Retrofitting Hospital Workers Co-operative

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).

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Ontario Toronto

Executive Summary

Through the TowerWise program, The Atmospheric Fund (TAF) 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 2014-2018, retrofits were undertaken at Hospital Workers Co-operative in Toronto. Built in 1995, Hospital Workers Co-operative is an 11-storey highrise, with a lower five-storey wing. There are 132 apartments in total, ranging from one- to three-bedroom units.

The project team aimed to achieve major reductions in utility costs and carbon emissions, while enhancing resident comfort and wellbeing. The results demonstrate that retrofits can provide a compelling return on investment while reducing environmental impacts and generating green jobs.

The retrofit conservation measures targeted all resource types:

Gas

- Condensing boiler retrofits
- Installing dedicated domestic hot water boilers

Electricity

- Variable speed drives for domestic cold water
- Make-up air unit variable speed drive
- Lighting upgrades
- Chiller replacement

Water

- Low-flow toilets
- Low-flow showerheads
- Aerators

Outcomes

- **$82,888 annual utility cost saving**
- **157 tCO_2eq emission savings**
- **37 per cent reduction in domestic hot water gas use**

Key recommendation

Sequence work accordingly. Understanding how systems affect one another and sequencing work accordingly can help avoid duplication and unnecessary effort.

Content

Hospital Workers Co-operative Retrofit

TAF and Hospital Workers Co-op partner for multi-measure retrofit

The Atmospheric Fund (TAF) and Hospital Workers Co-operative partnered to undertake an energy efficiency retrofit as part of the TowerWise program.

Built in 1995, Hospital Workers Co-operative is an 11-storey multi-unit residential building, with a lower five-storey wing. There are 132 apartments in total (5 one-bedroom, 58 two-bedroom, and 29 three-bedroom). The gross floor area of the building is approximately 12,077 m^2.

Hospital Workers Co-operative: central cooling plant, 2-pipe fancoil system

Space heating is provided to the building by 2-pipe fancoil system. It serves all suites as well as a number of common areas including the lobby, offices, meeting room, fitness room, and laundry rooms with the exception of the common service rooms which are served by unit heaters and forced-flow heaters. Three gas-fired, copper-fin boilers formed the central heating plant that provides the hot water for the space heating and domestic hot water.

A central cooling plant consisting of one 165-ton capacity chiller provided the chilled water for the 2-pipe fancoil system. It uses R-22, a refrigerant with a high global warming potential, whose production is to be phased out by this year under the Montreal Protocol. A number of auxiliary spaces on the ground floor are also cooled by three split-type air conditioners. Ventilation is provided by a pressurized corridor system, with fresh air provided by two make-up air units located on the roof. Each suite has its own individual kitchen range hood as well as bathroom exhaust fans, which are vented out the side of the building and operated by manual toggle switches.

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

August 2014
Investment Grade Energy Audit

June 2015
Installation begins

December 2015
Substantial completion

January 2016 - September 2018
Utility consumption monitoring

Energy and Water Conservation Measures

Multiple resource conservation measures undertaken

Through the integrated project delivery process, TAF worked with Finn Projects and Hospital Workers Co-operative to determine which resource conservation measures (RCMs) would allow the project to meet its ambitious goals. The retrofit approach focused on grouping shorter and longer payback measures that target resource consumption while simultaneously addressing the need to upgrade existing systems.

The following retrofit measures were implemented:

- Installed condensing boilers for space heating and domestic hot water (DHW)
- Introduced variable speed drives for domestic cold water (DCW)
- Introduced variable speed drives for make-up air units (MAUs)
- Replaced and upgraded lighting
- Installed low-flow toilets, low-flow showerheads, and aerators
- Improved weatherstripping
- Introduced voltage optimization
- Installed a water flow management device

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

RCM	Reason for Exclusion
Rooftop solar panels	Small building footprint plus equipment located on the roof makes this unfeasible
Solar wall	With significant amounts of glazing, the building has no vertical surface suitable for a solar wall installation
High-efficiency motors	Except for MAUs, all motors are either fractional HP or run at less than 1,000hrs/year, making replacement not economically feasible

Table 1: RCMs not installed

Project financials

Construction costs, incentives and projected savings from the RCMs are shown in Table 2. Savings of approximately 164 tCO_2eq were expected annually[i], resulting in a 25 per cent reduction from pre-retrofit emissions.

