Cost/Benefit Analysis of

Proposed Energy Efficiency Requirements

for the

Toronto Green Standard:

Final Report

SUSTAINABLE BUILDINGS CANADA
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November 2012

This document was prepared for the City of Toronto Planning Department by Energy Profiles Limited under subcontract to Sustainable Buildings Canada (SBC).

Funding for the project was provided by the Toronto Atmospheric Fund through a grant to SBC.

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The project team would like to express their appreciation to the Reference Group who provided their review and guidance, including the following members:
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November 2012

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1.0 Executive Summary

This cost-benefit study is the second phase of a project to provide City of Toronto Planning with recommendations for changing the energy efficiency requirements of the Toronto Green Standard (TGS) so that requirements for buildings constructed in Toronto would match or exceed those required by the Ontario Building Code (OBC). It seems reasonable for TGS Tier 1 to move the market forward in a manner that anticipates the next edition of the Building Code, and to then raise the bar as the Building Code is released. This has been the practice followed in the current TGS.

Effective January 1, 2012, the OBC adopted the same requirements for energy efficiency in buildings and housing as the current TGS (TGS-1). For Part 9 low-rise residential housing the first phase report recommended a performance equivalent to EnerGuide 83 for Tier 1 and EnerGuide 85 for Tier 2. For Part 9 non-residential and Part 3 buildings, the recommendation for Tier 1 was a performance improvement of 5% better than the Building Code for an initial phase-in period moving eventually to 15% above code, and for Tier 2 a performance improvement of 15% for a phase-in period rising to 25% above code.

This cost-benefit study closely follows the methodology presented in the cost-benefit study undertaken for TGS-1. This methodology consists of defining sets of energy efficient measure packages (EMPs) that could be implemented in a new building to improve the energy performance of one energy archetype for Part 9 low-rise housing, and five energy archetypes for Part 3 buildings, for each performance level defined in the Phase 1 report. These five Part 3 archetypes are:

- Multi-Unit Residential building
- Office building
- Retail building
- School building
- Warehouse building

For each building type, the following steps were taken:

- Three[1] EMPs were developed that met each defined performance increment.
- The incremental cost of each EMP was determined.
- The cost impact was evaluated on the basis of simple payback and payback adjusted for the interest cost and energy escalation rate, adjusted internal rate of return, and net present value over 25, 50, and 75 years.

In addition, the immediate impact on the resulting GHG emissions was calculated for each EMP, and the overall avoided GHG emissions from new buildings constructed during the period from 2012 to 2016, and from 2017 to 2021, have been evaluated. Finally the additional investment per unit of gross floor area is presented in each table,

A total of 48 EMPS were evaluated in this manner. While not all EMPs across all building types and performance levels were cost-effective under all three evaluation methods, at the lower performance levels they were, and for the higher performance levels at least one EMP was cost-effective. Furthermore, for an exercise of this type, the EMPs can only address larger steps

[1] Only two EMPs were developed for the Warehouse building

that might be taken while a design team following an integrated design process could implement a large number of small design improvements with a consequent major impact on energy use.

Finally, an effort was made to introduce two advanced technologies having the potential to significantly reduce energy use in select building types but for which the final cost and energy impact will not be fully understood until they are more widely applied.

2.0 Proposed Energy Efficiency Requirements for the Toronto Green Standard

In the Phase 1 report, Sustainable Buildings Canada (SBC) recommended the energy performance requirements for the next edition of the Toronto Green Standard (TGS-2) as shown in Table 2.0-1.

Table 2.0-1: Proposed Energy Performance Requirements for TGS-2

Toronto Green Standard - Commencing When Implemented		
	Requirement	
Project Category	Tier 1	Tier 2
Low-Rise Residential Development	Design building(s) to achieve at least EnerGuide 83 energy efficiency rating	Design and construct building(s) to achieve at least EnerGuide 85 energy efficiency rating
Small (Part 9) Building Non-Residential	Building designed to exceed SB-10 Div. 4 by at least 5% in Phase 1, and by at least 15% in Phase 2.	Building designed to exceed the SB-10 Div. 4 by at least 15% in Phase 1, and by at least 25% in Phase 2.
Mid - High Rise Part 3 Building (any use) $< 2000\ m^2$	Building designed to exceed SB-10 Div. 3 by at least 5% in Phase 1, and by at least 15% in Phase 2.	Building designed to exceed SB-10 Div. 3 by at least 15% in Phase 1, and by at least 25% in Phase 2.
Mid - High Rise Part 3 Building (any use) $\geq 2000\ m^2$	Building designed to exceed SB-10 Div. 3 by at least 5% in Phase 1, and by at least 15% in Phase 2.	Building designed to exceed SB-10 Div. 3 by at least 15% in Phase 1, and by at least 25% in Phase 2.

These proposed performance improvements became significant because of the new energy efficiency requirements in the Building Code that took effect on January 1, 2012, and now match those in TGS-1.

On November 7, 2012, the Ministry of Municipal Affairs and Housing announced the release of the 2012 Building Code (OBC 2012). In the information released, several key announcements were included:

- The new Building Code will come into force on January 1, 2014.
- The next incremental improvement in energy performance, to be made effective January 1, 2017, will be 13% for buildings and 15% for low-rise residential housing through SB-10 and SB-12, respectively, and this timing will not necessarily be linked to the timing of the subsequent Building Code.
- The Building Code will implement a new objective to reduce greenhouse gas emissions.

- The Building Code will implement a new objective to reduce peak electricity demand.

All of these changes will work in favour of Toronto on a number of fronts, but they will also mean that the TGS will need to regularly update its requirements, particularly for energy and also for peak electrical demand and GHG emissions, in order to stay abreast of or ahead of the Building Code.

3.0 Methodology and Determination of Cost/Benefit Analysis Factors

The methodology followed in this study was to extrapolate energy performance and costs of specific building archetypes using recent studies as the foundation, combined with very current experience with builders and developers through the delivery of an innovative demand-side management (DSM) program for Enbridge Gas Distribution program by SBC, launched on January 1, 2012. The methodology followed is described in detail in the following sections.

It should be noted that this study is only able to propose energy measures that have a medium to large scale effect. Capable design teams, using an integrated design process, can provide many more detailed design features that individually may not have a significant effect, but collectively can have a major impact. Furthermore, they can be more readily incorporated in a manner that is more carefully integrated with other key requirements and aspects of the building in the overall result.

3.1. Methodology

The methodology relies on a number of references, described herein by building category as defined in the Building Code.

Part 9 Low-Rise Housing
The following reference studies were used for housing:

1. *A Study of Prescriptive Requirements for EnerGuide 80 in Ontario's Building Code.* Prepared for the Ontario Ministry of Municipal Affairs and Housing, Building and Development Branch by Enerquality and Lio & Associates. 2010.[2]
2. *Multi-Criteria Assessment of New Residential Building Envelope Typologies That Meet 2012 Ontario Building Code Requirements*. Prepared for Ryerson University by Richard Jaan Roos in fulfillment of requirements for MASc in Building Science. 2011.[3]
3. *2012 ENERGY STAR for New Homes Standard*. Natural Resources Canada's Office of Energy Efficiency. 2012.[4]
4. *Next Generation ENERGY STAR for New Homes, Summary of Recommendations from ESNH Builder Option Package Working Groups: Ontario and Saskatchewan*. Natural Resources Canada's Office of Energy Efficiency. 2011[5].

[2] http://www.mah.gov.on.ca/Asset8297.aspx?method=1
[3] Provided by the author
[4] http://library.constantcontact.com/download/get/file/1102918552263-339/2012+ESNH+Standard_Final+31-May-2012.pdf
[5] Public consultation document, withdrawn from circulation

All of these studies included detailed energy measures and associated costing information that would exceed the performance level required by the OBC effective January 1, 2012, and were used to develop measures packages and related costs for this study.

Part 3 Buildings

The main reference studies for Part 3 buildings included the following:

5. *Toronto Green Development Standard, Cost - Benefit Study.* Prepared for Policy and Research, City Planning, by the University of Toronto, John H. Daniels Faculty of Architecture and Design, Ted Kesik and Anne Miller, 2008[6]
6. *Development and Evaluation of Potential Energy Efficiency Changes to the Ontario Building Code,* Prepared for the Ontario Ministry of Municipal Affairs and Housing, Building and Development Branch by Caneta Research Inc., 2006[7]
7. A Baseline Reference Study on building archetypes for use in evaluating approaches to meeting the requirements in SB-10 Division 3. This study is not publicly available.

All three studies developed energy archetypes and costs that would meet defined performance levels that exceeded the then current building code. Energy archetypes representing 85% to 90% of the Ontario building stock were used from Reference Study 5 as these were developed for the three energy code options cited in OBC Supplementary Standard SB-10 (SB-10) that met the fundamental performance requirement of exceeding the MNECB by 25%[8]. The archetypes selected were modelled to represent the energy performance specified in ASHRAE 90.1-2010 and SB-10/Division 3 (SB-10/D3) that came into effect on January 1, 2012. They were also modelled to exceed the requirements of SB-10/D3 in anticipation of energy efficiency requirements in OBC 2017.[9] For each building type, incremental costing was provided in the study and, if necessary, updated for inflation.

From the information in these and other studies, a set of Energy Measures Packages (EMPs) were developed for each building type that would meet or exceed the proposed energy performance levels specified in the Phase I report. These EMPs were then assessed for their incremental cost and energy and energy cost performance in detail using information from the three studies as well as from other industry references.

These studies are described more fully in Section 4 of this report.

Enbridge Savings By Design Program

The main objective of this program is to assist proponents to exceed the energy performance defined in the SB-12 for Part 9 low-rise housing, and SB-10/D3 (Part 3 buildings and Part 9 non-residential buildings) by 25%.

Delivery of this program by SBC has provided very current measures and costing information that has proven to be useful in the study. The program offers proponents assistance in achieving the target of an energy performance 25% better than the current OBC by providing a one-day design charrette that focuses on energy performance and other sustainable performance targets. Experts with specific knowledge about various aspects of building design and performance are invited to participate, and SBC organizes and facilitates the day, as well as

[6] http://www.toronto.ca/planning/environment/consultantsreport.htm
[7] http://www.mah.gov.on.ca/Asset8298.aspx?method=1
[8] *Development of Energy Efficiency Requirements for the Toronto Green Standard: Final Report, p. 25*. Sustainable Buildings Canada, 2012.
[9] *Ibid., p. 27*

providing a final report to the proponent. Of particular interest is that some low-rise builders can achieve the performance target with very little change to their current design and construction practice.

3.2. Evaluation Methods

To evaluate the various EMPs in terms of cost effectiveness, three analyses were completed for each EMP. The costing evaluation methods include Simple Payback (SPB), Adjusted Internal Rate of Return (AIRR), and Net Present Value (NPV) assessment over 25, 50, and 75 year timeframes. With the exception of AIRR, the methodologies from Reference Study 5 have generally been followed to provide a simple comparison with past results.

The cost analysis approaches used in this study are based on standard methods, and selected to reflect the economic perspectives of key stakeholders. The three key stakeholders concerned with buildings are builder/developers, consumers (building owners and tenants), and society, and the three measures of cost effectiveness reflect the concerns of these three key stakeholder groups, as follows:

- Internal rate of return is the concern of the builders/developers who want to know that the extra incremental cost will be worthwhile to their business and will provide the same rate of return as the business-as-usual approach.
- Payback periods are the concern of building owners and tenants who want to know how long it will take for savings, in this case from energy conservation measures, to pay back their original incremental cost.
- Net present value is a life cycle cost and is the concern of society. As used in this report it expresses only the energy and capital costs associated with a particular proposal over a specific timeframe. This number is then easily compared to other proposals to come up with the best alternative for the building.

The following formulae were used in the determination of the three factors:

1. <u>Payback and Modified:</u>

$$\text{Simple Payback} = \frac{\text{Initial Investment Cost}}{\text{Annual Operating Savings}}$$

$$\text{Payback} = \frac{\log\left[1 + (SPB)(1-(1-i)/(1+e))\right]}{\log\left[(1+e)/(1+i)\right]}$$

where:

SPB = simple payback, or the period of time, expressed in years, over which investments are recovered to the break even point.
i = interest or discount rate.

e = escalation rate.

Simple Payback does not take into account the cost of money and the escalation of energy costs, while the modified Payback does this. Both Simple Payback and the modified Payback are provided for each Energy Measure Package.

2. Adjusted Internal Rate of Return:

$$AIRR = (1+i)\ SIR^{1/N} - 1$$

where:

i = interest or discount rate.
SIR = Savings to Investment Ratio: present value of operational savings divided by present value of additional investment costs.
N = number of periods.

AIRR, also called Modified Internal Rate of Return, is a geometric average of the compounded future value of positive cash flows over the discounted present value of negative cash flows and overcomes some of the shortcomings of IRR. AIRR assumes that the reinvestment rate from the cash flows is the cost of capital. This is in contrast to IRR's assumption where reinvestment rate is IRR itself. In most cases MIRR is less than IRR.

3. Modified Uniform Present Value (UPV*):

$$UPV^* = (1+e)/(i-e)[1-((1+e)/(1+i))^N]$$

$$PV = A_0 \times UPV^*$$

where:

A_0 = annually recurring cost at base-date prices
i = interest or discount rate.
e = escalation rate.
N = number of periods.

This method takes into account changing annual amounts due to escalation.

4. Net Present Value of EMP:

$$NPV = (NPV_{Base} + EMP_{Cost}) - (UPV^* \times E_{Savings})$$

where:

NPV_{Base} = Net present value of baseline annual energy costs
EMP_{Cost} = Cost of energy measure package.

$E_{Savings}$ = Net present value of annual energy savings for EMP.

This value may be positive or negative – a positive value over the defined period indicates that the EMP has lowered the present value of overall cost of the building, while a negative value indicates that it did not provide a positive financial result within the defined time period.

3.3. Determination of Discount Rate and Fuel Escalation Rate

To perform the modified Simple Payback, Adjusted Internal Rate of Return, and the Net Present Value calculations, two factors are required: the interest or discount rate and the energy escalation rate.

The discount rate is defined as the annual interest rate used to evaluate the net present value of future costs, and savings. As an investment decision tool, the discount rate represents the minimum acceptable interest or discount rate for an investment. Private sector property owners need to consider the discount rate when deciding whether to invest some of their profits in components or systems that can reduce future operating costs and/or increase revenues, or whether to give the profit back to their shareholders. In an ideal world, they would only invest if the shareholders would get a bigger profit later.

The fuel escalation rate is defined as the compounding increase in energy (or energy savings) every year.

In the *Toronto Green Development Standard Cost-Benefit study* undertaken in 2008, a "Current" rate scenario and a "High" rate scenario were specified for the two factors, and these are presented in Table 3.2-1.

Table 3.2-1: Discount and Energy Escalation Rates Used in the Earlier Cost-Benefit Study

U of T Cost-Benefit Study, 2008	Current Rate Scenario	High Rate Scenario
Discount (Interest) rate	5.5%	7.0%
Annual Energy Cost Escalation rate	8.0%	12.0%

Review of Electricity Forecasts

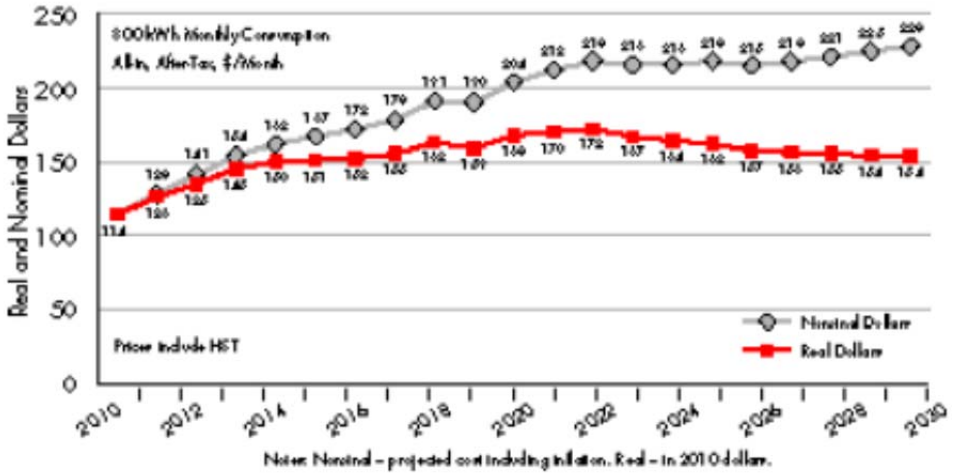
For the Annual Fuel Cost Escalation rate for electricity, we examined the rates cited in *Ontario's Long Term Energy Plan* (2010)[10] (LTEP), and in a recent study by the Pembina Institute entitled *Behind the Switch, Pricing Ontario Electricity Options* (2011)[11]. The provincial government's plan for electricity projected average annual increases of 2.7% for the period from 2010 to 2030 for industrial users, and 7.9% over 5 years averaging out to 3.5% for small business and homeowners, including inflation in each case.

The projected increase for homeowners from the LTEP is shown in Figure 3.2-1, in both "Real" dollars (constant 2010 dollars – in red) and "Nominal" dollars (inflated dollars – in grey). It should also be noted that the costs shown on the Y-axis are the average monthly bills that a customer using 800 kWh/month would pay. Because there is not an equivalent chart provided

[10] http://www.mei.gov.on.ca/en/pdf/MEI_LTEP_en.pdf
[11] http://www.pembina.org/pub/2238

for the commercial sector, we have elected to use the more detailed projections provided for the small business and homeowners rate as the representative cost to estimate the electricity escalation rate for this study.

Figure 3.2-1: Residential Long Term Electricity Plan Projections



The Pembina Study examined the impact of reducing renewables against a current plan scenario and a reduced renewables scenario, which resulted in very little difference. In addition, they examined a high natural gas price scenario and a high nuclear price scenario. In all cases, the time horizon was 20 years (2010 to 2030) and the fuel price is in constant 2010 dollars. These are presented in the Figures 3.2-2 and 3.2-3.

Figure 3.2-2: Pembina Report Electricity Projections – High Natural Gas Prices

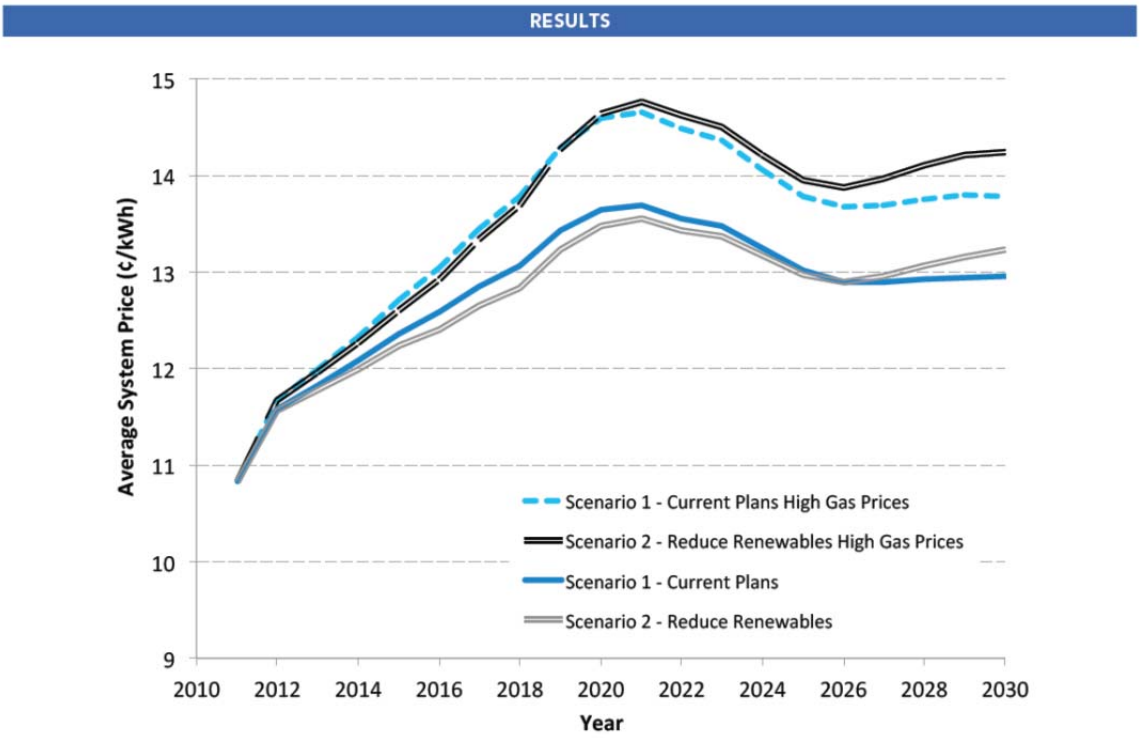


Figure 18: Simulation results with high natural gas prices (2010 constant Canadian dollars)

Figure 3.2-3: Pembina Report Electricity Projections – Increased Nuclear Costs

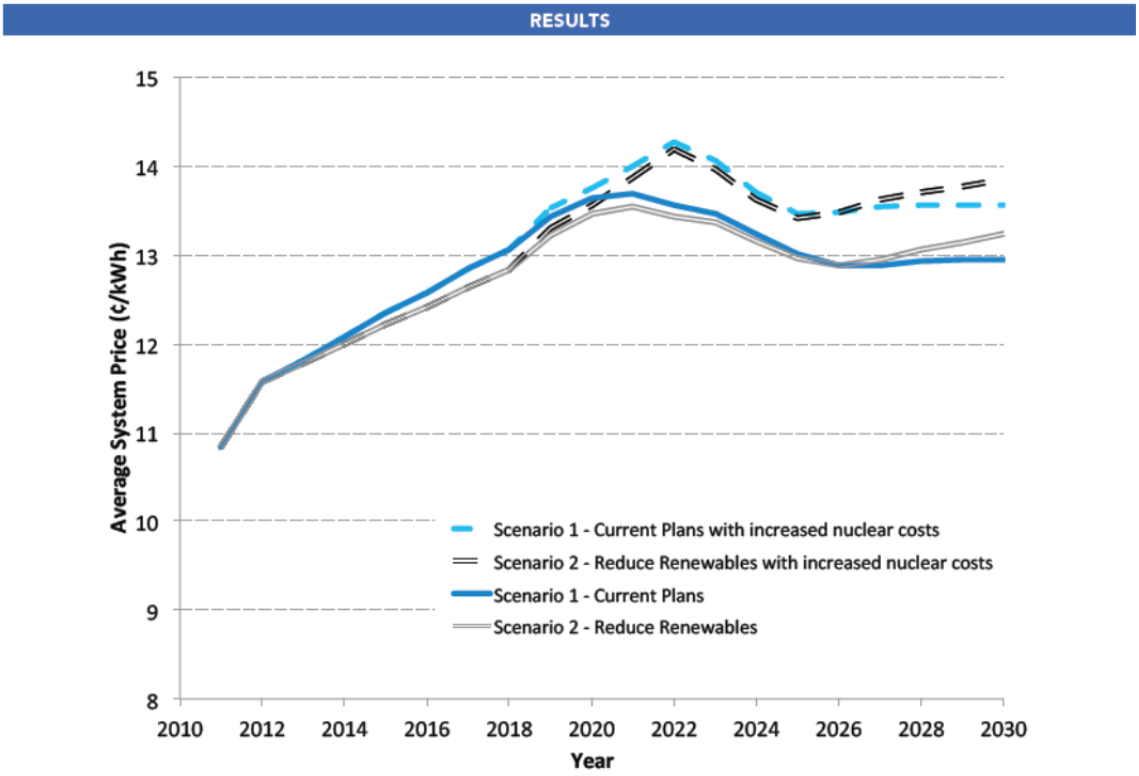


Figure 19: Simulation results with 25 per cent increase in nuclear costs (2010 constant Canadian dollars)

This study used the “system cost”, defined as the sum of producer selling price to the grid and transmission costs, but did not include distribution costs, stranded debt charges, plus some other costs that makeup the total cost charged to a business or a consumer for one kilowatt-hour (kWh).

