Technical Bulletin

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Deep Energy Retrofit of the Belmont

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Introduction

A visionary group of condominium owners in Vancouver have taken a decisive step to retrofit their 13-storey, 37-unit residential building and achieve deep energy savings. Energy benchmarking was used to plan for and track energy savings from the $3.6 million building renewal project that improved the comfort, durability, acoustics, aesthetics and energy efficiency of their building, the Belmont, while modernizing its appearance. The energy efficiency upgrades represented only 2% of the overall project cost incurred by the owners, while BC Hydro provided an additional $50,000 (program incentive and a grant) to upgrade the windows. Completed in 2012, the first phase of the deep retrofit project has won several awards, including the Association of Professional Engineers and Geoscientists of BC's Sustainability Award, the Canada Green Building Council and Sustainable Architecture and Building Magazine's Technical Achievement Award, and the Fenestration Association of BC's Project of the Year Award.

The Belmont's experience could be replicated in thousands of multi-unit residential buildings across Canada, timed to correspond with required building envelope renewals.

Energy benchmarking

Building energy benchmarking has played an ongoing and critical role in supporting this deep energy retrofit project. Nine consecutive years of electricity and natural gas bills were assembled in the ENERGY STAR® Portfolio Manager tool. Portfolio Manager normalizes energy consumption data to adjust for changing weather conditions that affect space heating and cooling, thereby enabling an "apples-to-apples" comparison of multiple years of energy use intensity (EUI) per unit of building floor area (m2 or ft2). Two of the standard outputs from Portfolio Manager are provided in Figure 1, illustrating the source energy use intensity[2] and greenhouse gas emissions from the building.

[2] Source energy accounts for energy use as billed, as well as energy lost in the generation and transmission of electricity.

