Ensuring social and affordable housing is part of a just and equitable transition to a low carbon future

BUILDING THE BUSINESS CASE FOR RETROFITS, BRIEF 1: Benefits and Costs

May 2023

This project has received funding from:

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Table of Contents

Acknowledgements:
This project benefited from the invaluable contributions of Stefanie Drozda and Mike Mellross [Alberta Ecotrust], Cam McDonald [Right at Home Housing Society], Hazel Navarozza and Joanne Cabrera [Civida], Jonathan Lay and Nick Lilley [Home Ed], Councillor Anne Stevenson, Barbara Daly, Andrea Soler, Lauren Hall and Lisa Dockman [City of Edmonton], Mike Krokis and Faisal Husain [3D Energy], Matt Zipchen, Tim Stoate and Beata Domanska [Efficiency Capital].

1 INTRODUCTION

Achieving the ambitious greenhouse gas (GHG) emission reductions stated in Edmonton's Community Energy Transition Strategy and Calgary's Climate Strategy will require transformative and rapid change across all sources of emissions. Both cities have committed to net-zero emissions by mid-century. Residential buildings are a significant emission source, accounting for 18% and 32% of community-wide emissions in Edmonton and Calgary, respectively. These buildings also have a service life of 40-80 years. Attaining the cities' targets in the next 30 years will thus require deep energy and GHG saving retrofits (upgrades) to most existing residential buildings.

Yet, progress has been doggedly slow—especially in the social and affordable housing sector where an assortment of unique barriers limits the uptake of retrofits. Two critical barriers are that the business case is poorly understood and challenging for decision-makers to justify, compounded by a lack of awareness of available funding support and financing options. The presence of these and other barriers means individuals and families in subsidized housing will have limited opportunities to benefit from access to low-carbon goods and services, improved housing and the enhanced quality of life offered by decarbonization. For Edmonton's and Calgary's transition to be considered "just, equitable and inclusive"—a guiding principle of both cities' Strategies—all residents must have fair access to these opportunities.

Failure to include the social and affordable housing sector in the transition to a low-carbon future is not an option. The 2,950 social and affordable housing buildings in Edmonton and Calgary generate about 200,000 tonnes of carbon dioxide equivalent (t CO_2e) per year—that is a lot of potential emission reductions to leave on the table. Furthermore, tenants of these buildings will almost certainly be part of Edmonton's and Calgary's "energy poor"—households who are unable to maintain adequate energy services at a reasonable cost. Energy poverty is a form of material deprivation that can result in financial stress, cold homes and poor health, the need to cut other basic expenditures, lower educational attainment, social isolation and risk-taking behaviours, as well as less tangible non-material deprivation, like loss of dignity. Retrofitting deep energy savings into social and affordable housing buildings will help reduce energy poverty in the sector, giving rise to a range of important social and economic benefits.

For the purpose of this Brief, a deep retrofit is a multi-measure retrofit project that achieves at least a 25% reduction in current levels of energy consumption.[1]

Deep retrofit ≥ 25% energy savings

[1] This level of savings was chosen as it is the minimum level of energy savings required to be eligible for FCM's Sustainable Affordable Housing, Retrofit Capital Projects funding initiative (see www.greenmunicipalfund.ca/sustainable-affordable-housing). Other resources view energy savings of *at least* 40% as defining a deep retrofit. Indeed, the Canada Greener Affordable Housing (CGAH) program defines a deep energy retrofit as delivering a 70% reduction in pre-retrofit energy consumption.

1.1 Project goal

The project is intended to:

1. Prove and demystify the business case for deep energy retrofits of buildings typical of the social and affordable housing sector; and
2. Introduce financing options and funding support and show how housing providers can improve the business case for action.

This Brief is focused on the first barrier; a companion Brief focuses on the second barrier. By addressing these two critical barriers to the uptake of deep energy and GHG saving retrofits, it is hoped that these Briefs will support and inform dialogue between decision-makers in the social and affordable sector and providers of funding and financing support to kick-start and accelerate retrofits across the sector's inventory of buildings.

The content of both Briefs is based on detailed energy and financial assessments of four case study buildings in Edmonton (managed by HomeEd, Right at Home Housing Society and CIVIDA) and a workshop (held on Thursday, November 10th, 2022) to explore financing options, attended by other social and affordable housing providers, policymakers, and interested stakeholders from the green building industry, non-profits, and sources of financial support.

2 THE OPPORTUNITY

Demand for social and affordable housing increasingly exceeds available supply. A major obstacle to addressing the housing shortfall is that it takes too long to get new units to market. One way to help meet growing demand is to focus on restoring, retrofitting, or reusing existing buildings that may otherwise be repurposed or demolished—thereby extending their useful service life. About 8-10% of subsidized housing units in Edmonton and Calgary are in need of major repairs.[2] Renewing an existing building structure for continued use is less expensive than new construction, and generally more sustainable. Importantly, capital renewal projects also provide an opportunity to overlay deep energy and GHG saving upgrades on top of planned refurbishments. This improves the cost-effectiveness and business case for the upgrades since the building envelope, and mechanical and electrical systems are already being rehabilitated. In essence, only the incremental cost of the energy and GHG saving measures beyond business-as-usual upgrades count as 'new' capital expenditures. Furthermore, a very high percentage of the existing social and affordable housing inventory in both cities was constructed prior to the adoption of the 2011 National Energy Code of Canada for Buildings in Alberta and are thus considerably more energy intensive than newer construction. This means there is plenty of scope for improving the energy efficiency of these buildings

> *"Our typical buildings are either row townhouses or walk-up apartments built around 1980. That's true of the other non-profit housing providers in Edmonton. They're all 40+ years old."*
>
> Housing provider in Edmonton

[2] Statistics Canada, 2022, Table 98-10-0247-01, core housing need by tenure including presence of mortgage payments and subsidized housing.

and generating material utility cost savings for both housing providers and tenants alike. The majority of tenants pay at least one utility bill: "*Tenants pay for power, but we pay for heat and water*" (a comment typical of housing providers in Edmonton)[3]. Housing providers will simultaneously benefit from lower maintenance costs, increased valuations for owned properties, and enhanced resilience to energy price volatility and extreme weather impacts.

More broadly, deep energy saving retrofits of the social and affordable housing inventory have the potential to generate significant triple bottom line benefits—including the health and well-being of tenants, the local economy, and climate change mitigation. Analysis of actions to address energy poverty in Edmonton, for example, has shown that for each 10% reduction in the average energy bill of an energy poor household, the number of energy poor households in the city would decline by nearly 2%. That equates to 360-915 fewer households experiencing the adverse impacts of energy poverty outlined above.[4]

The main social, economic and environmental benefits of deep energy and GHG saving retrofits to social and affordable housing buildings are listed in Figure 1. The figure also shows the relative significance assigned to each benefit stream by participants at the project workshop. In the view of participants, the most significant benefits relate to the utility bill savings that would accrue to both the housing providers and those tenants that paid bills. The importance of the former cannot be overstated as a potential source of funding for retrofits of buildings in the sector. For some housing providers, borrowing is a viable option to fund retrofits, but only if the savings they accrue exceed the costs of servicing the debt. Other housing providers—for whom borrowing is not currently an option—are willing to use their cash reserves to fund retrofits; but to pay for deep retrofits they must build-up these reserves over multiple years through operational cost savings. This of course serves as a barrier to the rapid adoption of deep retrofits by some housing providers.

> "*If our savings, on a month-to-month basis, are more than our debt servicing, then the* [retrofit] *project makes sense. That is the framing we look at.*"
>
> "*…whatever savings I get I put into reserve funds and then build that up for major, deep energy retrofits.*"
>
> Housing providers in Calgary and Edmonton

[3] Though, in some cases, the tenant does not have any utility bills in their name or is directly responsible for all utility bills.

[4] Assumes a household is 'energy poor' if its energy cost burden exceeds 6% or 10% of after-tax income, implying about 50,765 and 19,840 households in Edmonton, respectively, are experiencing energy poverty (as per the Energy Poverty and Equity Explorer accessible at www.energypoverty.ca).

Figure 1: Key social, economic and environmental benefits of deep energy and GHG saving retrofits of social and affordable housing stock

Description of benefits	Most significant benefits
Reduced utility bills for housing provider	25%
Reduced maintenance costs for housing provider	9%
Extended useful service life of property	2%
Increased property value	0%
Avoided capital rehabilitation / renewal investments in future years	2%
Reduced utility bills, improved affordability and more disposable income for tenants	21%
Improved thermal comfort, physical and mental health, safety and wellbeing of tenants	11%
Reduced risk of tenant going into arrears	0%
Increased resilience to energy price volatility / shocks and carbon price escalation	7%
Increased resilience of building to extreme weather impacts and climate change	5%
Inclusive energy transition—reduced inequality and disparities in community	5%
Reduced community greenhouse gas (GHG) emissions	11%
Local employment and growth opportunities for green building sector	4%

Note: the percentages and bars represent the relative frequency of participant votes for their two most significant benefits

3 THE CHALLENGES

Given the wealth of potential benefits from retrofitting deep energy and GHG savings into the social and affordable housing stock, why has the uptake of retrofits been stubbornly slow? The reality is—housing providers face many challenges when it comes to pursuing deep retrofits to reduce energy consumption and GHG emissions. The main barriers are listed in Figure 2. The relative significance assigned to each barrier by participants at the project workshop is also displayed. The most important challenges relate to the scarcity of available capital and competing needs for that pool of limited funds. Capital renewal of social and affordable housing buildings is frequently done to very tight budgets with no scope to include energy or GHG savings measures beyond minimum code requirements, despite the potential for larger operating cost savings. As one housing provider in Edmonton put it: "*Like most non-profits* […] *we have too much to do and not enough dollars to do it*."

> "*…most of our funding is to ensure the buildings we have don't fall down.*"
>
> "*…for money to come out of our reserves, it's not going to be used for* [energy] *efficiency, it's going to be used to keep our buildings going.*"
>
> "*All of our buildings are 50-55 years old and they're all reaching the end of life … the primary goal* [of our real estate strategy] *is to extend the life of an asset to the best of our ability with the funding that we have.*"
>
> Housing providers in Calgary and Edmonton

Relatedly, while housing providers are interested in reducing their GHG emissions and environmental stewardship generally, it does not motivate or influence business decisions. Dollars influence business decisions in the sector with emissions savings viewed as a co-benefit: "*oh, by the way*, [the project] *will also reduce GHG emissions*" (comment from a housing provider).

