LIFE-CYCLE COST EVALUATION OF BUILDING ENVELOPE ENERGY RETROFITS

by

Afarin Maleki

A thesis submitted in conformity with the requirements

for the degree of Master of Applied Science

Graduate Department of Civil Engineering

University of Toronto

Your file Votre référence
ISBN: 978-0-494-52659-0
Our file Notre référence
ISBN: 978-0-494-52659-0

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ABSTRACT

Improving the energy efficiency of our existing building stock is attainable by upgrading the building envelope through carrying out various retrofit measures. The objective of this thesis is to evaluate the life-cycle cost implications of energy retrofits for existing buildings. Measures examined include improving insulation and air-tightness with over-cladding strategies. The life-cycle costs of the upgrades are determined for an existing building and compared with model energy performance. A life-cycle cost evaluation for the building envelope upgrades is provided, together with the payback period and the projected return on investment (ROI) for two energy escalation rate scenarios. A cost-benefit matrix for various over-cladding strategies is provided to facilitate the evaluation of each option. Further, this thesis presents a simplified ROI algorithm to enable owners, architects and engineers to evaluate the cost-benefit of their building envelope retrofit options.

Acknowledgment

No job in my life has ever been accomplished without help and this one is no exception. I would like to express my sincere gratitude to my thesis advisor, Dr. Kim Pressnail, at the University of Toronto, Department of Civil Engineering, for his continual guidance and support throughout the development of this study. Without his assistance this research would not have been possible.

I also wish to extend my appreciation to Mr. Kevin Day of Halsall Associates Ltd., for his guidance, insight and encouragement throughout.

I gratefully acknowledge Halsall Associates Ltd. and the Neil B. Hutcheon Bequest for providing the opportunity and financial support needed for this study.

And last but not least I am indebted to my husband, Ray, for his care, support and encouragement, and to Armin and Tara for their unconditional love and patience.

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1.0 INTRODUCTION

A large number of concrete frame high-rise buildings that were built in the 1960s and 1970s exist in Canada and mainly Toronto. These buildings are, in general, energy inefficient. Poor energy performance is due to building envelope construction as well as the mismatched design of the building envelope and its mechanical system. In addition, the majority of buildings of this era now exhibit various levels of deterioration and experience comparatively higher energy consumption than modern glass box buildings. As the existing high-rise building stock ages and deteriorates, incorporating building envelope upgrades becomes intuitively beneficial. Further, as the cost of heating and cooling buildings continues to rise, the need for thermal insulation upgrades also increases. The recent 20 percent increase in natural gas prices[1] in Canada and increased environmental concerns provide strong motivations for the energy retrofit of building envelopes.

Building owners and managers have an opportunity to reduce the size of their ecological footprint. Energy retrofits can lead to operational cost savings over the life cycle of the building; they can also lead to more marketable, more responsible 'greener' buildings. Furthermore, retrofitted buildings can be more durable and more comfortable for the occupants.

Although the mechanical system (and how it operates) plays the most important role in determining the energy efficiency of our buildings, the building envelope also has an influence on gross energy consumption. Improving the energy efficiency of our existing building stock is made possible by means of building envelope upgrades. Thus, when building envelope retrofits are undertaken, it is an ideal opportunity to incorporate energy-saving measures into the repair and rehabilitation work, especially on buildings with robust precast concrete cladding, or masonry walls. In the case of deteriorated building envelopes, restoring the components would normally be the main objective of the project. However,

[1] This refers to the July 2008 price increase.

adapting the retrofit work to include a thermal envelope upgrade is an additional and easily attainable objective.

Many energy-saving options are available for envelope rehabilitation. Over-cladding strategies provide the potential for significantly improving the thermal performance of exterior walls. Thermal insulation levels can be increased to reduce heat loss, and at the same time, air-tightness measures can improve overall thermal performance and moisture management. Howarth and Sanstad [1.1] demonstrated in a study that building envelope retrofit technologies provide hidden benefits by simultaneously reducing costs, improving the quality of energy services, and increasing indoor comfort by reducing air leakage and radiation heat losses. The technology exists for such upgrades; however, its economic viability needs to be evaluated. This thesis provides a comparison of various thermal insulation levels which may be incorporated into building envelope restoration projects. An economic evaluation will be presented and the value proposition for the retrofit investment will be compared to the associated paybacks.

A few studies have outlined the cost savings of building envelope energy retrofits, including a study of strategies for reducing building energy use via building envelope technologies, conducted by Canadian Mortgage and Housing Corporation (CMHC) [1.2]. The study by CMHC presents a cost-benefit analysis of building envelope technologies such as double facades, atria and window retrofits. Kesik [1.3] has presented a study of high-rise residential buildings and available retrofit strategies, as well as the cost effectiveness of some retrofit options. This thesis aims to build on previous research by specifically looking at the anticipated energy savings achieved by over-cladding strategies and the economic implication of the associated incremental and life-cycle costs.

The primary objective of this thesis has been to conduct an economic assessment of over-cladding energy retrofits along with window replacement options, taking into account initial costs, energy savings, escalation rates and deferred maintenance costs. After considering the factors affecting the economics of a building envelope retrofit, a method was developed. The research method included an evaluation of the construction costs for the energy efficient upgrades of the building envelope. The energy performance of the building before and after the building envelope energy retrofit was determined using model energy performance. Current energy prices and energy price escalation rates were used to account for expected trends in energy prices. The life-cycle economic assessment of energy retrofits accounted for initial costs, energy savings and escalation rates. Finally, a cost-benefit matrix with supporting graphical data was developed as a decision-making tool for building energy retrofits.

2.0 BUILDING ENERGY CONSUMPTION

Energy consumption in buildings, other than lighting and miscellaneous equipment, is primarily associated with space heating and cooling. The main factors affecting the energy consumption of a building include:

i) the efficiency of the heating, ventilation, and air conditioning (HVAC) system;
ii) the lifestyle of building occupants;
iii) the performance of the building envelope.

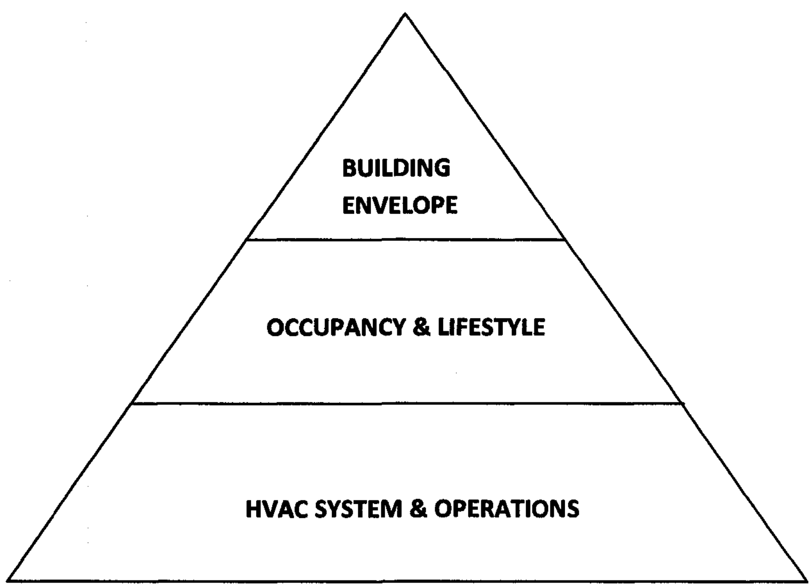

FIGURE 2.1 –BUILDING ENERGY CONSUMPTION PYRAMID (CREATED BY AUTHOR)

The factors affecting the energy performance of a building are illustrated in Figure 2.1.

1- The efficiency of the heating, ventilation and cooling system is a major factor affecting the energy performance of a building. Inefficient HVAC systems will result in poor energy performance regardless of the building envelope system.

2- Occupants of a building and their lifestyle are the next factors affecting the energy performance of a building. In multi-unit residential buildings where occupants pay a lump sum for heating and cooling, energy use often increases. For example occupants tend to turn up the heat or their air conditioners, while leaving windows wide open, and because they do not pay the energy bills there is not much motivation to conserve energy.

3- Building envelope systems and construction have an impact on the energy efficiency of buildings. Improved building envelope performance will result in reduced heat loss and heat gain through the envelope. Building envelope upgrades can lead to a reduction in peak demands for heating and cooling. Thus, heating and cooling systems can be downsized and this results in further savings.

This research aims to identify the impact of building envelope upgrades on the energy consumption of buildings.

2.1 HEAT TRANSFER MECHANISMS

Heat transfer through the building envelope components occurs when there is a temperature difference between two adjacent areas. The energy transfer is linked to radiation and also involves conductive and convective exchanges. The four heat transfer mechanisms are:

- **Conduction**, which occurs by the molecule-to-molecule transfer of kinetic energy (one molecule becomes energized and, in turn, energizes adjacent molecules);
- **Convection** that is the transfer of heat by physically moving the molecules from one place to another;
- **Radiation**, which is the transfer of heat through space via electromagnetic waves (radiant energy); and
- **Air leakage,** movement of air through discontinuities of air barrier. Unsealed openings and cracks have a significant impact on annual space heating and cooling as well as peak energy demand. The air movement can either be into the building

(infiltration) or out of the building (exfiltration) and is driven by a pressure differential.

The basic relationship for one-dimensional heat flow at steady state, is given by Fourier's law [2.1], and states that:

$$\mathbf{q = A \cdot k/l\,(t1 - t2)} \tag{1}$$

where,

q	is the rate of heat flow,
A	is the area transverse to the flow,
k	is the coefficient of thermal conductivity
l	is the length of the flow path,
(t1 – t2)	is the temperature difference producing flow

The primary focus of this thesis is to examine heat losses through the building envelope. Due to our heating-dominated climate, winter heating loads and energy consumptions were the main parameters of this study. A study by CMHC [2.2] presents a breakdown of heat loss in multi-unit residential buildings, and claims that air leakage represents up to 24% of space heating energy use. During specifically designed winter conditions, air leakage can be as much as 40% of the peak space-heating load. Air leakage contributes significantly to electric demand charges in electrically heated buildings as the greatest air leakage occurs during the coldest periods of the year. In air-conditioned buildings, air leakage contributes significantly to cooling loads and energy- peak- demand charges. Thus, building envelope upgrades that result in reducing any of the heat transfer mechanisms will improve the thermal performance of the envelope system. Higher thermal performance of building envelope components will result in lower heat loss and heat gain by the building and therefore result in lower heating and cooling loads. As the heating and cooling system accounts for a significant portion of a typical building's energy use, improved thermal performance of the building envelope systems will have a direct impact on its energy consumption.

2.2 BUILDING ENERGY EFFICIENCY RETROFITS

Building energy-efficiency retrofits range from upgrading the building systems (which do not involve the building envelope) to the strategies that are applied to the building envelope.

The energy-efficiency of a building can be improved through retrofit measures applied to:

i) The mechanical system and its operation;
ii) The electrical system, and
iii) The building envelope.

Building envelope retrofit measures include:

1) Improved air tightness,
2) Enhanced insulation, and
3) High-performance windows.

Upgrades to the building systems include incorporating heat recovery ventilation (HRV) systems, high-efficiency condensing boilers, and lighting controls. Based on Toronto's Green Development Standard (TGDS) Cost-Benefit Study, the payback period for these upgrades (systems and envelope upgrades) combined is less than 7 years [2.3].

A study by Gray et al. [2.4] investigates the cost implications of building energy-efficient homes and the energy retrofitting of existing homes. It compares the construction and the energy costs of new homes: one home built to the prescribed minimum standard established by the Ontario Building Code and one home built with energy-efficiency measures incorporated. The study suggests that adopting energy- efficient measures in new home construction – measures such as upgrading the thermal insulation of exterior walls from R-17 to R-20 and basement insulation from R-6 to R-12 (full height), and replacing no coatings air-filled windows with low E, argon- filled windows, as well as installing a heat- recovery ventilator (HRV) may result in an investment that yields an internal rate of return of over 14%. The IRR was calculated for a period of 25 years assuming no fuel cost escalation.

The Net Zero Impact: A Sustainability Workshop [2.5] held in Toronto presented possibilities for achieving net zero impact buildings and developments. Workshop participants represented a cross-section of stakeholders who were interested in improving the sustainability of future developments. First it was concluded that the proposed development can approach a net zero impact condition provided that the highly inefficient existing buildings were retrofitted such that the reductions in energy, water, storm water and solid waste were sufficient to account for the new buildings and facilities. Second, it was very difficult, both technically and economically, to construct new developments having lower impacts on servicing requirements. Regeneration projects that involve both the retrofitting of existing buildings mixed with new building construction may have more potential to offset increases in servicing requirements. As part of this workshop, a cost-benefit analysis of energy and water conservation measures for a hypothetical development was presented. The existing '70s vintage apartment towers were assessed in detail using computer simulations confirmed with typical utility data available for this era of uninsulated, single-glazed, reinforced concrete tower buildings. The results indicated that for the existing towers, some items, such as boilers and heat recovery ventilators, were cost effective investments with payback periods of less than five years. The comprehensive retrofit of a typical 20-storey tower building included additional roof and wall insulation, window and boiler replacement, an 80% efficiency heat recovery system and water conservation strategies. The comprehensive retrofit was found to yield payback periods in the range of 10 to 12 years, and resulted in an approximately 50% reduction in energy consumption, and a 30% reduction in water consumption. The return on investment for the comprehensive retrofit ranged from 13.1% to 17.3%, depending on the energy escalation rate [2.5].

Hepting and Jones [2.6] carried out an energy performance workshop for condominium buildings to assess the cost effectiveness of various energy efficiency measures. A life-cycle economic analysis was conducted based on a 5.5% discount rate and energy escalation rate of 8%. Two different combinations of energy-efficiency measures were studied and the energy performance was compared with a baseline design.

Combination A includes an improved wall system with 40% glazing to wall ratio with the 60% opaque walls at 80% masonry and 20% spandrel. The masonry walls have an additional one inch of rigid insulation, garage occupancy sensors controlling two-thirds of the lighting, in-suite heat recovery handling 80% of make-up air unit, a condensing boiler plant, low-flow domestic hot water (DHW) fixtures, and variable speed pumps.

Combination B includes an improved wall system with 50% glazing to wall ratio with the 50% opaque walls at 80% masonry and 20% spandrel. The masonry walls have an additional one inch of rigid insulation, garage occupancy sensors controlling two-thirds of the lighting, in-suite heat recovery handling 80% of make-up air unit, a condensing boiler plant, low-flow domestic hot water (DHW) fixtures, and variable speed pumps [2.6].

The conclusions of the study by Hepting and Jones are summarized in Table 2.1.

TABLE 2.1 – COMPARISON OF TWO ENERGY-EFFICIENCY UPGRADES [2.6]

	Annual Energy Savings ($)	**Capital Cost ($)**	**Payback Period (Yrs)**	**Energy Savings (%)**
Combination A	$134,000	$862,500	6	28.8%
Combination B	$127,600	$952,500	6.8	26.5%

Both upgrade combinations A and B present viable investment opportunities, in comparison to common available investment options.

The isolated effects of applying additional insulation to the exterior walls were not presented in the study. This thesis aims to assess the building envelope retrofit processes that help improve the air-tightness and thermal performance of a building.

2.3 BUILDING ENVELOPE ENERGY RETROFIT MEASURES

Building envelope retrofit measures can be interior, exterior or a combination of both. Interior retrofits are generally disruptive to the occupants and may require vacating the building during the process. These retrofits alone do not improve the appearance of the building or its water-tightness and require an exterior component. Exterior retrofits are often the most cost-effective approach and do not cause disruption to the occupants. These strategies include improved air-tightness and increased insulation, over-cladding, replacement of windows with high performance options, and the enclosure of balconies.

2.3.1 IMPROVED AIR-TIGHTNESS STRATEGIES

Considering air-tightness, multi-unit high-rise residential buildings built in the 70's are typically very leaky. Reducing air leakage can provide benefits such as reduced space heating costs, improved building envelope durability, better occupant comfort, and improved HVAC system performance.

A study by CMHC [2.7] presents a breakdown of heat loss in multi-unit residential buildings. In this report, air leakage in buildings accounted for up to 24% of overall heat loss. Air leakage has a significant impact on electrical charges in electrically heated buildings as the greatest air leakage occurs during the coldest periods of the year. As well, air leakage contributes significantly to cooling loads, peak-demand charges and reduces indoor thermal comfort.

Moisture migrates into, through and out of the building envelope along with air leakage. When warm moist indoor air leaks out of a building, it may come into contact with cold surfaces within the building envelope. When it does, condensation will occur and wall materials will become wet. Moisture carried by air leakage can cause corrosion of fasteners and steel studs and other wall components. It may cause wet insulation which results in reduced thermal resistance and may cause deterioration of exterior cladding or interior wall finishes. In addition, air leakage in buildings will cause drafts and therefore uncomfortable indoor conditions may occur.

A main consideration in high-rise building energy retrofits is the control of air leakage. Pressurizing hallways with make-up air that has been pre-conditioned only to have most of it escape through elevator shafts and stairwells wastes a great deal of energy [2.8]. The highest levels of energy conservation may not be achieved by thermal envelope improvements alone, unless ventilation and air leakage are also addressed.

2.3.2 ENCLOSING BALCONIES

Major improvements in the thermal performance of a building are made possible by enclosing balconies with insulated panels. High performance glazing with operable sections to allow for natural ventilation may be applied. A CMHC study of strategies for reducing building energy use via building envelope technologies reveals the potential cost savings of enclosing balconies [2.9]. In this study a cost-benefit analysis of building envelope technologies such as sun spaces, atria and window retrofits is presented. The study concluded that there will be ongoing opportunities to integrate energy-saving technologies into the building envelope of existing multi-unit residential buildings. Given the age of the building it is assumed that rehabilitation work is inevitable. Any energy-saving upgrade that can be incorporated into the repair work at reasonable incremental costs would be attractive to the property management industry. Among various energy-saving technologies, strategies for enclosing recessed and protruding balconies were studied in detail. The results revealed that enclosing protruding balconies tended to result in increased space heating energy use because of the increased envelope area. Enclosing recessed balconies not only saves energy but also reduces repair and maintenance costs associated with concrete balconies and metal railings. The payback period on the incremental cost of enclosing balconies with single-pane glazing for seasonal use was reported as 10 years, and 25 years for enclosing balconies with double-pane high performance glazing [2.9]. Enclosing balconies has regulatory implications in terms of property assessments because the enclosed balcony could be viewed as living space. This could represent a taxation premium for increased floor space, so change in municipal tax policy may be necessary to permit this measure without added cost.

Ideally, there should be no heating or air conditioning provided within balcony enclosures in order that they may act as a thermal buffer zone. However, the occupants should be discouraged (prevented) from introducing space heaters and air conditioners for these spaces, since adding these appliances will diminish the energy savings of the enclosure (or else add to the energy consumption). Thermal enclosure of balconies is the most cost-effective retrofit strategy, but faces complications unless a coordinated and consistent policy is developed to address planning and zoning issues [2.10].

Modelling balcony enclosure scenarios was not simulated due to the complexity of the factors involved. Therefore, this energy-efficiency retrofit strategy was not evaluated in this thesis.

2.3.3 Enhanced Thermal Insulation

When choosing the type and thickness of thermal insulation used on a building envelope upgrade, optimizing the insulation type and thickness requires a forecast of the energy savings over the life of the building. Figure 2 presents the characteristic curves. When capital and operating costs are expressed in terms of annual cost for various amounts of insulation used, the economic thickness is determined by the lowest annual cost [2.11]. It should be noted that this method does not account for real energy cost escalation.

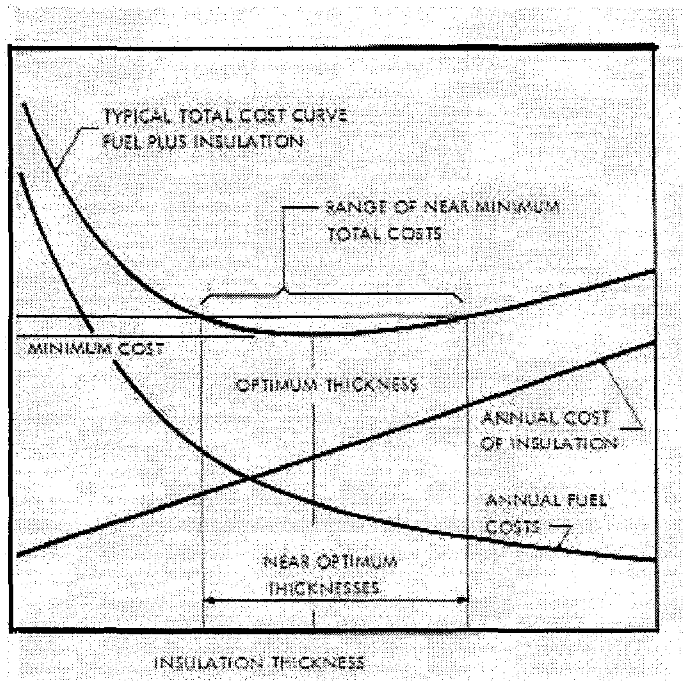

FIGURE 2.2–TYPICAL COST THICKNESS CURVE FOR INSULATION [2.12]

Kesik and Miller [2.13] conducted a comparative life-cycle economic assessment to investigate the cost effectiveness of the addition of 75 mm (3 inches) of extruded polystyrene (XPS) insulation to the exterior of a standard wood stud wall assembly in a typical Canadian residential construction built to Ontario Building Code requirements (baseline). Using HOT2000 software, the operating energy per square meter of wall area was calculated. The authors concluded that the addition of XPS would result in a lower life cycle cost (LCC) than that of the baseline. The study revealed that the incremental capital cost of the XPS wall system is significantly higher in Ontario than in other locations in Canada; however, the LCC of the XPS wall system is often equal to or lower than the LCC of the base case in all but the short term (10 years) LCC study period scenarios.

2.3.4 Over-cladding Strategies

With over-cladding strategies, thermal insulation levels can be easily increased up to RSI 3.5 (R-20) which will result in significantly reducing the rate of heat loss from the wall assembly. Over-cladding strategies can improve the hygrothermal performance of the building by improving the air-tightness of the exterior wall assemblies. Positioning a continuous exterior layer of insulation mitigates thermal bridging, and takes advantage of the building's thermal mass. As well, it protects the building and wall assemblies from temperature extremes that result in undesirable thermal movements.

Kesik and Saleff [2.14] have presented a survey of post-war high-rise building types and available retrofit strategies. The cost effectiveness of some retrofit options for multi-unit residential buildings built in the '60s and '70s was discussed. Over-cladding is currently preferred over other strategies for the envelope retrofit of high-rise residential buildings built in the '60s and '70s. The study presents a case of over-cladding of all opaque wall elements combined with window replacement, and applied to a typical twenty- storey building. Using the CBIP Screening Tool software [2.15] the building's energy consumption was estimated and compared to over-cladding and window replacement costs. Interest rates of 4% and 6% were used to represent low and high interest rate scenarios. Energy escalation rates of 2.5% and 4% above inflation were also used in the study. The study revealed that the payback period for comprehensive over-cladding and window replacement was between 8.25 to 9 years, and the internal rate of return (IRR) was from 10% to 11.7% depending on the energy escalation rate.

An energy-efficiency retrofit case study presented by the Canada Mortgage and Housing Corporation (CMHC) [2.16] describes a retrofit project of a fifteen- storey high-rise building. The upgrades related to the building envelope included the installation of site-applied exterior insulation and finish system (EIFS) (RSI 1.96) over the existing masonry, as well as replacement of single-glazed windows with double-glazed, and roof replacement. The energy performance of the building after retrofit was simulated using a DOE-2 energy simulation program. It was concluded that EIFS cladding decreased the natural gas consumption by 3.2 per cent, and the payback period on the investment in cladding upgrade was reported to be 147 years. This payback period is for all costs and not incremental costs of the upgrade. This thesis will evaluate the incremental costs of energy-efficiency upgrades.

Kesik [2.17] prepared an economic assessment of energy conservation measures for an eleven- storey multi-unit residential building in Toronto. The retrofit measures included over-cladding with 2" and 3" EIFS, window replacement, and a combination of both. Building energy simulation was performed using NRCan's Screening Tool software [2.18]. The assessment concluded that all retrofit measures were cost effective; however, over-cladding with 2" EIFS yielded the highest internal rate of return. The IRR of over-cladding combined with window replacement ranged from 14% to 27% with a payback period of 6 to 8 years depending on the energy escalation rate. The building's energy- performance evaluation was based on NRCan's Screening Tool software, which has limitations in detailed analysis of building systems and may not include the full effects of HVAC systems, envelope systems, or the geometry, and location of a building.

Energy savings are influenced by factors such as percentage of window area to wall area. In case of high window area to wall area ratios, the impact of additional wall insulation without window upgrades will be relatively small. In the case of a lower window area to wall area ratio, over-cladding strategies will result in higher energy savings.

3.0 STUDY METHOD

The aim of this study was to build on the previous research in the area of LCC of energy-efficiency measures by specifically looking at the incremental cost of insulation where over-cladding is required. A model building was selected for the study. Various levels of exterior insulation that represent different over-cladding scenarios with and without window replacement were then assessed and the economic implications of the associated incremental and life-cycle costs were evaluated. The cost of standard building envelope restoration work was considered as the baseline cost. The additional costs of incorporating energy-efficiency measures were then compared with potential energy savings.

A typical multi-unit, 25 storey residential building was selected as the model building. The energy consumption of the model building with the existing condition was simulated using the computer building energy simulation tool (EQUEST3.6) [3.1]. The existing building without any energy-efficiency upgrades was considered as the baseline for the study. Next, various exterior insulation options were applied to the existing building to represent a variety of over-cladding scenarios. The energy consumption of the model building was simulated after each retrofit was applied and compared with the baseline. The building's energy performance and energy savings were then evaluated with the cost of upgrades.

3.1 MODEL BUILDING

The model building used for this study is a typical multi-unit residential high-rise building. The building was constructed in or around 1975. It consists of 25 above-grade storeys which include 157 residential units and one level of underground parking. The total building area is 975m^2, the gross floor area is 26,530m^2 and the gross wall area is 9500m^2 consisting of 5000m^2 of opaque walls, and 4500m^2 windows. The glazed area represents 48% of the total wall area.

The building was constructed with concrete slabs, shear walls and columns. The cladding consists of precast concrete panels with uninsulated slab edges. Windows are typically single-glazed, aluminum frame units. Typical detail drawings are provided in Appendix A. The model building is heated with a central gas-fired boiler and re-circulating radiant heating system. Heating and cooling circulating systems include hot water coils and chilled water coils respectively.

3.2 ENERGY CONSUMPTION EVALUATION

The existing building condition was modelled to represent the energy consumption of the building before incorporating any energy retrofit measures. The construction of a typical exterior wall as presented in the Architectural "as-built" drawings consists of:

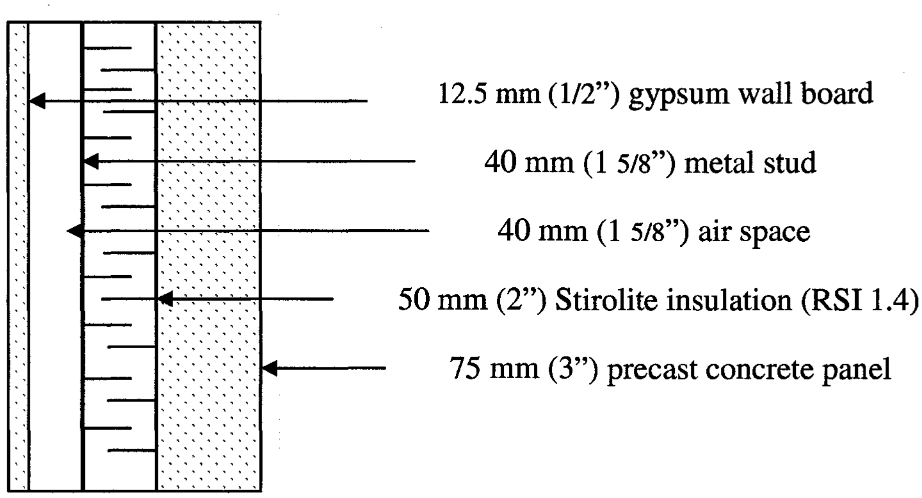

FIGURE 3.1–CROSS SECTION – TYPICAL EXTERIOR WALL

The average thermal resistance of the exterior wall is RSI 0.96 (R6). Related calculations are provided in Appendix B.

After modelling the building with the average thermal resistance of RSI 0.96 (baseline), three different insulation materials were applied to the entire exterior opaque surface of the walls to replicate an over-cladding scenario. The insulation options included 50 mm (2") and 75 mm (3") expanded polystyrene (EPS) and 75 mm (3") extruded polystyrene (XPS) foam insulation. The thermal resistance values for the insulation material used are presented in Table 3.1. The energy performance of the building with the additional insulation layer was simulated and compared to the baseline case.

The precast cladding surface constitutes approximately 50% of the total building surface area and the remaining 50% consists of windows and balcony doors. Windows are weak points in the building envelope, in terms of thermal properties and air leakage. Since windows are significant contributors to heat loss in winter and heat gain in summer, the impact of exterior insulation is strongly related to the window/wall ratio. In the case of high window area to wall area ratios, the impact of additional wall insulation without window upgrades will be relatively small. Single glazing provides RSI 0.15 (R1), double glazing, low E, RSI 0.5 (R3), and reflective double or triple glazing up to RSI 0.7 (R4). Thermally, the main section of double glazing is essentially two air films plus the air space. The two sheets of glass contribute only 2% to the resistance of heat flow. [3.2] In the case of our model building, single-glazed windows which are typical for buildings of that era plus balcony sliding doors, constitutes approximately 50% of the total building surface area and the remaining 50% consists of precast concrete panels.

At the next phase of this model study, window replacement was examined using double-glazed (low E, argon-filled) thermally broken aluminum frames. Also, a triple-glazed option was evaluated and combined with exterior insulation options. The thermal resistance properties of the windows are presented in Table 3.1. For the purpose of modelling, the operation of the mechanical and electrical systems were kept constant for all modelling runs, and the insulation type, thickness and window types were the only variables tested. This was intended to examine the isolated effects of the energy retrofit measures applied to the building envelope.

TABLE 3.1 – THERMAL PROPERTIES OF WALLS & WINDOWS

WALLS	RSI VALUE	R VALUE	SHADING COEFFICIENT
Existing Condition	0.96 ~ 1.0	Average 6	-
Over-cladding - EIFS (2" EPS)	1.0 + 1.4 = 2.4	R14	-
Over-cladding - EIFS (3" EPS)	1.0 + 2.1 = 3.1	R18	-
Over-cladding - EIFS (3" XPS)	1.0 + 3.2 = 4.2	R24	-
WINDOWS*			
Existing Windows – Single-Glazed	0.15	1.15	1
Double-Glazed, Low E., Argon filled	0.57	3.2	0.63
Triple-Glazed, Low E., Argon filled	0.68	3.9	0.58

* J. Timusk [3.3]

3.2.1 ENERGY MODELLING – CBIP SCREENING TOOL

The NRCan's CBIP Screening Tool for new building design was used at the first stage of this study to simulate the energy consumption of the building. This Screening Tool software, developed by Natural Resources Canada, provides a rough estimate of the building's energy performance and an estimate of green house gas emissions. The screening tool provides a quick estimate of the energy performance of a proposed building design relative to the Model National Energy Code for Buildings (MNECB). By conducting this preliminary screening, the impact of a single measure or a combination of measures can be assessed to maximize the energy performance of the building design. The software is a helpful tool for use at the preliminary design stage to provide an estimate of building energy consumption. However it has some limitations and does not take into account details such as site and orientation, the specifics of the mechanical and electrical systems and the operation and schedules of the building.

The subject building was modelled using different insulation materials; the energy performance of the retrofitted building was simulated and compared to the baseline case. The energy consumption of the building in every test condition was measured using the Screening Tool for new building design, and the annual energy costs for each condition were calculated using current energy costs in Ontario: natural gas[2], \$0.48/m³, and electricity, \$0.11/kWh [3.4]. The results of the Screening Tool are presented in Table 3.2. The complete energy performance report is presented in Appendix C.

