Energy efficiency in an apartment building in Canada

In 1995, a non-profit cooperative began a retrofit project of a 15-story, 112-unit high-rise apartment building located in Toronto, Canada. The retrofit was required to bring the 30-year-old building and its components up to the requirements of the Ontario Ministry of Housing and the Fire Marshal's Act of Ontario. Some of the changes were designed to improve energy efficiency; others were undertaken for independent reasons such as the rehabilitation of the building envelope, which were also expected to affect energy efficiency

Description of Retrofit

The Rehabilitation program cost $6 million in total, took place over a period of approximately two years, and was conducted while the building was occupied.

Modification and upgrades included:

- Installation of a site-applied exterior insulation and finish system (EIFS) over the existing masonry wall (Energy Upgrade)
- Replacement of single-glazed windows with sealed double-glazed windows (fixed and operable units) (energy Upgrade)
- Replacement of existing wood balcony doors with insulated metal doors (Energy Upgrade)
- Replacement of roof, including an increase in insulation (Energy Upgrade)
- Replacement of showerheads with low-flow fixtures (Energy Upgrade)
- Replacement of lighting systems since light levels were inadequate; incorporate more energy-efficient fixtures (Life Safety and Energy Upgrade)
- Introduction of two make-up air units to serve the corridors (Required Upgrade)
- Enclosure of parking garage (Amenity upgrade)
- Replacement of exhaust fans in the garage and introduction of a CO monitor (Life Safety and Energy Upgrade)
- Replacement of existing boilers with more efficient units, including the installation of a control system (Required Maintenance and Energy Upgrade)
- Installation of thermostats in the suites (Required Maintenance and Energy Upgrade)
- Replacement of suite appliances (Required Maintenance Upgrade)
- Introduction of air conditioning in a party room, as part of an appearance upgrade for this room (Amenity Upgrade)

Other building retrofit measures included repairs to the concrete balconies. New balcony guards and repairs to the underground parking garage structure. Suite interior retrofits included cabinetry countertops, floor finishes and repainting.

The original walls of the building were solid masonry (brick on concrete block), 25 mm (1 in) of expanded polystyrene insulation metal lath and plaster. Windows were single-glazed with aluminum frames, and balcony doors were wood. The suites were heated with hydronic radiators supplied by natural-gas-fired boilers. Unheated fresh air was supplied to the corridors by a rooftop make-up air unit. A garage below the building was largely open to the exterior.

Study Methodology

To evaluate the overall changes in the energy efficiency of the building, the total energy consumption before and after the retrofit was simulated using eQuest version 2.13 software, an energy analysis tool based on the DOE-2 energy simulating program. Based on field testing and known properties of the materials and construction methods used, a "pre-retrofit model" was created to simulate the energy consumption during 1995 and 1996, and a "post-retrofit model" was created to simulate energy consumption during 1999 and 2000. Weather files purchased from Environment Canada for these time periods were integrated into the building models. To verify the accuracy of the models, the total consumption of natural gas and electricity predicted by the simulations for these time periods was compared with the actual utility bills. Both the pre- and post-retrofit models were judged to be reasonably accurate.

Next, to evaluate the contribution to changes in energy consumption of individual components of the retrofit, "incremental" simulations were carried out: for each simulation, the model for the post-retrofit building was modified to reverse a single change.

A comparison of the post-retrofit model and the altered model made it possible to calculate the contribution of that component of the retrofit. See Table 1.

Table 1 – Comparison of thermal resistance before and after building retrofit building element

Building element	Thermal resistance before retrofit	Thermal resistance after retrofit
Walls	Masonry 0.90 RSI (R5.1)	EIFS 1.96 RSI (R11.1)
Windows	Single-glazed 0.18 RSI (R1)	Sealed double-glazed 0.33 RSI (R5)
Balcony doors	Wood 0.20 RSI (R1)	Insulated metal 0.88 RSI
Roof	Existing 1.06 RSI (R6)	Replaced 2.17 RSI (R12.3)

Results: Energy Savings

Overall change in energy consumption

A comparison of the simulations based on the pre- and post-retrofit building models showed gas consumption to have decreased after the retrofit. However, due to the addition of certain electrical appliances and equipment and the increased use of certain existing appliances and the provision of new amenities, electricity consumption increased. These changes were confirmed by the actual utility bills. Overall energy costs were reduced by $ 18,719.