Housing providers are also challenged by knowledge and capacity gaps with respect to both (1) planning and coordinating the retrofits and (2) the available options to finance the required capital expenditures and existing restrictions on access to finance—in particular, restrictions on taking on (more) debt. One housing provider commented: "*the direction from our executive team and Board is that they currently do not want to take on any more debt*." Though not all social and affordable housing providers face borrowing limits or prohibitions; one provider in Edmonton with little debt against their portfolio uses debt financing to fund capital projects, which include energy saving retrofits.

Only a handful of workshop participants identified misaligned incentives as a key barrier to implementing deep energy retrofits. However, for some housing providers, they are the most important hurdle to overcome. When debt servicing of loans to pay for deep retrofits must be covered by utility bill savings, but the savings accrue partially or wholly to tenants because they pay the bills, the result was described by one housing provider in Edmonton as "*great for our tenants*" but "*our biggest problem*" to pursuing deep retrofits. Relatedly, the ownership of the property can be a significant hurdle. Within a housing provider's portfolio of properties, some will be owned, while many are only managed for the City of Edmonton (or City of Calgary) or the province. Several housing providers commented that while the cities are open to investing in deep energy saving retrofits, the province is not; "*The ones we manage for the province, we cannot do anything, there's zero opportunity*."

As stated above, the goal of this Brief and the companion Brief (focused more on financing options) is to help social and affordable housing providers in Edmonton and Calgary overcome these challenges.

Importantly for the transition to a low carbon future, failing to take advantage of the opportunity presented by routine capital renewal projects—i.e., to cost-effectively embed deep energy and GHG saving measures into the projects—risks locking in higher carbon footprints in the building stock for another 30-40 years, given the expected service life of building systems.

Figure 2: Key barriers to deep energy and GHG saving retrofits of social and affordable housing stock

Description of barriers	Most significant barriers
Limited understanding of the full business case—energy saving measures and their costs, utility savings potential, and non-energy co-benefits	7%
Poor knowledge of options to finance the initial capital investment at little or no up-front cost and overcome financing restrictions—like debt covenants imposed by existing lien holders that place limits on taking on more debt	23%
Retrofits offer longer paybacks and lower rates of return compared with alternative (uses of capital) investments	2%
Competing priorities for the limited available capital—like deferred maintenance or acquisition of new properties	25%
Uncertainty around the length of ownership of the property given the long lifespan of energy saving measures	0%
Concern that the estimated utility bill savings will not be realized (performance risk)	2%
Uncertainty relating to project costs, and concern for cost overruns, delays in completing projects and risks to building operations	0%
Limited understanding and capacity to manage and plan retrofits—coordinate with multiple organizations offering retrofit assessments, design and installation, and incentives and financing and their application processes	14%
Properties first require costly rehabilitation (construction upgrades) to enable the retrofit of energy saving measures	7%
Misaligned interests—depending on ownership, savings on operational expenses do not flow to decision-makers of capital investments, such as energy saving retrofits	2%
Misaligned interests—housing provider pays none or only a portion of the utility bill and thus has limited incentive to invest in retrofits to save energy	7%
Insufficient available capital	16%

Note: the percentages and bars represent the relative frequency of participant votes for their two most significant challenges

4 THE FINANCIAL CASE FOR DEEP RETROFITS

To demonstrate and demystify the financial case for deep energy retrofits for social and affordable housing providers in Edmonton and Calgary, four case study buildings in Edmonton were identified in tandem with project partners (Civida, HomeEd and Right at Home) for detailed energy and financial assessments. The overall approach to this aspect of the project is summarized in Figure 3.

Figure 3: Project approach

1. •Select case study buildings with project partners that are typical of the sector
2. •Perform baseline energy assessment of the case study buildings
3. •Build and calibrate energy model for each case study building
4. •Analyse energy and GHG savings retrofit potential and associated costs and benefits
5. •Identify financing options and assess cashflows of different financing scenarios

4.1 The case study buildings

The four case study buildings are presented in Table 1. They were selected to be representative of buildings in the sector. In 2020, about 55% of the social and affordable housing buildings in Alberta were semi-detached, row townhouses like Rundle Heights II and Woodvale Court, accounting for about 38% of available dwelling units.[5] Apartments like Lexington Manor with fewer than 5-storeys accounted for 9% of buildings (37% of dwelling units) in the province, with a further 2% of buildings (and 20% of dwelling units) comprising apartments with five or more storeys, as typified by Renfrew Arms.[6]

Table 1: Description of case study buildings

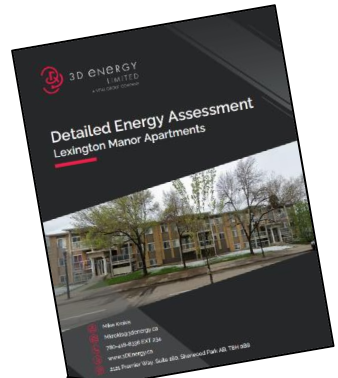
	Rundle Heights II	Woodvale Court	Renfrew Arms	Lexington Manor
				
Housing provider	Civida	Right at Home	Civida	Home Ed
Number of units	97	46	65 + parkades	40 + parkade
Types of units	2-, 3-, 4- & 5-bed	2- & 3-bed	1-bed	Studio, 1- &2-bed
Approximate floor area	12,420 m^2	5,980 m^2	4,890 m^2	2,790 m^2
Construction period	Circa 1970	Circa 1981	Circa 1981	Circa 2000

[5] Statistics Canada, 2022, Table 46-10-0001-01, Inventory of publicly owned social and affordable housing assets, Alberta.

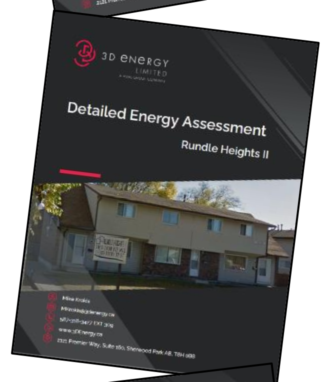
[6] Single detached houses could not be accommodated within the scope of the project; accounting for about 34% of buildings and 5% of dwelling units in Alberta.

4.2 Building energy assessments

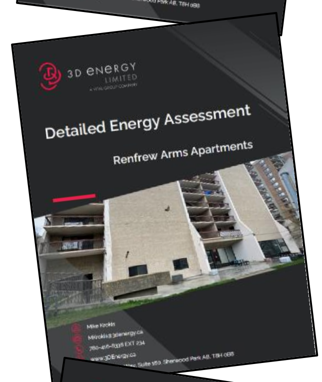
To develop an understanding of each building's current energy performance as well as energy and GHG saving opportunities, an energy assessment (sometimes called an "energy audit") was performed. Energy assessments can be performed at different levels of rigour and expense—though all share a common foundation, involving the determination of total building energy use and cost, based on a review of utility bills from at least the last two years. 3D Energy Limited was contracted to perform Level II Assessments (see Box 1) for each case study building.



Level II assessments provide a suitable basis for many decisions where the investment needs are modest or estimated savings are large enough to overshadow any uncertainties regarding their magnitude. However, when a large, capital investment—as is the case with a deep retrofit—is under consideration, a Level III audit reduces the risk that important assumptions are inaccurate or that interaction effects between building systems are overlooked. Failure to account for interaction effects will generally lead to overestimation of savings. Equally, taking interactions into account may also lead to opportunities to reduce equipment size and associated costs. Energy efficient lighting and windows, for example, may reduce heating loads sufficiently to downsize HVAC equipment.



Since this project is concerned with the financial case for deep retrofits with the potential for relatively large capital expenditures, 3D Energy Limited also developed building-specific energy models in the RETScreen Expert simulation software[7], to capture potential interaction effects and to provide more robust estimates of energy savings. Outputs from the energy models were entered into a spreadsheet built for this project in Microsoft Excel that performed the financial analysis of the identified retrofit measures (the spreadsheet is available separately).



The measured baseline energy use (in both physical units and dollars) of each case study building is provided in Table 2. The baseline energy performance of each building is also shown, expressed in terms of total energy consumption per m^2 of floor space (or the Energy Use Intensity, EUI). The row townhouse complexes are relatively more efficient than the apartment blocks (with lower EUIs). The estimated EUIs can be compared with similar, yet highly energy efficient buildings, making them useful as a basis for setting energy use reduction targets. Estimated GHG emissions in 2022 are also shown in Table 2.

[7] RETScreen Expert is accessible from: www.nrcan.gc.ca/maps-tools-and-publications/tools/modelling-tools/7417.

Box 1: Types of energy assessments

Level I

A Level I assessment builds on the energy use analysis of utility bills with a brief walk-through of the building and inspection of the building's energy consuming equipment. They identify no-cost and low-cost energy saving opportunities. However, estimated savings and project costs are based on simple calculations that typically do not account for interactions between building systems, such as the increased heating load that results from the installation of more efficient lighting. The energy saving estimates are thus less accurate, making Level I assessments unsuitable for financial decision-making on capital intensive upgrades.

Level II

Building on a Level I assessment, a Level II assessment includes a more in-depth investigation into the overall performance of major building systems, which is used to calculate a breakdown of energy consumption by end-use, including space heating and cooling, ventilation, water heating, motors, lighting, etc. With the increased understanding of the energy performance of all building systems, all practical energy saving measures—including capital intensive measures—are typically analyzed with the assessment report providing, at a minimum, estimated energy savings and project costs. A Level II assessment is adequate for most buildings.

Level III

A Level III assessment builds on a Level II assessment by providing a more detailed and accurate analysis of a building's energy performance and the identified energy saving measures. The key difference is that the Level III assessment accounts for the interaction effects of all building system upgrades, typically by using computer models to simulate building and equipment operations. The use of computer models allows for a rigorous engineering analysis that details the estimated savings with a level of confidence sufficient to support larger capital investment decisions. For this reason, a Level III assessment is often called an "investment grade" audit.

