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Lifecycle Cost Analysis

Energy Standards for New Buildings

Final Report

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Contents

Glossary 4
Summary 5
Introduction 9
Objectives..9
Scope 9
Report Structure 10
Section 2: Approach 11
Task 1 Establish Representative Archetypes 11
Task 2 Establish Energy Efficiency Actions 17
Task 3 Determine Costs 21
Task 4 Define LCC Costing Variables 22
Task 5. Model Energy 23
Task 6 Assess Cost Effectiveness.. 24
Task 7 Aggregate Results Based on Growth Projections........................ 24
Section 3: Results.. 27
Analysis of Residential Buildings.. 27
Analysis of Commercial Buildings.. 31
Aggregate Impacts 31
Section 4: Conclusions 34
References.. 36
Appendix 1: MNECB Prescriptive Requirements 37
Appendix 2: Pricing Data.. 46
Appendix 3: Financial Aggregation 51

List of Tables

Table 1: Segmentation 5
Table 2: Financial Summary For Residential Buildings 7
Table 3: Payback For Investment....7
Table 4: Scope of Analysis....9
Table 5: Residential Nominal Insulation Requirements 12
Table 6: Stick Frame Home Configuration 12
Table 7: Factory built Home Configuration 13
Table 8: MNECB Prescriptive Requirements.... 14
Table 9: Multi-Unit Residential Building Archetype.... 15
Table 10: Office Building Archetype 16
Table 11: Big Box Archetype 16
Table 12: CBIP Prescriptive Path for MURBS 20
Table 13: CBIP Prescriptive Path for Small Office 20
Table 14: CBIP Prescriptive Path for Big Box Retail 21
Table 15: Baseline Cost Estimates.... 21
Table 16: Location Mark-up Factors.... 21
Table 17: Current Energy Prices 22
Table 18: Greenhouse Gas Emission Factors 23
Table 19: Demographic Indicators.... 25
Table 20: Construction Activity in Yellowknife, 2000 - 2005 25
Table 21: Growth Rate by Segment 25
Table 22: Building Stock Growth, 2005 – 2024.... 26
Table 23: New Construction by Segment and Period 26
Table 24: Stick Built Summary Results.... 29
Table 25: Factory Built Summary Results 30
Table 26: MURB Summary Results 31
Table 27: Office Summary Results.... 31
Table 28: Big Box Retail Summary Results 31
Table 29: Savings in Electricity 32
Table 30: Savings in Oil 32
Table 31: Payback For Investment 32
Table 32: Financial Summary of Program 33
Table 33: GHG Impacts [Tonnes/year] 33

List of Figures

Figure 1 New Single Detached House Energy Use Breakdown by End-Use.... 18
Figure 2 New Single Detached House Energy Use by Building Component 18
Figure 3: Heating Oil Price Trend 22

Glossary

ACH	Air Changes per Hour Measure of the air tightness of a home
CBIP	The Commercial Building Incentive Program (CBIP) is a program supported through Natural Resources Canada to improve the energy efficiency of new construction. The program provides a financial incentive for buildings that achieve a 25% reduction in energy consumption, compared to a building constructed to meet the performance of the Model National Energy Code for Buildings (MNECB).
EGH 80	The Energuide for New Houses program is a federal program to support energy efficient new residential construction. A rating of EHG 80 is approximately equivalent to R2000 energy performance.
LCC	Lifecycle cost analysis is used to assess the cost effectiveness of alternative investment options.
R Value	Thermal resistance in imperial units [Sq ft F/BTU]
RSI	Thermal resistance in metric units Sq m C/W]
U Value	Thermal transmittance [W/sq m C]
Lighting Power Density	Electrical power allowance for lighting [W/sq m]

Summary

This report presents the results of an analysis to calculate the lifecycle cost (LCC) impacts of upgrades to the energy performance of new residential and commercial buildings in Yellowknife.

The objectives of the assignment were to:

1. Develop the business case for adopting an Energuide for Houses energy performance rating of 80 (EGH 80) for new residential construction in Yellowknife;
2. Develop the business case for adopting an energy performance requirement consistent with the Commercial Building Incentive Program (CBIP) for new commercial and institutional buildings in Yellowknife;
3. Provide a cost/benefit analysis of adopting residential and commercial standards from the perspective of the community;

The specific building types modeled in the analysis are summarised in Table 1. This list was defined through consultation with the client.

Table 1: Segmentation

Residential Building Segments	Commercial Building Segments
○ Stick Frame ○ Factory Built	○ Multi-unit Residential Building (MURB) ○ Office ○ Big Box Retail

The methodology to assess the cost effectiveness of energy standards includes a number of work-steps. Specifically, the analysis was based on the following sequence:

1. Establish representative archetypes,
2. Define actions to be modelled,
3. Determine costs of each individual action,
4. Determine LCC costing variables,
5. Model energy savings of actions,
6. Assess cost effectiveness and energy savings of individual actions and bundles, and
7. Aggregate results based on growth projections.

Based on this analysis, the following conclusions are made for the residential and commercial sectors respectively.

Residential

- An average new home in Yellowknife has an Energuide rating of 72. An Energuide 80 rating corresponds to an energy reduction of over 40% compared to typical practice

- The LCC to upgrade to an Energuide 80 is positive confirming that the energy upgrades are cost effective. The incremental improvements required to achieve the EGH Rating include:

    - Advanced framing
    - Increased wall insulation
    - Increased ceiling insulation
    - Increased basement/crawl space insulation
    - Increased thermal resistance of windows
    - Increased air tightness and heat recovery ventilation

- The estimated cost to upgrade a stick built house is $11,764 and the incremental cost to upgrade the factory built home is $8,064. The operating cost savings is $1,412 and $1,184 for the stick built and factory built homes, respectively. As a result, the payback period is 8.3 years for the stick built and 6.8 years for the factory built homes.

- From a cash flow perspective, implementation of an EGH 80 will result in a combined annual mortgage and energy expenditure savings of $546 and $590 for stick built and factory built homes, respectively, as summarised in Table 2. Based on the model results, this implies the net benefit after a 25 year mortgage period, the homeowner will have saved a total of $13, 625 for a stick built and $14,750 for a modular home.

Table 2: Financial Summary For Residential Buildings[1]

	Stick Built	Factory Built
Test 1: Payback Period		
Incremental Capital Cost[2]	$11,764	$8,064
Operating Cost Savings	$1,412	$1,184
Simple Payback Period [Years]	8.3	6.8
Test 2: Mortgage and Energy Benefit		
Incremental Mortgage Payment	($866)	($594)
Operating Cost Savings	$1,412	$1,184
Net Mortgage and Energy Cost Benefit	$545	$590

- It should be highlighted that upgrades for the factory built package needs to be completed at the factory. Therefore, it is recommended that the client consult with the local suppliers to develop an implementation plan.

Commercial

- For commercial buildings, the LCC is positive for all the archetypes modeled which confirms the cost effectiveness of CBIP adoption in Yellowknife.

- The payback period for upgrades for all segments ranges from a low of 1.7 years for the big box retail to a maximum of 8.3 years for the stick built home, as shown in Table 3.

Table 3: Payback For Investment

Segment	Simple Payback
Stick Built	8.3
Factory built	6.8
MURB	3.5
Office	3.7
Big Box	1.7

[1] Assumes a 25 year mortgage at 5.5%. The results show that while there is an increase in cost of a new house by $11,764, the incremental mortgage payment of $866 per year to pay for the increased capital is more than offset by the reduced operating cost savings of $1,412 per year. Therefore, undertaking these improvements will result in a reduction in house expenditures by $545 per year.

[2] This includes "hard" construction cost and does not include the "soft" costs of certification, program implementation or enforcement.

- Implementation of energy efficiency standards will result in an incremental cost of new construction of $35 million over the period 2005 to 2024. However, the net present value of the energy savings is $50 million, resulting in a benefit cost ratio of 1.4.

- Improved energy efficiency of new construction will reduce GHG emission in Yellowknife in 2024 by 21,621 Tonnes/year. This corresponds to a 4.1% reduction in emissions from the building sector.

- It should be highlighted that commencing in the summer of 2006, the prescriptive pathways will be replaced with a web based wizard for the calculation of CBIP compliance.

Recommendation

- Implementation of energy standards is cost effective. Therefore, it is recommended that Energuide 80 and CBIP compliance be used for new construction in Yellowknife.

Introduction

This report presents the results of an analysis to calculate the lifecycle cost (LCC) impacts of upgrades to the energy performance of new residential and commercial buildings in Yellowknife, Northwest Territories. The remainder of this document presents the methodology, assumptions and results of the analysis.

Objectives

The objectives of the assignment were to:

1. Develop the business case for adopting an Energuide for Houses energy performance rating of 80 (EGH 80) for new residential construction in Yellowknife;
2. Develop the business case for adopting an energy performance requirement consistent with the Commercial Building Incentive Program (CBIP) for new commercial and institutional buildings in Yellowknife;
3. Provide a cost/benefit analysis of adopting residential and commercial standards from the perspective of the community;

Scope

The analysis focuses on new residential and commercial building construction. The scope of the analysis was defined to meet timing and budget constraints of the client. Rather than examine the entire range of building types prevalent in the community, those building types that are expected to make up the majority of new construction over the study period were analysed. The specific building types modeled in the analysis are summarised in Table 4. This list was defined through consultation with the client.