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

Project Financials	Value
Total project cost[ii]	$905,600
Total incentives	$226,250
Net cost	$679,350
Projected annual utility savings	$67,250

Table 2: Project financials

Projected cost and carbon emission savings from all RCMs can be seen in Figure 1. The circle size reflects the full capital cost including design, equipment, installation, and commissioning. This project implemented a variety of measures with varied paybacks in order to maximize utility cost savings and carbon emissions reductions.

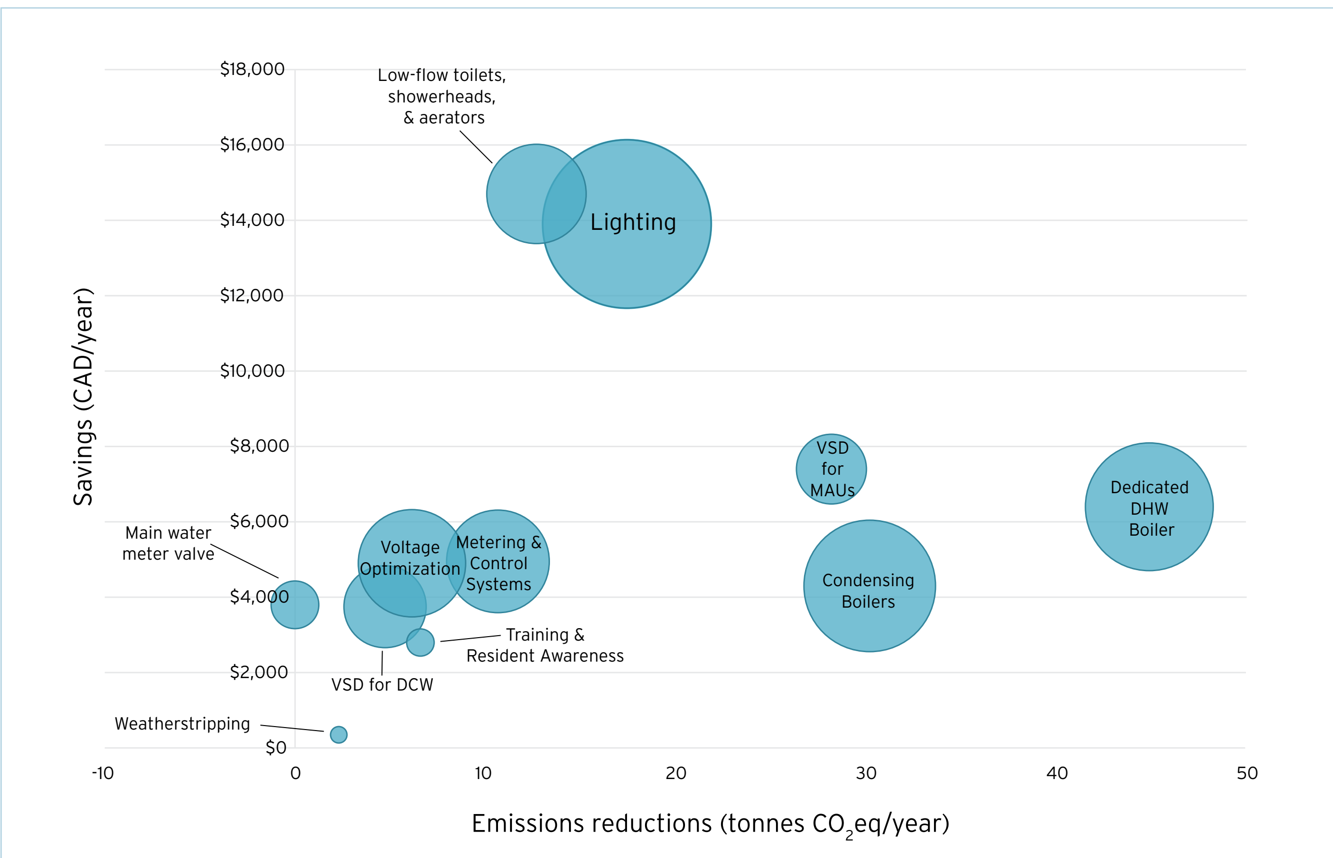

Figure 1: Estimated annual RCM savings, carbon emissions reductions, and measure costs

[i] Equivalent to the emissions from 19.4 average-sized homes over the course of a year.
[ii] Includes capital improvement cost of chiller replacement of $178,600.

