The Evaluation and Costing of the Proposed

ENERGY STAR for New Multi-Family Buildings

Program for Ontario

Sustainable Buildings Canada

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Executive Summary

Sustainable Buildings Canada (SBC) undertook to provide an evaluation for multi-unit residential buildings (MURBs) using the new ENERGY STAR for Multi-family Buildings (ESMFB) and the Toronto Green Standard Version III (TGSIII), compared to the current Building Code requirements for energy efficiency. Funding support was provided by Enbridge Gas Distribution and EnergyQuality Corporation. This report presents the results for ESMFB analysis, for which a description of the methodology including potential energy savings measures that would accommodate energy performance threshold of 15% and 20% better than Code (consistent with the proposed ESMFB performance requirements).

SBC provided three recently designed MURBs that met the current Building Code, a 6 storey low-rise, a 10 storey mid-rise, and a 20 storey high rise. Energy models were developed for each building, the low-rise and mid-rise by EQ Building Performance, and the high-rise by RWDI Consultants. Models were developed for both energy code options offered in Supplementary Standard SB-10 (2017).

The energy modellers then prepared list of energy conservation measures that would deliver an energy efficiency of 15%, and 20%, over SB-10 (2017). These results were compared to the energy efficiency of the Proposed Designs that just met SB-10 (2017).

In addition, SBC's cost consultant proved a detailed review of the additional costs required to meet the 15% and 20% improvement targets.

1.0 Introduction

Sustainable Buildings Canada (SBC), supported by Enbridge Gas Distribution and EnerQuality Corporation, undertook an evaluation of the proposed ENERGY STAR for Multi-Family Buildings (ESMFB), focusing on energy performance requirements, potential differences in results as related to the Building Code compliance paths, and expected energy conservation measures (ECMs) costs for achieving the ENERGY STAR performance requirements. This was also intended to assist in the finalization of the ESMFB energy target.

The following individuals provided specialized consulting services to the project:

- Michelle Xuereb, Quadrangle Architects, who contributed the Architectural Explorations.
- Samantha Menard and Craig McIntyre, EQ Building Performance (EQBP), who provided energy modelling support.
- Jennifer Harmer, Brandon Law, and Mike Williams, Rowan Williams Davies & Irwin Inc. (RWDI), who also provided supporting energy modelling, as well as the information and analysis on updating weather files and the BETGB analysis.
- Larry Brydon of Cricket Energy, Dave Petersen of Outside-in Design, Scott Armstrong of WSP and Dave Wacker who provided subject matter expertise as part of the design specifications.
- Mary Sye of Enbridge Gas Distribution who provided access to the Savings by Design (SBD) project reports.
- Mike Singleton, Sarah Jones, and Bob Bach, of SBC for site logistics, facilitation, and report preparation.

SBC would like to thank all those who participated in the development of this report.

1.1 Sample MURB Buildings

SBC provided information on three recently designed multi-unit residential buildings (MURBs) that had been through the first phase of the Enbridge Savings By Design (SBD) program, and which met the energy efficiency requirements specified in Supplementary Standard SB-10 (2017) Division 3. These were used as energy archetypes and are categorized as follows:

- Low-rise MURB, 4 to 6 storeys, conventional construction.
- Mid-rise MURB, 15 to 20 storeys.
- High-rise MURB, greater than 20 storeys.

Each archetype building was modelled using the two energy codes included in the Building Code Supplementary Standard SB-10 (2017), Division 3:

- ASHRAE 90.1-2013, as modified by SB-10 Division 3, Chapters 1 & 2.
- National Energy Code for Buildings (NECB) 2015, as modified by SB-10 Division 3, Chapters 1 & 3.

The low-rise building energy model was developed by RWDI using IES-Virtual Environment as the modelling program. The mid-rise and the high-rise buildings were modelled by EQBP using eQUEST as the modelling program. These results were presented by Jenn Harmer of RWDI and Samantha Menard of EQBP.

In addition to the development of the energy models, the two firms also developed Packages of Energy Conservation Measures (ECMs) for each energy archetype building that, if implemented, would meet the two proposed energy efficiency targets for the ESMFB program, described below. Energy models for these building variants were also developed, and the results presented in Sections 3.0 through 5.0.

The archetype buildings, and the energy models with and without the ECMs presented in Sections 3.0 through 5.0, and summarized in Section 6.0.

Subsequent to the meeting, Costing Consultant Dave Wacker prepared detailed assessments of the total Reference Building costs, the cost of each individual measure, the cost of each ECM package, and the percent cost increase over the Reference Building for each building type and option. This is presented in Section 7.0.

Michelle Xuereb prepared an overview of the many issues that architects and design teams must consider in the design of buildings that are intended to meet the energy efficiency requirements in the Building Code, and in enhanced programs that raise the energy performance and overall sustainability attributes for buildings. These include Toronto Green Standard Version III and the EnergyStar for Multi-family Buildings programs. This overview provided in Section 8.0.

1.2. Background on the ESMFB Program

Natural Resources Canada (NRCan) has contracted with EnerQuality Corporation to bring the US ENERGY STAR for New Multi-Family Buildings program to Ontario. Sustainable Buildings Canada is providing technical and other assistance to EnerQuality. It is anticipated that the program, once piloted in Ontario, will be expanded to other provinces. In the United States, the ENERGY STAR brand is owned by the Environmental Protection Agency. In Canada, this brand is used under license by NRCan.

The fundamental basis for the ESMFB program is to require that building owners and property managers who desire to have their new building certified must meet a more aggressive energy efficiency level than that required by local or regional energy performance requirements.

Some key aspects of this development include the following:

- The US program is based on the use of ASHRAE 90.1, the edition of which is selected to match that which is in use on the jurisdiction where the building is to be located. The Ontario adaptation will generally follow the US version, but the baseline energy performance requirements will be as defined in the Ontario Building Code Part 12, *Resource Conservation and Environmental Integrity*, as described in greater detail in Supplementary Standard SB-10 (2017), Division 3.
- Evaluation of individual energy conservation measures follows the Standard 90.1 practice of using energy cost. The Ontario program will use energy consumption as the evaluation metric, and will also provide information on CO_2e emissions and peak demand.
- The US program offers either a Prescriptive Path or a Performance Path to ensure program requirements are met. The Ontario program will only offer a Performance Path.

- The proposed incremental energy performance improvement will be either 15%, or 20%, better than the Building Code requirements. The final decision on this performance increment will be determined based on technical and market research, currently underway.
- SB-10 (2017), Division 3 offers the choice of selecting either ASHRAE 90.1-2013 or NECB 2015 as the energy code that will be used to determine the energy performance of the building. Both energy codes are substantially reinforced by SB-10 to raise their minimum performance level up to that required by the Building Code Part 12.
- The US program relies heavily on the participation of a Licensed Professional to be engaged by the developer to protect the integrity of the ENERGY STAR Brand, and to submit to the EPA program specific submittals. These submittals are used to demonstrate that the program's requirements have been met, that all prerequisites are included, and that each energy conservation measure is installed to specification.
- The Licensed Professional is responsible for submitting a Proposed Design Submittal, with an *ENERGY STAR MFHR Submittal Validation Form* to EPA, or its designated agent for approval, prior to beginning construction. The Licensed Professional is also responsible for preparing an As-Built Submittal, with an *ENERGY STAR MFHR Submittal Validation Form*, to EPA or its designated agent for approval. The Ontario program will follow a similar practice, specifying that either a licensed engineering or architecture professional certification will be required to fulfill this role. Project submittals will be similar to the US program version.

2.0 Energy Codes

Ontario was the first province in Canada to adopt an energy code for Part 3 buildings into the Building Code. It was preceded only by the City of Toronto and the City of Vancouver, who were both about 2 years ahead.