TABLE 3.2- ANNUAL ENERGY CONSUMPTION (Screening Tool)

	Electricity (kWh)	Natural Gas (GJ)[1]	Total Energy Cost (\$)	Base Case Savings (Δ)
Existing Building Condition - Repairs without Energy-Efficiency Upgrades	2,272,395	16,498	\$465,757	-
Over-cladding				
1.Over-cladding – EIFS (2″ EPS)	2,242,212	12,732	\$413,178	**\$52,579**
2.Over-cladding - EIFS (3″ EPS)	2,237,767	12,124	\$404,736	**\$61,021**
3.Over-cladding - EIFS (3″ XPS)	2,233,884	11,594	\$397,377	**\$68,380**
Over-cladding and Window Replacement Upgrades				
4. Window replacement only (double-glazed, low E, argon filled)	2,117,549	6,399	\$316,629	**\$149,128**
5. EIFS (2″ EPS) and window replacement (double-glazed, low E, argon filled)	2,124,784	5,397	\$304,319	**\$161,438**
6. EIFS (3″ EPS) and window replacement (double-glazed, low E, argon filled)	2,125,990	5,235	\$302,333	**\$163,424**

[2] The natural gas price is as of August 2008. Currently, the price of gas has decreased as a result of drop in world demand due to global economic slowdown; however, based on historical trends cost of energy continues to escalate in the long term.

7. EIFS (3" XPS) and window replacement (double-glazed, low E, argon filled)	2,127,045	5,094	$300,604	**$165,153**
8. EIFS (2" EPS) and window replacement (triple-glazed, low E, argon filled)	2,099,207	5,071	$297,241	**$168,516**
9. EIFS (3" EPS) and window replacement (triple-glazed, low E, argon filled)	2,100,632	4,930	$295,554	**$170,203**
10. EIFS (3" XPS) and window replacement (triple-glazed, low E, argon filled)	2,101,878	4,806	$294,069	**$171,688**

[1] 1 GJ = 947,817 BTUs
Natural Gas cost $0.48/ m³; 37.08 MJ/m³, 1 GJ= $13.00

The Screening Tool for new building design provides a rough estimate of the building's energy consumption but does not take into account details such as site and orientation, the specifics of the mechanical and electrical systems and the operation and schedules of the building. Thus, a more refined model (EQUEST 3.6), was used – a model that could incorporate these variables into the study.

3.2.2 Energy Modelling – EQUEST 3.6

The building for this study was simulated using an EQUEST 3.6 computer building energy performance simulation tool to achieve a more detailed and accurate evaluation. EQUEST 3.6 is derived from the latest version of DOE.2. However the EQUEST program expands and extends the capabilities of DOE-2 in several important ways including [3.5]:

i) Interactive operation,
ii) Dynamic/intelligent defaults, and
iii) Improvements to the shortcomings in DOE-2 that have limited its use.

The software allows for a detailed analysis of building materials and systems and includes the effects of HVAC systems, envelope systems, and the geometry, size and location of the building.

Using climatic data for Toronto, the baseline building was simulated without any energy-efficiency upgrades. After that, three different insulation materials were applied to the entire wall area to represent over-cladding. The existing single-glazed windows were also replaced with double- and triple-glazed, low E, argon-filled, thermally broken aluminum frames and the energy performance of the building was simulated and compared to the baseline case. As before, the roof construction, mechanical and electrical systems and their operations remained constant for all modelling runs, and the insulation type, thickness and window types varied during each test run. Assumptions for infiltration rate include:

- Existing condition: Perimeter (shell tightness), 0.7 ACH , building core 0.1 ACH;
- Over-cladding measures: Perimeter (shell tightness), 0.6 ACH , building core 0.1 ACH;
- Window replacement only: Perimeter (shell tightness) 0.5 ACH , building core 0.1 ACH;
- Over-cladding and window replacement measures: Perimeter (shell tightness) 0.5 ACH , building core 0.1 ACH;

In every test condition the energy consumption of the building was determined and the annual energy cost for each condition was calculated. The results are presented in Table 3.3. The complete energy performance reports are provided in Appendix D.

TABLE 3.3- ANNUAL ENERGY CONSUMPTION (EQUEST 3.6)

	Electricity (kWh)	Natural Gas (GJ)[1]	Total Energy Cost ($)	Base Case Savings (Δ)
Existing Building Condition - Repairs without Energy-Efficiency Upgrades	2,145,400	17,534	**$465,339**	-
Over-cladding				
1.Over-cladding – EIFS (2" EPS)	2,129,000	15,888	**$442,009**	**$23,330**
2.Over-cladding - EIFS (3" EPS)	2,127,000	15,741	**$439,857**	**$25,482**
3.Over-cladding - EIFS (3" XPS)	2,126,600	15,593	**$437,881**	**$27,458**
Over-cladding and Window Replacement Upgrades				
4.Window replacement **only** (double-glazed, low E, argon filled)	2,100,600	10,096	**$363,126**	**$102,213**
5.EIFS (2" EPS) and window replacement (double-glazed, low E, argon filled)	2,090,000	8,725	**$344,021**	**$121,318**
6.EIFS (3" EPS) and window replacement (double-glazed, low E, argon filled)	2,090,000	8,588	**$342,227**	**$123,112**
7. EIFS (3" XPS) and window replacement (double-glazed, low E, argon filled)	2,090,000	8,651	**$343,055**	**$122,284**
8.EIFS (2" EPS) and window replacement (triple-glazed, low E, argon filled)	2,027,000	8,366	**$332,399**	**$132,940**
9.EIFS (3" EPS) and window replacement (triple-glazed, low E, argon filled)	2,027,000	8,240	**$330,743**	**$134,596**
10. EIFS (3" XPS) and window replacement (triple-glazed, low E, argon filled)	2,027,000	8,113	**$329,087**	**$136,252**

[1] 1 GJ = 947,817 BTUs
Natural Gas Cost \$0.48/ m^3; 37.08 MJ/m^3, 1 GJ= \$13.08

Based on the EQUEST 3.6 the computer building energy simulation tool, applying the energy-efficiency measures to the model building, resulted in overall annual energy savings of up to $136, 252. The results showed that energy savings increased from energy-efficiency upgrade 1 to upgrade 10.

Results revealed that over-cladding strategies saved up to $27,458 of total energy costs. Window replacement resulted in $102,213 savings in total yearly energy cost. Over-cladding combined with window replacement reduced the total energy cost of the model building by up to $136,252.

3.3 MODEL BUILDING - HEAT LOAD COMPONENTS

In order to better understand the impact of various energy-efficiency measures on the gas consumption of the model building, the building peak load components are presented in Table 3.4. The breakdown is based on the EQUEST 3.6 computer building energy simulation tool.

TABLE 3.4- PEAK HEATING LOAD COMPONENTS

	Walls Conduction (KBtu/hr)	Roof Conduction (KBtu/hr)	Windows & Frames Conduction (KBtu/hr)	Underground Surface Conduction (KBtu/hr)	Infiltration (KBtu/hr)	Total (KBtu/hr)	Gas Savings (KBtu/hr)
Existing Condition (Aesthetic Repairs of Precast Concrete Panels)	743	16	3515	11	2959	7244	0
Over-cladding							
1. EIFS (2" EPS) (R8)	532	16	3532	11	2537	6628	616
2. EIFS (3" EPS) (R12)	486	16	3536	11	2536	6585	659
3. EIFS(3"XPS) (R18)	443	16	3540	11	2537	6547	697
Over-cladding and Window Replacement Upgrades							
4. Window replacement only (double-glazed, low E, argon filled)	770	16	1272	11	2114	4183	3061
5. EIFS (2" EPS) and (double-glazed, low E, argon filled)	550	16	3536	11	2536	6649	3699
6. EIFS (3" EPS) and (double-glazed, low E, argon filled)	502	16	1280	11	1691	3500	3744
7. EIFS (3" XPS) and (double-glazed, low E, argon filled)	457	16	1281	11	1691	3457	3787

8. EIFS (2" EPS) and (triple-glazed, low E, argon filled)	553	16	1094	11	1691	3366	3878
9. EIFS (3" EPS) and (triple-glazed, low E, argon filled)	505	16	1095	11	1691	3319	3925
10. EIFS (3" XPS) and (triple-glazed, low E, argon filled)	459	16	1096	11	1691	3274	3970

Figures 3.2 to 3.12 present the peak- heat- load components of the model building. The model building is presented with and without energy-efficiency measures.

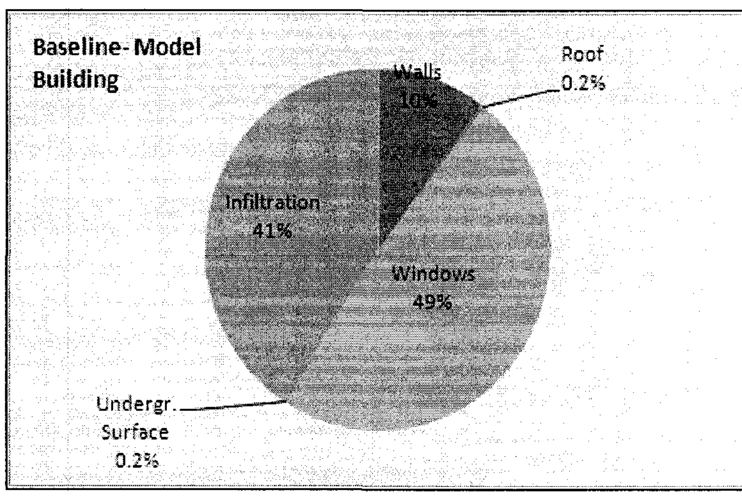

FIGURE 3-2–BASELINE – MODEL BUILDING

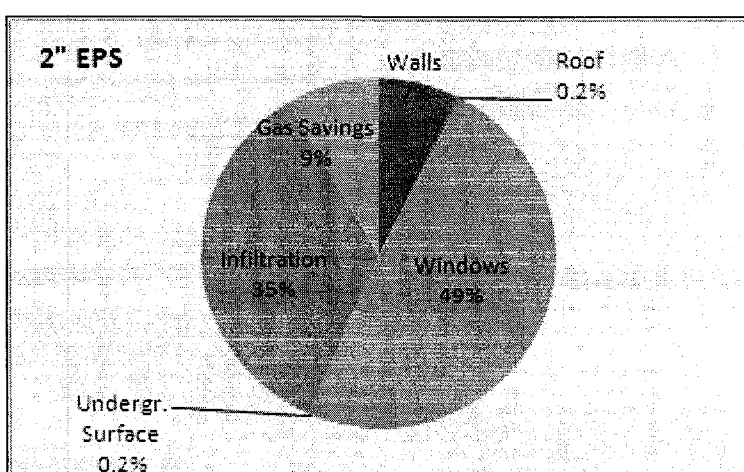

FIGURE 3.3–OVER-CLADDING – 2" EPS

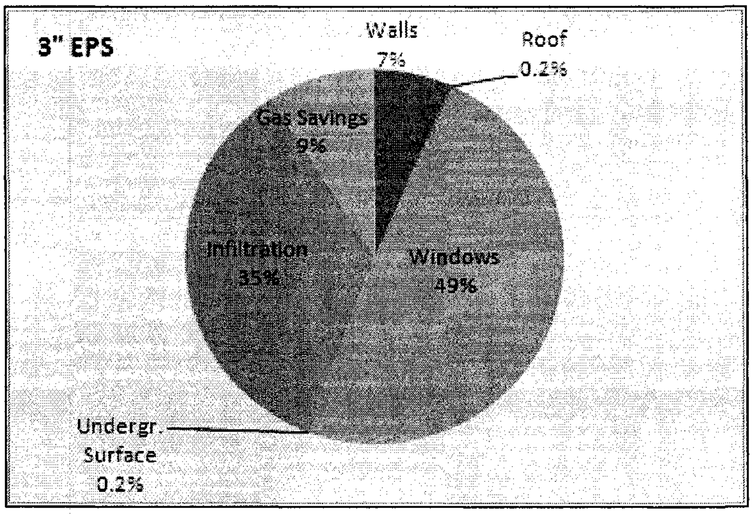

FIGURE 3.4–OVER-CLADDING – 3" EPS

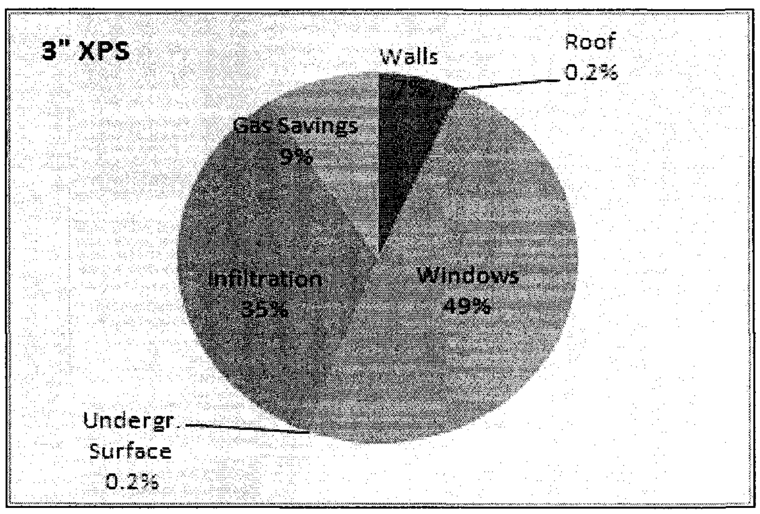

FIGURE 3.5–OVER-CLADDING – 3" XPS

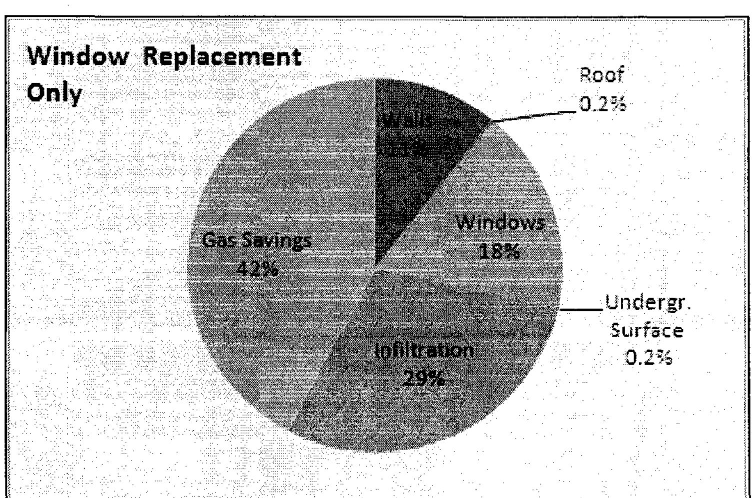

FIGURE 3.6–WINDOW REPLACEMENT – DOUBLE-GLAZED WINDOWS

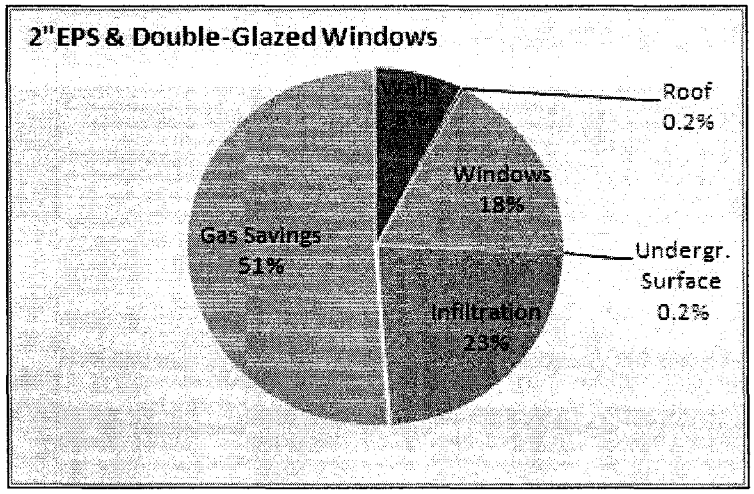

FIGURE 3.7–OVER-CLADDING – 2" EPS & DOUBLE-GLAZED WINDOWS

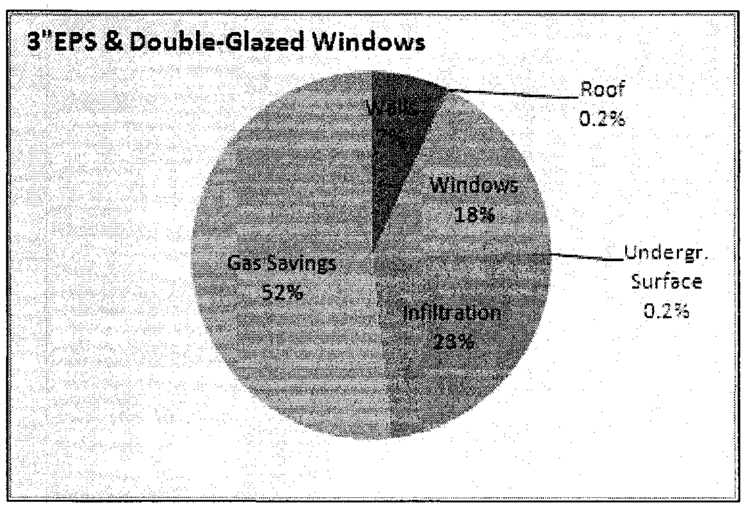

FIGURE 3.8–OVER-CLADDING – 3" EPS & DOUBLE-GLAZED WINDOWS

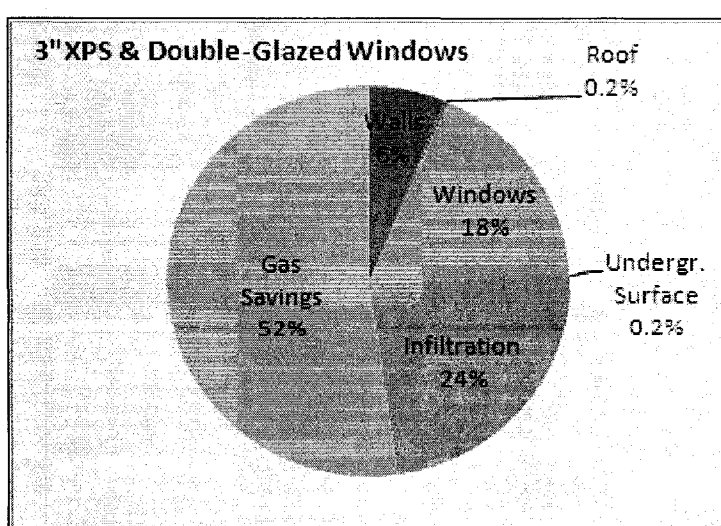

FIGURE 3.9–OVER-CLADDING – 3" XPS & DOUBLE-GLAZED WINDOWS

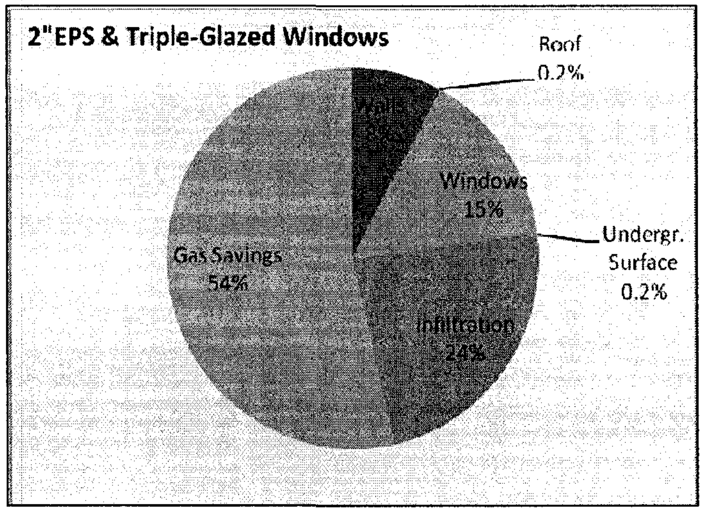

FIGURE 3.10–OVER-CLADDING – 2" EPS & TRIPLE-GLAZED WINDOWS

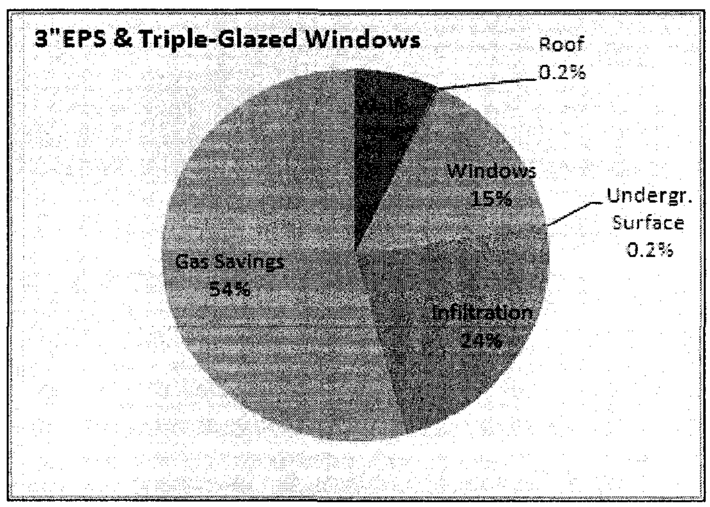

FIGURE 3.11–OVER-CLADDING – 3" EPS & TRIPLE-GLAZED WINDOWS

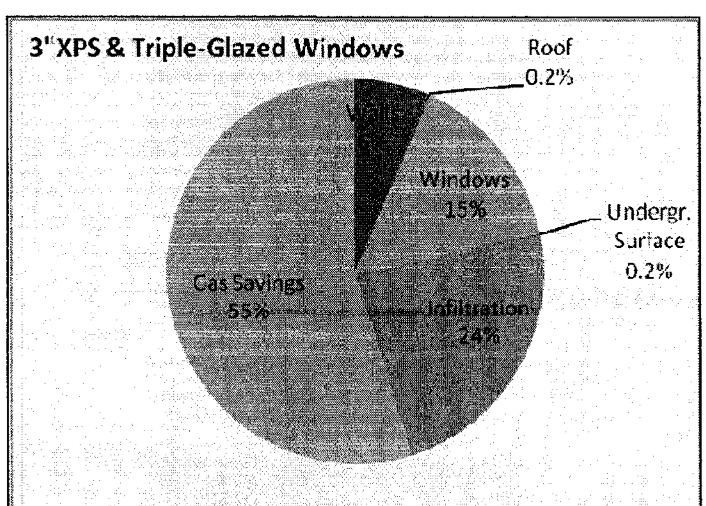

FIGURE 3.12–OVER-CLADDING – 3" XPS & TRIPLE-GLAZED WINDOWS

Over-cladding combined with window upgrades reduced building-peak energy consumption by 51% - 55%. Infiltration, which was 41% in the baseline case, was reduced to 23% with window replacement combined with over-cladding. Total wall and window contribution decreased from 59% in the baseline, to as low as 21% with over-cladding combined with window upgrades.

4.0 FINANCIAL ANALYSIS

4.1 ENERGY-EFFICIENCY RETROFIT COSTS

For this section of the study, the cost of incorporating energy-efficiency measures into building envelope restoration work was established. The purpose of this evaluation was to determine the economic viability of incorporating energy-efficiency measures into the building envelope repair and restoration work. It was assumed that building envelope restoration is inevitable for buildings built in the '60s and '70s. The intent of this analysis was to assess the incremental cost associated with energy-efficiency upgrades.

The building envelope upgrades we considered were:

- Improving the existing insulation and air-tightness of building exterior walls by means of over-cladding of the entire wall surface with exterior insulation and finish system (EIFS);
- Replacing existing single-glazed windows with double- and triple-glazed low E, argon-filled, thermally broken aluminum frames;
- Combining over-cladding and window replacement.

In order to perform the economic analysis, building-envelope retrofit costs were obtained from R.S. Means Construction Cost Data [4.1] and checked against current cost data made available by Halsall Associates Ltd. These estimated costs are presented in Table 4.4.

TABLE 4.1 - CONSTRUCTION COST DATA

Energy-Efficiency Upgrades	Unit Cost	Area (m²)	Total Cost
Baseline Repair Work			
Aesthetic Repairs of Precast Concrete Panels (without energy-efficiency upgrades)*	$ 50/ m²	5000 m²	$250,000
Window Replacement – Double-Glazed **	$600/ m²	4500 m²	$2,700,000
Over-cladding			
Over-cladding - EIFS (2" EPS) ***	$180/m²	5000 m²	$900,000
Over-cladding - EIFS (3" EPS) ***	$190/m²	5000 m²	$950,000
Over-cladding - EIFS (3" XPS) ****	$250/m²	5000 m²	$1,250,000
Window Upgrades			
Window Replacement – Double-Glazed, Low E., Argon filled	$700/ m²	4500 m²	$3,150,000
Window Replacement – Triple-Glazed, Low E., Argon filled	$800/ m²	4500 m²	$3,600,000

* Typical aesthetic repairs include routing and sealing, isolated patches and non-structural repairs.

** Original windows are typical single-glazed units, and replacement with standard performance double-glazed windows is considered a baseline cost.

*** Exterior insulation and finish system consisting of expanded polystyrene insulation (EPS) and polymer modified stucco - nominal R-values for assemblies are provided (2" EPS with assembly RSI 1.4 – R8, and 3" EPS with assembly RSI 2.1 - R12).

**** Exterior insulation and finish system consisting of 3" of extruded polystyrene insulation (XPS), and polymer modified stucco (RSI 3.16 - R18).

4.2 RETROFIT ANALYSIS – COSTS AND BENEFITS

The economic reasoning on which the decisions were generally based was straightforward. The most common criteria for decision-making are the net present value and the life-cycle cost. Cost-effective energy-efficient strategies that yeild the highest net present value and minimize life-cycle costs at prevailing prices and interest rates are considered to be acceptable retrofit measures.

The economic viability for energy-efficiency upgrades are presented in this section. Various thermal insulation levels that can be incorporated into building envelope restoration projects have been compared. An economic evaluation was carried out and the retrofit investment was compared to the associated paybacks.

4.2.1 FORECASTING RETROFIT BENEFITS

The current study presents an assessment of costs and benefits, and utilizes the common economic evaluation methods, including the payback period and the return on investment (ROI). The study considers two different energy-escalation rate scenarios. Scenarios include:

- First scenario, 5% interest rate, and energy escalation of 0% over the inflation rate, which equals 5%;
- In the second scenario, 5% interest rate, and energy escalation of 3% above the inflation rate, which equals 8% to represent higher energy prices than the current rate.

Both scenarios have been used for calculations throughout this study. However, based on past energy escalation rate trends, the second scenario is more likely to be used in the future. Current and historical trends suggest that energy prices are expected to exceed inflation rates in future, and a high-energy price scenario is predicted. The changing energy escalation rates need to be considered in the retrofitting of multi-unit high-rise buildings. These retrofitted buildings are intended to have an extended service life of at least 50 years after restoration and will therefore need to perform in a totally different energy market than today's.

4.2.2 Incremental Cost of Energy-Efficiency Upgrades

The economic assessment was based on the incremental cost of incorporating energy-efficiency measures into the building envelope restoration work. It is assumed that building envelope restoration is inevitable for buildings when deterioration is evident. The model building used for this study is approximately 33 years old. Signs of deterioration on the precast concrete cladding were evident. The original single-glazed windows were failing, and were indicative of poor thermal performance. Repair and restoration of the precast concrete panels, and window replacement seemed to be inevitable at this stage of the building's life.

The purpose of this evaluation was to determine the added costs associated with the energy-efficiency measures. In the case of our model building, the typical aesthetic repairs of the precast concrete cladding were considered as integral to the baseline building envelope restoration work. The typical aesthetic repairs included the routing and sealing of the cracked areas, localized and isolated patchwork, and non-structural repairs to the precast concrete panels. The incremental cost of incorporating additional insulation over the baseline cost (which belonged to aesthetic repairs only) was used for the analysis.

The original windows of the model building were typically single-glazed units, and replacing them with standard performance double-glazed windows was considered as the baseline cost. The incremental cost of high performance windows compared with baseline windows (which were standard performance double-glazed units) was used for the analysis. It was assumed that window replacement is inevitable at this stage of the building's life. The additional cost of installing high performance double- and triple-glazed, low E, argon-filled windows instead of baseline windows, was included in the calculations.

4.3 INTERNAL RATE-OF-RETURN

The internal rate-of-return (IRR) of an investment is the rate of interest earned on the unrecovered balance of an investment where the terminal balance is zero. IRR is the most commonly used rate-of-return method and is known as the true rate-of return method [4.2]. In this case, the IRR represents the equivalent interest rate that an energy-efficiency retrofit measure would yield over a period of time. The time period used in this assessment was 50 years and two energy escalation rate scenarios were used for the analysis. The retrofit is expected to extend the service life of the building by at least 50 years. The IRR provides the equivalent interest rate earned by the investment over the 50-year study period. The results are summarized in Table 4.5.

TABLE 4.2- IRR FOR ENERGY-EFFICIENCY UPGRADES

Indicator	Initial Cost	Incremental Cost [1]	Annual Energy Saving[2]	Escalation Rate	Total Energy Saving (50 Yrs)	Internal Rate of Return
Baseline Repair Work						
Existing Condition (Aesthetic Repairs of Precast Concrete Panels)	**$250,000**	-	-	-	-	-
Window Replacement Double-Glazed Standard Performance	**$2,700,000**	-	-	-	-	-
Over-cladding						
1. Over-cladding – EIFS (2" EPS) (RSI 1.4)	**$900,000**	**$650,000**	$23,330	**Current***	$5,129,493	**7.7%**
				High**	$14,460,325	**10.8%**
2. Over-cladding - EIFS (3" EPS) (RSI 2.1)	**$950,000**	**$700,000**	$25,482	**Current**	$5,600,540	**7.8%**
				High	$15,788,232	**10.9%**
3. Over-cladding - EIFS (3" XPS)(RSI 3.16)	**$1,250,000**	**$1,000,000**	$27,458	**Current**	$6,035,774	**6.4%**
				High	$17,015,182	**9.4%**

Over-cladding and Window Replacement Upgrades						
4. Window replacement only (double-glazed, low E, argon filled)	$3,150,000	$450,000	$102,213	Current	$22,470,647	28.9%
				High	$63,345,997	32.5%
5. EIFS (2" EPS) & window replacement (double-glazed, low E, argon filled)	$4,050,000	$1,100,000	$121,318	Current	$26,669,156	16.5%
				High	$75,181,828	19.8%
6. EIFS (3" EPS) & window replacement (double-glazed, low E, argon filled)	$4,100,000	$1,150,000	$123,112	Current	$27,063,089	16.2%
				High	$75,183,764	19.3%
7. EIFS (3" XPS) & window replacement (double-glazed, low E, argon filled)	$4,400,000	$1,450,000	$122,284	Current	$26,881,938	13.7%
				High	$75,781,670	16.9%
8. EIFS (2" EPS) & window replacement (triple-glazed low E, argon filled)	$4,500,000	$1,550,000	$132,940	Current	$29,224,754	13.8%
				High	$82,386,199	17.1%
9. EIFS (3" EPS) & window replacement (double-glazed low E, argon filled)	$4,550,000	$1,600,000	$134,596	Current	$29,587,057	13.7%
				High	$83,407,552	16.9%
10. EIFS (3" XPS) & window replacement (triple-glazed low E, argon filled)	$4,850,000	$1,900,000	$136,252	Current	$29,952,236	12.3%
				High	$84,437,011	15.5%

Interest Rate = 5%,

* Current: Fuel Escalation Rate = 0% over Inflation

** High: Fuel Escalation Rate = 3% over Inflation

1 Incremental Cost = Cost of Retrofit – Cost of Baseline Repair Work (from Table 4.4)

2 Annual Energy Savings = Building's Baseline Energy Consumption – Energy Consumption after Retrofit (from Table 3.3)

The study revealed that in general over-cladding without window replacement, presents an internal rate-of-return (IRR) of 6.4% to 10.9%. The study illustrated that the energy-efficiency upgrade no. 2, that is over-cladding with 3" expanded polystyrene insulation (EPS), yields an IRR of 7.8% to 10.9%, which is the highest IRR among the over-cladding options.

The results showed that replacing the existing single-glazed windows with double-glazed, low E, argon-filled windows without over-cladding yields an IRR of 28.9% to 32.5%.