Energy Monitoring

Measurement and verification was primarily done through building-wide utility monitoring of electricity, gas, and water usage. In addition, TAF and the project team designed and installed a Z3 controls monitoring system on one of the new DHW boilers. This system tracks the boiler's gas consumption, water flow, and the supply and return water temperatures. Table 3 summarizes key metering points at the site.

Metering Point	Resource Metered	Metering Interval
Whole building	Natural gas, electricity, water	Monthly
DHW boiler 1	Water flow	1-minute
DHW boiler 1	Gas flow	1-minute
DHW boiler 1 supply	Temperature	1-minute
DHW boiler 1 return	Temperature	1-minute

Table 3: Metering parameters

Project Energy, Water, and Carbon Emission Performance

This section details the energy and carbon emissions performance of the RCMs during the first two years of operation in 2016 and 2017. Total resource savings are detailed below, followed by descriptions of the individual measures implemented. Savings were determined by comparing the projected baseline gas, electric and water consumption to actual utility consumption for the year.

Projected emissions reductions and cost savings are shown in Figure 2, illustrating that often the resources with the greatest impact on cost savings do not have the largest impact on reducing carbon emissions. A balanced retrofit approach across all three resources allowed the project team to work towards multiple goals leading to a more comprehensive retrofit.

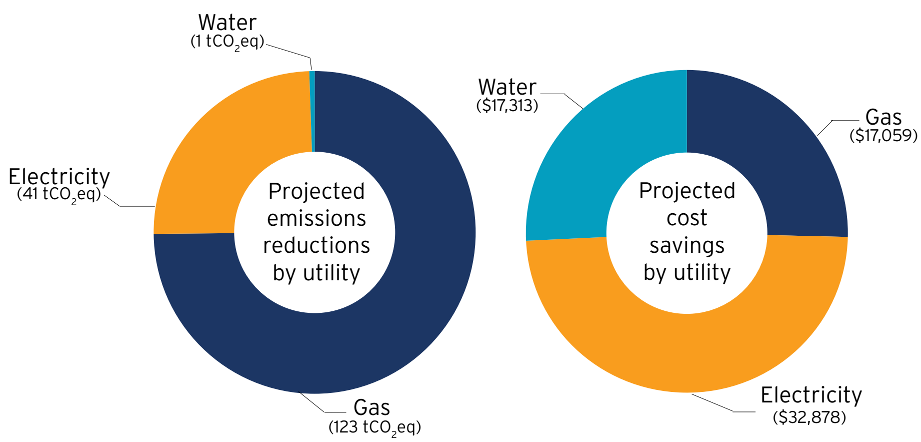

Figure 2: Projected emissions reductions and cost savings for the first year of post-retrofit operation

TOTAL RESOURCE SAVINGS

The project saved $82,888 in utilities costs over the course of the first year, exceeding the projected savings by 23 per cent. Year 2 saw similar achievements, saving $71,250 and exceeding the predicted project savings by six per cent. The greatest success came from the electricity savings, which were consistently above projections.

Electricity

Post-retrofit performance reveals that there was an average of 24 per cent electricity savings with 279,637 kWh and 284,413 kWh saved in Year 1 and Year 2, respectively. On average, electricity-related RCMs reduced carbon emissions by 47 tCO_2eq annually. Reductions in electricity use also resulted in the largest cost savings, saving $49,312 in Year 1 and $40,273 in Year 2.