Table 2: Baseline energy performance of case study buildings in 2022

	Rundle Heights II	Woodvale Court	Renfrew Arms	Lexington Manor
Electricity use	1,844 GJ	860 GJ	1,580 GJ	607 GJ
Natural gas use	8,512 GJ	5,739 GJ	5,736 GJ	2,936 GJ
Energy use intensity (EUI)	0.83 GJ / m^2	1.10 GJ / m^2	1.48 GJ / m^2	1.27 GJ / m^2
Electricity bill	\$46,540	\$23,595	\$47,085	\$33,900
Natural gas bill	\$122,170	\$30,480	\$45,235	\$20,775
Energy bill	\$168,710	\$54,075	\$92,320	\$54,675
GHG emissions	715 t CO_2e	427 t CO_2e	521 t CO_2e	242 t CO_2e
GHG emission intensity	0.06 t CO_2e / m^2	0.07 t CO_2e / m^2	0.11 t CO_2e / m^2	0.09 t CO_2e / m^2

Note: GJ = Gigajoule = 278 kWh (Kilowatt hours)

4.3 The identified energy and GHG saving opportunities

The energy assessments identified multiple energy saving measures for each case study property. A whole building approach was adopted with efficiency improvements identified for the following building systems: space heating equipment and schedules, domestic hot water equipment, ventilation equipment, building envelope (i.e., walls, foundation, roof, windows, doors), interior and exterior lighting, electrical equipment (e.g., dryers) and hot water end-use equipment (e.g., faucets, toilets). The full list of identified energy saving measures for the row townhouse complexes (Rundle Heights II and Woodvale Court) and the apartment blocks (Renfrew Arms and Lexington Manor) are provided in Table 3 and Table 4, respectively.

The energy assessments identified some equipment that was defective or nearing or past the end of its useful service life—for example, the windows and many domestic hot water heaters at both Rundle Heights II and Woodvale Court. In these cases, two sets of measures were identified: new equipment compliant with minimum code and upgraded equipment that is more energy efficient than minimum code. This distinction is important when it comes to the analysis of retrofit benefits and costs, since the installed costs of the required windows and domestic hot water heaters would in principle need to be incurred in the near future to maintain the properties in a state of good repair. As a result, when calculating Net Present Values as part of the business case analysis (discussed in Section 4.4), the total installed costs of the minimum code equipment should be treated as a monetary benefit (saving). As emphasized in Section 2, planning deep retrofits to coincide with major capital rehabilitation projects at buildings as part of standard asset management—such as replacing windows, siding, roofs, boilers, etc. at the end of their useful service life—provides opportunities to upgrade the energy performance of building systems at a lower incremental cost.

In addition to energy saving measures, the assessments identified opportunities to install solar photovoltaic (PV) systems on each building. The size of the systems varies considerably depending on the area of suitable roof space at each site—ranging from 25 panels at Renfrew Arms (with an installed capacity of 14 kilowatts) to 821 panels at Rundle Heights II (with an installed capacity of 443 kilowatts).

Table 3: Energy conservation measures and renewable energy measures identified for the row townhouse complexes

Measure ID	Building	Short description	Detailed description
ECM-1	RH	Low-cost measures	Door seals & sweeps, pipe insulation & DHW tank blankets, Low-flow aerators, furnace pipe
ECM-2	RH	Low-flow water fixtures	Low-flow washroom facets, low-flow kitchen faucets, dual-flow toilets
ECM-3	RH	Smart thermostats and HRV controls	Smart thermostats set back to 16C for unoccupied hours (2,920) plus addition of HRV controls
ECM-4	RH	Lighting upgrade	Replacement of all interior and exterior non-LED fixtures with LEDs (lighting load reduction = 0.6 Watts / m2)
ECM-5a	RH	DHW heater upgrade (above min. code)	Replace 50% existing storage DWHs at end of life with condensing tankless DWHs (EF from 59% to 93%)
ECM-5b	RH	DHW heater upgrade (min. code)	Replace 50% existing storage DWHs at end of life with storage type heater (EF from 59% to 67%)
ECM-6a	RH	Window upgrade (above min. code)	Replace existing windows at end of life with triple-pane, argon-filled, low-e windows (RSI from 0.222 to 0.621)
ECM-6b	RH	Window upgrade (min. code)	Replace existing windows at end of life with min. code double-pane, argon filled, low-e (RSI from 0.222 to 0.505)
ECM-7	RH	Exterior wall insulation upgrade	Install Extruded Polystyrene (XPS) insulation with thermal insulation (increase RSI from 1.76 to 4.05)
ECM-8	RH	Foundation walls, headers & rims insulation	Seal cracks, increase R-value of headers and rims to at least 20, increase R-value of foundation walls from 2.4 to 15
ECM-9	RH	Upgrade doors	Replace all existing exterior doors (R-2) with fiberglass doors (R-5)
REM-1	RH	Install solar PV system	Install grid-connected PV system comprising 821 x 540 W panels (cap. = 443.3 kW)
ECM-1	WC	Low-cost measures	Door seals & sweeps, pipe insulation & DHW tank blankets, Low-flow fixtures, furnace pipe
ECM-2	WC	Low-flow water fixtures	Low-flow washroom facets, Low-flow kitchen faucets
ECM-3	WC	Smart thermostats	Smart thermostats set back to 16C for unoccupied hours (2,920) plus addition of HRV controls
ECM-4	WC	Lighting upgrade	Replacement of all interior and exterior non-LED fixtures with LEDs (lighting load reduction = 3.02 Watts / m2)
ECM-5a	WC	DHW heater upgrade (above min. code)	Replace 50% existing storage DWHs at end of life with condensing tankless DWHs (EF from 57% to 93%)
ECM-5b	WC	DHW heater upgrade (min. code)	Replace 50% existing storage DWHs at end of life with storage type heater (EF from 57% to 67%)
ECM-6a	WC	Window upgrade (above min. code)	Replace existing windows at end of life with triple-pane, argon-filled, low-e windows (RSI from 0.383 to 0.592)
ECM-6b	WC	Window upgrade (min. code)	Replace existing windows at end of life with min. code double-pane, argon filled, low-e (RSI from 0.383 to 0.490)
ECM-7	WC	Exterior wall insulation upgrade	Install Extruded Polystyrene (XPS) insulation with thermal insulation (increase RSI from 1.76 to 3.87)
ECM-8	WC	Foundation walls, headers & rims insulation	Seal cracks, increase R-value of headers and rims to at least 20, increase R-value of foundation walls from 2.4 to 15
ECM-9	WC	Roof insulation upgrade	Blown-in cellulose insulation with thermal resistance of RSI-3.6 per mm (increase RSI from 4.23 to 8.81)
ECM-10	WC	Upgrade doors	Replace existing doors with doors that are rated R-5 or better (increase RSI from 0.383 to 1.23)
REM-1	WC	Install solar PV system	Install grid-connected PV system comprising 273 x 455 W panels (cap. = 124.2kW)

Notes: RH = Rundle Heights II; WC = Woodvale Court; DWH = domestic hot water; HRV = heat recovery ventilator; kW = kilowatt; R-value and RSI are both measures of thermal resistance (the higher the resistance value, the slower the rate of heat transfer through the insulating material; EF = efficiency factor (an EF of 80% means that 80% of the energy that is being used to heat your water is effectively converted into heat).

Table 4: Energy conservation measures and renewable energy measures identified for the apartment blocks

Measure ID	Building	Short description	Detailed description
ECM-1	RA	Low-cost measures	Door seals & sweeps, pipe insulation & DHW tank blankets, increase operational efficiency of supply fans, adjust AC unit temperature in mechanical room
ECM-2	RA	Smart thermostats	Smart thermostats set back to 16C for unoccupied hours (2,920) plus addition of HRV controls
ECM-3	RA	Lighting upgrade	Replacement of all non-LED fixtures with LEDs (lighting load reduction in suites, common areas & parkade = 4.2, 5.5 and 1.2 Watts / m^2, respectively)
ECM-4	RA	Heat transfer fluid additive	Installation of a heat transfer fluid enhancer for all water/glycol-based heating fluids
ECM-5a	RA	Window upgrade (above min. code)	Replace existing windows at end of life with triple-pane, argon-filled, low-e windows (RSI from 0.284 to 0.621)
ECM-5b	RA	Window upgrade (min. code)	Replace existing windows at end of life with min. code double-pane, argon filled, low-e (RSI from 0.284 to 0.505)
ECM-6	RA	Clothes Dryer Upgrade	5 existing electric dryers replaced with natural gas models (used for a combined 4 hours per day)
ECM-7	RA	Energy Recovery Wheel	Installation of one 11,000 cubic feet per minute Energy Recovery Wheel (ERW) for the ventilation system, plus 25 m of required ducting
REM-1	RA	Install solar PV system	Install grid-connected PV system comprising 25 x 550 W panels (cap. = 13.75 kW)
ECM-1	LM	Low-cost measures	Door seals & sweeps (30 m), low-flow aerators (40 devices)
ECM-2	LM	Smart thermostats	Smart thermostats set back to 16C for unoccupied hours (2,920) plus addition of HRV controls
ECM-3	LM	Heat transfer fluid additive	Installation of a heat transfer fluid enhancer for all water/glycol-based heating fluids
ECM-4	LM	Vestibule window upgrade	Replace existing vestibule windows with triple-pane, argon-filled, low-e windows (RSI from 0.159 to 1.031)
ECM-5a	LM	Near condensing boilers (AFUE 88%)	Replace the 2 existing boilers with 2 new near-condensing boilers (capacity = 246 kW, AFUE increase from 64.4% to 88%)
ECM-5b	LM	New min. code boilers (AFUE 80%)	Replace the 2 existing boilers with 2 new non-condensing (min. code) boilers (capacity = 246 kW, AFUE increase from 64.4% to 80%)
ECM-6	LM	Clothes dryer upgrade	Replace the 1 existing electric dryer with natural gas model (used for 40 loads per week)
REM-1	LM	Install solar PV system	Install grid-connected PV system comprising 88 panels with capacity = 36.8 kW

Notes: RA = Renfrew Arms; LM = Lexington Manor; DWH = domestic hot water; HRV = heat recovery ventilator; kW = kilowatt; R-value and RSI are both measures of thermal resistance (the higher the resistance value, the slower the rate of heat transfer through the insulating material; EF = efficiency factor (an EF of 80% means that 80% of the energy that is being used to heat your water is effectively converted into heat); AFUE = Annual Fuel Utilization Efficiency (an AFUE of 90% means that 90% of the energy in the boiler's fuel source becomes heat).

4.4 Analysis of retrofit costs and benefits

The main benefits provided by deep energy and GHG saving retrofits were listed in Figure 1. The primary motivation for housing providers in the sector to invest in deep retrofits is reduced utility bills concomitantly with extending the life of the property. The operational cost savings resulting from reduced energy (and water) consumption are complemented by a range of non-energy benefits; some of which can be readily monetized (e.g., reduced O&M costs, avoided costs of planned rehabilitation work), some of which are much more difficult to monetize (e.g., the improved comfort, health and wellbeing of tenants, increased resilience to extreme weather events). Furthermore, some of the monetary non-energy benefits afforded by deep retrofits may only interest the "market" rental sector—e.g., increased rental income (rental premiums, reduced vacancy periods, reduced turnover-related costs), increased property values resulting from increased net operating income.