Table 4: Scope of Analysis

Residential Building Segments	Commercial Building Segments
• Stick Frame • Factory built	• Multi-unit Residential Building (MURB) • Office • Big Box Retail

The analysis considers new construction only. Retrofit of existing buildings was not included. Institutional buildings, such as schools and hospitals were not included in the analysis, as there is a proposal from the Government of the Northwest Territories (GNWT) that all new institutional construction meet CBIP performance requirements.

The client group initially proposed analysis of multiple energy efficiency standards, including Energuide, R2000 and Built Green for residential construction, and CBIP, ASHRAE and LEED for new commercial construction. Due to budget constraints, the Energuide for New Homes rating of 80 (EGH 80) was chosen as the performance target for new residential construction. The Commercial Building Incentive Program (CBIP) was chosen as the performance target for commercial buildings. A brief description of these programs in terms of structure and status is presented in later sections of the report.

Report Structure

The remaining sections of this report is structured into the following:

- Section 2 presents the methodology applied to complete the LCC analysis,
- Section 3 presents results of the analysis,
- Section 4 provides conclusions

Section 2: Approach

This section provides a description of the methodology applied to complete the analysis. The methodology includes a number of work-steps, including:

1. Establish representative archetypes,
2. Define actions to be modelled,
3. Determine costs of each individual action,
4. Determine LCC costing variables,
5. Model energy savings of actions,
6. Assess cost effectiveness and energy savings of individual actions and bundles, and
7. Aggregate results based on growth projections.

The remainder of this section provides a detailed description of these work-steps, including baseline data, assumptions, and relevant data sources.

Task 1 Establish Representative Archetypes

The first task to assess the cost effectiveness of increased energy standards in Yellowknife was to determine typical new construction characteristics. This information is summarised below for residential and commercial building types, respectively.

Residential Construction

Analysis of residential construction includes stick frame and factory built homes. Multi-unit residential buildings (MURBS) are included in the analysis as a commercial building type. MURBS are treated as a commercial building for the purpose of modelling due to their additional complexity relative to smaller residential buildings. This section provides an overview of thermal "archetypes" used to model residential energy use.

The insulation requirements for new construction as specified by the City of Yellowknife are summarised in Table 5. These requirements provide a starting point to model the thermal characteristics of new construction.

Thermal Insulation Terminology

To convert R value to RSI, divide by 5.68.

R Value	RSI
20	3.5
R 28	4.9
40	7.0

To obtain thermal transmittance (U-Value), take the reciprocal of the RSI value.

RSI	U value
3	0.33
2	0.5
1	1

Table 5: Residential Nominal Insulation Requirements[3]

Assembly	Required insulation Level (R Value), [RSI]
Walls	R 20, [RSI 3.5]
Foundation Walls	R 12, [RSI 2.1]
Roof	R 40, [RSI 7.0]
Exposed Floor	R 28, [RSI 4.9]
Slab on Grade	R 15, [RSI 2.6]

Stick Frame Homes

A sample of 28 Energuide reports for recently constructed homes was reviewed as a basis for developing thermal archetypes for new stick frame homes. The result of that analysis is summarised in Table 6. As can be seen, a one storey home with a living area of 217 square meters was modeled. Comparing the minimum requirements specified by the City of Yellowknife to the sample of Energuides, it is evident that new construction exceeds the minimum requirements specified by the city. It is understood that a significant portion of new homes are two storey in height. Due to the increased surface area of the single storey archetype, model results are conservative. Further, the model assumes oil heating for space and water heat. The impact of these results is to provide a conservative estimate of the energy savings, since the savings of an electrically heated home would be higher.

Table 6: Stick Frame Home Configuration

Number of Storeys	1
Floor Area	2,300 Sq ft [217 Sq m]
Heated Volume	19,161 Cu ft [543 Cu m]
Air Tightness	3.74 ACH
Ceiling Insulation	R 40 [RSI 7.0]
Wall Insulation	R 27 [RSI 4.6]
Foundation Wall Insulation	R 20 [RSI 3.54]
Slab on Grade Insulation	R 15 [RSI 2.6]
Window Construction	Double glazed low e
Space Heating Fuel	Oil
Domestic Hot water Heating Fuel	Oil
Ventilation System	Exhaust fans

[3] Ref: City of Yellowknife, Bulletin #4, 1996

Factory Built Homes
Thermal characteristics of new factory built homes is summarised in Table 7. Consistent with building bylaw, it has been assumed that new factory built homes are equipped with a "northern package" that includes upgraded thermal insulation and windows.

Table 7: Factory built Home Configuration

Number of Storeys	1
Floor Area	1,290 Sq ft [120 Sq m]
Heated Volume	13,550 Cu ft [384 Cu m]
Air Tightness	5.5 ACH
Ceiling Insulation	R 36 [RSI 6.16]
Wall Insulation	R 20 [RSI 3.5]
Floor Insulation	R 28 [RSI 4.9]
Window Construction	Double glazed low e Argon
Space Heating Fuel	Oil
Domestic Hot water Heating Fuel	Oil
Ventilation System	Balanced fans

Commercial Construction

This section provides an overview of thermal "archetypes" used to model the commercial building types. Analysis of commercial construction includes multi-unit residential buildings, small office and big box retail buildings.

Insulation requirements for new commercial construction as specified by the Model National Energy Code for Buildings (MNECB) is summarised in Table 8. Discussions with local builders noted that new construction generally exceeds the requirements of the MNECB. It should be highlighted there are numerous prescriptive requirements to achieve MNECB compliance, as summarised in Appendix 1. These prerequisites are significant as they are mandatory for CBIP compliance. While these are requirements of the CBIP program, it should be highlighted that a number of the requirements are already being met or exceeded. For example, light power densities, equipment efficiency and thermal insulation requirements are all generally being met with current practice.

The MNECB prescriptive requirements provide a starting point to model the thermal characteristics of new commercial construction in Yellowknife. In addition to thermal insulation requirements, the MNECB also addresses lighting, heating ventilation and air conditioning, domestic hot water and electric power requirements, as summarised in Table 8.

Table 8: MNECB Prescriptive Requirements[4]

	Electricity, Other	Propane	Oil, Heat Pump
Assemblies in Contact With the Ground R value [RSI]			
Walls and roofs	R 18 [3.1]	R 14 [2.4]	R 14 [2.4]
Floors on ground			
With in floor heat	R 16 [2.8]	R 6 [1]	R 6 [1]
Other floors less than 0.6 m below grade	R 12 [1.9]	R 6 [1]	R 6 [1]
Above Ground Building Assemblies R value [RSI]			
Roofs			
Attic	R 58 [10.0]	R 48 [8.3]	R 41 [7.1]
Parallel cord trusses and joist roofs	R 44 [7.6]	R 25 [4.3]	R 25 [4.3]
All other roofs (eg concrete decks with rigid insulation)	R 26 [5.0]	R 20 [3.5]	R 20 [3.5]
Walls	R 20 [3.5]	R 18 [3.1]	R 18 [3.1]
Floors			
Parallel cord trusses	R 44 [7.6]	R 26 [4.5]	R 26 [4.5]
All other floors	R 26 [5.0]	R 20 [3.5]	R 20 [3.5]
Fixed Glazing without sash (U Value) [W/sq m C]			
<40%	1.2	2.1	2.1
Fixed Glazing with Sash (U value) [W/sq m C]			
<40%	1.6	2.8	2.8
Heat recovery on principal exhaust	Required		
Lighting	10 – 30 W/sq m		
Heating, ventilation and air conditioning	Equipment dependent	83%	80%
Domestic hot water		83%	80%

To better understand local building practices, a number of designers, builders and suppliers were interviewed to obtain information on typical construction practices. Based on those discussions, building archetypes were developed, and are summarised in Table 9 to Table 11. In general, insulation levels exceed the requirements specified in the MNECB. In addition, lighting levels are lower than specified in the MNECB reflecting the significant innovation that has occurred over the last ten years in lighting technologies. One departure was the use of heat recovery. The comment was made by a number of people interviewed that historically heat recovery was problematic and generally not installed in the extreme climate of Yellowknife, as the systems were found to freeze up during extreme cold periods. More recent applications that include a

4 REF Table A-3.3.1.2 MNECB, Pg 139-140

preheat for incoming air have generally overcome the historical problems of older installations.

A comparison of glazing requirements from Table 8 and the typical construction practices identified by interviewees suggests that windows in the office building and big box retail archetype do not meet the minimum requirements of the MNECB.