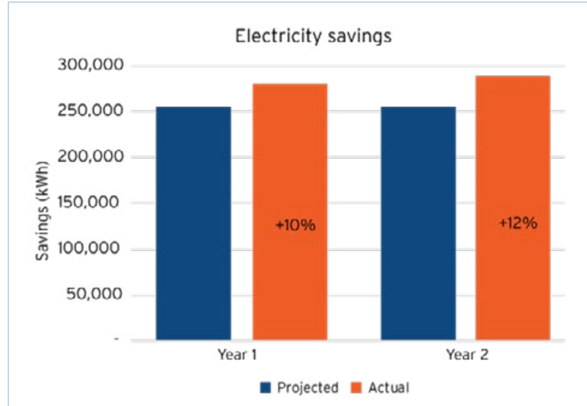

Figure 3: Projected and actual electricity savings for Year 1 and Year 2

Natural Gas

Natural gas savings were nine per cent lower than expected in Year 1, and 21 per cent lower than expected in Year 2. This is due to the fact that domestic hot water use is slightly higher than originally anticipated. Despite these shortcomings, annual average savings are 31 per cent over pre-retrofit consumption, resulting in emissions reductions of 105 tCO_2eq per year. Gas measures saved $18,498 in Year 1, and $17,404 in Year 2.

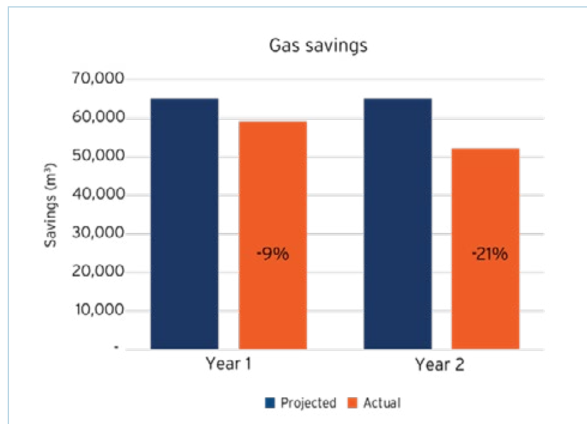

Figure 4: Projected and actual gas savings for Year 1 and Year 2

Water

Water conservation measures resulted in 19 per cent and 16 per cent savings in Year 1 and Year 2, respectively. This amounted to $15,078 and $13,573 savings in Year 1 and Year 2 respectively. The savings were 26 per cent lower than predicted in the first year, due to a number of residents who had installed their own fixtures within the units. This prevented the project team from retrofitting all units with the new low-flow water measures as predicted. Water conservation measures resulted in an average annual emissions reduction of 1 tCO_2eq.

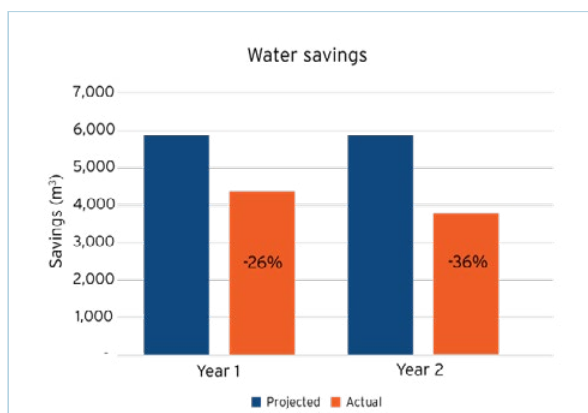

Figure 5: Projected and actual water savings for Year 1 and Year 2

INDIVIDUAL MEASURE DESCRIPTION AND PERFORMANCE

Condensing Boilers For Space Heating and Domestic Hot Water

Prior to the retrofits, space heating and DHW were provided to the building from one central heating plant. Three gas-fired, copper-fin Teledyne Laars boilers provided 2,450 MBTU/hr of heating input each. The existing boilers were original to the building, and over 18 years old. Though the boilers had some modulating capabilities, this was limited with a minimum firing rate of 30 per cent. In addition, the project team noted during on-site visits that the existing Tekmar controller required a review of its programming and setpoints.

As the DHW load was being supplied by the main boilers used for space heating, this meant that those boilers had to operate even in the summer months. With such a small summer load, the boilers were running inefficiently due to increased cycling. This presented ample opportunity for energy savings through the introduction of a dedicated DHW boiler.

