Comprehensive Retrofit of an Existing Multi-Unit Residential Building

Impacts on Energy Performance and Green House Gas Emissions

INTRODUCTION

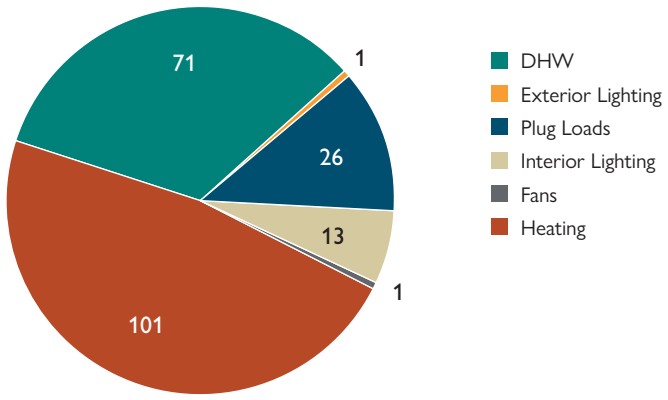
To better understand the energy, greenhouse gas (GHG), and cost impacts of energy upgrades undertaken at the time of major capital replacements, this study looked at a comprehensive retrofit of a typical 1970s rental apartment building located in Victoria, BC. The building owners approached the required capital replacements as an opportunity to not only improve the appearance of the building but also its energy efficiency. In addition to replacing the roof membrane, balconies, windows, sliding glass doors, and exterior wall cladding, the project involved several key energy efficiency upgrades including the addition of exterior insulation at the walls and roof as well as replacement of the existing heating boiler and domestic hot water heater with high-efficiency condensing equipment.

FINDINGS

1. The comprehensive retrofit project is estimated to have resulted in an overall energy savings of 32% and overall greenhouse gas emission savings of 39% compared to the existing operation.
2. The largest reductions applied to the heating system with a 57% reduction in the building's heating energy (Figure 1, 2); this was achieved through both load reduction due to improved thermal performance of the building enclosure and increased heating system efficiency.
3. The heating boiler replacement appears to have the largest individual impact, resulting in 16% overall energy savings and 20% overall greenhouse gas emission savings.
4. Comparing the comprehensive retrofit undertaken at this building to a typical "business-as-usual" retrofit, the incremental savings are estimated to be 19% for energy and 24% for greenhouse gas emissions.
5. Roof insulation (Table 1, Measure 2) was shown to have the least impact on energy compared to other retrofit measures; combined with a relatively high incremental cost, this measure is estimated to have a negative Net Present Value (NPV, -$149,700) over the 30-year analysis period
6. The installation of exterior insulation at walls was shown to have a moderate impact on overall energy savings as part of a wall and window retrofit. The NPV of this retrofit measure was shown to be marginal (i.e. breaks even at a 6% discount rate) over the 30-year analysis period.
7. For a wall and window retrofit measure, a positive NPV is achieved at a 14% reduction in incremental capital cost (Figure 3, Measure 1) compared to the typical "business-as-usual" retrofit; suggesting a relatively small reduction in the incremental capital costs will make this measure cost-effective.
8. For the roof retrofit (Figure 3, Measure 2), the incremental capital costs would have to decrease by over 90% before the measure achieves a positive NPV.
9. For the heating boiler retrofit and Domestic Hot Water (DHW) retrofit (Figure 3), the NPV is robustly positive and remains so even beyond a doubling of the incremental capital costs.
10. For wall and window retrofit measure (Figure 4, Measure 1), a positive NPV would be achieved with an approximately 16% increase in energy costs.
11. For the roof retrofit (Figure 4, Measure 2), energy costs would have to more than double before this measure achieves a positive NPV.
12. For the heating boiler retrofit and DHW heater retrofit, the NPV is robustly positive and remains so even beyond a 70% decrease in energy costs or energy savings.