Table 9: Multi-Unit Residential Building Archetype

Assembly	Description
Floor Area	80,700 Sq ft [7,500 Sq m]
Number of Floors	3 storeys
Number of Suites	75
Typical Unit Size	100
Wall Construction	Wood frame 2 by 6 construction at 16 in OC R 20 [RSI 3.5] batt insulation, Polyethylene air/vapour barrier
Roof	Wood frame R 40 [RSI 7]
Glazing U value	Low-e double glazed vinyl R value 0.42 (U value 2.4)
Glazing %	20%
Infiltration	0.1 l/sec/sq m @75 Pa
Interior Loads	3,500 kwh/yr
Lighting Power Density	Corridor: 9 W/sq m
HVAC	Corridor make-up air with design flow of 0.35 ACH Make -up air has heat. Suite ventilation provided via door undercut and bathroom/kitchen exhaust fans
Boiler	75% efficient
Suite	Baseboard hydronic heating
Set point	21 degrees C
Domestic Hot Water	75% efficient boiler 200 gallon storage tank

Table 10: Office Building Archetype

Assembly	Description
Floor Area	12,900 Sq ft [1,200 Sq m]
Number of Floors	2
Wall Construction	Steel Frame R 20 [RSI 3.5] rigid insulation, Peel and stick on exterior sheathing board air/vapour barrier
Roof	R 40 [RSI 7.0]
Glazing Description	Double Glazed low-e Aluminium frame with thermal break R Value – 0.31 (U value 3.2)
Glazing %	15%
Infiltration	0.1 L/sec/sq m @ 75 Pa
Interior Loads	7 W/sq m
Lighting Power Density	13 w/sq m
HVAC	Mid efficient Boiler (82% efficient) Radiant hydronic heating Oil fired packaged rooftop air handler unit with heat only
Set point	21 degrees for weekday, 18 degree weekend
Domestic Hot Water	Mid efficient boiler (80%)

Table 11: Big Box Archetype

Assembly	Description
Floor Area	21,500 Sq ft [2,000 Sq m]
Number of Floors	1 floor
Wall Construction	Steel Frame R 14 [RSI 2.4] Exterior Rigid Insulation
Roof	R 14 [RSI 2.4] Rigid Insulation Inverted Roof
Glazing Description	Double Glazed low-e Aluminium frame with thermal break R Value – 0.31 (U value 3.2)
Glazing %	5%
Infiltration	1 l/sec/sq m @ 75 Pa
Interior Loads	4.5 W/sq m
Lighting Power Density	14 W/sq m
HVAC	Packaged Rooftop Unit 75% efficient
Set point	21 degrees for weekday, 18 degree weekend
Domestic Hot Water	Mid efficient boiler (80%)

Task 2 Establish Energy Efficiency Actions

A range of energy efficient upgrades is possible to achieve the EGH 80 and CBIP compliance. This section reviews the procedure for assessing potential actions, and identifies the options that were analysed. A sample of window performance by construction type is summarised in the text box.

Typical Window Performance

Assembly	U value [W/sq m C]
Aluminium frame with thermal break, double glazed clear glass	3.2
Vinyl frame with double glazed clear glass	2.8
Vinyl frame with double glazed glass and low-e coating	1.92
Vinyl frame with double glazed glass and low-e coating and argon fill	1.67
Vinyl frame with triple glazed glass, low-e coating and argon fill	0.87

The performance of windows is highlighted above. As can be seen, the thermal transmittance (the U-value) of a typical window installed in Yellowknife is 1.92. Upgrades including triple glazing, additional low-e coatings and argon fill can reduce the thermal transmittance of the window by a factor of 2.

Energuide 80 Compliance for Residential Construction

Description of the Energuide for new Houses Program

The Energuide for New Houses program is an energy evaluation tool developed by Natural Resources Canada. Since 2005, the program has been used to audit new buildings. An average new home in Yellowknife has an Energuide rating of 72. An Energuide 80 rating corresponds to an energy reduction of over 40% compared to typical practice.

Recent changes to the Energuide program have eliminated federal funding for the program. However, it is understood that a number of provincial organisations will continue to support the program, independent of federal involvement. Should the City of Yellowknife choose to utilize an EGH 80 rating approach, it is likely the City will need to partner with a delivery organization.

Energy Use in New Homes

Energy consumption by end use is summarised in Figure 1 and Figure 2. As can be seen, approximately 84% of total energy use is attributable to space and water heating. On a component basis, the most significant sources of heat loss include basements/foundations, air leakage and windows.

Potential energy efficiency upgrades were established based on a review of energy consumption by end use of typical new houses. Actions analysed include:

- Envelope (ceilings, walls, basement and crawlspace walls, overhanging floors),
- Windows,
- Air tightness/Ventilation,
- Space heating systems and domestic water heating systems.

Figure 1 New Single Detached House Energy Use Breakdown by End-Use

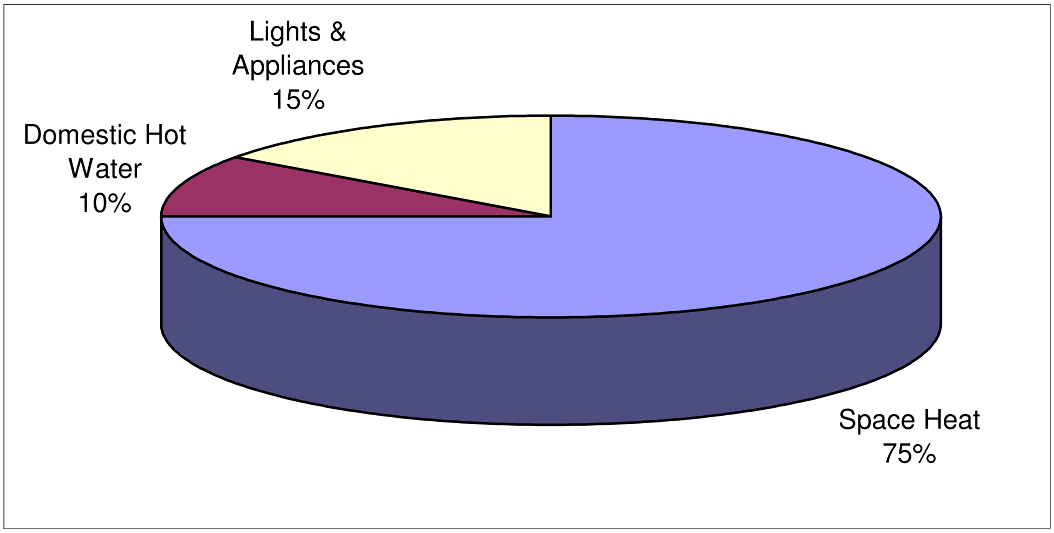
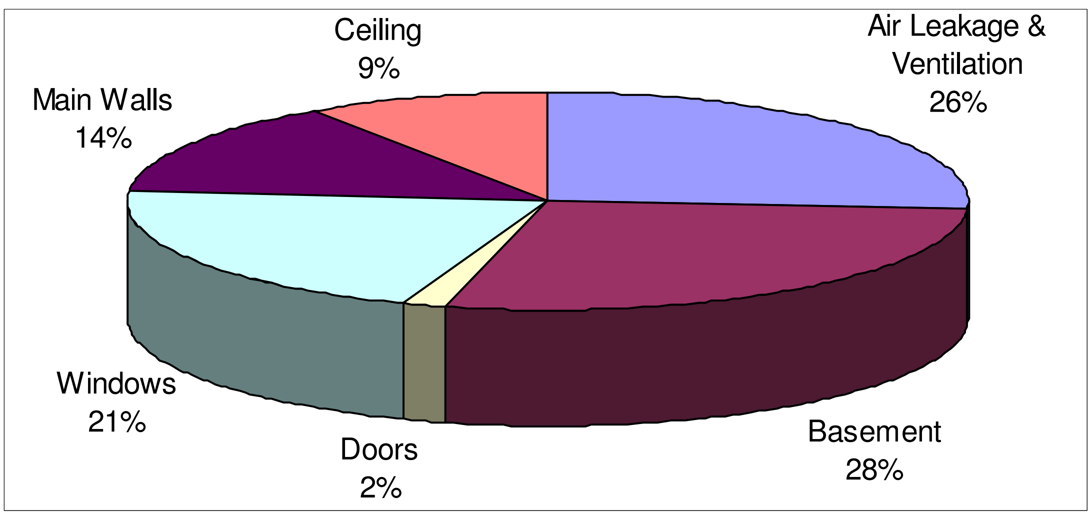


Figure 2 New Single Detached House Energy Use by Building Component



CBIP Compliance for Commercial Buildings

Description of the CBIP Program

The Commercial Building Incentive Program (CBIP) is a national incentive program delivered by the Office of Energy Efficiency. In order to be eligible for the program, participants must achieve a 25% reduction in energy use of their building, compared to a reference building designed to meet the requirements of the Model National Energy Code for Buildings (MNECB). The incentive level has been designed to cover the extra cost of designing higher efficiency buildings. Incentives are equivalent to twice the annual energy cost savings versus a similar building designed to just meet the Model National Energy Code for Building (MNECB) requirements. Incentives are capped at $60,000 or total verifiable design costs, whichever is less. Program details may be obtained from the CBIP website.[5]

Multi-unit Residential Buildings and CBIP
Multi-unit residential buildings (MURBs) have a difficult challenge meeting the Commercial Building Incentive Program's (CBIP's) 25 percent energy threshold. This is mainly due to the difficulties in specifying exterior walls with high levels of insulation, mechanical design strategies focusing on corridor pressurization systems for ventilation and excessive costs for high-performance fenestration products (curtain walls, patio doors and windows). In addition, MURBs have hot water, lighting and appliance loads that offer minimal energy savings credits towards CBIP compliance.

As a result a set of additional credits are available to MURBs. If a building is a MURB, these credits are available only if the residential portion of the building (suites only) comprises more than 50 percent of the total floor area (excluding parking garages) of the building.