Box 2: Estimating project value

The most commonly applied and simple method used for the economic analysis of retrofit projects is simple payback. Simple payback is the time, in years, for a retrofit's cumulative annual savings to equal its purchase and installation costs. A shorter payback period is preferable to a longer one. Payback has several drawbacks, however. For a start, it does not take into account the time value of money, though this can be addressed by calculating the discounted payback period—the number of years it takes discounted (present value) cumulative savings to recoup the initial investment. A drawback with both payback methods is they do not account for any benefits or costs that occur after the upfront investment has been recovered. Based on payback calculations a retrofit can initially appear to be unattractive, yet a more thorough economic analysis may suggest it to be a highly profitable investment.

Net present value (NPV)—a form of lifecycle cost analysis—provides a more robust evaluation of a retrofit's economic merits. Not only does it consider all cash flows over the useful life of a retrofit project, but it also accounts for the time value of money. A project's cash flows include the purchase and installation costs of equipment, energy and water cost savings, and all other costs and benefits, such as reduced O&M costs and any avoided planned capital rehabilitation expenditures. Using the housing provider's chosen discount rate, all cash flows are expressed as present values—i.e., in comparable dollars today when decisions are made. A positive NPV indicates a retrofit project's present value cash inflows (the benefits) exceed the present value of its cash outflows (the costs) over the term of the analysis (typically, the expected useful service life of the measures). Simply put, a project with a positive NPV is profitable. In contrast, a negative NPV indicates the project is unprofitable.

There are alternative methods related to NPV for determining the worth of a retrofit project, including internal rate of return (IRR) and modified internal rate of return (MIRR). Nonetheless, NPV is the preferred method for the economic analysis of energy saving retrofit projects, with one noteworthy exception. A subsidized housing provider is very unlikely to have unlimited access to capital and able to execute all profitable projects with a positive NPV. In reality, housing providers will have constraints on how much funds they have to invest in their building portfolio, let alone in energy saving retrofit projects. When there are more worthy projects than funds available, the housing provider will have to exercise 'capital rationing' and prioritize the projects according to their attractiveness. But how does the housing provider decide which retrofit projects are most attractive? Simply ranking the projects according to their NPV is not correct. This is because the level of capital expenditure needed to generate the benefits embedded in the estimated NPV is being ignored—and it is that expenditure that is being rationed.

To ration capital efficiently across multiple worthy projects with positive NPVs the profitability index (PI) can be used. The PI is equal to 1 + (NPV ÷ initial capital expenditure). In the context of deep retrofits, PI thus provides a metric of the operational cost savings per unit of investment. The higher the PI, the more attractive the project—and rationed capital should first be allocated to projects with the highest PI so that savings are maximized for a given level of capital expenditure.

The analysis of retrofit costs and benefits is presented separately below for each case study building. Key assumptions underpinning the analysis are summarized in Table 5. Utility bill savings are based on estimated changes to the total variable costs of supply as opposed solely to the commodity charge for electricity, natural gas or water. Using total variable costs provides a more accurate measure of potential operational cost savings; moreover, it will generate large savings and strengthen the retrofit business case. All values are measured in constant (real) 2022 dollars—i.e., the influence of general price inflation on costs and benefits has been removed. Even with the impact of inflation removed, relative utility prices are still projected to rise year-on-year. Since the analysis is based on constant prices, all present value calculations of future costs and benefits must be based on a real discount rate (assumed to be 3%).

There is always some uncertainty regarding anticipated savings. To allow for this, it is assumed that only 90% of estimated savings are realized.

To reflect the GHG emissions intensity of electricity delivered to end-users, estimated GHG savings are based on the 'consumption-intensity' of the provincial grid, as opposed to the 'generation-intensity'. The latter reflects the GHG emissions intensity of electricity delivered to the grid only, failing to capture losses associated with transmission and distribution from generating sites to end-users.

Table 5: Key assumptions for the analysis of retrofit benefits and costs

Key variable	Units	2022	2050
Variable cost of electricity [a, b]	\$ 2022 per kWh	0.097	0.127
Variable cost of natural gas [a, b]	\$ 2022 per GJ	5.34	8.35
Variable cost of water [a, c]	\$ 2022 per m^3	3.60	4.76
GHG-intensity of electricity grid (consumption-based) [d]	g CO_2e per kWh	516	246
Realized savings (uncertainty)	%	90	
Nominal discount rate (real discount rate)	% per year	5 (3)	

Notes: a) the starting value in 2022 is derived from a statistical analysis of utility bills; b) real terms increases in electricity and natural gas costs are based on the "current policies" projections for residential end-use in Canada's Energy Outlook 2022; c) water costs assumed to escalate a 1% per year in real terms; d) based on the AESO 2021 Reference Case and Canada's National GHG Inventory Report 2022, Part 3.

4.4.1 Retrofit project value: Rundle Heights II

The estimated energy, water, operational cost and GHG savings of individual measures identified for Rundle Heights II are shown in Table 6, along with the required upfront investment expenditure ("CAPEX"). The table also provides two indicators of the economic performance of each measure: NPV and PI (recall Box 2). In addition, an indicator of the cost-effectiveness of each measure in reducing baseline GHG emissions is shown—i.e., the net marginal abatement cost. This signifies the net cost of reducing baseline emissions by one tonne of CO_2e; a negative value indicates the measure generates a net benefit (i.e., lifetime operational cost savings in excess of the initial CAPEX) for each tonne of CO_2e avoided.

Table 6: Lifetime costs and benefits of individual energy and GHG saving measures: Rundle Heights II

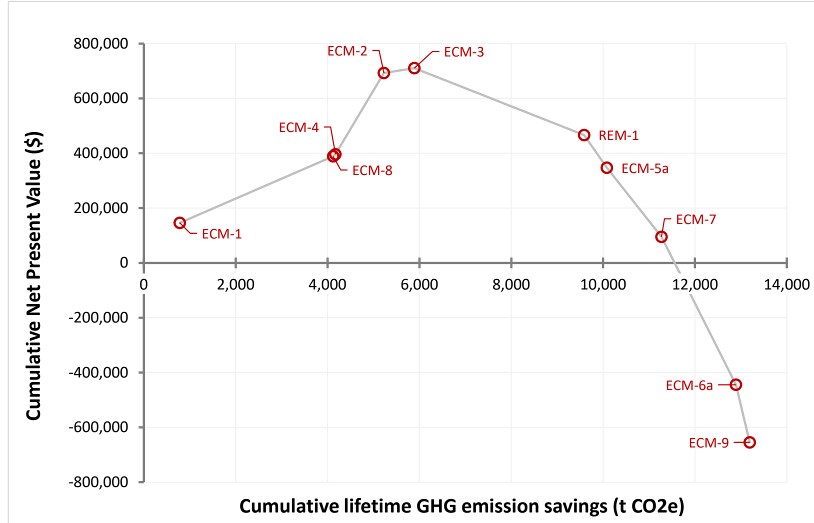
Indicator	Units	Energy and GHG saving measures									
		ECM-1	ECM-2	ECM-3	ECM-4	ECM-5a	ECM-6a	ECM-7	ECM-8	ECM-9	REM-1
Lifetime utility savings - physical											
Electricity	GJ	0	0	2,233	529	0	0	0	0	0	35,730
Natural gas	GJ	14,765	19,980	7,547	-288	9,369	30,645	22,437	63,153	5,730	0
Sub-total	GJ	14,765	19,980	9,780	241	9,369	30,645	22,437	63,153	5,730	35,730
Water	m3	28,688	113,454	0	0	0	0	0	0	0	0
Lifetime GHG emission savings											
Electricity	t CO2e	0	0	262	64	0	0	0	0	0	3,697
Natural gas	t CO2e	781	1,057	399	-15	496	1,621	1,187	3,341	303	0
Sub-total	t CO2e	781	1,057	661	49	496	1,621	1,187	3,341	303	3,697
Lifetime savings - $ undiscounted											
Electricity	$	0	0	63,801	14,888	0	0	0	0	0	1,083,568
Natural gas	$	112,413	169,861	55,580	-2,069	67,319	260,529	190,749	536,897	48,714	0
Sub-total	$	112,413	169,861	119,381	12,819	67,319	260,529	190,749	536,897	48,714	1,083,568
Water	$	125,028	528,829	0	0	0	0	0	0	0	0
Total	$	237,440	698,690	119,381	12,819	67,319	260,529	190,749	536,897	48,714	1,083,568
Lifetime savings - $ discounted											
Electricity	$	0	0	52,692	12,843	0	0	0	0	0	753,721
Natural gas	$	87,249	108,588	45,783	-1,782	57,980	166,550	121,941	343,226	31,142	0
Sub-total	$	87,249	108,588	98,475	11,060	57,980	166,550	121,941	343,226	31,142	753,721
Water	$	97,455	342,592	0	0	0	0	0	0	0	0
Total	$	184,704	451,180	98,475	11,060	57,980	166,550	121,941	343,226	31,142	753,721
Capital investment											
CAPEX - gross	$	38,480	155,300	80,510	3,400	177,600	705,840	374,170	100,700	241,300	997,425
Grants	$	0	0	0	0	0	0	0	0	0	0
CAPEX - net	$	38,480	155,300	80,510	3,400	177,600	705,840	374,170	100,700	241,300	997,425
Economic performance metrics											
Present value benefits	$	184,704	451,180	98,475	11,060	57,980	166,550	121,941	343,226	31,142	753,721
Net Present Value (NPV)	$	146,224	295,880	17,965	7,660	-119,620	-539,290	-252,229	242,526	-210,158	-243,704
Profitability Index (PI)	ratio	4.8	2.9	1.2	3.3	0.3	0.2	0.3	3.4	0.1	0.8
Marginal abatement cost (MAC) - net	$ per t CO2e	-234	-414	-32	-178	274	492	314	-107	1,025	92

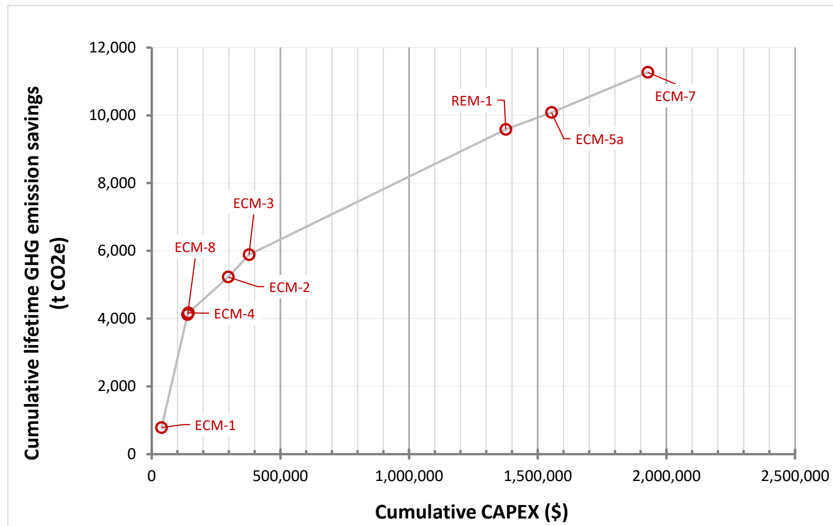
Notes: Measures ID: ECM-1 = low-cost measures; ECM-2 = Low-flow water fixtures; ECM-3 = Smart thermostats and HRV controls; ECM-4 = Lighting upgrade; ECM-5a = DWH heater (above minimum code); ECM-6a = Window upgrade (above minimum code); ECM-7 = Exterior wall insulation upgrade; ECM-8 = Foundation walls, heaters and rims insulation; ECM-9 = Install Energy Star doors; and REM-1 = Install solar PV system.