Total modeled heat loss through the building envelopes was reduced by about 30 percent: heat loss by conduction through the exterior walls was reduced by 12 percent; heat loss due to infiltration was reduced by 8 percent; and heat loss due to window conduction was reduced by 19 percent. Heat loss from the parking garage increased as it was closed-in and heated during the retrofit and was incorporated into the post-retrofit building model as a conditioned space. Since the walls and roof of the garage remained uninsulated, they represented a significant source of heat loss in the post-retrofit building.

Energy savings due to installation of EIFS cladding

The post-retrofit building model was compared to a model in which the exterior brick was clad with uninsulated metal siding. The models included both infiltration and conducting through the walls. The EIFS cladding was shown to have decreased gas consumption by 3.2 percent compared to the altered model with metal siding. This translated to an annual saving of $2,187.

Energy saving due to window replacement and sealing of window and door perimeters

The post-retrofit building model was compared to one with the original air leakage performance. The impact of changing windows from single pane to double pane windows was not considered, as this would have been the minimum replacement specification, thus, not an “energy-driven” consideration. Reducing infiltration by sealing the window and door perimeters over what would have otherwise been done as part of a routine window replacement was shown to have offered a reduction in gas consumption of 0.98 percent, which translated to an annual savings of $603.

The tested air leakage rate of the existing windows, both fixed and operable, was between two to three times the A1 operable window air tightness rating (see CSA A440-98, Table1, pg. 38).

Energy savings due to installation of low-flow showerheads

Low-flow showerheads were assumed to reduce water consumption for showers by about 40 percent (from 0.32 l/s to 0.19 l/s). To simulate the contribution of low flow showerheads to energy efficiency, the estimation of hot water use in the building at different times of the day was adjusted. The post-retrofit building model was compared to one in which the amount of water used for showers during peak morning and evening periods was greater than in the post-retrofit model. The installation of low-flow showerheads was estimated to have offered a reduction in hot water related gas consumption of 23.6 percent, which translated to an annual savings of $8,217.

This estimation is higher than the savings achieved in practice likely due to the assumptions made concerning pre- and post-retrofit hot water usage.

Energy savings due to boiler replacement

The post-retrofit model was compared to one with aging boilers was estimated at 70 percent and of the new ones at 83 percent. The replacement of the boilers responsible for space heat was calculated to have offered an 18.8 percent reduction in space heating related gas consumption. This translated to an annual savings of $6,560.

Cost-Benefit Analysis

Table 2 summarizes the energy consumption savings, total costs, and payback period for the incremental investment for each improvement (March 2002 data). The boilers installed were believed to be of standard efficiency. Thus, no additional investment was made to purchase them over the minimal cost required for replacement of the ageing boilers and no incremental cost was incurred.

Table 2: Investment made and savings accrued

	Percent Reduction in Gas Consumption	Annual Savings (in $)	Total Incremental Investment (in $)	Payback Period (in years)
Cladding upgrade	3.2	2,187	322,000 (EIFS: 23/sqft, installed vs metal cladding: $10/sqft)	147
Sealing of door and window perimeters	0.89	603	13,125 ($1.25/lin.Ft)	2.18
Boiler replacement	18.8	6,560	0	Immediate
Showerhead replacement	23.6	8,217	6,000	0.7

Conclusion

The reduction in gas consumption due to improvements in the building envelope – installation of EIFS siding and sealing of door and window perimeters – was quite low (less than 5%). The payback period for EIFS cladding, at 147 years, was excessively long; this measure was thus not cost effective from an energy saving perspective. In contrast, the payback period for the installation of low-flow showerheads, at 0.7 years, was very short; this was thus clearly a cost-effective measure. Replacement of the aging boilers yielded modest savings; however, since the boilers installed were of standard efficiency, the payback could be considered to be immediate. The provision of heating in the poorly insulated parking garage, and the installation of heated corridor air system, while improving conditions within the building, likely represented a significant energy increase that reduced the overall energy savings.

Despite the low energy savings and long payback period for improvements to the building envelope, it should be noted that there were other, less easily quantified benefits of these changes for the occupants: improved air tightness meant reduced cold drafts and wind noise. The insulated EIFS cladding reduced moisture condensation on interior wall finishes and mold growth on outside walls. The rain screen provided by the EIFS cladding reduced exterior moisture penetration. Finally, the EIFS cladding covered the edges of the floor slabs, keeping them warmer and more comfortable under foot. Sealing window and door frames with expandable foam likely yielded (15) similar benefits with a short payback period, and was therefore an effective investment.

Overall, the energy efficiency improvements saved the building owners $18,719 per year in combined electricity and natural gas costs.

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