Adjusted Pre-Retrofit Model: End-Use Breakdown (kWh/m^2)

Figure 1: Energy End-use Pre-Retrofit



Actual Post-Retrofit Model: End-Use Breakdown (kWh/m²)

Figure 2: Energy End-use Pre-Retrofit

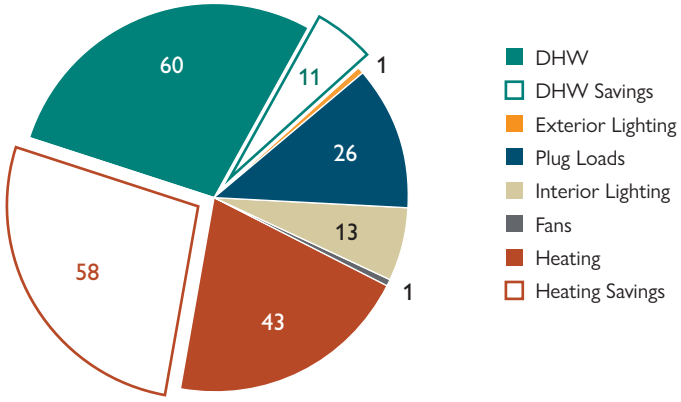


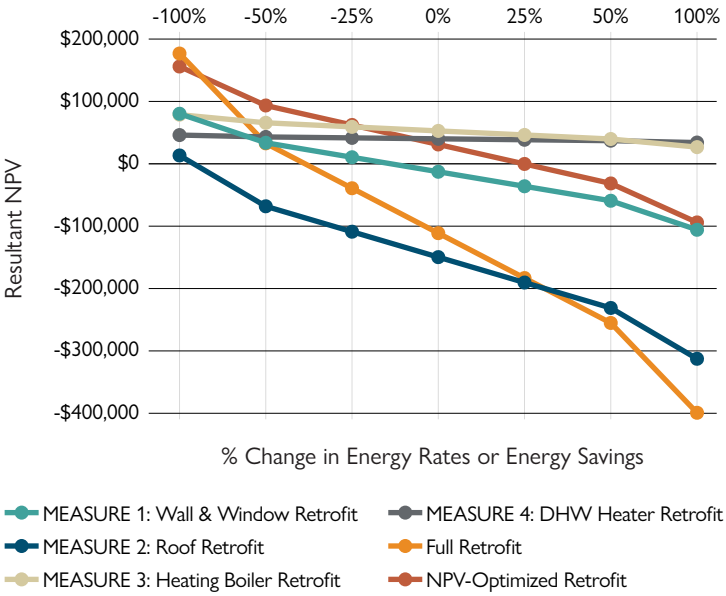
Table 1: Summary of Financial Metrics

Measure	NPV[1]		DISCNTD IRR	DISCNTD PAYBACK
	$	$/m² GFA	%	Years
Measure 1: Wall & Window Retrofit	-$12,800	-$1.3	6%	>30
Measure 2: Roof Retrofit	-$149,700	-$14.9	-	>30
Measure 3: Heating Boiler Retrofit	$52,700	$5.2	22%	7
Measure 4: DHW Heater Retrofit	$40,000	$4.0	54%	3
All Measures: Full Retrofit	- $111,200	-$11.1	3%	>30

[1] NPV based on 30-year measure life and 7% discount rate.

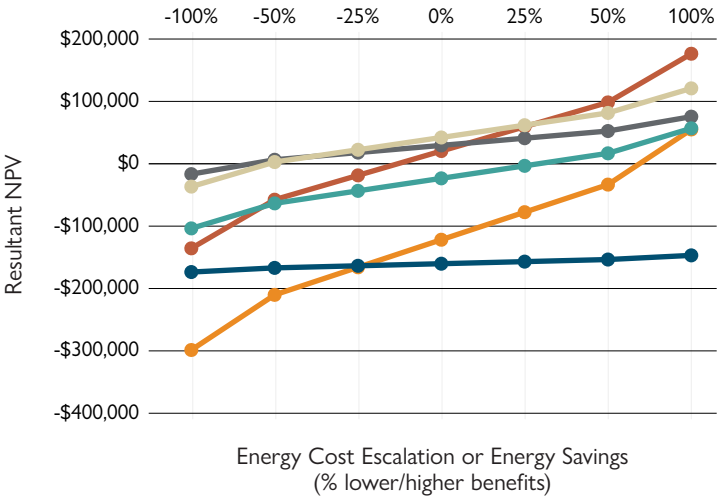
NPV sensitivity to incremental capital cost

Figure 3: Basic sensitivity analysis showing resultant NPV for changing capital costs.