2.1 Background on Energy Codes Specified in SB-10 Division 3.

The two energy codes specified in SB-10 (2017) Division 3, come from very different backgrounds. These are described as follows:

American Society of Heating, Refrigerating and Air Conditioning Engineers (AHRAE) Standard 90.1, *Energy Standard for Buildings Except Low-Rise Residential Buildings*: The original Standard 90 was published in 1975, and revised editions were published in 1980, 1989, and 1999 using the ANSI and ASHRAE periodic maintenance procedures. The ASHRAE Board of Directors voted in 1999 to place the standard on continuous maintenance, permitting it to be updated several times each year through the publication of approved addenda to the standard. As of the 2001 edition, the standard is now published in its entirety in the Fall of every third year, when all approved addenda and errata are included in the new edition. Standard 90.1 is an energy code that is developed in the USA, and uses energy costs, constructions costs, and climate influences from that country in its development.

Ontario adopted ASHRAE 90.1-1989 into the Building Code by an amendment that took effect on July 1, 1993. An objective for Resource Conservation was added to the Building Code in 2006, and this resulted in the development of Part 12, *Resource Conservation*, at the same time. Supplementary Standard SB-10 was introduced in 2006, and in 2012, all requirements related to energy efficiency were moved into SB-10.

The National Energy Code of Canada for Buildings 2015 **(NECB 2015)**: This code and all others published by Codes Canada is an objective-based National Model Code that can be adopted by provincial and territorial governments. These governments have the authority to enact legislation that regulates building design and construction within their jurisdictions, either without change or with modifications to suit local needs, and the enactment of other laws and regulations regarding building design and construction, including the requirements for professional involvement. The NECB is a model code in the sense that it helps promote consistency among provincial and territorial building codes.

The development of a Canadian energy code was launched in 1990 in response to a request from several stakeholders, with funding from Natural Resources Canada. Considerable research was undertaken by the Canadian Codes Centre, as well as significant consultation with stakeholders. This effort finally resulted in the publication of the Model National Energy Code of Canada for Buildings 1997. While the word, “Model,” was only added at the last meeting of the committee, it has since been dropped for the 2011 and 2013 editions. One initiative that has set the Canadian energy code from its American cousin has been the provision of compliance energy modelling software for MENCB 1997 and NECB 2011 that automatically generates the Reference Building model, with no further input beyond the Proposed Design. This has not yet been released for NECB 2015

Ontario was the first province to adopt MNECB, citing it in the Building Code in 1997, and continues to cite the two subsequent versions in SB-10.

Ontario has modified both energy codes extensively since 2006, incorporating these changes in SB-10. The most recent edition contains the most extensive change, indicating that the energy codes are not staying abreast of Ontario's aggressive targets for energy conservation for new buildings constructed in the province.

2.2 Energy Code Measures and Performance Comparison

The two energy codes specified in SB-10 (2017) Division 3 have notable differences for the Reference Building Prescriptive Criteria. For any project using the Performance Path, the Reference Building is derived from the Proposed Design, but modified by following the Prescriptive Criteria in the selected energy code and, when the energy efficiency is evaluated using the same energy modelling software as for the Proposed Design, determines the code compliant (baseline) energy efficiency. These differences for the Building Envelope are presented in the Table 2-1, and are specific to Climate Zone 5, which includes Toronto and southwestern Ontario.

Table 2-1: Comparison of Reference Building Defined in Energy Codes Followed in Ontario

Characteristic	NECB Reference (NECB 2015 as modified by SB10-2017)	ASHRAE Reference (ASHRAE Standard 90.1-2013 as modified by SB10-2017)
Roofs	RSI-6.4 (R-36.4)	Insulation entirely above deck RSI-6.1 (R-34.6)
Walls, Above Grade	RSI-3.6 (R-20.4)	Steel framed RSI-3.7 (R-20.8)
Walls, Below Grade	Fully conditioned RSI-2.6 (R-15.0)	Below grade wall RSI-2.6 ci (R-14.8 ci)
Floors	RSI-5.5 (R-31.0)	Steel joist RSI-5.2 (R-29.3)
Slab-On-Grade Floors	RSI-1.3 (R-7.5) for 1200 mm	Unheated RSI-2.6 ci (R-14.8 ci) for 1200 mm
Glazing	All USI-1.9 (U-0.33) SHGC: 0.40	Metal framing, fixed USI-2.15 (U-0.38) SHGC: 0.40
Doors	USI-1.9 (U-0.33)	Swinging USI-2.56 (U-0.45)

The Reference Building criteria for Lighting Power Density for the two energy codes are shown in the Table 2-2. Since these are both modified by SB-10 to achieve the same Lighting Power Density (LPD), the same requirements are listed for both energy codes.

Note that the fixture water flow requirements are specified in the Building Code and not in SB-10, and are therefore consistent for both energy codes.

Table 2-2: Comparison of Reference Buildings Defined in Energy Codes Followed in Ontario (2)

Characteristic	NECB Reference (NECB 2015 as modified by SB10-2017)	ASHRAE Reference (ASHRAE Standard 90.1-2013 as modified by SB10-2017)
Lighting Power Densities	LPDs are adjusted by SB10 to match between both references Suites – 5.0 W/m2 Corridors – 7.1 W/m2 Amenity – 6.7 W/m2 Retail – 9.1 W/m2 Parking Garage – 1.5 W/m2	
DHW Fixtures – Lavatory	Per OBC, 8.35 Litres per Minute (LPM)	
– Kitchen Faucet	Per OBC, 8.35 LPM	
– Shower	Per OBC, 7.6 LPM for Residential	

The design details for the heating, ventilating and air conditioning (HVAC) system specifications for the respective Reference Buildings are shown in Table 2-3.

Table 2-3: Comparison of Reference Building Defined in Energy Codes Followed in Ontario (3)

For Climate Zone 5, Residential Buildings

Characteristic	NECB Reference (NECB 2015 as modified by SB10-2017)	ASHRAE Reference (ASHRAE Standard 90.1-2013 as modified by SB10-2017)
Air-Side Heat Recovery	Not required for dwelling units in Climate Zone 5	55% energy recovery effectiveness where required by ASHRAE
Boiler Efficiency	90%	90%
DHW Heater Efficiency	90%	90%
HVAC System Selection	Identical system as proposed building	Depends on proposed cooling system Air-cooled = PTACs Water-cooled = Fan Coil Units
Heating Equipment	Same as proposed building	Depends on proposed heating type Fossil fuel = Boiler Electric Resistance = Electric Res. Heat Pump = Electric Heat Pump
Cooling Equipment	Depends on proposed cooling system Direct Expansion or Water-cooled water chiller	Depends on proposed cooling system Air-cooled = Direct Expansion (DX) Water-cooled = Chilled Water

These differences will mean that for all buildings, there will be a different energy performance result depending on the energy code selected. Note also that only one energy code may be selected, and the requirements therein must be followed in their entirety, except for the modifications specified in SB-10 (2017) Division 3. These differences were assessed as part of the following analyses and are shown in Sections 3.0 to 5.0.

3.0 Low-Rise Building – Proposed Design

The low-rise building archetype was described by of EQ Building Performance, as follows:

- Toronto, Ontario
- 6 stories + 2 below grade parking
- 5,200 m^2 + 2,600 m^2 parking
- Primarily residential, with retail at grade (10% of total GFA)
- Peak occupants: 156 – 86 residential units
- WWR of 32% (whole building)
- Heating set points:
  - 22°C in units and amenity
  - 18°C in support spaces
- Cooling set points:
  - 24°C in units and amenity
  - 26°C in support spaces

3.1 Energy Model Specifications

The Model Specifications for the Proposed Design are presented in the following tables.