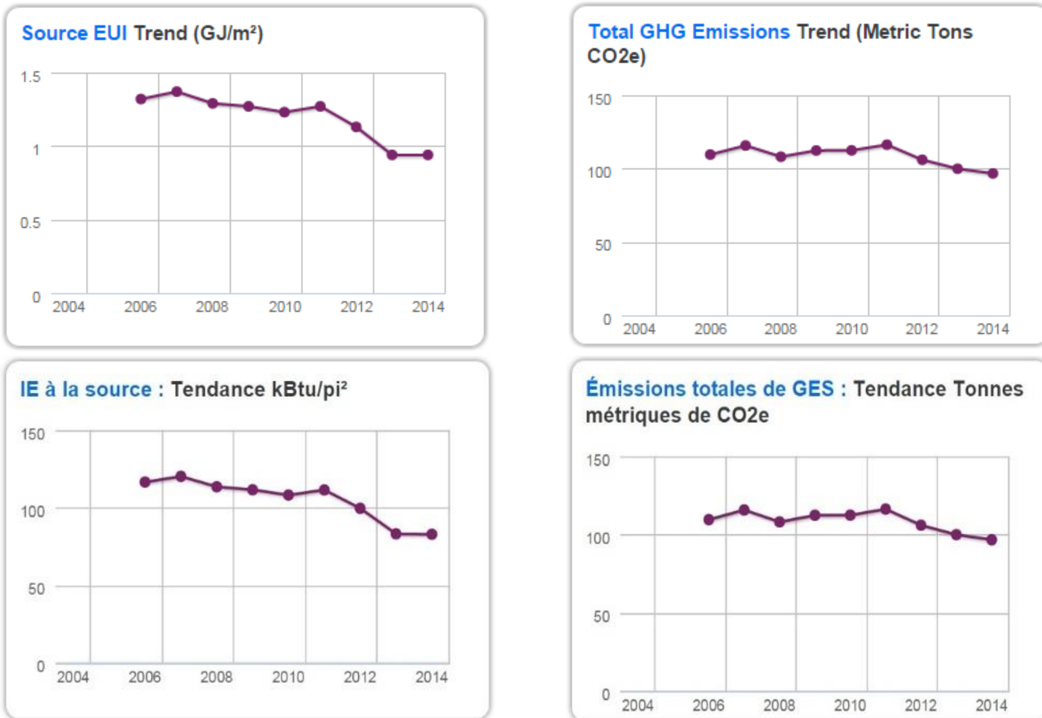

Figure 1 – Summary Charts in ENERGY STAR Portfolio Manager

Portfolio Manager can serve as a retrofit planning tool to establish a range of potential energy savings based on similar buildings' energy performance, assuming a large cohort of buildings have been benchmarked, as is the case in southwest British Columbia. Portfolio Manager can also be used to track the persistence of savings after a retrofit is complete. Figure 2 illustrates the site EUI,[3] showing energy savings of 22% in 2013 and 19% in 2014, as compared to the average, weather-normalized consumption from 2006 to 2011. The two-year average reduction is 20%.

[3] For more information on the difference between site and source energy, please see our technical reference on Source Energy.

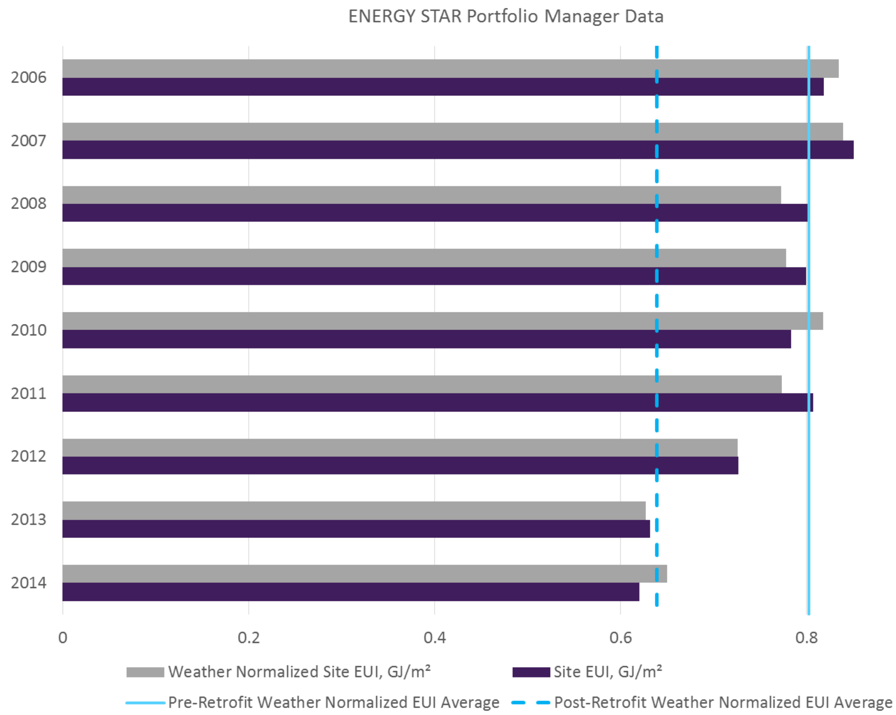

Figure 2: Site EUI and Weather Normalized Site EUI

Prior to using Portfolio Manager, the project team manually calculated EUI by adjusting for changes in weather (heating degree days), and used the analysis to inform the calibration of the computer simulation model to evaluate energy efficiency measures.

Planning for the Deep Energy Retrofit

The Belmont's owners hired RDH Building Engineering Ltd. to conduct a building enclosure condition assessment, followed by an in-depth energy research project to help them evaluate potential energy efficiency upgrades to major building systems (including mechanical systems) that use or affect the use of energy. These would be carried out during the building renewal. The research included calibrated energy modelling[4] of the whole building's energy performance, which used six years of metered energy consumption data. A number of "what-if" scenarios were applied to the model to assess the benefits and costs of six energy efficiency measures (EEMs) beyond common industry practices for existing building upgrades. The research project's sponsors included national and local governments, utilities and a non-profit association[5]. The partnership also facilitated access to aggregated energy consumption data from dozens of individual electricity meters and one natural gas meter.

[4] Calibrated energy modelling involves developing a computer simulation that accurately predicts the energy use of the building based on the input of assumptions about components, equipment and systems. This enables a "what-if" analysis of how the building would perform with various upgrades. The term "calibrated" means that the simulation is adjusted to predict consumption that matches the historic energy bills. RDH used DesignBuilder software for this analysis.