These credits include:

1. Parking garage lighting
2. Parking garage use of building exhaust air and low grade heating
3. Residential suite lighting credit
4. Energy efficient appliances and hot water conserving appliances
5. Energy efficient elevators

Commercial Building Energy Upgrades Actions
The actions modeled in the current work are summarised in Table 12 to Table 14. These upgrades conform to the prescriptive path currently provided by the CBIP program. Each package of measure provides a prescriptive means to achieve CBIP. The rationale for choosing one path over another is the cost impact of adopting a particular measure set, and this will vary from project to project. It should be highlighted that commencing in the summer of 2006, the prescriptive pathways will be replaced with a web based wizard for the calculation of CBIP compliance.

[5] http://oee.nrcan.gc.ca/commercial/financial-assistance/new-buildings/index.cfm?attr=20

Table 12: CBIP Prescriptive Path for MURBS

Measure Set A (25.8%)	Measure Set B (27.3%)	Measure Set C (28.5%)
• Air-to-air heat recovery fresh air – 70% annual effectiveness • High-efficiency boiler for space heating – Et = 88% • Condensing boiler for SHW – Et = 92% • Low-flow shower and fixtures • Overall fenestration value < 1.37 W/m2ºC • Common area lighting package • Wall and roof insulated to RSI 0.9 above MNECB	• Overall fenestration U-value < 1.37 W/m2ºC • Air-to-air heat recovery on fresh air – 70% annual effectiveness • Garage air heat recovery Common area and garage lighting packages	• Air-to-air heat recovery on fresh air – 70% annual effectiveness • Low-flow shower and tap fixtures • Common area lighting package • Wall and roof insulated to RSI 0.9 above MNECB • Overall fenestration U-value < 1.37 W/m2ºC • Garage air heat recovery

Table 13: CBIP Prescriptive Path for Small Office

Measure Set A (26%)	Measure Set B (26%)	Measure Set C (31%)
• Lighting power density of 11.5 W/m2 • Overall fenestration U-value of 1.48 W/m2˚C • Condensing boiler to serve rooftops	• Wall insulated to ¤RSI 1.7 above MNECB • Overall fenestration U-value of 1.37 W/m2˚C • Lighting power density of 11.5 W/m2 • Upgrade rooftop unit (inlet vane control, low-leakage damper, optimum start)	• Lighting power density of 11.5 W/m2 • Overall fenestration U-value of 1.48 W/m2˚C • Air-to-air heat recovery on fresh air – 60% annual effectiveness
Measure Set D (42%)	**Measure Set E (42%)**	**Measure Set F (56%)**
• Lighting power density of 11.5 W/m2 • Overall fenestration U-value of 1.48 W/m2˚C • Air-to-air heat recovery on fresh air – 60% annual effectiveness • Perimeter daylighting with light dimming • Water-loop heat pump system with condensing boiler and cooling tower	• Wall insulated to ¤RSI 2.8 above MNECB • Lighting power density of 11.5 W/m2 • Overall fenestration U-value of 1.48 W/m2˚C • Active solar shading • Radiant ceiling heating/cooling, displacement • ventilation with heat recovery, water economizer, condensing boiler and chiller	• Lighting power density of 10.8 W/m2 • Wall insulated to ¤RSI 0.9 above MNECB • Overall fenestration U-value of 1.37 W/m2˚C • Two-pipe ground source heat pump system (EER = 15.5, COP = 3.4)

Table 14: CBIP Prescriptive Path for Big Box Retail

Set A (31%)	Set B (32%)
• Wall insulated to □RSI 0.9 above MNECB • Roof insulated to □RSI 0.9 above MNECB • Window U-value < 1.6 W/m2oC* • Lighting power allowance < 15 W/m2 x area factor • Mid-Efficiency Rooftops • HRV or ERV	• Wall insulated to □RSI 0.9 above MNECB • Roof insulated to □RSI 0.9 above MNECB • Window U-value < 1.6 W/m2oC* • Lighting power allowance < 18 W/m2 area factor • Mid-Efficiency Rooftops • HRV or ERV

Task 3 Determine Costs

Base Costs for New Construction

Costing was obtained through a survey of local designers and suppliers. The base cost for construction is summarised in Table 15. A number of the survey respondents noted that prices have escalated significantly over the last year.

Table 15: Baseline Cost Estimates

Segment	Typical Construction Costs [$/Sq ft]	Typical Construction Costs [$/sq m]
Stick Frame Home	$140/Sq ft	$ 1,500/Sq m
Factory built	$ 84/Sq ft	$ 900/Sq m
Multi Unit Residential Building	$150/Sq ft	$ 1,600/Sq m
Office	$ 230/Sq ft	$ 2,500/Sq m
Big Box Retail	$176/Sq ft	$ 1,900/Sq m

Upgrade Costs for Energy Efficiency Upgrades

Costs for individual upgrades are summarised in Appendix 2. These costs are based on discussions with local suppliers. Where no source of local data was available, Hanscomb (2006) data was used, applying a mark-up factor based on research by DIAND (2005), and summarised in Table 16. Finally, where equipment was replaced periodically, the equipment price was assumed to increase at a rate of 2.5% per year

Table 16: Location Mark-up Factors

	Buildings		Utilities		
	Non-residential	Residential	Mechanical	Electrical	Water/sewer
Yellowknife	1.3	1.34	1.33	1.18	1.35
Vancouver	1	1	0.98	1.04	0.95
Edmonton	1.21	1.31	1.1	1.11	0.89

Task 4 Define LCC Costing Variables

Energy Prices

Energy prices are summarised in Table 17 (excluding GST). Electricity pricing was obtained from the client is an average, based on typical consumption to reflect the complexity of consumption and demand charges.

Table 17: Current Energy Prices

	Electricity [$/KWh] (excluding GST)	Oil[6] [$/Litre]
Residential	$0.172	$0.88
Commercial	$0.155	$0.88

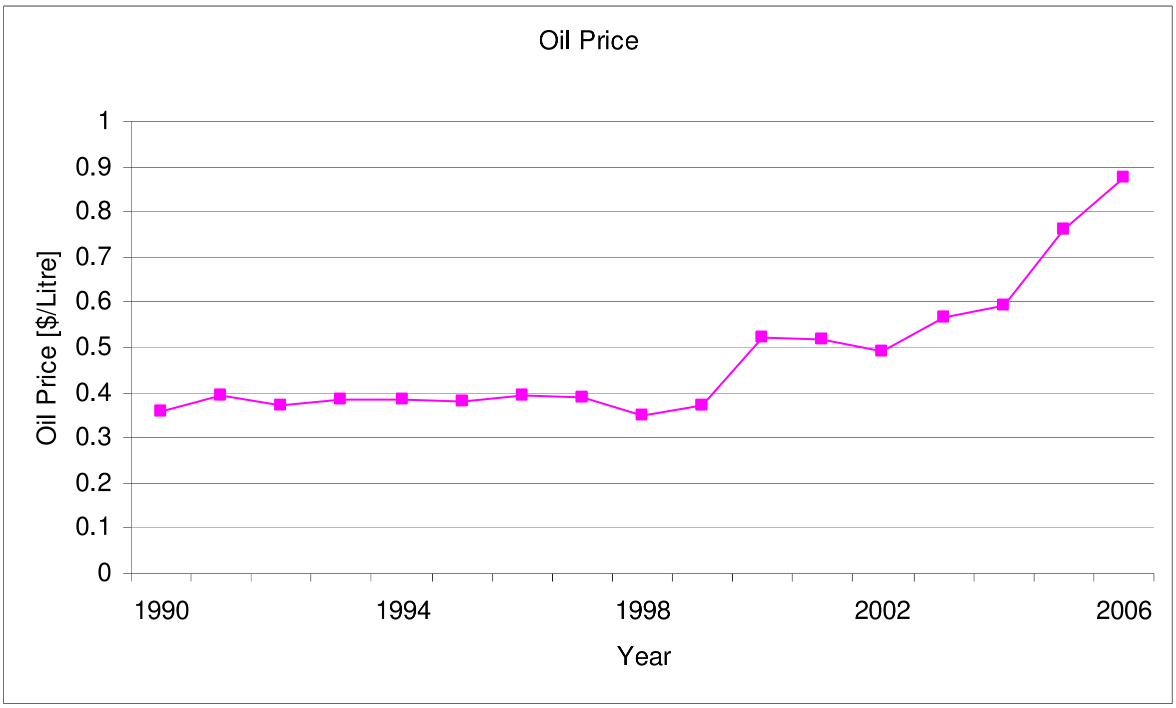


Figure 3: Heating Oil Price Trend

As shown in Figure 3, the cost of heating oil has more than doubled over the last five years. In addition to the long-term upward trend in heating oil prices, there are also significant seasonal fluctuations. This creates uncertainty in projecting future costs and benefits of energy efficiency upgrades to new

[6] http://www40.statcan.ca/l01/cst01/econ152r.htm

construction. However, given current trends to increased energy prices, an inflation rate of 2.5% was applied to energy in the calculations.

Discount Rate
The real discount rate used to complete the analysis is 6%. Inflation was estimated at 2.5%

Project Life
In general, upgrades were assumed to have the same expected life as the baseline assembly. For example, a high efficiency furnace and a mid efficiency furnace are both expected to have a 25-year life. When different life spans were encountered, this information was included within the LCC.