Information was taken from LTEP using Figure 3.2-1 as the baseline. The current plan was corrected for the difference between the system cost and the retail price. The three scenarios from the Pembina study, the current plan, high natural gas, and increased nuclear cost scenarios (Figures 3.2-2 and 3.2-3) are presented in Table 3.2-2 below, along with a fourth, and worst-case scenario that combines high gas prices and increased nuclear costs. These data from the Ontario study were corrected to a cost per kWh, and the data from the Pembina study were adjusted to correct for the additional costs beyond the system cost paid by a business or consumer. The annual escalation rate for each of the scenarios was analyzed to determine the escalation rate with no inflation, and with inflation at an annual 2% consistent with the stated policy of the Bank of Canada to maintain the economy at or near this level. The results are presented in Table 3.2-2.

Table 3.2-2: Summary of Electricity Escalation Rates

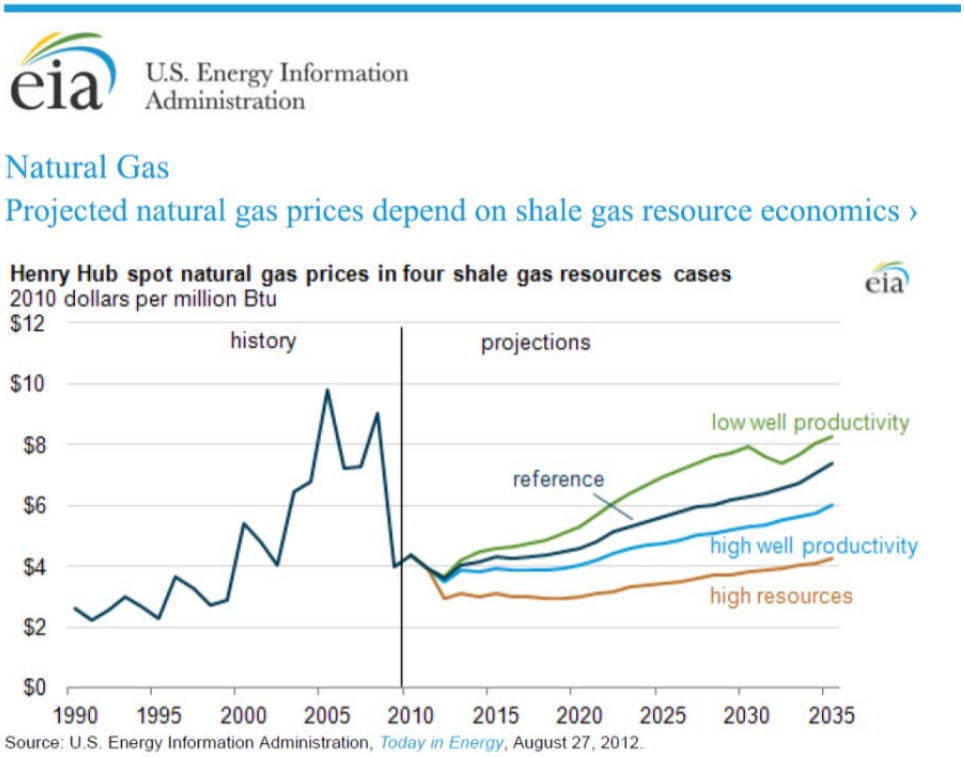
Source	Scenario	2010 System Cost, $/kWh	2010 Total Cost, $/kWh	2030 System Cost Using 2010 $	2030 TotaL Cost Using 2010 $	2030 TotaL Cost Including Inflation @ 2%
Ontario's Long Term Electricity Supply Plan	Current Plan scenario		$0.143		$0.193	$0.288
	Annual electricity price escalation rate				1.51%	3.57%
Pembina "Behind The Switch" Report	Current Plan scenario	$0.107	$0.143	$0.130	$0.193	$0.289
	Annual electricity price escalation rate			0.96%	1.51%	3.58%
	High Gas Prices scenario	$0.107	$0.143	$0.138	$0.206	$0.308
	Annual electricity price escalation rate			1.28%	1.83%	3.91%
	Increase in Nuclear Costs scenario	$0.107	$0.143	$0.136	$0.203	$0.304
	Annual electricity price escalation rate			1.21%	1.76%	3.84%
	High Gas Prices + Increase in Nuclear Costs	$0.11	$0.143	$0.145	$0.215	$0.323
	Annual electricity price escalation rate			1.53%	2.07%	4.15%

Review of Natural Gas Forecasts

For natural gas we used the latest forecast prepared by the US-DOE Energy Information Administration (2012)[12], which is valid for Canada because the market for natural gas is set on a North American wide basis. This is shown in Figure 3.2-4. Note that prices are in constant 2010 dollars.

[12] http://www.eia.gov/todayinenergy/detail.cfm?id=7710

Figure 3.2-4: US-DOE Energy Information Administration Natural Gas Forecast



A similar analysis of the EIA data was conducted to determine an average annual escalation rate for natural gas, corrected for an annual inflation rate of 2%. The results are presented in Table 3.2-3.

Table 3.2-3: Summary of Natural Gas Escalation Rates

Source	Scenario	2010 Natural Gas Cost, $/10^6 Btu	2030 Cost Using Constant 2010 $	2030 Cost Including Inflation @ 2%
US - DOE Energy Information Administration	Reference Case	$3.95	$6.15	$9.21
	Annual fuel price escalation rate		2.24%	4.32%
	Low Well Productivity scenario	$3.95	$7.95	$11.91
	Annual fuel price escalation rate		3.56%	5.67%

Recommended Rates for This Study:
Discount Rate

The current discount rate cannot be precisely determined for new buildings due to variations in ownership of building types and their perspective on the length of time the building will remain as that type, their investment objectives and horizon, their ability to increase revenues for "green" features, and a number of other variables. In general, building owners and developers have a longer term focus. Therefore, in spite of the current low interest rates, we recommend continuing with the two discount rates assumed in the previous study.

Energy Escalation Rate

The energy escalation rate for the current scenario could reasonably be assumed as a blend of the current scenario for electricity (3.57%) and the reference case for natural gas (4.32%). Since most buildings utilize electricity and natural gas within a range of 40% to 60% and 60% to 40%, respectively, depending upon their internal loads, we propose a blended rate on a 50% - 50% basis. However, electricity costs in Ontario have a long history of exceeding their forecasts, and EIA has noted the potential aspects that could affect natural gas costs including low or high well productivity particularly related to shale gas. For these reasons, we have used a current rate scenario of 5.0% and a high rate scenario of 8.0%.

Final Interest (discount) and Energy Escalation Rates

The factors used in this report are summarized in Table 3.2-4.

Table 3.2-4: Summary of Interest and Escalation Rates

SBC Cost-Benefit Study, 2012	Current Rate Scenario	High Rate Scenario
Discount (Interest) rate	5.5%	7.0%
Annual Energy Cost Escalation rate	5.0%	8.0%

Modified Uniform Present Value Factors (UPV*)

Table 3.2-5 shows the UPV* factors that have been calculated from the factors presented in Table 3.2-4.

Table 3.2-5: Discount and Energy Escalation Rates Used in the Cost-Benefit Study

Modified Uniform Present Value (UPV*)Factors		
Interest (Discount) Rate	5.5%	7.0%
Annual Energy Cost Escalation rate	5.0%	8.0%
Period - 25 years	23.5166	28.2772
50 years	44.3996	63.9581
75 years	62.9442	108.9812

These factors are significantly lower than those used in the TGS-I costing study due to the lower energy escalation rates. For instance, the 25 year current scenario factor was 34.3830, and the 75 year high scenario was 665.9612 in the earlier study.

Energy Costs

The current energy costs for electricity and natural gas that have been applied to the projected annual energy consumption are presented in Table 3.2-6.

Table 3.2-6: Summary of Energy Costs

Energy Source	Unit Cost
Electricity, $/kWh	$0.11
Natural Gas, $/$m^3$	$0.22

4.0 Review of Reference Costing Studies

4.1. ENERGY STAR for New Houses

The Part 9 archetype residential building was derived from a research report entitled *A Study of Prescriptive Requirements for EnerGuide 80 in Ontario's Building Code.*[13] The research undertaken resulted in the prescriptive packages published in Supplementary Standard SB-12 that could be adopted by a builder to meet a performance level equivalent to EnerGuide 80. SB-12 became the OBC requirement for Part 9 residential construction effective January 1, 2012. The original archetype achieved an EnerGuide rating (ERS) of 77, and the report includes annual energy consumption and construction costs for the prescriptive packages included in SB-12 that were deemed to meet ERS 80.

The basis of the energy conservation measures to exceed ERS 80 is the public consultation document entitled *Next Generation ENERGY STAR for New Homes, Summary of Recommendations from Next Generation ESNH Building Option Package, Working Groups: Ontario and Saskatchewan*[14]. The ENERGY STAR for New Homes (ESNH) program requires an energy performance level of 20% above ERS 80, and this report provides a comprehensive set of Builder Option Packages (BOPs) including their performance impact and incremental cost. The working group who developed these BOPs also evaluated options for performance improvements above ERS-80 ranging from 15%-30%, and these have been used to meet the proposed performance requirements for TGS-2.

The basic systems and equivalent values for Ontario Zone 1 (≤ 5000 heating degree-days - includes Toronto) BOPs are listed in Table 4.1-1, which is adapted from Section 6.1.4, Table 8 of *2012 ESNH Standard.*

[13] http://www.mah.gov.on.ca/Asset8297.aspx?method=1
[14] Prepared for internal committee review. July 8, 2011

Table 4.1-1: ENERGY STAR Prescriptive Approach – Ontario Climate Zone 1 Core Builder Option Package Requirements

Item	Zone 1 (0-4999 HDD) RSI (RVALUE)
Ceilings below attic	8.66 (49.2)
Cathedral ceilings and flat roofs	4.87 (27.7)
Walls above grade	3.08 (17.5)
Floors over unheated spaces	4.87 (27.7)
Foundation Walls below or in contact with the ground	2.98 (16.9)
Unheated floors – above frost line	1.96 (11.1)
Heated or Unheated floors on ground on permafrost	n/a
Heated floors on ground	2.32 (13.2)
Slab on grade with integral footing	1.96 (11.1)
Fenestration	ENERGY STAR Zone B
Space Heating	95% AFUE ENERGY STAR furnace or boiler
	Air-source heat pump
	Ground-source heat pump
Water Heating	EF 0.67
Combined space and water heating	95% AFUE Energy Star boiler
Ventilation Electrical Savings Minimum BOP options (per table 9 of *2012 Energy Star for New Homes Standard)*	60% SRE @ 0°C; 55% SRE @ -25°C 400kWh/yr 2.4 points

4.2. Part 3 Building Archetype Reference Study

The Building Archetype Reference Study[15] provided the five energy archetypes used in this report. These archetypes were developed for a Toronto location using energy modeling to meet the performance requirements specified in SB-10/D3, are therefore the baseline against which the performance of the EMPs have been evaluated. There is one change to the study archetypes relating to Warehouse buildings due to an exemption introduced in the final version of SB-10, and this is discussed in Section 5.6 and is reflected in the following tables.

The building descriptions and the energy end-use intensity of each type are presented in Tables 4.2-1 and 4.2-2, respectively.

[15] At the time of writing this report, the study was not available to the public.

Table 4.2-1: Building Archetype Descriptions

Building Type	Gross Floor Area, ft^2, (m^2)	No. of Storeys	Window-to-Wall Ratio	Wall-to-Roof Area Ratio	Building Envelope	Zoning	Space Heating Fuel	HVAC
High Rise Office	144,000 (13,378)	10	40.0%	4.3	Walls are 75% curtain wall & 25% concrete block with brick veneer and interior insulation & drywall	5 uniformly loaded zones/flr with a 1570 ft^2 permiter zone on each of 4 major orientations plus a core zone using 57% of floorspace.	NG	6 built up VAV systems with 1 gas boiler. Cooling by reciprocating chiller and a cooling tower.
High Rise MURB	146,450 (13,605)	20	50.0%	8.1	Walls are 75% window wall and 25% concrete block with brick veneer and interior insulation and drywall.	6 dwelling units and I core zone per flr.	NG	2-pipe Fancoil in each DU supplied by a single gas boiler and a single water-cooled chiller. Central corridor ventilation from gas-fired/DX rooftop unit.
Retail	190,118 (17,662	1	18.2%	0.42	Walls are insulated cavity with brick veneer	One 89,115 ft^2 anchor store with several small retail stores sized from 600 to 2400 ft^2.	NG	Separate rooftop htg/clg/vent constant volume systems with natural gas htg and DX clg for each retails store, and several similar systems for the anchor store.
School	69697 (6475)	2	16.3%	0.7	Walls are insulated cavity with brick veneer	Classroooms, administration area, gymnasium.	NG	2 packaged VAV systems for classrooms, I packaged VAV system for admin, 1 packaged single zone system for gym. All systems include hydronic heating and DX cooling; reheat in the zones is hydronic.
Warehouse	41,884 (3,891)	1	3.5%	0.7	Walls are poured concrete with no insulation.	Office (10% of floorspace); warehouse	NG	10% Office area with rooftop HVAC. Warehouse htg by unit htrs, no A/C

Table 4.2-2: Building Archetype Energy End-Use Intensity

Archetype Energy End-Use Intensity, ekWh/ft^2/yr					
Energy End-Use	High-rise Office	High-Rise MURB	Retail	School	Warehouse
Space Heating	6.3	6.7	6.5	8.4	17.5
Space Cooling	0.8	0.6	0.8	1.0	0.05
Lighting	1.6	1.8	5.5	2.7	1.9
Water Heating	3.4	5.1	1.0	3.3	0.8
Auxiliary Equip.	3.3	1.2	0.8	1.3	0.3
Auxiliary Motors	1.7	2.1	1.9	1.9	0.9
Total	17.1	17.6	16.5	18.7	21.4

4.3. SB-12, SB-10 Division 3, and ASHRAE 90.1-2010

Ontario Supplementary Standard SB-12 is now reference in the Building Code as the only document that specifies the energy efficiency requirements for Part 9 residential buildings. The options offered include:

- A prescriptive path to achieve an energy performance equivalent to a rating of ERS 80
- A performance path that meets the equivalent of ERS-80
- Meeting the technical requirements of the ENERGY STAR for New Homes (ESNH) technical requirements.

Ontario Supplementary Standard SB-10 is now referenced in the Building Code as the single document that establishes the energy efficiency design and construction of all buildings except Part 9 residential buildings. Division 3 of SB-10 modifies the Building Envelope of Standard 90.1 by substituting the tables that specify the thermal performance of envelope components from Standard 189.1-2009 for those found in Standard 90.1-2010. This was found to be necessary to meet the energy performance originally specified in the OBC 2006 on a floorspace weighted, building occupancy type weighted, average for the province.

The American Society of Heating, Refrigerating and Air Conditioning Engineers (ASHRAE) Standard 90.1-2010 has as its purpose to provide minimum requirements for the energy-efficient design of buildings except low-rise residential buildings, for:

1. design, construction, and a plan for operation and maintenance, and
2. utilization of on-site, renewable energy resources.

Standard 90.1-2010 includes a significant number of improvements to energy efficient design practice not previously required, including:

- Air or water economizers for specific HVAC systems
- Greater use of controls that match energy use to part load operation of HVAC systems
- Energy recovery for specific air system types and applications
- Automatic lighting controls including daylight sensing controls, for specified applications
- Automatic control of receptacles for specified loads and applications.

The effect of the energy efficiency requirements specified in these documents has been to significantly raise the bar for new houses and buildings that apply for a permit after December 31, 2011.

4.4. ASHRAE Advanced Energy Design Guides

ASHRAE has published the Advanced Energy Design Guide (AEDG) series that provides a sensible approach to easily achieve advanced levels of energy savings without having to resort to detailed calculations or analysis. The four-color guides offer designers the tools, including recommendations for practical products and off-the-shelf technology, that can provide guidance to achieving significant energy savings.

The first series[16] offers an energy performance for select building types that is 30% less than buildings that meet the minimum requirements of ANSI/ASHRAE/IESNA Standard 90.1-1999. The energy savings target of 30% is the first step in the process toward achieving a net-zero energy building, which is defined as a building that, on an annual basis, draws from outside resources equal or less energy than it provides using on-site renewable energy sources. Building types include:

- Small Hospitals and Healthcare Facilities
- Highway Lodging Hotels
- Small Warehouse and Self-Storage Buildings
- Kindergarten to Grade 12 School Buildings
- Small Retail Buildings
- Small Office Buildings

The second series[17] offers contractors and designers the tools, including recommendations for practical products and off-the-shelf technology, needed for achieving a 50% energy savings compared to buildings that meet the minimum requirements of ANSI/ASHRAE/IESNA Standard 90.1-2004. Building types include:

- Small to Medium Office Buildings
- Kindergarten to Grade 12 School Buildings

Where applicable and useful, these design guides provided some guidance on design methods for exceeding the current Building Code requirements.

4.5. Toronto Green Standard Phase I – Cost/Benefit Study

This study[18], undertaken by the University of Toronto School of Architecture and Design, provided the analysis methodology and reference energy performance and capital cost information for Part 3 buildings. It provides an excellent background description to the methodology, along with extensive discussion about the measures. However, with the

[16] http://www.ashrae.org/standards-research--technology/advanced-energy-design-guides/30-percent-aedg-free-download
[17] http://www.ashrae.org/standards-research--technology/advanced-energy-design-guides/50-percent-aedg-free-download
[18] http://www.toronto.ca/planning/environment/consultantsreport.htm

introduction of the energy efficiency requirements in SB-10/D3, a significant number of the measures included in this report have been overtaken and are now required practice.

An interesting aspect of the approach taken in this study was to use a total energy cost for the reference building and to compare this to the total energy cost for each energy efficient measure or package of measures. The definition in the TGS-I clearly states that the performance increment will be based on energy performance and not energy cost performance, and the proposals recommended for TGS-2 follow this methodology.

4.6. Other Information Sources

A number of other reports and presentations provided information of relevance to this study. These are briefly described herein.

Part 9 Housing

- *In-Suite Ventilation in High-Rise MURBS* Presentation by Subhi Alsayed of Tower Labs, Toronto.[19]
- *New Housing Programs' 2012 Energy Credits.* NRCan ecoEnergy Initiatve.
- *ENERGY STAR for New Homes Tables for Calculating Effective Thermal Resistance of Opaque Assemblies 2012.* NRCan.
- *2012 R-2000 Standard.* NRCan

Part 3 Buildings

- *Towards Carbon Neutral Buildings in BC*; *Framework for High-Rise Multi-Unit Residential Buildings*. Light House Sustainable Building Centre Society and Intep LLC. June 12, 2012[20]
- *SB-10 – The Envelope Ultimatum.* Presentation by Scott Armstrong, MMM Group Limited[21]
- *Archetype Condo Project.* Presentation by the project team[22]
- *Effective Mechanical Ventilation for Multi-Unit Residential Buildings*. Presentation by Mark Salerno, CMHC[23]
- *Cost of Green Revisited: Reexamining the Feasibility and Cost Impact of Sustainable Design in the Light of Increased Market Adoption.* Davis Langdon. July 2007[24]

5.0 Cost/Benefit Analysis

This section includes a description of the baseline energy and energy cost performance for each building archetype, as well as the annual greenhouse gas emissions resulting from their use of energy. For each TGS-2 proposed performance level of 5% (Tier I Phase 1), 15% (Tier I Phase 2 and Tier II Phase 1), and 25% (Tier II Phase 2), a set of EMPs have been developed that will meet those energy performance levels. In addition, incremental capital costs, energy costs,

[19]. Presentation at the SBC *2012 Green Building Festival*
[20] http://www.sustainablebuildingcentre.com/research/
[21] Presentation at the SBC *2012 Green Building Festival*
[22] Presentation at the SBC *2012 Green Building Festival*
[23] Presentation at the SBC *2012 Green Building Festival*
[24] http://www.davislangdon.com/USA/Research/ResearchFinder/2007-The-Cost-of-Green-Revisited/

GHG emissions, and the cost of each EMP per square foot of gross floor area have been developed and are presented in the tables.