[5] This project was completed with the support of the following funding partners: Homeowner Protection Office branch of BC Housing, BC Hydro, FortisBC, National Resources Canada, City of Vancouver, City of North Vancouver, City of Surrey, City of New Westminster, City of Richmond and the BC Sustainable Energy Association.

The following six EEMs (including two window options) were considered:

1. Adding wall insulation and low-conductivity cladding attachments outside of the concrete slabs[6]
2. Upgrading the windows, replacing aluminium-framed windows with:
    - Option a: double-glazed fibreglass-framed windows or
    - Option b: triple-glazed fibreglass-framed windows[7]
3. Improving the whole-building airtightness with new windows and a liquid-applied air barrier system, enabling a 55% improvement[8]
4. Replacing in-suite gas fireplaces[9]
5. Installing in-suite heat recovery ventilators[10] to replace the pressurized corridor ventilation; along with air sealing between suites
6. Replacing the make-up air unit with a high-efficiency natural gas unit[11]

These six EEMs, divided into a building enclosure (BE) package (measures 1 to 3) and a heating system package (measures 4 to 6), will facilitate an overall 30% reduction in energy use. The owners decided to start with the BE package, with a targeted 20% energy efficiency improvement and a 32% reduction in electricity use. A planned second phase of the project will see the implementation of the remaining measures.

Measurement and Verification

Detailed measurement and verification research work has been conducted since the upgrades were installed in 2012. The research included sub-metering of many energy-using systems, energy bill tracking, benchmarking and further calibration of the simulation models. See the following paper for more details on the completed building enclosure retrofit:

→ Brittany Hanam. American Council for an Energy Efficient Economy 2014 buildings conference:
Deep Energy Retrofits of High-Rise Multi-Unit Residential Buildings

A separate analysis was conducted on space heating impacts and found that the BE upgrades achieved a 62% reduction in electric space heating in suites.

Figure 3 shows the energy performance of 39 buildings that were examined in a 2012 study on energy consumption and conservation in mid- and high-rise multi-unit residential buildings. The average energy use of all 39 buildings studied was 0.77 GJ/m² (213 kwh/m²), and the median was 0.75 GJ/m² (208 kwh/m²) as indicated by the dotted line.

[6] Walls now have an effective thermal resistance of RSI-2.82 (R-16), compared to previous RSI-0.7 (R-4).
[7] The thermal transmittance of the old windows was USI-3.12 (U-0.55). Option a) offered a USI-value of 1.59 (U-0.28); option b), 1.14 (U-0.20).
[8] Post-retrofit airtightness was 1.63 L/s-m² (0.32 cfm/ft²) @75Pa, verified with whole-building airtightness testing before and after the retrofit.
[9] Targeting fireplace efficiency of at least 80%.
[10] With a sensible heat-recovery efficiency of 60%.
[11] With an annual fuel utilization efficiency of at least 90%.

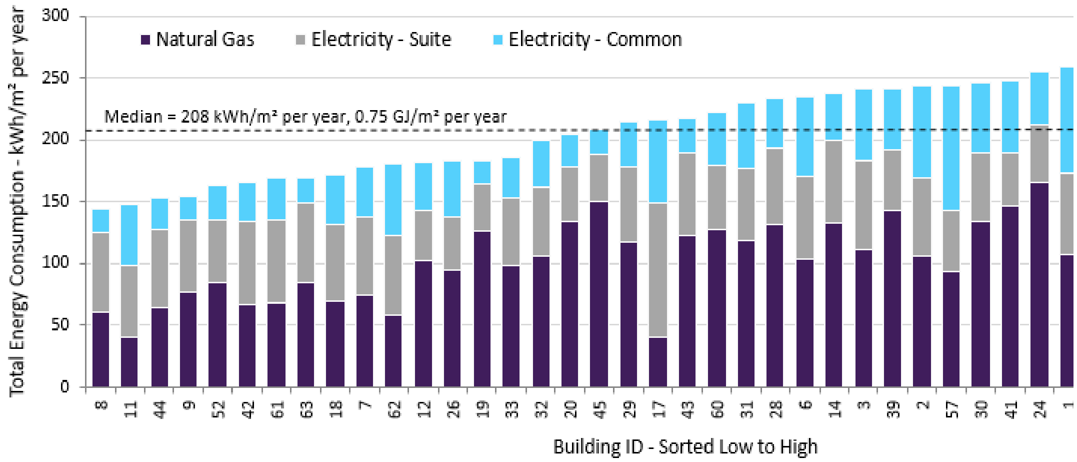

Figure 3: Site Energy Use Intensity of Multi-Unit Residential Buildings in South West British Columbia