Figure 6: New boilers for space heating

The three existing boilers were replaced with two 2000 MBTU Camus Dynaforce boilers for space heating, and two smaller 1000 MBTU/hr for DHW. Condensing boilers have rated efficiency of 90-95 per cent, and with a 5:1 turndown ratio, their minimum firing rate is only 20 per cent. By separating the loads, the larger space heating boilers will only be operated during the heating season, resulting in an estimated 14 per cent reduction in gas used for space heating.

Having dedicated boilers for different loads also allowed the smaller DHW boilers to operate more efficiently year-round. Estimated savings with the new configuration of boilers for DHW were 37 per cent as shown in Figure 7.

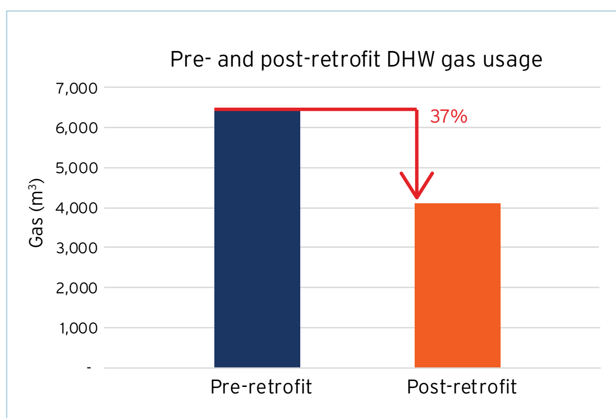

Figure 7: Pre- and post-retrofit DHW gas usage

Variable Speed Drives for Domestic Cold Water

The existing booster pumps for DCW allowed for just two stages of flow control. This system could not adequately match demand during minimal water consumption periods, resulting in energy losses. Replacing the existing booster pumps with a new pump equipped with a variable speed drive and cushion tank created the ability to match system pumping requirements to the actual water consumption.

Variable Speed Drives for Make-Up Air Units

Fresh air is provided to the suites via a pressurized corridor system, with make-up air units supplying a constant amount of fresh air 24 hours a day, regardless of the building's actual needs. In order to take advantage of this opportunity for energy use reduction, a VSD was installed on the existing MAUs. This allows for variable fan speeds. The new devices were then programmed on a time-of-day schedule, to match the fresh air supply with building demand, based on assumed building occupancy.

This RCM reduces the amount of electricity required to run the fans year-round, as well as reducing the amount of gas required to heat the fresh air supply to the corridors during the winter months.

Lighting Retrofits

A visual inspection of the various lighting systems at Hospital Workers Co-operative revealed that storage and utility areas were a mix of T12 and T8 lighting, and elevator lighting used T8 fixtures. Corridors, offices, and meeting rooms were also primarily lit by T8 fixtures. LED tube lighting appeared to be implemented randomly throughout the facility and in the elevators. All exit signs were LED technology.

Common area lighting was changed to reduced wattage 24W T8 lamps, with the exception of corridors, which were changed to LEDs. All T12 magnetic ballast fixtures were replaced with T8 32W electronic ballast fixtures. This is because, at the time of the retrofit it was more cost effective to replace the non-24-hour lighting with T8-32W fixtures and replace only 24-hour lighting with LED lamps.

Figure 8: Motion sensor located in laundry room.

Ceiling mounted occupancy sensors were also introduced into laundry rooms, garbage chutes, and the bike room, to ensure that lighting would only be used in these areas when occupied.

Within individual suites, a mixture of compact fluorescent and incandescent lighting was found. Post-retrofit, lighting fixtures were replaced with new compact fluorescent fixtures with GU-24 sockets. All exterior lighting was replaced with LED equivalents.

Low-Flow Water Fixtures

A number of measures were taken to help reduce water usage in suites and common areas, including low-flow toilets, showerheads, and aerators.