NPV sensitivity to energy rates/savings

Figure 4: Basic sensitivity analysis showing resultant NPV for changing energy rates or energy savings.



IMPLICATIONS FOR THE HOUSING INDUSTRY

The analysis highlights opportunities for existing 1970s multi-unit residential buildings to achieve energy savings of 32% and GHG emission savings of 39% through comprehensive retrofit projects. In addition, the project demonstrated that non-energy saving related goals such as improved thermal comfort and increased building envelope durability were achieved. While the study demonstrates the utility of conducting a rigorous financial analysis of energy saving measures to develop cost optimized approaches, it also demonstrates that non-financial benefits associated with some measures can offer equally important benefits to occupants, building owners and managers.

FURTHER READING

Full report - *Comprehensive Retrofit of an Existing Multi-Unit Rental Building - Impacts on Energy Performance and Greenhouse Gas Emissions* (https://eppdscrmssa01.blob.core.windows.net/cmhcprodcontainer/sf/project/archive/research_2/comprehensive_retrofit_murb_impacts_energy_performance_greenhouse_gas.pdf)

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ALTERNATIVE TEXT AND DATA FOR FIGURES

Figure 1: Energy End-use Pre-Retrofit

	Adjusted Pre-Retrofit Model: End-Use Breakdown (kWh/m²)
Plug Loads	26
Interior Lighting	13
Fans	1
Heating	101
DHW	71
Exterior Lighting	1

Figure 2: Energy End-use Pre-Retrofit

	Actual Post-Retrofit Model: End-Use Breakdown (kWh/m²)
Plug Loads	26
Interior Lighting	13
Fans	1
Heating	43
Heating Savings	58
DHW	60
DHW Savings	11
Exterior Lighting	1

Figure 3: Basic sensitivity analysis showing resultant NPV for changing capital costs.

	Capital Cost (percentage difference from average)						
	-100%	-50%	-25%	0%	25%	50%	100%
Measure 1: Wall & Window Retrofit	$80,231	$33,731	$10,481	-$12,769	-$36,019	-$59,269	-$105,769
Measure 2: Roof Retrofit	$13,372	-$68,128	-$108,878	-$149,628	-$190,378	-$231,128	-$312,628
Measure 3: Heating Boiler Retrofit	$78,745	$65,745	$59,245	$52,745	$46,245	$39,745	$26,745
Measure 4: DHW Heater Retrofit	$46,059	$43,059	$41,559	$40,059	$38,559	$37,059	$34,059
Full Retrofit	$176,805	$32,805	-$39,195	-$111,195	-$183,195	-$255,195	-$399,195
NPV-Optimized Retrofit	$156,005	$93,505	$62,255	$31,005	-$245	-$31,495	-$93,995

Figure 4: Basic sensitivity analysis showing resultant NPV for changing energy rates or energy savings.

	Energy Cost Escalation or Energy Savings (% lower/higher benefits)						
	-100%	-50%	-25%	0%	25%	50%	100%
Measure 1: Wall & Window Retrofit	-$93,000	-$52,884	-$32,827	-$12,769	$7,289	$27,347	$67,462
Measure 2: Roof Retrofit	-$163,000	-$156,314	-$152,971	-$149,628	-$146,285	-$142,942	-$136,256
Measure 3: Heating Boiler Retrofit	-$26,000	$13,373	$33,059	$52,745	$72,432	$92,118	$131,491
Measure 4: DHW Heater Retrofit	-$6,000	$17,029	$28,544	$40,059	$51,573	$63,088	$86,117
Full Retrofit	-$288,000	-$199,597	-$155,396	-$111,195	-$66,993	-$22,792	$65,611
NPV-Optimized Retrofit	-$125,000	-$46,998	-$7,996	$31,005	$70,006	$109,007	$187,010