A summary of the difference in NPV of the baseline energy cost, and the sum of the NPV of the energy use with the EMP included and the incremental cost of the EMP, is presented to show the incremental cost savings for the three periods. Where the result is negative, the figures are shown in red.

5.1. Low-Rise Housing

The NPV of the energy consumed by the Reference House that meets Supplementary Standard SB-12 – approximately equivalent to ERS 80 – is presented in Table 5.1-1, including the energy costs, GHG emissions, and net present value of energy costs under the current and high scenarios, and for the three study periods of 25, 50 and 75 years.

There is a significant discussion on the EnerGuide Rating System in the Toronto Green Standard Phase 1 report.[25] Most of the improvements in the energy performance have traditionally come from the building structure, but with the introduction of *ESNH* for 2012, improvements in mechanical system efficiency and appliances such as ENERGY STAR are now included.

Table 5.1-1: Part 9 Residential Reference Building Baseline Energy Performance

Economic Assessment Parameters — **Low-Rise Housing**

Two interest (discount) rate and energy escalation rate scenarios are considered in this analysis

	Current	*High*
Interest Rate	5.5%	7.0%
Energy Escalation Rate	5.0%	8.0%
Study Period, years	25	25
	50	50
	75	75

Building GFA, ft^2	2,150		Annual	Current				High			
		Cost, $: Measure $/ft2; Measure $;	Savings, $; % Energy Cost; % Energy	Payback, yrs, Simple; Adjusted		IRR	NPV	Payback, years		IRR	NPV
Baseline		$0	$0	N/A		(25 yr NPV)	$ 32,030	N/A		N/A	$ 38,514
$ 869	Electricity		0%			(50 yr NPV)	$ 60,472				$ 87,111
$ 493	Nat. gas					(75 yr NPV)	$ 85,730				$ 148,432
5	T of CO_2e										

5.1.1 EMPs to Meet an Energy Performance Improvement ≥ 15%

A rating of ERS 83 is equivalent to an energy performance improvement in the range of 15% to 20%. Therefore a target of at least 15% was used for the three sets of EMPs presented in Table 5.1-2.

[25] *Development of Energy Efficiency Requirements for the Toronto Green Standard: Final Report*, pg 10.

Table 5.1-2: Energy Measure Packages ≥ 15%

Economic Assessment Parameters — **Low-Rise Housing**

Two interest (discount) rate and energy escalation rate scenarios are considered in this analysis

	Current	*High*
Interest Rate	**5.5%**	**7.0%**
Energy Escalation Rate	**5.0%**	**8.0%**
Study Period, years	**25**	**25**
	50	**50**
	75	**75**

EMP 1: Above grade walls RSI 3.90 (R24); Tankless water heater EF ≥ 0.90; Improve air tightness by 1.0 ACH.

TGS Category - Tier 1					**Current**			**High**		
Baseline Energy Cost		**Cost**	**Annual Savings**		**Payback, years**	**IRR**	**NPV**	**Payback, years**	**IRR**	**NPV**
		$ 0.79								
		$ 1,700	$ 100		17.0	6.9%	**$ 31,378**	17.0	9.2%	**$ 37,386**
$ 869	Electricity	$ 869	7.3%		17.8		**$ 57,732**	15.7		**$ 82,415**
$ 493	Nat. gas	$ 393	15.4%				**$ 81,136**			**$ 139,234**
5	T of CO_2e	4								

EMP 2: Above grade walls RSI 4.48(R25.4); Tankless water heater EF ≥ 0.90, HRV with 75% SRE. Below grade walls RSI 4.67(R27), Drain water heat recovery unit (≥ 42% steady state efficiency, serving one shower)

TGS Category - Tier 1					**Current**			**High**		
Baseline Energy Cost		**Cost**	**Annual Savings**		**Payback, years**	**IRR**	**NPV**	**Payback, years**	**IRR**	**NPV**
		$ 1.13								
		$ 2,420	$ 110		22.0	5.8%	**$ 29,656**	22.0	8.1%	**$ 35,170**
$ 869	Electricity	$ 869	8.1%		23.3		**$ 53,844**	19.9		**$ 76,497**
$ 493	Nat. gas	$ 383	16.9%				**$ 75,322**			**$ 128,643**
5	T of CO_2e	4								

EMP 3: Above grade walls RSI 4.79 (R27.2); Drain water heat recovery unit (≥ 42% steady state efficiency, serving one shower).

TGS Category - Tier 1					**Current**			**High**		
Baseline Energy Cost		**Cost**	**Annual Savings**		**Payback, years**	**IRR**	**NPV**	**Payback, years**	**IRR**	**NPV**
		$ 1.21								
		$ 2,600	$ 103		25.2	5.2%	**$ 29,836**	25.2	7.5%	**$ 35,350**
$ 869	Electricity	$ 869	7.6%		27.0		**$ 54,024**	22.6		**$ 76,677**
$ 493	Nat. gas	$ 390	15.8%				**$ 75,502**			**$ 128,823**
5	T of CO_2e	4								

Summary: NPV of Baseline Energy Costs minus NPV of Energy Measure Package Total Costs

EMP 1	**$ 652**		**$ 1,128**
	$ 2,740		**$ 4,696**
	$ 4,594		**$ 9,198**
EMP 2	**$ 2,374**		**$ 3,344**
	$ 6,628		**$ 10,614**
	$ 10,408		**$ 19,789**
EMP 3	**$ 2,194**		**$ 3,164**
	$ 6,448		**$ 10,434**
	$ 10,228		**$ 19,609**

The three EMPs offers an acceptable paybacks ranging from 17 to 27 years, IRRs from a high of 7% down to 5%, and the NPVs are positive for both scenarios and over all time periods, making them very attractive to a homebuyer. Improvements to the building envelope are particularly attractive due to their permanence over the lifetime of the house.

5.1.2 EMPs to Meet an Energy Performance Improvement ≥ 25%

A rating of ERS 85 is equivalent to an energy performance improvement in the range of 25% to 35%. Therefore a target of at least 25% was used for the three sets of EMPs presented in Table 5.1-3.

Table 5.1-3: Energy Measure Packages ≥ 25%

Economic Assessment Parameters — **Low-Rise Housing**

Two interest (discount) rate and energy escalation rate scenarios are considered in this analysis

	Current	*High*
Interest Rate	**5.5%**	**7.0%**
Energy Escalation Rate	**5.0%**	**8.0%**
Study Period, years	**25**	**25**
	50	**50**
	75	**75**

EMP 1: Achieve EnerGuide 85: Above grade walls RSI 4.67(R27); Tankless water heater with EF ≥ 0.95, HRV unit with SRE ≥ 84%; Improve air tightness by 1.0 ACH.

TGS Category - Tier 2					**Current**			**High**		
Baseline Energy Cost		**Cost**	**Annual Savings**		**Payback, years**	**IRR**	**NPV**	**Payback, years**	**IRR**	**NPV**
		$ 1.77								
		$ 3,800	$ 170		22.4	5.7%	**$ 31,832**	22.4	8.0%	**$ 37,506**
$ 869	Electricity	$ 873	12.5%		23.7		**$ 56,724**	20.2		**$ 80,038**
$ 493	Nat. gas	$ 319	26.6%				**$ 78,829**			**$ 133,706**
5	T of CO_2e	4								

EMP 2: Above grade walls RSI 4.79 (R27.2); foundation walls to RSI 4.19 (R23.8); tankless water heater with EF ≥ 0.90; Improve air tightness by 1.0 ACH, HRV with 75% SRE.

TGS Category - Tier 2					**Current**			**High**		
Baseline Energy Cost		**Cost**	**Annual Savings**		**Payback, years**	**IRR**	**NPV**	**Payback, years**	**IRR**	**NPV**
		$ 2.27								
		$ 4,880	$ 173		28.2	4.7%	**$ 32,841**	28.2	7.0%	**$ 38,502**
$ 869	Electricity	$ 871	12.7%		30.4		**$ 57,671**	24.9		**$ 80,926**
$ 493	Nat. gas	$ 318	26.8%				**$ 79,721**			**$ 134,459**
5	T of CO_2e	4								

EMP 3: Above grade walls RSI 4.67(R27); Foundation walls RSI 4.19 (R23.8); Condensing hot water tank with TE ≥ 94%; Improve air tightness by 1.0 ACH; Drain water heat recovery unit (SRE ≥ 42% , serving one shower).

TGS Category - Tier 2					**Current**			**High**		
Baseline Energy Cost		**Cost**	**Annual Savings**		**Payback, years**	**IRR**	**NPV**	**Payback, years**	**IRR**	**NPV**
		$ 2.32								
		$ 4,990	$ 184		27.1	4.9%	**$ 32,693**	27.1	7.2%	**$ 38,301**
$ 869	Electricity	$ 872	13.5%		29.1		**$ 57,293**	24.1		**$ 80,333**
$ 493	Nat. gas	$ 306	28.6%				**$ 79,138**			**$ 133,370**
5	T of CO_2e	4								

Summary: NPV of Baseline Energy Costs minus NPV of Energy Measure Package Total Costs

EMP 1							**$ 198**			**$ 1,007**
							$ 3,748			**$ 7,073**
							$ 6,901			**$ 14,727**
EMP 2							**-$ 812**			**$ 12**
							$ 2,801			**$ 6,185**
							$ 6,009			**$ 13,974**
EMP 3							**-$ 663**			**$ 213**
							$ 3,180			**$ 6,778**
							$ 6,592			**$ 15,063**

This set of EMPs offers a longer payback, ranging from 24 to 30 years, and IRRs ranging from 5.7% down to 4.9%. This results from both a higher capital investment and the fact that the energy savings are only in natural gas. For both EMP 2 and EMP 3 under the current scenario, a positive NPV is not achieved within 25 years, but is achieved in the 50 and 75 year term. This

is partly due to the unfavourable difference between the interest rate and the escalation rate. Under the high scenario, the three measures have a positive NPV for all periods.

5.1.3 Summary and Conclusions

The energy performance of low-rise housing in Ontario has been improved significantly over the past 20 years following the introduction of some of the R2000 program design approaches in the late 1980s through to the current introduction of ERS-80 into the Building Code. Because of the nature of the EnerGuide Rating System, most of these improvements have been made through changes in the building envelope. Under the new ENERGY STAR for New Houses program, other measures such as more efficient appliances may offer more cost-effective alternatives.

5.2. Part 3 Buildings – Multi-unit Residential

The NPV of the energy consumption of the Multi-unit Residential Building (MURB) reference building that meets Supplementary Standard SB-10/D3 is presented in Table 5.2-1, including the energy costs, GHG emissions, and net present value of energy costs under the current and high scenarios, and for the three study periods of 25, 50 and 75 years.

From an energy perspective, the performance of this type of building is very much external load driven (local climate, including temperature, humidity, wind, and solar radiation), due to the low occupant density, limited ventilation requirements - recommended overall combined ventilation rate for is 0.06 cfm/ft^2 for the building – the relatively low connected lighting power – 0.60 W/ft^2,average throughout the building - and the very intermittent use of appliances and lighting (with the exception of lighting in common areas and parking garages). The overall impact is that the energy performance of the building tends to be more affected by the building envelope and less by the efficiency of lighting, HVAC, and SWH systems.

Table 5.2-1: Reference Multi-Unit Residential Building Reference Baseline Energy Performance

Economic Assessment Parameters

Two interest (discount) rate and energy escalation rate scenarios are considered in this analysis

	Current	*High*
Interest Rate	**5.5%**	**7.0%**
Energy Escalation Rate	**5.0%**	**8.0%**
Study Period, years	**25**	**25**
	50	**50**
	75	**75**

Building GFA, ft²	**146,450**	**Annual Cost, $: Measure $/ft2; Measure $;**	**Annual Savings, $; % Energy Cost; % Energy**	**Current**			**High**		
				Payback, yrs, Simple; Adjusted	**IRR**	**NPV**	**Payback, years**	**IRR**	**NPV**
				N/A					
Baseline		$0	$0	N/A	(25 yr NPV)	**$ 3,136,826**	N/A	N/A	**$ 3,771,839**
$ 97,114	Electricity		**% Energy Cost**		(50 yr NPV)	**$ 5,922,380**			**$ 8,531,243**
$ 36,274	Nat. gas		**% Energy**		(75 yr NPV)	**$ 8,395,997**			**$ 14,536,783**
433	T of CO_2e								

5.2.1 Energy Measure Packages to Meet the Energy Performance Level ≥ 5%

The performance improvement level of 5% better than SB-10 has been proposed for TGS-2 - Tier I/Phase 1. The three EMPs selected to meet the 5% energy performance improvement are presented in Table 5.2-2, and include the calculated GHG emissions and both the energy cost and energy comparison, as well as the complete economic analysis.

Table 5.2-2: Energy Measure Packages to Meet 5% Energy Performance Level

Economic Assessment Parameters — **Multi-Unit Residential Building**

Two interest (discount) rate and energy escalation rate scenarios are considered in this analysis

	Current	*High*
Interest Rate	**5.5%**	**7.0%**
Energy Escalation Rate	**5.0%**	**8.0%**
Study Period, years	**25**	**25**
	50	**50**
	75	**75**

EMP 1: Low-flow domestic hot water fixtures (1.5 gpm (5.7 lpm)shower heads and 1.0 gpm (3.8 lpm) faucets); Service water heating boilers having a thermal efficiency ≥ 92%; Lighting power density reduced by 10% in common areas.

TGS Category - Tier 1 Ph1					**Current**			**High**		
Baseline Energy Cost		**Cost**	**Annual Savings**		**Payback, years**	**IRR**	**NPV**	**Payback, years**	**IRR**	**NPV**
		$ 0.25								
		$ 36,500	$ 4,166		8.8	9.7%	**$ 3,075,356**	8.8	12.1%	**$ 3,690,536**
$ 97,141	Electricity	$ 95,447	3.1%		9.0		**$ 5,773,911**	8.4		**$ 8,301,294**
$ 36,274	Nat. gas	$ 33,802	5.1%				**$ 8,170,271**			**$ 14,119,268**
433	T of CO_2e	410								

EMP 2: Lighting power density in common areas reduced by 10%; Lead condensing space heating boiler, other boilers ≥ 88% efficient.

TGS Category - Tier 1 Ph1					**Current**			**High**		
Baseline Energy Cost		**Cost**	**Annual Savings**		**Payback, years**	**IRR**	**NPV**	**Payback, years**	**IRR**	**NPV**
		$ 0.28								
		$ 41,100	$ 4,342		9.5	9.4%	**$ 3,075,818**	9.5	11.8%	**$ 3,690,159**
$ 97,141	Electricity	$ 95,447	3.3%		9.7		**$ 5,770,696**	9.0		**$ 8,294,637**
$ 36,274	Nat. gas	$ 33,626	6.9%				**$ 8,163,793**			**$ 14,104,687**
433	T of CO_2e	409								

EMP 3: Space heating boilers having a thermal efficiency ≥ 88%; Service water heating boilers having a thermal efficiency ≥ 92%

TGS Category - Tier 1 Ph1					**Current**			**High**		
Baseline Energy Cost		**Cost**	**Annual Savings**		**Payback, years**	**IRR**	**NPV**	**Payback, years**	**IRR**	**NPV**
		$ 0.34								
		$ 49,600	$ 3,734		13.3	7.9%	**$ 3,098,616**	13.3	10.3%	**$ 3,715,852**
$ 97,141	Electricity	$ 97,141	2.8%		13.8		**$ 5,806,191**	12.5		**$ 8,342,024**
$ 36,274	Nat. gas	$ 32,540	6.9%				**$ 8,210,563**			**$ 14,179,447**
433	T of CO_2e	402								

Summary: NPV of Baseline Energy Costs minus NPV of Energy Measure Package Total Costs

EMP 1	**$ 61,470**	**$ 81,303**
	$ 148,469	**$ 229,949**
	$ 225,725	**$ 417,516**
EMP 2	**$ 61,009**	**$ 81,680**
	$ 151,683	**$ 236,606**
	$ 232,204	**$ 432,096**
EMP 3	**$ 38,211**	**$ 55,987**
	$ 116,188	**$ 189,220**
	$ 185,434	**$ 357,336**

Achieving this level of performance can be accomplished with improvements to mechanical and lighting systems. The payback is under 10 years for EMP 1 & 2 and under 14 years for EMP 3, the IRR for all measures ranges from 8% to 10%, and the incremental NPV is positive for both scenarios and all time periods. These EMPs offer a lower energy cost savings due to the current

low price of natural gas, and they do result in a significant reduction in GHG emissions. However, with respect to the net present value, the service life of some mechanical measures may meet 25 years, but is unlikely to exceed that time period by a significant amount.

5.2.2 Energy Measure Packages to Meet the Energy Performance Level ≥ 15%

The performance improvement level of 15% better than SB-10 has been proposed for TGS-2 - Tier I/Phase 2 and Tier II/Phase 1. The three EMPS selected to meet the energy performance improvement are presented in Table 5.2-3, and include the calculated GHG emissions and both the energy and energy cost comparison, as well as the complete economic analysis.

Table 5.2-3: Energy Measure Packages to Meet a 15% Energy Performance Improvement

Economic Assessment Parameters — **Multi-Unit Residential Building**

Two interest (discount) rate and energy escalation rate scenarios are considered in this analysis

	Current	*High*
Interest Rate	**5.5%**	**7.0%**
Energy Escalation Rate	**5.0%**	**8.0%**
Study Period, years	**25**	**25**
	50	**50**
	75	**75**

EMP 1: Condensing lead space heating boiler, other 88% efficient; Service water heating boilers having a thermal efficiency ≥ 95%; In-suite ERV units with SRE ≥ 65%.

TGS Category - Tier 1 Ph2					**Current**			**High**		
Baseline Energy Cost		**Cost**	**Annual Savings**		**Payback, years**	**IRR**	**NPV**	**Payback, years**	**IRR**	**NPV**
		$ 1.26								
		$ 184,600	$ 8,953		20.6	6.1%	**$ 3,110,883**	20.6	8.4%	**$ 3,703,273**
$ 97,141	Electricity	$ 96,921	6.7%		21.8		**$ 5,709,470**	18.8		**$ 8,143,227**
$ 36,274	Nat. gas	$ 27,541	16.3%				**$ 8,017,058**			**$ 13,745,675**
433	T of CO_2e	359								

EMP 2: Condensing lead space heating boiler, other 88% efficient; Service water heating boilers having a thermal efficiency ≥ 95%; Window to wall ratio ≤ 40%; SHSC on south and west exposure ≤ 0.32, U-value ≤ 1.85; Lighting power density in common areas reduced by 15%; Low-flow domestic hot water fixtures (1.5 gpm (5.7 lpm)shower heads and 1.0 gpm (3.8 lpm) faucets)

TGS Category - Tier 1 Ph2					**Current**			**High**		
Baseline Energy Cost		**Cost**	**Annual Savings**		**Payback, years**	**IRR**	**NPV**	**Payback, years**	**IRR**	**NPV**
		$ 1.41								
		$ 206,500	$ 13,316		15.5	7.3%	**$ 3,030,180**	15.5	9.6%	**$ 3,601,800**
$ 97,141	Electricity	$ 91,180	10.0%		16.1		**$ 5,537,654**	14.4		**$ 7,886,077**
$ 36,274	Nat. gas	$ 28,919	15.6%				**$ 7,764,332**			**$ 13,292,090**
433	T of CO_2e	363								

EMP 3:Condensing lead space heating boiler, other 88% efficient; Fenestration: Window to wall ratio ≤ 40%; SHSC on south and west exposure ≤ 0.32; U-value ≤ 1.85; In-suite ERV units with HRE ≥ 60%.

TGS Category - Tier 1 Ph2					**Current**			**High**		
Baseline Energy Cost		**Cost**	**Annual Savings**		**Payback, years**	**IRR**	**NPV**	**Payback, years**	**IRR**	**NPV**
		$ 1.50								
		$ 220,376	$ 10,882		20.3	6.1%	**$ 3,101,295**	20.3	8.4%	**$ 3,684,503**
$ 97,141	Electricity	$ 94,003	8.2%		21.3		**$ 5,659,599**	18.5		**$ 8,055,627**
$ 36,274	Nat. gas	$ 28,530	15.4%				**$ 7,931,414**			**$ 13,571,226**
433	T of CO_2e	363								

Summary: NPV of Baseline Energy Costs minus NPV of Energy Measure Package Total Costs		
EMP 1	**$ 25,944**	**$ 68,566**
	$ 212,910	**$ 388,017**
	$ 378,939	**$ 791,109**
EMP 2	**$ 106,646**	**$ 170,039**
	$ 384,726	**$ 645,166**
	$ 631,665	**$ 1,244,694**
EMP 3	**$ 35,531**	**$ 87,336**
	$ 262,781	**$ 475,616**
	$ 464,582	**$ 965,557**

Achieving this level of performance can just be accomplished with a wider variety of improvements to mechanical systems including in-suite HRVs or ERVs, but if any of these are

not implemented, it becomes necessary to improve the building envelope as in EMP 3. The payback ranges from 16 to 22 years for these EMPs, the IRR ranges from just under 6% to 7.3%, and the incremental NPV is positive for both scenarios and all time periods. The EMPs offer a lower energy cost savings due to the current low price of natural gas, and they do result in a significant reduction in GHG emissions. However, with respect to the net present value, the life of some mechanical measures may exceed 25 years, but is unlikely to exceed that time period by a significant amount.