Pollution Costs
The LCC analysis excludes the financial impact of reduced greenhouse gas emissions or Common air contaminants (CACs).

Task 5. Model Energy

Residential Buildings

Energy modelling was completed using HOT-2000 (Version 9.31) energy simulations. As noted previously, baseline thermal archetypes were developed based on the Energuide for Houses database, and in consultation with individuals in the Yellowknife area who are knowledgeable about local building practices.

Commercial Buildings

Commercial building archetypes were modelled using the CBIPScreen on-line audit tool[7]. CBIPScreen is a simplified tool that may be used to evaluate energy efficiency measures during the concept design stage of construction.

Once the energy savings were calculated, the impact on greenhouse gas emissions was evaluated. Emission factors for heating oil and electricity are summarised in Table 18.

Table 18: Greenhouse Gas Emission Factors[8]

Fuel	Emission Factor
Heating Oil	0.26 Kg CO2/kwh
Electricity	0.04 kg co2/kwh

[7] http://cbipscreen.nrcan.gc.ca/cgi-bin/frameset0.cgi
[8] Ref YK_Energy_Baseline_-_20153183.xls

Task 6 Assess Cost Effectiveness

To assess the cost effectiveness of the proposed upgrades, the incremental capital cost and reduced operating cost were combined using a lifecycle cost approach. In addition, potential changes to the operating and maintenance costs were included to account for the fact that some additional equipment (such as heat recovery ventilators or condensing furnaces require additional maintenance. The net stream of costs and benefits were summed over the project life (assumed to be 30 years) to calculate the LCC.

Results of Tasks 3, 4 and 5 were used to perform the LCC analysis. The LCC analysis was completed initially for each action on a stand-alone basis. Once the cost effectiveness threshold was defined for the individual actions, those actions with a positive Net Present Value (NPV) were combined into bundles to calculate the overall impact of upgrades. These bundles were then modelled to calculate the energy savings and the present value.

The incremental lifecycle cost was calculated using the equation:

$$\Delta LCC = \Delta C + \sum_{i=1}^{n} \Delta E_i \frac{P_i}{(1+r)^{i-1}} + \sum_{i=1}^{n} \frac{\Delta O + M}{(1+r)^{i-1}}$$

Where:

ΔLCC	The change in lifecycle cost (LCC)
ΔC	Incremental capital cost of energy efficiency investment (capital and labour costs)
P_i	Energy price per year in year I (in today's dollars)
ΔE	Reduction in energy consumption in year i
r	Real discount rate
$\Delta O + M$	Incremental annual operating and maintenance costs

A positive LCC implies that the incremental capital cost of an investment is paid for through reduced operating and maintenance cost and the investment is cost effective. Conversely, a negative LCC shows an investment that is not cost effective.

Task 7 Aggregate Results Based on Growth Projections

Projections of the impact of energy efficiency actions are presented for milestone years 2009, 2014, 2019 and 2024. To develop these impact projections, estimates of growth in the building stock were combined with the energy and cost savings estimates developed in the previous tasks.

Historical Population Trends

A demographic profile of Yellowknife is summarised in Table 19. As can be seen, the population has increased from 16,541 to over 20,000 in the last 5 years, corresponding to a growth of 21%. Over the long term, population growth is expected to be 1.6% per year based on GNWT statistics.

Table 19: Demographic Indicators

Indicator	Estimate
2006 Population	20,000 (estimate)
2001 Census Population	16,541
2001 - 2006 Change	21%
Number of Dwellings	6,514

This population growth has translated into significant building activity as shown by historical construction activity for the last six years in Table 20.

Table 20: Construction Activity in Yellowknife, 2000 - 2005

Type	2000	2001	2002	2003	2004	2005	Totals
Stick Built	20	11	33	28	18	15	125
Factory built	2	20	74	78	39	20	233
MURB (Units)	3	8	161	152	119	120	563
MURB (Buildings)	1	2	6	6	4	4	23
Commercial	11	12	9	15	18	26	91

On the basis of the information above, the portion of residential growth by segment is presented in Table 21. As can be seen, MURBs account for over 60% of new housing units in Yellowknife, followed by factory built and stick built style homes.

Table 21: Growth Rate by Segment

Segment	Growth Rate [%]
Stick Built	14%
Factory built	25%
MURB	61%

Forecast Building Demand

Forecasting building demand is challenging. Historically, the cyclical fluctuation of the territorial economy has resulted in significant fluctuations in construction activity. Notwithstanding, the City has developed estimates of residential building demand[9]. Based on that analysis, estimated demand for new residential buildings is summarised in Table 22.

[9] City of Yellowknife, Residential Growth Study, April 2005.

Table 22: Building Stock Growth, 2005 – 2024

Period	Incremental Growth [# of Units]
2005 – 2009	740
2010 – 2014	715
2015 – 2019	575
2020 - 2024	575

Combining historical growth rates by segment with projected housing demand provides an estimate of new construction by segment. There is no data available for understanding the growth rate in the commercial sector by segment, and for the purpose of the current analysis, it is assumed that historical growth rates will continue and that commercial construction is split between office and big box retail. The split between office and big box was determined by the client through a review of historical trends.

Based on the assumptions noted above, an estimate of construction activity by milestone year is presented in Table 23.

Table 23: New Construction by Segment and Period

Period	Stick	Factory built	MURB	Office	Big Box
2005 - 2009	104	185	451	70	10
2010 - 2014	100	179	436	70	10
2015 - 2019	81	144	351	70	10
2020 - 2024	81	144	351	70	10
Total	365	651	1,589	280	40

Section 3: Results

This section presents the results of the analysis.

Analysis of Residential Buildings

A summary of the energy savings and lifecycle cost impacts of energy efficiency upgrades is summarised in Table 24 for stick built and in Table 25 for factory built buildings. As can be seen, a new single family home built to typical Yellowknife specifications achieves an Energuide rating of 71. With the addition of energy efficiency measures, the Energuide rating increases to 80. Similarly, a new factory built home has an EGH rating of 73. In both cases, the LCC to upgrade to an Energuide 80 is positive confirming that the energy upgrades are cost effective.

The incremental improvements to achieve the EGH 80 Rating include:

- Advanced framing
- Increased wall insulation
- Increased ceiling insulation
- Increased basement/crawl space insulation
- Increased thermal resistance of windows
- Increased air tightness with heat recovery ventilation

> **What is Advanced Framing?**
>
> Advanced Framing techniques include:
>
> - Designing homes on 2-foot modules to make the best use of common sheet good sizes and reduce waste and labor.
> - Spacing wall studs up to 24 inches on-center.
> - Spacing floor joists and roof rafters up to 24 inches on-center.
> - Using two-stud corner framing and inexpensive drywall clips or scrap lumber for drywall backing instead of studs.
> - Eliminating headers in non-load-bearing walls.
> - Using in-line framing in which floor, wall, and roof framing members are verticallyin line with one another and loads are transferred directly downward.
> - Using single lumber headers and top plates when appropriate.
>
> Ref:
> www.energystar.gov/ia/home_improvement/home_solutions/doeframing.pdf

Based on experience elsewhere, high efficiency oil furnaces were not incorporated into the upgrade package, as it has been found that condensing oil furnaces provide minimal energy savings and continue to have reliability issues associated with the acidity of the condensate, as well as freezing of the exhaust.

As can be seen, the estimated cost to upgrade a stick built house is $11,764 and the incremental cost to upgrade the factory built home is $8,064. These numbers are consistent with the analysis completed for Iqaluit[10].

The analysis does not include the soft costs associated with ensuring EGH 80 compliance such as plan checking and enforcement. Currently the cost to

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[10] Marbek Resource Consultants, An Energy Standard for Homes in Iqaluit – A Business Case, Pg 13.

complete plan checking and the air tightness test is $550. No estimate of the enforcement cost has been developed. The rationale for omitting these costs within the analysis is they may be borne by the city, whereas the direct costs will be borne by the consumer. In addition, the soft costs may be reduced over time through development of prescriptive compliance paths, so it is difficult to estimate their magnitude over the study period. Finally, the magnitude of these costs are small, and sensitivity analysis confirms the impact of including the soft costs is small.

It should be highlighted that upgrades for the factory built package needs to be completed at the factory. Therefore, it is recommended that the client consult with the local suppliers to develop an implementation plan.

From a cash flow perspective, implementation of an EGH 80 will result in a combined annual mortgage and energy expenditure savings of $545 and $590 for stick built and factory built homes, respectively[11]. Therefore, based on the current analysis, improving energy efficiency will result in a positive LCC and lower monthly costs for homeowners.

Based on the analysis, upgrades to windows are not cost effective on a stand-alone basis. However, when bundled, with the other measures, the package remains cost effective.

A challenge to achieve an EGH 80 in Yellowknife is the presence of partially heated crawl spaces. From an Energuide modeling perspective, conditioned crawl spaces are heated to 15 degrees Celsius by default, causing a significant penalty. Finally, it should be noted that partially conditioned attached garage spaces are not modelled in the EGH program that can have significant impacts on overall energy use in homes. In developing an energy standard, the city may wish to consider a separate bylaw to address garage construction.