Figure 4: Maximizing retrofit project value for different levels of investment accounting for interaction effects and assuming self-financing: Rundle Heights II

Measure ID	Cumulative reduction in baseline energy use	Cumulative annual average utility bill savings	Cumulative investment costs	Cumulative NPV	Cumulative reduction in baseline annual GHG emissions
	%	$ per year	$	$	%
ECM-1	8%	13,964	38,480	146,224	6%
ECM-8	21%	27,279	139,180	388,750	18%
ECM-4	22%	28,613	142,580	396,410	19%
ECM-2	31%	51,273	297,880	692,291	23%
ECM-3	32%	59,410	378,390	710,256	29%
REM-1	46%	102,752	1,375,815	466,552	50%
ECM-5a	51%	108,027	1,553,415	346,932	55%
ECM-7	58%	113,120	1,927,585	94,703	60%
ECM-6a *	67%	120,170	2,633,425	-444,586	66%
ECM-9 *	68%	121,481	2,874,725	-654,745	67%

* The inclusion of these measures in the portfolio of implemented projects results in a negative cumulative NPV; hence, they are not shown in the "cumulative CAPEX" graph to the right.





Notes: Measures ID: ECM-1 = low-cost measures; ECM-2 = Low-flow water fixtures; ECM-3 = Smart thermostats and HRV controls; ECM-4 = Lighting upgrade; ECM-5a = DWH heater (above minimum code); ECM-6a = Window upgrade (above minimum code); ECM-7 = Exterior wall insulation upgrade; ECM-8 = Foundation walls, heaters and rims insulation; ECM-9 = Install Energy Star doors; and REM-1 = Install solar PV system.

In the table and accompanying charts in Figure 4 the energy and GHG saving measures are rank-ordered according to their estimated PI (Profitability Index). Given the importance attached to operational cost savings by housing providers in the sector relative to GHG emission savings (recall the comments in Section 3), ranking projects using PI allows decision-makers to select a portfolio of measures that maximizes the operational cost savings for a given level of investment; in some cases, this may also maximize GHG emission savings. The following conclusions are evident from the analysis summarized in Figure 4:

- ✓ The **technical potential** for energy and GHG emission savings at the property are, respectively, a 68% reduction in baseline annual energy consumption and a 67% reduction in baseline annual emissions. The technical potential maximizes savings at the property but does not account for the economic performance of the portfolio of measures. To realize the full technical potential of Rundle Heights II an investment of $2,874,725 is required producing annual utility savings of $121,480 over the functional life of the installed measures. The resulting NPV is negative, however. Attempting to achieve the full technical potential for energy and GHG emission savings at the property will lose the housing provider about $654,745 in present value terms.
- ✓ The **economic potential** for energy and GHG emission savings at the property are, respectively, a 58% reduction in baseline annual energy consumption and a 60% reduction in baseline annual emissions. The economic potential only includes measures that maintain a positive cumulative NPV across all implemented measures. Hence, ECM-6a (windows upgrade above minimum code) and ECM-9 (upgrade doors) are not included since that would result in a negative project NPV (this is evident in the line chart in the upper right of Figure 4). To realize the economic potential of the property an investment of $1,927,585 is required producing annual utility savings of $113,120 over the functional life of the installed measures. The resulting project NPV is positive, at $94,705.
- ✓ The NPV from investing in energy and GHG emission saving measures is maximized by adopting measures ECM-1, ECM-8, ECM-4, ECM-2 and ECM-3. An investment of $378,390 in these measures would reduce baseline annual energy consumption and annual GHG emissions by 32% and 29%, respectively. Annual utility bill savings are $59,410 and the retrofit project NPV is maximized at $710,255. Adopting additional measures—like REM-1 (install solar PV system) and ECM-5a (upgrade DHW heaters above minimum code)—begins to reduce the maximum potential NPV accrued by the housing provider.
- ✓ Faced with a fixed budget, the housing provider would maximize operational cost savings by selecting the measures with the highest PI first, then working down the list of measures in order of the next highest PI until the available budget was exhausted. By way of example, given a retrofit budget of $150,000, the housing provider would adopt measures ECM-1, ECM-8 and ECM-4 for a total investment of $142,580. This retrofit project would reduce baseline annual energy consumption and annual GHG emissions by 22% and 19%, respectively. Annual utility bill savings are maximized for the available budget, at $28,615, and the project's NPV is $396,410.

Note that the results presented in Figure 4—and in particular, the calculated NPVs—assume the retrofits are self-financed by the housing provider. That is, the required investment is paid from cash reserves. The accompanying Brief examines the impact of alternative funding and financing options on project economics.

4.4.2 Retrofit project value: Woodvale Court

The estimated energy, water, operational cost and GHG savings of individual measures identified for Woodvale Court are shown in Table 7, along with the required upfront investment expenditure ("CAPEX"). The table also provides the estimated NPV and PI, as well as the net marginal abatement cost. Similar to Rundle Heights II, the energy and GHG saving measures for Woodvale Court are rank-ordered according to their estimated PI and presented in the tables and accompanying charts in Figure 5. The following conclusions are drawn from the analysis summarized in Figure 5:

- ✓ The **technical potential** for energy and GHG emission savings at Woodvale Court are, respectively, a 47% reduction in baseline annual energy consumption and a 48% reduction in baseline annual emissions. To realize the technical potential for retrofits an investment of $1,099,030 is required producing annual utility savings of $45,745 over the functional life of the installed measures. Like Rundle Heights II, the resulting NPV of attempting to achieve the full technical potential for Woodvale Court is negative, losing the housing provider about $275,825 in present value terms.
- ✓ The **economic potential** for energy and GHG emission savings at the property are, respectively, a 41% reduction in baseline annual energy consumption and a 43% reduction in baseline annual emissions. The following measures are not part of the economic potential for Woodvale Court: ECM-6a (windows upgrade above minimum code) and ECM-10 (doors upgrade). Their inclusion would result in a negative project NPV (see the line chart in the upper right of Figure 5). To realize the economic potential of the property an investment of $713,830 is required producing annual utility savings of $43,275 over the functional life of the installed measures. The resulting project NPV is $50,960.
- ✓ The NPV from investing in energy and GHG emission saving measures is maximized by adopting measures ECM-1, ECM-2, ECM-8, ECM-4 and ECM-3. An investment of $146,280 in these measures would reduce both baseline annual energy consumption and annual GHG emissions by 22%. Annual utility bill savings are $23,645 and the NPV is maximized across all available measures, at $277,790. Adopting additional measures—like REM-1 (install solar PV system) and ECM-9 (upgrade roof insulation)—begins to reduce the maximum retrofit NPV available to the housing provider.
- ✓ Faced with a retrofit budget of $105,000, for example, the housing provider would adopt measures ECM-1, ECM-2 and ECM-8 for a total investment of $100,140. This retrofit project would reduce baseline annual energy consumption and annual GHG emissions by 18% and 16%, respectively. Annual utility bill savings are maximized for the available budget, at $18,535, and the project's NPV is $257,320.

Table 7: Lifetime costs and benefits of individual energy and GHG saving measures: Woodvale Court

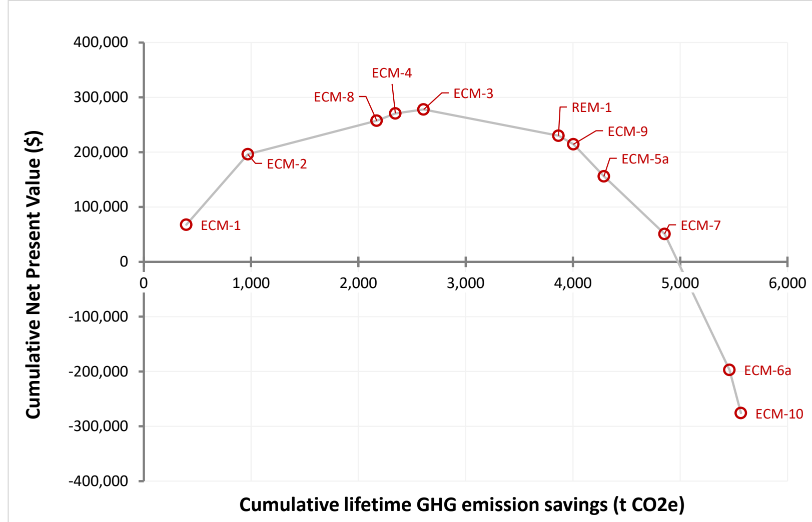
Indicator	Units	Energy and GHG saving measures										
		ECM-1	ECM-2	ECM-3	ECM-4	ECM-5a	ECM-6a	ECM-7	ECM-8	ECM-9	ECM-10	REM-1
Lifetime utility savings - physical												
Electricity	GJ	0	0	0	2,121	0	0	0	0	0	0	12,150
Natural gas	GJ	7,482	10,854	4,982	-1,323	5,373	11,448	10,692	22,707	2,619	1,998	0
Sub-total	GJ	7,482	10,854	4,982	798	5,373	11,448	10,692	22,707	2,619	1,998	12,150
Water	m3	15,162	48,141	0	0	0	0	0	0	0	0	0
Lifetime GHG emission savings												
Electricity	t CO2e	0	0	0	244	0	0	0	0	0	0	1,257
Natural gas	t CO2e	396	574	264	-70	284	606	566	1,201	139	106	0
Sub-total	t CO2e	396	574	264	174	284	606	566	1,201	139	106	1,257
Lifetime savings - $ undiscounted												
Electricity	$	0	0	0	61,189	0	0	0	0	0	0	368,473
Natural gas	$	45,537	73,765	29,819	-7,919	30,862	77,802	72,664	154,320	17,799	13,579	0
Sub-total	$	45,537	73,765	29,819	53,270	30,862	77,802	72,664	154,320	17,799	13,579	368,473
Water	$	59,177	200,950	0	0	0	0	0	0	0	0	0
Total	$	104,714	274,715	29,819	53,270	30,862	77,802	72,664	154,320	17,799	13,579	368,473
Lifetime savings - $ discounted												
Electricity	$	0	0	0	49,097	0	0	0	0	0	0	256,307
Natural gas	$	35,343	47,156	23,843	-6,332	26,581	49,737	46,453	98,653	11,379	8,681	0
Sub-total	$	35,343	47,156	23,843	42,765	26,581	49,737	46,453	98,653	11,379	8,681	256,307
Water	$	46,127	130,182	0	0	0	0	0	0	0	0	0
Total	$	81,470	177,338	23,843	42,765	26,581	49,737	46,453	98,653	11,379	8,681	256,307
Capital investment												
CAPEX - gross	$	13,850	48,760	16,800	29,340	85,100	297,800	151,250	37,530	26,900	87,400	304,300
Grants	$	0	0	0	0	0	0	0	0	0	0	0
CAPEX - net	$	13,850	48,760	16,800	29,340	85,100	297,800	151,250	37,530	26,900	87,400	304,300
Economic performance metrics												
Present value benefits	$	81,470	177,338	23,843	42,765	26,581	49,737	46,453	98,653	11,379	8,681	256,307
Net Present Value (NPV)	$	67,620	128,578	7,043	13,425	-58,519	-248,063	-104,797	61,123	-15,521	-78,719	-47,993
Profitability Index (PI)	ratio	5.9	3.6	1.4	1.5	0.3	0.2	0.3	2.6	0.4	0.1	0.8
Marginal abatement cost (MAC) - net	$ per t CO2e	-214	-331	-33	-94	234	606	274	-75	166	1,101	53