It was evident that in general, over-cladding strategies combined with window replacement yields an IRR of 12.3% to 19.8%. Over-cladding with 2" expanded polystyrene insulation (EPS), combined with replacement of existing windows with double-glazed, low E, argon-filled windows resulted in an IRR of 16.5% to 19.8% depending on the energy escalation rate; and, was the highest IRR of the over-cladding and window replacement options.

4.4 PAYBACK PERIOD

A simple payback period is the length of time required to recover the cost of investment in energy-efficiency measures; however there are two major flaws. The first is that it ignores the time value of money and disregards interest rates. Second, it ignores the benefits achieved after the payback period, ignores the expected service life of the building, and therefore may not provide a true evaluation for long-term projects. To overcome the disadvantages of this method, a discounted payback period was used. The present worth of each year's energy savings was subtracted from the incremental cost of that particular energy-efficiency upgrade until the incremental cost was reduced to zero [4.3]. The number of years of savings required to do this is the discounted payback period for the building's energy retrofit. The payback periods for energy-efficiency upgrades were calculated using current and high-energy escalation rate scenarios and are presented in Table 4.6.

TABLE 4.3 - PAYBACK PERIOD FOR ENERGY EFFICIENCY UPGRADES

Indicator	Initial Cost	Incremental Cost [1]	Annual Energy Saving[2]	Escalation Rate	Total Energy Saving (50 Yrs)	Payback Period
Baseline Repair Work						
Existing Condition (Aesthetic Repairs of Precast Concrete Panels)	$250,000	-	-	-	-	-
Window Replacement Double-Glazed Standard Performance	$2,700,000	-	-	-	-	-
Over-cladding						
1. EIFS (2" EPS) (RSI 1.4)	$900,000	$650,000	$23,330	Current*	$5,129,493	17.4
				High**	$14,460,325	14.6
2. EIFS (3" EPS) (RSI 2.1)	$950,000	$700,000	$25,482	Current	$5,600,540	17.2
				High	$15,788,232	14.5
3.EIFS (3" XPS)(RSI3.16)	$1,250,000	$1,000,000	$27,458	Current	$6,035,774	20.7
				High	$17,015,182	17
Over-cladding and Window Replacement Upgrades						
4. Window replacement only (double-glazed, low E, argon filled)	$3,150,000	$450,000	$102,213	Current	$22,470,647	4
				High	$63,345,997	3.8
5. EIFS (2" EPS) & (double-glazed, low E, argon filled)	$4,050,000	$1,100,000	$121,318	Current	$26,669,156	7.4
				High	$75,181,828	6.8
6. EIFS (3" EPS) & (double-glazed, low E, argon filled)	$4,100,000	$1,150,000	$123,112	Current	$27,063,089	7.6
				High	$75,183,764	7

7. EIFS (3" XPS) & (double-glazed, low E, argon filled)	**$4,400,000**	**$1,450,000**	$122,284	**Current**	$26,881,938	**9.2**
				High	$75,781,670	**8.2**
8. EIFS (2" EPS) & (triple-glazed low E, argon filled)	**$4,500,000**	**$1,550,000**	$132,940	**Current**	$29,224,754	**9.1**
				High	$82,386,199	**8.1**
9. EIFS (3" EPS) & (triple-glazed low E, argon filled)	**$4,550,000**	**$1,600,000**	$134,596	**Current**	$29,587,057	**9.2**
				High	$83,407,552	**8.2**
10. EIFS (3" XPS) & (triple-glazed low E, argon filled)	**$4,850,000**	**$1,900,000**	$136,252	**Current**	$29,952,236	**10.5**
				High	$84,437,011	**9**

Interest Rate = 5%,

* Current: Fuel Escalation Rate = 0% over Inflation

** High: Fuel Escalation Rate = 3% over Inflation

1 Incremental Cost = Cost of Retrofit – Cost of Baseline Repair Work (from Table 4.4)

2 Annual Energy Savings = Building's Baseline Energy Consumption – Energy Consumption after Retrofit (from Table 3.3)

Return on investment (ROI) represents the percentage of energy saving benefit over the cost of the energy-efficiency measures. The study revealed that in general, over-cladding without window replacement resulted in a payback period of 14.5 to 20.7 years. The results showed that replacing the existing single-glazed windows with double-glazed low E, argon-filled windows without over-cladding yields a payback period of 3.8 to 4 years.

It was evident that in general, over-cladding strategies combined with window replacement present a payback period of between 6.8 to 10.5 years. Over-cladding with 2" expanded polystyrene insulation (EPS), combined with the replacement of existing windows with double-glazed, low E, argon-filled windows resulted in a payback period of between 6.8 to 7.4 years depending on the energy escalation rate.

4.4.1 25-YEAR RETROFIT LOAN PAYMENT

The economic assessment for this study was based on the incremental cost of incorporating energy-efficiency measures into the model building's envelope restoration work. The purpose of this evaluation was to determine the added costs associated with the energy-efficiency measures introduced. The cost of borrowing money for the incremental cost of energy-efficiency upgrades was compared with the energy savings involved. A 25-year loan payment (based on a 5% interest rate) was assumed. Figure 4.1 shows the net savings of the over-cladding option with EIFS – 3" expanded polystyrene (EPS) insulation. An annual loan payment of $49,700 for 25 years at a 5% interest rate was used to represent the incremental cost of $700,000. Energy savings were calculated based on: no fuel escalation rates and, an escalation rate of 3% over inflation. It is evident that the energy saving benefits continues to increase long after the loan payment is complete.

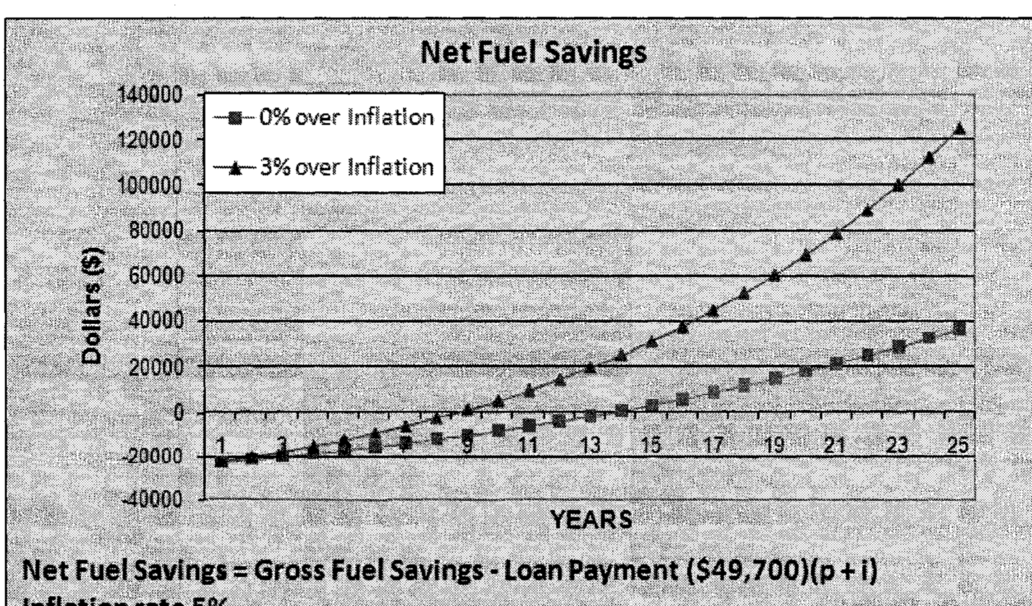

FIGURE 4.1- NET SAVING VS. TIME (25 YEAR LOAN) 3" (EPS) INSULATION

Figure 4.2 illustrates the net savings of an example of over-cladding combined with window replacement. Over-cladding walls with EIFS - 3" expanded polystyrene (EPS) insulation and replacement of existing windows with double-glazed, low E, argon-filled windows is presented. An annual loan payment of $81,650 for 25 years (based on a 5% interest rate) was used to represent the incremental cost of $1,150,000. The calculation of energy savings was based on fuel escalation rates of 0% and 3% over inflation.

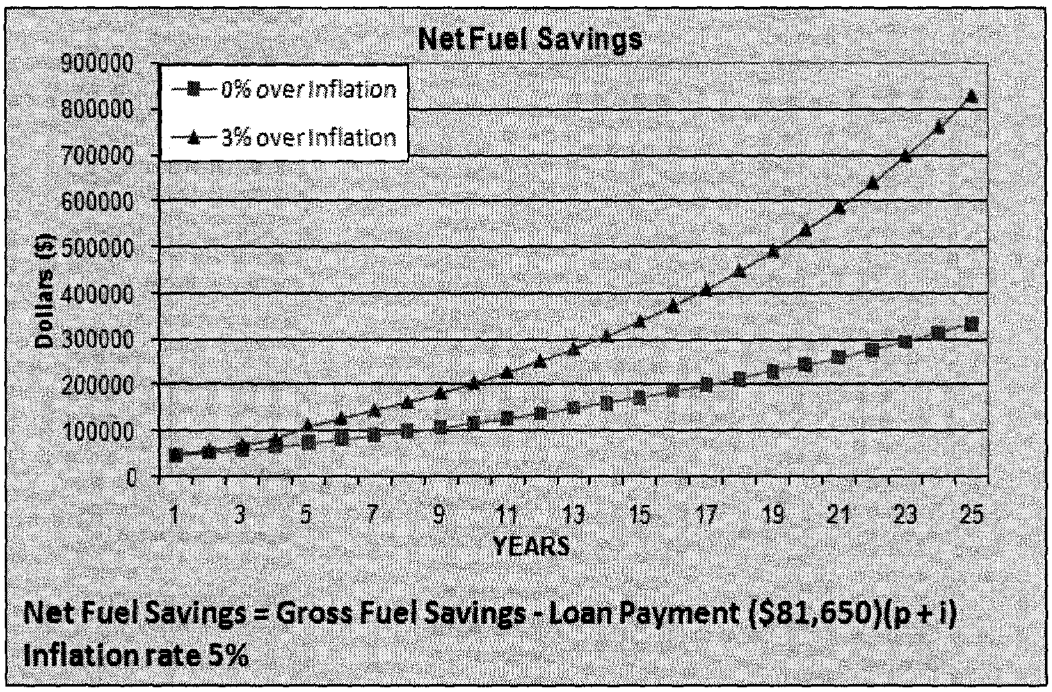

FIGURE 4.2 – NET SAVING VS. TIME – (25 YEAR LOAN) 3" EPS INSULATION & DOUBLE-GLAZED, LOW E, ARGON FILL WINDOWS

Figure 4.3 presents the net savings for window replacement with double-glazed, low E, argon-filled windows, during a 25-year loan payment. An annual loan payment of $31,950 for 25 years (at a 5% interest rate) was used to represent the incremental cost of $450,000.

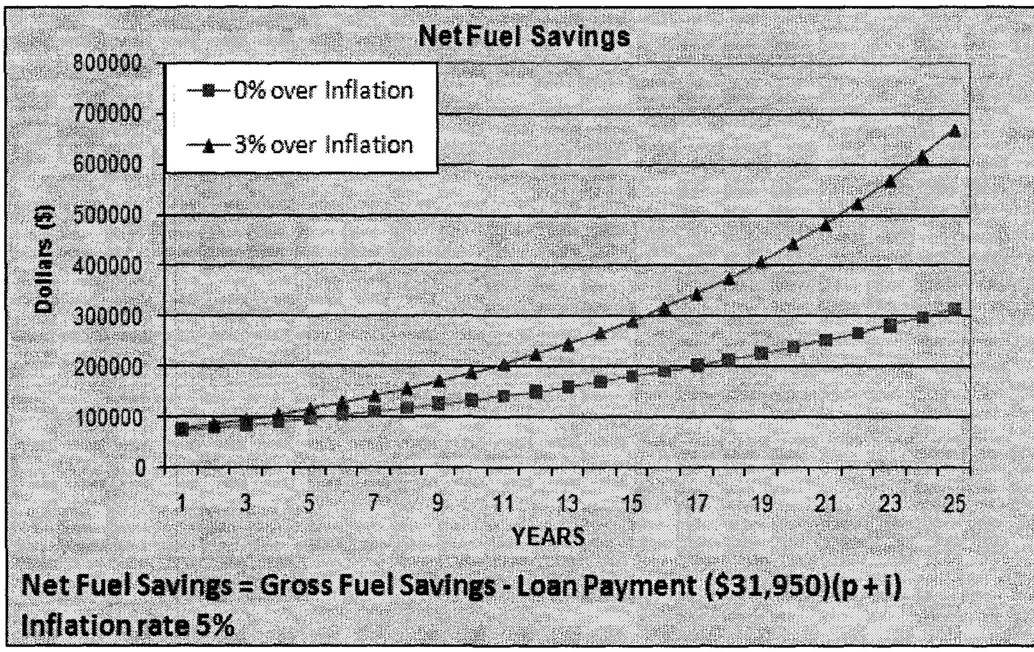

FIGURE 4.3- NET SAVING VS. TIME – (25 YEAR LOAN) REPLACEMENT OF WINDOWS WITH DOUBLE-GLAZED, LOW E, ARGON FILL WINDOWS

4.4.2 10-YEAR RETROFIT LOAN PAYMENT

Building owners/managers typically prefer a shorter loan payment for energy-efficiency retrofits. In the event that a shorter loan payment is desired, 10-year loan payment periods are also illustrated.

An over-cladding option with exterior insulation and finish system using 3" expanded polystyrene (EPS) insulation is shown in Figure 4.4. An annual loan payment of $90,650 for 10 years (based on a 5% interest rate) was used to represent the incremental cost of $700,000.

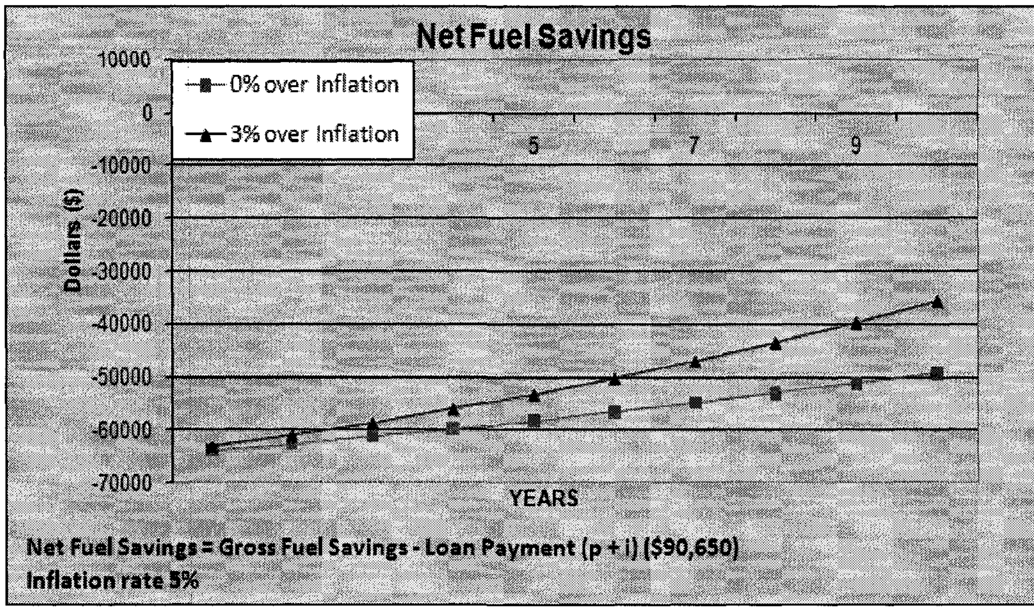

FIGURE 4.4 – NET SAVING VS. TIME – (10 YEAR LOAN) 3" EPS INSULATION

Figure 4.5 presents the net fuel savings for EIFS (3" EPS) over-cladding and replacement of existing windows with double-glazed, low E, argon-filled windows. An annual loan payment of $148,925 for 10 years (at a 5% interest rate) was used to represent the incremental cost of $1,150,000.

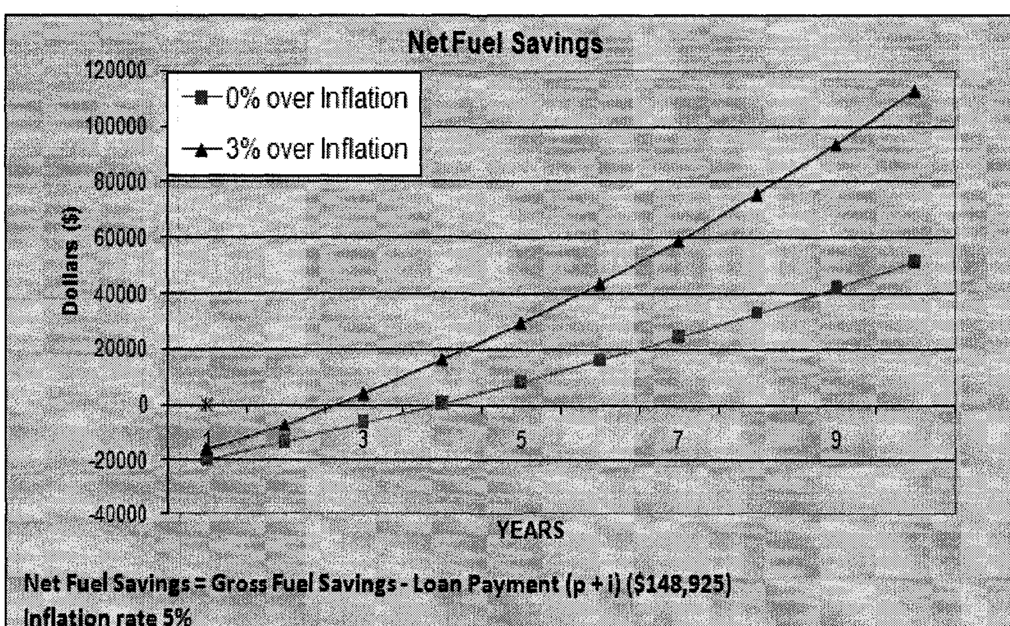

FIGURE 4.5 – NET SAVING VS. TIME – (10 YEAR LOAN) 3" EPS INSULATION & DOUBLE-GLAZED, LOW E, ARGON FILL WINDOWS

Figure 4.6 presents a scenario of replacement of existing windows with double-glazed, low E, argon-filled windows. An annual loan payment of $ 58,275 for 10 years (at a 5% interest rate) was used to represent the incremental cost of $450,000.

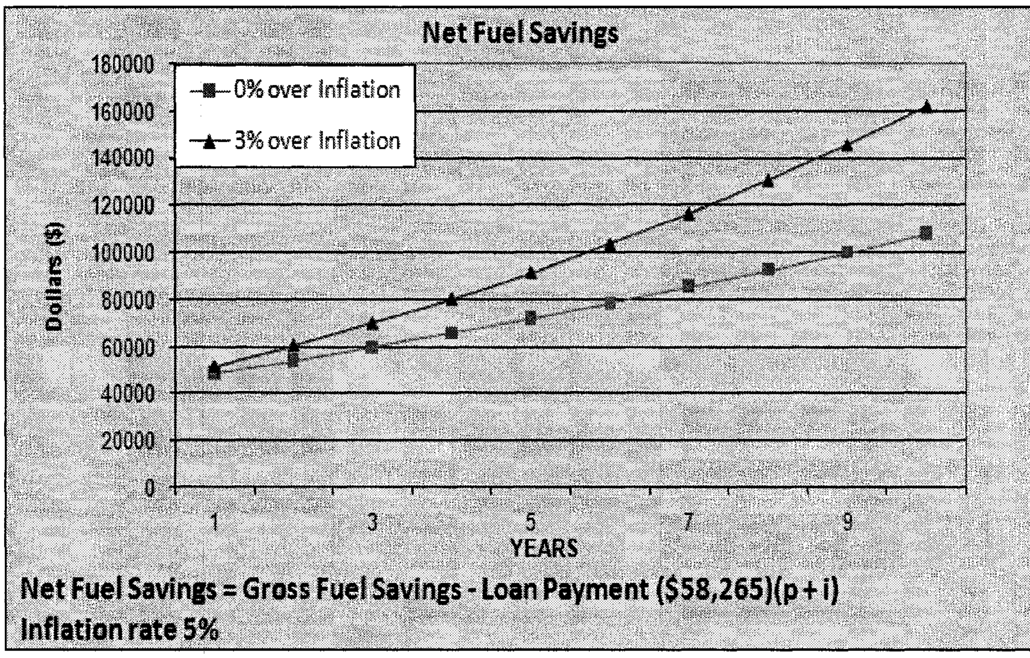

FIGURE 4.6 – NET SAVING VS. TIME – (10 YEAR LOAN) REPLACEMENT OF WINDOWS WITH DOUBLE-GLAZED, LOW E, ARGON FILL WINDOWS

The study showed that investment in measures such as increased thermal insulation, over-cladding and window replacement, continued to provide an additional return-on-investment over the remaining service life of these new retrofit components, which is in proportion to the escalation rate of energy. Energy-efficiency measures seem to provide a steady investment as the cost of energy continues to escalate.

4.5 PRESENT WORTH COMPARISONS

The Net Present Worth of the energy-efficiency measures is the difference between the present worth of the total energy savings and the initial cost plus future costs of the energy-efficiency upgrade. The present worth (PW) analysis is performed to reveal the sum in constant dollars that is equivalent to a future cash flow stream. A future costs method is generally easier to interpret. To eliminate the inflation effects, all cash flows, are converted to units that have a constant purchasing power that is called constant dollars [4.4].

Net Present Worth = PW (Energy Saving Benefits) – PW (Energy-Efficiency Measure)

Among mutually exclusive project alternatives, the one that maximizes net present worth (NPW) or simply the one that yields the larger positive PW is a more economically viable option. A negative PW means that the alternative does not meet the internal rate-of-return requirement.

For the purpose of this analysis, the following life spans were assumed for each energy upgrade alternative and components:

- A life span of 10 years was estimated for the aesthetic and non-structural repairs of the existing precast concrete panels, meaning that localized repairs are anticipated every 10 years;
- For EIFS over-cladding (all insulation thicknesses), a life span of 30 years was assumed, with maintenance and painting occurring every 10 years;
- Windows were given a life expectancy of 30 years, and the time and cost of periodic maintenance and painting was assumed to be the same for all window types.

Energy-efficiency measures were compared on the basis of equivalent outcomes. To accommodate present-worth comparison of the unequal-life energy retrofits, the *least common-multiple* method was used. The least common-multiple of lives of the retrofit alternatives was 30 years. Alternatives were co-terminated by selecting an analysis period of

30 years, which means that the retrofit measures with a life of 30 years would be replaced once, and the measures with a 10-year life span would be replaced three times during the analysis period. The comparison is presented in Table 4.4.

TABLE 4.4 - NET PRESENT WORTH (30 YEARS)

NET PRESENT WORTH (NPW)			
Study Period	30 Years	Assumed Annual Escalation Rate	3% over Inflation
		Assumed Annual Interest Rate	5.00%
	EXISTING CONDITION - PRECAST CONCRETE PANELS		
	Initial Repair Cost		(250,000)
	Total Annual Energy Savings		-
	Total Non-Structural Repairs		(1,704,970)
	Net Present Value		**(1,954,970)**
	Over-cladding Upgrades		
1	**OVER-CLADDING - EIFS (2" EPS)**		
1.1	Initial Cost		(650,000)
1.2	Total Annual Energy Savings		2,877,659
1.3	Maintenance & Painting		(204,596)
1.4	Net Present Value		**2,023,063**
2	**OVER-CLADDING - EIFS (3" EPS)**		
2.1	Initial Cost		(700,000)
2.2	Total Annual Energy Savings		3,143,099
2.3	Maintenance & Painting		(238,696)
2.4	Net Present Value		**2,204,404**
3	**OVER-CLADDING - EIFS (3" XPS)**		
3.1	Initial Cost		(1,000,000)
3.2	Total Annual Energy Savings		3,386,831
3.3	Maintenance & Painting		(272,795)
3.4	Net Present Value		**2,114,036**
	Over-cladding and Window Upgrades*		
4	**EXISTING CONDITION & DOUBLE-GLAZED WINDOWS**		
4.1	Initial Cost		(450,000)
4.2	Total Annual Energy Savings		12,607,551
4.3	Net Present Value		**12,157,551**
5	**EIFS (2" EPS) & DOUBLE-GLAZED WINDOWS**		
5.1	Initial Cost		(1,100,000)
5.2	Total Annual Energy Savings		14,964,074
5.3	Maintenance & Painting - cladding		(204,596)
5.4	Net Present Value		**13,659,478**

TABLE 4.4- NET PRESENT WORTH (30 YEARS) – CONT'D

NET PRESENT WORTH (NPW)				
Study Period	30 Years	Assumed Annual Escalation Rate		3% over Inflation
		Assumed Annual Interest Rate		5.00%
6	**EIFS (3" EPS) & DOUBLE-GLAZED WINDOWS**			
6.1	Initial Cost			(1,150,000)
6.2	Total Annual Energy Savings			15,185,357
6.3	Maintenance & Painting - cladding			(238,696)
6.3	Net Present Value			**13,796,661**
7	**EIFS (3" XPS) & DOUBLE-GLAZED WINDOWS**			
7.1	Initial Cost			(1,450,000)
7.2	Total Annual Energy Savings			15,083,226
7.3	Maintenance & Painting - cladding			(272,795)
7.3	Net Present Value			**13,360,431**
8	**EIFS (2" EPS) & TRIPLE-GLAZED WINDOWS**			
8.1	Initial Cost			(1,550,000)
8.2	Total Annual Energy Savings			16,397,600
8.3	Maintenance & Painting - cladding			(204,596)
8.3	Net Present Value			**14,643,003**
9	**EIFS (3" EPS) & TRIPLE-GLAZED WINDOWS**			
9.1	Initial Cost			(1,600,000)
9.2	Total Annual Energy Savings			16,601,860
9.3	Maintenance & Painting - cladding			(238,696)
9.3	Net Present Value			**14,763,165**
10	**EIFS (3" XPS) & TRIPLE-GLAZED WINDOWS**			
10.1	Initial Cost			(1,900,000)
10.2	Total Annual Energy Savings			16,806,121
10.3	Maintenance & Painting - cladding			(272,795)
10.3	Net Present Value			**14,633,326**
	* Window maintenace and painting costs are assumed to be equal for all upgrade options.			

The results indicate that over-cladding with EIFS - 3" expanded polystyrene (EPS) insulation, presents the highest net present value of all over-cladding only options. Replacement of windows with double-glazed, low E, argon-filled units yielded a net present value of $12,157,551. The cost of maintenance and periodic repairs were assumed to be the same for all window types, and therefore not included.

Over-cladding with EIFS - 3" expanded polystyrene (EPS) combined with replacement of windows with triple-glazed, low E, argon-filled windows, was seen to result in a net present value of $15,001,860 which was the highest NPW of all over-cladding and window replacement options.

The NPW can also use a *study-period* method. The study-period method uses either the shortest life of all competing alternatives; the time before a better replacement becomes available, or the known duration of required services [4.5]. For the purpose of this analysis a 50-year study period was also be considered, as the known duration of services. The 50- year period corresponds to the length of the project life or the period of time the retrofitted building is expected to be in service. Restored buildings are expected to have an extended service life of at least 50 years. NPW analysis using a 50-year study period presented results that were proportional to the results of the 30-year study period.

5.0 LIFE-CYCLE COST-BENEFIT ASSESSMENT

By comparing the total cost of incorporating energy-efficiency measures with the total energy savings over the life cycle of the building, a decision maker can readily judge the feasibility of a retrofit measure. In this section, the energy cost savings predicted by the energy modelling software were assessed in order to determine whether the retrofit investment was a financially viable option. A period of 30 years was assumed for the cost-benefit analysis of the energy retrofit measures. The present worth of total costs and benefits for all energy retrofit measures were calculated on an energy escalation scenario of 3% over interest rate (5%). Current and historical trends suggest that energy prices are expected to exceed the inflation rate in future years, and a higher energy escalation scenario is to be anticipated. Restored high-rise buildings are intended to have a service life which extends beyond 30 years, and will therefore need to perform in a different energy market from today's.

A life-cycle cash flow that includes the initial cost and expected life span of the components pertaining to each upgrade option is presented in Table 5.1. The projected cash flows for the existing building's condition as well as the ten energy retrofit options were planned for a 30-year period. The existing condition refers to maintaining the existing precast cladding and performing some aesthetic repairs without any energy-efficiency upgrades. The proposed aesthetic and non-structural repairs include routing and sealing of cracked areas, with localized and isolated patch works. Typical non-energy-efficiency repairs have historically been performed on buildings when cladding deterioration occurs.

TABLE 5.1 - RETROFIT COSTS AND LIFE EXPECTANCIES

Item	ENERGY-EFFICIENCY UPGRADES	Year of Study	Normal Expected Life	Remaining Life Expectancy	Repair or Replacement Year	Current Repair or Replacement Cost
				Study Period		30 Years
	Study Year	2008		Assumed Annual Escalation Rate		3% over Inflation
	Investment Year	2008		Assumed Annual Interest Rate		5.00%
	EXISTING CONDITION - PRECAST CONCRETE PANELS					
	Initial Cost of Aesthetic Repairs*	2008	10	10	2018	(250,000)
	Annual Energy Savings	2008	1	1	2009	-
	Over-cladding Upgrades					
1.00	OVER-CLADDING - EIFS (2" EPS)					
1.01	Initial Cost	2008	30	30	2039	(650,000)
1.02	Annual Energy Savings	2008	1	1	2009	23,330
1.03	Maintenance & Painting	2008	10	10	2018	(30,000)
2.00	OVER-CLADDING - EIFS (3" EPS)					
2.01	Initial Cost	2008	30	30	2039	(700,000)
2.02	Annual Energy Savings	2008	1	1	2009	25,482
2.03	Maintenance & Painting	2008	10	10	2018	(35,000)
3.00	OVER-CLADDING - EIFS (3" XPS)					
3.01	Initial Cost	2008	30	30	2039	(1,000,000)
3.02	Annual Energy Savings	2008	1	1	2009	27,458
3.03	Maintenance & Painting	2008	10	10	2018	(40,000)
	Over-cladding and Window Upgrades*					
4.00	EXISTING CONDITION & DOUBLE-GLAZED WINDOWS					
4.01	Initial Cost	2008	30	30	2039	(450,000)
4.02	Annual Energy Savings	2008	1	1	2009	102,213
5.00	EIFS (2" EPS) & DOUBLE-GLAZED WINDOWS					
5.01	Initial Cost	2008	30	30	2039	(1,100,000)
5.02	Annual Energy Savings	2008	1	1	2009	121,318
5.03	Maintenance & Painting - Cladding	2008	10	10	2018	(30,000)

TABLE 5.1 - RETROFIT COSTS AND LIFE EXPECTANCIES – CONT'D

			Study Period			30 Years
	Study Year	2008	Assumed Annual Escalation Rate			3% over Inflation
	Investment Year	2008	Assumed Annual Interest Rate			5.00%
Item	**ENERGY-EFFICIENCY UPGRADES**	**Year of Study**	**Normal Expected Life**	**Remaining Life Expectancy**	**Repair or Replacement Year**	**Current Repair or Replacement Cost**
6.00	EIFS (3" EPS) & DOUBLE-GLAZED WINDOWS					
6.01	Initial Cost	2008	30	30	2039	(1,150,000)
6.02	Annual Energy Savings	2008	1	1	2009	123,112
6.03	Maintenance & Painting - Cladding	2008	10	10	2018	(35,000)
7.00	EIFS (3" XPS) & DOUBLE-GLAZED WINDOWS					
7.01	Initial Cost	2008	30	30	2039	(1,450,000)
7.02	Annual Energy Savings	2008	1	1	2009	122,284
7.03	Maintenance & Painting - Cladding	2008	10	10	2018	(40,000)
8.00	EIFS (2" EPS) & TRIPLE-GLAZED WINDOWS					
8.01	Initial Cost	2008	30	30	2039	(1,550,000)
8.02	Annual Energy Savings	2008	1	1	2009	132,940
8.03	Maintenance & Painting - Cladding	2008	10	10	2018	(30,000)
9.00	EIFS (3" EPS) & TRIPLE-GLAZED WINDOWS					
9.01	Initial Cost	2008	30	30	2039	(1,600,000)
9.02	Annual Energy Savings	2008	1	1	2009	134,596
9.03	Maintenance & Painting - Cladding	2008	10	10	2018	(35,000)
10.00	EIFS (3" XPS) & TRIPLE-GLAZED WINDOWS					
10.01	Initial Cost	2008	30	30	2039	(1,900,000)
10.02	Annual Energy Savings	2008	1	1	2009	136,252
10.03	Maintenance & Painting - Cladding	2008	10	10	2018	(40,000)
	* Window maintenace and painting costs are assumed to be equal for all upgrade options.					