[11] Assuming a 25 year mortgage at 5.5%.

Table 24: Stick Built Summary Results

Single Detached Stick-built		Archetype base file for Yellowknife SD	Raised heel truss (12"); Blown cell.., attic, R60	Adv., 2x6 @ 24" OC clad; fg batt, R22 + XPS, R7.5	Conv., 2x6 @ 24" OC clad; fg batt, R22 + XPS, R7.5	Conv. 2x4 @ 24" OC double 12"; fg batt, R28, 23" + fg batt, R12, 23"	TG, 2 low E, Argon, insul. spacer, vinyl;	DG, casement, HM TC88, Krypton;	Conv., 2x4 @ 24" OC; fg batt, R12, 23" + fg batt, R12, 23", full height	HRV, air tighten to 1.5 ac/h	W4, C0, B5, J2, F2, A8, G9	W9, C5, B5, J2, F2, A8, G9
	Type:		A8	W5	W4	W9	G4	G9	B5	0	Combined	Combined**
Results for: Oil heat		Base	Attic	Walls	Walls	Walls	Windows	Windows	Basement	Option 1	All	All
Technical	Units											
Framing		Standard	**Advanced**	**Advanced**	Standard	Standard	Standard	Standard	Standard	Standard	Standard	Standard
Wall insulation	nom RSI	4.54	4.54	**5.20**	**5.20**	**7.04**	4.54	4.54	4.54	4.54	**5.20**	**7.04**
Ceiling insulation	nom RSI	7.00	**10.57**	7.00	7.00	7.00	7.00	7.00	7.00	7.00	**10.57**	**10.57**
Joist Ceiling insulation	nom RSI	4.93	4.93	4.93	4.93	4.93	4.93	4.93	4.93	4.93	4.93	4.93
Overhung Floor insulation	nom RSI	4.93	4.93	4.93	4.93	4.93	4.93	4.93	4.93	4.93	4.93	4.93
C/S wall insulation	nom RSI	2.20	2.20	2.20	2.20	2.20	2.20	2.20	2.20	2.20	2.20	**5.20**
Basement wall insulation	nom RSI	2.64	2.64	2.64	2.64	2.64	2.64	2.64	**4.23**	2.64	**4.23**	**4.23**
Coverage		full height	full height	full height	full height	full height	full height	full height	full height	full height	full height	full height
Windows	eff. RSI	0.510	0.510	0.510	0.510	0.510	**0.75**	**0.90**	0.510	0.510	**0.90**	**0.90**
Heating system		Oil	Oil	Oil	Oil	Oil	Oil	Oil	Oil	Oil	Oil	Oil
Furnace fan		Auto	Auto	Auto	Auto	Auto	Auto	Auto	Auto	Auto	Auto	Auto
DHW		Oil	Oil	Oil	Oil	Oil	Oil	Oil	Oil	Oil	Oil	Oil
Air tightness	ac/h_{50Pa}	3.74	3.74	3.74	3.74	3.74	3.74	3.74	3.74	**1.50**	**1.50**	**1.50**
Ventilation*	Type	balanced	balanced	balanced	balanced	balanced	balanced	balanced	balanced	**HRV**	**HRV**	**HRV**
	L/s	10	10	10	10	10	10	10	10	34	34	34
	hr/day	EGH	EGH	EGH	EGH	EGH	EGH	EGH	EGH	EGH	EGH	EGH
Oct-Apr avg. air changes	ac/h	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	**0.32**	**0.32**	**0.32**
Electric utilities (inside)	kWh/d	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0
Temperature - main floor	C	21.0	21.0	21.0	21.0	21.0	21.0	21.0	21.0	21.0	21.0	21.0
- basement	C	19.0	19.0	19.0	19.0	19.0	19.0	19.0	19.0	19.0	19.0	19.0
Electricity consumption	MJ/yr	34,077	33,979	34,010	34,014	33,904	33,913	33,890	34,029	34,575	34,169	34,020
Oil consumption	MJ/yr	171,111	164,869	167,063	167,321	160,350	160,356	159,351	168,185	146,376	120,549	111,277
Space heat reduction	%	0.0%	4.2%	2.7%	2.5%	7.2%	7.2%	7.8%	1.9%	16.5%	33.6%	39.8%
Electricity savings	MJ/yr	0	98	67	63	173	164	187	48	-498	-92	57
Oil Savings	MJ/yr	0	6,242	4,047	3,789	10,760	10,755	11,759	2,925	24,735	50,562	59,834
Total Savings	MJ/yr	0	6,340	4,115	3,852	10,933	10,919	11,946	2,973	24,237	50,470	59,891
Total Savings	%	0.0%	3.2%	2.0%	1.9%	5.6%	5.6%	6.2%	1.5%	13.4%	32.6%	41.2%
GHG Reduction	kg/yr	0	480	310	290	830	830	910	230	1,690	3,690	4,400
Financial		Period of Analysis	**30**	years	Discount Rate:	**8.65%**		Electricity inflation	**2.5%**		Oil inflation	**2.5%**
Incremental capital cost	$	N/A	$638	$712	$1,020	$3,299	$3,996	$4,678	$491	$1,275	$8,101	$11,764
NPV of energy savings	$	N/A	$2,170	$1,410	$1,320	$3,744	$3,736	$4,090	$1,019	$7,953	$16,933	$20,159
Total LCC (Cf base)	**$**		**$1,532**	**$698**	**$300**	**$446**	**-$260**	**-$587**	**$528**	**$6,679**	**$8,832**	**$8,396**
LCC/Incremental Cost	%		240%	98%	29%	14%	-7%	-13%	107%	524%	109%	71%
Unit LCC (Cf base)	$\$/m^2$		**$9.01**	**$6.70**	**$2.88**	**$4.28**	**-$10.85**	**-$24.47**	**$13.96**		**$16.91**	**$16.08**
EnerGuide value		71									77	80

Table 25: Factory Built Summary Results

Single Detached, Modular (open c/s)

		Archetype base file for Yellowknife Modular	Raised heel truss (12"); Blown cell.., attic, R40	Raised heel truss (12"); Blown cell.., attic, R60	Conv., 2x6 @ 24" OC clad; fg batt, R22 + XPS, R7.5	Conv., 2x6 @ 16" OC; fg batt, R22	TG, 2 low E, Argon, insul. spacer, vinyl;	DG, casement, HM TC88, Krypton;	Conv., 12" open web @ 16" OC; fg batt, R40, 15"	HRV, air tighten to 2.5 ac/h	W3, C0, B2, J2, F5, A8, G4	W4, C0, B2, J2, F5, A8, G9
	Type:		A4	A8	W4	W3	G4	G9	F5	0	Combined	Combined
Results for: Oil heat		Base	Attic	Attic	Walls	Walls	Windows	Windows	Floors	Option 1	All	All
Technical	Units											
Framing		Standard	**Advanced**	**Advanced**	Standard	Standard	Standard	Standard	Standard	Standard	Standard	Standard
Wall insulation	nom RSI	3.52	3.52	3.52	**5.20**	**3.87**	3.52	3.52	3.52	3.52	**3.87**	**5.20**
Ceiling insulation	nom RSI	6.16	**7.00**	**10.57**	6.16	6.16	6.16	6.16	6.16	6.16	**10.57**	**10.57**
Joist Ceiling insulation	nom RSI	4.93	4.93	4.93	4.93	4.93	4.93	4.93	4.93	4.93	4.93	4.93
Overhung Floor insulation	nom RSI	4.93	4.93	4.93	4.93	4.93	4.93	4.93	**7.04**	4.93	**7.04**	**7.04**
C/S wall insulation	nom RSI	2.20	2.20	2.20	2.20	2.20	2.20	2.20	2.20	2.20	2.20	2.20
Basement wall insulation	nom RSI	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Coverage		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Windows	eff. RSI	0.510	0.510	0.510	0.510	0.510	**0.75**	**0.90**	0.510	0.510	**0.75**	**0.90**
Heating system		Oil	Oil	Oil	Oil	Oil	Oil	Oil	Oil	Oil	Oil	Oil
Furnace fan		Auto	Auto	Auto	Auto	Auto	Auto	Auto	Auto	Auto	Auto	Auto
DHW		Oil	Oil	Oil	Oil	Oil	Oil	Oil	Oil	Oil	Oil	Oil
Air tightness	ac/h_{50Pa}	3.37	3.37	3.37	3.37	3.37	3.37	3.37	3.37	**2.50**	**2.50**	**2.50**
Ventilation*	Type	balanced	balanced	balanced	balanced	balanced	balanced	balanced	balanced	**HRV**	**HRV**	**HRV**
	L/s	10	10	10	10	10	10	10	10	21	21	21
	hr/day	EGH	EGH	EGH	EGH	EGH	EGH	EGH	EGH	EGH	EGH	EGH
Oct-Apr avg. air changes	ac/h	0.31	0.31	0.31	0.31	0.31	0.31	0.31	0.31	**0.30**	**0.30**	**0.30**
Electric utilities (inside)	kWh/d	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0
Temperature - main floor	C	21.0	21.0	21.0	21.0	21.0	21.0	21.0	21.0	21.0	21.0	21.0
- basement	C	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Electricity consumption	MJ/yr	33,346	33,339	33,264	33,113	33,297	33,254	33,242	33,255	33,534	33,243	33,049
Oil consumption	MJ/yr	119,766	119,302	114,602	105,289	116,632	113,945	113,206	114,092	106,654	88,633	76,503
Space heat reduction	%	0.0%	0.5%	5.2%	14.6%	3.2%	5.9%	6.6%	5.7%	13.2%	31.4%	43.7%
Electricity savings	MJ/yr	0	8	83	233	50	92	105	92	-188	104	298
Oil Savings	MJ/yr	0	464	5,165	14,478	3,134	5,822	6,561	5,674	13,113	31,133	43,263
Total Savings	MJ/yr	0	472	5,247	14,711	3,184	5,914	6,665	5,766	12,925	31,237	43,561
Total Savings	%	0.0%	0.3%	3.5%	10.6%	2.1%	4.0%	4.6%	3.9%	9.2%	25.6%	39.8%
GHG Reduction	kg/yr	0	30	400	1,120	240	450	500	430	910	2,310	3,240
Financial	Period of Analysis		**30**	years	Discount Rate:	**8.65%**	Electricity inflation		**2.5%**		Oil inflation	**2.5%**
Incremental capital cost	$	N/A	$541	$1,389	$1,905	$440	$2,398	$2,807	$740	$1,223	$6,190	$8,064
NPV of energy savings	$	N/A	$162	$1,797	$5,038	$1,090	$2,025	$2,282	$1,975	$4,272	$10,543	$14,764
Total LCC (Cf base)	**$**		**-$379**	**$407**	**$3,133**	**$650**	**-$373**	**-$524**	**$1,235**	**$3,049**	**$4,353**	**$6,700**
LCC/Incremental Cost	%		-70%	29%	164%	148%	-16%	-19%	167%	249%	70%	83%
Unit LCC (Cf base)	$\$/m^2$		**-$2.84**	**$3.05**	**$27.46**	**$5.69**	**-$25.90**	**-$36.40**	**$9.24**		**$10.90**	**$16.78**
EnerGuide value		73									77	80