Table 3-1: Building Envelope

Characteristic	Proposed
Typical Exterior Wall Performance	Nominal: Brick RSI-3.72 (R-21.1) | Spandrel RSI-2.0 (R-11.5) Traditional: RSI-3.14 (R-17.8) | Spandrel: RSI-0.82 (R-4.7) Enhanced Thermal Bridging Overall Total RSI-1.4 (R-7.9)
Typical Roof Performance	RSI-5.65 (R-32.1)
Glazing Performance	USI-1.99 (U-0.35)
Glazing SHGC	0.33
Infiltration	0.25 L/s-m^2-façade

Table 3-2: Internal Loads

Characteristic	Proposed
Average Lighting Power Density	5.3 W/m^2
Average Equipment Load	2.5 W/m^2
DHW Fixture Flow Rates	Lavatory: 1.9 LPM, Kitchen: 5.7 LPM, Shower: 5.7 LPM

Table 3-3: HVAC Systems

Characteristic	Proposed
Primary HVAC Type	DOAS Fan Coil Units with In-Suite ERV
Airside Heat Recovery	76% sensible / 65% latent
Heating Distribution	Hydronic
Cooling Distribution	Hydronic
Outdoor Air Rates	Units per ASHRAE Standard 62.2, Others per ASHRAE 62.1

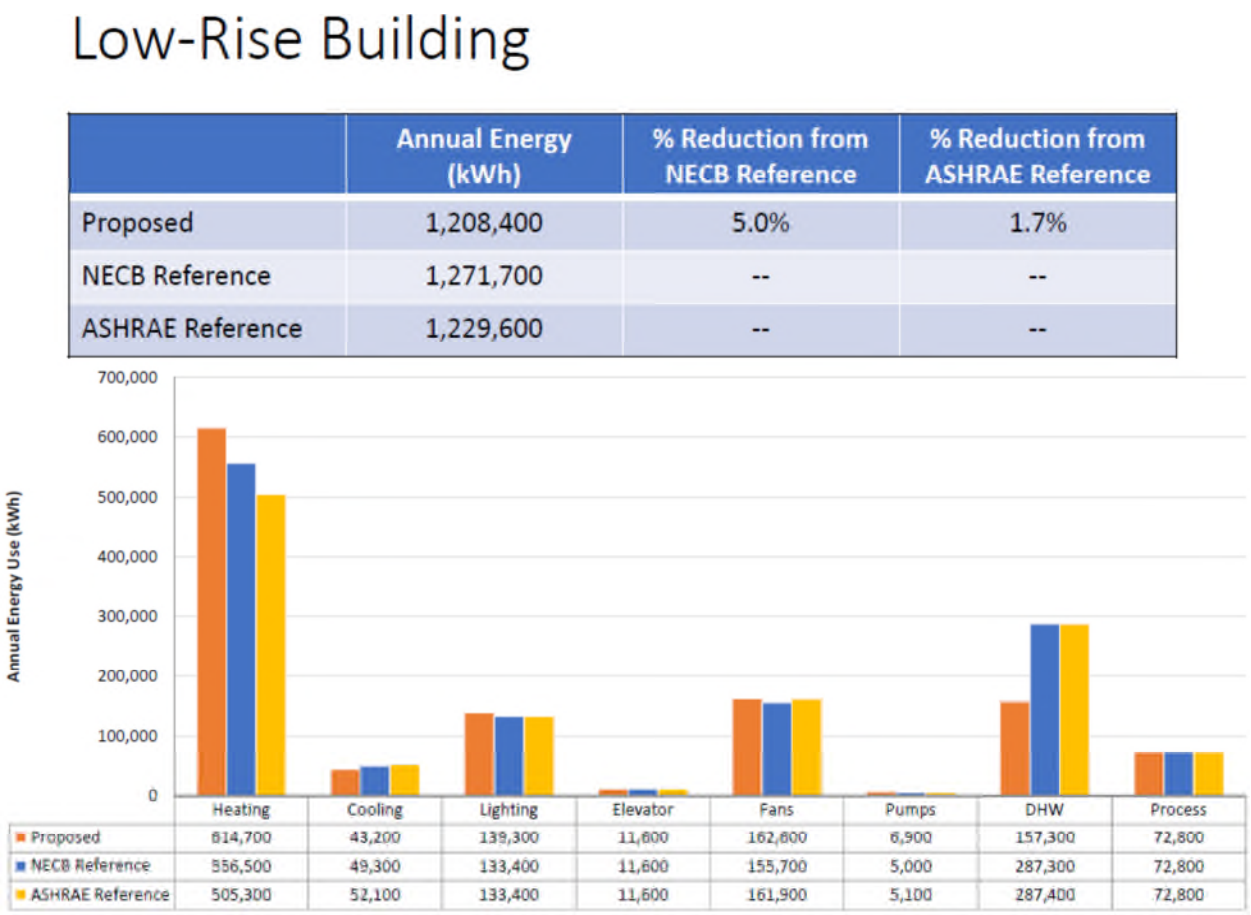
Table 3-4: HVAC Plant

Characteristic	Proposed
Space Heating Equipment	Condensing Boiler, 94% Efficiency
Space Cooling Equipment	Air Cooled Chiller, COP 2.87
DHW Equipment	94% Efficiency

3.2 Low-Rise Energy Modelling Results

The energy performance results for the low-rise Proposed Design, NECB 2015 Reference Building, and the ASHRAE 90.1-2013 Reference Building, (both as modified by SB-10 (2017) Division 3), delineating 8 end-uses, are presented in the following tables and charts.

Figure 3-1: Energy Performance Results for Low-rise MURB

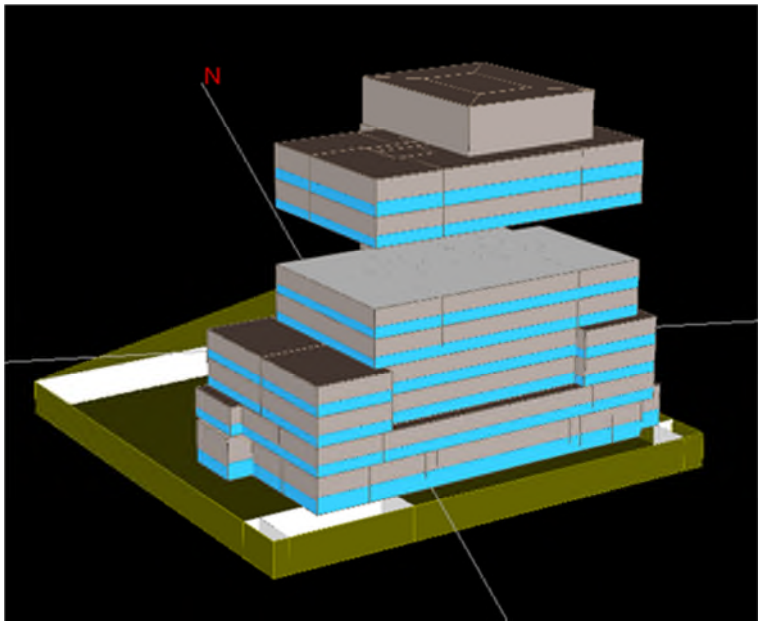


As noted in the top table, the Proposed Design is projected to use 5.0% less energy annually than the NECB 2015 Reference Building, and 1.7% less energy than the ASHRAE 90.1-2013 Reference Building. From the column charts, most of this improvement comes from lower space cooling and service water heating energy.

4.0 Mid-Rise Building – Proposed Design

The mid-rise building was described by Samantha Menard of EQ Building Performance, and is defined as follows:

- Located in Toronto
- 10 Stories
- 7,603 m^2
- Residential Building
- 245 Occupants
- 38% WWR
- Heating setpoint 22°C (72°F) with 18°C (64°F) setback in corridors
- Cooling set point 24°C (75°F)



4.1 Energy Model Specifications

The Specifications for the Proposed Design are presented in the following tables:

Table 4-1: Building Envelope

Characteristic	Proposed
Typical Exterior Wall Performance	Terracotta + Spandrel: Nominal RSI-3.5 (R-20) Traditional Overall Total RSI-2.4 (R-13.3) Enhanced Thermal Bridging Overall Total RSI-1.05 (R-5.7)
Typical Roof Performance	Effective RSI-5.28 (R-30)
Glazing Performance	USI-1.99 (U-35)
Glazing SHGC	SHGC 0.35
Infiltration	0.25 L/s-m^2-façade

Table 4-2: Internal Loads

Characteristic	Proposed
Average Lighting Power Density	4.2 W/m2 (0.39 W/ft2)
Average Equipment Load	2.6 W/m2 (0.25 W/ft2)
DHW Fixture Flow Rates	5.7 LPM Lavs, 7.6 LPM Showers, 5.7 LPM Sinks

Table 4-3: HVAC System

Characteristic	Proposed
Primary HVAC Type	Fan Coil System
Airside Heat Recovery	65% Efficient Heat Recovery in Suites
Heating Distribution	Hydronic
Cooling Distribution	Hydronic
Outdoor Air Rates	75 cfm/ERV in suite ; 40 cfm/suite in MUA