The projected cash flows for the energy retrofits were planned to show the years in which retrofit related costs occur throughout the lifespan of the building. The projected cash flows were based on the incremental costs, periodic repairs and maintenance costs, and on annual energy savings. The life expectancy for exterior insulation and finish system (EIFS) was anticipated to be 30 years, with painting and repairs occurring every 10 years. Repair and painting costs occur at years 2018 and 2028. Year 2038 will be the end of the cladding service life and the end of our study period, and therefore repairs and painting were not budgeted for that year. The maintenance and painting costs were assumed to be the same for all window upgrade options, and therefore were not included in the projected cash flows. The projected cash flows for all upgrade options are presented in Figures 5.1 and 5.2. Detailed cash flow tables are provided in Appendix E.

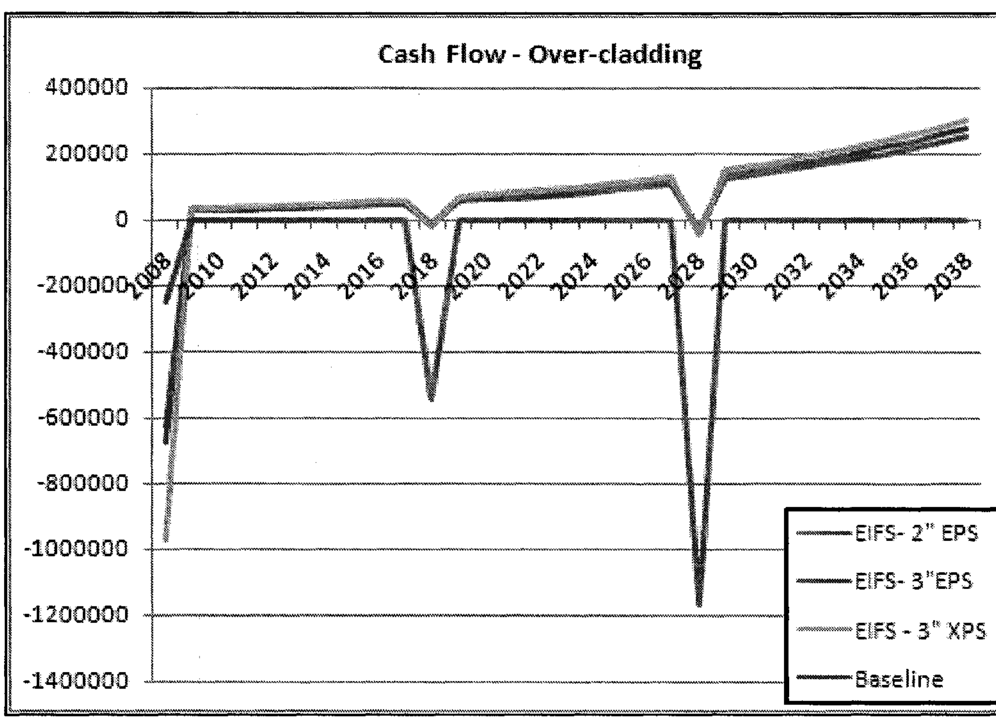

FIGURE 5.1 - PROJECTED CASH FLOW CHART– OVER-CLADDING

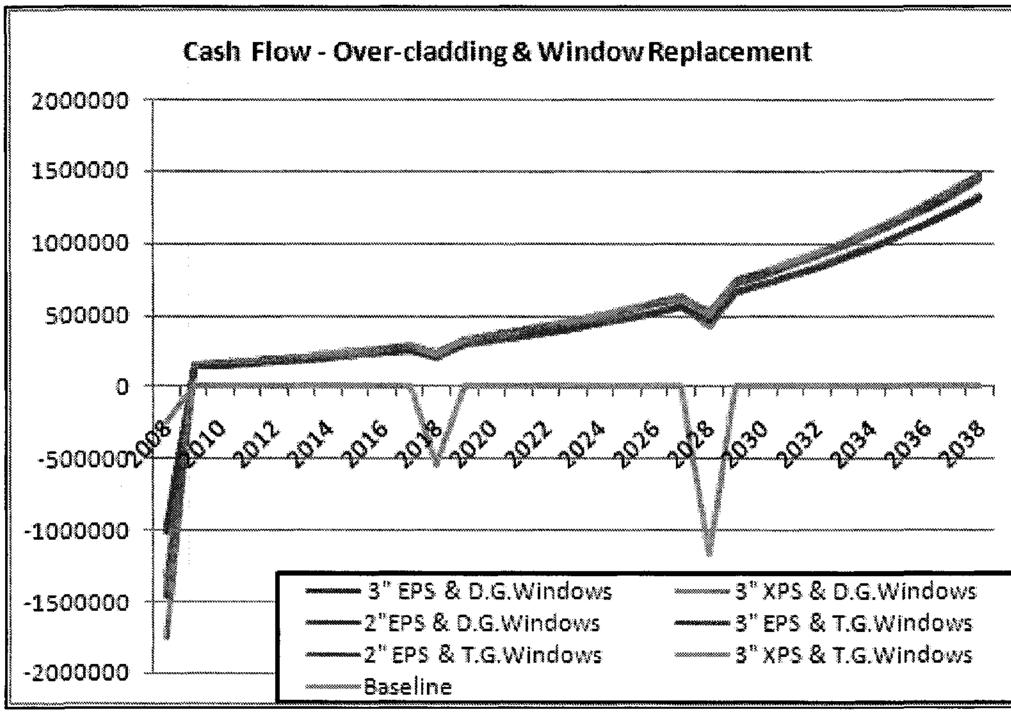

FIGURE 5.2- PROJECTED CASH FLOW CHART– OVER-CLADDING AND WINDOW UPGRADES

In this section, the energy cost savings predicted by the energy modelling software were compared with the life-cycle costs of energy-efficiency measures in order to determine whether the retrofit investment is financially viable. Cost-benefit analysis is a method of evaluating options by quantifying the pros and cons of alternatives so that the options can be ranked. [5.1] Other engineering economic analysis methods which were presented earlier in this report, such as present worth (PW) or internal rate-of-return (IRR) are commonly used for analysis of alternative projects; however, the cost-benefit method analyzes alternatives when quantification of benefits are more difficult.

The ten energy retrofits and the option for maintaining existing conditions with aesthetic repairs were analyzed. Data for comparison of options are shown in Table 5.2, where the figures are presented in thousand-dollar increments. A period of 30 years and an energy escalation rate of 3% over inflation were assumed for the cost-benefit analysis.

TABLE 5.2 – LIFE-CYCLE COST-BENEFIT ANALYSIS

Cost-Benefit Analysis								
	PW of Benefits	PW of Costs	PW of B-C	PW of Net B/C	Incremental			
					ΔB	ΔC	ΔB/ΔC	ΔB-ΔC
Existing Condition (Aesthetic Repairs of Precast Concrete Panels)	-	-1,954	-1,954	-	2,877	1,100	3	3,978
1. Over-cladding – EIFS (2" EPS) (RSI 1.4)	2,877	-854	2,023	3.4	265	84	3	349
2. Over-cladding - EIFS (3" EPS) (RSI 2.1)	3,143	-938	2,204	3.4	243	334	1	-90
3. Over-cladding - EIFS (3" XPS)(RSI 3.16)	3,386	-1,272	2,114	2.7				
Over-cladding and Window Replacement Upgrades								
4. Window replacement only (double-glazed, low E, argon filled)	12,607	-450	12,157	28.0	2,356	854	3	1,501
5. EIFS (2" EPS) & window replacement (double-glazed, low E, argon filled)	14,964	-1,304	13,659	11.5	221	84	2.6	137
6. EIFS (3" EPS) & window replacement (double-glazed, low E, argon filled)	15,185	-1,388	13,796	10.9	-102	334	-0.3	-436
7. EIFS (3" XPS) & window replacement (double-glazed, low E, argon filled)	15,083	-1,722	13,360	8.8	1,314	31	41.3	1,282
8. EIFS (2" EPS) & window replacement (triple-glazed low E, argon filled)	16,397	-1,754	14,643	9.3	204	84	2.4	120
9. EIFS (3" EPS) & window replacement (triple-glazed low E, argon filled)	16,601	-1,838	14,763	9	204	334	0.6	-129
10. EIFS (3" XPS) & window replacement (triple-glazed low E, argon filled)	16,806	-2,172	14,633	7.7				

The life-cycle cost-benefit assessment showed that energy-efficiency upgrade 4 which consisted of replacing existing windows with double-glazed, low E, argon fill without any over- cladding, requires the minimum amount of investment of all the energy-efficiency upgrades. If funds are limited and the lowest investment is desired, window replacement without over-cladding can result in significant energy savings.

Energy-efficiency upgrade 3 - over-cladding with 3" extruded polystyrene (XPS), and energy-efficiency upgrade 10 - over-cladding with 3" extruded polystyrene (XPS) and window replacement with triple-glazed, low E, argon filled, resulted in the highest benefits, and therefore should be considered if maximum energy saving benefits over the life-cycle of the building is the selection criteria.

Energy-efficiency upgrade 2 - over-cladding with (EIFS) using 3" expanded polystyrene (EPS), presented the highest benefits over cost (B - C) advantage of the over-cladding only strategies. Of all over-cladding and window replacement options, upgrade 9 - over-cladding with (EIFS) using 3" expanded polystyrene (EPS), combined with replacement of windows with triple-glazed, low E, argon-filled windows resulted in the maximum advantage of benefits over costs (B - C) which were $2,204,000 and $14,763,000 respectively.

Upgrade 4 - replacement of existing windows with double-glazed, low E, argon filled without any over-cladding – presented a benefit/cost ratio of 28 – the highest benefit/cost ratio of all the energy-efficiency upgrades. Upgrade 2 - EIFS over-cladding with 3" expanded poly styrene (EPS) resulted in a benefit/cost ratio of 3.3, which was the highest such ratio of all over-cladding options. Upgrade 5 – EIFS over-cladding with 2" expanded polystyrene (EPS) combined with replacement of windows with double-glazed, low E, argon-filled windows yielded a benefit/cost ratio of 11.5 which was the highest such ratio of all over-cladding when combined with window upgrades.

Upgrades 1 and 2 – EIFS over-cladding with 2" and 3" expanded polystyrene (EPS) had the maximum incremental benefit/cost ratio ($\Delta B/\Delta C$) of 3 which was higher than the other over-cladding option. Upgrade 8 - EIFS over-cladding with 2" expanded polystyrene (EPS) combined with replacement of windows with triple-glazed, low E, argon-filled windows had the maximum incremental benefit/cost ratio ($\Delta B/\Delta C$) of 41.3 which was the highest of all over-cladding combined with window replacement options.

Upgrade 1 – EIFS over-cladding with 2" expanded polystyrene (EPS) had the maximum incremental advantage of benefit over cost (ΔB - ΔC) of $3,978,000 which was the highest of all over-cladding options; and upgrade 5 – EIFS over-cladding with 2" expanded polystyrene (EPS) combined with replacement of windows with double-glazed, low E, argon-filled windows had an incremental advantage of benefit over cost (ΔB - ΔC) of $1,501,000 that was the highest among all over-cladding when combined with window upgrades.

Upgrade 3 – EIFS over-cladding with 3" extruded polystyrene (XPS) shall be rejected because of its negative (ΔB - ΔC) component, and the ($\Delta B/\Delta C$) ratio of 1. Given funds are available for upgrades 1 and 2, while the additional expense for upgrade 3 is not justified; upgrades 1 and 2 are both acceptable alternatives.

Upgrade 7- EIFS over-cladding with 3" extruded polystyrene (XPS) combined with double-glazed, low E, argon-filled window replacement; and upgrade 10 - EIFS over-cladding with 3" extruded polystyrene (XPS) combined with triple-glazed low E, argon-filled window replacement, shall be rejected among the over-cladding and window upgrades because of the negative (ΔB - ΔC) component, and the ($\Delta B/\Delta C$) ratio which is less than 1; meaning that the additional cost for upgrades 7 and 10 does not seem to be justified.

6.0 OBSERVATIONS

The annual energy consumption of the model building was simulated using the computer building energy simulation tool (EQuest 3.6) with the building's existing conditions and with improved insulation, over-cladding and window replacement options. Using available data, this thesis compared the costs and energy savings associated with the energy-efficient upgrades applied. Based on the findings of the study the following observations can be made:

- **Energy efficiency measures overall**

The study revealed that based on the EQUEST 3.6 energy simulation tool, the incorporation of energy-efficiency measures into the model building resulted in an overall annual energy savings of up to 30% ($136,252) and the peak load gas savings specifically were up to 54% for the model building. The energy-efficiency retrofits yielded an internal rate-of-return of 6.4% to 32.5% overall. The general payback period for energy-efficiency upgrades ranged from 3.8 years to 20.7 years depending on the energy escalation rate. The net benefit/cost ratio for the energy-efficiency measures in general ranged from 2.7 to 28.

- **Over-cladding strategies**

It was evident that over-cladding without window replacement presented an internal rate-of-return of 6.4% to 10.9%. The payback period for over-cladding upgrades ranged from 14.5 to 20.7 years depending on the energy escalation rate. The study by Hepting and Jones concluded that adding a one inch layer of continuous rigid insulation to masonry walls will improve the R-value from RSI 1.7 (R10) to RSI 2.6 (R15), and will yield an internal rate-of-return of 10.9%. [6.1]

Our results showed that the energy-efficiency upgrade number 2 – over-cladding the entire building wall area with 3" expanded polystyrene insulation (EPS) - yields an internal rate-of-return of 7.8% to 10.9%, which is the highest of all over-cladding options. Among the over-cladding strategies applied to the model building upgrade number 2 - over-cladding with 3” expanded polystyrene insulation (EPS) – resulted in the highest net present worth (NPW) i.e., $2,114,036. The net benefit/cost ratio for the over-cladding strategies studied ranged from 2.7 to 3.4, with upgrades number 1and 2 having the highest benefit/cost ratio of 3.4.

- **Window replacement**

The results showed that replacing the existing single-glazed windows with double-glazed low E, argon-filled windows, without other energy-efficiency measures yields an internal rate-of-return of 28.9% to 32.5%. The payback period for window upgrades without any other energy-efficiency measures, ranges from 3.8 to 4 years. Replacing the existing windows with double-glazed, low E, argon-filled windows, resulted in a NPW of $12,157,551. The net benefit/cost ratio for the window replacement was 28.

- **Over-cladding combined with window upgrades**

It was evident that over-cladding strategies combined with window replacement, generally, presented an internal rate-of-return of 12.3% to 19.8%. The payback period for over-cladding combined with window upgrades were between 6.8 and 10.5 years overall, depending on the energy escalation rate. Upgrade number 5 - over-cladding with 2” expanded polystyrene insulation (EPS), combined with replacement of existing windows with double-glazed low E, argon-filled units - resulted in an internal rate-of-return of 16.5% to 19.8% depending on the energy escalation rate, and the payback period was 6.8 to 7.4 years – the shortest period for over-cladding measures when combined with window upgrade options. Upgrade number 6 resulted in a NPW of $14,035,357, which was the highest among all combinations of over-cladding and window upgrades. The net benefit/cost ratio for the over-cladding combined with window upgrades generally ranged from 7.7 to 11.5. Upgrades 5 and 6 – over-cladding with 2” and 3” expanded polystyrene insulation (EPS), combined with replacement of existing windows with double-glazed low-E, argon-filled windows resulted in a benefit/cost ratio of 11.5 and 10.9 respectively, which were the highest among all over-cladding and window upgrade combinations. Between upgrades 5 and 6, upgrade 6 - over-cladding with 3" expanded polystyrene insulation (EPS), combined with double-glazed, low E, argon-filled window replacement-resulted in higher life-cycle benefit – cost (B-C) that is $ 13,796,000. Upgrade 5 also presents an incremental benefit-cost ratio (ΔB/ΔC) of 3 which is higher relative to upgrade 6 and all other options of combined over-cladding and window upgrade strategies.

The economic analysis provided, was based on estimates of anticipated annual energy usage and cost savings. A number of factors, such as building specifications, climatic conditions, building occupancy and operation, and utility rates may affect the actual energy usage and costs. The energy saving results may also differ for buildings using other types of fuel. The payback period for building energy-efficiency upgrades will be reduced in the case of buildings that are heated electrically. The economic analysis provides an evaluation method that is a building-dependent technique, and the results presented in this report may vary from building to building based on the specific characteristics of each building. The relatively large glazing area as a percentage of the building envelope diminishes the effectiveness of the over-cladding. The anticipated annual energy and cost savings for over-cladding will be increased in the case of a building with a lower window/wall ratio. As well, window replacement will result in increased energy savings in the case of a building with a higher window/ wall ratio.

7.0 CONCLUSIONS AND FUTURE WORK

The annual energy consumption of the model building was simulated using the computer building energy simulation tool (EQuest 3.6) with the existing conditions of the building and with improved insulation, over-cladding and window replacement options. Using available data, this thesis has compared the costs and associated energy savings of the energy-efficiency upgrades applied. Based on the findings of the study, our specific conclusions are:

- The return on investment algorithm that best demonstrates how owners should evaluate their building envelope retrofits is [7.1]:

  - Cost of Building Envelope Rehabilitation (with Upgrades) – Cost of Deferred Maintenance (Avoided) = Premium for Building Envelope Upgrades
  - Premium for Building Envelope Upgrades/Annual Energy Cost Reduction = Payback Period

- In general, improved insulation and over-cladding of the model building resulted in an internal rate-of-return ranging between 6.4% and 10.9%, and payback periods of from 14.5 to 20.7 years. The relatively large glazing area as a percentage of the building envelope diminishes the effectiveness of the over-cladding.
- Among options for improved insulation and over-cladding, EIFS (3" EPS) RSI 2.1 (R12) was the most cost effective option and presented an internal rate-of-return ranging from 7.8% to 10.9%.
- It was evident that replacing existing windows that are typically single-glazed windows in buildings of 30 years and older, with double-glazed, low E, argon- filled windows, without any other building upgrades presented an internal rate-of-return of 28.9% to 32.5%.
- The combination of improved insulation and over-cladding with window replacement resulted in an internal rate-of-return ranging between 12.3% and 19.8%.

- Over-cladding with EIFS (2" EPS) RSI 1.4 (R8) combined with replacing existing windows with double-glazed, low E, argon filled, resulted in an internal rate-of-return of between 16.5% and 19.8% – the highest of the over-cladding and window replacement options.
- Over-cladding with EIFS (2" EPS) RSI 1.4 (R8) combined with replacing existing windows with double-glazed, low E, argon filled, results in a payback period of 6.8 to 7.4 years which was the shortest payback period of all the over-cladding and window replacement options.
- The cost implications of borrowing money for the incremental cost of energy-efficiency upgrades were evaluated. The cost of borrowing money for the upgrades was compared with the energy savings, and was based on a 10- and 25-year loan payment plan at a 5% interest rate. It was evident that the energy saving benefits continues to increase long after the loan payment is complete.
- Building owners should be aware that the payback period for building energy-efficiency upgrades will be reduced in the case of buildings that are heated electrically. The reduced payback period is based on current energy costs.

The overall conclusion was that all energy-efficiency upgrade options presented an investment opportunity that yield an IRR of between 6.4% and 32.5%, which is greater than what will be achieved by other common investment options. The comparison of the rate-of-return versus the payback period requires a decisive paradigm shift on the part of owners. Reducing energy costs is not all about saving money, especially as corporate and public governance becomes more sensitive to the ecological footprint of our current building stock, and it is likely that IRR's over 5% can be seen as a steady investment as the cost of energy continues to escalate.

The return on investment analysis requires forecasting of expected energy use. However, owners will appreciate their savings when analyzing their actual energy costs. This analysis requires accounting for the relative severity of each winter and summer (using heating and cooling degree days).

At the completion of this research it became obvious that further study is required in a number of areas. In the author's opinion, future research should be focused on the following issues:

- This study revealed that over-cladding and window replacement strategies result in improved thermal performance of the building envelope, part of it due to improved thermal resistance and part related to improved air-tightness. Over-cladding buildings with systems such as exterior insulation and finish system (EIFS) combined with window replacement will result in improved air-tightness; however the exact levels of the air-tightness improvement are not known and the actual performance of the over-clad building is not determined. On-site measurement of the actual air-tightness of an over-clad building, using methods such as a blower-door- test method and comparison with the building's performance before the over-cladding upgrade will be very useful.
- This thesis studied the energy-efficiency measures applied to a precast concrete panel clad building. The results presented were based on the anticipated improvements in the performance of the model building. Applying energy-efficiency measures to buildings with other cladding systems (eg. over-cladding a leaky masonry building) may result in increased energy efficiency and cost savings. Assessment of energy-efficiency upgrades applied to buildings with an exposed masonry cladding system provides a potential area for further research.
- The energy performance modelling for other energy-efficiency strategies such as enclosure of balconies which was not carried out by this study, presents another potential area for further research. An evaluation of the energy savings and costs associated with enclosing existing balconies in high-rise residential buildings will be useful.
- A sensitivity analysis to determine the risk exposure levels to fluctuating energy prices will provide valuable information.

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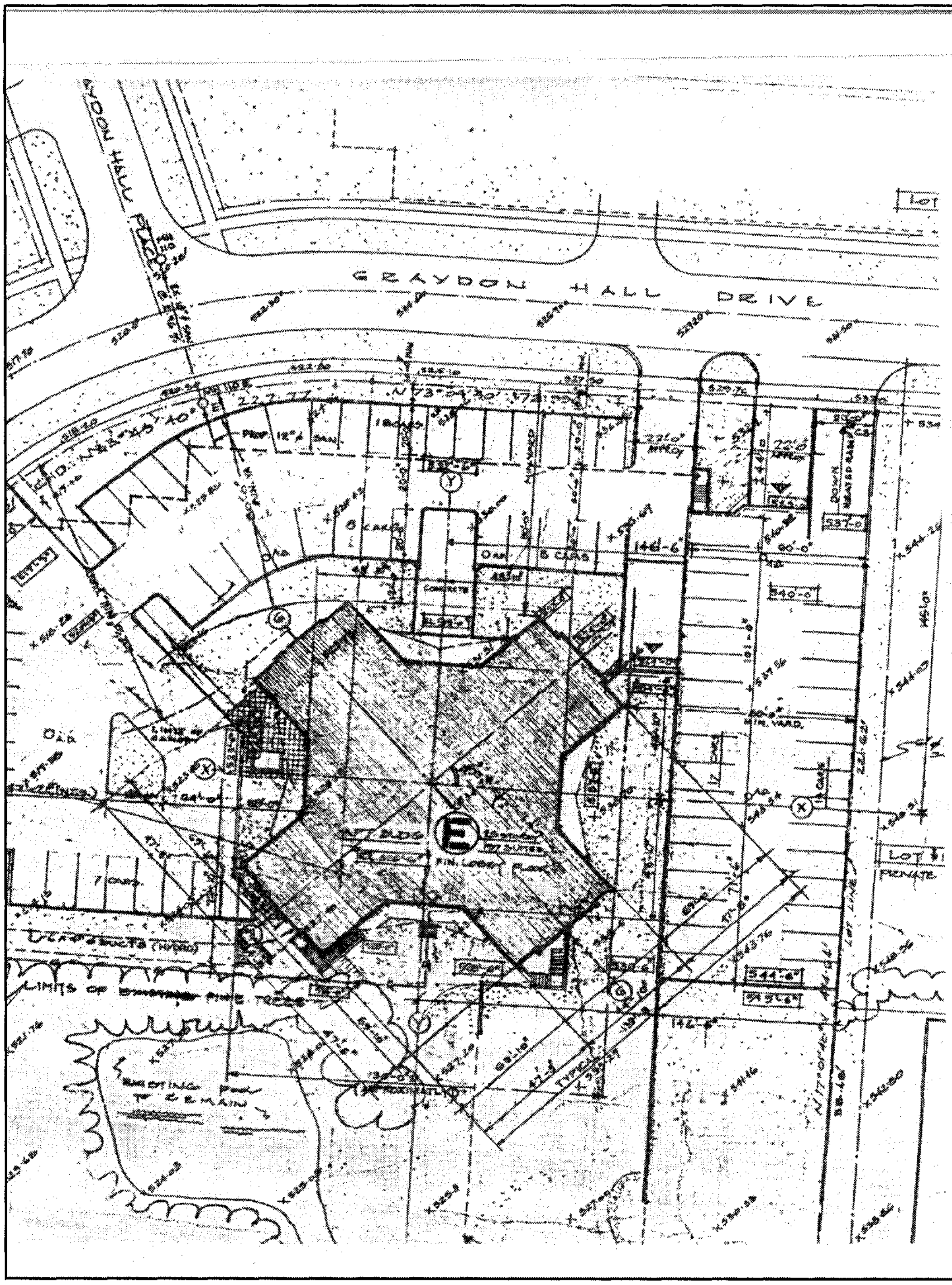
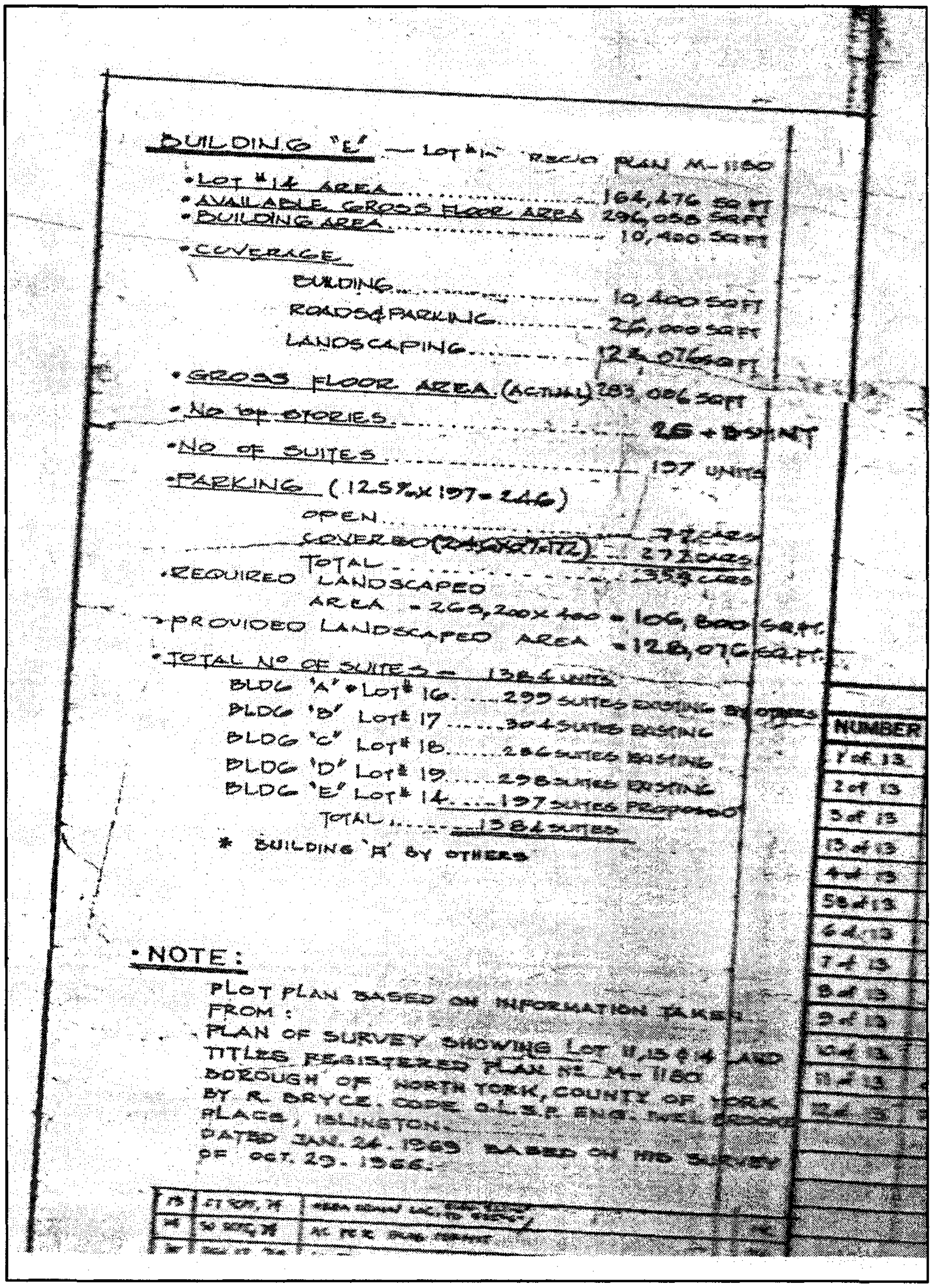
Appendix A- Drawings - Model Building



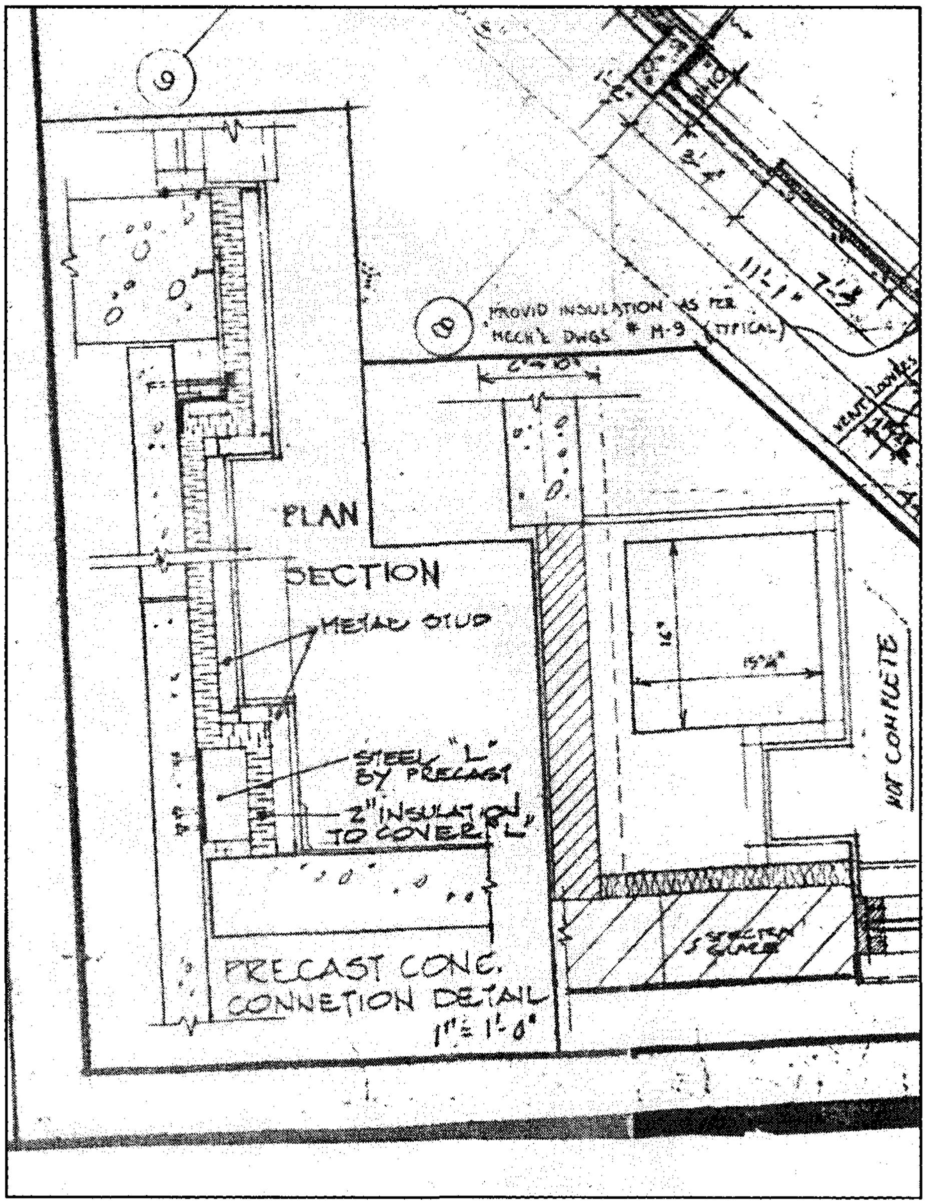
Site Plan – Reprint of Architectural drawings prepared for Peel Village Developments by, Joseph Barna Architect.


