCW line. The sensor acts as a feedback monitor for the VFD, and pressure along the line is maintained. The VFD itself allows for the pumps, which were operating at a constant speed, to adjust dynamically to changes in cold water demand, thus lowering energy consumption.

The space heating at R.J. Smith Apartments is distributed across seven heating pumps, sending water to different zones. The heating valves for this system were replaced with new Siemens three-way valves, optimized to provide the same flow to all zones. This measure will not generate any energy savings, but is an asset renewal measure.

Financial Performance

Actual costs savings in the first year of post-retrofit operations exceeded projections by 6 per cent. Actual cost savings were $123,957, exceeding projected savings by $7,846. Savings were exceeded in two of three resources: electricity savings exceeded projections by 19 per cent and water savings exceeded projections by 62 per cent. Gas savings were 40 per cent below predicted in the first year of operations.

Table 5 highlights the financial performance of R.J. Smith Apartments as well as the overall project portfolio of three sites.

Financial Category	R.J. Smith Apartments		Portfolio (all three sites)[ii]	
	Original Projection	Actual Performance	Original Projection	Actual Performance
Year 1 cost savings	$116,111	$123,957	$417,707	$501,990
Net present value (NPV)[iii]	$1,865,934	$2,051,908	$5,021,603	$6,830,223
Internal rate of return (IRR)	15.6%	16.6%	12.4%	14.9%
IRR (10 year)	7.8%	9.2%	3.5%	7.2%
Simple payback (years)	7.6	7.1	9.4	7.9
Return on investment (ROI)[iv]	462%	500%	286%	364%

Table 5: Site and portfolio financial performance[v, vi]

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

[iii] Discount rate of 4%, utility cost inflation rate of 3%.

[iv] Based on average project lifetime.

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

[vi] 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 resource conservation measures 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 savings and emission reductions, improve thermal comfort and air quality, and 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 project's overall financial, emission, and energy goals.

Based on TAF's experience with large-scale retrofit projects at R.J. Smith Apartments and other MURBs, the following are some best practice recommendations that can be applied to projects in the future:

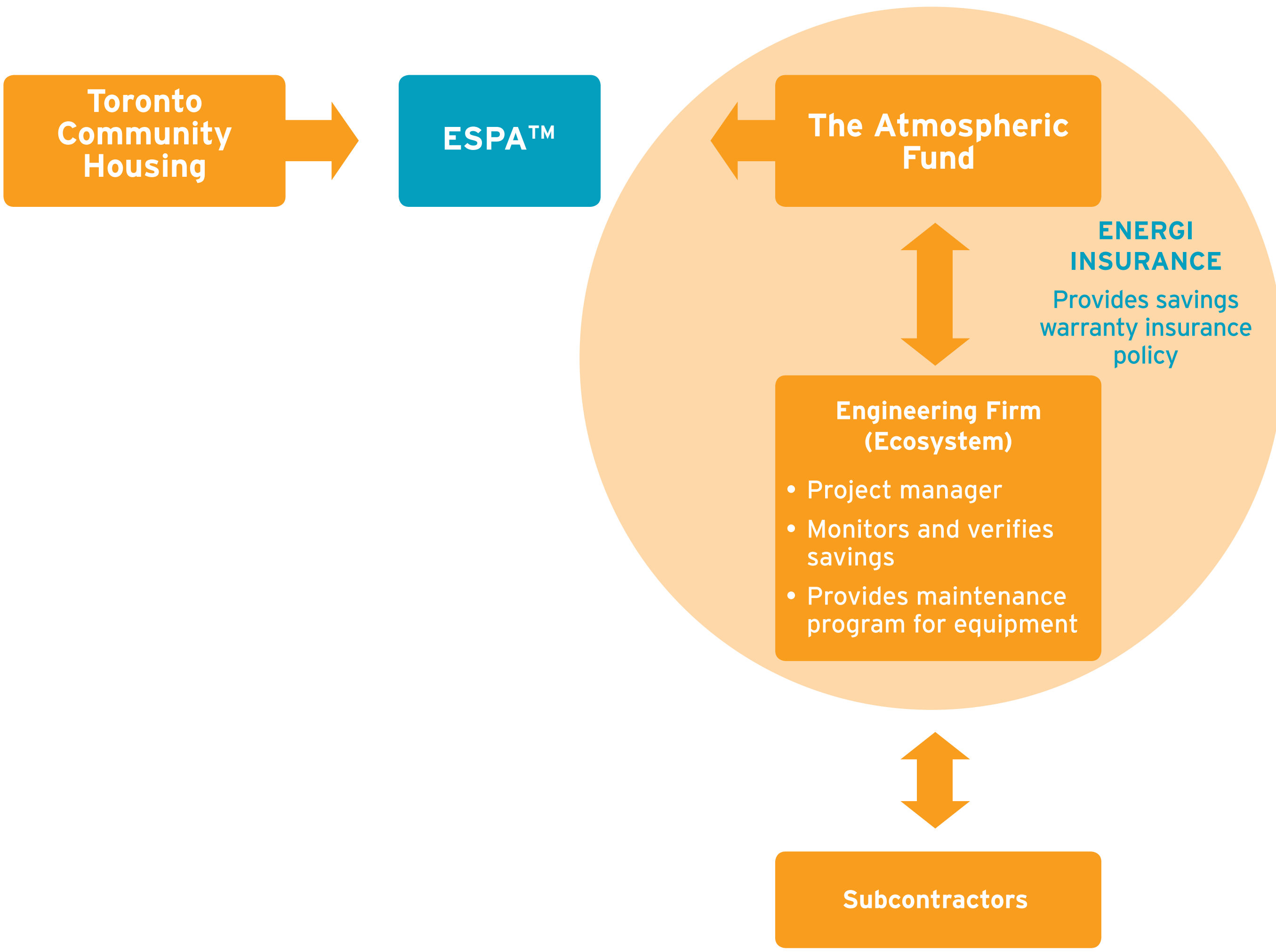
- **Integrate multiple measures.** Integration across utilities enhances savings, improves financial performance, and reduces risk of underperformance. In this project the water savings represented the highest cost savings, yet water savings may not be typically considered as part of a building 'energy' 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 they can expect. Within this case study this was done by holding 'town hall' meetings as well as simply providing more details on notices of entry that explained the work and benefits.
- **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 oversized significantly. 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 R.J. Smith Apartments), and has led to reductions in capital costs and energy consumption and improved resident comfort.