Table 4-4: HVAC Plant

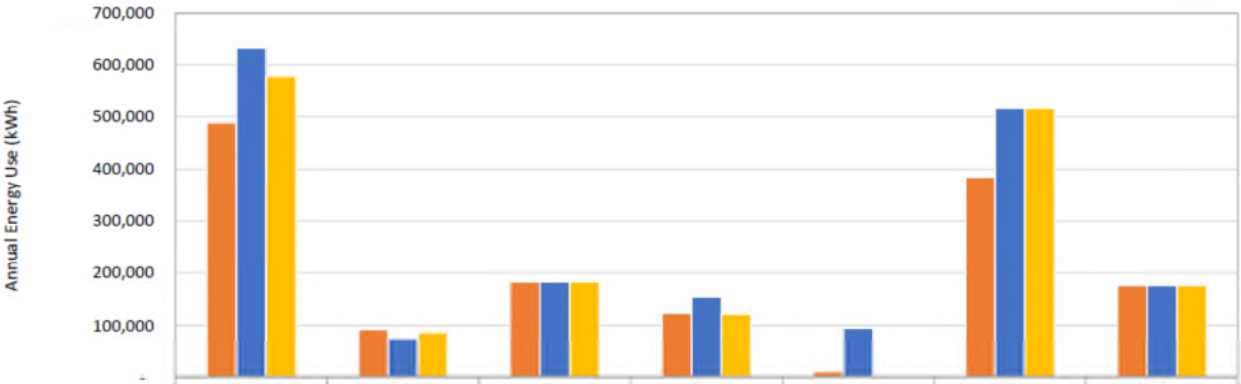
Characteristic	Proposed
Space Heating Equipment	Condensing Boilers – 94%
Space Cooling Equipment	Air-Cooled Screw Chiller – COP 3.0
DHW Equipment	Condensing Boilers – 94%

4.2 Mid-Rise Energy Modelling Results

The energy performance results for the mid-rise Proposed Design, NECB 2015 Reference Building, and the ASHRAE 90.1-2013 Reference Building, (both as modified by SB-10 (2017) Division 3), delineating 7 energy end-uses, are presented in the following table and chart.

Figure 4-1: Mid-rise Energy Performance Results

	Annual Energy (kWh)	% Reduction from NECB Reference	% Reduction from ASHRAE Reference
Proposed	1,585,720	13.4 %	4.8 %
NECB Reference	1,832,037	--	--
ASHRAE Reference	1,666,732	--	--

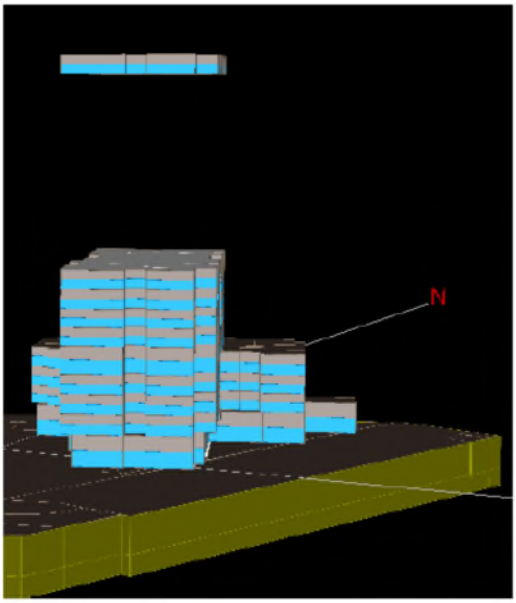


	Heating	Cooling	Lighting	Fans	Pumps	DHW	Process
Proposed	488,121	92,350	182,972	123,642	10,870	384,989	176,292
NECB Reference	632,565	74,507	182,972	154,376	94,782	516,541	176,292
ASHRAE Reference	578,655	86,637	182,972	121,825	3,809	516,541	176,292

As noted in the top table, the Proposed Design is projected to use 13.4% less energy annually than the NECB 2015 Reference Building, and 4.8% less energy than the ASHRAE 90.1-2013 Reference Building. From the column charts, most of this improvement comes from lower energy for space heating, space cooling, fans and pumps, and service water heating.

5.0 High-Rise Building – Proposed Design

The high-rise building was defined as follows:



- Located in Toronto
- 20 stories
- 16,457 m^2
- Residential building with ground floor retail
- 323 occupants
- WWR 51%
- Heating setpoint 22°C (72°F) with 18°C (64°F) setback in corridors
- Cooling set point 24°C (75°F)

5.1 Energy Model Specifications

The Specifications for the Proposed Design are presented in the following tables:

Table 5-1: Building Envelope

Characteristic	Proposed
Typical Exterior Wall Performance	Brick + Precast Concrete: Nominal RSI-4.4 (R-25) Traditional Overall Total RSI-3.5 (R-20) Enhanced Thermal Bridging Overall Total RSI-1.0 (R-5.9)
Typical Roof Performance	Effective RSI-5.3 (R-30)
Glazing Performance	USI-1.99 (U-0.35)
Glazing SHGC	SHGC 0.35
Infiltration	0.25 L/s-m^2-façade

Table 5-2: Internal Loads

Characteristic	Proposed
Average Lighting Power Density	4.46 W/m2 (0.41 W/ft2)
Average Equipment Load	2.85 W/m2 (0.27 W/ft2)
DHW Fixture Flow Rates	5.7 LPM Lavs 8.3 LPM Sinks 5.7 LPM Showers

Table 5-3: HVAC System

Characteristic	Proposed
Primary HVAC Type	Fan Coil System
Airside Heat Recovery	60% Efficient Heat Recovery in Suites
Heating Distribution	Hydronic
Cooling Distribution	Hydronic
Outdoor Air Rates	60 cfm/ERV in suite ; 50 cfm/suite in MUA

Table 5-4: HVAC Equipment

Characteristic	Proposed
Space Heating Equipment	Condensing Boilers – 93%
Space Cooling Equipment	Air-Cooled Scroll Chiller – COP 3
DHW Equipment	Condensing Boilers – 95%

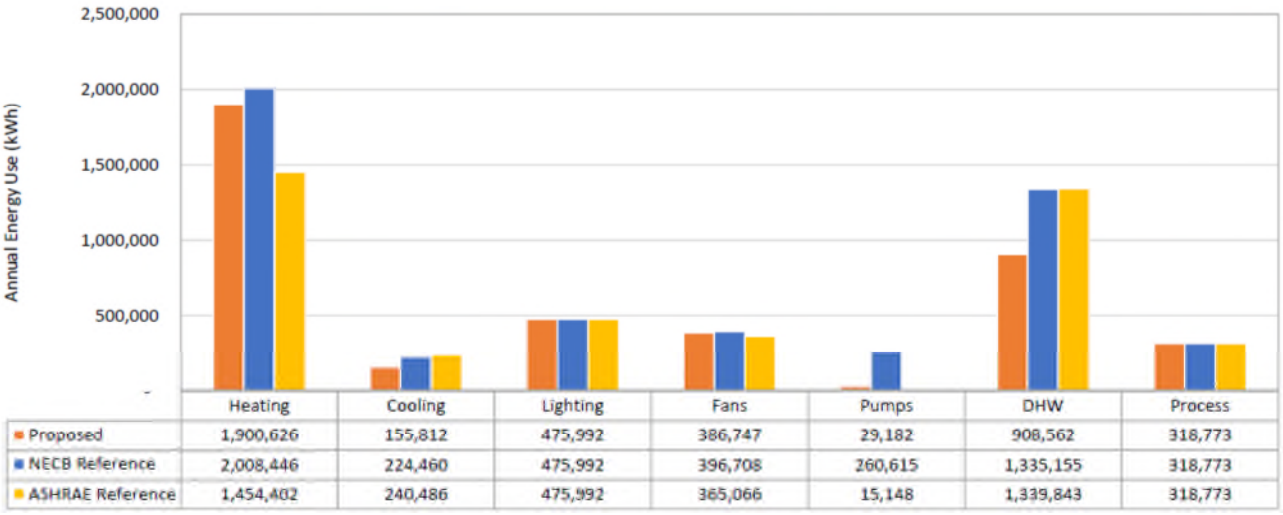
5.2 High-Rise Energy Modelling Results

The energy performance results for the high-rise Proposed Design, NECB 2015 Reference Building, and the ASHRAE 90.1-2013 Reference Building, (both as modified by SB-10 (2017) Division 3), delineating 7 end-uses, are presented in the following table and chart.