The existing toilets were rated at 6L per flush and were upgraded to 3L per flush low-flow toilets. Similarly, the original showerheads had been rated between 5.7-7.6 litres per minute and were replaced with 5.7 litres per minute fixtures. Existing sinks were rated between 3.8-8.3 litres per minute. These were replaced with 3.8 litres per minute aerators in the bathrooms, and 5.7 litres per minute aerators in the kitchens.

While introducing low-flow toilets directly impacts water usage, introducing water saving measures on showers and sinks where hot water is used results not only in water savings, but gas savings as well.

Weatherstripping

While the building envelope is in good condition, some of the original weatherstripping is either worn out or missing. Weatherstripping around the sides and tops of doors as well as sweeps and seals on the bottom of doors were replaced.

Improved weather sealing reduces air infiltration and drafts, improving the thermal comfort of residents. It also results in improved energy efficiency by reducing energy losses. It is a low-cost RCM that does not cause much disruption to residents' daily lives.

Voltage Optimization

There is an optimal minimum voltage level below the primary level, at which lights, motors, and the like can operate without any effects to their practical performance. In order to take advantage of this, an on-load automatic electronic tap changer with a high efficiency autotransformer was installed to regulate voltage within the building.

Water Flow Management Device

Air bubbles in cold water pipes can cause turbulent water flows. As water meters measure both the volume of water and air passing through the meter, this can cause water meters to record a volume higher than the actual water usage. In order to resolve this issue, a water flow management device is used which creates a backpressure on the main water line and reduces the turbulence, resulting in more accurate readings.

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].

At Hospital Workers Co-operative, 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, including 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 the site's annual energy costs by $2,800 annually.

Financial Performance

Actual savings in the first year of post-retrofit operations exceeded projections by 23 per cent. This is largely attributable to the better-than-projected electricity savings. Despite not reaching the projected savings per each utility, the overall business case is still quite strong. Table 4 highlights the financial performance of the retrofits at Hospital Workers Co-operative.

Financial Category	Original Projection	Actual Performance
Year One savings	$67,250	$82,888
Net Present Value (NPV) [iii]	$680,929	$747,223
Internal Rate of Return (IRR)	10.4%	13.4%
IRR (10 year)	0.1%	4.3%
Simple Payback (years)	10	8.2
Return on Investment (ROI) [iv]	166%	228%

Table 4: Site financial performance

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

[iv] Based on average project lifetime.

Recommendations

At Hospital Workers Co-operative the project team worked to implement conservation measures across multiple utilities: gas, electricity, and water. Through this holistic approach, the team was able to make significant reductions to resource consumption in the 11-storey building. The team monitored performance at the whole building and systems level for the first two years of post-retrofit operation, providing data analysis which aided in the development of the following recommendations:

- **Integrate multiple measures.** Integration across utilities enhances resource and cost savings, improves financial performance, and reduces risk of underperformance. In this project the electricity savings represented the highest cost savings, helping to offset the lower-than-predicted natural gas and water savings.
- **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 necessary times that the building's water supply had to be shut down. When this happens the debris on the inner walls of the pipes (calcium deposits etc.) 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, the replacement of the old aerators with the new retrofits should be performed 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 there is an opportunity to maximize the expected outcomes.
- **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 this project, separating the DHW and heating boilers created a more efficient system, where the larger heating boilers could be shut down when not needed. Careful examination of a building's needs and an openness to challenging existing system design helps identify opportunities that would otherwise be missed.
- **Continuous commissioning is critical.** Commissioning and ongoing optimization ensures that systems are operating as designed. This requires a stable and functioning building automation system. 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.
- **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: Pre-Retrofit Building Information