Analysis of Commercial Buildings

Summary results of the financial modelling are presented in Table 26 to Table 28. As can be seen, there is a positive LCC for all the archetypes modeled, which confirms the cost effectiveness of CBIP adoption in Yellowknife. In addition, the payback period ranges from 1.7 years to 3.7 years, suggesting that from a financial perspective, investment in energy efficiency is within typical business thresholds.

Table 26: MURB Summary Results

Baseline Operating Cost	$147,156
Incremental Cap Cost	$135,000
Annual Energy Cost Savings	$38,069
LCC @ 6%Discount Rate, Energy Inflation @2.5%	$312,871
Payback [Years]	3.5

Table 27: Office Summary Results

Baseline Operating Cost	$37,004
Incremental Cap Cost	$51,000
Annual Energy Cost Savings	$13,714
LCC @ 6%Discount Rate, Energy Inflation @2.5%	$110,341
Payback [Years]	3.7

Table 28: Big Box Retail Summary Results

Baseline Operating Cost	$91,345
Incremental Cap Cost	$66,490
Annual Energy Cost Savings	$38,100
LCC @ 6%Discount Rate, Energy Inflation @2.5%	$381,745
Payback [Years]	1.7

Therefore, based on the current analysis, improving energy efficiency will result in a positive LCC for businesses.

Aggregate Impacts

Energy Impact

The energy impacts of implementing new standards were combined with the growth projections to estimate aggregate impacts over the next 20 years. Total electricity and oils savings by milestone year are summarised in Table 29 and Table 30 respectively. As can be seen, implementation of the energy standards will result in a net savings of 7,900 GJ/yr of electricity and 366,000 GJ/yr of oil in 2024. The savings are largely from reduced space heating energy, resulting in the significantly larger savings in oil use.

Table 29: Savings in Electricity

	Savings [GJ]	Savings [KWh]
2005 - 2009	1,258	349,567
2010 - 2014	2,510	697,178
2015 - 2019	3,722	1,033,835
2020 - 2024	4,934	1,370,493

Table 30: Savings in Oil

	Savings [GJ]	Savings [Litres]
2005 - 2009	79,728	2,131,771
2010 - 2014	158,027	4,225,315
2015 - 2019	228,319	6,104,791
2020 - 2024	298,612	7,984,267

Financial Impact

The simple payback for increasing the energy performance of the different building types is summarised in Table 31. As can be seen, the payback period ranges from a low of 1.7 years for the big box retail to a maximum of 8.3 years for the stick built home. Detailed financial calculations are included in Appendix 3.

Table 31: Payback For Investment

Segment	Simple Payback
Stick Built	8.3
Factory built	6.8
MURB	3.5
Office	3.7
Big Box	1.7

A financial summary of implementing energy efficiency standards is provided in Table 32. Implementation of energy efficiency standards will result in an incremental cost of new construction of $35 million over the period 2005 to 2024. However, the net present value of the energy savings is $50 million, resulting in a benefit cost ratio of 1.4.

Table 32: Financial Summary of Program

Indicator	Value
Incremental Investment	$35 Million
NPV of Energy Savings	$50 Million
Benefit Cost Ratio	1.4

These estimates do not include the indirect costs of training local building trades or design professionals on how to build to the new performance level. While these costs are transitional, they may be significant in the short term. In addition, the additional requirement for high performance assemblies may result in price changes that will impact the analysis. For example, as the saturation of high performance windows increase, their cost is likely to come down.

GHG Impact

The GHG reduction impact is presented in Table 33. By 2024, GHG emissions will be reduced by 21,600 tonnes per year. In 2004 GHG emissions from residential, commercial and institutional buildings was estimated at 307,918 Tonnes[12]. By 2024, GHG emissions from buildings will increase to 524,600 tonnes.[13] Therefore, the current initiative would reduce emissions by 4.1% below the current trajectory.

Table 33: GHG Impacts [Tonnes/year]

Year	GHG Impact (Tonnes/ year)
2005 - 2009	5,772
2010 - 2014	11,441
2015 - 2019	16,531
2020 - 2024	21,621

[12] This estimate is obtained from the City of Yellowknife Energy and GHG Baseline (June 2006). It includes residential, commercial and institutional buildings.
[13] Assuming current growth trends of 2.7% per year.

Section 4: Conclusions

Based on this analysis, the following conclusions are made:

- The LCC to upgrade to an Energuide 80 is positive confirming that the energy upgrades are cost effective. The incremental improvements to achieve the EGH Rating include:
    - Advanced framing,
    - Increased wall insulation,
    - Increased ceiling insulation,
    - Increased basement/crawl space insulation,
    - Increased thermal resistance of windows, and
    - Increased air tightness and heat recovery ventilation.

- The estimated cost to upgrade a stick built house is $11,764 and the incremental cost to upgrade a factory built home is $8,064.

- From a cash flow perspective, implementation of an EGH 80 will result in a reduction of combined mortgage and energy expenditure of $545 and $590 for stick built and factory built homes, respectively.

- For commercial buildings, the LCC is positive for all the archetypes modeled which confirms the cost effectiveness of CBIP adoption in Yellowknife.

- The simple payback period ranges from a low of 1.7 years for the big box retail to a maximum of 8.3 years for the stick built home.

- Implementation of energy efficiency standards will result in an incremental cost of residential and commercial new construction of $37 million over the period 2005 to 2024. $50 million, resulting in a benefit cost ratio of 1.4.

- By 2024, GHG emissions will be reduced by 21,600 tonnes per year with the introduction of the energy efficiency standards. In 2004 GHG emissions from residential, commercial and institutional buildings was estimated at 307,918 Tonnes[14]. By 2024, GHG emissions from buildings will increase to 524,600 tonnes.[15] Therefore, the current initiative would reduce emissions by 4.1% below the current trajectory.

[14] This estimate is obtained from the City of Yellowknife Energy and GHG Baseline (June 2006). It includes residential, commercial and institutional buildings.
[15] Assuming current growth trends of 2.7% per year.

Therefore, it is recommended that Energuide 80 and CBIP compliance be used for new construction in Yellowknife.