Figure 5-1: High-rise Energy Performance Results

High-Rise Building

	Annual Energy (kWh)	Proposed % Change From Reference
Proposed	4,175,693	--
NECB Reference	5,020,149	17%
ASHRAE Reference	4,209,710	1%



	Heating	Cooling	Lighting	Fans	Pumps	DHW	Process
Proposed	1,900,626	155,812	475,992	386,747	29,182	908,562	318,773
NECB Reference	2,008,446	224,460	475,992	396,708	260,615	1,335,155	318,773
ASHRAE Reference	1,454,402	240,486	475,992	365,066	15,148	1,339,843	318,773

As noted in the top table, the Proposed Design is projected to use 17% less energy annually than the NECB 2015 Reference Building, and 1% less energy than the ASHRAE 90.1-2013 Reference Building. From the column charts, most of this improvement comes from lower space heating, space cooling, pumps, and service water heating.

6.0 Energy Conservation Measures to Meet the ESMFB Energy Performance Requirement

The energy modelling teams and subject matter experts were challenged to identify packages of energy conservation measures (ECMs) for each of the three archetype buildings that would ensure that each alternative would meet either a 15% energy performance improvement, or a 20% energy improvement, over the Reference Building. For this part of the exercise, ASHRAE 90.1-2013, as modified by SB-10 (2017) Division 3, was used as the energy code.

6.1 Energy Conservation Measure Options

The package of measures was chosen from the following list:

Glazing Improvement

- High performance double glazed: USI-1.85 (U-0.33) SHGC: 0.35
- Triple glazed: USI-1.4 (U-0.25) SHGC: 0.30

Exterior Wall Improvement

- Replace spandrel with higher-performance wall type

Window-to-Wall Ratio

- Reduce to 40%

Lighting

- All-LED lighting system

Infiltration

- Improve air-tightness to 0.168 L/s-m^2-façade

Air-Side Heat Recovery

- Increase energy recovery effectiveness: 80% Sensible, 75% Latent

DHW Low Flow Fixtures

- Lavatory to 1.9 LPM
- Kitchen to 5.7 LPM
- Shower to 5.7 LPM

System Upgrades

- Improved boiler efficiency: 94%
- Improved chiller efficiency: COP 4.1
- Improved DHW heater efficiency: 94%

6.2 Low-Rise ECM Packages

For the Low-rise building, in the following table the “Proposed” column lists the performance characteristics of the major components affecting overall energy efficiency for the Proposed Design that meets the energy efficiency performance required by SB-10 (2017), Division 3. The ECM Package 1 column shows the ECMs that will meet the ESMFB requirement for a 15% energy performance improvement. The ECM Package 2 column shows the ECMs selected that will meet the ESMFB requirement for a 20% energy performance improvement.

Table 6-1: Low-rise Energy Conservation Measures

Characteristic	Proposed	ECM Package 1 – 15% Reduction	ECM Package 2 – 20% Reduction
Glazing Performance	USI-1.99 (U-35) SHGC 0.35	USI-1.85 (U-0.33) SHGC 0.35	USI-1.4 (U-0.25) SHGC 0.30
Remove Spandrel, Reduce Thermal Bridges	RSI-1.4 (R-7.9)	RSI-1.9 (R-10.8)	-
Infiltration	0.25 l/s/m2	0.168 l/s/m2	-
LED Lighting in Common Areas	Average LPD 5.3 W/m2 (0.49 W/ft2)	Average LPD 4.4 W/m2 (0.41 W/ft2)	-
Air-Side Heat Recovery in Suites	76%	80	-
Chiller COP	3	-	4.1

The measures for the 15% Reduction Package are:

- Double-glazed fenestration with a small improvement in thermal transmittance,
- Improvements in opaque wall thermal performances,
- Reduced infiltration through better air tightness,
- LED lamps and fixtures with higher efficacy,
- Improved heat recovery effectives for in-suite HRVs/ERVs.

For the 20% Reduction Package, the only measure selected is fenestration that meets the specified performance criteria. This is expected to be triple-glazed.

All of the measures shown above are available in the marketplace.

6.3 Mid-Rise ECM Packages

For the Mid-rise building, in the following table the “Proposed” column lists the performance characteristics of the major components affecting overall energy efficiency for the Proposed Design that meets the energy efficiency performance required by SB-10 (2017), Division 3. The ECM Package 1 column shows the package of ECMs that will meet the ESMFB requirement for a 15% energy performance improvement. The ECM Package 2 column shows the ECMs selected that will meet the ESMFB requirement for a 20% energy performance improvement.

Table 6-2: Mid-rise Energy Conservation Measures

Characteristic	Proposed	ECM Package 1 – 15% Reduction	ECM Package 2 – 20% Reduction
Glazing Performance	USI-1.99 (U-35) SHGC 0.35	USI-1.85 (U-0.33) SHGC 0.35	USI-1.4 (U-0.25) SHGC 0.30
Remove Spandrel	RSI-1.05 (R-5.7)	RSI-1.12 (R-6.8)	-
Infiltration	0.25 l/s/m2	-	0.168 l/s/m2
LED Lighting in Common Areas	Average LPD 4.2 W/m2 (0.39 W/ft2)	Average LPD 3.9 W/m2 (0.36 W/ft2)	-
Lower Flow Fixtures	5.7 LPM Lavs 5.7 LPM Sinks 7.6 LPM Showers	1.9 LPM Lavs 5.7 LPM Sinks 5.7 LPM Showers	-
Air-Side Heat Recovery in Suites	65%	-	80%

The measures for the 15% Reduction Package are:

- Double-glazed fenestration with a small improvement in thermal transmittance,
- Improvements in opaque wall thermal performances by removing spandrel component,
- Reduced infiltration through better air tightness,
- LED lamps and fixtures with higher efficacy,
- Lower flow water fixtures,
- Improved heat recovery effectives for in-suite HRVs/ERVs.

The measures for the 20% Reduction Package are:

- Fenestration that meets the specified performance criteria, expected to be triple-glazed.
- Reduced infiltration through better air tightness,
- Improved heat recovery effectives for in-suite HRVs/ERVs

All of the measures shown above are available in the marketplace.

6.4 High-Rise ECM Packages

For the High-rise building, in the following table the “Proposed” column lists the performance characteristics of the major components affecting overall energy efficiency for the Proposed Design that meets the energy efficiency performance required by SB-10 (2017), Division 3. The ECM Package 1 column shows the package of ECMs that will meet the ESMFB requirement for a 15% energy performance improvement. The ECM Package 2 column shows the ECMs selected that will meet the ESMFB requirement for a 20% energy performance improvement.

Table 6-3: High-rise Energy Conservation Measures

Characteristic	Proposed	ECM Package 1 – 15% Reduction	ECM Package 2 – 20% Reduction
Glazing Performance	USI-2.15 (U-0.38) SHGC 0.35	USI-1.85 (U-0.33) SHGC 0.35	USI-1.4 (U-0.25) SHGC 0.30
Lower Flow Fixtures	5.7 LPM Lavs 8.3 LPM Sinks 5.7 LPM Showers	1.9 LPM Lavs 5.7 LPM Sinks 5.7 LPM Showers	-
LED Lighting in Common Areas	Average LPD 4.46 W/m2 (0.41 W/ft2)	-	Average LPD 4.20 W/m2 (0.39 W/ft2)
Hot Water Boilers	93% Condensing	94% Condensing	-
Window-to-Wall ratio	51%	40%	-
Infiltration rates	0.250 L/s.m2	-	0.168 L/s.m2
Air-Side Heat Recovery in Suites	65%	80%	-
Chiller COP	3	-	4.1

The measures for the 15% Reduction Package are:

- Double-glazed fenestration with a small improvement in thermal transmittance,
- Lower flow water fixtures,
- Improvements in the thermal efficiency of the space heating boilers,
- Reduced window-to-wall area from 51% to 40%,
- Improved heat recovery effectives for in-suite HRVs/ERVs.