BUILDING "E" — LOT #14 REG'D PLAN M-1180
• LOT #14 AREA .... 164,476 SQ FT
• AVAILABLE GROSS FLOOR AREA 296,058 SQ FT
• BUILDING AREA .... 10,400 SQ FT
• COVERAGE
BUILDING .... 10,400 SQ FT
ROADS & PARKING .... 26,000 SQ FT
LANDSCAPING .... 128,076 SQ FT
• GROSS FLOOR AREA (ACTUAL) 283,006 SQ FT
• NO OF STORIES .... 26 + BSMNT
• NO OF SUITES .... 197 UNITS
• PARKING (125% x 197 = 246)
OPEN .... 77 CARS
COVERED (246x... =172) ... 272 CARS
TOTAL .... 35? CARS
• REQUIRED LANDSCAPED AREA = 266,200 x 40% = 106,800 SQ FT.
→ PROVIDED LANDSCAPED AREA = 128,076 SQ FT.
• TOTAL NO OF SUITES = 1384 UNITS
BLDG 'A' * LOT# 16 ..... 299 SUITES EXISTING BY OTHERS
BLDG 'B' LOT# 17 ..... 304 SUITES EXISTING
BLDG 'C' LOT# 18 ..... 286 SUITES EXISTING
BLDG 'D' LOT# 19 ..... 298 SUITES EXISTING
BLDG 'E' LOT# 14 ..... 197 SUITES PROPOSED
TOTAL ..... 1384 SUITES
* BUILDING 'A' BY OTHERS

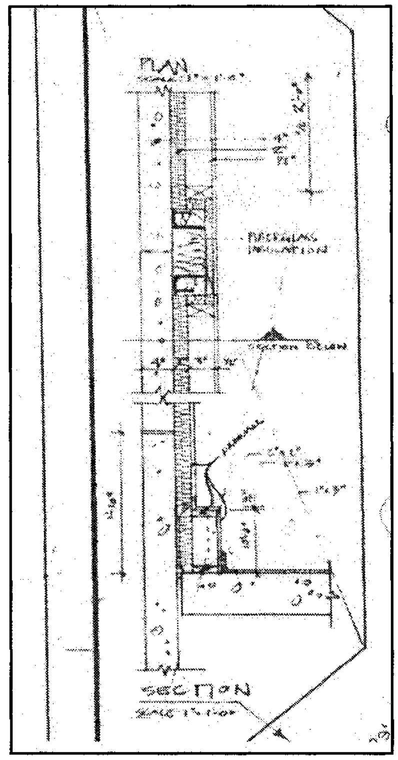
• NOTE:
PLOT PLAN BASED ON INFORMATION TAKEN FROM:
PLAN OF SURVEY SHOWING LOT 11, 13 & 14 LAND TITLES REGISTERED PLAN NO. M-1180 BOROUGH OF NORTH YORK, COUNTY OF YORK BY R. BRYCE, CODE O.L.S.P. ENG. ... PLACE, ISLINGTON.
DATED JAN. 24. 1969 BASED ON HIS SURVEY OF OCT. 29. 1966.

NUMBER
1 of 13
2 of 13
3 of 13
13 of 13
4 of 13
5 of 13
6 of 13
7 of 13
8 of 13
9 of 13
10 of 13
11 of 13
12 of 13

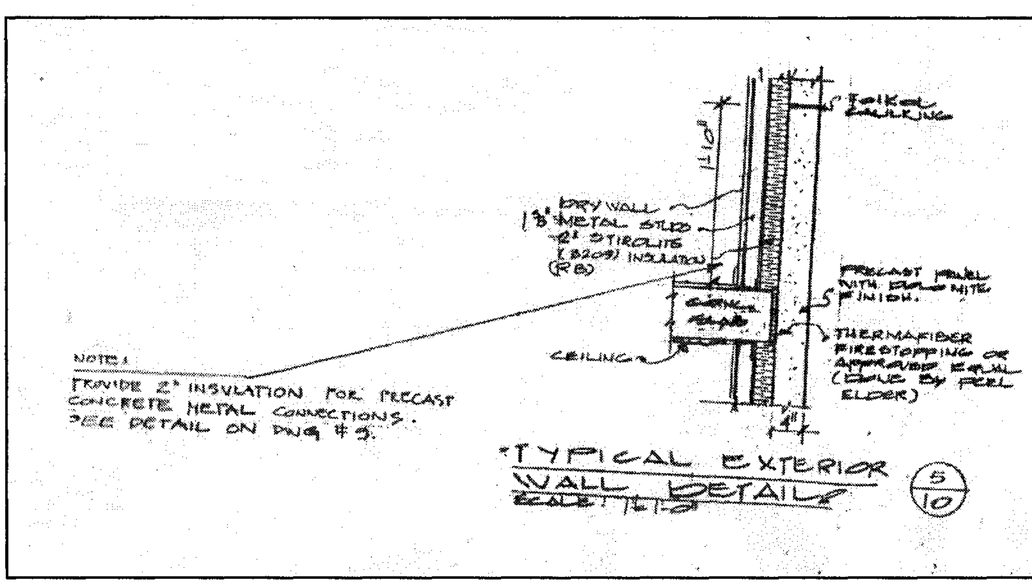
Site Data — Reprint of Architectural drawings prepared for Peel Village Developments by, Joseph Barna Architect.



Precast Concrete Connection Detail – Reprint of Architectural drawings prepared for Peel Village Developments by, Joseph Barna Architect.



Typical Exterior Wall Detail



Typical Exterior Wall Detail - Reprint of Architectural drawings prepared for Peel Village Developments by, Joseph Barna Architect.

Appendix B-Thermal Resistance Calculation
Model Building (Existing Condition)

Thermal resistance of the exterior wall is:

Rtotal (wall) = 0.03+0.06+1.404+0.0009+0.08+0.12= 1.59 (m^2.K/W) ~R9

R (slab edge) = 0.03+0.06+0.08+0.12= 0.29 (m^2.K/W) ~R1.7

Wall area = 85%, slab edge area = 15%

Qtotal = Q1 +Q2

= (0.85A/1.59) (Δt.t) + (0.15A/0.29)(Δt.t)

= 0.53A + 0.51A (Δt.t)

= 1.04A (Δt.t)

Wall Average R value = 1/104 = RSI 0.96 (R6)

Appendix C- CBIP SCREENING TOOL

ENERGY MODELLING – CBIP SCREENING TOOL – DETAILED REPORTS

ENERGY MODELING – NRC SCREENING TOOL – DETAILED REPORTS

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Office of Energy Efficiency

Screening Tool For New Building Design

Screening Tool Summary

Project Description

Your Project Description:

Baseline - Existing Condition

Building Profile Summary

Proposed Building:	Multi-Unit Residential, 27747 m²
Location:	Toronto (A), Ontario
Heating System:	Fossil

Utility Rates

Your marginal utility rates (including any taxes and fees):

$ 0.110 per kWh	$ 13.000 per GJ
$ 0.000 per kW	$ 0 per litre oil/propane

Building Shell

	Reference Building	Your Design	
Average window-to-wall-area ratio:	40	50	%
Overall window USI-value:	3.2	6.5	W/m²°C
Window shading coefficient:	0.736	1	
Overall wall RSI-value:	1.818	1	m²°C/W
Gross exterior wall area:	10000	10000	m²
Roof type:	All other	All other	
Overall roof RSI-value:	2.128	2	
Gross exterior roof area:	975	975	m²

Mechanical System

	Reference Building	Your Design	
Heating efficiency:	80	80	%
Minimum outside air:	0.3	0.3	l/s/m²
Demand control ventilation (DCV) type:	None	None	
Percent of outside air controlled by DCV:	0	0	%
Percent of floor area cooled:	90	90	%
Cooling efficiency:	2.5	2.5	COP
Outdoor air economizer?	No	No	
Efficiency of exhaust air heat recovery:	0	0	%
Service water heating fuel type:	Fossil	Fossil	
Service water heating efficiency:	80	80	%
Service water savings:	0	0	%

Mechanical Efficiency Options (only applies to Your Design):

Heating plant option:	On/Off
Variable speed fans:	Yes

Lighting

	Reference Building	Your Design
Average lighting density:	10	8 W/m²

Lighting controls (select if applicable and enter floor area):

None	0 %
None	0 %

Parkade lighting

	Reference Building	Your Design
Parkade floor area:	0	0 m²
Average lighting density:	3.2	3.2 W/m²
Percent of lighting load with occupancy sensor control:	0	0 %

Process Loads

	Reference Building	Your Design
Average process load density:	0	0
Percent served by electricity:	0	0 %

Building Performance Results

Based on the information you provided, your building design is not 25% more energy efficient than the reference building that meets the Model National

Energy Code for Buildings.

Current Design Performance

Annual Energy Use (GJ)

Reference Building	14,664	
Your Design	24,678	
Energy Savings	**-10,014**	**-68.3%**

Annual Energy Cost Savings **$-141,145.37**

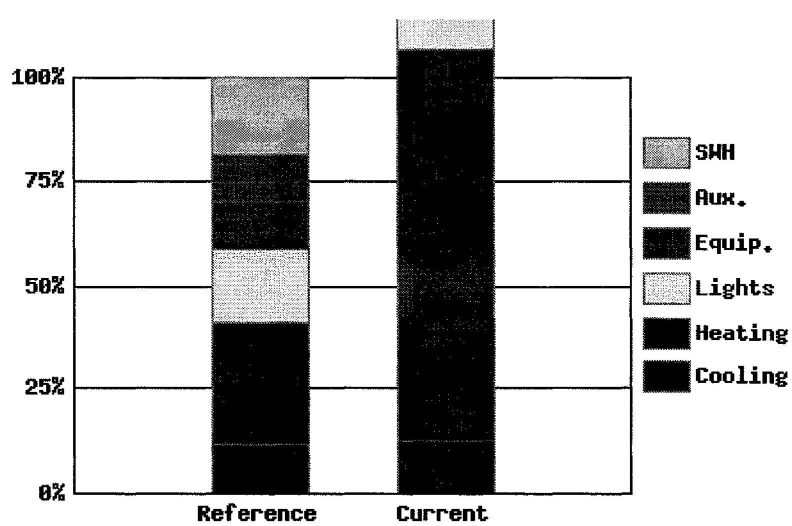
LEED® Canada Energy & Atmosphere (EA)

Does not qualify (EA Prerequisite 2 is not satisfied)

Emissions Savings

Carbon Dioxide (CO_2) -568,285 kg

Annual Energy Use Comparison



Your Design

End Use	Electricity kWh	Fossil Fuel GJ	Total Energy GJ	Costs
Cooling	517,192	0	1,862	$56,891
Heating	0	13,775	13,775	$179,044
Lights	655,534	0	2,360	$72,109
Equip.	466,749	0	1,680	$51,342
Aux.	632,920	0	2,279	$69,621
SWH	0	2,723	2,723	$35,387
Totals	2,272,395	16,498	24,678	$464,395

Reference Building

End Use	Electricity kWh	Fossil Fuel GJ	Total Energy GJ	Costs
Cooling	472,412	0	1,701	$51,965
Heating	0	4,387	4,387	$57,018
Lights	712,225	0	2,564	$78,345
Equip.	466,749	0	1,680	$51,342
Aux.	447,198	0	1,610	$49,192
SWH	0	2,723	2,723	$35,387
Totals	2,098,585	7,109	14,664	$323,249

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Screening Tool For New Building Design

Screening Tool Summary

Project Description

Your Project Description:

Overcladding - 2" EPS

Building Profile Summary

Proposed Building:	Multi-Unit Residential, 27747 m²
Location:	Toronto (A), Ontario
Heating System:	Fossil

Utility Rates

Your marginal utility rates (including any taxes and fees):

\$ 0.110 per kWh	\$ 13.000 per GJ
\$ 0.000 per kW	\$ 0 per litre oil/propane

Building Shell

	Reference Building	Your Design
Average window-to-wall-area ratio:	40	50 %
Overall window USI-value:	3.2	6.5 W/m²°C
Window shading coefficient:	0.736	1
Overall wall RSI-value:	1.818	2.4 m²°C/W
Gross exterior wall area:	10000	10000 m²
Roof type:	All other	All other
Overall roof RSI-value:	2.128	2
Gross exterior roof area:	975	975 m²

Mechanical System

	Reference Building	Your Design
Heating efficiency:	80	80 %
Minimum outside air:	0.3	0.3 l/s/m²
Demand control ventilation (DCV) type:	None	None
Percent of outside air controlled by DCV:	0	0 %
Percent of floor area cooled:	90	90 %
Cooling efficiency:	2.5	2.5 COP
Outdoor air economizer?	No	No
Efficiency of exhaust air heat recovery:	0	0 %
Service water heating fuel type:	Fossil	Fossil
Service water heating efficiency:	80	80 %
Service water savings:	0	0 %

Mechanical Efficiency Options (only applies to Your

Design):

Heating plant option:	On/Off
Variable speed fans:	Yes

Lighting

	Reference Building	Your Design
Average lighting density:	10	8 W/m²

Lighting controls (select if applicable and enter floor area):

None	0 %
None	0 %

Parkade lighting

	Reference Building	Your Design
Parkade floor area:	0	0 m²
Average lighting density:	3.2	3.2 W/m²
Percent of lighting load with occupancy sensor control:	0	0 %

Process Loads

	Reference Building	Your Design
Average process load density:	0	0
Percent served by electricity:	0	0 %

Building Performance Results

Based on the information you provided, your building design is not 25% more energy efficient than the reference building that meets the Model National Energy Code for Buildings.

Current Design Performance

Annual Energy Use (GJ)

Reference Building	14,664
Your Design	20,804
Energy Savings	**-6,139** **-41.9%**

Annual Energy Cost Savings **$-88,876.50**

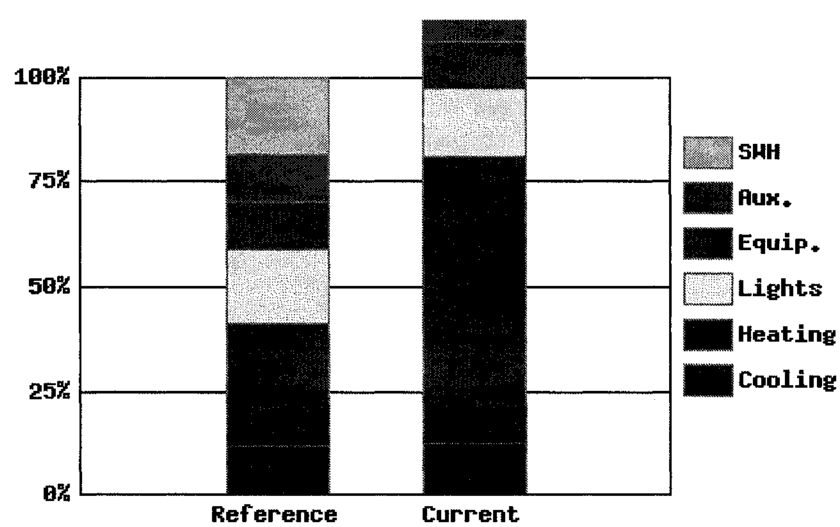
LEED® Canada Energy & Atmosphere (EA)

Does not qualify (EA Prerequisite 2 is not satisfied)

Emissions Savings

Carbon Dioxide (CO_2) -361,749 kg

Annual Energy Use Comparison



Your Design

End Use	Electricity kWh	Fossil Fuel GJ	Total Energy GJ	Costs
Cooling	520,587	0	1,874	$57,265
Heating	0	10,009	10,009	$130,095
Lights	655,534	0	2,360	$72,109
Equip.	466,749	0	1,680	$51,342
Aux.	599,341	0	2,158	$65,927
SWH	0	2,723	2,723	$35,387
Totals	2,242,212	12,732	20,804	$412,126

Reference Building

End Use	Electricity kWh	Fossil Fuel GJ	Total Energy GJ	Costs
Cooling	472,412	0	1,701	$51,965
Heating	0	4,387	4,387	$57,018
Lights	712,225	0	2,564	$78,345
Equip.	466,749	0	1,680	$51,342
Aux.	447,198	0	1,610	$49,192
SWH	0	2,723	2,723	$35,387
Totals	2,098,585	7,109	14,664	$323,249

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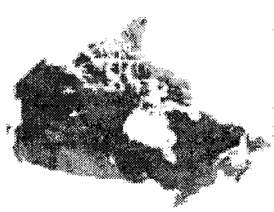
Screening Tool For New Building Design



Screening Tool Summary

Project Description

Your Project Description:

Overcladding- 3" EPS

Building Profile Summary

Proposed Building:	Multi-Unit Residential, 27747 m²
Location:	Toronto (A), Ontario
Heating System:	Fossil

Utility Rates

Your marginal utility rates (including any taxes and fees):

$ 0.110 per kWh	$ 13.000 per GJ
$ 0.000 per kW	$ 0 per litre oil/propane

Building Shell

	Reference Building	Your Design
Average window-to-wall-area ratio:	40	50 %
Overall window USI-value:	3.2	6.5 W/m²°C
Window shading coefficient:	0.736	1
Overall wall RSI-value:	1.818	3.1 m²°C/W
Gross exterior wall area:	10000	10000 m²
Roof type:	All other	All other
Overall roof RSI-value:	2.128	2
Gross exterior roof area:	975	975 m²

Mechanical System

	Reference Building	Your Design
Heating efficiency:	80	80 %
Minimum outside air:	0.3	0.3 l/s/m²
Demand control ventilation (DCV) type:	None	None
Percent of outside air controlled by DCV:	0	0 %
Percent of floor area cooled:	90	90 %
Cooling efficiency:	2.5	2.5 COP
Outdoor air economizer?	No	No
Efficiency of exhaust air heat recovery:	0	0 %
Service water heating fuel type:	Fossil	Fossil

Service water heating efficiency:	80	80 %
Service water savings:	0	0 %

Mechanical Efficiency Options (only applies to Your Design):

Heating plant option:	On/Off
Variable speed fans:	Yes

Lighting

	Reference Building	Your Design
Average lighting density:	10	8 W/m²

Lighting controls (select if applicable and enter floor area):

None	0 %
None	0 %

Parkade lighting

	Reference Building	Your Design
Parkade floor area:	0	0 m²
Average lighting density:	3.2	3.2 W/m²
Percent of lighting load with occupancy sensor control:	0	0 %

Process Loads

	Reference Building	Your Design
Average process load density:	0	0
Percent served by electricity:	0	0 %

Building Performance Results

Based on the information you provided, your building design is not 25% more energy efficient than the reference building that meets the Model National Energy Code for Buildings.

Current Design Performance

Annual Energy Use (GJ)

Reference Building	14,664	
Your Design	20,180	
Energy Savings	**-5,516**	**-37.6%**

Annual Energy Cost Savings **$-80,492.62**

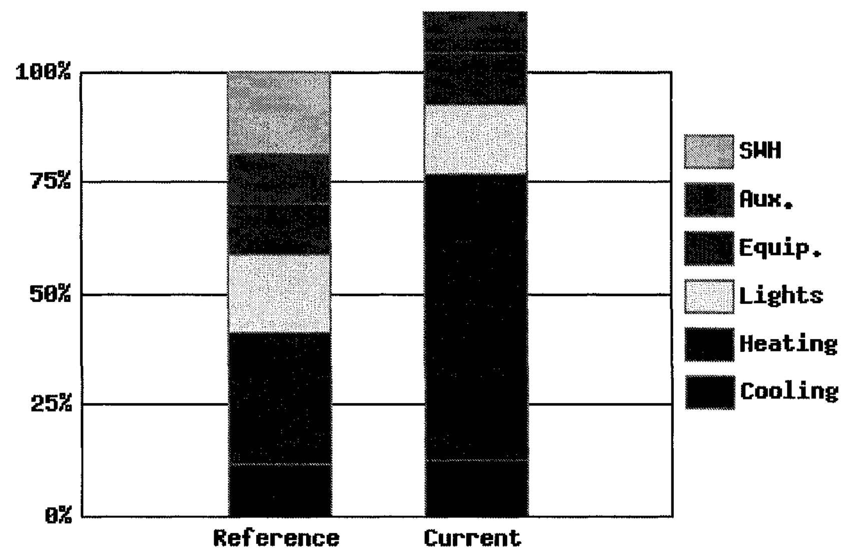
LEED® Canada Energy & Atmosphere (EA)

Does not qualify (EA Prerequisite 2 is not satisfied)

Emissions Savings

Carbon Dioxide (CO_2) -328,666 kg

Annual Energy Use Comparison



Your Design

End Use	Electricity kWh	Fossil Fuel GJ	Total Energy GJ	Costs
Cooling	521,558	0	1,878	$57,371
Heating	0	9,402	9,402	$122,200
Lights	655,534	0	2,360	$72,109
Equip.	466,749	0	1,680	$51,342
Aux.	593,925	0	2,138	$65,332
SWH	0	2,723	2,723	$35,387
Totals	2,237,767	12,124	20,180	$403,742

Reference Building

End Use	Electricity kWh	Fossil Fuel GJ	Total Energy GJ	Costs
Cooling	472,412	0	1,701	$51,965
Heating	0	4,387	4,387	$57,018
Lights	712,225	0	2,564	$78,345
Equip.	466,749	0	1,680	$51,342
Aux.	447,198	0	1,610	$49,192
SWH	0	2,723	2,723	$35,387
Totals	2,098,585	7,109	14,664	$323,249

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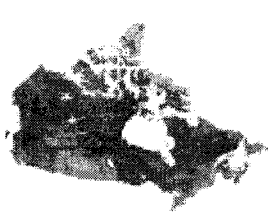
Screening Tool For New Building Design



Screening Tool Summary

Project Description

Your Project Description:

Overcladding - 3" XPS

Building Profile Summary

Proposed Building:	Multi-Unit Residential, 27747 m²
Location:	Toronto (A), Ontario
Heating System:	Fossil

Utility Rates

Your marginal utility rates (including any taxes and fees):

$ 0.110 per kWh	$ 13.000 per GJ
$ 0.000 per kW	$ 0 per litre oil/propane

Building Shell

	Reference Building	Your Design
Average window-to-wall-area ratio:	40	50 %
Overall window USI-value:	3.2	6.5 W/m²°C
Window shading coefficient:	0.736	1
Overall wall RSI-value:	1.818	4.16 m²°C/W
Gross exterior wall area:	10000	10000 m²
Roof type:	All other	All other
Overall roof RSI-value:	2.128	2
Gross exterior roof area:	975	975 m²

Mechanical System

	Reference Building	Your Design

Heating efficiency:	80	80 %
Minimum outside air:	0.3	0.3 l/s/m²
Demand control ventilation (DCV) type:	None	None
Percent of outside air controlled by DCV:	0	0 %
Percent of floor area cooled:	90	90 %
Cooling efficiency:	2.5	2.5 COP
Outdoor air economizer?	No	No
Efficiency of exhaust air heat recovery:	0	0 %
Service water heating fuel type:	Fossil	Fossil
Service water heating efficiency:	80	80 %
Service water savings:	0	0 %
Mechanical Efficiency Options (only applies to Your Design):		
Heating plant option:		On/Off
Variable speed fans:		Yes

Lighting

	Reference Building	Your Design
Average lighting density:	10	8 W/m²
Lighting controls (select if applicable and enter floor area):		
None		0 %
None		0 %

Parkade lighting

	Reference Building	Your Design

Parkade floor area:	0	0 m^2
Average lighting density:	3.2	3.2 W/m^2
Percent of lighting load with occupancy sensor control:	0	0 %

Process Loads

	Reference Building	Your Design
Average process load density:	0	0
Percent served by electricity:	0	0 %

Building Performance Results

Based on the information you provided, your building design is not 25% more energy efficient than the reference building that meets the Model National Energy Code for Buildings.

Current Design Performance

Annual Energy Use (GJ)

Reference Building	14,664	
Your Design	19,636	
Energy Savings	**-4,971**	**-33.9%**

Annual Energy Cost Savings **$-73,168.26**

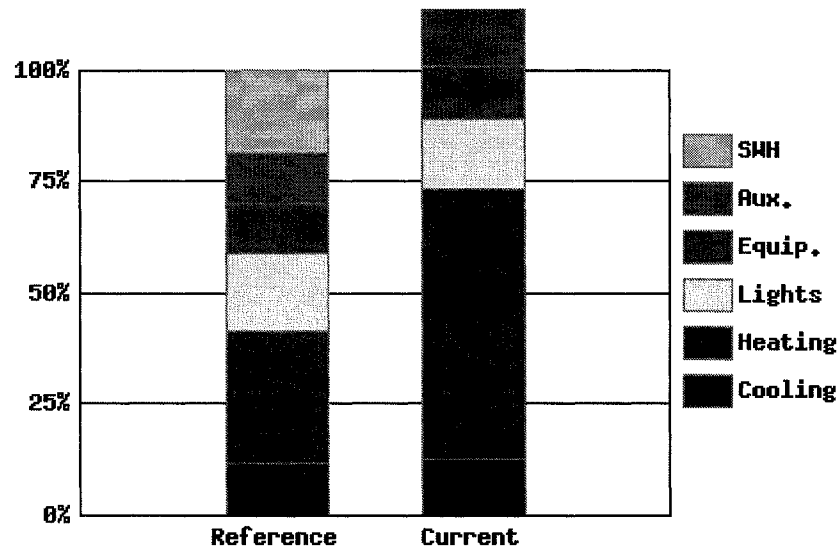
LEED® Canada Energy & Atmosphere (EA)

Does not qualify (EA Prerequisite 2 is not satisfied)

Emissions Savings

Carbon Dioxide (CO_2) -299,764 kg

Annual Energy Use Comparison



Your Design

End Use	Electricity kWh	Fossil Fuel GJ	Total Energy GJ	Costs
Cooling	522,407	0	1,881	$57,465
Heating	0	8,871	8,871	$115,303
Lights	655,534	0	2,360	$72,109
Equip.	466,749	0	1,680	$51,342
Aux.	589,193	0	2,121	$64,811
SWH	0	2,723	2,723	$35,387

Totals	2,233,884	11,594	19,636	$396,418

Reference Building

End Use	Electricity kWh	Fossil Fuel GJ	Total Energy GJ	Costs
Cooling	472,412	0	1,701	$51,965
Heating	0	4,387	4,387	$57,018
Lights	712,225	0	2,564	$78,345
Equip.	466,749	0	1,680	$51,342
Aux.	447,198	0	1,610	$49,192
SWH	0	2,723	2,723	$35,387
Totals	2,098,585	7,109	14,664	$323,249

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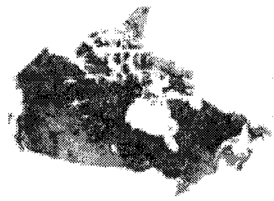


Screening Tool For New Building Design

Screening Tool Summary

Project Description

Your Project Description:

Window Replacement Only

Building Profile Summary

Proposed Building:	Multi-Unit Residential, 27747 m^2
Location:	Toronto (A), Ontario
Heating System:	Fossil

Utility Rates

Your marginal utility rates (including any taxes and fees):

$ 0.110 per kWh	$ 13.000 per GJ
$ 0.000 per kW	$ 0 per litre oil/propane

Building Shell

	Reference Building	Your Design
Average window-to-wall-area ratio:	40	50 %
Overall window USI-value:	3.2	1.8 W/m²°C
Window shading coefficient:	0.736	0.63
Overall wall RSI-value:	1.818	1 m²°C/W
Gross exterior wall area:	10000	10000 m^2
Roof type:	All other	All other

Overall roof RSI-value:	2.128	2
Gross exterior roof area:	975	975 m²

Mechanical System

	Reference Building	Your Design
Heating efficiency:	80	80 %
Minimum outside air:	0.3	0.3 l/s/m²
Demand control ventilation (DCV) type:	None	None
Percent of outside air controlled by DCV:	0	0 %
Percent of floor area cooled:	90	90 %
Cooling efficiency:	2.5	2.5 COP
Outdoor air economizer?	No	No
Efficiency of exhaust air heat recovery:	0	0 %
Service water heating fuel type:	Fossil	Fossil
Service water heating efficiency:	80	80 %
Service water savings:	0	0 %

Mechanical Efficiency Options (only applies to Your Design):

Heating plant option:		On/Off
Variable speed fans:		Yes

Lighting

	Reference Building	Your Design
Average lighting density:	10	8 W/m²

Lighting controls (select if applicable and enter floor area):

None	0 %
None	0 %

Parkade lighting

	Reference Building	Your Design
Parkade floor area:	0	0 m²
Average lighting density:	3.2	3.2 W/m²
Percent of lighting load with occupancy sensor control:	0	0 %

Process Loads

	Reference Building	Your Design
Average process load density:	0	0
Percent served by electricity:	0	0 %

Building Performance Results

Based on the information you provided, your building design is not 25% more energy efficient than the reference building that meets the Model National Energy Code for Buildings.

Current Design Performance

Annual Energy Use (GJ)

Reference Building	14,664	
Your Design	14,022	
Energy Savings	**642**	**4.4%**

Annual Energy Cost Savings **$7,144.45**

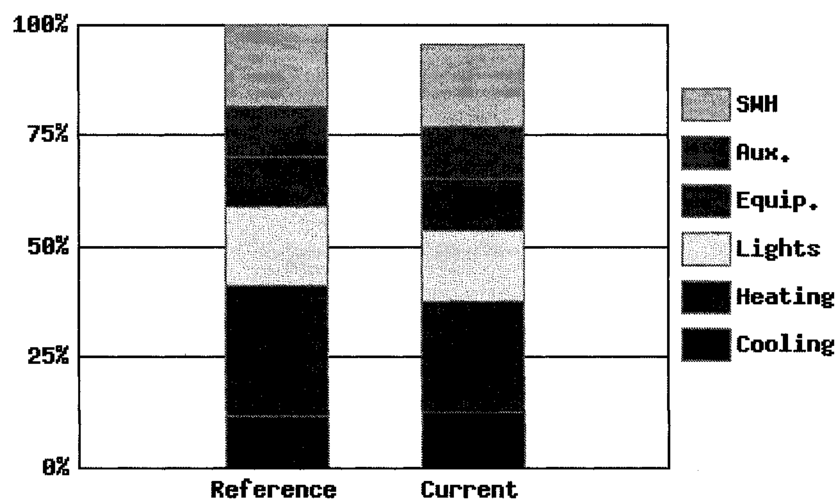
LEED® Canada Energy & Atmosphere (EA)

Does not qualify (EA Prerequisite 2 is not satisfied)

Emissions Savings

Carbon Dioxide (CO_2) 25,590 kg

Annual Energy Use Comparison



Your Design

End Use	Electricity kWh	Fossil Fuel GJ	Total Energy GJ	Costs
Cooling	513,502	0	1,849	$56,485
Heating	0	3,677	3,677	$47,787

Lights	655,534	0	2,360	$72,109
Equip.	466,749	0	1,680	$51,342
Aux.	481,763	0	1,734	$52,994
SWH	0	2,723	2,723	$35,387
Totals	2,117,549	6,399	14,022	$316,105

Reference Building

End Use	Electricity kWh	Fossil Fuel GJ	Total Energy GJ	Costs
Cooling	472,412	0	1,701	$51,965
Heating	0	4,387	4,387	$57,018
Lights	712,225	0	2,564	$78,345
Equip.	466,749	0	1,680	$51,342
Aux.	447,198	0	1,610	$49,192
SWH	0	2,723	2,723	$35,387
Totals	2,098,585	7,109	14,664	$323,249

Office of Energy Efficiency

Screening Tool For New Building Design

Screening Tool Summary

Project Description

Your Project Description:

Overcladding- 2" EPS & Double Glazed Window s

Building Profile Summary

Proposed Building:	Multi-Unit Residential, 27747 m^2
Location:	Toronto (A), Ontario
Heating System:	Fossil

Utility Rates

Your marginal utility rates (including any taxes and fees):

$ 0.110 per kWh	$ 13.000 per GJ
$ 0.000 per kW	$ 0 per litre oil/propane

Building Shell

	Reference Building	Your Design
Average window-to-wall-area ratio:	40	50 %
Overall window USI-value:	3.2	1.8 W/m²°C
Window shading coefficient:	0.736	0.63
Overall wall RSI-value:	1.818	2.4 m²°C/W

Gross exterior wall area:	10000	10000 m²
Roof type:	All other	All other
Overall roof RSI-value:	2.128	2
Gross exterior roof area:	975	975 m²

Mechanical System

	Reference Building	Your Design
Heating efficiency:	80	80 %
Minimum outside air:	0.3	0.3 l/s/m²
Demand control ventilation (DCV) type:	None	None
Percent of outside air controlled by DCV:	0	0 %
Percent of floor area cooled:	90	90 %
Cooling efficiency:	2.5	2.5 COP
Outdoor air economizer?	No	No
Efficiency of exhaust air heat recovery:	0	0 %
Service water heating fuel type:	Fossil	Fossil
Service water heating efficiency:	80	80 %
Service water savings:	0	0 %
Mechanical Efficiency Options (only applies to Your Design):		
Heating plant option:		On/Off
Variable speed fans:		Yes

Lighting

	Reference Building	Your Design

Average lighting density:	10	8 W/m²

Lighting controls (select if applicable and enter floor area):

None	0 %
None	0 %

Parkade lighting

	Reference Building	Your Design
Parkade floor area:	0	0 m²
Average lighting density:	3.2	3.2 W/m²
Percent of lighting load with occupancy sensor control:	0	0 %

Process Loads

	Reference Building	Your Design
Average process load density:	0	0
Percent served by electricity:	0	0 %

Building Performance Results

Based on the information you provided, your building design is not 25% more energy efficient than the reference building that meets the Model National Energy Code for Buildings.