- **Continuous commissioning is critical.** Commissioning and ongoing optimization is critical in ensuring systems are operating as designed. However, properly commissioning and optimizing systems requires a stable and functioning 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. Looking for opportunities to recomission and optimize exisiting systems in tandem with other retrofit measure also poses a significant resource and cost saving opportunity. In this project, recomissioning of the existing DHW boilers resulted in the discovery of an incorrect configuration that had been causing a two-year-old system to run inefficiently.

- **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.

Appendix A: ESPA™ Structure



Appendix B: Pre-Retrofit Building Information

Building Type	Social housing Studio units, most earmarked for seniors
Name & Address	R.J. Smith Apartments 101, 111, 121 Kendleton Drive
Year of Construction	1965
Major Renovations	N/A
Number of Floors	7, 11, 7
Parking Levels	N/A
Number/Type of Apartments	471, predominantly studio suites with some one-bedroom suites
Gross Floor Area	25,950 m^2
Heating	Hydronic baseboards located in every room of the unit (except bathrooms). Heat for the baseboards of all three buildings is provided from two 9.8 MMBH boilers located at 121 Kendleton.
Cooling	No central cooling; residents can purchase their own window-mounted or externally ducted portable air conditioners. The MAU at 111 Kendleton has some cooling capability for corridors.
Domestic Hot Water	Each building has two 600 MBH boilers located in the penthouse mechanical room to supply DHW. At 101 and 121 these were less than two years old. At 111 Kendleton, DHW boilers were 10-12 years old and issues were noted by site staff.
Ventilation	MAU provide 100% fresh air through pressurized corridor system. MAU at 101 and 121 provide pre-heating, at 111 they provide both heating and cooling.
Miscellaneous Equipment/Facilities	Community assembly room located on the ground floor connecting 101 and 121 Kendleton. Laundry rooms.

Appendix C: RCM Costs

Resource Conservation Measures	Gross Cost[vii]	Incentives[viii]	Net Cost	Projected Annual Savings	Estimated Asset Lifetime[ix]
Condensing boilers	$598,199	$0	$5,360	$206	18
DHW boiler recommissioning	$5,443	$49,800	$461,672	$31,361	25
LED lighting interior/exterior common areas	$145,828	$16,462	$141,486	$12,511	19
New 3L toilets	$237,299	$0	$198,750	$30,782	30
Cold water VFD	$18,966	$4,782	$8,649	$3,594	18
Total	**$1,005,733**	**$97,948**	**$886,218**	**$116,111**	**–**
Simple payback			7.6		
NPV			$1,865,934		
IRR			15.6%		

Capital Renewal Measures	Net Cost [x]
Heating valve replacement	$41,085
Chimney lining	$414,000
Exit sign replacement	$40,670
Shut-off valve replacement	$10,297
Total	**$506,052**

[vii] Includes design, construction documents, management, construction, commissioning, & M&V plan fees.
[viii] Audit incentives ($21,567.46) are not included. Total measure & audit incentives is $119,515.
[ix] Calculated based on weighted average between lifetime of individual asset components and their costs.
[x] Incentives are not applicable to measures that address capital renewal or differed maintenance.