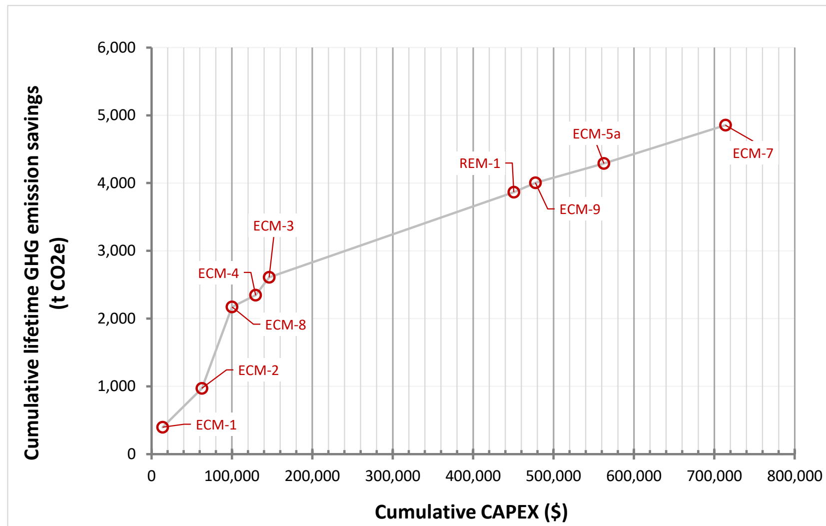
Notes: Measures ID: ECM-1 = low-cost measures; ECM-2 = Low-flow water fixtures; ECM-3 = Smart thermostats; ECM-4 = Lighting upgrade; ECM-5a = DWH heater (above minimum code); ECM-6a = Window upgrade (above minimum code); ECM-7 = Exterior wall insulation upgrade; ECM-8 = Foundation walls, heaters and rims insulation; ECM-9 = Roof insulation upgrade; ECM-10 = Upgrade doors; and REM-1 = Install solar PV system.

Figure 5: Maximizing retrofit project value for different levels of investment accounting for interaction effects and assuming self-financing: Woodvale Court

Measure ID	Cumulative reduction in baseline energy use	Cumulative annual average utility bill savings	Cumulative investment costs	Cumulative NPV	Cumulative reduction in baseline annual GHG emissions
	%	$ per year	$	$	%
ECM-1	7%	6,158	13,850	67,620	5%
ECM-2	9%	14,686	62,610	196,198	9%
ECM-8	18%	18,534	100,140	257,321	16%
ECM-4	22%	22,144	129,480	270,746	19%
ECM-3	22%	23,645	146,280	277,789	22%
REM-1	30%	38,384	450,580	229,796	34%
ECM-9	34%	38,916	477,480	214,274	34%
ECM-5a	36%	41,335	562,580	155,755	40%
ECM-7	41%	43,275	713,830	50,958	43%
ECM-6a *	47%	45,381	1,011,630	-197,105	47%
ECM-10 *	47%	45,747	1,099,030	-275,825	48%

* The inclusion of these measures in the portfolio of implemented projects results in a negative cumulative NPV; hence, they are not shown in the "cumulative CAPEX" graph to the right.





Notes: Measures ID: ECM-1 = low-cost measures; ECM-2 = Low-flow water fixtures; ECM-3 = Smart thermostats; ECM-4 = Lighting upgrade; ECM-5a = DWH heater (above minimum code); ECM-6a = Window upgrade (above minimum code); ECM-7 = Exterior wall insulation upgrade; ECM-8 = Foundation walls, heaters and rims insulation; ECM-9 = Roof insulation upgrade; ECM-10 = Upgrade doors; and REM-1 = Install solar PV system.

4.4.3 Retrofit project value: Renfrew Arms

The estimated energy, water, operational cost and GHG savings of individual measures identified for Renfrew Arms are shown in Table 8, along with the required upfront investment expenditure ("CAPEX"). The table also provides the estimated NPV and PI, as well as the net marginal abatement cost. The same measures are rank-ordered according to their estimated PI and presented in the tables and accompanying charts in Figure 6. The following conclusions are drawn from the analysis summarized in Figure 6:

- ✓ The **technical potential** for energy and GHG emission savings at the Renfrew Arms are, respectively, a 22% reduction in baseline annual energy consumption and a 24% reduction in baseline annual emissions. To realize the technical potential for retrofits an investment of $327,765 is required producing annual utility savings of $23,970 over the functional life of the installed measures. Attempting to achieve the full technical potential of Renfrew Arms will, nonetheless, lose the housing provider about $30,470 in present value terms.
- ✓ The **economic potential** for energy and GHG emission savings at the property are, respectively, a 20% reduction in baseline annual energy consumption and a 22% reduction in baseline annual emissions. The following measure is not part of the economic potential of Renfrew Arms: ECM-5a (windows upgrade above minimum code). The inclusion of this measure would result in a negative project NPV (evident in the line chart in the upper right of Figure 6). To realize the economic potential of the property an investment of $170,875 is required producing annual utility savings of $22,690 over the functional life of the installed measures. The resulting project NPV is $101,920.
- ✓ The NPV from investing in energy and GHG emission saving measures is maximized by adopting measures ECM-1, ECM-6, ECM-7, ECM-4, ECM-3 and ECM-2. An investment of $136,500 in these measures would reduce baseline annual energy consumption and annual GHG emissions by 19% and 21%, respectively. Annual utility bill savings are $21,275 and the NPV is maximized across all available retrofit measures at $111,685. Adopting REM-1 (install solar PV system) reduces the maximum NPV available to the housing provider.
- ✓ Faced with a retrofit budget of $50,000, for example, the housing provider would adopt measures ECM-1, ECM-6, ECM-7 and ECM-4 for a total investment of $46,790. This retrofit project would reduce baseline annual energy consumption and annual GHG emissions by 11% and 12%, respectively. Annual utility bill savings are maximized for the available budget at $11,615 and the project's NPV is $85,235.

Table 8: Lifetime costs and benefits of individual energy and GHG saving measures: Renfrew Arms

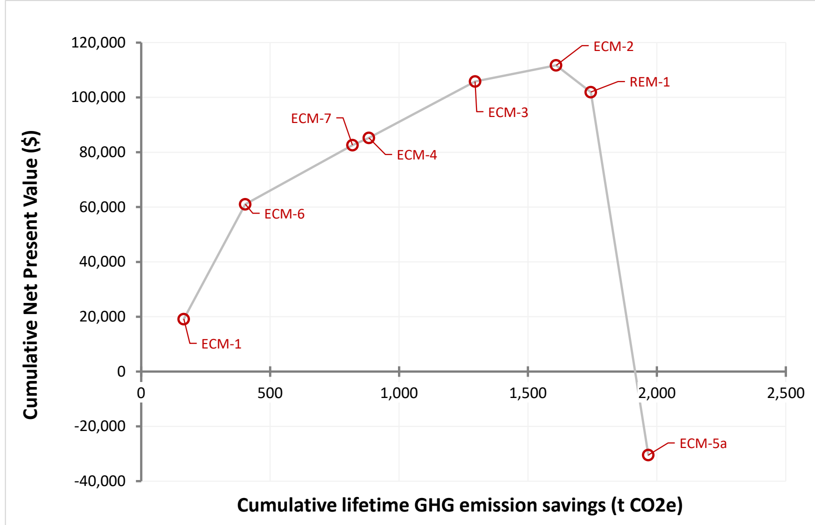
Indicator	Units	Energy and GHG saving measures							
		ECM-1	ECM-2	ECM-3	ECM-4	ECM-5a	ECM-6	ECM-7	REM-1
Lifetime utility savings - physical									
Electricity	GJ	28	1	4,094	0	2	3,691	1	1,298
Natural gas	GJ	3,065	5,940	-1,107	1,203	4,212	-3,686	7,857	0
Sub-total	GJ	3,092	5,941	2,987	1,204	4,214	5	7,858	1,298
Water	m3	0	0	0	0	0	0	0	0
Lifetime GHG emission savings									
Electricity	t CO2e	3	0	471	0	0	433	0	134
Natural gas	t CO2e	162	314	-59	64	223	-195	416	0
Sub-total	t CO2e	165	314	412	64	223	238	416	134
Lifetime savings - $ undiscounted									
Electricity	$	715	25	106,193	11	54	94,786	31	35,377
Natural gas	$	24,527	47,542	-8,860	9,018	38,274	-29,013	64,477	0
Sub-total	$	25,242	47,567	97,333	9,029	38,329	65,773	64,508	35,377
Water	$	0	0	0	0	0	0	0	0
Total	$	25,242	47,567	97,333	9,029	38,329	65,773	64,508	35,377
Lifetime savings - $ discounted									
Electricity	$	574	20	85,208	10	35	78,282	24	24,608
Natural gas	$	19,612	38,014	-7,084	8,120	24,468	-23,899	49,304	0
Sub-total	$	20,185	38,034	78,124	8,130	24,503	54,383	49,328	24,608
Water	$	0	0	0	0	0	0	0	0
Total	$	20,185	38,034	78,124	8,130	24,503	54,383	49,328	24,608
Capital investment									
CAPEX - gross	$	1,040	32,160	57,550	5,500	156,890	12,500	27,750	34,375
Grants	$	0	0	0	0	0	0	0	0
CAPEX - net	$	1,040	32,160	57,550	5,500	156,890	12,500	27,750	34,375
Economic performance metrics									
Present value benefits	$	20,185	38,034	78,124	8,130	24,503	54,383	49,328	24,608
Net Present Value (NPV)	$	19,145	5,874	20,574	2,630	-132,387	41,883	21,578	-9,767
Profitability Index (PI)	ratio	19.4	1.2	1.4	1.5	0.2	4.4	1.8	0.7
Marginal abatement cost (MAC) - net	$ per t CO2e	-141	-23	-61	-45	878	-208	-66	101