Building Type	Co-operative
Name & Address	Hospital Workers Co-operative 100 Merton Ave., Toronto, ON
Year of Construction	1995
Major Renovations	N/A
Number of Floors	11 & 5
Parking Levels	1 underground
Apartments	132 (45 one-bedroom, 58 two-bedroom, 29-three bedroom)
Gross Floor Area	12,077 m^2
Heating	A 2-pipe fancoil system serves all residence and most of the common areas (including offices, lobby, meeting room, fitness room, laundry room, etc.). These are operated by non-programmable thermostats. Hot water is supplied by three gas-fired, copper-fin boilers providing 7,350 MBTU/hr total heating output (2,450 MBTU/hr each).
Cooling	A 165-ton chiller provides cold water to the fancoil system for cooling in summer. Three split-type air conditioning units serve various common areas on the ground floor (party room, fitness room, offices, etc.). The total cooling capacity of these air conditioning units is 7 tons.
Domestic Hot Water	DHW for the building is supplied by a brazed-plate heat exchanger, using hot water from the main boilers described above. DHW is stored in a 1,000-gallon vertical storage tank, maintained at 130°F.
Ventilation	Each unit Is equipped with individual kitchen range hoods and bathroom exhaust fans, operated by manual toggle switches. The exhaust fans are equipped with fractional HP motors.
Miscellaneous Equipment/ Facilities	There are a number of on-site amenities including offices, a party room, a fitness room, meeting rooms, and a laundry room with 8 washers and 8 dryers, all electric. A glycol snow-melting system serves the garage access ramp.

Appendix B: RCM Costs

Resource Conservation Measures	Gross Cost	Incentives	Net Cost	Projected Annual Savings	Estimated Asset Lifetime
Condensing heating boilers	$115,600	($6,350)	$109,250	$4,300	31
Condensing DHW boilers	$109,000	($9,450)	$99,550	$6,400	15
VSD for domestic cold water	$45,000	($22,250)	$22,750	$3,750	18
VSD for MAUs	$32,600	($18,750)	$13,850	$7,400	15
Metering & control systems	$70,500	($35,200)	$35,300	$4,950	16
Lighting	$189,500	($94,750)	$94,750	$13,900	10
Low-flow toilets, shower heads, and aerators	$66,100		$66,100	$14,700	15
Replace door seals	$1,800		$1,800	$350	8
Voltage optimization	$76,800	($38,000)	$38,800	$4,900	40
Main water meter valve	$15,100		$15,100	$3,800	20
Training and resident awareness	$5,000	($1,500)	$3,500	$2,800	10
Total	**$727,000**	**($226,250)**	**$500,750**	**$67,250**	**18**
Simple payback			10 years		
NPV			$502,329		
IRR			10.4%		

Capital Renewal Measures	Net Cost
Chiller replacement	$178,600
Total	**$178,600**

Appendix C: Projected RCM Savings

Resource Conservation Measures	Projected Annual Savings			
	Electricity (kWh)	Natural Gas (m^3)	Water (m^3)	Carbon Emissions (tCO_2e)
Condensing heating boilers		15,900		30
Condensing DHW boilers		23,640		45
VSD for domestic cold water	29,750			5
VSD for MAUs	32,300	12,140		28
Metering & control systems	32,800	2,870		11
Lighting	109,700			17
Low-flow toilets, showerheads, and aerators		6,680	4,360	13
Weatherstripping		1,210		2
Voltage optimization	38,650			6
Main water meter valve			1,290	0
Training and resident awareness	11,700	2,490	220	7
Total	**254,900**	**64,930**	**5,870**	**149**

Emissions Factors[2]	
Electricity	159 gCO_2eq/kWh
Natural Gas	1899 gCO_2eq/m^3
Water	150 gCO_2eq/m^3

Appendix D: Equipment Details

Equipment	Manufacturer	Quantity	Description
DynaForce DRNH2000	CAMUS	2	Condensing boiler
DynaForce DRNW1000	CAMUS	2	Condensing boiler
DCW Booster Pump	Armstrong	1	Vertical multi-stage booster pump with VFD.
Chiller (160 tons)	DAIKIN/Carrier	1	Air cooled chiller, part of capital renewal measures.

Appendix E: Savings Tables

Year	Utility	Consumption			Actual Savings
		Baseline	Projected	Actual	
Year 1:	Electricity (kWh)	1,204,079	949,179	891,705	279,637
	Gas (m^3)	221,372	156,442	190,673	59,165
	Water (m^3)	22,932	17,062	18,560	4,339
Year 2:	Electricity (kWh)	1,155,715	900,815	886,929	284,413
	Gas (m^3)	226,202	161,272	198,370	51,468
	Water (m^3)	22,900	17,030	19,152	3,747

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,
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