5.2.3 Energy Measure Packages to Meet the Energy Performance Level ≥ 25%

The performance improvement level of 25% better than SB-10 has been proposed for TGS-2 - Tier II/Phase 2. The three EMPS selected to meet the energy performance improvement are presented in Table 5.2-4, and include the calculated GHG emissions and both the energy and energy cost comparison, as well as the complete economic analysis.

Table 5.2-4: Energy Measure Packages to Meet a 25% Energy Performance Improvement

Economic Assessment Parameters — **Multi-Unit Residential Building**

Two interest (discount) rate and energy escalation rate scenarios are considered in this analysis

	Current	*High*
Interest Rate	**5.5%**	**7.0%**
Energy Escalation Rate	**5.0%**	**8.0%**
Study Period, years	**25**	**25**
	50	**50**
	75	**75**

EMP 1: Fenestration: Window to wall ratio ≤ 40%; SHSC on south and west exposure ≤ 0.32; All windows U-value ≤ 1.85; In-suite ERV units with HRE ≥ 70%; Condensing lead space heating boiler, other 88% efficient; Service water heating boilers having a thermal efficiency ≥ 95%; Low-flow DHW fixtures; Lighting power density in common areas reduced by 15%.

TGS Category - Tier 2 Ph2					**Current**			**High**		
Baseline Energy Cost		**Cost**		**Annual Savings**	**Payback, years**	**IRR**	**NPV**	**Payback, years**	**IRR**	**NPV**
		$ 2.30								
		$ 336,700	$	18,424	18.3	6.6%	**$ 3,040,257**	18.3	8.9%	**$ 3,587,560**
$ 97,141	Electricity	$ 91,022		13.8%	19.2		**$ 5,441,061**	16.8		**$ 7,689,579**
$ 36,274	Nat. gas	$ 23,969		24.9%			**$ 7,573,013**			**$ 12,865,614**
433	T of CO_2e	321								

EMP 2: Fenestration:Window to wall ratio ≤ 40%; SHSC on south and west exposure ≤ 0.35; U-value ≤ 1.70; Opaque wall R-value ≥ 20 ci; Condensing boilers; In-suite HRV units with SRE ≥ 75%; Variable speed drives on two pipe distribution system; Service water heating boilers having a thermal efficiency ≥ 88%; Lighting power density in common areas reduced by 20%; Low-flow domestic hot water fixtures.

TGS Category - Tier 2 Ph2					**Current**			**High**		
Baseline Energy Cost		**Cost**		**Annual Savings**	**Payback, years**	**IRR**	**NPV**	**Payback, years**	**IRR**	**NPV**
		$ 2.45								
		$ 358,750	$	19,665	18.2	6.6%	**$ 3,033,123**	18.2	8.9%	**$ 3,574,518**
$ 97,141	Electricity	$ 89,592		14.7%	19.1		**$ 5,408,011**	16.8		**$ 7,632,257**
$ 36,274	Nat. gas	$ 24,158		25.0%			**$ 7,516,950**			**$ 12,752,418**
433	T of CO_2e	320								

EMP 3: Ground source Heat Pump, EER ≥ 18.1, COP ≥ 3.9.

TGS Category - Tier 2 Ph2					**Current**			**High**		
Baseline Energy Cost		**Cost**		**Annual Savings**	**Payback, years**	**IRR**	**NPV**	**Payback, years**	**IRR**	**NPV**
		$ 8.84								
		$ 1,295,264	-$	41,585	-31.1	-204.3%	**$ 5,410,027**	-31.1	-206.6%	**$ 6,243,011**
$ 97,141	Electricity	$ 175,000		-31.2%	-29.1		**$ 9,064,003**	-36.6		**$ 12,486,205**
$ 36,274	Nat. gas	$0		41.0%			**$ 12,308,794**			**$ 20,364,030**
433	T of CO_2e	223								

Summary: NPV of Baseline Energy Costs minus NPV of Energy Measure Package Total Costs		
EMP 1	**$ 96,569**	**$ 184,279**
	$ 481,319	**$ 841,664**
	$ 822,983	**$ 1,671,169**
EMP 2	**$ 103,703**	**$ 197,321**
	$ 514,369	**$ 898,986**
	$ 879,047	**$ 1,784,365**
EMP 3	**-$ 2,273,200**	**-$ 2,471,172**
	-$ 3,141,623	**-$ 3,954,962**
	-$ 3,912,797	**-$ 5,827,247**

For EMP 1 and EMP 2, this level of performance cannot be achieved with only improvements to the mechanical systems - it is also necessary to improve the building envelope in a significant way, including a reduction in the window-to-gross wall ratio to approximately 40%. If this is not done, overall window and wall performance will need to be very significantly improved. EMP 1 and 2 suggest alternate approaches to improving the building envelope performance, combined with mechanical and lighting system measures. The payback and IRR for these EMPs remains attractive. It should also be noted that the useful life of envelope measures generally matches the useful life of the building.

EMP 3, a ground source heat pump system sized to provide all the space and service water heating, does achieve the specified energy performance improvement by only a change to the mechanical systems, but at the expense of a significant increase in energy cost to a level higher than the baseline. This is mainly due to the relatively high cost of electricity versus natural gas, both current and projected, which is examined in detail in Section 3. Note that there is no payback. There may be a more cost effective hybrid solution that combines a GSHP sized for the cooling load with supplemental heat provided by a conventional gas boiler, but this was not evaluated.

5.2.4 Summary and Conclusions

MURBs can gain only a limited advantage from improving internal loads such as lighting, and no advantage for appliance loads. The most significant gains come from improving the building envelope, ventilation heat recovery above 50% effectiveness, and improvements in mechanical equipment efficiency and controls.

5.3. Part 3 Buildings – Office

The NPV of the energy consumption of the Office reference building that meets Supplementary Standard SB-10/Division 3 is presented in Table 5.3-1, including the energy costs, GHG emissions, and net present value of energy costs under the current and high scenarios, and for the three study periods of 25, 50 and 75 years.

From an energy perspective, the performance of this type of building is very much internal load driven, including a high occupant density and schedule, connected lighting power – maximum overall lighting power density is 0.90W/ft^2 - receptacle load, and ventilation load – recommended overall combined ventilation rate for is 0.90 cfm/ft^2 for the building. During occupied periods, most of these loads are at or near peak capacity, and some office buildings require space cooling throughout most of the year.

The impact is that the energy performance of this building type tends to be more affected by the efficiency of lighting, HVAC and SWH systems, and less by the building envelope.

Table 5.3-1: Office Reference Building Baseline Energy Performance

Economic Assessment Parameters			**Office Building**								
Two interest (discount) rate and energy escalation rate scenarios are considered in this analysis											
			Current	***High***							
		Interest Rate	**5.5%**	**7.0%**							
		Energy Escalation Rate	**5.0%**	**8.0%**							
		Study Period, years	**25**	**25**							
			50	**50**							
			75	**75**							
Building GFA, ft^2	**144,000**	**Annual**	**Current**					**High**			
	Cost, $: Measure $/ft2; Measure $;	**Savings, $; % Energy Cost; % Energy**	**Payback, yrs, Simple; Adjusted**		**IRR**		**NPV**	**Payback, years**	**IRR**		**NPV**
Baseline	$0	$0	N/A		(25 yr NPV)	**$**	**3,398,992**	N/A	N/A	**$**	**4,087,076**
$ 116,447 Electricity		**% Energy Cost**			(50 yr NPV)	**$**	**6,417,352**			**$**	**9,244,255**
$ 28,089 Nat. gas		**% Energy**			(75 yr NPV)	**$**	**9,097,705**			**$**	**15,751,718**
388 T of CO_2e											

5.3.1 Energy Measure Packages to Meet the Energy Performance Level ≥ 5%

The performance improvement level of at least 5% better than SB-10 has been proposed for TGS-2 - Tier I/Phase 1. The three EMPS selected to meet the 5% energy performance improvement are presented in Table 5.3-2, and include the calculated GHG emissions and both the energy cost and energy comparison, as well as the complete economic analysis.

Table 5.3-2: Energy Measure Packages to Meet ≥ 5% Energy Performance Level

Economic Assessment Parameters **Office Building**

Two interest (discount) rate and energy escalation rate scenarios are considered in this analysis

	Current	*High*
Interest Rate	**5.5%**	**7.0%**
Energy Escalation Rate	**5.0%**	**8.0%**
Study Period, years	**25**	**25**
	50	**50**
	75	**75**

EMP 1: Condensing lead space heating boiler, other 88% efficient; Service water heating boiler ≥ 92% efficient.

TGS Category - Tier 1 Ph1					**Current**			**High**		
Baseline Energy Cost		**Cost**		**Annual Savings**	**Payback, years**	**IRR**	**NPV**	**Payback, years**	**IRR**	**NPV**
		$ 0.50								
		$ 72,000	$	5,507	13.1	8.0%	**$ 3,341,486**	13.1	10.4%	**$ 4,003,354**
$ 116,447	Electricity	$ 112,772		3.8%	13.5		**$ 6,244,843**	12.3		**$ 8,964,038**
$ 28,089	Nat. gas	$ 26,257		5.1%			**$ 8,823,072**			**$ 15,223,558**
388	T of CO_2e	368								

EMP 2: Lighting power density reduced by 15%, on average; Low-flow DHW fixtures; SWH Boilers ≥ 95% efficient.

TGS Category - Tier 1 Ph1					**Current**			**High**		
Baseline Energy Cost		**Cost**		**Annual Savings**	**Payback, years**	**IRR**	**NPV**	**Payback, years**	**IRR**	**NPV**
		$ 0.37								
		$ 53,000	$	10,278	5.2	12.1%	**$ 3,210,288**	5.2	14.5%	**$ 3,849,443**
$ 116,447	Electricity	$ 107,387		7.1%	5.2		**$ 6,014,012**	5.0		**$ 8,639,894**
$ 28,089	Nat. gas	$ 26,871		5.8%			**$ 8,503,765**			**$ 14,684,609**
388	T of CO_2e	366								

EMP 3: Lighting power density in common areas reduced by 15%; Lead condensing space heating boiler, other boilers 88% efficient.

TGS Category - Tier 1 Ph1					**Current**			**High**		
Baseline Energy Cost		**Cost**		**Annual Savings**	**Payback, years**	**IRR**	**NPV**	**Payback, years**	**IRR**	**NPV**
		$ 0.35								
		$ 51,000	$	6,248	8.2	10.1%	**$ 3,303,060**	8.2	12.5%	**$ 3,961,401**
$ 116,447	Electricity	$ 112,772		4.3%	8.3		**$ 6,190,943**	7.8		**$ 8,895,645**
$ 28,089	Nat. gas	$ 25,516		6.6%			**$ 8,755,430**			**$ 15,121,803**
388	T of CO_2e	361								

Summary: NPV of Baseline Energy Costs minus NPV of Energy Measure Package Total Costs		
EMP 1	**$ 57,506**	**$ 83,723**
	$ 172,509	**$ 280,217**
	$ 274,634	**$ 528,159**
EMP 2	**$ 188,703**	**$ 237,633**
	$ 403,340	**$ 604,361**
	$ 593,940	**$ 1,067,109**
EMP 3	**$ 95,931**	**$ 125,676**
	$ 226,409	**$ 348,610**
	$ 342,275	**$ 629,914**

Achieving this level of performance can be accomplished with limited improvements to mechanical and lighting systems. The payback ranges from 5 to 14 years for the three EMPs, the IRR is 8% to 12%, and the incremental net present value of the EMPs is very positive in both scenarios and all time periods. The energy cost savings varies by EMP depending on

whether electricity or natural gas is conserved. They all result in a significant reduction in GHG emissions. However, with respect to the net present value, the service life of some mechanical measures may meet 25 years, but is unlikely to exceed that time period by a significant amount.

5.3.2 Energy Measure Packages to Meet the Energy Performance Level ≥ 15%

The performance improvement level of 15% better than SB-10 has been proposed for TGS-2 - Tier I/Phase 2 and Tier II/Phase 1. The three EMPS selected to meet the energy performance improvement are presented in Table 5.3-3, and include the calculated GHG emissions and both the energy and energy cost comparison, as well as the complete economic analysis.

Table 5.3-3: Energy Measure Packages to Meet ≥ 15% Energy Performance Improvement

Economic Assessment Parameters — **Office Building**

Two interest (discount) rate and energy escalation rate scenarios are considered in this analysis

	Current	*High*
Interest Rate	**5.5%**	**7.0%**
Energy Escalation Rate	**5.0%**	**8.0%**
Study Period, years	**25**	**25**
	50	**50**
	75	**75**

EMP 1: Condensing lead space heating boiler, other 88% efficient; Service water heating boilers having a thermal efficiency ≥ 95%; Ventilation energy recovery sytem effectiveness ≥ 70%; Reduce window to opaque wall ratio to 35%.

TGS Category - Tier 1 Ph2					**Current**			**High**		
Baseline Energy Cost		**Cost**		**Annual Savings**	**Payback, years**	**IRR**	**NPV**	**Payback, years**	**IRR**	**NPV**
		$ 0.75								
		$ 108,000	$	10,753	10.0	9.2%	**$ 3,254,118**	10.0	11.5%	**$ 3,891,012**
$ 116,447	Electricity	$ 112,440		7.4%	10.3		**$ 6,047,922**	9.6		**$ 8,664,514**
$ 28,089	Nat. gas	$ 21,343		15.2%			**$ 8,528,867**			**$ 14,687,843**
388	T of CO_2e	325								

EMP 2: Condensing lead space heating boiler, other 88% efficient; Service water heating boilers having a thermal efficiency ≥ 95%; Ventilation energy recovery sytem effectiveness ≥ 70%; Chiller with a 15% better COP; Lighting power density reduced by 15%, on average; Window U-value ≤ 2.25.

TGS Category - Tier 1 Ph2					**Current**			**High**		
Baseline Energy Cost		**Cost**		**Annual Savings**	**Payback, years**	**IRR**	**NPV**	**Payback, years**	**IRR**	**NPV**
		$ 2.17								
		$ 312,000	$	11,672	26.7	5.0%	**$ 3,436,506**	26.7	7.2%	**$ 4,069,025**
$ 116,447	Electricity	$ 112,293		8.1%	28.7		**$ 6,211,119**	23.8		**$ 8,809,737**
$ 28,089	Nat. gas	$ 20,571		16.8%			**$ 8,675,021**			**$ 14,791,689**
388	T of CO_2e	319								

EMP 3: Condensing lead space heating boiler, other 88% efficient; Service water heating boilers having a thermal efficiency ≥ 95%; Lighting power density reduced by 15%, on average; Window U-value ≤ 1.85.

TGS Category - Tier 1 Ph2					**Current**			**High**		
Baseline Energy Cost		**Cost**		**Annual Savings**	**Payback, years**	**IRR**	**NPV**	**Payback, years**	**IRR**	**NPV**
		$ 2.67								
		$ 385,000	$	11,289	34.1	3.9%	**$ 3,518,513**	34.1	6.2%	**$ 4,152,855**
$ 116,447	Electricity	$ 112,772		7.8%	37.3		**$ 6,301,124**	29.5		**$ 8,907,232**
$ 28,089	Nat. gas	$ 20,475		16.8%			**$ 8,772,129**			**$ 14,906,429**
388	T of CO_2e	318								

Summary: NPV of Baseline Energy Costs minus NPV of Energy Measure Package Total Costs

EMP 1	**$ 144,874**	**$ 196,065**
	$ 369,429	**$ 579,741**
	$ 568,839	**$ 1,063,875**
EMP 2	**-$ 37,515**	**$ 18,051**
	$ 206,233	**$ 434,519**
	$ 422,684	**$ 960,028**
EMP 3	**-$ 119,522**	**-$ 65,779**
	$ 116,228	**$ 337,023**
	$ 325,577	**$ 845,289**

Achieving this level of performance cannot be accomplished only with improvements to mechanical and lighting systems. For EMP 1, a reduction in window-to-gross wall ratio from

40% to 35% has been included. In EMP 2, a reduction in window U-value has been included. EMP 3 includes a combination of mechanical, lighting and building envelope measures. In EMP 2 and EMP 3, this adds noticeably to the capital investment.

The payback period for EMP 1 is 10 years, and the IRR is 9%. For EMP 2 the equivalent vales are 29 years and 5%. The incremental NPV is positive for EMP 1 for both scenarios and all three time periods, but for EMP 2 under the current scenario it is not positive until past 25 years. For EMP 3 the effect of more costly building envelope measures causes the payback period to rise to 37 years, the IRR is 4%, and the incremental NPV is positive only after 25 years in both scenarios.

5.3.3 Energy Measure Packages to Meet the Energy Performance Level ≥ 25%

The performance improvement level of 25% better than SB-10 has been proposed for TGS-2 - Tier II/Phase 2. The three EMPS selected to meet the energy performance improvement are presented in Table 5.3-4, and include the calculated GHG emissions and both the energy and energy cost comparison, as well as the complete economic analysis.

Table 5.3-4: Energy Measure Packages to Meet ≥ 25% Energy Performance Improvement

Economic Assessment Parameters **Office Building**

Two interest (discount) rate and energy escalation rate scenarios are considered in this analysis

	Current	*High*
Interest Rate	**5.5%**	**7.0%**
Energy Escalation Rate	**5.0%**	**8.0%**
Study Period, years	**25**	**25**
	50	**50**
	75	**75**

EMP 1: Condensing lead space heating boiler, other 88% efficient; Service water heating boilers having a thermal efficiency ≥ 95%; Lighting power density reduced by 20%, on average; Wall U-value increased by R-10; Window U-value reduced by 45%; Ventilation energy recovery sytem effectiveness ≥ 70%; Chiller with a 15% better COP.

TGS Category - Tier 2 Ph2					**Current**			**High**		
Baseline Energy Cost		**Cost**	**Annual Savings**		**Payback, years**	**IRR**	**NPV**	**Payback, years**	**IRR**	**NPV**
		$ 3.62								
		$ 521,800	$ 17,875		29.2	4.6%	**$ 3,500,433**	29.2	6.9%	**$ 4,103,422**
$ 116,447	Electricity	$ 110,085	12.4%		31.5		**$ 6,145,508**	25.7		**$ 8,622,804**
$ 28,089	Nat. gas	$ 16,576	26.7%				**$ 8,494,378**			**$ 14,325,479**
388	T of CO_2e	282								

EMP 2: Condensing lead space heating boiler, other 88% efficient; Service water heating boilers having a thermal efficiency ≥ 95%; Low-flow domestic hot water fixtures (1.5 gpm (5.7 lpm) shower heads and 1.0 gpm (3.8 lpm) faucets); Window to wall ratio ≤ 35%; Window U-value reduced by 45%; Install Dynamic window sytem; Ventilation energy recovery sytem effectiveness ≥ 70%; Chiller with a 15% better COP.

TGS Category - Tier 2 Ph2					**Current**			**High**		
Baseline Energy Cost		**Cost**	**Annual Savings**		**Payback, years**	**IRR**	**NPV**	**Payback, years**	**IRR**	**NPV**
		$ 5.80								
		$ 835,000	$ 19,390		43.1	3.0%	**$ 3,778,006**	43.1	5.2%	**$ 4,373,782**
$ 116,447	Electricity	$ 108,818	13.4%		48.3		**$ 6,391,443**	36.1		**$ 8,839,108**
$ 28,089	Nat. gas	$ 16,328	25.3%				**$ 8,712,218**			**$ 14,473,572**
388	T of CO_2e	278								

EMP 3: Condensing lead space heating boiler, other 88% efficient; Service water heating boilers having a thermal efficiency ≥ 95%; Install SunCentral lighting system; Window U-value reduced by 45%; Ventilation energy recovery sytem effectiveness ≥ 70%; Chiller with a 15% better COP.

TGS Category - Tier 2 Ph2					**Current**			**High**		
Baseline Energy Cost		**Cost**	**Annual Savings**		**Payback, years**	**IRR**	**NPV**	**Payback, years**	**IRR**	**NPV**
		$ 7.35								
		$1,059,000	$ 30,627		34.6	3.9%	**$ 3,737,750**	34.6	6.1%	**$ 4,280,031**
$ 116,447	Electricity	$ 94,245	21.2%		37.9		**$ 6,116,524**	29.9		**$ 8,344,411**
$ 28,089	Nat. gas	$ 19,664	25.3%				**$ 8,228,914**			**$ 13,472,951**
388	T of CO_2e	288								

Summary: NPV of Baseline Energy Costs minus NPV of Energy Measure Package Total Costs

EMP 1	**-$ 101,442**	**-$ 16,345**
	$ 271,844	**$ 621,451**
	$ 603,327	**$ 1,426,239**
EMP 2	**-$ 379,014**	**-$ 286,705**
	$ 25,909	**$ 405,148**
	$ 385,487	**$ 1,278,145**
EMP 3	**-$ 338,758**	**-$ 192,954**
	$ 300,828	**$ 899,845**
	$ 868,791	**$ 2,278,767**

Achieving this level of performance requires a combination of lighting, HVAC, SWH, and building envelope measures.