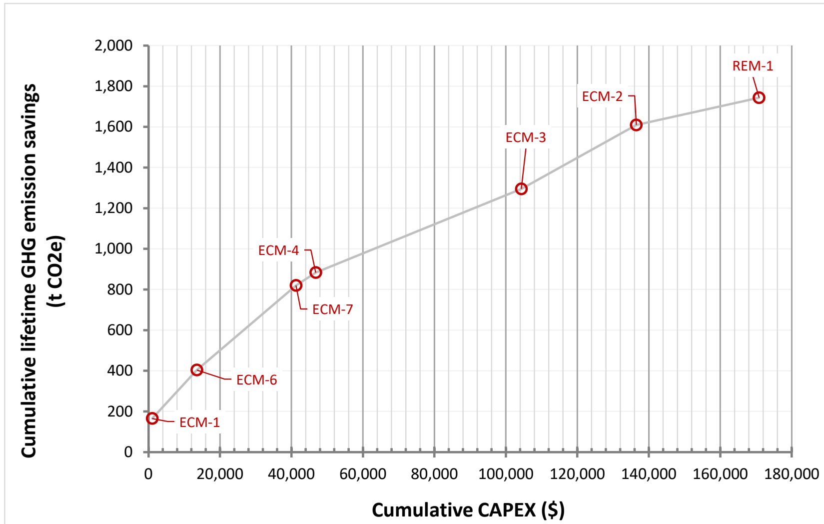
Notes: Measures ID: ECM-1 = low-cost measures; ECM-2 = Smart thermostats; ECM-3 = Lighting upgrade; ECM-4 = Heat transfer fluid additive; ECM-5a = Window upgrade (above minimum code); ECM-6 = Clothes dryer upgrade (convert from electrical to natural gas dryers); ECM-7 = Energy recovery wheel; and REM-1 = Install solar PV system.

Figure 6: Maximizing retrofit project value for different levels of investment accounting for interaction effects and assuming self-financing: Renfrew Arms

Measure ID	Cumulative reduction in baseline energy use	Cumulative annual average utility bill savings	Cumulative investment costs	Cumulative NPV	Cumulative reduction in baseline annual GHG emissions
	%	$ per year	$	$	%
ECM-1	2.8%	1,683	1,040	19,145	2%
ECM-6	3%	6,742	13,540	61,029	6%
ECM-7	9%	10,326	41,290	82,606	10%
ECM-4	11%	11,616	46,790	85,237	12%
ECM-3	14%	18,105	104,340	105,811	17%
ECM-2	19%	21,276	136,500	111,685	21%
REM-1	20%	22,691	170,875	101,918	22%
ECM-5a *	22%	23,969	327,765	-30,469	24%

* The inclusion of this measure in the portfolio of implemented projects results in a negative cumulative NPV; hence, it is not shown in the "cumulative CAPEX" graph to the right.





Notes: Measures ID: ECM-1 = low-cost measures; ECM-2 = Smart thermostats; ECM-3 = Lighting upgrade; ECM-4 = Heat transfer fluid additive; ECM-5a = Window upgrade (above minimum code); ECM-6 = Clothes dryer upgrade (convert from electrical to natural gas dryers); ECM-7 = Energy recovery wheel; and REM-1 = Install solar PV system.

4.4.4 Retrofit project value: Lexington Manor

The estimated energy, water, operational cost and GHG savings of individual measures identified for Lexington Manor are shown in Table 9, along with the required upfront investment expenditure ("CAPEX"). The table also provides the estimated NPV and PI, as well as the net marginal abatement cost. The same measures are rank-ordered according to their estimated PI and presented in the tables and accompanying charts in Figure 7. The following conclusions are drawn from the analysis summarized in Figure 7:

- ✓ The **technical potential** for energy and GHG emission savings at the Lexington Manor are, respectively, a 30% reduction in baseline annual energy consumption and a 27% reduction in baseline annual emissions. To realize the technical potential of Lexington Manor an investment of $186,920 is required producing annual utility savings of $17,220 over the functional life of the installed measures. Attempting to achieve the full technical potential for energy and GHG emission savings at Lexington Manor produces a positive NPV of $70,845 for the housing provider; this is in contrast to the other three case study properties were realizing the full technical potential resulted in a net loss (negative NPV).
- ✓ The **economic potential** of Lexington Manor is the same as the technical potential, as the full portfolio of retrofit measures results in a positive NPV.
- ✓ The NPV from investing in energy and GHG emission saving measures at Lexington Manor is maximized by adopting measures ECM-1, ECM-6, ECM-2, REM-1, ECM-3 and ECM-5a. This reduces baseline annual energy consumption and annual GHG emissions by, respectively, 29% and 27%. Virtually the same as the economic and technical potential. The following minor measure is not included when attempting to maximize NPV: ECM-4 (upgrade of the vestibule window). The required investment is $176,840, producing annual utility savings of $17,130 over the functional life of the installed measures. The resulting project NPV is $79,205.
- ✓ Faced with a retrofit budget of $115,000, for example, the housing provider would adopt measures ECM-1, ECM-6, ECM-2 and REM-1 for a total investment of $112,490. This retrofit project would reduce baseline annual energy consumption and annual GHG emissions by 13% and 15%, respectively. Annual utility bill savings are maximized for the available budget at $12,350 and the project's NPV is $67,670.

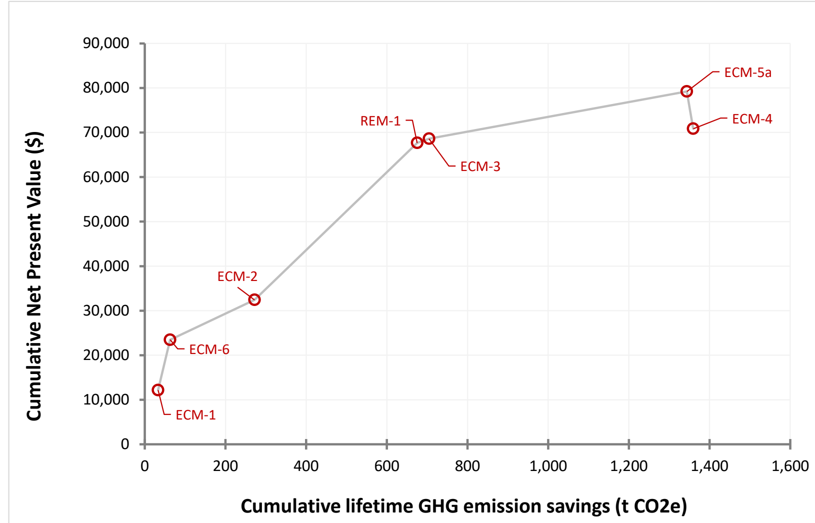
Table 9: Lifetime costs and benefits of individual energy and GHG saving measures: Lexington Manor

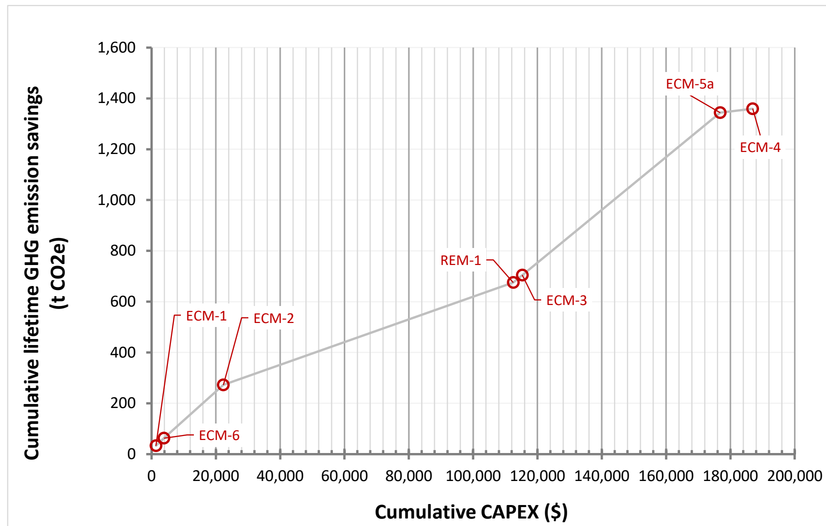
Indicator	Units	Energy and GHG saving measures						
		ECM-1	ECM-2	ECM-3	ECM-4	ECM-5a	ECM-6	REM-1
Lifetime utility savings - physical								
Electricity	GJ	0	101	0	0	0	470	3,896
Natural gas	GJ	621	3,740	554	297	12,083	-480	0
Sub-total	GJ	621	3,840	554	297	12,083	-10	3,896
Water	m3	2,925	0	0	0	0	0	0
Lifetime GHG emission savings								
Electricity	t CO2e	0	12	0	0	0	55	403
Natural gas	t CO2e	33	198	29	16	639	-25	0
Sub-total	t CO2e	33	209	29	16	639	30	403
Lifetime savings - $ undiscounted								
Electricity	$	0	4,442	0	0	0	20,489	180,281
Natural gas	$	4,749	29,804	4,137	2,687	104,747	-3,760	0
Sub-total	$	4,749	34,245	4,137	2,687	104,747	16,728	180,281
Water	$	10,956	0	0	0	0	0	0
Total	$	15,705	34,245	4,137	2,687	104,747	16,728	180,281
Lifetime savings - $ discounted								
Electricity	$	0	3,564	0	0	0	16,921	125,402
Natural gas	$	4,090	23,831	3,726	1,718	72,158	-3,098	0
Sub-total	$	4,090	27,395	3,726	1,718	72,158	13,824	125,402
Water	$	9,449	0	0	0	0	0	0
Total	$	13,540	27,395	3,726	1,718	72,158	13,824	125,402
Capital investment								
CAPEX - gross	$	1,380	18,450	2,798	10,080	61,550	2,500	90,160
Grants	$	0	0	0	0	0	0	0
CAPEX - net	$	1,380	18,450	2,798	10,080	61,550	2,500	90,160
Economic performance metrics								
Present value benefits	$	13,540	27,395	3,726	1,718	72,158	13,824	125,402
Net Present Value (NPV)	$	12,160	8,945	927	-8,362	10,608	11,324	35,242
Profitability Index (PI)	ratio	9.8	1.5	1.3	0.2	1.2	5.5	1.4
Return on Investment (ROI)	ratio	8.8	0.5	0.3	-0.8	0.2	4.5	0.4
Marginal abatement cost (MAC) - net	$ per t CO2e	-421	-52	-34	787	-23	-450	-121