Current Design Performance

Annual Energy Use (GJ)

Reference Building	14,664	
Your Design	13,046	
Energy Savings	**1,618**	**11.0%**

Annual Energy Cost Savings **$19,376.35**

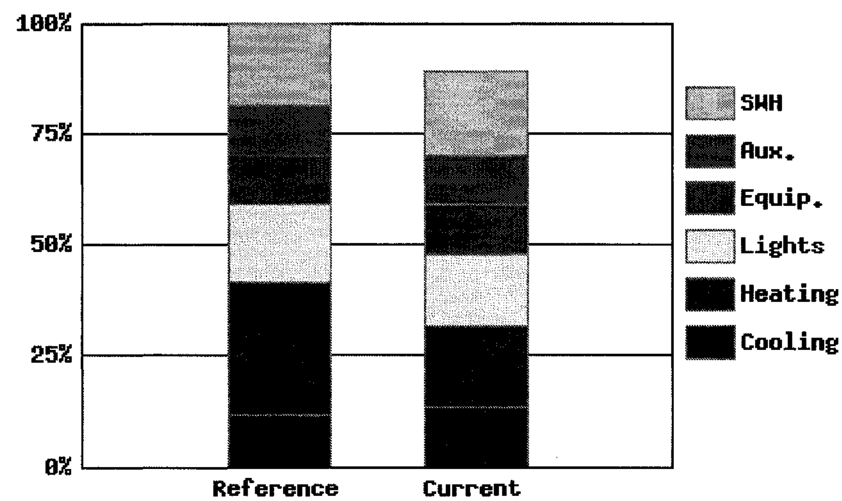
<u>LEED® Canada</u> **Energy & Atmosphere (EA)**

Does not qualify (EA Prerequisite 2 is not satisfied)

Emissions Savings

Carbon Dioxide (CO_2) 72,287 kg

Annual Energy Use Comparison



Your Design

End Use	Electricity kWh	Fossil Fuel GJ	Total Energy GJ	Costs

Cooling	546,068	0	1,966	$60,067
Heating	0	2,674	2,674	$34,760
Lights	655,534	0	2,360	$72,109
Equip.	466,749	0	1,680	$51,342
Aux.	456,432	0	1,643	$50,208
SWH	0	2,723	2,723	$35,387
Totals	2,124,784	5,397	13,046	$303,873

Reference Building

End Use	Electricity kWh	Fossil Fuel GJ	Total Energy GJ	Costs
Cooling	472,412	0	1,701	$51,965
Heating	0	4,387	4,387	$57,018
Lights	712,225	0	2,564	$78,345
Equip.	466,749	0	1,680	$51,342
Aux.	447,198	0	1,610	$49,192
SWH	0	2,723	2,723	$35,387
Totals	2,098,585	7,109	14,664	$323,249

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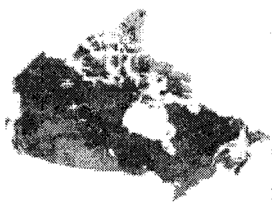


Screening Tool For New Building Design

Screening Tool Summary

Project Description

Your Project Description:

Overcladding - 3" EPS & Double Glazed Windows

Building Profile Summary

Proposed Building:	Multi-Unit Residential, 27747 m²
Location:	Toronto (A), Ontario
Heating System:	Fossil

Utility Rates

Your marginal utility rates (including any taxes and fees):

$ 0.110 per kWh	$ 13.000 per GJ
$ 0.000 per kW	$ 0 per litre oil/propane

Building Shell

	Reference Building	Your Design
Average window-to-wall-area ratio:	40	50 %
Overall window USI-value:	3.2	1.8 W/m²°C

Window shading coefficient:	0.736	0.63
Overall wall RSI-value:	1.818	3.1 m²°C/W
Gross exterior wall area:	10000	10000 m²
Roof type:	All other	All other
Overall roof RSI-value:	2.128	2
Gross exterior roof area:	975	975 m²

Mechanical System

	Reference Building	Your Design
Heating efficiency:	80	80 %
Minimum outside air:	0.3	0.3 l/s/m²
Demand control ventilation (DCV) type:	None	None
Percent of outside air controlled by DCV:	0	0 %
Percent of floor area cooled:	90	90 %
Cooling efficiency:	2.5	2.5 COP
Outdoor air economizer?	No	No
Efficiency of exhaust air heat recovery:	0	0 %
Service water heating fuel type:	Fossil	Fossil
Service water heating efficiency:	80	80 %
Service water savings:	0	0 %
Mechanical Efficiency Options (only applies to Your Design):		
Heating plant option:		On/Off
Variable speed fans:		Yes

Lighting

	Reference Building	Your Design
Average lighting density:	10	8 W/m²

Lighting controls (select if applicable and enter floor area):

None	0 %
None	0 %

Parkade lighting

	Reference Building	Your Design
Parkade floor area:	0	0 m²
Average lighting density:	3.2	3.2 W/m²
Percent of lighting load with occupancy sensor control:	0	0 %

Process Loads

	Reference Building	Your Design
Average process load density:	0	0
Percent served by electricity:	0	0 %

Building Performance Results

Based on the information you provided, your building design is not 25% more energy efficient than the reference building that meets the Model National Energy Code for Buildings.

Current Design Performance

Annual Energy Use (GJ)

Reference Building	14,664
Your Design	12,889

Energy Savings	**1,776**	**12.1%**

Annual Energy Cost Savings **$21,344.82**

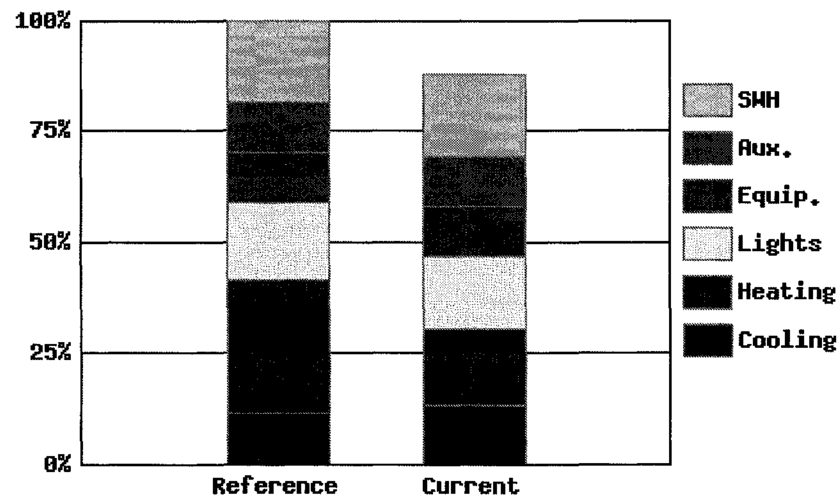
<u>LEED® Canada</u> Energy & Atmosphere (EA)

Does not qualify (EA Prerequisite 2 is not satisfied)

Emissions Savings

Carbon Dioxide (CO_2) 79,797 kg

Annual Energy Use Comparison



Your Design

End Use	Electricity kWh	Fossil Fuel GJ	Total Energy GJ	Costs
Cooling	551,360	0	1,985	$60,650
Heating	0	2,513	2,513	$32,658
Lights	655,534	0	2,360	$72,109
Equip.	466,749	0	1,680	$51,342
Aux.	452,346	0	1,628	$49,758
SWH	0	2,723	2,723	$35,387
Totals	2,125,990	5,235	12,889	$301,904

Reference Building

End Use	Electricity kWh	Fossil Fuel GJ	Total Energy GJ	Costs
Cooling	472,412	0	1,701	$51,965
Heating	0	4,387	4,387	$57,018
Lights	712,225	0	2,564	$78,345
Equip.	466,749	0	1,680	$51,342
Aux.	447,198	0	1,610	$49,192
SWH	0	2,723	2,723	$35,387
Totals	2,098,585	7,109	14,664	$323,249

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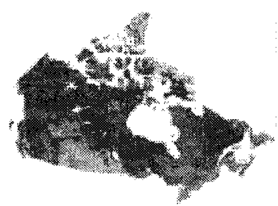
Screening Tool For New Building Design



Screening Tool Summary

Project Description

Your Project Description:

Overcladding - 3" XPS & Double Glazed Window s

Building Profile Summary

Proposed Building:	Multi-Unit Residential, 27747 m²
Location:	Toronto (A), Ontario
Heating System:	Fossil

Utility Rates

Your marginal utility rates (including any taxes and fees):

$ 0.110 per kWh	$ 13.000 per GJ
$ 0.000 per kW	$ 0 per litre oil/propane

Building Shell

	Reference Building	Your Design
Average window-to-wall-area ratio:	40	50 %
Overall window USI-value:	3.2	1.8 W/m²°C
Window shading coefficient:	0.736	0.63
Overall wall RSI-value:	1.818	4.16 m²°C/W
Gross exterior wall area:	10000	10000 m²
Roof type:	All other	All other
Overall roof RSI-value:	2.128	2
Gross exterior roof area:	975	975 m²

Mechanical System

	Reference Building	Your Design
Heating efficiency:	80	80 %
Minimum outside air:	0.3	0.3 l/s/m²
Demand control ventilation (DCV) type:	None	None
Percent of outside air controlled by DCV:	0	0 %
Percent of floor area cooled:	90	90 %
Cooling efficiency:	2.5	2.5 COP
Outdoor air economizer?	No	No
Efficiency of exhaust air heat recovery:	0	0 %
Service water heating fuel type:	Fossil	Fossil
Service water heating efficiency:	80	80 %
Service water savings:	0	0 %

Mechanical Efficiency Options (only applies to Your

Design):

Heating plant option:	On/Off
Variable speed fans:	Yes

Lighting

	Reference Building	Your Design
Average lighting density:	10	8 W/m²

Lighting controls (select if applicable and enter floor area):

None	0 %
None	0 %

Parkade lighting

	Reference Building	Your Design
Parkade floor area:	0	0 m²
Average lighting density:	3.2	3.2 W/m²
Percent of lighting load with occupancy sensor control:	0	0 %

Process Loads

	Reference Building	Your Design
Average process load density:	0	0
Percent served by electricity:	0	0 %

Building Performance Results

Based on the information you provided, your building design is not 25% more energy efficient than the reference building that meets the Model National Energy Code for Buildings.

Current Design Performance

Annual Energy Use (GJ)

Reference Building	14,664
Your Design	12,751
Energy Savings	**1,913** **13.0%**

Annual Energy Cost Savings **$23,064.53**

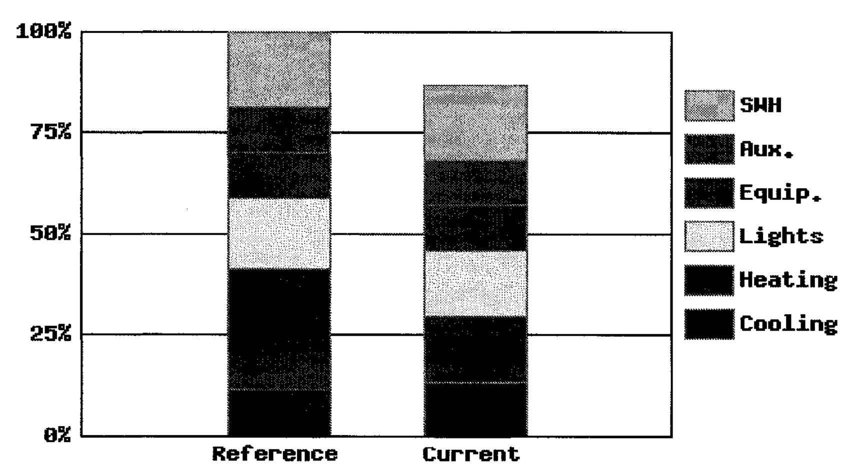
LEED® Canada **Energy & Atmosphere (EA)**

Does not qualify (EA Prerequisite 2 is not satisfied)

Emissions Savings

Carbon Dioxide (CO_2) 86,358 kg

Annual Energy Use Comparison



Your Design

End Use	Electricity kWh	Fossil Fuel GJ	Total Energy GJ	Costs
Cooling	555,984	0	2,002	$61,158
Heating	0	2,371	2,371	$30,823
Lights	655,534	0	2,360	$72,109
Equip.	466,749	0	1,680	$51,342
Aux.	448,777	0	1,616	$49,365
SWH	0	2,723	2,723	$35,387
Totals	2,127,045	5,094	12,751	$300,185

Reference Building

End Use	Electricity kWh	Fossil Fuel GJ	Total Energy GJ	Costs
Cooling	472,412	0	1,701	$51,965
Heating	0	4,387	4,387	$57,018
Lights	712,225	0	2,564	$78,345
Equip.	466,749	0	1,680	$51,342
Aux.	447,198	0	1,610	$49,192
SWH	0	2,723	2,723	$35,387
Totals	2,098,585	7,109	14,664	$323,249

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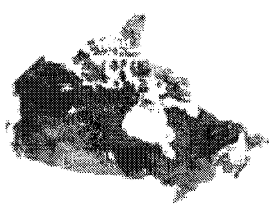


Screening Tool For New Building Design

Screening Tool Summary

Project Description

Your Project Description:

Overcladding - 2" EPS & Triple Glazed Window s

Building Profile Summary

Proposed Building:	Multi-Unit Residential, 27747 m²
Location:	Toronto (A), Ontario
Heating System:	Fossil

Utility Rates

Your marginal utility rates (including any taxes and fees):

$ 0.110 per kWh $ 13.000 per GJ

$ 0.000 per kW	$ 0 per litre oil/propane

Building Shell

	Reference Building	Your Design
Average window-to-wall-area ratio:	40	50 %
Overall window USI-value:	3.2	1.5 W/m²°C
Window shading coefficient:	0.736	0.58
Overall wall RSI-value:	1.818	2.4 m²°C/W
Gross exterior wall area:	10000	10000 m²
Roof type:	All other	All other
Overall roof RSI-value:	2.128	2
Gross exterior roof area:	975	975 m²

Mechanical System

	Reference Building	Your Design
Heating efficiency:	80	80 %
Minimum outside air:	0.3	0.3 l/s/m²
Demand control ventilation (DCV) type:	None	None
Percent of outside air controlled by DCV:	0	0 %
Percent of floor area cooled:	90	90 %
Cooling efficiency:	2.5	2.5 COP
Outdoor air economizer?	No	No
Efficiency of exhaust air heat recovery:	0	0 %
Service water heating fuel type:	Fossil	Fossil
Service water heating efficiency:	80	80 %

Service water savings:	0	0 %

Mechanical Efficiency Options (only applies to Your Design):

Heating plant option:	On/Off
Variable speed fans:	Yes

Lighting

	Reference Building	Your Design
Average lighting density:	10	8 W/m²

Lighting controls (select if applicable and enter floor area):

None	0 %
None	0 %

Parkade lighting

	Reference Building	Your Design
Parkade floor area:	0	0 m²
Average lighting density:	3.2	3.2 W/m²
Percent of lighting load with occupancy sensor control:	0	0 %

Process Loads

	Reference Building	Your Design
Average process load density:	0	0
Percent served by electricity:	0	0 %

Building Performance Results

Based on the information you provided, your building design is not 25% more energy efficient than the reference building that meets the Model National

Energy Code for Buildings.

Current Design Performance

Annual Energy Use (GJ)

Reference Building	14,664	
Your Design	12,628	
Energy Savings	**2,036**	**13.9%**

Annual Energy Cost Savings **$26,423.82**

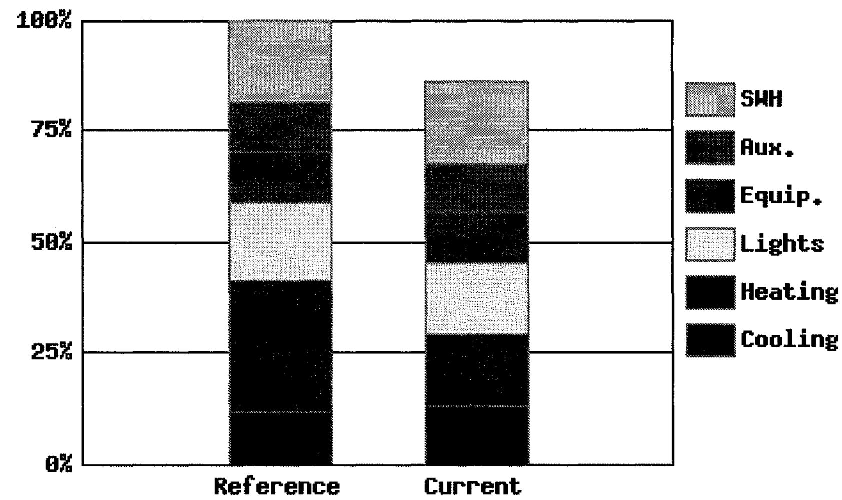
LEED® Canada **Energy & Atmosphere (EA)**

Does not qualify (EA Prerequisite 2 is not satisfied)

Emissions Savings

Carbon Dioxide (CO_2) 102,595 kg

Annual Energy Use Comparison



Your Design

End Use	Electricity kWh	Fossil Fuel GJ	Total Energy GJ	Costs
Cooling	536,900	0	1,933	$59,059
Heating	0	2,349	2,349	$30,526
Lights	655,534	0	2,360	$72,109
Equip.	466,749	0	1,680	$51,342
Aux.	440,023	0	1,584	$48,403
SWH	0	2,723	2,723	$35,387
Totals	2,099,207	5,071	12,628	$296,825

Reference Building

End Use	Electricity kWh	Fossil Fuel GJ	Total Energy GJ	Costs
Cooling	472,412	0	1,701	$51,965
Heating	0	4,387	4,387	$57,018
Lights	712,225	0	2,564	$78,345
Equip.	466,749	0	1,680	$51,342
Aux.	447,198	0	1,610	$49,192
SWH	0	2,723	2,723	$35,387
Totals	2,098,585	7,109	14,664	$323,249

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Office of Energy Efficiency

Screening Tool For New Building Design

Screening Tool Summary

Project Description

Your Project Description:

Overcladding - 3" EPS & Triple Glazed Windows

Building Profile Summary

Proposed Building:	Multi-Unit Residential, 27747 m^2
Location:	Toronto (A), Ontario
Heating System:	Fossil

Utility Rates

Your marginal utility rates (including any taxes and fees):

$ 0.110 per kWh	$ 13.000 per GJ
$ 0.000 per kW	$ 0 per litre oil/propane

Building Shell

	Reference Building	Your Design
Average window-to-wall-area ratio:	40	50 %
Overall window USI-value:	3.2	1.5 W/m^2°C
Window shading coefficient:	0.736	0.58
Overall wall RSI-value:	1.818	3.1 m^2°C/W
Gross exterior wall area:	10000	10000 m^2
Roof type:	All other	All other
Overall roof RSI-value:	2.128	2
Gross exterior roof area:	975	975 m^2

Mechanical System

	Reference Building	Your Design
Heating efficiency:	80	80 %
Minimum outside air:	0.3	0.3 l/s/m²
Demand control ventilation (DCV) type:	None	None
Percent of outside air controlled by DCV:	0	0 %
Percent of floor area cooled:	90	90 %
Cooling efficiency:	2.5	2.5 COP
Outdoor air economizer?	No	No
Efficiency of exhaust air heat recovery:	0	0 %
Service water heating fuel type:	Fossil	Fossil
Service water heating efficiency:	80	80 %
Service water savings:	0	0 %
Mechanical Efficiency Options (only applies to Your Design):		
Heating plant option:		On/Off
Variable speed fans:		Yes

Lighting

	Reference Building	Your Design
Average lighting density:	10	8 W/m²
Lighting controls (select if applicable and enter floor area):		
None		0 %
None		0 %

Parkade lighting

	Reference Building	Your Design
Parkade floor area:	0	0 m²
Average lighting density:	3.2	3.2 W/m²
Percent of lighting load with occupancy sensor control:	0	0 %

Process Loads

	Reference Building	Your Design
Average process load density:	0	0
Percent served by electricity:	0	0 %

Building Performance Results

Based on the information you provided, your building design is not 25% more energy efficient than the reference building that meets the Model National Energy Code for Buildings.

Current Design Performance

Annual Energy Use (GJ)

Reference Building	14,664	
Your Design	12,492	
Energy Savings	**2,172**	**14.8%**

Annual Energy Cost Savings **$28,106.78**

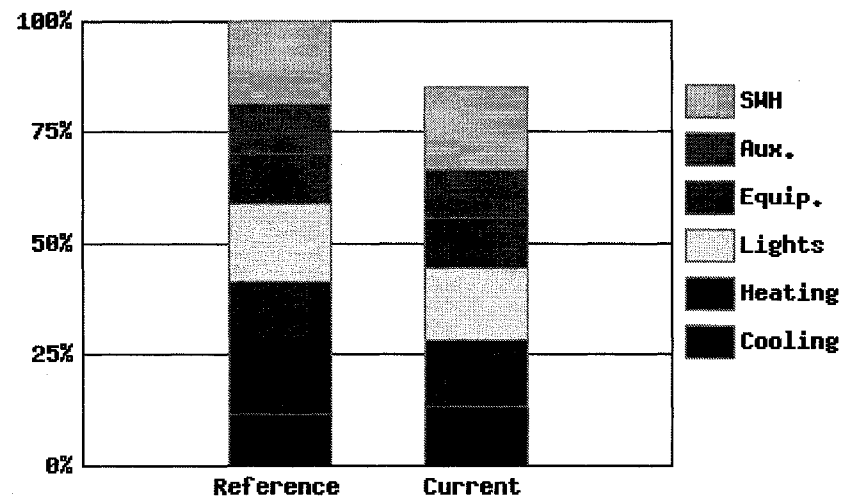
LEED® Canada **Energy & Atmosphere (EA)**

Does not qualify (EA Prerequisite 2 is not satisfied)

Emissions Savings

Carbon Dioxide (CO_2) 108,971 kg

Annual Energy Use Comparison



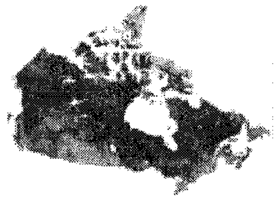
Your Design

End Use	Electricity kWh	Fossil Fuel GJ	Total Energy GJ	Costs
Cooling	542,260	0	1,952	$59,649
Heating	0	2,207	2,207	$28,686
Lights	655,534	0	2,360	$72,109
Equip.	466,749	0	1,680	$51,342
Aux.	436,088	0	1,570	$47,970

SWH	0	2,723	2,723	$35,387
Totals	2,100,632	4,930	12,492	$295,142

Reference Building

End Use	Electricity kWh	Fossil Fuel GJ	Total Energy GJ	Costs
Cooling	472,412	0	1,701	$51,965
Heating	0	4,387	4,387	$57,018
Lights	712,225	0	2,564	$78,345
Equip.	466,749	0	1,680	$51,342
Aux.	447,198	0	1,610	$49,192
SWH	0	2,723	2,723	$35,387
Totals	2,098,585	7,109	14,664	$323,249



Screening Tool For New Building Design

Screening Tool Summary

Project Description

Your Project Description:

3" XPS & Triple Glazed Windows

Building Profile Summary

Proposed Building:	Multi-Unit Residential, 27747 m²
Location:	Toronto (A), Ontario
Heating System:	Fossil

Utility Rates

Your marginal utility rates (including any taxes and fees):

$ 0.110 per kWh	$ 13.000 per GJ
$ 0.000 per kW	$ 0 per litre oil/propane

Building Shell

	Reference Building	Your Design
Average window-to-wall-area ratio:	40	50 %
Overall window USI-value:	3.2	1.5 W/m²°C
Window shading coefficient:	0.736	0.58
Overall wall RSI-value:	1.818	4.16 m²°C/W
Gross exterior wall area:	10000	10000 m²
Roof type:	All other	All other

Overall roof RSI-value:	2.128	2
Gross exterior roof area:	975	975 m²

Mechanical System

	Reference Building	Your Design
Heating efficiency:	80	80 %
Minimum outside air:	0.3	0.3 l/s/m²
Demand control ventilation (DCV) type:	None	None
Percent of outside air controlled by DCV:	0	0 %
Percent of floor area cooled:	90	90 %
Cooling efficiency:	2.5	2.5 COP
Outdoor air economizer?	No	No
Efficiency of exhaust air heat recovery:	0	0 %
Service water heating fuel type:	Fossil	Fossil
Service water heating efficiency:	80	80 %
Service water savings:	0	0 %

Mechanical Efficiency Options (only applies to Your Design):

Heating plant option:		On/Off
Variable speed fans:		Yes

Lighting

	Reference Building	Your Design
Average lighting density:	10	8 W/m²

Lighting controls (select if applicable and enter floor area):

None	0 %
None	0 %

Parkade lighting

	Reference Building	Your Design
Parkade floor area:	0	0 m²
Average lighting density:	3.2	3.2 W/m²
Percent of lighting load with occupancy sensor control:	0	0 %

Process Loads

	Reference Building	Your Design
Average process load density:	0	0
Percent served by electricity:	0	0 %

Building Performance Results

Based on the information you provided, your building design is not 25% more energy efficient than the reference building that meets the Model National Energy Code for Buildings.

Current Design Performance

Annual Energy Use (GJ)

Reference Building	14,664	
Your Design	12,373	
Energy Savings	**2,292**	**15.6%**

Annual Energy Cost Savings **$29,577.05**

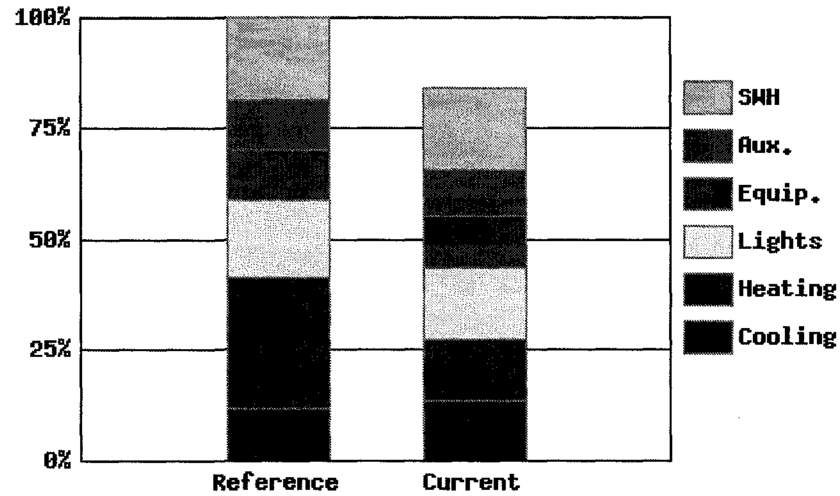
<u>LEED® Canada</u> Energy & Atmosphere (EA)

Does not qualify (EA Prerequisite 2 is not satisfied)

Emissions Savings

Carbon Dioxide (CO_2) 114,541 kg

Annual Energy Use Comparison



Your Design

End Use	Electricity kWh	Fossil Fuel GJ	Total Energy GJ	Costs
Cooling	546,943	0	1,969	$60,164
Heating	0	2,083	2,083	$27,078
Lights	655,534	0	2,360	$72,109
Equip.	466,749	0	1,680	$51,342
Aux.	432,651	0	1,558	$47,592
SWH	0	2,723	2,723	$35,387

Totals	2,101,878	4,806	12,373	$293,672

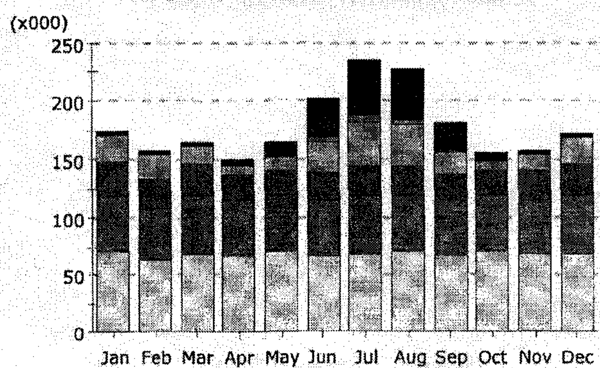
Reference Building

End Use	Electricity kWh	Fossil Fuel GJ	Total Energy GJ	Costs
Cooling	472,412	0	1,701	$51,965
Heating	0	4,387	4,387	$57,018
Lights	712,225	0	2,564	$78,345
Equip.	466,749	0	1,680	$51,342
Aux.	447,198	0	1,610	$49,192
SWH	0	2,723	2,723	$35,387
Totals	2,098,585	7,109	14,664	$323,249

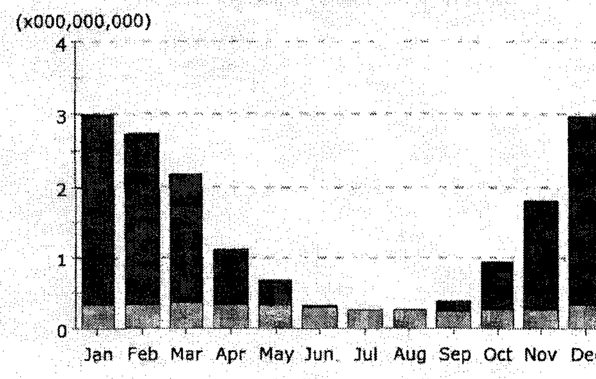
Appendix D- EQUEST 3.6

ENERGY MODELING – EQUEST 3.6 - DETAILED REPORTS

Electric Consumption (kWh)



Gas Consumption (Btu)