Appendix D: RCM Savings

Resource Conservation Measures	Projected Annual Savings			
	Electricity (kWh)	Natural Gas (m^3)	Water (m^3)	Carbon Emissions (tCO_2e)
Condensing boilers	-	167,858	-	319
DHW boiler recommissioning	-	7,132	-	5
LED lighting interior/exterior common areas	156,064	-10,623	-	14
New 3L toilets	-	-	9,760	1.5
Cold water VFD	24,986	-	-	4
Total	**181,050**	**164,367**	**9,760**	**341**

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

Appendix E: IPMVP Approaches

RCM	Primary M&V Approach per IPMVP	Supplemental Performance Monitoring
Condensing boilers	Option C – Gas	Option B – Gas and thermal
Smart thermostats	Option C - Gas	
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
Space heating boilers	Viessmann	3	Vitocrossal 300 CA3
Heating valves	Siemens	6, 6	239 series actuators and valve bodies
Pumps	Armstrong	2	4380 6x6x6 5 HP
Suction guide	Armstrong	1	Sg66
Gas regulator	Sensus	1	121 gas regulator
Gas relief valve	Emerson	1	289H relief valve
Low flow toilets	Hennessy & Hinchcliffe	475	3LPF toilet
Lighting tubes	Osram	800	SubstiTUBE 12W
Lighting CFL	GE	144	LED12G2AQ
Lighting tubes	GE	125	Refit LED tubes
Occupancy sensors	Lutron	29	Maestro MS OPS5M
Ballasts	Osram	70	Quicktronic QHE ballasts
Chimney liner	Security Chimney	1	SSD type BH venting
Exit signs	Beghelli	93	Stella RM