EMP 1 exceeds the 25% target by 7%, but it includes a combination of all these measure types. The payback is 32 years, the IRR is 4.6%, and the incremental NPV becomes positive after 25 years.

EMP 2 includes a more advanced fenestration technology, "dynamic glass[26]," that has the ability to change its characteristics to match the solar and light conditions with a consequent reduction in energy consumption, and to therefore eliminate interior and/or exterior shading. This technology is now manufactured in North America and has the potential to optimize natural light and to significantly reduce cooling load.

EMP 3 includes a different advanced technology developed in BC[27] that brings natural light from outside deep into the building, and includes daylight sensing controls to conserve energy.

The capital cost estimates for the more conventional measures included in EMP 1 have been determined with reasonable accuracy for the archetype building. Those for the advanced technologies included in EMP 2 and EMP 3 are less certain, as is the precise effect on energy consumption, so they should be conservative. The payback periods have increased, the IRR has decreased, and the incremental NPV is not positive until after 25 years for EMP 2, and after 50 years for EMP 3.

5.3.4 Summary and Conclusions

The range of building envelope options is limited for this building type due to the effect of the high internal loads, so these must be addressed to achieve this performance level.

5.4. Part 3 Buildings – Retail

The NPV of the energy consumption of the Retail reference building that meets Supplementary Standard SB-10/Division 3 is presented in Table 5.4-1, including the energy costs, GHG emissions, and net present value of energy costs under the current and high scenarios, and for the three study periods of 25, 50, and 75 years.

From an energy perspective, the performance of this type of building is very much internal load driven, particularly with respect to connected lighting power – specified maximum lighting power density is 1.40 W/ft^2 - but also including high occupant density and schedule, and ventilation load - recommended overall combined ventilation rate for is 0.90 cfm/ft^2 for the building - the latter being the result of both occupant density and significant infiltration due to high rates of ingress and egress. During occupied periods, the occupant density can vary widely, but is very high at or near peak periods. Due to the high lighting loads and occupant loads, it is not uncommon for retail buildings to require space cooling throughout most of the year. Also, retailers are generally very demanding about lighting systems, and their criterion is the light their products in a very specific manner – energy efficiency is a much lower priority.

[26] http://www.soladigm.com/
[27] http://www.suncentralinc.com/

The impact is that the energy performance of this building type tends to be more affected by the efficiency of lighting, HVAC and SWH systems, and less by the building envelope.

Table 5.4-1: Retail Reference Building Baseline Energy Performance

Economic Assessment Parameters												
Retail Building												
Two interest (discount) rate and energy escalation rate scenarios are considered in this analysis												
						Current	***High***					
					Interest Rate	**5.5%**	**7.0%**					
					Energy Escalation Rate	**5.0%**	**8.0%**					
					Study Period, years	**25**	**25**					
						50	**50**					
						75	**75**					
	Building GFA, ft^2		**190,118**	**Annual**		**Current**				**High**		
			Cost, $: Measure $/ft2; Measure $;	**Savings, $; % Energy Cost; % Energy**		**Payback, years**	**IRR**	**NPV**		**Payback, years**	**IRR**	**NPV**
Baseline			$0	$0		N/A	(25 yr NPV)	**$ 4,918,746**		N/A	N/A	**$ 5,914,487**
$	187,520	Electricity		**% Energy Cost**			(50 yr NPV)	**$ 9,286,674**				**$ 13,377,541**
$	21,641	Nat. gas		**% Energy**			(75 yr NPV)	**$ 13,165,465**				**$ 22,794,615**
	423	T of CO_2e										

5.4.1 Energy Measure Packages to Meet the Energy Performance Level ≥ 5%

The performance improvement level of at least 5% better than SB-10 has been proposed for TGS-2 - Tier I/Phase 1. The three EMPS selected to meet the 5% energy performance improvement are presented in Table 5.4-2, and include the calculated GHG emissions and both the energy cost and energy comparison, as well as the complete economic analysis.

Table 5.4-2: Energy Measure Packages to Meet ≥ 5% Energy Performance Level

Economic Assessment Parameters — **Retail Building**

Two interest (discount) rate and energy escalation rate scenarios are considered in this analysis

	Current	*High*
Interest Rate	**5.5%**	**7.0%**
Energy Escalation Rate	**5.0%**	**8.0%**
Study Period, years	**25**	**25**
	50	**50**
	75	**75**

EMP 1: Lighting power density reduced by 10%, on average; Low-flow DHW fixtures; SWH Boilers ≥ 92% efficient.

TGS Category - Tier 1 Ph1					**Current**			**High**		
Baseline Energy Cost		**Cost**	**Annual Savings**		**Payback, years**	**IRR**	**NPV**	**Payback, years**	**IRR**	**NPV**
		$ 0.28								
		$ 54,000	$ 12,193		4.4	12.8%	**$ 4,686,009**	4.4	15.2%	**$ 5,623,703**
$ 187,520	Electricity	$ 176,632	5.8%		4.5		**$ 8,799,309**	4.3		**$ 12,651,700**
$ 21,641	Nat. gas	$ 20,336	5.9%				**$ 12,451,987**			**$ 21,519,807**
423	T of CO_2e	398								

EMP 1: Lighting power density in common areas reduced by 5% on average; Lead condensing space heating boiler, other boilers 88% efficient.

TGS Category - Tier 1 Ph1					**Current**			**High**		
Baseline Energy Cost		**Cost**	**Annual Savings**		**Payback, years**	**IRR**	**NPV**	**Payback, years**	**IRR**	**NPV**
		$ 0.22								
		$ 41,000	$ 8,441		4.9	12.4%	**$ 4,761,243**	4.9	14.8%	**$ 5,716,799**
$ 187,520	Electricity	$ 182,362	4.0%		4.9		**$ 8,952,896**	4.7		**$ 12,878,670**
$ 21,641	Nat. gas	$ 18,358	7.6%				**$ 12,675,153**			**$ 21,915,705**
423	T of CO_2e	389								

EMP 3: Condensing lead space heating boiler, other 88% efficient; Service water heating boiler ≥ 92% efficient.

TGS Category - Tier 1 Ph1					**Current**			**High**		
Baseline Energy Cost		**Cost**	**Annual Savings**		**Payback, years**	**IRR**	**NPV**	**Payback, years**	**IRR**	**NPV**
		$ 0.29								
		$ 55,000	$ 3,798		14.5	7.6%	**$ 4,884,431**	14.5	9.9%	**$ 5,862,091**
$ 187,520	Electricity	$ 187,520	1.8%		15.0		**$ 9,173,044**	13.5		**$ 13,189,628**
$ 21,641	Nat. gas	$ 17,843	6.8%				**$ 12,981,403**			**$ 22,435,704**
423	T of CO_2e	391								

Summary: NPV of Baseline Energy Costs minus NPV of Energy Measure Package Total Costs

EMP 1	**$ 232,737**	**$ 290,784**
	$ 487,365	**$ 725,841**
	$ 713,478	**$ 1,274,808**
EMP 2	**$ 157,503**	**$ 197,688**
	$ 333,777	**$ 498,870**
	$ 490,312	**$ 878,910**
EMP 3	**$ 34,316**	**$ 52,397**
	$ 113,630	**$ 187,913**
	$ 184,062	**$ 358,911**

Achieving this level of performance can be accomplished with limited improvements to mechanical and lighting systems. The payback is 5 years for EMP 1 and 2, the IRR is 13%, and the NPV is positive for both scenarios and all time periods. For EMP 3, because the energy cost saving comes only from natural gas, the payback is longer and the IRR is lower. The NPV is

positive for both scenarios and all three time periods. They all result in a reduction in GHG emissions. However, with respect to the net present value, the service life of some mechanical measures may meet 25 years, but is unlikely to exceed that time period by a significant amount.

5.4.2 Energy Measure Packages to Meet the Energy Performance Level ≥ 15%

The performance improvement level of 15% better than SB-10 has been proposed for TGS-2 - Tier I/Phase 2 and Tier II/Phase 1. The three EMPS selected to meet the energy performance improvement are presented in Table 5.4-3, and include the calculated GHG emissions and both the energy and energy cost comparison, as well as the complete economic analysis.

Table 5.4-3: Energy Measure Packages to Meet a 15% Energy Performance Improvement

Economic Assessment Parameters — **Retail Building**

Two interest (discount) rate and energy escalation rate scenarios are considered in this analysis

	Current	*High*
Interest Rate	**5.5%**	**7.0%**
Energy Escalation Rate	**5.0%**	**8.0%**
Study Period, years	**25**	**25**
	50	**50**
	75	**75**

EMP 1: Condensing lead space heating boiler, other 88% efficient; Service water heating boilers having a thermal efficiency ≥ 95%; Low-flow DHW fixtures; Lighting power density reduced by 15%, on average; Chiller with a 15% better COP.

TGS Category - Tier 1 Ph2				**Current**			**High**		
Baseline Energy Cost		**Cost**	**Annual Savings**	**Payback, years**	**IRR**	**NPV**	**Payback, years**	**IRR**	**NPV**
		$ 0.56							
		$ 107,000	$ 24,311	4.4	12.8%	**$ 4,454,035**	4.4	15.3%	**$ 5,334,040**
$ 187,520	Electricity	$ 168,477	11.6%	4.5		**$ 8,314,274**	4.3		**$ 11,929,655**
$ 21,641	Nat. gas	$ 16,373	15.7%			**$ 11,742,229**			**$ 20,252,173**
423	T of CO_2e	354							

EMP 2: Condensing lead space heating boiler, other 88% efficient; Service water heating boilers having a thermal efficiency ≥ 92%; Ventilation energy recovery sytem effectiveness ≥ 70%; Lighting power density reduced by 5%, on average.

TGS Category - Tier 1 Ph2				**Current**			**High**		
Baseline Energy Cost		**Cost**	**Annual Savings**	**Payback, years**	**IRR**	**NPV**	**Payback, years**	**IRR**	**NPV**
		$ 0.67							
		$ 127,000	$ 14,470	8.8	9.7%	**$ 4,705,462**	8.8	12.1%	**$ 5,632,316**
$ 187,520	Electricity	$ 180,930	6.9%	9.0		**$ 8,771,211**	8.4		**$ 12,579,067**
$ 21,641	Nat. gas	$ 13,761	16.3%			**$ 12,381,663**			**$ 21,344,657**
423	T of CO_2e	348							

EMP 3: Condensing lead space heating boiler, other 88% efficient; Ventilation energy recovery sytem effectiveness ≥ 70%; Chiller with a 15% better COP; Window U-value reduced by 30%, SHSC by 15% on south & west.

TGS Category - Tier 1 Ph2				**Current**			**High**		
Baseline Energy Cost		**Cost**	**Annual Savings**	**Payback, years**	**IRR**	**NPV**	**Payback, years**	**IRR**	**NPV**
		$ 1.57							
		$ 298,000	$ 22,015	13.5	7.9%	**$ 4,699,029**	13.5	10.2%	**$ 5,589,965**
$ 187,520	Electricity	$ 172,023	10.5%	14.0		**$ 8,607,216**	12.7		**$ 12,267,503**
$ 21,641	Nat. gas	$ 15,123	16.7%			**$ 12,077,749**			**$ 20,693,394**
423	T of CO_2e	348							

Summary: NPV of Baseline Energy Costs minus NPV of Energy Measure Package Total Costs

EMP 1	**$ 464,711**	**$ 580,447**
	$ 972,400	**$ 1,447,885**
	$ 1,423,236	**$ 2,542,442**
EMP 2	**$ 213,285**	**$ 282,171**
	$ 515,463	**$ 798,474**
	$ 783,802	**$ 1,449,958**
EMP 3	**$ 219,717**	**$ 324,523**
	$ 679,458	**$ 1,110,038**
	$ 1,087,716	**$ 2,101,221**

Achieving this level of performance can still be accomplished with improvements to mechanical and lighting systems, as is presented in EMP 1 and EMP 2. However, in EMP 3, a change to the

window performance has been substituted for mechanical measures, resulting in a significant increase in capital cost.

The payback periods for the EMP 1 and EMP 2 are 4.5 and 9 years, respectively, the IRR is 13% and 10%, and the NPV is positive for both scenarios and all time periods. In the case of EMP 3, the higher value of the energy savings due to reduced electricity consumption offsets the greater capital cost to a significant degree. The payback is 14 years, the IRR is 8%, and the NPV is positive for both scenarios and all three periods.

5.4.3 Energy Measure Packages to Meet the Energy Performance Level ≥ 25%

The performance improvement level of 25% better than SB-10 has been proposed for TGS-2 - Tier II/Phase 2. The three EMPS selected to meet the energy performance improvement are presented in Table 5.4-4, and include the calculated GHG emissions and both the energy and energy cost comparison, as well as the complete economic analysis.

Table 5.4-4: Energy Measure Packages to Meet a 25% Energy Performance Improvement

Economic Assessment Parameters **Retail Building**

Two interest (discount) rate and energy escalation rate scenarios are considered in this analysis

	Current	*High*
Interest Rate	**5.5%**	**7.0%**
Energy Escalation Rate	**5.0%**	**8.0%**
Study Period, years	**25**	**25**
	50	**50**
	75	**75**

EMP 1: Condensing lead space heating boiler, other 88% efficient; Service water heating boilers having a thermal efficiency ≥ 92%; Low-flow DHW fixtures; Lighting power density reduced by 20%, on average; Window U-value reduced by 30%, SHSC by 15% on south & west; Ventilation energy recovery sytem effectiveness ≥ 70%; Chiller with a 10% better COP.

TGS Category - Tier 2 Ph2					**Current**			**High**		
Baseline Energy Cost		**Cost**	**Annual Savings**		**Payback, years**	**IRR**	**NPV**	**Payback, years**	**IRR**	**NPV**
		$ 1.93								
		$ 367,000	$ 35,547		10.3	9.0%	**$ 4,449,803**	10.3	11.4%	**$ 5,276,318**
$ 187,520	Electricity	$ 161,682	17.0%		10.6		**$ 8,075,400**	9.8		**$ 11,471,022**
$ 21,641	Nat. gas	$ 11,932	25.8%				**$ 11,294,989**			**$ 19,287,661**
423	T of CO_2e	308								

EMP 2: Condensing lead space heating boiler, other 88% efficient; Service water heating boilers having a thermal efficiency ≥ 95%; Lighting power density reduced by 20%, on average; Install Dynamic Window sytem; Ventilation energy recovery sytem effectiveness ≥ 70%.

TGS Category - Tier 2 Ph2					**Current**			**High**		
Baseline Energy Cost		**Cost**	**Annual Savings**		**Payback, years**	**IRR**	**NPV**	**Payback, years**	**IRR**	**NPV**
		$ 2.73								
		$ 519,000	$ 34,660		15.0	7.4%	**$ 4,622,663**	15.0	9.8%	**$ 5,453,400**
$ 187,520	Electricity	$ 163,236	16.6%		15.6		**$ 8,266,782**	14.0		**$ 11,679,753**
$ 21,641	Nat. gas	$ 11,265	26.5%				**$ 11,502,820**			**$ 19,536,327**
423	T of CO2e	304								

EMP 3: Condensing lead space heating boiler, other 88% efficient; Service water heating boilers having a thermal efficiency ≥ 95%; Install SunCentral lighting system; Window U-value reduced by 40%, SHSC by 15% on south & west; Ventilation energy recovery sytem effectiveness ≥ 70%.

TGS Category - Tier 2 Ph2					**Current**			**High**		
Baseline Energy Cost		**Cost**	**Annual Savings**		**Payback, years**	**IRR**	**NPV**	**Payback, years**	**IRR**	**NPV**
		$ 11.91								
		$2,264,000	$ 43,358		52.2	2.2%	**$ 6,163,116**	52.2	4.4%	**$ 6,952,445**
$ 187,520	Electricity	$ 153,369	20.7%		60.2		**$ 9,625,594**	42.4		**$ 12,868,445**
$ 21,641	Nat. gas	$ 12,434	27.7%				**$ 12,700,332**			**$ 20,333,408**
423	T of CO_2e	301								

Summary: NPV of Baseline Energy Costs minus NPV of Energy Measure Package Total Costs		
EMP 1	**$ 468,943**	**$ 638,170**
	$ 1,211,274	**$ 1,906,519**
	$ 1,870,476	**$ 3,506,954**
EMP 2	**$ 296,084**	**$ 461,088**
	$ 1,019,892	**$ 1,697,788**
	$ 1,662,645	**$ 3,258,288**
EMP 3	**-$ 1,244,369**	**-$ 1,037,957**
	-$ 338,920	**$ 509,095**
	$ 465,133	**$ 2,461,207**

Achieving this level of performance requires a combination of lighting, HVAC, SWH and building envelope measures.

EMP 1 includes a combination of all these measure types. It has a payback of 11years, IRR of 9%, and has a positive NPV for both scenarios and all time periods.

EMP 2 includes a more advanced fenestration technology, "dynamic glass[28]," that has the ability to change its characteristics to match the solar and light conditions with a consequent reduction in energy consumption, and the ability to eliminate interior and/or exterior shading.

EMP 3 includes a different advanced technology developed in BC[29] that brings natural light from outdoors deep into the building, and includes daylight sensing controls to conserve energy. This technology could be very effective for this type of building.

The application details, final energy savings, and capital cost estimates for the more conventional measures included in EMP 1 have been determined with reasonable accuracy for the archetype building. Those for EMP 2 and EMP 3 are less certain, but they have been included for their significant potential as well as for other added benefits.

5.4.4 Summary and Conclusions

Retail buildings present an interesting problem due to the variety of lessees and their specific lighting requirements. Recent advances in technology offer the potential to significantly reduce lighting energy consumption. Other energy measures for ventilation, the introduction and control of natural light, and the effective matching of energy use to internal loads, offer the potential for both energy savings and improved indoor environmental conditions.

5.5. Part 3 Buildings – Education

The energy performance of the primary school reference building is presented in Table 5.5-1, including the energy costs, GHG emissions, and net present value of energy costs under the current and high scenarios, and for the three study periods of 25, 50 and 75 years.

From an energy perspective, the performance of this type of building is fairly balanced between internal and external loads. When occupied, the occupant density is fairly high at 15 to 25 people per 1000 $ft^{2,}$ but the total period of occupancy is limited. Lighting power density is also relatively high at 0.99 W/ ft^2, but the resulting energy consumption is also reduced by the occupancy schedule. The combined ventilation rate of 13 to 15 cfm/ ft^2 can be considered mid-range.

The energy performance of this building type tends to be affected by the efficiency of lighting, HVAC and SWH systems, and also by the effect local climate defined by the performance of the building envelope.

[28] http://www.soladigm.com/
[29] http://www.suncentralinc.com/

Table 5.5-1: Education Reference Building Baseline Energy Performance

Economic Assessment Parameters				**School Building**								
Two interest (discount) rate and energy escalation rate scenarios are considered in this analysis												
					Current	***High***						
				Interest Rate	**5.5%**	**7.0%**						
				Energy Escalation Rate	**5.0%**	**8.0%**						
				Study Period, years	**25**	**25**						
					50	**50**						
					75	**75**						
	Building GFA, ft^2		**69,697**	**Annual**	**Current**					**High**		
			Cost, $:	**Savings,**	**Payback,**							
			Measure	**$;**	**yrs,**							
			$/ft2;	**% Energy Cost;**	**Simple;**					**Payback,**		
			Measure $;	**% Energy**	**Adjusted**	**IRR**		**NPV**		**years**	**IRR**	**NPV**
Baseline			$0	$0	N/A	(25 yr NPV)	**$**	**1,638,712**		N/A	N/A	**$**	**1,970,450**
$	53,333	Electricity		% Energy Cost		(50 yr NPV)	**$**	**3,093,916**				**$**	**4,456,815**
	16,350	Nat. gas		% Energy		(75 yr NPV)	**$**	**4,386,160**				**$**	**7,594,174**
	208	T of CO_2e											

5.5.1 Energy Measure Packages to Meet the Energy Performance Level ≥ 5%

The performance improvement level of at least 5% better than SB-10 has been proposed for TGS-2 - Tier I/Phase 1. The three EMPS selected to meet the 5% energy performance improvement are presented in Table 5.5-2, and include the calculated GHG emissions and both the energy cost and energy comparison, as well as the complete economic analysis.

Table 5.5-2: Energy Measure Packages to Meet ≥ 5% Energy Performance Level

Economic Assessment Parameters **School Building**

Two interest (discount) rate and energy escalation rate scenarios are considered in this analysis

	Current	*High*
Interest Rate	**5.5%**	**7.0%**
Energy Escalation Rate	**5.0%**	**8.0%**
Study Period, years	**25**	**25**
	50	**50**
	75	**75**

EMP 1: Lighting power density reduced by 10%, on average; Low-flow DHW fixtures; SWH Boilers ≥ 92% efficient.

TGS Category - Tier 1 Ph1					**Current**			**High**		
Baseline Energy Cost		**Cost**	**Annual Savings**		**Payback, years**	**IRR**	**NPV**	**Payback, years**	**IRR**	**NPV**
		$ 0.33								
		$ 23,000	$ 3,508		6.6	11.0%	**$ 1,579,216**	6.6	13.4%	**$ 1,894,253**
$ 53,333	Electricity	$ 51,366	5.0%		6.7		**$ 2,961,162**	6.3		**$ 4,255,449**
$ 16,350	Nat. gas	$ 14,809	7.3%				**$ 4,188,352**			**$ 7,234,868**
208	T of CO_2e	192								

EMP 1: Lighting power density in common areas reduced by 5% on average; Lead condensing space heating boiler, other boilers 88% efficient.