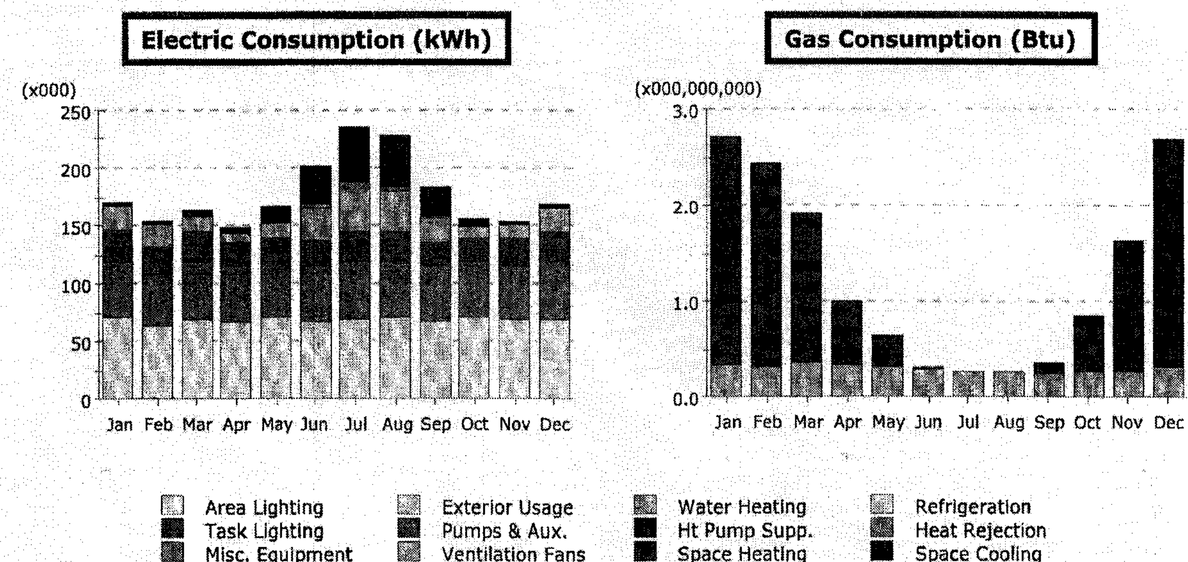
Area Lighting, Task Lighting, Misc. Equipment, Exterior Usage, Pumps & Aux., Ventilation Fans, Water Heating, Ht Pump Supp., Space Heating, Refrigeration, Heat Rejection, Space Cooling

Electric Consumption (kWh x000)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	4.2	3.8	4.2	5.5	13.3	34.0	48.7	44.6	24.8	6.9	4.0	4.2	198.2
Heat Reject.	-	-	-	0.0	0.2	2.7	5.4	4.2	2.3	0.1	0.0	-	15.0
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	-	-	-	-	-	-	-	-	-	-	-	-	-
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	-	-	-	-	-	-	-	-	-	-	-	-	-
Vent. Fans	22.6	20.3	15.2	7.9	11.9	26.7	36.7	34.6	18.9	8.7	13.0	22.3	238.9
Pumps & Aux.	28.1	25.3	27.8	22.0	20.8	24.1	26.6	26.4	21.7	21.2	24.5	28.0	296.3
Ext. Usage	-	-	-	-	-	-	-	-	-	-	-	-	-
Misc. Equip.	49.3	44.5	49.2	47.6	49.3	47.6	49.2	49.2	47.6	49.2	47.7	49.2	579.6
Task Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Area Lights	70.0	62.8	69.1	66.6	70.0	66.6	69.2	69.5	67.0	69.6	67.9	69.1	817.5
Total	174.1	156.7	165.5	149.5	165.5	201.7	235.8	228.4	182.4	155.7	157.1	172.8	2,145.4

Gas Consumption (Btu x000,000,000)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	-	-	-	-	-	-	-	-	-	-	-	-	-
Heat Reject.	-	-	-	-	-	-	-	-	-	-	-	-	-
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	2.67	2.40	1.80	0.77	0.36	0.03	-	0.00	0.13	0.67	1.52	2.64	13.01
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	0.34	0.32	0.35	0.34	0.32	0.29	0.27	0.26	0.25	0.27	0.28	0.32	3.61
Vent. Fans	-	-	-	-	-	-	-	-	-	-	-	-	-
Pumps & Aux.	-	-	-	-	-	-	-	-	-	-	-	-	-
Ext. Usage	-	-	-	-	-	-	-	-	-	-	-	-	-
Misc. Equip.	-	-	-	-	-	-	-	-	-	-	-	-	-
Task Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Area Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Total	3.01	2.71	2.15	1.11	0.68	0.32	0.27	0.26	0.38	0.94	1.80	2.96	16.62



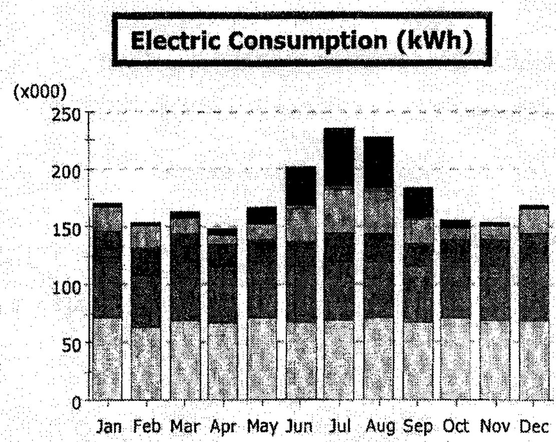
Electric Consumption (kWh x000)

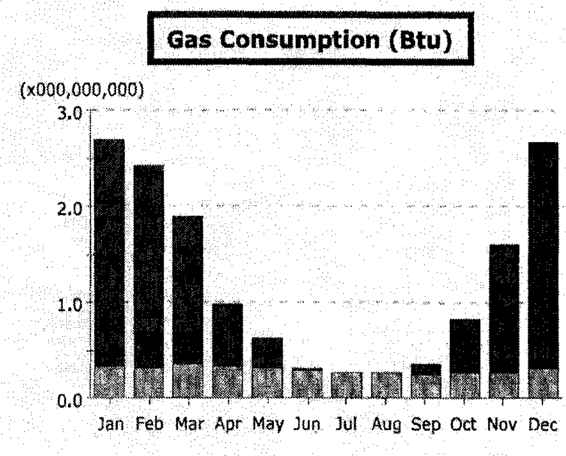
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	4.1	3.7	4.1	5.9	14.5	34.8	48.8	44.5	25.5	7.3	3.9	4.1	201.1
Heat Reject.	-	-	-	0.0	0.3	2.7	5.3	4.2	2.3	0.1	0.0	-	15.0
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	-	-	-	-	-	-	-	-	-	-	-	-	-
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	-	-	-	-	-	-	-	-	-	-	-	-	-
Vent. Fans	20.2	18.1	13.0	7.4	12.4	27.2	36.5	34.5	19.4	8.3	11.5	20.0	228.6
Pumps & Aux.	27.2	24.5	26.9	20.8	20.5	23.7	26.0	25.8	21.4	20.1	23.5	27.0	287.3
Ext. Usage	-	-	-	-	-	-	-	-	-	-	-	-	-
Misc. Equip.	49.3	44.5	49.2	47.6	49.3	47.6	49.2	49.2	47.6	49.2	47.7	49.2	579.6
Task Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Area Lights	70.0	62.8	69.1	66.6	70.0	66.6	69.2	69.5	67.0	69.6	67.9	69.1	817.5
Total	170.7	153.6	162.4	148.3	166.9	202.5	234.9	227.8	183.2	154.7	154.5	169.4	2,129.0

Gas Consumption (Btu x000,000,000)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	-	-	-	-	-	-	-	-	-	-	-	-	-
Heat Reject.	-	-	-	-	-	-	-	-	-	-	-	-	-
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	2.38	2.13	1.56	0.65	0.31	0.02	-	0.00	0.10	0.57	1.34	2.38	11.46
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	0.34	0.32	0.35	0.34	0.32	0.29	0.27	0.26	0.25	0.27	0.28	0.32	3.61
Vent. Fans	-	-	-	-	-	-	-	-	-	-	-	-	-
Pumps & Aux.	-	-	-	-	-	-	-	-	-	-	-	-	-
Ext. Usage	-	-	-	-	-	-	-	-	-	-	-	-	-
Misc. Equip.	-	-	-	-	-	-	-	-	-	-	-	-	-
Task Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Area Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Total	2.72	2.45	1.91	0.99	0.63	0.31	0.27	0.26	0.35	0.84	1.62	2.69	15.06

Project/Run: EIFS - overcladding only - EIFS -3EPS   Run Date/Time: 01/05/09 @ 20:54





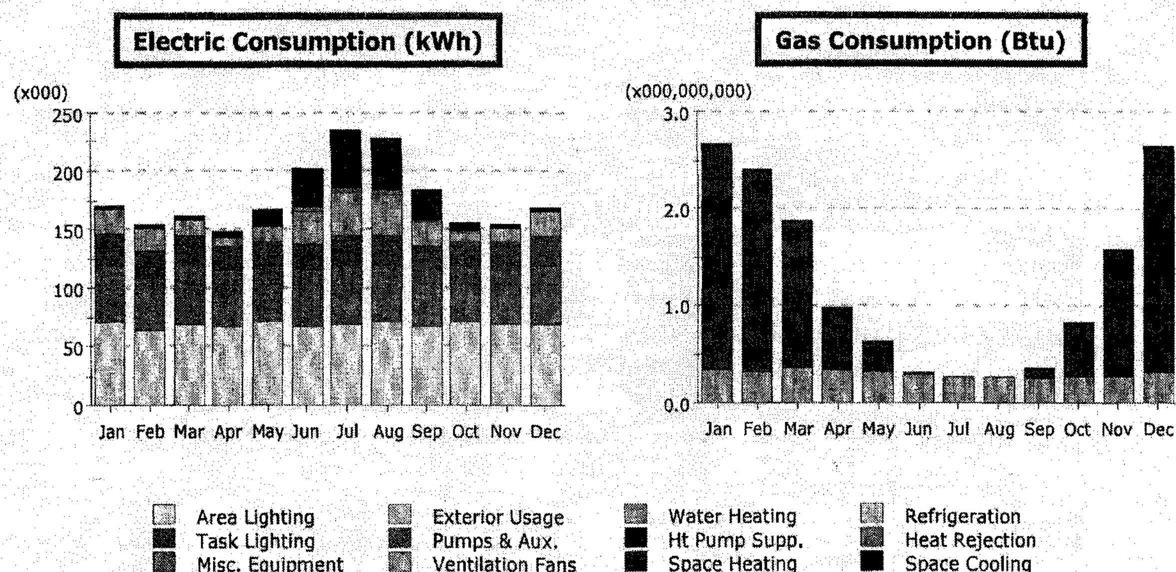
Electric Consumption (kWh x000)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	4.1	3.7	4.1	6.0	14.6	34.8	48.8	44.5	25.5	7.4	3.9	4.1	201.3
Heat Reject.	-	-	-	0.0	0.3	2.7	5.3	4.2	2.3	0.1	0.0	-	15.0
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	-	-	-	-	-	-	-	-	-	-	-	-	-
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	-	-	-	-	-	-	-	-	-	-	-	-	-
Vent. Fans	20.0	17.8	12.8	7.4	12.5	27.2	36.4	34.5	19.4	8.3	11.4	19.8	227.6
Pumps & Aux.	27.1	24.5	26.8	20.7	20.5	23.7	25.9	25.8	21.4	20.1	23.4	26.9	286.7
Ext. Usage	-	-	-	-	-	-	-	-	-	-	-	-	-
Misc. Equip.	49.3	44.5	49.2	47.6	49.3	47.6	49.2	49.2	47.6	49.2	47.7	49.2	579.6
Task Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Area Lights	70.0	62.8	69.1	66.6	70.0	66.6	69.2	69.5	67.0	69.6	67.9	69.1	817.5
Total	170.4	153.3	162.1	148.2	167.1	202.6	234.8	227.7	183.3	154.8	154.3	169.1	2,127.6

Gas Consumption (Btu x000,000,000)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	-	-	-	-	-	-	-	-	-	-	-	-	-
Heat Reject.	-	-	-	-	-	-	-	-	-	-	-	-	-
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	2.36	2.11	1.54	0.64	0.31	0.02	-	0.00	0.10	0.56	1.33	2.35	11.31
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	0.34	0.32	0.35	0.34	0.32	0.29	0.27	0.26	0.25	0.27	0.28	0.32	3.61
Vent. Fans	-	-	-	-	-	-	-	-	-	-	-	-	-
Pumps & Aux.	-	-	-	-	-	-	-	-	-	-	-	-	-
Ext. Usage	-	-	-	-	-	-	-	-	-	-	-	-	-
Misc. Equip.	-	-	-	-	-	-	-	-	-	-	-	-	-
Task Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Area Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Total	2.69	2.42	1.89	0.98	0.63	0.31	0.27	0.26	0.35	0.83	1.60	2.67	14.92

Project/Run: EIFS - overcladding only - EIFS-3XPS   Run Date/Time: 01/05/09 @ 20:53



Electric Consumption (kWh x000)

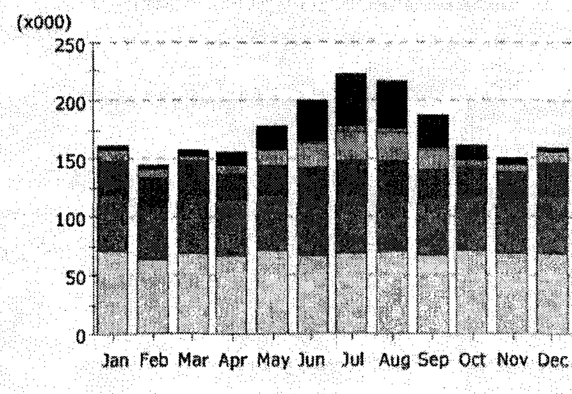
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	4.1	3.7	4.1	6.1	14.7	34.8	48.7	44.5	25.6	7.5	3.9	4.0	201.7
Heat Reject.	-	-	-	0.0	0.3	2.7	5.3	4.2	2.3	0.1	0.0	-	15.0
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	-	-	-	-	-	-	-	-	-	-	-	-	-
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	-	-	-	-	-	-	-	-	-	-	-	-	-
Vent. Fans	19.7	17.6	12.6	7.4	12.6	27.3	36.4	34.5	19.5	8.3	11.2	19.6	226.8
Pumps & Aux.	27.1	24.4	26.7	20.7	20.4	23.7	25.9	25.7	21.3	20.1	23.3	26.8	286.2
Ext. Usage	-	-	-	-	-	-	-	-	-	-	-	-	-
Misc. Equip.	49.3	44.5	49.2	47.6	49.3	47.6	49.2	49.2	47.6	49.2	47.7	49.2	579.6
Task Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Area Lights	70.0	62.8	69.1	66.6	70.0	66.6	69.2	69.5	67.0	69.6	67.9	69.1	817.5
Total	170.1	153.0	161.8	148.3	167.3	202.7	234.8	227.7	183.4	154.8	154.0	168.8	2,126.6

Gas Consumption (Btu x000,000,000)

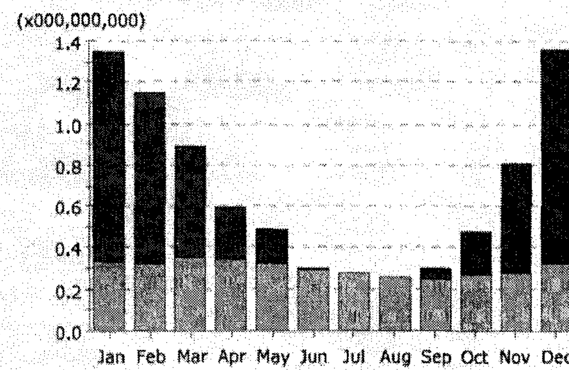
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	-	-	-	-	-	-	-	-	-	-	-	-	-
Heat Reject.	-	-	-	-	-	-	-	-	-	-	-	-	-
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	2.33	2.08	1.51	0.63	0.30	0.02	-	0.00	0.10	0.55	1.31	2.33	11.17
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	0.34	0.32	0.35	0.34	0.32	0.29	0.27	0.26	0.25	0.27	0.28	0.32	3.61
Vent. Fans	-	-	-	-	-	-	-	-	-	-	-	-	-
Pumps & Aux.	-	-	-	-	-	-	-	-	-	-	-	-	-
Ext. Usage	-	-	-	-	-	-	-	-	-	-	-	-	-
Misc. Equip.	-	-	-	-	-	-	-	-	-	-	-	-	-
Task Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Area Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Total	2.67	2.40	1.87	0.97	0.62	0.31	0.27	0.26	0.35	0.82	1.59	2.64	14.78

Project/Run: Over-Cladding Window Replacement - 2EPS DG Low E Window — Run Date/Time: 01/05/09 @ 21:38

Electric Consumption (kWh)



Gas Consumption (Btu)



Area Lighting	Exterior Usage	Water Heating	Refrigeration
Task Lighting	Pumps & Aux.	Ht Pump Supp.	Heat Rejection
Misc. Equipment	Ventilation Fans	Space Heating	Space Cooling

Electric Consumption (kWh x000)

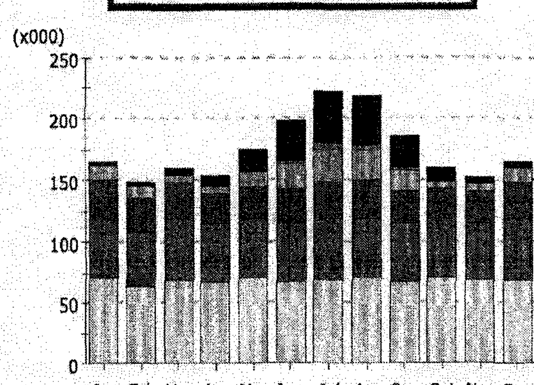
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	4.9	4.4	6.1	10.8	19.5	34.6	43.9	41.9	27.0	11.3	5.4	4.7	214.4
Heat Reject.	-	-	-	0.0	0.3	2.3	5.0	3.3	2.5	0.1	0.0	-	13.6
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	-	-	-	-	-	-	-	-	-	-	-	-	-
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	-	-	-	-	-	-	-	-	-	-	-	-	-
Vent. Fans	8.0	6.6	4.5	6.6	12.3	20.6	25.1	24.3	16.1	7.0	4.9	8.3	144.3
Pumps & Aux.	29.4	26.5	29.0	23.6	25.6	27.7	29.3	29.2	25.8	22.9	23.8	28.4	321.2
Ext. Usage	-	-	-	-	-	-	-	-	-	-	-	-	-
Misc. Equip.	49.3	44.5	49.2	47.6	49.3	47.6	49.2	49.2	47.6	49.2	47.7	49.2	579.6
Task Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Area Lights	70.0	62.8	69.1	66.6	70.0	66.6	69.2	69.5	67.0	69.6	67.9	69.1	817.5
Total	161.6	144.7	157.9	155.1	177.0	199.4	221.7	217.4	186.1	160.2	149.6	159.8	2,090.6

Gas Consumption (Btu x000,000,000)

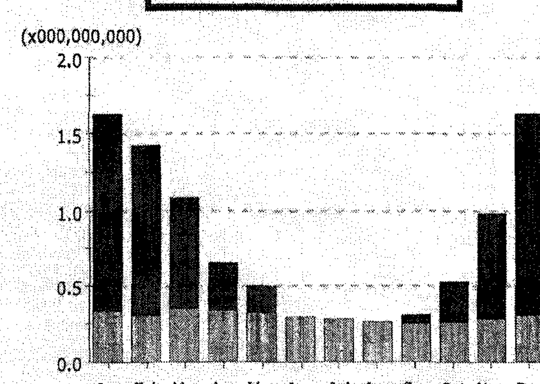
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	-	-	-	-	-	-	-	-	-	-	-	-	-

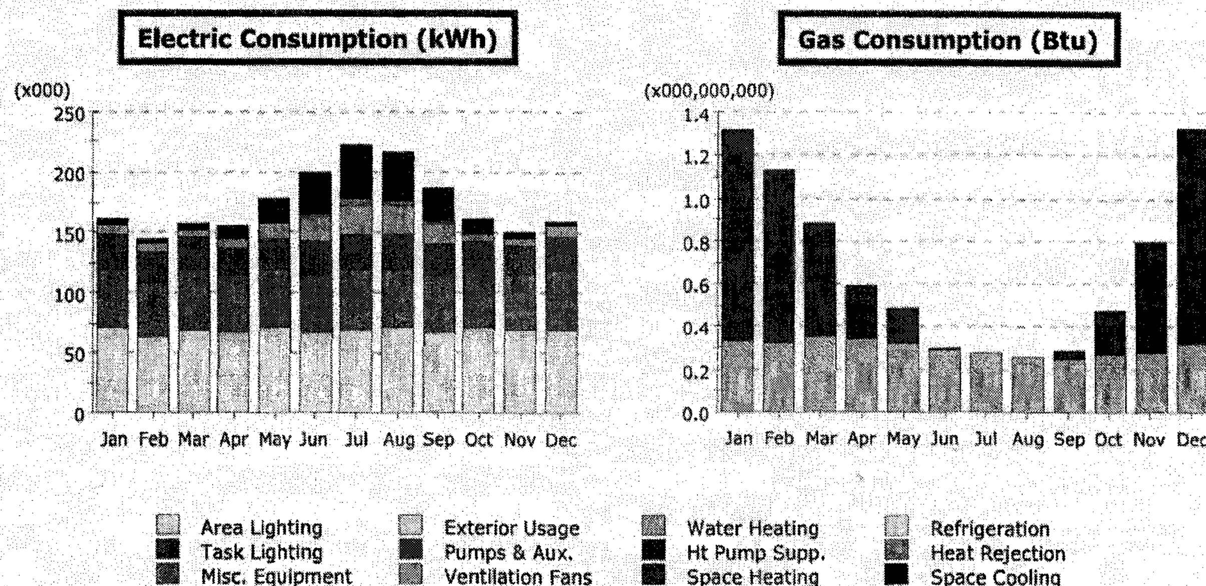
Project/Run: Window Replacement Only - Double G-Low E-Argon Filled — Run Date/Time: 01/05/09 @ 21:19

Electric Consumption (kWh)



Gas Consumption (Btu)



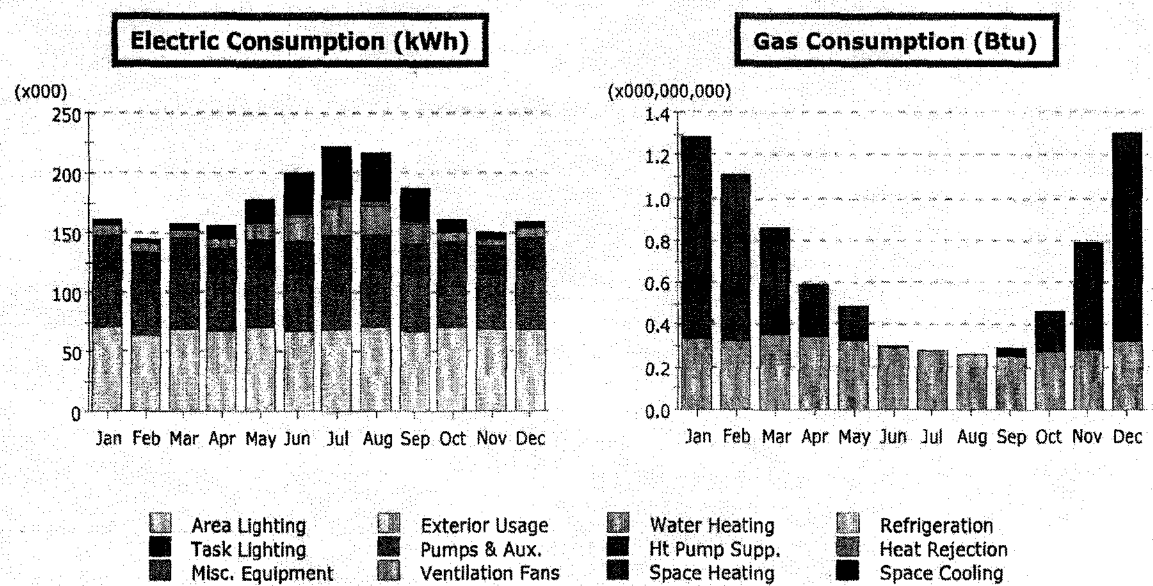


Electric Consumption (kWh x000)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	4.9	4.4	6.2	11.0	19.7	34.7	43.9	41.9	27.1	11.5	5.4	4.7	215.4
Heat Reject.	-	-	-	0.0	0.3	2.3	5.0	3.3	2.5	0.1	0.0	-	13.6
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	-	-	-	-	-	-	-	-	-	-	-	-	-
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	-	-	-	-	-	-	-	-	-	-	-	-	-
Vent. Fans	7.8	6.3	4.5	6.7	12.5	20.6	25.1	24.3	16.1	7.1	4.8	8.1	143.8
Pumps & Aux.	29.4	26.5	28.9	23.6	25.6	27.7	29.2	29.2	25.8	22.9	23.7	28.4	320.9
Ext. Usage	-	-	-	-	-	-	-	-	-	-	-	-	-
Misc. Equip.	49.3	44.5	49.2	47.6	49.3	47.6	49.2	49.2	47.6	49.2	47.7	49.2	579.6
Task Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Area Lights	70.0	62.8	69.1	66.6	70.0	66.6	69.2	69.5	67.0	69.6	67.9	69.1	817.5
Total	161.4	144.5	157.8	155.5	177.4	199.5	221.6	217.4	186.3	160.5	149.5	159.6	2,090.8

Gas Consumption (Btu x000,000,000)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	-	-	-	-	-	-	-	-	-	-	-	-	-
Heat Reject.	-	-	-	-	-	-	-	-	-	-	-	-	-
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	0.98	0.81	0.53	0.25	0.17	0.01	-	-	0.04	0.20	0.52	1.01	4.53
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	0.34	0.32	0.35	0.34	0.32	0.29	0.27	0.26	0.25	0.27	0.28	0.32	3.61
Vent. Fans	-	-	-	-	-	-	-	-	-	-	-	-	-
Pumps & Aux.	-	-	-	-	-	-	-	-	-	-	-	-	-
Ext. Usage	-	-	-	-	-	-	-	-	-	-	-	-	-
Misc. Equip.	-	-	-	-	-	-	-	-	-	-	-	-	-
Task Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Area Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Total	1.31	1.13	0.88	0.59	0.49	0.30	0.27	0.26	0.29	0.47	0.80	1.33	8.14

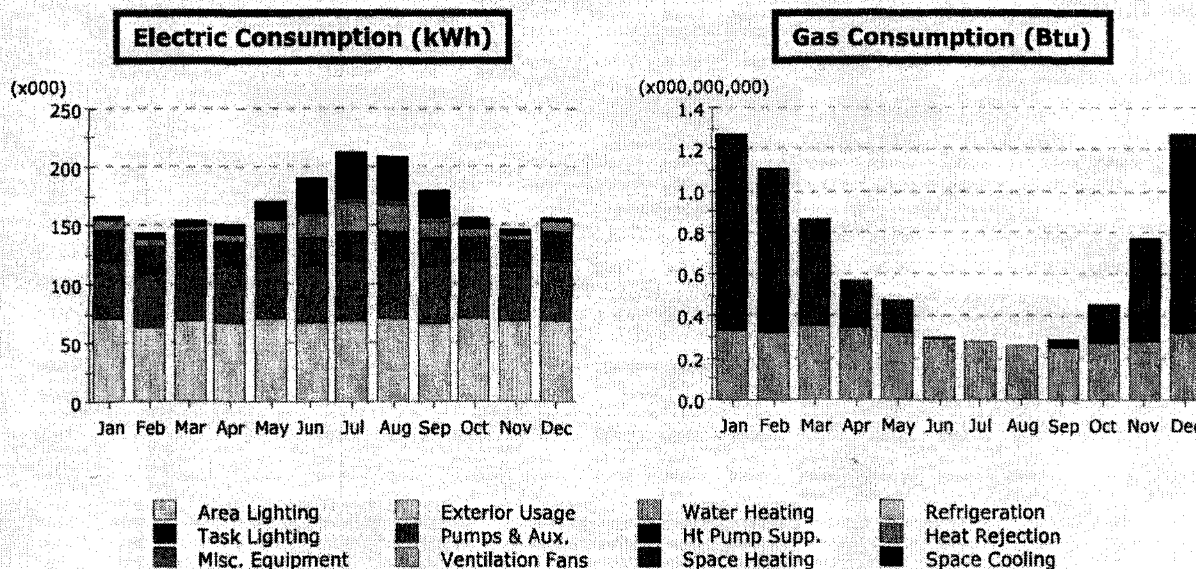


Electric Consumption (kWh x000)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	4.9	4.4	6.3	11.2	19.9	34.7	43.9	41.9	27.2	11.6	5.5	4.8	216.3
Heat Reject.	-	-	-	0.0	0.3	2.3	5.0	3.3	2.5	0.1	0.0	-	13.6
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	-	-	-	-	-	-	-	-	-	-	-	-	-
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	-	-	-	-	-	-	-	-	-	-	-	-	-
Vent. Fans	7.5	6.1	4.4	6.8	12.6	20.7	25.0	24.3	16.2	7.2	4.7	7.9	143.4
Pumps & Aux.	29.4	26.5	28.9	23.6	25.7	27.7	29.2	29.1	25.9	23.0	23.6	28.4	320.9
Ext. Usage	-	-	-	-	-	-	-	-	-	-	-	-	-
Misc. Equip.	49.3	44.5	49.2	47.6	49.3	47.6	49.2	49.2	47.6	49.2	47.7	49.2	579.6
Task Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Area Lights	70.0	62.8	69.1	66.6	70.0	66.6	69.2	69.5	67.0	69.6	67.9	69.1	817.5
Total	161.1	144.3	157.9	155.8	177.8	199.6	221.5	217.3	186.5	160.9	149.3	159.3	2,091.3

Gas Consumption (Btu x000,000,000)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	-	-	-	-	-	-	-	-	-	-	-	-	-
Heat Reject.	-	-	-	-	-	-	-	-	-	-	-	-	-
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	0.95	0.79	0.51	0.25	0.17	0.01	-	-	0.04	0.20	0.51	0.99	4.42
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	0.34	0.32	0.35	0.34	0.32	0.29	0.27	0.26	0.25	0.27	0.28	0.32	3.61
Vent. Fans	-	-	-	-	-	-	-	-	-	-	-	-	-
Pumps & Aux.	-	-	-	-	-	-	-	-	-	-	-	-	-
Ext. Usage	-	-	-	-	-	-	-	-	-	-	-	-	-
Misc. Equip.	-	-	-	-	-	-	-	-	-	-	-	-	-
Task Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Area Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Total	1.29	1.11	0.86	0.59	0.49	0.30	0.27	0.26	0.29	0.47	0.78	1.31	8.02

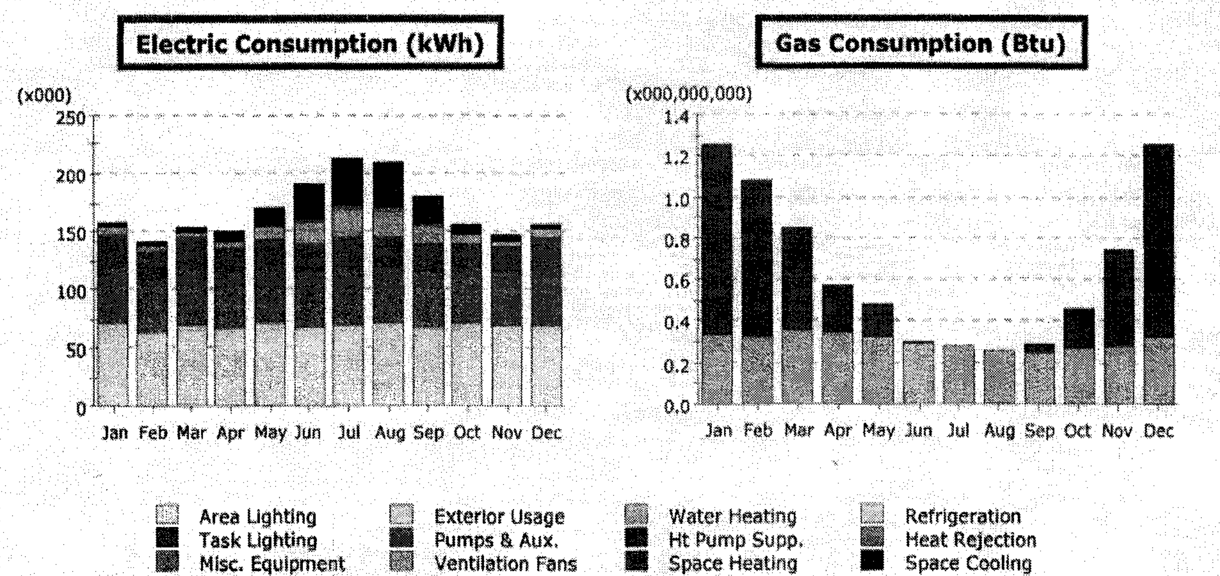


Electric Consumption (kWh x000)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	4.4	3.9	5.3	9.3	17.4	31.4	40.2	38.3	24.8	10.2	4.8	4.3	194.5
Heat Reject.	-	-	-	0.0	0.3	2.1	4.6	3.0	2.3	0.1	0.0	-	12.5
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	-	-	-	-	-	-	-	-	-	-	-	-	-
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	-	-	-	-	-	-	-	-	-	-	-	-	-
Vent. Fans	7.5	6.2	4.1	5.7	11.0	18.7	23.0	22.2	14.7	6.4	4.4	7.7	131.6
Pumps & Aux.	26.9	24.2	26.4	20.9	22.7	25.2	26.7	26.6	23.4	20.5	21.5	26.0	291.1
Ext. Usage	-	-	-	-	-	-	-	-	-	-	-	-	-
Misc. Equip.	49.3	44.5	49.2	47.6	49.3	47.6	49.2	49.2	47.6	49.2	47.7	49.2	579.6
Task Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Area Lights	70.0	62.8	69.1	66.6	70.0	66.6	69.2	69.5	67.0	69.6	67.9	69.1	817.5
Total	158.1	141.7	154.2	150.1	170.6	191.6	212.9	208.9	179.9	156.1	146.3	156.4	2,026.7