The measures for the 20% Reduction Package are:

- Fenestration that meets the specified performance criteria, expected to be triple-glazed.
- LED lamps and fixtures with higher efficacy,
- Reduced infiltration through better air tightness,
- Improved chillers with higher COP rating.

All of the measures shown above are available in the marketplace.

6.5 Energy Conservation Package Performance Results

Table 6-4 provides a summary of the energy performance results for the Proposed Design, ECM Package 1 (15% energy performance improvement) and ECM Package 2 (20% energy performance improvement) for each of the three energy archetype buildings. This includes the total annual energy consumption (kWh/yr), the energy use intensity (ekWH/ft^2/yr), and the energy efficiency improvement over the NECB 2015 and the ASHRAE Reference Buildings.

Table 6-4: Summary of Energy Efficiency Modelling Results for Three Buildings

Building		Proposed	ECM Package 1 – 15% Reduction	ECM Package 2 – 20% Reduction
Low-Rise	Annual Energy (kWh)	1,208,400	1,005,500	952,200
	Energy Use Intensity (kWh/m²-year)	232.4	193.4	183.1
	% Change from ASHRAE Baseline	1.7%	18.2%	22.6%
Mid-Rise	Annual Energy (kWh)	1,585,720	1,398,589	1,302,663
	Energy Use Intensity (kWh/m²-year)	208.6	183.9	171.3
	% Change from ASHRAE Baseline	4.8 %	16.0 %	22.0 %
High-Rise	Annual Energy (kWh)	4,175,693	3,498,857	3,238,462
	Energy Use Intensity (kWh/m²-year)	253.7	212.6	196.8
	% Change from ASHRAE Baseline	0.8%	16.9%	23.1%

As shown, each of the packages surpass the performance requirements at both levels of performance indicating that achieving the ENERGYSTAR thresholds is possible with commercially available technologies.

7.0 Estimated Capital Costs of Energy Conservation Measures

A detailed estimate of incremental capital costs for each package of energy efficient measures was prepared by SBC's costing specialist, Dave Wacker, for each building type, and for the two proposed energy performance thresholds

The following tables show the incremental total capital for each measure, and the incremental cost per square metre and per square foot. In addition, the total Reference Building cost estimate is provided, along with the incremental cost for the total package of ECMs as a percent of the total building cost.

7.1. Low-Rise MURB

A summary of the ECM Package Costs for the Low-Rise MURB packages are presented in Tables 7-1 and 7-1.

Table 7-1: ECM 15% Package Cost Breakdown for Low-Rise MURB

ECM No.	Measure	Total Cost	Cost/m^2	Cost/ft^2
1.	Glazing performance improvements -double glazed	$47,520.43	$9.14	$0.85
2.	Exterior wall performance - replace spandrel with brick, 3" mineral v	-$15,422.68	-$2.97	-$0.28
3.	Improve air-tightness to 0.168 l/s·m^2	$6,000.00	$1.15	$0.11
4.	Upgrade to LED lighting in common areas	$6,179.42	$7.18	$0.67
5.	Air side heat recovery: Increase EREto 0.80	$17,200.00	$3.31	$0.31
	Direct Costs, no General Contractor Fees Incuded	$61,477.17	$17.81	$1.66
	HST @ 13%	$7,992.03	$2.32	$0.22
	Direct Costs of ECM Package including HST	**$69,469.20**	**$20.13**	**$1.88**
	Estimated Reference Buildings Cost including HST; Estimated ECM Package Cost, % of total Reference Building Cost	**$13,861,153.72**	**0.50%**	

Table 7-2: ECM 20% Package Cost Breakdown for Low-Rise MURB

ECM No.	Measure	Total Cost	Cost/m^2	Cost/ft^2
1.	Glazing performance improvements -Triple-glazed	$502,104.02	$89.20	$8.29
2.	Improve AC chiller COP to 4.1	$17,886.14	$21.80	$2.03
	Direct Costs, no General Contractor Fees Incuded	$519,990.16	$111.00	$10.32
	HST @ 13%	$67,598.72	$14.43	$1.34
	Direct Costs of ECM Package including HST	**$587,588.88**	**$125.43**	**$11.66**
	Estimated Reference Buildings Cost including HST; Estimated ECM Package Cost, % of total Reference Building Cost	**$13,861,153.72**	**4.24%**	

For the 15% ECM package, 5 measures were selected, one that produced a cost reduction and four that increased cost. Overall the cost of ECM Package 1 was an increase of 0.50%.over the Proposed Design.

For the 20% energy ECM package, two measures were selected. The triple-glazed fenestration added significantly to the overall Proposed Design costs, while the Chiller efficiency improvement was a much smaller cost. Overall, the cost of ECM Package 2 wasan increase of 4.24% over the Proposed Design.

7.2 Mid-Rise MURB

A summary of the ECM Package Costs for the Mid-Rise MURB packages is presented in Tables 7-3 and 7-4.

Table 7-3: ECM 15% Package Cost Breakdown for Mid-Rise MURB

ECM No.	Measure	Total Cost	Cost/m ^{2}	Cost/ft^2
1.	Glazing performance improvement - double glazed	$64,841.76	$8.53	$0.79
2.	Exterior wall performance - remove spandrel	-$19,677.42	-$2.59	-$0.24
3.	Upgrade to LED lighting in common areas	$36,708.00	$4.83	$0.45
4.	DHW low-flow fixture	$49,950.00	$6.57	$0.61
	Direct Costs, no General Contractor Fees Incuded	$131,822.34	$17.34	$1.61
	HST @ 13%	$17,136.90	$2.25	$0.21
	Direct Costs including HST	**$148,959.24**	**$19.59**	**$1.82**
	Estimated Reference Buildings Cost including HST; Estimated ECM Package Cost, % of total Reference Building Cost	**$22,635,030.62**	**0.66%**	

Table 7-4: ECM 20% Package Cost Breakdown for Mid-Rise MURB

ECM No.	Measure	Total Cost	Cost/m ^{2}	Cost/ft^2
1.	Glazing performance improvements -triple glazed	$685,122.32	$83.31	$7.74
2.	Improve Air-tightness to 0.168 l/s·m^2	$6,900.00	$0.91	$0.08
3.	Air side heat recovery: Increase EREto 0.80	$67,500.00	$8.88	$0.82
	Direct Costs, no General Contractor Fees Incuded	$759,522.32	$93.10	$8.64
	HST @ 13%	$98,737.90	$12.10	$1.12
	Direct Costs including HST	**$1,617,782.54**	**$198.30**	**$18.40**
	Estimated Reference Buildings Cost including HST; Estimated ECM Package Cost, % of total Reference Building Cost	**$22,635,030.62**	**7.15%**	

For the 15% ECM package, 4 measures were selected, one that produced a cost reduction and three that increased cost. Overall the cost of ECM Package 2 increased the Proposed Design cost by 0.66%.

The 20% ECM package included 3 measures, of which the triple-glazed fenestration was the most expensive, with a total incremental cost increase of of 7.15% over the Proposed Design.

7.3 Mid-Rise MURB

A summary of the ECM Package Costs for the High-Rise MURB is presented in Tables 7-5 and 7-6.