Notes: Measures ID: ECM-1 = low-cost measures; ECM-2 = Smart thermostats; ECM-3 = Heat transfer fluid additive; ECM-4 = Vestibule window upgrade; ECM-5a = Boiler upgrade (install near condensing boilers with AFUE = 88%); ECM-6 = Clothes dryer upgrade (convert from electrical to natural gas dryers); and REM-1 = Install solar PV system.

Figure 7: Maximizing retrofit project value for different levels of investment accounting for interaction effects and assuming self-financing: Lexington Manor

Measure ID	Cumulative reduction in baseline energy use	Cumulative annual average utility bill savings	Cumulative investment costs	Cumulative NPV	Cumulative reduction in baseline annual GHG emissions
	%	$ per year	$	$	%
ECM-1	1.8%	1,570	1,380	12,160	1.4%
ECM-6	2%	2,857	3,880	23,483	2%
ECM-2	9%	5,140	22,330	32,428	8%
REM-1	13%	12,352	112,490	67,670	15%
ECM-3	16%	12,943	115,288	68,597	16%
ECM-5a	29%	17,132	176,838	79,206	27.0%
ECM-4	30%	17,222	186,918	70,844	27.2%





Notes: Measures ID: ECM-1 = low-cost measures; ECM-2 = Smart thermostats; ECM-3 = Heat transfer fluid additive; ECM-4 = Vestibule window upgrade; ECM-5a = Boiler upgrade (install near condensing boilers with AFUE = 88%); ECM-6 = Clothes dryer upgrade (convert from electrical to natural gas dryers); and REM-1 = Install solar PV system.

5 SYNTHESIS OF FINDINGS

Notwithstanding the multiple benefits of deep energy and GHG emission saving building retrofits, the primary motivation for housing providers in the subsidized housing sector to invest in such retrofits is to reduce operational costs concomitantly with extending the useful life of the property. Analyses of retrofit costs and benefits for each of four case study buildings in Edmonton were presented in Section 4.4. Across both townhouse case study properties—typical of about 55% (and 38%) of the social and affordable housing building stock (dwelling units) in Alberta—the profitable energy saving retrofits were:

- Low-cost weatherization measures.
- Upgrading foundation (basement) walls, headers and rims insulation.
- Low flow water fixtures.
- Switching all lighting to LEDs.
- Smart thermostats and HRV controls.

Each of these retrofits generated utility bill savings in excess of the costs of realizing those savings (in present value terms).

Across both walk-up apartment case study properties—typical of about 11% (and 57%) of the social and affordable housing building stock (dwelling units) in Alberta—the profitable energy saving retrofits were:

- Low-cost weatherization measures.
- Switching electric to natural gas dryers.
- Incorporating energy recovery wheel in the ventilation system.
- Switching all lighting to LEDs.
- Adding a heat transfer fluid enhancer to heating/cooling system.
- Smart thermostats.
- New condensing boilers.

Installing solar PV was profitable on the property with the larger flat roof space.

The performance of all energy and GHG emission saving measures investigated as part of the case studies is summarized in Table 10 (for the row townhouses) and Table 11 (for the walk-up apartment blocks). The costs and benefits (energy, GHG emission and utility bill savings) of each measure are expressed relative to the number of dwelling units and the total floor area of the case study properties. For example, the installed cost of a package of low-cost measures in a row townhouse is approximately $365 per dwelling unit or $2.85 per m^2 of total floor space. The corresponding utility bill savings are about $140 per unit ($1.10 per m^2) in the first year of operation and about $2,025 per unit ($15.75 per m^2) over the expected life of the installed measures. These measures will reduce GHG emissions by roughly 8,230 kg CO_2e per unit (65 kg CO_2e per m^2) over their expected life. This creates a set of simple performance metrics that could be used by a housing provider to generate a rough estimate of costs and benefits to advance a business case for deep retrofits to a row townhouse or walk-up apartment block.

It should be noted that the analysis of deep retrofit costs and benefits presented in this Brief assumes all projects are self-financed from reserves. The business case for deep retrofits can be improved through innovative financing options and more and better funding supports. These topics are the focus of the companion Brief [Financing Solutions].

5.1 At-scale in Edmonton and Calgary

In 2020, there were approximately 2,945 row townhouse and walk-up apartment (social and affordable) properties in Edmonton and Calgary. With a property being bought or refinanced and simultaneously subject to a major refurbishment every 15 years, on average, about 6-7% of these properties could receive deep energy and GHG emission saving retrofits every year. By 2050—subject to accessible financing and funding support—about 85% of the existing building stock could thus be retrofitted to achieve higher energy efficiency standards. To illustrate the potential scale-up impacts of this project, the costs and benefits resulting from this level of building upgrades in Calgary and Edmonton have been simulated—assuming 6-7% of the 2,945 properties are retrofitted annually between 2023-2050 to achieve the "economic potential" for energy and GHG emission savings identified at the four case study properties. The resultant impacts are listed below:

- Total incremental **investment costs** = **$227 million** (2022 dollars) or $8.1 million per year, on average.
- **Lifetime energy savings** = **23 PJ** or 0.5 PJ per year, on average. This is equivalent to a 28% reduction in baseline energy consumption over the period 2023-2050.
- **Lifetime utility bill savings** = **$439 million** (2022 dollars) or $8.8 million per year, on average.
- **Lifetime GHG emissions savings** = **1,347,730 t CO_2e** or 26,955 t CO_2e per year, on average. This is equivalent to a 27% reduction in baseline GHG emissions over the period 2023-2050.

This level of investment each year would directly and indirectly contribute **$3-4 million** to **household incomes**, support roughly **35-40 full-time jobs**, and contribute **$6-7 million** to provincial **GDP** annually through 2050.

Table 10: Summary performance metrics for row townhouses

	Low-cost measures	Low-flow water fixtures	Smart thermostats & HRV controls	Lighting upgrade	DHW heater upgrade (above min. code)	Window upgrade (above min. code)	Exterior wall insulation upgrade	Foundation walls, headers & rims insulation	Roof insulation upgrade	Upgrade to Energy Star doors	Install solar PV system
Investment costs:											
$ per dwelling unit	365	1,425	680	230	1,835	7,020	3,675	965	585	5,485	9,105
$ per m^2 floor space	2.85	11.10	5.30	1.80	14.30	54.55	28.55	7.50	4.50	42.60	70.75
Expected useful life (years)	17	30	15	15	15	30	30	30	30	30	25
Energy savings – first year											
MJ per dwelling unit	10,170	125	120	1,665	85	90	115	45	475	500	65
MJ per m^2 floor space	80	60	65	5	90	85	65	175	15	15	115
Utility bill savings – first year											
$ per dwelling unit	140	215	80	35	70	70	55	140	10	15	400
$ per m^2 floor space	1.10	1.65	0.60	0.30	0.55	0.55	0.40	1.10	0.10	0.10	3.10
Utility bill savings – lifetime											
$ per dwelling unit	2,025	5,075	895	450	620	1,710	1,360	3,480	385	315	7,850
$ per m^2 floor space	15.75	39.45	6.95	3.50	4.85	13.30	10.60	27.05	3.00	2.45	61.00
GHG savings – lifetime											
kg CO_2e per dwelling unit	8,230	11,405	6,470	1,555	5,455	15,575	12,255	31,765	3,010	2,860	34,645
kg CO_2e per m^2 floor space	65	90	50	10	40	120	95	245	25	20	270
Profitability Index	5.1	3.1	1.3	1.6	0.3	0.2	0.3	3.2	0.4	0.6	0.8
Simple payback	2.6	6.7	8.5	6.4	21.9	>30	>30	6.9	>30	>30	20.7

Table 11: Summary performance metrics for walk-up apartments

	Low-cost measures	Smart thermostats	Lighting upgrade	Window upgrade (above min. code)	Near condensing boilers (AFUE 88%)	Heat transfer fluid additive	Energy Recovery Wheel	Clothes Dryer Upgrade	Install solar PV system
Investment costs:									
$ per dwelling unit	25	480	885	2,415	1,540	80	425	145	1,185
$ per m^2 floor space	0.30	6.60	11.75	32.10	22.05	1.10	5.65	1.95	16.20
Expected useful life (years)	10-15	15	15	30	25	7	18	13	25
Energy savings – first year									
MJ per dwelling unit	2,840	6,900	3,405	2,400	13,425	2,660	7,465	-	2,200
MJ per m^2 floor space	40	95	45	30	190	35	100	-	30
Utility bill savings – first year									
$ per dwelling unit	30	50	105	15	95	20	55	65	80
$ per m^2 floor space	0.45	0.70	1.40	0.25	1.35	0.25	0.70	0.90	1.10
Utility bill savings – lifetime									
$ per dwelling unit	390	780	1,495	590	2,620	125	990	785	2,055
$ per m^2 floor space	5.35	10.65	19.90	7.85	37.55	1.70	13.20	10.75	28.10
GHG savings – lifetime									
kg CO_2e per dwelling unit	1,885	4,990	6,340	3,430	15,980	885	6,395	2,555	5,120
kg CO_2e per m^2 floor space	25	70	85	45	230	10	85	35	70
Profitability Index	13.9	1.3	1.4	0.2	1.2	1.4	1.8	4.5	1.2
Simple payback	0.7	8.3	8.5	>30	14.1	4.2	7.0	2.2	13.6

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