Gas Consumption (Btu x000,000,000)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	-	-	-	-	-	-	-	-	-	-	-	-	-
Heat Reject.	-	-	-	-	-	-	-	-	-	-	-	-	-
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	0.94	0.79	0.51	0.23	0.16	0.01	-	-	0.04	0.19	0.49	0.96	4.33
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	0.34	0.32	0.35	0.34	0.32	0.29	0.27	0.26	0.25	0.27	0.28	0.32	3.61
Vent. Fans	-	-	-	-	-	-	-	-	-	-	-	-	-
Pumps & Aux.	-	-	-	-	-	-	-	-	-	-	-	-	-
Ext. Usage	-	-	-	-	-	-	-	-	-	-	-	-	-
Misc. Equip.	-	-	-	-	-	-	-	-	-	-	-	-	-
Task Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Area Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Total	1.28	1.11	0.87	0.57	0.47	0.30	0.27	0.26	0.29	0.46	0.77	1.28	7.93

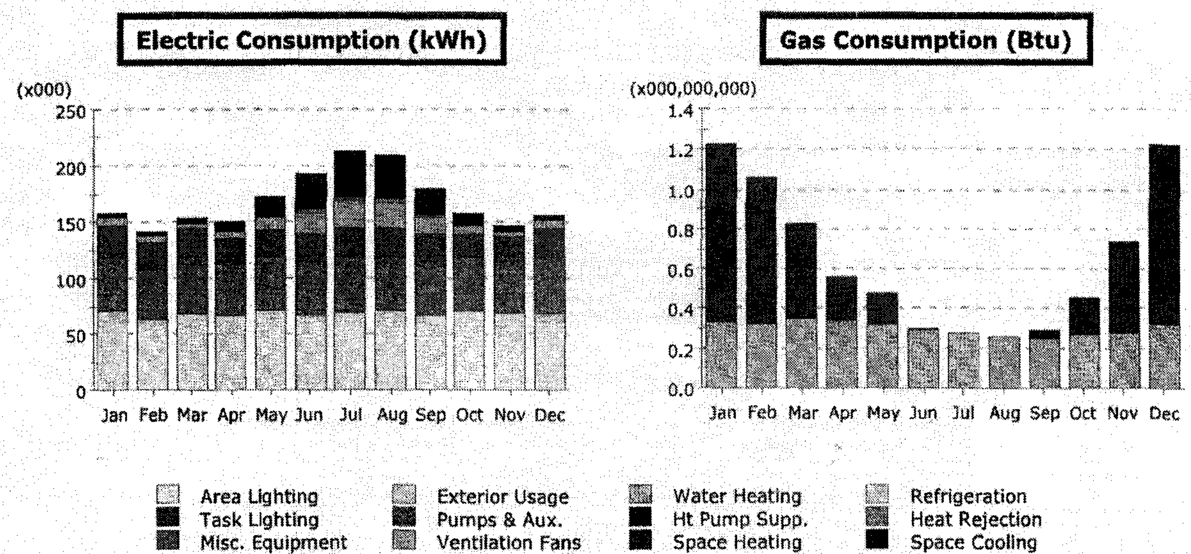


Electric Consumption (kWh x000)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	4.5	4.0	5.4	9.6	17.6	31.5	40.2	38.3	24.9	10.4	4.9	4.3	195.4
Heat Reject.	-	-	-	0.0	0.3	2.1	4.6	3.0	2.3	0.1	0.0	-	12.5
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	-	-	-	-	-	-	-	-	-	-	-	-	-
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	-	-	-	-	-	-	-	-	-	-	-	-	-
Vent. Fans	7.2	6.0	4.0	5.8	11.1	18.8	22.9	22.2	14.8	6.5	4.3	7.4	131.1
Pumps & Aux.	26.9	24.2	26.3	21.0	22.8	25.1	26.7	26.6	23.4	20.6	21.5	25.9	291.0
Ext. Usage	-	-	-	-	-	-	-	-	-	-	-	-	-
Misc. Equip.	49.3	44.5	49.2	47.6	49.3	47.6	49.2	49.2	47.6	49.2	47.7	49.2	579.6
Task Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Area Lights	70.0	62.8	69.1	66.6	70.0	66.6	69.2	69.5	67.0	69.6	67.9	69.1	817.5
Total	157.8	141.4	154.1	150.5	171.0	191.6	212.8	208.9	180.1	156.4	146.3	156.0	2,027.0

Gas Consumption (Btu x000,000,000)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	-	-	-	-	-	-	-	-	-	-	-	-	-
Heat Reject.	-	-	-	-	-	-	-	-	-	-	-	-	-
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	0.91	0.76	0.49	0.23	0.15	0.01	-	-	0.04	0.18	0.47	0.93	4.20
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	0.34	0.32	0.35	0.34	0.32	0.29	0.27	0.26	0.25	0.27	0.28	0.32	3.61
Vent. Fans	-	-	-	-	-	-	-	-	-	-	-	-	-
Pumps & Aux.	-	-	-	-	-	-	-	-	-	-	-	-	-
Ext. Usage	-	-	-	-	-	-	-	-	-	-	-	-	-
Misc. Equip.	-	-	-	-	-	-	-	-	-	-	-	-	-
Task Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Area Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Total	1.25	1.08	0.85	0.57	0.47	0.30	0.27	0.26	0.29	0.45	0.75	1.25	7.81



Electric Consumption (kWh x000)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	4.5	4.0	5.5	9.8	17.8	31.5	40.1	38.3	25.0	10.5	4.9	4.3	196.3
Heat Reject.	-	-	-	0.0	0.3	2.1	4.6	3.0	2.3	0.1	0.0	-	12.5
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	-	-	-	-	-	-	-	-	-	-	-	-	-
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	-	-	-	-	-	-	-	-	-	-	-	-	-
Vent. Fans	7.0	5.7	4.0	5.9	11.3	18.8	22.9	22.2	14.8	6.6	4.2	7.2	130.7
Pumps & Aux.	26.8	24.2	26.3	21.0	22.8	25.2	26.7	26.5	23.4	20.6	21.3	25.8	290.8
Ext. Usage	-	-	-	-	-	-	-	-	-	-	-	-	-
Misc. Equip.	49.3	44.5	49.2	47.6	49.3	47.6	49.2	49.2	47.6	49.2	47.7	49.2	579.6
Task Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Area Lights	70.0	62.8	69.1	66.6	70.0	66.6	69.2	69.5	67.0	69.6	67.9	69.1	817.5
Total	157.6	141.2	154.1	150.9	171.4	191.8	212.7	208.8	180.2	156.7	146.1	155.7	2,027.2

Gas Consumption (Btu x000,000,000)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	-	-	-	-	-	-	-	-	-	-	-	-	-
Heat Reject.	-	-	-	-	-	-	-	-	-	-	-	-	-
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	0.89	0.74	0.48	0.22	0.15	0.01	-	-	0.04	0.18	0.46	0.91	4.08
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	0.34	0.32	0.35	0.34	0.32	0.29	0.27	0.26	0.25	0.27	0.28	0.32	3.61
Vent. Fans	-	-	-	-	-	-	-	-	-	-	-	-	-
Pumps & Aux.	-	-	-	-	-	-	-	-	-	-	-	-	-
Ext. Usage	-	-	-	-	-	-	-	-	-	-	-	-	-
Misc. Equip.	-	-	-	-	-	-	-	-	-	-	-	-	-
Task Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Area Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Total	1.22	1.06	0.83	0.56	0.47	0.30	0.27	0.26	0.29	0.45	0.74	1.23	7.69

Appendix E- CASH FLOWS

PROJECTED CASH FLOWS

PROJECTED CASH FLOWS – YEAR 2008 – 2017 (ESCALATION = 0% OVER INFLATION)

					Study Period			30 Years			
	Study Year	2008			Assumed Annual Escalation Rate			0% over Inflation			
	Investment Year	2008			Assumed Annual Interest Rate			5.00%			
		Cash Flow (2008 to 2017)									
		2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
	EXISTING CONDITION - PRECAST CONCRETE PANELS										
	Initial Cost of Aesthetic Repairs*	-250,000									
	Annual Energy Savings										
	Over-cladding Upgrades										
1.00	**OVER-CLADDING - EIFS (2" EPS)**										
1.01	Initial Cost	-650,000									
1.02	Annual Energy Savings	23,330	24,497	25,721	27,007	28,358	29,776	31,264	32,828	34,469	36,192
1.03	Maintenance & Painting										
2.00	**OVER-CLADDING - EIFS (3" EPS)**										
2.01	Initial Cost	-700,000									
2.02	Annual Energy Savings	25,482	26,756	28,094	29,499	30,974	32,522	34,148	35,856	37,649	39,531
2.03	Maintenance & Painting										
3.00	**OVER-CLADDING - EIFS (3" XPS)**										
3.01	Initial Cost	-1,000,000									
3.02	Annual Energy Savings	27,458	28,831	30,272	31,786	33,375	35,044	36,796	38,636	40,568	42,596
3.03	Maintenance & Painting										
	Over-cladding and Window Upgrades*										
4.00	**EXISTING CONDITION & DOUBLE-GLAZED WINDOWS**										
4.01	Initial Cost	-450,000									
4.02	Annual Energy Savings	102,213	107,324	112,690	118,324	124,241	130,453	136,975	143,824	151,015	158,566
5.00	**EIFS (2" EPS) & DOUBLE-GLAZED WINDOWS**										
5.01	Initial Cost	-1,100,000									
5.02	Annual Energy Savings	121,318	127,384	133,753	140,441	147,463	154,836	162,578	170,707	179,242	188,204
5.03	Maintenance & Painting - Cladding										

					Study Period			30 Years			
	Study Year	2008			Assumed Annual Escalation Rate			0% over Inflation			
	Investment Year	2008			Assumed Annual Interest Rate			5.00%			
		Cash Flow (2008 to 2017)									
		2008	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**
6.00	**EIFS (3" EPS) & DOUBLE-GLAZED WINDOWS**										
6.01	Initial Cost	-1,150,000									
6.02	Annual Energy Savings	123,112	132,961	135,731	142,518	149,643	157,126	164,982	173,231	181,892	190,987
6.03	Maintenance & Painting - Cladding										
7.00	**EIFS (3" XPS) & DOUBLE-GLAZED WINDOWS**										
7.01	Initial Cost	-1,450,000									
7.02	Annual Energy Savings	122,284	132,067	134,818	141,559	148,637	156,069	163,872	172,066	180,669	189,703
7.03	Maintenance & Painting - Cladding										
8.00	**EIFS (2" EPS) & TRIPLE-GLAZED WINDOWS**										
8.01	Initial Cost	-1,550,000									
8.02	Annual Energy Savings	132,940	139,587	146,566	153,895	161,589	169,669	178,152	187,060	196,413	206,234
8.03	Maintenance & Painting - Cladding										
9.00	**EIFS (3" EPS) & TRIPLE-GLAZED WINDOWS**										
9.01	Initial Cost	-1,600,000									
9.02	Annual Energy Savings	134,596	141,326	148,392	155,812	163,602	171,782	180,372	189,390	198,860	208,803
9.03	Maintenance & Painting - Cladding										
10.00	**EIFS (3" XPS) & TRIPLE-GLAZED WINDOWS**										
10.01	Initial Cost	-1,900,000									
10.02	Annual Energy Savings	136,252	143,065	150,218	157,729	165,615	173,896	182,591	191,720	201,306	211,372
10.03	Maintenance & Painting - Cladding										
	* Window maintenace and painting costs are assumed to be equal for all upgrade										

							Study Period			30 Years	
	Study Year			2008			umed Annual Escalation Rate			0% over Inflation	
	Investment Year			2008			Assumed Annual Interest Rate			5.00%	
		Cash Flow (2018 to 2027)									
		2018	2019	2020	2021	2022	2023	2024	2025	2026	2027
	EXISTING CONDITION - PRECAST CONCRETE PANELS										
	Initial Cost of Aesthetic Repairs*	-250,000									
	Annual Energy Savings										
	Over-cladding Upgrades										
1.00	**OVER-CLADDING - EIFS (2" EPS)**										
1.01	Initial Cost										
1.02	Annual Energy Savings	38,002	39,902	41,897	43,992	46,192	48,501	50,926	53,473	56,146	58,954
1.03	Maintenance & Painting	-48,867									
2.00	**OVER-CLADDING - EIFS (3" EPS)**										
2.01	Initial Cost										
2.02	Annual Energy Savings	41,507	43,583	45,762	48,050	50,453	52,975	55,624	58,405	61,325	64,392
2.03	Maintenance & Painting	-57,011									
3.00	**OVER-CLADDING - EIFS (3" XPS)**										
3.01	Initial Cost										
3.02	Annual Energy Savings	44,726	46,962	49,311	51,776	54,365	57,083	59,937	62,934	66,081	69,385
3.03	Maintenance & Painting	-65,156									
	Over-cladding and Window Upgrades*										
4.00	**EXISTING CONDITION & DOUBLE-GLAZED WINDOWS**										
4.01	Initial Cost										
4.02	Annual Energy Savings	166,494	174,819	183,560	192,738	202,375	212,493	223,118	234,274	245,988	258,287
5.00	**EIFS (2" EPS) & DOUBLE-GLAZED WINDOWS**										
5.01	Initial Cost										
5.02	Annual Energy Savings	197,614	207,495	217,870	228,763	240,201	252,211	264,822	278,063	291,966	306,565
5.03	Maintenance & Painting - Cladding	-48,867									

						Study Period				30 Years	
	Study Year			2008		umed Annual Escalation Rate				0% over Inflation	
	Investment Year			2008		Assumed Annual Interest Rate				5.00%	
		Cash Flow (2018 to 2027)									
		2018	2019	2020	2021	2022	2023	2024	2025	2026	2027
6.00	**EIFS (3" EPS) & DOUBLE-GLAZED WINDOWS**										
6.01	Initial Cost										
6.02	Annual Energy Savings	200,536	210,563	221,091	232,146	243,753	255,941	268,738	282,175	296,284	311,098
6.03	Maintenance & Painting - Cladding	-57,011									
7.00	**EIFS (3" XPS) & DOUBLE-GLAZED WINDOWS**										
7.01	Initial Cost										
7.02	Annual Energy Savings	199,188	209,147	219,604	230,585	242,114	254,220	266,931	280,277	294,291	309,006
7.03	Maintenance & Painting - Cladding	-65,156									
8.00	**EIFS (2" EPS) & TRIPLE-GLAZED WINDOWS**										
8.01	Initial Cost										
8.02	Annual Energy Savings	216,545	227,373	238,741	250,678	263,212	276,373	290,191	304,701	319,936	335,933
8.03	Maintenance & Painting - Cladding	-48,867									
9.00	**EIFS (3" EPS) & TRIPLE-GLAZED WINDOWS**										
9.01	Initial Cost										
9.02	Annual Energy Savings	219,243	230,205	241,715	253,801	266,491	279,815	293,806	308,496	323,921	340,117
9.03	Maintenance & Painting - Cladding	-57,011									
10.00	**EIFS (3" XPS) & TRIPLE-GLAZED WINDOWS**										
10.01	Initial Cost										
10.02	Annual Energy Savings	221,940	233,037	244,689	256,923	269,770	283,258	297,421	312,292	327,907	344,302
10.03	Maintenance & Painting - Cladding	-65,156									
	* Window maintenace and painting costs are assumed to be equal for all upgrade options.										

							Study Period			30 Years	
	Study Year			2008			umed Annual Escalation Rate			0% over Inflation	
	Investment Year			2008			Assumed Annual Interest Rate			5.00%	
		Cash Flow (2028 to 2038)									
		2028	2029	2030	2031	2032	2033	2034	2035	2036	2037
	EXISTING CONDITION - PRECAST CONCRETE PANELS										
	Initial Cost of Aesthetic Repairs*	-1,165,239									
	Annual Energy Savings										
	Over-cladding Upgrades										
1.00	**OVER-CLADDING - EIFS (2" EPS)**										
1.01	Initial Cost										
1.02	Annual Energy Savings	61,901	64,997	68,246	71,659	75,242	79,004	82,954	87,102	91,457	96,029
1.03	Maintenance & Painting	-79,599									
2.00	**OVER-CLADDING - EIFS (3" EPS)**										
2.01	Initial Cost										
2.02	Annual Energy Savings	67,611	70,992	74,541	78,269	82,182	86,291	90,606	95,136	99,893	104,887
2.03	Maintenance & Painting	-92,865									
3.00	**OVER-CLADDING - EIFS (3" XPS)**										
3.01	Initial Cost										
3.02	Annual Energy Savings	72,854	76,497	80,322	84,338	88,555	92,983	97,632	102,513	107,639	113,021
3.03	Maintenance & Painting	-106,132									
	Over-cladding and Window Upgrades*										
4.00	**EXISTING CONDITION & DOUBLE-GLAZED WINDOWS**										
4.01	Initial Cost										
4.02	Annual Energy Savings	271,202	284,762	299,000	313,950	329,647	346,129	363,436	381,608	400,688	420,723
5.00	**EIFS (2" EPS) & DOUBLE-GLAZED WINDOWS**										
5.01	Initial Cost										
5.02	Annual Energy Savings	321,893	337,987	354,887	372,631	391,263	410,826	431,367	452,935	475,582	499,361
5.03	Maintenance & Painting - Cladding	-79,599									
6.00	**EIFS (3" EPS) & DOUBLE-GLAZED WINDOWS**										
6.01	Initial Cost										
6.02	Annual Energy Savings	326,653	342,985	360,135	378,141	397,049	416,901	437,746	459,633	482,615	506,746
6.03	Maintenance & Painting - Cladding	-92,865									

							Study Period			30 Years	
	Study Year			2008			umed Annual Escalation Rate			0% over Inflation	
	Investment Year			2008			Assumed Annual Interest Rate			5.00%	
		Cash Flow (2028 to 2038)									
		2028	**2029**	**2030**	**2031**	**2032**	**2033**	**2034**	**2035**	**2036**	**2037**
6.00	**EIFS (3" EPS) & DOUBLE-GLAZED WINDOWS**										
6.01	Initial Cost										
6.02	Annual Energy Savings	326,653	342,985	360,135	378,141	397,049	416,901	437,746	459,633	482,615	506,746
6.03	Maintenance & Painting - Cladding	-92,865									
7.00	**EIFS (3" XPS) & DOUBLE-GLAZED WINDOWS**										
7.01	Initial Cost										
7.02	Annual Energy Savings	324,456	340,679	357,713	375,598	394,378	414,097	434,802	456,542	479,369	503,338
7.03	Maintenance & Painting - Cladding	-106,132									
8.00	**EIFS (2" EPS) & TRIPLE-GLAZED WINDOWS**										
8.01	Initial Cost										
8.02	Annual Energy Savings	352,729	370,366	388,884	408,328	428,745	450,182	472,691	496,326	521,142	547,199
8.03	Maintenance & Painting - Cladding	-79,599									
9.00	**EIFS (3" EPS) & TRIPLE-GLAZED WINDOWS**										
9.01	Initial Cost										
9.02	Annual Energy Savings	357,123	374,979	393,728	413,415	434,086	455,790	478,579	502,508	527,634	554,015
9.03	Maintenance & Painting - Cladding	-92,865									
10.00	**EIFS (3" XPS) & TRIPLE-GLAZED WINDOWS**										
10.01	Initial Cost										
10.02	Annual Energy Savings	361,517	379,593	398,573	418,501	439,426	461,398	484,468	508,691	534,125	560,832
10.03	Maintenance & Painting - Cladding	-106,132									
	* Window maintenace and painting costs are assumed to be equal for all upgrade options.										

					Study Period			30 Years			
		2008			Assumed Annual Escalation Rate			3% over Inflation			
	Investment Year	2008			Assumed Annual Interest Rate			5.00%			
		Cash Flow (2008 to 2017)									
		2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
	EXISTING CONDITION - PRECAST CONCRETE PANELS										
	Initial Cost of Aesthetic Repairs*	-250,000									
	Annual Energy Savings										
	Over-cladding Upgrades										
1.00	**OVER-CLADDING - EIFS (2" EPS)**										
1.01	Initial Cost	-650,000									
1.02	Annual Energy Savings	23,330	25,196	27,212	29,389	31,740	34,279	37,022	39,984	43,182	46,637
1.03	Maintenance & Painting										
2.00	**OVER-CLADDING - EIFS (3" EPS)**										
2.01	Initial Cost	-700,000									
2.02	Annual Energy Savings	25,482	27,521	29,722	32,100	34,668	37,441	40,437	43,672	47,165	50,939
2.03	Maintenance & Painting										
3.00	**OVER-CLADDING - EIFS (3" XPS)**										
3.01	Initial Cost	-1,000,000									
3.02	Annual Energy Savings	27,458	29,655	32,027	34,589	37,356	40,345	43,572	47,058	50,823	54,889
3.03	Maintenance & Painting										
	Over-cladding and Window Upgrades*										
4.00	**EXISTING CONDITION & DOUBLE-GLAZED WINDOWS**										
4.01	Initial Cost	-450,000									
4.02	Annual Energy Savings	102,213	110,390	119,221	128,759	139,060	150,184	162,199	175,175	189,189	204,324
5.00	**EIFS (2" EPS) & DOUBLE-GLAZED WINDOWS**										
5.01	Initial Cost	-1,100,000									
5.02	Annual Energy Savings	121,318	131,023	141,505	152,826	165,052	178,256	192,516	207,918	224,551	242,515
5.03	Maintenance & Painting - Cladding										

				Study Period				30 Years			
		2008		Assumed Annual Escalation Rate				3% over Inflation			
	Investment Year	2008		Assumed Annual Interest Rate				5.00%			
		Cash Flow (2008 to 2017)									
		2008	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**
6.00	**EIFS (3" EPS) & DOUBLE-GLAZED WINDOWS**										
6.01	Initial Cost	-1,150,000									
6.02	Annual Energy Savings	123,112	132,961	143,598	155,086	167,493	180,892	195,363	210,992	227,872	246,101
6.03	Maintenance & Painting - Cladding										
7.00	**EIFS (3" XPS) & DOUBLE-GLAZED WINDOWS**										
7.01	Initial Cost	-1,450,000									
7.02	Annual Energy Savings	122,284	132,067	142,632	154,043	166,366	179,675	194,049	209,573	226,339	244,446
7.03	Maintenance & Painting - Cladding										
8.00	**EIFS (2" EPS) & TRIPLE-GLAZED WINDOWS**										
8.01	Initial Cost	-1,550,000									
8.02	Annual Energy Savings	132,940	143,575	155,061	167,466	180,863	195,332	210,959	227,836	246,063	265,748
8.03	Maintenance & Painting - Cladding										
9.00	**EIFS (3" EPS) & TRIPLE-GLAZED WINDOWS**										
9.01	Initial Cost	-1,600,000									
9.02	Annual Energy Savings	134,596	145,364	156,993	169,552	183,116	197,766	213,587	230,674	249,128	269,058
9.03	Maintenance & Painting - Cladding										
10.00	**EIFS (3" XPS) & TRIPLE-GLAZED WINDOWS**										
10.01	Initial Cost	-1,900,000									
10.02	Annual Energy Savings	136,252	147,152	158,924	171,638	185,369	200,199	216,215	233,512	252,193	272,368
10.03	Maintenance & Painting - Cladding										
	* Window maintenace and painting costs are assumed to be equal for all up										

		2018	2019	2020	2021	2022	2023	2024	2025	2026	2027
							Study Period			30 Years	
				2008			ssumed Annual Escalation Rate			3% over Inflation	
	Investment Year			2008			Assumed Annual Interest Rate			5.00%	
		Cash Flow (2018 to 2027)									
		2018	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**
	EXISTING CONDITION - PRECAST CONCRETE PANELS										
	Initial Cost of Aesthetic Repairs*	-539,731									
	Annual Energy Savings										
	Over-cladding Upgrades										
1.00	**OVER-CLADDING - EIFS (2" EPS)**										
1.01	Initial Cost										
1.02	Annual Energy Savings	50,368	54,397	58,749	63,449	68,525	74,007	79,927	86,321	93,227	100,685
1.03	Maintenance & Painting	-64,768									
2.00	**OVER-CLADDING - EIFS (3" EPS)**										
2.01	Initial Cost										
2.02	Annual Energy Savings	55,014	59,415	64,168	69,301	74,846	80,833	87,300	94,284	101,827	109,973
2.03	Maintenance & Painting	-75,562									
3.00	**OVER-CLADDING - EIFS (3" XPS)**										
3.01	Initial Cost										
3.02	Annual Energy Savings	59,280	64,022	69,144	74,675	80,649	87,101	94,070	101,595	109,723	118,501
3.03	Maintenance & Painting	-86,357									
	Over-cladding and Window Upgrades*										
4.00	**EXISTING CONDITION & DOUBLE-GLAZED WINDOWS**										
4.01	Initial Cost										
4.02	Annual Energy Savings	220,670	238,324	257,390	277,981	300,219	324,237	350,176	378,190	408,445	441,121

						Study Period				30 Years	
				2008		ssumed Annual Escalation Rate				3% over Inflation	
	Investment Year			2008		Assumed Annual Interest Rate				5.00%	
		Cash Flow (2018 to 2027)									
		2018	2019	2020	2021	2022	2023	2024	2025	2026	2027
6.00	**EIFS (3" EPS) & DOUBLE-GLAZED WINDOWS**										
6.01	Initial Cost										
6.02	Annual Energy Savings	265,790	287,053	310,017	334,818	361,604	390,532	421,775	455,517	491,958	531,315
6.03	Maintenance & Painting - Cladding	-75,562									
7.00	**EIFS (3" XPS) & DOUBLE-GLAZED WINDOWS**										
7.01	Initial Cost										
7.02	Annual Energy Savings	264,002	285,122	307,932	332,566	359,172	387,906	418,938	452,453	488,649	527,741
7.03	Maintenance & Painting - Cladding	-86,357									
8.00	**EIFS (2" EPS) & TRIPLE-GLAZED WINDOWS**										
8.01	Initial Cost										
8.02	Annual Energy Savings	287,007	309,968	334,766	361,547	390,471	421,708	455,445	491,880	531,231	573,729
8.03	Maintenance & Painting - Cladding	-64,768									
9.00	**EIFS (3" EPS) & TRIPLE-GLAZED WINDOWS**										
9.01	Initial Cost										
9.02	Annual Energy Savings	290,583	313,829	338,936	366,050	395,335	426,961	461,118	498,008	537,848	580,876
9.03	Maintenance & Painting - Cladding	-75,562									
10.00	**EIFS (3" XPS) & TRIPLE-GLAZED WINDOWS**										
10.01	Initial Cost										
10.02	Annual Energy Savings	294,158	317,690	343,106	370,554	400,199	432,214	466,792	504,135	544,466	588,023
10.03	Maintenance & Painting - Cladding	-86,357									
	* Window maintenace and painting costs are assumed to be equal for all upgrade options.										

							Study Period			30 Years	
				2008			Assumed Annual Escalation Rate			3% over Inflation	
	Investment Year			2008			Assumed Annual Interest Rate			5.00%	
		Cash Flow (2028 to 2038)									
		2028	**2029**	**2030**	**2031**	**2032**	**2033**	**2034**	**2035**	**2036**	**2037**
	EXISTING CONDITION - PRECAST CONCRETE PANELS										
	Initial Cost of Aesthetic Repairs*	-1,165,239									
	Annual Energy Savings										
	Over-cladding Upgrades										
1.00	**OVER-CLADDING - EIFS (2" EPS)**										
1.01	Initial Cost										
1.02	Annual Energy Savings	108,740	117,439	126,834	136,981	147,940	159,775	172,557	186,361	201,270	217,372
1.03	Maintenance & Painting	-139,829									
2.00	**OVER-CLADDING - EIFS (3" EPS)**										
2.01	Initial Cost										
2.02	Annual Energy Savings	118,771	128,272	138,534	149,617	161,586	174,513	188,474	203,552	219,836	237,423
2.03	Maintenance & Painting	-163,134									
3.00	**OVER-CLADDING - EIFS (3" XPS)**										
3.01	Initial Cost										
3.02	Annual Energy Savings	127,981	138,219	149,277	161,219	174,116	188,045	203,089	219,336	236,883	255,834
3.03	Maintenance & Painting	-186,438									
	Over-cladding and Window Upgrades*										
4.00	**EXISTING CONDITION & DOUBLE-GLAZED WINDOWS**										
4.01	Initial Cost										
4.02	Annual Energy Savings	476,410	514,523	555,685	600,140	648,151	700,003	756,003	816,484	881,802	952,347
5.00	**EIFS (2" EPS) & DOUBLE-GLAZED WINDOWS**										
5.01	Initial Cost										
5.02	Annual Energy Savings	565,458	610,695	659,550	712,314	769,299	830,843	897,311	969,096	1,046,623	1,130,353
5.03	Maintenance & Painting - Cladding	-139,829									

							Study Period			30 Years	
				2008			Assumed Annual Escalation Rate			3% over Inflation	
	Investment Year			2008			Assumed Annual Interest Rate			5.00%	
		Cash Flow (2028 to 2038)									
		2028	2029	2030	2031	2032	2033	2034	2035	2036	2037
6.00	**EIFS (3" EPS) & DOUBLE-GLAZED WINDOWS**										
6.01	Initial Cost										
6.02	Annual Energy Savings	573,820	619,725	669,303	722,848	780,675	843,129	910,580	983,426	1,062,100	1,147,068
6.03	Maintenance & Painting - Cladding	-163,134									
7.00	**EIFS (3" XPS) & DOUBLE-GLAZED WINDOWS**										
7.01	Initial Cost										
7.02	Annual Energy Savings	569,960	615,557	664,802	717,986	775,425	837,459	904,456	976,812	1,054,957	1,139,354
7.03	Maintenance & Painting - Cladding	-186,438									
8.00	**EIFS (2" EPS) & TRIPLE-GLAZED WINDOWS**										
8.01	Initial Cost										
8.02	Annual Energy Savings	619,628	669,198	722,734	780,552	842,997	910,436	983,271	1,061,933	1,146,888	1,238,639
8.03	Maintenance & Painting - Cladding	-139,829									
9.00	**EIFS (3" EPS) & TRIPLE-GLAZED WINDOWS**										
9.01	Initial Cost										
9.02	Annual Energy Savings	627,346	677,534	731,737	790,276	853,498	921,777	995,520	1,075,161	1,161,174	1,254,068
9.03	Maintenance & Painting - Cladding	-163,134									
10.00	**EIFS (3" XPS) & TRIPLE-GLAZED WINDOWS**										
10.01	Initial Cost										
10.02	Annual Energy Savings	635,065	685,870	740,740	799,999	863,999	933,118	1,007,768	1,038,389	1,175,460	1,269,497
10.03	Maintenance & Painting - Cladding	-186,438									
	* Window maintenace and painting costs are assumed to be equal for all upgrade options.										