Table 7-5: ECM 15% Package Cost Breakdown for High-Rise MURB

ECM No.	Measure	Total Cost	Cost/m ^{2}	Cost/ft^2
1.	Glazing performance improvements -double glazed	$201,952.51	$12.27	$1.14
2.	DHW low-flow fixture	$65,860.00	$4.00	$0.37
3.	Improve boiler η to 0.94	$7,087.50	$2.31	$0.21
4.	Reduce WWR to 40%	-$112,652.17	-$6.85	-$0.64
5.	Air side heat recovery: Increase EREto 0.80	$89,000.00	$5.41	$0.50
	Direct Costs, no General Contractor Fees Incuded	$251,247.84	$17.14	$1.58
	HST @ 13%	$32,662.22	$2.23	$0.21
	Direct Costs including HST	**$283,910.06**	**$19.37**	**$1.79**
	Estimated Reference Buildings Cost including HST; Estimated ECM Package Cost, % of total Reference Building Cost	**$51,530,898.70**	**0.55%**	

Table 7-6: ECM 20% Package Cost Breakdown for Mid-Rise MURB

ECM No.	Measure	Total Cost	Cost/m ^{2}	Cost/ft^2
1.	Glazing performance improvements -triple glazed	$1,972,675.78	$119.87	$11.14
2.	Upgrade to LED lighting in common areas	$4,889.00	5.08	0.47
3.	Improve Air-tightness to 0.168 l/s·m^2	$20,400.00	$1.24	$0.12
4.	Improve AC chiller COP to 4.1	$7,087.50	$5.94	$0.55
	Direct Costs, no General Contractor Fees Incuded	$2,005,052.28	$132.13	$12.28
	HST @ 13%	$260,656.80	$17.18	$1.60
	Direct Costs including HST	**$2,265,709.08**	**$149.31**	**$13.88**
	Estimated Reference Buildings Cost including HST; Estimated ECM Package Cost, % of total Reference Building Cost	**$51,530,898.70**	**4.40%**	

For this building, the 15% energy efficiency improvement was achieved with 5 measures, one that produced a cost reduction and four that increased cost, increasing the Proposed Design cost by 0.55%.

The 20% reduction was achieved by 4 measures, of which the triple-glazed fenestration was the most expensive, with a total incremental cost for the package of measures estimated at 4.40% over the Proposed Design.

8.0 Architectural Explorations

Opportunities for potential energy savings inherent in architectural design are becoming more and more significant, as The Ontario Building Code (OBC) takes a stepped approach towards net zero buildings.

As part of meeting this target, the Ontario Building Code is proposing to remove exceptions for calculating thermal bridging effects in large buildings, such as slab edges and balconies, by 2020. The OBC will be limiting allowable trade-offs between building envelope components and mechanical system efficiencies and requiring mandatory air tightness testing, targeting the same date. In the National Energy Code for Buildings 2015 (NECB 2015) and the Toronto Green Standard Version 3 are also considering mandating absolute energy and carbon targets in the next three to five years in lieu of the Reference Building Model approach to establishing an energy efficiency baseline.

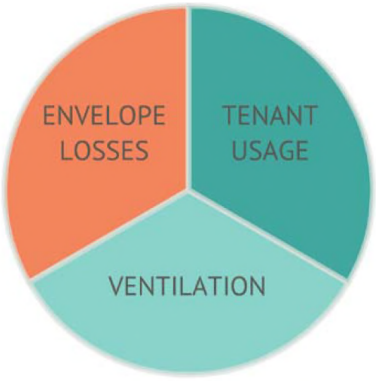
While it is currently possible to rely upon improved mechanical and lighting system efficiencies, the changes identified above will require that building designers use passive architectural measures as a means to meeting mandated energy targets. These measures will include orientation and massing responsive to the local environmental conditions and high-performance glazing and wall systems with reduced thermal bridging.

8.1 Key Design Considerations

The point in time at which decision makers (developers, designers, and planners) have the greatest opportunity to impact the energy usage of a building is at the concept design stage. A building's massing and orientation will impact its energy usage for as long as the building is standing and in use. Finding ways to increase the dialogue around massing and orientation in a way that promotes good decision making is key.

Energy

The energy usage within a typical condo can be broken down into thirds:



The design must consider all of these elements when setting out the massing and orientation of the building.

Other MURB Concerns

Other key issues impacting the design of buildings in our current environment include issues of adaptability to and mitigation of climate change and resilience. The interesting thing about all of these issues is that the solutions lie in passive architectural solutions.

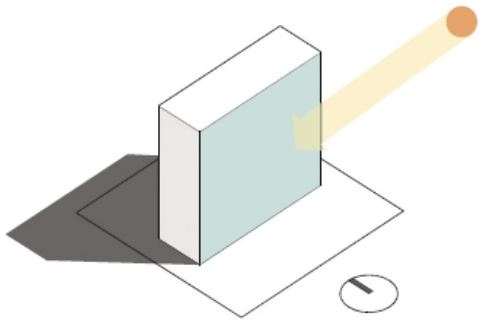
Our building codes and standards, though they have been updated over time, tend to consider life safety in terms of evacuation. In the age of changing climate, it is important that the buildings be designed to allow people to shelter in place for periods of time in the event of a prolonged power failure.

The concept of passive survivability refers to a building's ability to maintain critical life-support functions and conditions for its occupants during extended periods of absence of power, heating fuel, and/or water. A building's ability to remain livable includes its ability to maintain livable temperatures during these times – not overheating without air conditioning and not freezing on the coldest days. Passive architectural solutions, though not strictly mandated by code are again the solution.

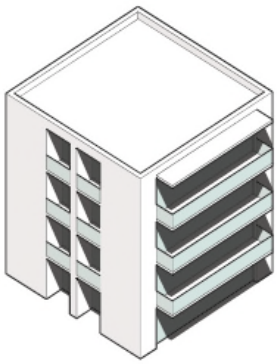
Orientation and Mass

In a reference building approach, the energy performance of the building is not significantly affected by the orientation and massing of the building since the Design Building is reoriented to respond to the cardinal directions, so too is the Reference Building. For this reason, no comparative saving is seen between the two models.

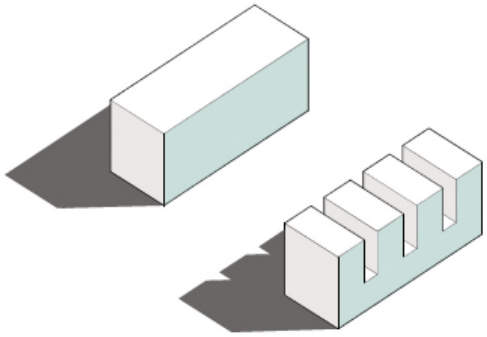
In a move to absolute metrics, such as energy use intensity (EUI), the resultant effects of orientation that allows for passive cooling through natural shading (i.e. locating balconies on the south side and inset balconies on the east and west) is reflected in the EUI value.



Orient building with long axis facing south.



Locate projected balconies on South and inset on East and West for passive self-shading in summer and free heat in winter.



Less envelop = less heat loss
More envelop = sun & air penetration
Balance the two

8.2 Modelling Effective R-Value Accurately

The thermal effectiveness of a building envelope is greatly affected by thermal bridging. Highly conductive components such as steel stud framing, shelf angles, metal flashing and Z-girts, if not detailed properly relative to the insulation, can transfer cold through the envelope from the outside to the inside. Adding more insulation has now been proven to have a diminishing impact if the thermal bridging s not affected.

The current OBC, NECB and ASHRAE 90.1 do not address how to properly assess the impacts of these, seemingly minor, building elements. As a result, outdated charts are used to determine the overall effective R-values of opaque assemblies. This can have an enormous effect.

In 2011, ASHRAE Research Project 1365, “Thermal Performance of Building Envelope Details for Mid- and High-Rise Buildings” was prepared by Morrison Hershfield. This document provides a methodology for calculating the true impacts of thermal bridging in typical assemblies. Out of this document, the Building Envelope Thermal Bridging Guide (BETBG) was also prepared by Morrison Hershfield, and published online by BC Hydro. It is a more comprehensive catalogue of typical details to assist building practitioners in accurately determining the effective R-value of the building envelope.