TGS Category - Tier 1 Ph1					**Current**			**High**		
Baseline Energy Cost		**Cost**	**Annual Savings**		**Payback, years**	**IRR**	**NPV**	**Payback, years**	**IRR**	**NPV**
		$ 0.30								
		$ 21,000	$ 2,499		8.4	9.9%	**$ 1,600,944**	8.4	12.3%	**$ 1,920,785**
$ 53,333	Electricity	$ 52,401	3.6%		8.6		**$ 3,003,961**	8.1		**$ 4,317,983**
$ 16,350	Nat. gas	$ 14,783	6.7%				**$ 4,249,863**			**$ 7,342,830**
208	T of CO_2e	193								

EMP 3: Condensing lead space heating boiler, other 88% efficient; Service water heating boiler ≥ 92% efficient.

TGS Category - Tier 1 Ph1					**Current**			**High**		
Baseline Energy Cost		**Cost**	**Annual Savings**		**Payback, years**	**IRR**	**NPV**	**Payback, years**	**IRR**	**NPV**
		$ 0.43								
		$ 30,000	$ 2,167		13.8	7.8%	**$ 1,617,752**	13.8	10.1%	**$ 1,939,173**
$ 53,333	Electricity	$ 53,333	3.1%		14.4		**$ 3,027,702**	13.0		**$ 4,348,217**
$ 16,350	Nat. gas	$ 14,183	8.3%				**$ 4,279,760**			**$ 7,388,012**
208	T of CO_2e	189								

Summary: NPV of Baseline Energy Costs minus NPV of Energy Measure Package Total Costs

EMP 1	**$ 59,496**	**$ 76,196**
	$ 132,754	**$ 201,365**
	$ 197,808	**$ 359,306**
EMP 2	**$ 37,768**	**$ 49,665**
	$ 89,955	**$ 138,831**
	$ 136,297	**$ 251,344**
EMP 3	**$ 20,960**	**$ 31,277**
	$ 66,214	**$ 108,597**
	$ 106,400	**$ 206,162**

Achieving this level of performance can be accomplished with limited improvements to mechanical and lighting systems. The payback is less than 10 years for EMP 1 and 2, the IRR is 11% and 10%, respectively, and the incremental NPV is positive for both scenarios and all time periods. For EMP 3, because the energy cost saving comes only from natural gas, the payback

at just over 14% is a little longer, the IRR is 8%, and the NPV is positive for both scenarios and all time periods. The energy cost savings varies by EMP. They all result in a reduction in GHG emissions. However, with respect to the net present value, the service life of most mechanical and lighting measures may meet exceed 25 years, but is unlikely to exceed that time period by a significant amount.

5.5.2 Energy Measure Packages to Meet the Energy Performance Level ≥ 15%

The performance improvement level of 15% better than SB-10 has been proposed for TGS-2 - Tier I/Phase 2 and Tier II/Phase 1. The three EMPS selected to meet the energy performance improvement are presented in Table 5.5-3, and include the calculated GHG emissions and both the energy and energy cost comparison, as well as the complete economic analysis.

Table 5.5-3: Energy Measure Packages to Meet ≥ 15% Energy Performance Improvement

Economic Assessment Parameters **School Building**

Two interest (discount) rate and energy escalation rate scenarios are considered in this analysis

	Current	*High*
Interest Rate	**5.5%**	**7.0%**
Energy Escalation Rate	**5.0%**	**8.0%**
Study Period, years	**25**	**25**
	50	**50**
	75	**75**

EMP 1: Condensing lead space heating boiler, other 88% efficient; Service water heating boilers having a thermal efficiency ≥ 95%; Low-flow DHW fixtures; Lighting power density reduced by 15%, on average; Rooftop A/C with IEER higher by ≥ 25%.

TGS Category - Tier 1 Ph2					**Current**			**High**		
Baseline Energy Cost		**Cost**	**Annual Savings**		**Payback, years**	**IRR**	**NPV**	**Payback, years**	**IRR**	**NPV**
		$ 0.92								
		$ 64,150	$ 7,719		8.3	10.0%	**$ 1,521,338**	8.3	12.4%	**$ 1,816,328**
$ 53,333	Electricity	$ 48,800	11.1%		8.5		**$ 2,815,345**	8.0		**$ 4,027,272**
$ 16,350	Nat. gas	$ 13,164	15.4%				**$ 3,964,444**			**$ 6,817,098**
208	T of CO_2e	175								

EMP 2: Condensing lead space heating boiler, other 88% efficient; Service water heating boilers having a thermal efficiency ≥ 92%; Ventilation energy recovery sytem effectiveness ≥ 70%; Lighting power density reduced by 5%, on average.

TGS Category - Tier 1 Ph2					**Current**			**High**		
Baseline Energy Cost		**Cost**	**Annual Savings**		**Payback, years**	**IRR**	**NPV**	**Payback, years**	**IRR**	**NPV**
		$ 1.14								
		$ 79,336	$ 6,026		13.2	8.0%	**$ 1,576,338**	13.2	10.3%	**$ 1,879,387**
$ 53,333	Electricity	$ 50,753	8.6%		13.6		**$ 2,905,699**	12.4		**$ 4,150,739**
$ 16,350	Nat. gas	$ 12,904	15.0%				**$ 4,086,195**			**$ 7,016,789**
208	T of CO_2e	175								

EMP 3: Condensing lead space heating boiler, other 88% efficient; Ventilation energy recovery sytem effectiveness ≥ 70%; Lighting power density reduced by 10%, on average; Chiller with a 15% better COP; Window U-value reduced by 30%, SHSC by 15% on south & west.

TGS Category - Tier 1 Ph2					**Current**			**High**		
Baseline Energy Cost		**Cost**	**Annual Savings**		**Payback, years**	**IRR**	**NPV**	**Payback, years**	**IRR**	**NPV**
		$ 1.23								
		$ 85,567	$ 7,809		11.0	8.8%	**$ 1,540,638**	11.0	11.1%	**$ 1,835,200**
$ 53,333	Electricity	$ 48,635	11.2%		11.3		**$ 2,832,766**	10.4		**$ 4,042,933**
$ 16,350	Nat. gas	$ 13,239	15.2%				**$ 3,980,196**			**$ 6,828,707**
208	T of CO_2e	175								

Summary: NPV of Baseline Energy Costs minus NPV of Energy Measure Package Total Costs

EMP 1	**$ 117,374**	**$ 154,122**
	$ 278,571	**$ 429,543**
	$ 421,716	**$ 777,076**
EMP 2	**$ 62,375**	**$ 91,062**
	$ 188,216	**$ 306,076**
	$ 299,966	**$ 577,385**
EMP 3	**$ 98,074**	**$ 135,250**
	$ 261,150	**$ 413,882**
	$ 405,964	**$ 765,467**

Achieving this level of performance can still be accomplished with improvements to mechanical and lighting systems, as is presented in EMP 1 and EMP 2. However, in EMP 3, a change to the

window performance has been substituted for some mechanical measures, resulting in a significant increase in capital cost. It must be recognized that the longer anticipated service life of the envelope measure will offset its greater cost.

The payback periods for EMP 1, 2, and 3 are 8.5 years, 14 years, and 11 years, respectively, the IRR is 10%, 8%, and 9%, and the NPV is positive for both scenarios and all time periods. In the case of EMP 3, the change to window performance is low because of the low window-to-gross wall ratio (WWR) of 16.3%.

5.5.3 Energy Measure Packages to Meet the Energy Performance Level ≥ 25%

The performance improvement level of 25% better than SB-10 has been proposed for TGS-2 - Tier II/Phase 2. The three EMPS selected to meet the energy performance improvement are presented in Table 5.5-4, and include the calculated GHG emissions and both the energy and energy cost comparison, as well as the complete economic analysis.

Table 5.5-4: Energy Measure Packages to Meet ≥ 25% Energy Performance Improvement

Economic Assessment Parameters **School Building**

Two interest (discount) rate and energy escalation rate scenarios are considered in this analysis

	Current	*High*
Interest Rate	**5.5%**	**7.0%**
Energy Escalation Rate	**5.0%**	**8.0%**
Study Period, years	**25**	**25**
	50	**50**
	75	**75**

EMP 1: Condensing lead space heating boiler, other 88% efficient; Service water heating boilers having a thermal efficiency ≥ 95%; Low-flow DHW fixtures; Lighting power density reduced by 20%, on average; Window U-value reduced by 30%, SHSC by 15% on south & west; Ventilation energy recovery sytem effectiveness ≥ 75%; Rooftop A/C with IEER higher by ≥ 25%.

TGS Category - Tier 2 Ph2					**Current**			**High**		
Baseline Energy Cost			**Cost**	**Annual Savings**	**Payback, years**	**IRR**	**NPV**	**Payback, years**	**IRR**	**NPV**
			$ 2.05							
			$ 143,000	$ 18,608	7.7	10.3%	**$ 1,344,116**	7.7	12.7%	**$ 1,587,268**
$ 53,333		Electricity	$ 38,718	26.7%	7.8		**$ 2,410,727**	7.4		**$ 3,409,682**
$ 16,350		Nat. gas	$ 12,357	25.5%			**$ 3,357,895**			**$ 5,709,252**
208		T of CO_2e	155							

EMP 2: Condensing lead space heating boiler, other 88% efficient; Service water heating boilers having a thermal efficiency ≥ 95%; Low-flow DHW fixtures; Lighting power density reduced by 20%, on average; Install Dynamic Window sytem; Ventilation energy recovery sytem effectiveness ≥ 75%.

TGS Category - Tier 2 Ph2					**Current**			**High**		
Baseline Energy Cost			**Cost**	**Annual Savings**	**Payback, years**	**IRR**	**NPV**	**Payback, years**	**IRR**	**NPV**
			$ 1.92							
			$ 134,000	$ 14,354	9.3	9.5%	**$ 1,435,156**	9.3	11.8%	**$ 1,698,559**
$ 53,333		Electricity	$ 44,206	20.6%	9.6		**$ 2,590,603**	8.9		**$ 3,672,760**
$ 16,350		Nat. gas	$ 11,123	26.4%			**$ 3,616,660**			**$ 6,163,858**
208		T of CO2e	151							

EMP 3Condensing lead space heating boiler, other 88% efficient; Service water heating boilers having a thermal efficiency ≥ 95%; Low-flow DHW fixtures; Install SunCentral lighting system; Window U-value reduced by 40%, SHGC by 15% on south & west; Ventilation energy recovery sytem effectiveness ≥ 75%.

TGS Category - Tier 2 Ph2					**Current**			**High**		
Baseline Energy Cost			**Cost**	**Annual Savings**	**Payback, years**	**IRR**	**NPV**	**Payback, years**	**IRR**	**NPV**
			$ 2.12							
			$ 148,000	$ 18,364	8.1	10.1%	**$ 1,354,854**	8.1	12.5%	**$ 1,599,167**
$ 53,333		Electricity	$ 39,036	26.4%	8.2		**$ 2,426,561**	7.7		**$ 3,430,288**
$ 16,350		Nat. gas	$ 12,283	25.6%			**$ 3,378,253**			**$ 5,740,843**
208		T of CO_2e	155							

Summary: NPV of Baseline Energy Costs minus NPV of Energy Measure Package Total Costs

EMP 1	**$ 294,596**	**$ 383,182**
	$ 683,189	**$ 1,047,132**
	$ 1,028,265	**$ 1,884,922**
EMP 2	**$ 203,557**	**$ 271,891**
	$ 503,312	**$ 784,055**
	$ 769,501	**$ 1,430,316**
EMP 3	**$ 283,858**	**$ 371,282**
	$ 667,355	**$ 1,026,527**
	$ 1,007,907	**$ 1,853,331**

Achieving this level of performance requires a combination of lighting, HVAC, SWH and building envelope measures.

EMP 1 includes a combination of all these measure types, has a payback of 8 years, and IRR over 10%, and is positive for both scenarios and three time periods.

EMP 2 includes a more advanced fenestration technology, "dynamic glass[30]," that has the ability to change its characteristics to match the solar and light conditions with a consequent reduction in energy consumption, and the ability to eliminate glare without any interior and/or exterior shading. The low WWR reduces the cost for this measure.

EMP 3 includes a different advanced technology developed in BC[31] that brings natural light from outdoors deep into the building, and includes daylight sensing controls to conserve energy. This measure would seem to be ideally suited for this building type.

The capital cost estimates for the more conventional measures included in EMP 1 have been determined with reasonable accuracy for the archetype building. Those for EMP 2 and EMP 3 are less certain, as is the precise effect on energy consumption.

The payback period for all three packages ranges between 8 and 10 years, the IRR from 9.5% to 10.3%, and the NPV is positive for both scenarios and all time periods.

5.5.4 Summary and Conclusions

Most measures are relatively straightforward for this type of building. One key driver for educators is to provide a better learning environment for the students, and improvements to lighting, especially bring bringing in more natural light, as well as ventilation, provide the ancillary benefit.

School property managers have genuine concerns about vandalism, which can influence their decisions regarding windows, although there are steps that can be taken to counter this. The typical primary school building is one or two storeys, and the application of the SunCentral natural lighting system should be very suitable.

5.6. Part 3 Buildings – Warehouse

There is a statement provided as Note a in SB-10 Division 3, Table 5.5-6, *Building Envelope Requirements for Climate Zone 6:*

> Note a: Mass walls with a heat capacity greater than 245 kJ/m^2•°K (12 Btu/ft^2•°F) which are unfinished or finished only on the interior do not need to be insulated.

This provision, which is not contained in the original ASHRAE version of the tables, will apply to a building with poured concrete walls over 9" thick with medium-density concrete. As a result, the archetype warehouse has been modified to assume this construction as it will be the preferred approach by many developers.

[30] http://www.soladigm.com/
[31] http://www.suncentralinc.com/

The energy performance of the warehouse reference building is presented in Table 5.6-1, including the energy costs, GHG emissions, and net present value of energy costs under the current and high scenarios, and for the three study periods of 25, 50 and 75 years.

From an energy perspective, the performance of this type of building is heavily dependent on the heating and lighting in the warehouse area, with the former being the dominant energy use. Because of this characteristic, there are only two EMPs offered at each performance level.

Table 5.6-1: Warehouse Reference Education Building Economic Assessment

Economic Assessment Parameters				**Warehouse Building**							
Two interest (discount) rate and energy escalation rate scenarios are considered in this analysis											
					Current	***High***					
				Interest Rate	**5.5%**	**7.0%**					
				Energy Escalation Rate	**5.0%**	**8.0%**					
				Study Period, years	**25**	**25**					
					50	**50**					
					75	**75**					
	Building GFA, ft^2		**41,884**	**Annual**	**Current**				**High**		
			Cost, $: Measure $/ft2; Measure $;	**Savings, $; % Energy Cost; % Energy**	**Payback, yrs, Simple; Adjusted**	**IRR**		**NPV**	**Payback, years**	**IRR**	**NPV**
					N/A						
Baseline			$0	$0	N/A	(25 yr NPV)	**$**	**697,121**	N/A	N/A	**$ 838,245**
$	14,315	Electricity		% Energy Cost		(50 yr NPV)	**$**	**1,316,176**			**$ 1,895,964**
$	15,329	Nat. gas		% Energy		(75 yr NPV)	**$**	**1,865,907**			**$ 3,230,621**
	149	T of CO_2e									

5.6.1 Energy Measure Packages to Meet the Energy Performance Level ≥ 5%

The performance improvement level of at least 5% better than SB-10 has been proposed for TGS-2 - Tier I/Phase 1. The two EMPS selected to meet the 5% energy performance improvement are presented in Table 5.6-2, and include the calculated GHG emissions and both the energy cost and energy comparison, as well as the complete economic analysis.

Table 5.6-2: Energy Measure Packages to Meet ≥ 5% Energy Performance Level

Economic Assessment Parameters — **Warehouse Building**

Two interest (discount) rate and energy escalation rate scenarios are considered in this analysis

	Current	*High*
Interest Rate	**5.5%**	**7.0%**
Energy Escalation Rate	**5.0%**	**8.0%**
Study Period, years	**25**	**25**
	50	**50**
	75	**75**

EMP 1: Improve unit heater efficiency to 90% TE

TGS Category - Tier 1 Ph1					**Current**			**High**		
Baseline Energy Cost		**Cost**	**Annual Savings**		**Payback, years**	**IRR**	**NPV**	**Payback, years**	**IRR**	**NPV**
		$ 0.10								
		$ 4,000	$ 1,167		3.4	13.9%	**$ 673,677**	3.4	16.4%	**$ 809,245**
$ 14,315	Electricity	$ 14,315	3.9%		3.5		**$ 1,268,361**	3.4		**$ 1,825,324**
$ 15,329	Nat. gas	$ 14,162	6.5%				**$ 1,796,451**			**$ 3,107,440**
149	T of CO_2e	139								

EMP 2: Insulate warehouse walls to R-5

TGS Category - Tier 1 Ph1					**Current**			**High**		
Baseline Energy Cost		**Cost**	**Annual Savings**		**Payback, years**	**IRR**	**NPV**	**Payback, years**	**IRR**	**NPV**
		$ 0.96								
		$ 40,000	$ 921		43.4	2.9%	**$ 715,462**	43.4	5.2%	**$ 852,201**
$ 14,315	Electricity	$ 14,315	3.1%		48.8		**$ 1,315,284**	36.3		**$ 1,877,058**
$ 15,329	Nat. gas	$ 14,408	5.1%				**$ 1,847,935**			**$ 3,170,249**
149	T of CO_2e	141								

Summary: NPV of Baseline Energy Costs minus NPV of Energy Measure Package Total Costs

EMP 1							**$ 23,444**			**$ 28,999**
							$ 47,814			**$ 70,639**
							$ 69,456			**$ 123,181**
EMP 2							**-$ 18,341**			**-$ 13,957**
							$ 892			**$ 18,905**
							$ 17,972			**$ 60,372**

Achieving this level of performance can be accomplished with an improvement to the efficiency of the gas-fired unit heaters in the warehouse, or with the addition of a nominal amount of insulation to the warehouse walls. The payback is dramatically different however, at less than 4 years for EMP 1 and 49 years for EMP 2. The IRR ranges from less than 14% to 3% under the current scenario. The NPV for EMP 1 is positive for both scenarios and all three time periods, while for EMP 2, it is not positive under the current scenario until after 25 years. It should be noted that the first amount of insulation is relatively expensive due to the cost of providing framing and an inside finish, while greater insulation values will be cheaper in proportion. Another construction approach that is used in the Toronto area is to provide a factory manufactured concrete/insulation “sandwich” assembly, and this would likely result in lower overall costs for the insulated wall. Also with respect to the NPV, the service life of envelope measures will far exceed most mechanical and lighting measures by a significant amount.

5.6.1 Energy Measure Packages to Meet the Energy Performance Level ≥ 15%

The performance improvement level of 15% better than SB-10 has been proposed for TGS-2 - Tier I/Phase 2 and Tier II/Phase 1. The two EMPS selected to meet this energy performance improvement are presented in Table 5.6-3, and include the calculated GHG emissions and both the energy and energy cost comparison, as well as the complete economic analysis.

Table 5.6-3: Energy Measure Packages to Meet ≥ 15% Energy Performance Level

Economic Assessment Parameters — **Warehouse Building**

Two interest (discount) rate and energy escalation rate scenarios are considered in this analysis

	Current	*High*
Interest Rate	**5.5%**	**7.0%**
Energy Escalation Rate	**5.0%**	**8.0%**
Study Period, years	**25**	**25**
	50	**50**
	75	**75**

EMP 1: Insulate warehouse walls to R-10.

TGS Category - Tier 1 Ph2					**Current**			**High**		
Baseline Energy Cost			**Cost**	**Annual Savings**	**Payback, years**	**IRR**	**NPV**	**Payback, years**	**IRR**	**NPV**
			$ 1.22							
			$ 51,000	$ 2,927	17.4	6.8%	**$ 679,288**	17.4	9.1%	**$ 806,477**
$ 14,315		Electricity	$ 14,315	9.9%	18.2		**$ 1,237,218**	16.1		**$ 1,759,758**
$ 15,329		Nat. gas	$ 12,402	16.3%			**$ 1,732,669**			**$ 2,962,633**
149		T of CO_2e	124							

EMP 2: Insulate warehouse walls to R-5; Improve unit heater efficiency to 93% TE; Lighting power density reduced by 15%, on average.

TGS Category - Tier 1 Ph2					**Current**			**High**		
Baseline Energy Cost			**Cost**	**Annual Savings**	**Payback, years**	**IRR**	**NPV**	**Payback, years**	**IRR**	**NPV**
			$ 1.38							
			$ 58,000	$ 4,733	12.3	8.3%	**$ 643,817**	12.3	10.6%	**$ 762,409**
$ 14,315		Electricity	$ 12,203	16.0%	12.7		**$ 1,164,032**	11.6		**$ 1,651,250**
$ 15,329		Nat. gas	$ 12,708	16.8%			**$ 1,625,992**			**$ 2,772,813**
149		T of CO_2e	124							
Summary: NPV of Baseline Energy Costs minus NPV of Energy Measure Package Total Costs										
EMP 1							**$ 17,833**			**$ 31,767**
							$ 78,958			**$ 136,205**
							$ 133,238			**$ 267,988**
EMP 2							**$ 53,304**			**$ 75,836**
							$ 152,144			**$ 244,714**
							$ 239,915			**$ 457,808**

Achieving this level of performance can be accomplished with the addition of a greater amount of insulation to the warehouse walls, or with an improvement to the efficiency of the gas-fired unit heaters in the warehouse and the lighting and insulation. The payback is significantly different however, at 18 years for EMP 1 and 13 years for EMP 2. The IRR is 7% for EMP 1, and over 8% for EMP 2 due to the greater cost savings resulting from the inclusion of a measure that saves electricity. The net present value of the two EMPs is positive for both scenarios and all three time periods.