Appendix G: Monitoring Details

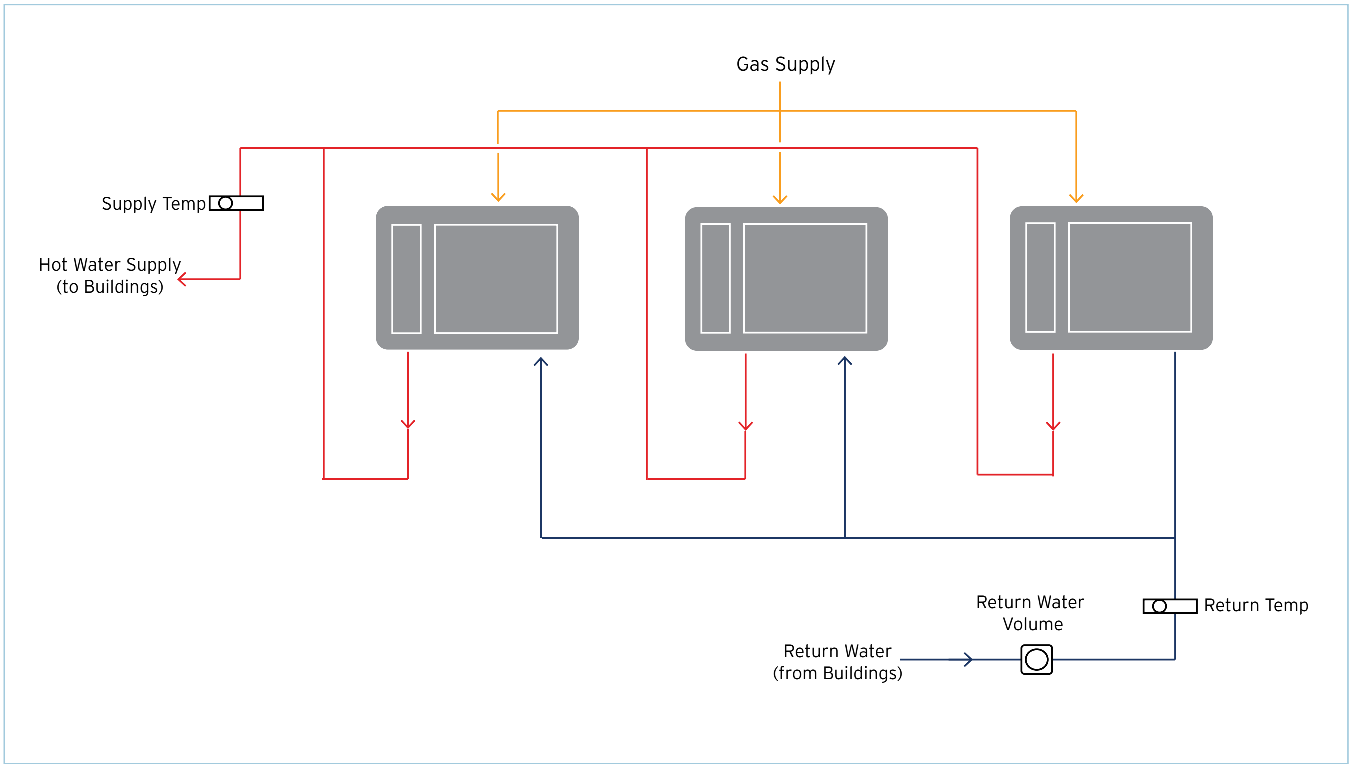
101 Kendleton

Type	Manufacturer and Model	Location	Range		Operational Accuracy	
			Min	Max	At Min Flow	At Max Flow
Gas, condensing DHW boilers	Sierra, Quadra Therm 780i	Supply to condensing boilers	0	28 m^3/h	± 0.75% of reading plus 0.5% of full scale below 50% of full scale flow	± 0.75% of reading above 50% of the full scale flow
Temperature	Rosemount RTD Sensor 068 + Transmitter	Supply to condensing boilers	N/A	N/A	0.35C (0.352 sensor at 100C+ 0.032 transmitter)	
		Return to condensing boilers				
Water flow, condensing DHW boilers	Rosemount 8750WA	Supply to condensing boilers	0	30 m^3/h	0.0015 m/s from low flow cutoff to 1.0 ft/s (0.3 m/s).	0.50%
Water flow, DCW	Rosemount 8750WA	DCW feed into condensing boilers	0	30 m^3/h	0.0015 m/s from low flow cutoff to 1.0 ft/s (0.3 m/s).	0.50%

121 Kendleton

Type	Manufacturer and Model	Location	Range		Operational Accuracy	
			Min	Max	At Min Flow	At Max Flow
Gas, condensing DHW boilers	Sierra Quadra Therm 640i	Supply to condensing boilers	0	28 m^3/h	± 0.75% of reading plus 0.5% of full scale below 50% of full scale flow	± 0.75% of reading above 50% of the full scale flow
Gas, condensing SH boilers	Enbridge Utility Gas Meter	Exterior	-	-	-	-
Water flow, condensing DHW boilers	Sierra Quadra Therm 640i	Supply to condensing boilers	0	28 m^3/h	± 0.75% of reading plus 0.5% of full scale below 50% of full scale flow	± 0.75% of reading above 50% of the full scale flow
Water flow, condensing SH boilers	Krohne Optiflux 4000	Return from condensing boilers	0.32 m/s	2.05 m/s	0.62% at 0.32 m/s (90 GPM)	0.35% at 2.05 m/s (575 GPM)
Temperature	Rosemount RTD Sensor 068 + Transmitter	Supply to condensing boilers Return to condensing boilers	N/A	N/A	0.35C (0.352 sensor at 100C+ 0.032 transmitter)	
Temperature	Rosemount 8750WA	Supply to condensing boilers	0	30 m^3/h	0.0015 m/s from low flow cutoff to 1.0 ft/s (0.3 m/s).	0.50%
Temperature	Rosemount 8750WA	DCW feed into condensing boilers	0	30 m^3/h	0.0015 m/s from low flow cutoff to 1.0 ft/s (0.3 m/s).	0.50%

Appendix H: Monitoring Layout



Appendix I: M&V Utility Savings

	Annual Consumption[xli]			
Utility	M&V Baseline	Projected	Actual	Actual Savings
Electricity (kWh)	348,029	166,979	131,879	216,150
Gas (m^3)	473,455	309,088	375,573	97,882
Water (m^3)	54,943	45,183	39,100	15,843

xii Consumption associated with measures that were implemented.

References

[1] Clarissa Binkley, 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] Chen, H., J. Wang, Q. Li, A. Yagouti, E. Lavigne, R. Foty, R. T. Burnett, P. J. Villeneuve, S. Cakmak, and R. Copes. "Assessment of the Effect of Cold and Hot Temperatures on Mortality in Ontario, Canada: A Population-based Study." *CMAJ Open* 4, no. 1 (2016): 48-58. doi:10.9778/cmajo.20150111.

[3] 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