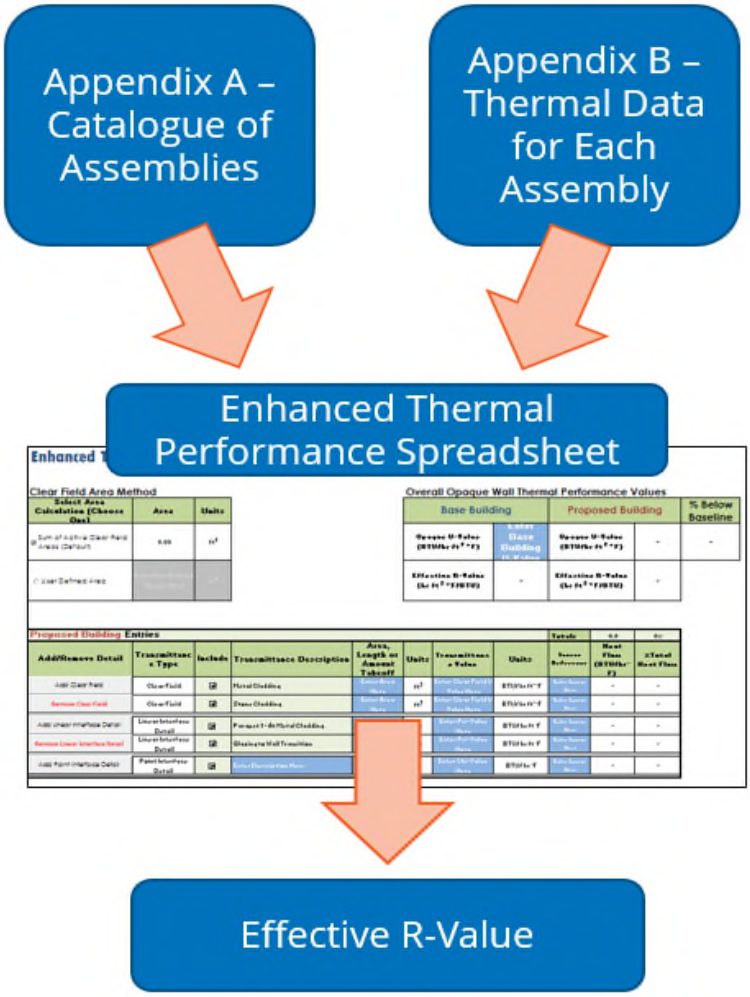
The City of Toronto, in the proposed Toronto Green Standard Version III, is mandating the use of the BETBG in their energy modeling guidelines. TGSIII is expected to be adopted be adopted in 2018. Discussions are happening within the OBC and NECB committees about adopting this same methodology in pending codes.

In the sample buildings studied for this report, all energy modeling was done using the BETBG method for calculating the effective R-value. For each building size, the nominal, traditional (OBC norm) and BETBG values have been provided to demonstrate the significant impact of thermal bridging.

Building Size	Nominal R-value	Traditional R-value	BETBG R-value	Window to Wall Ratio
15+ Storey	R-25	R-20	R-5.9	51%
7-14 Storey	R-20	R-13.3	R-5.7	38%
4-6 Storey	R-21.1/R11.5	R-17.8/R-4.7	R-7.9	32%

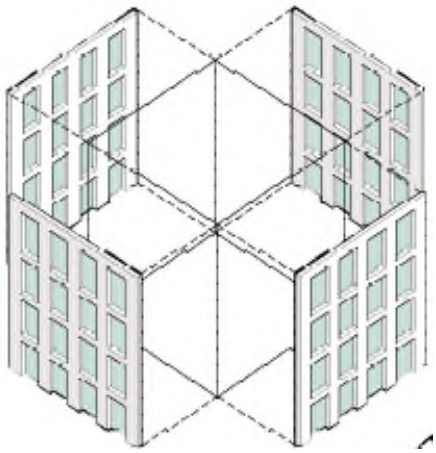
8.3 Using the Building Envelope Thermal Bridging Guide (BETBG)

To use the BETBG, all conditions must be carefully identified – parapets, balcony conditions, mullions, slab edges, windows etc. The BETBG "Catalogue of Assemblies" is then used to determine the thermal data for each assembly. The area and thermal value of each assembly is calculated, area weighted and added together to determine an overall effective R-value for the building envelope.

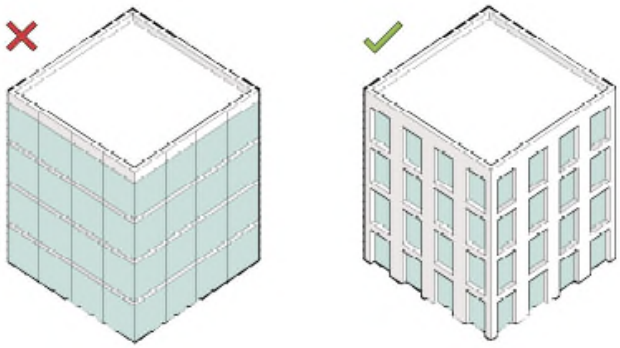


If the BETBG is used as the basis for the BETBG, the following key architectural strategies were used to meet the 15% better than target:

- Window to wall ratio of 40% or lower (punched windows rather than window wall);
- Replacement of opaque spandrel with rain-screen wall assemblies;
- Rain-screen assembly to include thermally broken shelf angles and/or clip system with continuous exterior insulation;
- Improved air infiltration rate from 0.25 to 0.168l/s/m2;
- High performance double glazed window assembly with improved performance from USI-1.99 (U-35), aluminum window wall to USI-1.85 (U-0.33), thermally broken aluminum curtainwall.



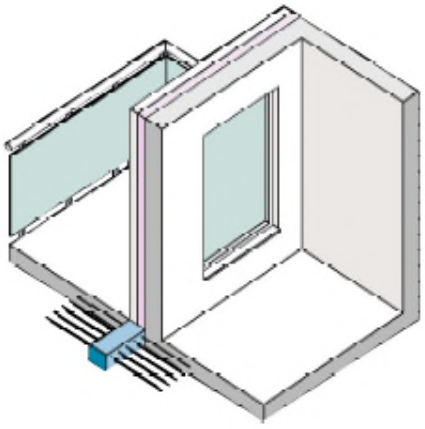
Keep the Window to Wall Ratio to 40%



Use Walls not Window Walls

If the BETBG is used as the basis for the ESMFB program, the following key architectural strategies will likely be required to meet the 20% better than target:

- All of the measures included for the 15% reduction, plus;
- Thermally broken balconies;
- High performance triple glazed window assembly with improved performance USI-1.4 (U-0.25), thermally broken aluminum curtainwall.



Thermally break balconies.

8.4 Recommended Architectural Prescriptive Requirements

The ESMFB program aims to be simpler and faster than other methodologies as well as to be a rigorous and trusted label. The simplest path forward may be to mandate a selection of key architectural design principles along with the 15% or 20% better than target including:

- Maximum 40% window to wall ratio;
- Submission of Thermal Bridging calculations per BETBG;
- Mandatory Air tightness testing.

Passive architectural measures are a real means to meeting mandated energy targets while also addressing both climate change mitigation and adaptation strategies. A building that is sited to take advantage of passive heating and cooling opportunities with a robust building envelope will resist both air and water penetration and have the ability to maintain comfortable indoor air temperatures.

9.0 Conclusions and Recommendations

1. This project began with the selection of three MURB buildings of very recent design that were intended to meet the 2017 Ontario Building Code energy efficiency requirements. This qualified them to function as suitable energy archetypes for the project. It would be possible to find many other MURB buildings having significant design variations that might also have served this purpose.

2. The two energy codes cited in SB-10 (2017) Division 3 were never intended to deliver identical energy efficiency results, and so they do not as demonstrated in Section 2.0. When considered in the context of the wide variety of building types to which the Building Code can be applied, these differences in results will be very broad. One step towards resolving this might be for the ESMFB program to specify the use of only one energy code for purposes of the program.

3. The package of energy conservation measures were chosen by the energy modelling teams to offer one example of a way to meet the proposed targets for the ESMFB program of a 15% or a 20% energy efficiency improvement over the Building Code. Many other ECM Packages could also have been selected.

4. The costing exercise was undertaken to provide estimates of the additional cost for each MURB building size for the Energy Conservation Measures Packages selected. These packages were not selected to meet a minimum cost increase target. This should be also viewed from the perspective that the costs are all based on historical data. Experience has shown that, as new products that deliver higher levels of performance are mandated by code, the market responds by delivering these products at lower cost, and often with even better performance.

5. While there is no doubt that the building capital cost increases as the energy efficiency is raised, there will also be a significant savings in operating costs, and this is expected to rise as the cost of energy increases. There may also be cost trade-offs that occur as a result of the smaller heating and cooling loads associate with advanced envelope performance.

6. By taking a longer term view of investments in capital costs, the building industry is finding that higher investments do have a payback, and one that is often better than expected. A reduction in CO_2e emissions will also be a likely result.