5.6.2 Energy Measure Packages to Meet the Energy Performance Level ≥ 25%

The performance improvement level of 25% better than SB-10 has been proposed for TGS-2 - Tier II/Phase 2. The two EMPS selected to meet the energy performance improvement are presented in Table 5.6-4, and include the calculated GHG emissions and both the energy and energy cost comparison, as well as the complete economic analysis.

Table 5.6-4: Energy Measure Packages to Meet ≥ 25% Energy Performance Improvement

Economic Assessment Parameters — **Warehouse Building**

Two interest (discount) rate and energy escalation rate scenarios are considered in this analysis

	Current	*High*
Interest Rate	**5.5%**	**7.0%**
Energy Escalation Rate	**5.0%**	**8.0%**
Study Period, years	**25**	**25**
	50	**50**
	75	**75**

EMP 1: Insulate warehouse walls to R-15.2.

TGS Category - Tier 2 Ph2						**Current**			**High**		
Baseline Energy Cost			**Cost**		**Annual Savings**	**Payback, years**	**IRR**	**NPV**	**Payback, years**	**IRR**	**NPV**
			$ 1.38								
			$ 58,000	$	4,879	11.9	8.4%	**$ 640,384**	11.9	10.8%	**$ 758,280**
$	14,315	Electricity	$ 14,315		16.5%	12.3		**$ 1,157,550**	11.2		**$ 1,641,912**
$	15,329	Nat. gas	$ 10,450		27.2%			**$ 1,616,802**			**$ 2,756,901**
	149	T of CO_2e	107								

EMP 2: Insulate warehouse walls to R-12; Improve unit heater efficiency to 93% TE; Lighting power density reduced by 15%, on average.

TGS Category - Tier 2 Ph2						**Current**			**High**		
Baseline Energy Cost			**Cost**		**Annual Savings**	**Payback, years**	**IRR**	**NPV**	**Payback, years**	**IRR**	**NPV**
			$ 1.46								
			$ 61,000	$	6,651	9.2	9.5%	**$ 601,712**	9.2	11.9%	**$ 711,173**
$	14,315	Electricity	$ 12,203		22.4%	9.4		**$ 1,081,874**	8.8		**$ 1,531,578**
$	15,329	Nat. gas	$ 10,790		27.5%			**$ 1,508,265**			**$ 2,566,787**
$	149	T of CO2e	108								
Summary: NPV of Baseline Energy Costs minus NPV of Energy Measure Package Total Costs											
EMP 1								**$ 56,737**			**$ 79,964**
								$ 158,626			**$ 254,052**
								$ 249,105			**$ 473,719**
EMP 2								**$ 95,409**			**$ 127,072**
								$ 234,302			**$ 364,385**
								$ 357,642			**$ 663,834**

Achieving this level of performance can be accomplished with the addition of a greater amount of insulation to the warehouse walls, or with an improvement to the efficiency of the gas-fired unit heaters in the warehouse, and also to the lighting and insulation. The payback is similar at 12 years for EMP 1 and 9 years for EMP 2. The IRR is 8% for EMP 1, and over 9% for EMP 2 due to the greater cost savings resulting from the inclusion of a measure that saves electricity. The net present value of the two EMPs is positive for both scenarios and all three time periods.

5.6.3 Summary and Conclusions

Most measures are relatively straightforward for this type of building, and while some changes could be made to the office area, including windows, HVAC equipment efficiencies, and lighting, the major benefits will come from the measures applied to the warehouse area.

6.0 City of Toronto Emissions Reduction

This section follows on the Phase I report, Section 7 that provided projected GHG emissions using slightly different data. The number of building types has been expanded, the estimates for residential dwelling unit additions have been provided by the reference group, and the projected emissions factors for electricity have been provided by TAF. The methodology is otherwise similar, and is described as follows:

- Projections are based on the 5-year Building Code cycle. Implementation of new requirements took place on January 1, 2012, and will be replaced by new requirements on January 1, 2017. For Part 3 buildings and Part 9 non-residential buildings, these will require an building type-weighted, floorspace-weighted energy efficiency improvement of 13%, and for Part 9 residential buildings, the requirement will be for a 15% improvement[32].
- Energy reduction projections are based of the percent reductions that would be achieved by following the Tier I/Phase 2 – Tier 2/Phase requirement of 15% better than the Building Code. This is intended to recognize that there is a phase in period for requiring a 5% improvement until January 1, 2014, the proposed requirements will not come into effect until early in 2013, but some buildings will comply with Tier2 after the phase-in period.
- The estimates of the annual emissions reductions have been prepared for 2017 and 2022 based on the end of the period for which the OBC and the TGS will have been in effect.
- Baseline energy utilization and TGS-2 energy utilization for new low-rise residential dwelling units have been taken from Section 5.1 of this report.
- Baseline energy utilization and TGS-2 energy utilization for multi-unit residential buildings have been taken from Section 5.2 of this report.
- Baseline energy utilization and TGS-2 energy utilization for commercial buildings have been taken from Section 5 of this report as applicable. For building types not included in this report, information has been taken from the Background Report on the City of Toronto Energy Plan, and adjusted as necessary.
- Growth in housing dwelling units is based on projections provided by the reference group.
- Growth in commercial buildings has been taken from the background report.

[32] Based on information released by the Ministry of Municipal Affairs and Housing on November 5, 2012.

6.1. Estimate of GHG Emissions Reductions for the Toronto Green Standard

Residential Buildings – Avoided GHG Emissions

The projection for avoided GHG emissions for Part 9 and Part 3 residential dwelling units that would have been constructed to the OBC requirements that came into force on January 1, 2012 in the absence of the TGS but are projected to follow the proposed requirements for the TGS, for the period from 2012 to 2016 inclusive, and projected GHG emissions avoided in 2022 for the same building types using the projected emissions factor for electricity for that year are presented in Table 6.1-1. Note that in this table, energy use per dwelling unit has been adjusted to accommodate differing types of Part 9 residential buildings.

Table 6.1-1: Avoided GHG Emissions for Residential Buildings Constructed from 2012 to 2016, for the Years 2017 and 2022

Housing Unit Type	No. of Dwelling Units Added From 2012 to 2016	Energy Use per Dwelling Unit for Residential Buildings Designed to OBC 2012		Annual Avoided GHG Emissions by Dwelling Units Designed to TGS 2012, for 2017, tonnes CO_{2e}			Annual Avoided GHG Emissions by Dwelling Units Designed to TGS 2012, for 2022, tonnes CO_{2e}		
		Electricity, kWh/yr	Natural Gas, kWh/yr	Electricity	Natural Gas	Total	Electr-icity	Natural Gas	Total
CO_{2e} Factor, gm/kWh				68	171		56	171	
Part 9 Housing	5,010	6,715	18,488	343	2,376	2,719	283	2,376	2,658
Part 3 Dwelling Units	45,087	14,714	30,228	6,767	34,958	41,725	5,573	34,958	40,531
Total	50,097	Total		7,110	37,334	44,444	5,855	37,334	43,189

The projected GHG emissions avoided for residential buildings constructed during the period from 2017 to 2021 that would be designed to meet the revised TGS requirements following the introduction of a new OBC 2017 are presented in Table 6.1-2.

Table 6.1-2: Avoided GHG Emissions for Residential Buildings Constructed from 2017 to 2022, for the Year 2022

Housing Unit Type	No. of Dwelling Units Added From 2017 to 2021	Energy Use per Dwelling Unit for Residential Buildings Designed to OBC 2017		Annual Avoided GHG Emissions by Dwelling Units Designed to TGS 2017, for 2022, tonnes CO_{2e}		
		Electricity, kWh/yr	Natural Gas,	Electricity	Natural Gas	Total
CO_{2e} Factor, gm/kWh				56	171	
Part 9 Housing	5,010	5,708	15,714	240	2,019	2,260
Part 3 Dwelling Units	45,087	12,801	26,298	4,848	26,358	31,207
Total	50,097	Total		5,088	28,378	33,466

Commercial/Institutional Buildings – Avoided GHG Emissions

The avoided GHG emissions for commercial/institutional buildings that could have been constructed to the OBC requirements that came into force on January 1, 2012 in the absence of the TGS but are projected to follow the proposed requirements for the TGS, for the period from 2012 to 2016 inclusive, and projected GHG emissions avoided in 2022 for the same buildings using the projected emissions factor for electricity for that year, are presented in Table 6.1-3. Note that an average scenario (equal energy savings from electricity and gas) and a high scenario (greater natural gas energy savings and lower electricity savings) are also presented to demonstrate the impact of reduced GHG emissions in future from electricity over natural gas.

Table 6.1-4: Avoided GHG Emissions for Commercial/Institutional Buildings Constructed from 2012 to 2016, for the Years 2017 and 2022

Building Type	Amount of Floorspace Added From 2012 - 2016, ft^2	Energy Intensity for Buildings Designed to OBC 2012, ekWh/ft^2/yr		Average Scenario, Annual Avoided GHG Emissons by Buildings Designed to TGS 2012, for 2017, tonnes CO_{2e}			High Scenario, Annual Avoided GHG Emissons by Buildings Designed to TGS 2012, for 2017, tonnes CO_2e			Annual Avoided GHG Emissons from Buildings Designed to TGS 2012, for 2022, tonnes CO_{2e}		
		Electr-icity	Natural Gas	Electr-icity	Natural Gas	Total	Electr-icity	Natural Gas	Total	Electr-icity	Natural Gas	Total
CO_{2e} Factor, gm/kWh				68	171		68	171		56	171	
Office	59,432,302	9.4	11.3	5,668	17,132	22,800	1,889	26,624	28,513	4,668	17,132	21,800
Retail	8,067,013	9.0	7.5	741	1,550	2,291	247	2,790	3,037	610	1,550	2,160
Accommodation Total	4,566,671	10.9	11.8	505	1,387	1,892	168	2,233	2,401	416	1,387	1,803
Recreation	3,431,495	11.7	13.5	408	1,190	1,598	136	1,874	2,010	336	1,190	1,526
Healthcare	3,365,887	14.1	15.3	482	1,324	1,806	161	2,132	2,292	397	1,324	1,721
Transmission/Utility	972,609	15.7	18.8	156	469	624	52	729	781	128	469	597
Education	472,604	6.9	11.8	33	143	176	11	199	210	27	143	170
Food Retail	193,406	23.7	10.1	47	50	97	16	128	144	38	50	89
Emergency Measures Services	48,423	16.2	19.5	8	24	32	3	38	40	7	24	31
			Total	8,049	23,268	**31,316**	2,683	36,747	**39,429**	6,628	23,268	**29,896**

The avoided GHG emissions for commercial/institutional buildings that will be constructed to the OBC requirements that come into force on January 1, 2017 but are projected to follow the proposed requirements for the TGS, for the period from 2017 to 2021, inclusive, and projected GHG emissions avoided in 2022 for these are presented in Table 6.1-5.

Table 6.1-5: Avoided GHG Emissions for Commercial/Institutional Buildings Constructed from 2017 to 2022, for the Year 2022

Building Type	Amount of Floorspace Added From 2017 - 2021, ft^2	Energy Intensity for Buildings Designed to OBC 2017, ekWh.ft^2/yr		Annual Avoided GHG Emissons by Buildings Designed to TGS 2017, for 2022, tonnes CO_{2e}		
		Electr-icity	Natural Gas	Electr-icity	Natural Gas	Total
CO_{2e} Factor, gm.kWh				56	171	
Office	65,740,543	8.2	9.8	4,518	16,599	21,117
Retail	7,061,250	3.9	10.5	234	118	351
Accommodation Total	4,568,805	9.5	10.4	364	75	440
Recreation	3,433,098	10.2	11.8	294	65	359
Healthcare	3,500,523	12.3	13.4	362	75	436
Transmission/Utility	880,629	13.7	16.5	102	23	125
Education	265,208	6.0	10.3	13	4	18
Food Retail	193,497	20.7	8.9	34	3	36
Emergency Measures S	21,795	14.2	17.0	3	1	3
			Total	5,923	16,962	**22,885**

Summary of GHG Emissions Avoided

Table 6.1-6 shows the summary of GHG emission that would be avoided through the implementation of the TGS incorporating the recommendations included in this report, followed by a revised TGS having the same incremental improvement over OBC 2017.

Table 6.1-6: Summary of Avoided GHG Emissions for the Years 2017 and 2022

Building Type	Period of Construction	Annual GHG Emissions Avoided, tonnes CO_{2e}	
		2017	2022
Residential	2012 - 2016	44,444	43,189
	2017 - 2021		43,189
Commercial/ Institutional	2012 - 2016	31,316	29,896
	2017 - 2021		22,855
	Total	**75,760**	**139,129**

7.0 Summary and Conclusions

This report begins for Part 3 buildings with a set of five hypothetical archetypes the energy performance of which meet the requirements of Supplementary Standard SB-10 Division 3, Chapter 1, Sentence 1.1.2.1.(1)(c). This energy performance is further defined by a set of energy end-uses. Knowing this information, a set of measures could be evaluated for their impact on energy use and cost, and their incremental capital cost, and then tested for their short

term, medium term, and long-term impact using payback, rate of return, and net present value techniques.

The significant limitation of this approach is that it does not begin with the schematic design of a real building followed by a determination of how best its energy performance could be improved. A capable owner and design team, organized in a manner similar to an integrated design process and supported by experts in the application of new and innovative construction techniques and technologies, could take the sustainability of their design to much greater performance levels. The remarkable growth over the past five years of initiatives such as Architecture 2030 and The Living Building Challenge in both Canada and the USA, amply demonstrate this potential for both the buildings and their designers.

From this report, the following conclusions can be drawn:

1. Modifications to the standard building designs can be made to advance their baseline energy performance on a cost-effective basis. This is true at all three proposed performance improvement levels of 5%, 15%, and 25%. However there are limitations to how far this can be taken, as is evident by the limited number of options at the highest performance level.
2. Buildings will have to be constructed in different ways to meet the performance levels being required in codes and standards. The tried and true is no longer adequate.
3. New technologies will need to be understood and employed in order to achieve prescribed performance levels. The cycle of adoption and implementation has shortened considerably, and represents both a challenge and an opportunity for all stakeholders. The ancillary benefits include better indoor environmental conditions, improved productivity, and superior performance in areas other than energy. Some of these have marketing and branding potential for the building because they are visible from the outside based on how they change the appearance of the building, and visible from the inside because of how they change the indoor environment.
4. Perhaps more significantly, building designers are also being forced to meet the more stringent demands of their owner/developer clients who understand their markets, and the owner/tenants who understand the needs and desires of their employees who will occupy the buildings.

8.0 Acronyms and Abbreviations used in this Document

AEDG	Advanced Energy Design Guide (ASHRAE)
AIRR	Adjusted internal rate of return
ASHRAE	American Society of Heating, Refrigerating and Air Conditioning Engineers
BOP	Builder Option Package
DOE	Department of Energy
EIA	The Energy Information Agency
EMP	Energy measures package
ERS	EnerGuide Rating System
ESNH	ENERGY STAR® for New Houses
EUI	Energy utilization intensity
GHG	Greenhouse gas
HVAC	Heating, Ventilating, and Air Conditioning
IRR	Internal rate of return
MNECB	Model National Energy Code for Buildings
MURB	Multi-unit Residential Building
NBC	National Building Code
NPV	Net present value
NRCan	Natural Resources Canada
OBC	Ontario Building Code
SB-10	Supplementary Standard SB-10: Energy Efficiency Supplement (Part 3 Buildings and Part 9 Non-Residential Buildings)
SB-12	Supplementary Standard SB-12: Energy Efficiency for Housing (Part 9 Residential Buildings)
SWH	Service Water Heating
TGS-1	Current Toronto Green Standard
TGS-2	Proposed Toronto Green Standard
UPV*	Modified uniform present value
WWR	Window-to-gross wall ratio

Appendix A: Detailed Energy Measure Package Costs

- Part 9 Residential Building
- Part 3 Multi-Unit Residential Building
- Part 3 Office Building
- Part 3 Retail Building
- Part 3 School Building
- Part 3 Warehouse Building

Part 9 Low-Rise Residential Building

Category	EMP	ECM		Capital Cost ESNH	Capital Cost Final
15%	1		EMP 1: Above grade walls RSI 3.90 (R24); Tankless water heater EF ≥ 0.90; Improve air tightness by 1.0 ACH.		
		1	Above grade walls RSI 3.90 (R22.1);	$500	$500
		2	Tankless water heater EF ≥ 0.90	$150	$150
		3	Improve air tightness by 1.0 ACH.	$1,050	$1,050
			Total		$1,700
15%	2		EMP 2: Above grade walls RSI 4.48(R25.4); Tankless water heater EF ≥ 0.90, HRV with 75% SRE. Below grade walls RSI 4.67(R27), Drain water heat recovery unit (≥ 42% steady state efficiency, serving one shower)		
		1	Above grade walls RSI 4.48(R25.4)	$1,530	$880
		2	Tankless water heater EF ≥ 0.90	$150	$79
		3	HRV with 75% SRE	$739	$388
		4	Below grade walls RSI 4.67(R27)	$1,663	$874
		5	Drain water heat recovery unit (≥ 42% steady state efficiency, serving one shower)	$378	$199
			Total		$2,420
15%	3		EMP 3: Above grade walls RSI 4.79 (R27.2); Drain water heat recovery unit (≥ 42% steady state efficiency, serving one shower).		
		1	Above grade walls RSI 4.79 (R27.2)	$2,222	$2,222
		2	Drain water heat recovery unit (≥ 42% steady state efficiency, serving one shower).	$378	$378
			Total		$2,600
25%	1		EMP 1: Achieve EnerGuide 85: Above grade walls RSI 4.67(R27); Tankless water heater with EF ≥ 0.95, HRV unit with SRE ≥ 84%; Improve air tightness by 1.0 ACH.		
		1	Above grade walls RSI 4.67(R27)	$1,660	$1,660
		2	Tankless water heater with EF ≥ 0.95	$150	$150
		3	HRV unit with SRE ≥ 84%	$940	$940
		4	Improve air tightness by 1.0 ACH)	$1,050	$1,050
			Total		$3,800
25%	2		EMP 2: Above grade walls RSI 4.79 (R27.2); foundation walls to RSI 4.19 (R23.8); tankless water heater with EF ≥ 0.90; Improve air tightness by 1.0 ACH, HRV with 75% SRE.		
		1	Above grade walls RSI 4.79 (R27.2	$2,222	$2,222
		2	Foundation walls to RSI 4.19 (R23.8)	$1,663	$1,663
		3	Tankless water heater with EF ≥ 0.90	$150	$150
		4	Improve air tightness by 1.0 ACH	$845	$845
		6	HRV with 75% SRE		$4,880
			Total		
25%	3		EMP 3: Above grade walls RSI 4.67(R27); Foundation walls RSI 4.19 (R23.8); Condensing hot water tank with TE ≥ 94%; Improve air tightness by 1.0 ACH; Drain water heat recovery unit (SRE ≥ 42% , serving one shower).		
		1	Above grade walls RSI 4.67(R27)	$1,660	$1,660
		2	Foundation walls to RSI 4.19 (R23.8)	$1,663	$1,663
		3	Condensing hot water tank with TE ≥ 94%	$444	$444
		4	Improve air tightness by 1.0 ACH	$845	$845
		5	Drain water heat recovery unit (SRE ≥ 42% , serving one shower).	$378	$378
			Total		$4,990

Part 3 Multi-Unit Residential Buildng

Category	EMP	ECM		Capital Cost Reference 1	Capital Cost Reference 2	Final Total for EMP
5%	1		Low-flow domestic hot water fixtures (1.5 gpm (5.7 lpm)shower heads and 1.0 gpm (3.8 lpm) faucets); Service water heating boilers having a thermal efficiency ≥ 92%; Lighting power density reduced by 10% in common areas.			
		1	Low-flow DHW fixtures	$37,152	$6,000	$10,000
		2	Service water heating boilers having a thermal efficiency ≥ 92%			$25,000
		3	LP Density - 10%		$1,465	$1,500
			Total			$36,500
5%	2		Lighting power density in common areas reduced by 10%; Lead condensing space heating boiler, other boilers 88% efficient.			
		1	Lighting power density in common areas reduced by 10%;			$1,500
		2	Condensing lead space heating boiler, other 88% efficient	$45,176		$39,600
			Total			$41,100
5%	3		Modulating space heating boilers having a thermal efficiency ≥ 88%; Service water heating boilers having a thermal efficiency ≥ 92%			
		1	Space Htg Boilers 88%		$25,000	$14,600
		2	SWH Boilers 92%			$35,000
			Total			$49,600
15%	1		Condensing lead space heating boiler, other 88% efficient; Service water heating boilers having a thermal efficiency ≥ 92%; In-suite ERV units with SRE ≥ 65%.			
		1	Condensing lead space heating boiler, other 88% efficient	$45,176		$39,600
		2	Service water heating boilers having a thermal efficiency ≥ 92%			$35,000
		3	In-suite ERV units with SRE ≥ 65%	$112,941	$0	$110,000
			Total			$184,600
15%	2		Condensing lead space heating boiler, other 88% efficient; Service water heating boilers having a thermal efficiency ≥ 95%; Window to wall ratio ≤ 40%; SHSC on south and west exposure ≤ 0.32, U-value ≤ 1.85; Lighting power density in common areas reduced by 15%; Low-flow domestic hot water fixtures (1.5 gpm (5.7 lpm)shower heads and 1.0 gpm (3.8 lpm) faucets)			
		1	Condensing lead space heating boiler, other 88% efficient			$39,600
		2	Service water heating boilers having a thermal efficiency ≥ 95%			$45,000
		1	Window to wall ratio ≤ 40%;	-$90,000		-$47,304
		2	SHSC on south and west exposure ≤ 0.32; U-value ≤ 1.85;	$254,118	$124,000	$157,680
		4	Lighting power density in common areas reduced by 15%;			$1,500
		5	Low-flow DHW fixtures			$10,000
			Total			$206,476
15%	3		Condensing lead space heating boiler, other 88% efficient; Fenestration: Window to wall ratio ≤ 40%; SHSC on south and west exposure ≤ 0.32; U-value ≤ 1.85; In-suite ERV units with HRE ≥ 60%.			
		4	Condensing lead space heating boiler, other 88% efficient			$39,600
		1	Window to wall ratio ≤ 40%;			-$47,304
		2	SHSC on south and west exposure ≤ 0.32; U-value ≤ 1.85;			$157,680
		3	In-suite ERV units with HRE ≥ 65%			$110,000
			Total			$220,376