Source: 2012: [Energy Consumption and Conservation in Mid- and High-Rise Residential Buildings]

Figure 4 demonstrates the Belmont's pre-retrofit and post-retrofit performance relative to this median. As indicated, the retrofit to date (BE package) reduced the Belmont's site EUI from slightly above the median to well below.

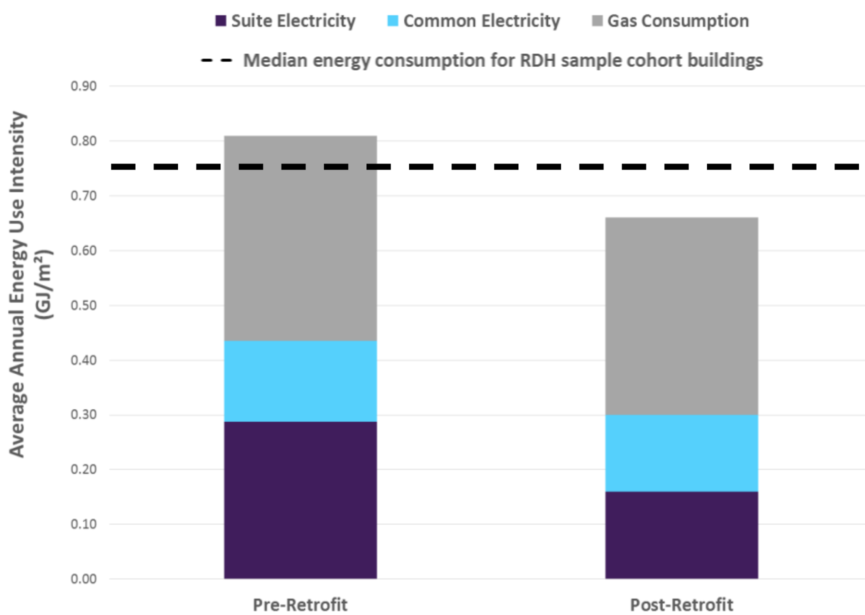

Figure 4: Belmont Site Energy Use Intensity Pre-Retrofit and Post-Retrofit relative to MURB Average

A benefit-cost analysis was also conducted, including both the BE improvements completed in 2012 and the heating system EEMs to be implemented in the future. The following financial indicators were calculated based on current BC Hydro residential electricity conservation (stepped) rates, FortisBC natural gas rates and BC's revenue-neutral carbon tax ($30/tonne):

- Net present value (NPV) – discounted future benefits from lower energy bills and avoided carbon tax, minus incremental capital cost of EEMs. Benefits and costs were considered for a period of 30 years. A positive NPV indicates a "profitable" investment, whereby benefits exceed costs after applying the 6% (real) discount rate (net of normal inflation).
- Internal rate of return (IRR) – the rate of return that corresponds to an NPV of zero; or a "break-even" point for the investment. The IRR can be compared to the discount rate or required rate of return. If it is larger than the discount rate, then the investment is considered economically attractive.
- Simple payback period – the number of years of energy savings (benefits) required to exceed the incremental capital costs. It is difficult to pinpoint an appropriate "cost-effective" payback period, but in principal, if the payback period is less than the life of the EEM, then it is cost-effective. In practice, industry and consumers often consider a 5-10 year payback period acceptable.