Part 3 Multi-Unit Residential Buildng (2)

Category	EMP	ECM		Capital Cost Reference 1	Capital Cost Reference 2	Final Total for EMP
25%	1		Fenestration: Window to wall ratio ≤ 40%; SHSC on south and west exposure ≤ 0.32; All windows U-value ≤ 1.85; In-suite ERV units with HRE ≥ 70%; Condensing lead space heating boiler, other 88% efficient; Service water heating boilers having a thermal efficiency ≥ 95%; Low-flow DHW fixtures; Lighting power density in common areas reduced by 15%.			
		1	Window to wall ratio ≤ 40%;			-$47,304
		2	SHSC on south and west exposure ≤ 0.32; U-value ≤ 1.85;			$157,680
		3	In-suite ERV units with HRE ≥70%	$200,000	$0	$130,000
		4	Condensing lead space heating boiler, other 88% efficient	$80,000		$39,600
		6	Service water heating boilers having a thermal efficiency ≥ 95%			$35,000
		7	Low-flow DHW fixtures	$64,500		$10,000
		8	Lighting power density in common areas reduced by 15%;			$1,500
			Total			$326,476
25%	2		Fenestration: Window to wall ratio ≤ 40%; SHSC on south and west exposure ≤ 0.32; All windows U-value ≤ 1.85; Opaque wall overall R-value ≥ R25; In-suite ERV units with HRE ≥ 70%; Condensing lead space heating boiler, other 88% efficient; Service water heating boilers having a thermal efficiency ≥ 92%; Improve chiller COP by 10%; Lighting power density in common areas reduced by 15%.			
		1	Window to wall ratio ≤ 40%;			-$47,304
		2	SHSC on south and west exposure ≤ 0.32; U-value ≤ 1.85;			$157,680
		3	Opaque wall overall R-value ≥ R25	$31,059		$32,120
		4	In-suite ERV units with HRE ≥ 70%			$130,000
		5	Condensing lead space heating boiler, other 88% efficient			$39,600
		6	Service water heating boilers having a thermal efficiency ≥ 95%			$35,000
		7	Improve chiller COP by 10%	$30,857		$30,000
		8	Lighting power density in common areas reduced by 15%;			$1,500
			Total			$378,596
25%	3		EMP 3:			
		1	Ground source Heat Pump, EER ≥ 18.1, COP ≥ 3.9.	$ 1,295,264		$1,295,264
			Total			$1,295,264

Part 3 Office Building

Category	EMP	ECM		Capital Cost Reference 1	Capital Cost Reference 2	Final Total for EMP
			Condensing lead space heating boiler, other 88% efficient;			
5%	1		Service water heating boiler ≥ 92% efficient.			
		1	Condensing lead space heating boiler, other 88% efficient	$19,800	$45,176	$39,600
		2	SWH Boilers 92%			$32,000
						$71,600
			Lighting power density reduced by 15%, on average; Low-flow			
5%	2		DHW fixtures; SWH Boilers ≥ 95% efficient.			
		1	Lighting power density reduced by 15%, on average;	$64,500	$10,000	$11,000
		2	Low-flow DHW fixtures	$64,500	$10,000	$10,000
		3	SWH Boilers ≥ 95% efficient		$35,000	$32,000
						$53,000
			Lighting power density in common areas reduced by 15%; Lead condensing space heating boiler, other boilers 88%			
5%	3	1	efficient.			
		2	Lighting power density reduced by 15%, on average;	$64,500		$11,000
		3	Condensing lead space heating boiler, other 88% efficient	$80,000		$39,600
						$50,600
			Condensing lead space heating boiler, other 88% efficient; Service water heating boilers having a thermal efficiency ≥ 95%; Ventilation energy recovery sytem effectiveness ≥ 70%;			
15%	1		Reduce window to opaque wall ratio to 35%.			
		1	Condensing lead space heating boiler, other 88% efficient	$80,000		$39,600
		2	Service water heating boilers having a thermal efficiency ≥ 95%			$32,000
		4	Ventilation energy recovery sytem effectiveness ≥ 75%	$65,455	$48,000	$48,000
		4	Chiller with a 15% better COP	$28,800		$28,800
		5	Reduce window to opaque wall ratio to 35%			-$40,000
						$108,400
			Condensing lead space heating boiler, other 88% efficient; Service water heating boilers having a thermal efficiency ≥ 95%; Ventilation energy recovery sytem effectiveness ≥ 70%; Chiller with a 15% better COP; Lighting power density			
15%	2		reduced by 15%, on average; Window U-value ≤ 2.25.			
		1	Condensing lead space heating boiler, other 88% efficient			$39,600
		2	Service water heating boilers having a thermal efficiency ≥ 95%			$32,000
		3	Ventilation energy recovery sytem effectiveness ≥ 70%			$51,000
		4	Chiller with a 15% better COP			$28,800
		5	Lighting power density reduced by 15%, on average;			$11,000
		6	Window U-value ≤ 2.25.			$150,000
						$312,400
			Condensing lead space heating boiler, other 88% efficient; Service water heating boilers having a thermal efficiency ≥ 95%; Lighting power density reduced by 15%, on average;			
15%	3		Window U-value ≤ 1.85			
		1	Condensing lead space heating boiler, other 88% efficient			$39,600
		2	Service water heating boilers having a thermal efficiency ≥ 95%			$32,000
		3	Lighting power density reduced by 15%, on average;			$11,000
		4	Window U-value reduced by 45%	$302,400		$302,400
						$385,000

Part 3 Office Building (2)

Category	EMP	ECM		Capital Cost Reference 1	Capital Cost Reference 2	Final Total for EMP
			Condensing lead space heating boiler, other 88% efficient; Service water heating boilers having a thermal efficiency ≥ 95%; Lighting power density reduced by 20%, on average; Wall U-value increased by R-10; Window U-value reduced by 45%; Ventilation energy recovery sytem effectiveness ≥ 70%;			
25%	1		Chiller with a 15% better COP.			
		1	Condensing lead space heating boiler, other 88% efficient			$39,600
		2	Service water heating boilers having a thermal efficiency ≥ 92%			$32,000
		3	Lighting power density reduced by 20%, on average;			$14,000
		4	Wall U-value increased by R-10		$53,722	$54,000
		5	Window U-value reduced by 45%	$302,400		$302,400
		6	Ventilation energy recovery sytem effectiveness ≥ 70%			$51,000
		7	Chiller with a 15% better COP			$28,800
						$521,800
			Condensing lead space heating boiler, other 88% efficient; Service water heating boilers having a thermal efficiency ≥ 95%; Low-flow domestic hot water fixtures (1.5 gpm (5.7 lpm) shower heads and 1.0 gpm (3.8 lpm) faucets); Window to wall ratio ≤ 35%; Window U-value reduced by 45%; Install Dynamic window sytem; Ventilation energy recovery sytem			
25%	2		effectiveness ≥ 70%; Chiller with a 15% better COP.			
		1	Condensing lead space heating boiler, other 88% efficient	$80,000		$39,600
		2	Service water heating boilers having a thermal efficiency ≥ 92%			$32,000
		3	Low-flow domestic hot water fixtures (1.5 gpm (5.7 lpm) show	$64,500		$10,000
		4	Window to wall ratio ≤ 35%;	-$58,909		-$47,304
		5	Window U-value reduced by 45%			$302,400
		6	Install Dynamic window sytem	$604,800		$418,560
		7	Ventilation energy recovery sytem effectiveness ≥ 70%			$51,000
		8	Chiller with a 15% better COP			$28,800
						$835,056
			Condensing lead space heating boiler, other 88% efficient; Service water heating boilers having a thermal efficiency ≥ 95%; Install SunCentral lighting system; Window U-value reduced by 45%; Ventilation energy recovery sytem			
25%	3		effectiveness ≥ 70%; Chiller with a 15% better COP.			
		4	Condensing lead space heating boiler, other 88% efficient			$39,600
		6	Service water heating boilers having a thermal efficiency ≥ 92%			$32,000
		3	Install SunCentral lighting system	$604,800	$604,800	$604,800
		4	Window U-value reduced by 45%			$302,400
		3	Ventilation energy recovery sytem effectiveness ≥ 70%			$51,000
		4	Chiller with a 15% better COP			$28,800
						$1,058,600

Part 3 Retail Building

Category	EMP	ECM		Capital Cost Reference	Other	Final
5%	1		Lighting power density reduced by 10%, on average; Low-flow DHW fixtures; SWH Boilers ≥ 92% efficient.			
		1	Lighting power density reduced by 10%, on average;	$19,000		$22,000
		2	Low-flow DHW fixtures	$18,375		$10,000
		3	SWH Boilers ≥ 92% efficient			$22,000
						$54,000
5%	2	1	Lighting power density reduced by 5%, on average; Lead condensing space heating boiler, other boilers 88% efficient.			
		2	Lighting power density reduced by 5%, on average;			$8,000
		3	Condensing lead space heating boiler, other 88% efficient	$33,000		$33,000
						$41,000
5%	3		Condensing lead space heating boiler, other 88% efficient; Service water heating boiler ≥ 92% efficient.			
		1	Condensing lead space heating boiler, other 88% efficient			$33,000
		2	SWH Boilers ≥ 92% efficient			$22,000
						$55,000
15%	1		Condensing lead space heating boiler, other 88% efficient; Service water heating boilers having a thermal efficiency ≥ 95%; Low-flow DHW fixtures; Lighting power density reduced by 15%, on average; Chiller with a 15% better COP.			
		1	Condensing lead space heating boiler, other 88% efficient			$33,000
		2	Service water heating boilers having a thermal efficiency ≥ 95%			$22,000
		3	Low-flow DHW fixtures			$10,000
		4	Lighting power density reduced by 15%, on average;	$23,750		$27,500
		5	Chiller with a 15% better COP	$14,400		$14,100
						$106,600
15%	2		Condensing lead space heating boiler, other 88% efficient; Service water heating boilers having a thermal efficiency ≥ 92%; Ventilation energy recovery sytem effectiveness ≥ 70%; Lighting power density reduced by 5%, on average.			
		1	Condensing lead space heating boiler, other 88% efficient			$33,000
		2	Service water heating boilers having a thermal efficiency ≥ 92%			$22,000
		3	Ventilation energy recovery sytem effectiveness ≥ 70%	$75,000	$48,180	$64,200
		4	Lighting power density reduced by 5%, on average;			$8,000
						$127,200
15%	3		Condensing lead space heating boiler, other 88% efficient; Ventilation energy recovery sytem effectiveness ≥ 70%; Chiller with a 15% better COP; Window U-value reduced by 30%, SHSC by 15% on south & west.			
		1	Condensing lead space heating boiler, other 88% efficient	$80,000		$33,000
		3	Ventilation energy recovery sytem effectiveness ≥ 70%	$100,000	$64,240	$64,200
		4	Chiller with a 10% better COP	$44,000		$5,640
		4	Window U-value reduced by 30%, SHSC by 15% on south & west:	$201,728	$185,000	$195,000
						$297,840

Part 3 Retail Building (2)

Category	EMP	ECM		Capital Cost Reference	Other	Final
25%	1		Condensing lead space heating boiler, other 88% efficient; Service water heating boilers having a thermal efficiency ≥ 92%; Low-flow DHW fixtures; Lighting power density reduced by 20%, on average; Window U-value reduced by 30%, SHSC by 15% on south & west; Ventilation energy recovery sytem effectiveness ≥ 70%; Chiller with a 10% better COP.			
		1	Condensing lead space heating boiler, other 88% efficient			$33,000
		2	Service water heating boilers having a thermal efficiency ≥ 92%			$22,000
		2	Low-flow DHW fixtures			$10,000
		3	Lighting power density reduced by 20%, on average;			$37,125
		4	Window U-value reduced by 30%, SHSC by 15% on south & west:			$195,000
		3	Ventilation energy recovery sytem effectiveness ≥ 70%			$64,200
		4	Chiller with a 10% better COP			$5,640
						$366,965

25%	2		Condensing lead space heating boiler, other 88% efficient; Service water heating boilers having a thermal efficiency ≥ 95%; Lighting power density reduced by 20%, on average; Install Dynamic Window sytem; Ventilation energy recovery sytem effectiveness ≥ 70%.			
		1	Condensing lead space heating boiler, other 88% efficient			$33,000
		2	Service water heating boilers having a thermal efficiency ≥ 92%			$35,000
		3	Lighting power density reduced by 20%, on average;			$37,125
		5	Install Dynamic window sytem	$353,024		$350,000
		6	Ventilation energy recovery sytem effectiveness ≥ 70%			$64,200
						$519,325

25%	3		Condensing lead space heating boiler, other 88% efficient; Service water heating boilers having a thermal efficiency ≥ 95%; Install SunCentral lighting system; Window U-value reduced by 40%, SHSC by 15% on south & west; Ventilation energy recovery sytem effectiveness ≥ 70%.			
		1	Condensing lead space heating boiler, other 88% efficient	$80,000		$39,600
		2	Service water heating boilers having a thermal efficiency ≥ 95%			$35,000
		4	Install SunCentral lighting system	$1,036,800	$1,037,000	$1,500,000
		5	Window U-value reduced by 40%, SHSC by 15% on south & west	$618,625	$558,787	$625,000
		3	Ventilation energy recovery sytem effectiveness ≥ 70%	$100,000	$64,240	$64,240
						$2,263,840

Part 3 School Building

Category	EMP	ECM		Capital Cost Reference 1	Reference 2	Final
5%	1		Lighting power density reduced by 10%, on average; Low-flow DHW fixtures; SWH Boilers ≥ 92% efficient.			
		1	Lighting power density reduced by 10%, on average;		$6,900	$6,900
		2	Low-flow DHW fixtures			$4,000
		3	SWH Boilers ≥ 92% efficient	$11,910		$11,910
						$22,810
5%	2	1	Lighting power density reduced by 5% on average; Lead condensing space heating boiler, other boilers 88% efficient.			
		2	Lighting power density reduced by 5%, on average;			$2,760
		1	Condensing lead space heating boiler, other 88% efficient	$19,800	$10,500	$18,000
						$20,760
5%	3		Condensing lead space heating boiler, other 88% efficient; Service water heating boiler ≥ 92% efficient.			
		1	Condensing lead space heating boiler, other 88% efficient			$18,000
		2	SWH Boilers ≥ 92% efficient			$11,910
						$29,910
15%	1		Condensing lead space heating boiler, other 88% efficient; Service water heating boilers having a thermal efficiency ≥ 95%; Low-flow DHW fixtures; Lighting power density reduced by 15%, on average; Rooftop A/C with IEER higher by ≥ 25%.			
		1	Condensing lead space heating boiler, other 88% efficient			$18,000
		2	Service water heating boilers having a thermal efficiency ≥ 95%			$11,910
		2	Low-flow DHW fixtures	$64,500		$4,000
		1	Lighting power density reduced by 15%, on average;	$64,500		$11,040
		4	Rooftop A/C with IEER higher by ≥ 25%	$44,000		$19,200
						$64,150
15%	2		Condensing lead space heating boiler, other 88% efficient; Service water heating boilers having a thermal efficiency ≥ 92%; Ventilation energy recovery sytem effectiveness ≥ 70%; Lighting power density reduced by 5%, on average.			
		1	Condensing lead space heating boiler, other 88% efficient			$18,000
		2	Service water heating boilers having a thermal efficiency ≥ 92%			$11,910
		3	Ventilation energy recovery sytem effectiveness ≥ 70%	$100,000	$46,667	$46,667
		5	Lighting power density reduced by 5%, on average;			$2,760
						79,336
15%	3		Condensing lead space heating boiler, other 88% efficient; Ventilation energy recovery sytem effectiveness ≥ 70%; Lighting power density reduced by 10%, on average; Chiller with a 15% better COP; Window U-value reduced by 30%, SHSC by 15% on south & west:			
		1	Condensing lead space heating boiler, other 88% efficient			$18,000
		3	Ventilation energy recovery sytem effectiveness ≥ 70%			$46,667
		3	Lighting power density reduced by 10%, on average;			$6,900
		4	Window U-value reduced by 30%, SHSC by 15% on south & west:	$14,201		$14,000
						$85,567

Part 3 School Building (2)

Category	EMP	ECM		Capital Cost Reference 1	Reference 2	Final
25%	1		Condensing lead space heating boiler, other 88% efficient; Service water heating boilers having a thermal efficiency ≥ 95%; Low-flow DHW fixtures; Lighting power density reduced by 20%, on average; Window U-value reduced by 30%, SHSC by 15% on south & west; Ventilation energy recovery sytem effectiveness ≥ 75%; Rooftop A/C with IEER higher by ≥ 25%.			
		1	Condensing lead space heating boiler, other 88% efficient			$18,000
		2	Service water heating boilers having a thermal efficiency ≥ 95%			$11,910
		2	Low-flow DHW fixtures			$4,000
		3	Lighting power density reduced by 20%, on average;			$17,664
		4	Window U-value reduced by 30%, SHSC by 15% on south & west:			$14,000
		3	Ventilation energy recovery sytem effectiveness ≥ 75%			$58,333
		4	Rooftop A/C with IEER higher by ≥ 25%			$19,200
						$143,107
25%	2		Condensing lead space heating boiler, other 88% efficient; Service water heating boilers having a thermal efficiency ≥ 95%; Low-flow DHW fixtures; Lighting power density reduced by 20%, on average; Install Dynamic Window sytem; Ventilation energy recovery sytem effectiveness ≥ 75%.			
		1	Condensing lead space heating boiler, other 88% efficient			$18,000
		2	Service water heating boilers having a thermal efficiency ≥ 92%			$11,910
		2	Low-flow DHW fixtures			$4,000
		3	Lighting power density reduced by 20%, on average;			$17,664
		5	Install Dynamic window sytem	$23,668		$24,000
		6	Ventilation energy recovery sytem effectiveness ≥ 75%			$58,333
						$133,907
25%	3		Condensing lead space heating boiler, other 88% efficient; Service water heating boilers having a thermal efficiency ≥ 95%; Low-flow DHW fixtures; Install SunCentral lighting system; Window U-value reduced by 40%, SHGC by 15% on south & west; Ventilation energy recovery sytem			
		1	Condensing lead space heating boiler, other 88% efficient	$80,000		$18,000
		2	Service water heating boilers having a thermal efficiency ≥ 95%			$11,910
		2	Low-flow DHW fixtures	$64,500		$4,000
		4	Install SunCentral lighting system	$33,135	$33,135	$33,135
		5	Window U-value reduced by 40%, SHGC by 15% on south & west	$14,201		$22,400
		6	Ventilation energy recovery sytem effectiveness ≥ 75%	$100,000	$64,240	$58,333
						$147,778

Part 3 Warehouse Building

Category	EMP	ECM		Capital Cost Reference 1	Reference 2	Final
5%	1		Improve unit heater efficiency to 90% TE			
		1	Improve unit heater efficiency to 90% TE		$4,000	$4,000
5%	2		Insulate warehouse walls to R-5			
		1	Walls insulated to R-5		$39,579	$40,000
15%	1		Insulate warehouse walls to R-10			
		1	Insulate warehouse walls to R10	$85,000		$46,000
15%	2		Insulate warehouse walls to R-5; Improve unit heater efficiency to 93% TE; Lighting power density reduced by 15%, on average.			
		1	Improve unit heater efficiency to 93% TE		$4,800	$4,800
		2	Walls insulated to R-5;		$65,000	$40,000
		3	Lighting power density reduced by 15%, on average;			$6,000
						$50,800
25%	1		Insulate warehouse walls to R-15.2.			
		1	Insulate warehouse walls to R-15.2			$57,500
25%	2		Insulate warehouse walls to R-12; Improve unit heater efficiency to 93% TE; Lighting power density reduced by 15%, on average.			
		1	Walls insulated to R-12;	$85,000		$50,600
		2	Improve unit heater efficiency to 93% TE		$4,200	$4,200
		3	Lighting power density reduced by 15%, on average;			$6,000
						$60,800

Appendix B: Advanced Technologies

- SunCentral Inc. – Daylighting System
- Soladigm – Dynamic Glass System (electrochromic)

SunCentral

Soladigm