Table 1 highlights the results of the economic analysis and indicates that all of the EEMs are "cost-effective," although some offer stronger financial benefits than others. For example, the Building Enclosure Package (20% energy efficiency improvement) demonstrates:

- Incremental capital costs of $11.94/m²
- A 1.7% increase in the project budget
- Annual energy and carbon tax savings of $5.09/m²
- A net benefit (over and above capital costs) of nearly $53/m²
- A rate of return of 34%
- A simple payback period of 2 years
- Electricity savings of approximately 700 GJ/year (200 megawatt-hours/year)
- An improved site energy use intensity (EUI) of 0.63 GJ/m² (175 kWh/m²) compared to the 0.80 GJ/m² (223 kWh/m²) baseline.

EEM #	Energy Efficiency Measures (EEMs)	Incremental Cost	% of Total Cost	Annual Savings (energy, carbon tax and O&M)	Annual Electricity Savings	Annual Gas Savings	Annual GHG Reductions	Net Present Value	Internal Rate of Return	Simple Payback
		$/m²	%	$/m²/yr	kWh/yr	GJ/yr	t/yr	$/m²	%	years
1	Insulation and low-conductivity cladding attachments	$0.00	0.0%	$1.20	45,964	13	1.20	$15.31	>100%	0

EEM #	Energy Efficiency Measures (EEMs)	Incremental Cost	% of Total Cost	Annual Savings (energy, carbon tax and O&M)	Annual Electricity Savings	Annual Gas Savings	Annual GHG Reductions	Net Present Value	Internal Rate of Return	Simple Payback
2a	Double-glazed fibreglass windows	$0.54	0.1%	$1.89	71,939	25	2.11	$23.56	>100%	0
2b	Triple-glazed fibreglass windows	$11.94	1.8%	$2.72	104,303	27	2.60	$22.73	19%	4
3	Airtightness improvement	$0.00	0.0%	$0.45	17,749	0	0.21	$5.77	>100%	0
4	Fireplace replacement	$2.79	0.4%	$0.52	20,272	3	0.39	$3.89	16%	5
5	In-suite HRV	$14.73	2.2%	$3.16	80,606	545	28.22	$26.66	19%	5
6	Make-up air unit replacement	$4.68	0.7%	$0.44	0	217	10.85	$1.36	9%	11
	Building Enclosure (BE) package (20% savings)	$11.94	1.7%	$5.09	193,823	66	5.63	$52.93	34%	2
	BE and heating system packages (30% savings)	$34.13	5.0%	$5.05	144,229	670	35.23	$31.43	13%	7

Table 1: Benefit Cost Analysis of the Deep Energy Retrofit

If the remaining three EEMs are implemented, as is planned for a future phase of this overall project, the targeted whole-building energy savings will increase to 30%, with the following benefits:

→ Natural gas savings of over 670 GJ

- 39 % reduction in greenhouse gas emissions
- Improved site EUI of 0.56 GJ/m^2 (156 kWh/m^2)
- Internal rate of return of 13% and simple payback period of 7 years

Note that the proposed future phase will address current ventilation challenges related to insufficient airflow from the make-up air unit into the residential suites. This will result in increased electricity consumption for ventilation, but improved indoor air quality and other benefits. Further information on airflow and ventilation is covered in a recent paper:

- Lorne Ricketts. 14th Canadian Conference on Building Science and Technology: Airflow in Mid to High-rise Multi-Unit Residential Buildings

Conclusion

Energy benchmarking provided a foundation for evaluating energy efficiency measures (EEMs) for the Belmont's 2012 major renewal project. Following the implementation of a deep energy retrofit of the building, energy benchmarking continues to provide value for tracking energy use intensity and illustrating the persistence of the EEMs. ENERGY STAR Portfolio Manager provides a convenient and effective tool for normalizing energy bills and illustrating ongoing energy performance. The research project has verified that the deep energy retrofit is cost-effective for the owners.

Disclaimer: Please note that the technical data in this report was provided by the subject and has not been verified by Natural Resources Canada. Natural Resources Canada is not responsible for the accuracy of the data provided.

For additional information on this and other topics, please visit our website, rdh.com, or contact us at contact@rdh.com.

Additional Resources

- For more information, please see RDH's case study on the Belmont retrofit project.
- Read the blog version of this Technical Bulletin on The Wall here: http://rdh.com/how-can-a-deep-energy-retrofit-make-a-difference-in-your-building