References

Canadian Council on Building and Fire Codes, Model National Energy Code for Buildings (MNECB), National Research Council of Canada, 1997

Department of Indian and Northern Development (DIAND) Cost Reference Manual, TID-MID-2, July 2005

Hanscomb Yardstick for Costing, 2006

Natural Resources Canada, Commercial Building Incentive Program Technical Guide, 2000

Appendix 1: MNECB Prescriptive Requirements

APPLICABILITY OF MNECB	
Building Type is not exempt.	1.1.2.1(1)-(5)
Building type and spaces definitions conforms with defined terms.	1.1.3.2, E-1.1.3.2-1
BUILDING ENVELOPE	
Partial Penetration of Envelope by Services	
Recessed heaters, pipes and ducts that partially penetrate the building envelope must be located on the conditioned side of the insulation and must not increase the overall U Value of the building envelope assembly.	5.2.8.1-1
If radiant heating sources, as opposed to recessed heaters are embedded in the ground envelope components, the overall U-Value at the projected area must not exceed 80% of the maximum overall U-Value allowed in the MNECB regional tables.	3.2.3.3-3
Full Envelope Penetration by Services	
Insulation must be installed tight against any pipes, ducts, through wall venting, packaged terminal A/C or heat pump units, shelf angles, anchors, ties and associated fasteners, and other minor structural members that must completely penetrate the building envelope to perform their intended purpose.	3.2.1.2-4
Pipes and ducts in exterior walls must not exceed the overall thermal transmittance to greater than allowable for wall assembly.	3.2.1.2-10
Unless it is required functionally that a roof or floor fully penetrate the building envelope, the U-value at the projected area of the floor or roof shall be:	3.2.1.2-7&8
… Concrete roof or floor: Not more than twice that of the associated wall.	
… Roof or floor other than concrete: Equal to or less than that of the associated wall.	
Partial Envelope Penetration by Major Structural Members	
Major structural members, such as columns or spandrel beams that run parallel to the building envelope may increase the U-value at the projected area of the member up to twice that shown in Table 3.3.1.1.A of Appendix A of the MNECB.	3.2.1.2-3
Full Penetration of Envelope by Structural Components	
Large components, such as floor slabs, beams, girders and columns, which must completely penetrate that building envelope to perform their required function, need not be	3.2.1.2-5

insulated if the sum of their cross-sectional areas does not exceed 2% of the building envelope area. Insulation must be tight against such penetrations.	
Insulation that is continuous across expansion joints, and wall and door intersections maintain an overall thermal transmittance not greater than highest allowable for the two.	3.2.1.2-11
All overhead doors separating conditioned from exterior space are weatherstripped on all edges in conformance.	3.2.4.3.5
Full Envelope Penetration by Walls	
Where a concrete or masonry foundation wall, firewall or party wall penetrates an exterior wall or roof, it must be insulated on both sides, back from and to the same U-value as the exterior assembly for distance of four times its depth.	3.2.1.2-6
Insulation Overlap	
At envelope locations where two planes of insulation do not physically join, the two continuous insulations shall overlap for a length of at least 4 times the distance separating them.	3.2.1.2-9
Windows and Doors	
Wall insulation must extend to meet door and window frames.	3.2.1.2-11
All windows comply with energy efficiency acts in force locally, or have been specified to maintain an A2 air leakage rating as described under CAN/CSA A440-M.	3.2.4.4.2
All sliding doors comply with energy efficiency acts in force locally, or have been specified to maintain and A2 air leakage rating as described under CAN/CGSB-82.1-M.	3.2.4.3
Confirm that air curtains are not being used in place of exterior doors.	3.2.4.3-6
Below Grade Insulation	
Building assemblies in contact with the ground must be constructed such that their area-weighted average RSI-value, including insulation, sheathing, exterior and interior finish materials and interior air films, shall not be less than that shown in Table 3.2.3.1 of Appendix A.	3.2.3.1a,.2a,.3a
If a below grade wall requires insulation, it may be insulated over its full height, or to a depth of 2.4m, whichever is shallower.	3.2.3.1-3
If the top of the footing is less than 0.6 m below grade, wall insulation shall extend down to the top of the footing and the same level of insulation shall be placed on top or below the floor for no less than 1 meter around the perimeter.	3.2.3.2-4
For heated crawl spaces, crawl space floors (whether	3.2.3.1

finished or not) that are less than 0.6 m below grade must be insulated to the level stipulated in MNECB Table 3.2.3.1 over the entire crawl space floor area.	
General	
The overall thermal transmittance of opaque components of the building envelope shall not be increased to more than 167% of the maximum overall thermal transmittance permitted in Section 3.3.	8.2.1.4-2
Vestibules	
Vestibules are required for all doors that separate conditioned space from the outdoors (Certain exceptions apply as indicated in MNECB.	3.2.2.3
HEATING, VENTILATION AND AIR CONDITIONING	
Equipment	
HVAC systems must be sized to meet the needs of conditioned spaces.	5.2.1.1-1
Equipment installed outdoors or in unconditioned spaces must be designed by the manufacturer for such installation.	5.2.1.1-1
HVAC equipment and components included in the scope of MNECB Table 5.2.13.1 must comply with the relevant local appliance/equipment energy efficiency act or the relevant standard listed.	5.2.13.1-1
Field-assembled equipment and components from more than one manufacturer must be designed with good engineering practice and provide the overall efficiency called for in Clause 5.2.13.1.	5.2.13.1
Temperature Controls	
Each system intended to provide comfort heating/cooling must have at least one automatic space temperature control device.	5.2.10.1
Thermostatic controls for comfort are to have the following characteristics:	5.2.10.3)
… Heating controls must be capable of adjusting the temperature of the space they serve down to at least 13°C.	
… Cooling controls must be capable of adjusting the temperature of the space up to at least 29°C.	
The sensors of wall-mounted thermostats must be installed in accordance with the manufacturer's instructions and are to be located as per Clause 5.2.10.4.	5.2.10.4
Electric baseboard heaters must be controlled by remotely mounted thermostats.	5.2.7.1
Heat pumps having supplementary heaters must be controlled to prevent supplementary heater operation when the heating load can be met by the heat pump alone, except during defrost cycles.	5.2.10.5

If separate space-heating and -cooling controls are used, simultaneous provision of heating and cooling must be prevented.	5.2.10.6
The heating/cooling of a zone must be regulated by individual thermostatic controls located in the zone unless a perimeter system is used, in which case there must be at least one space thermostatic control per orientation (provided that the orientation is at least 15m long).	5.2.10.6
Shut-off and Setback	
Each HVAC system with a heating or cooling capacity of 2 kW or more must have automatic equipment shut-off or temperature setback controls for periods of non-use, unless the system is intended to operate continuously. Unoccupied setback of heating set-point must not enable cooling, and unoccupied setup of cooling set-point must not enable heating.	5.2.12.1
Heating or cooling equipment with capacities below 2 kW may be controlled by accessible, manual controls.	5.2.12.1
Airflow Control Areas	
Each air distribution system serving multiple temperature control zones having a combined conditioned floor area > 2500 m2 must be divided into airflow control areas of not more than 2500 m2, or one storey, such that the supply of air to each area can be reduced or stopped independent of other areas. Areas requiring full flow continuously are exempt.	5.2.12.2-1 to 7
The zones within a given area must be on the same occupancy schedule and have off-hours setback or on/off controls	5.2.12.2-1
Where airflow control areas are served by VAV boxes, the central system must have at least a 50% reduction in fan power for a 50% reduction in air flow.	5.2.12.2-5
Air Distribution Systems	
Duct systems must be designed so that they can be balanced.	5.2.2.2-1
HVAC ducts and plenums must be sealed as per the SMACNA Duct Construction Standard and MNECB Table 5.2.2.3 unless they are RIA ducts in conditioned spaces and are downstream of coils/boxes.	5.2.2.4-1
HVAC ducts and plenums must be thermally insulated as per MNECB Table 5.2.2.5 (some exemptions apply).	5.2.2.5
S/A and RIA ducts located outdoors must be insulated to the level prescribed for exterior walls, and protected from mechanical damage, weathering and condensation.	5.2.2.6-2
Air Intake and Outlet Dampers	

Ducts or openings intended to discharge air from conditioned space to the outdoors or an unconditioned space, and outdoor air intakes must be equipped with motorized dampers. Exemptions to this requirement include combustion air intakes, kitchen exhausts, continuously operated systems, and very small ducts.	5.2.3.1
Humidification Systems	
Humidifiers and dehumidifiers must be provided with an automatic humidity control device. If the purpose of the humidity control is comfort, the controller must be able to prevent the use of energy to increase relative humidity above 30% or to decrease it below 60%.	5.2.11.1-2
Special Temperature and Humidity Requirements	
Spaces with special process temperature requirements, humidity requirements or both must be served by separate air distribution systems from those serving spaces requiring only comfort conditions, unless the comfort air is 10% or less of the total, or unless the total design air flow does not exceed 3000 L/s.	5.2.9.1-2
Hydronic Systems	
All hydronic systems must be designed so they can be balanced as per Appendix E.	5.2.4.2-1
Multiple boiler systems must prevent heat loss through boilers when they are not in operation through the use of such items as vent dampers or shut-off valves interlocked with burners.	5.2.12.4
Pipes containing fluids with design operating temperatures outside the 13°C to 40°C range must be insulated as per MNECB Table 5.2.4.3. Some exemptions apply.	5.2.4.3-4
HVAC piping outside the building envelope must be insulated to the maximum requirements of Table 5.2.4.3. Insulation must be protected where it may be subjected to mechanical damage, weathering or condensation.	5.2.4.3-5
Seasonal pumping systems, such as heated and chilled water pumping systems, must have automatic controls or readily accessible and clearly labeled manual controls to shut down the pumps when they are not required.	5.2.12.3
SERVICE WATER HEATING SYSTEMS	
Storage Vessels and Heating Equipment	
Service water heaters, boilers, storage tanks and pool heaters must conform to relevant appliance or equipment energy efficiency acts, or with MNECB Table 6.2.2.1 where such an act doesn't apply.	6.2.2.1-1
Hot service water storage tanks located outdoors or in unconditioned spaces must be covered with insulation	6.2.2.1-3

having a maximum U-value of 0.55 W/m2-°C.	
Hot water storage tanks within conditioned spaces must be covered with insulation having a maximum U-value of 0.8 W/m2-°C.	6.2.2.1-2
Tank insulation located where it may be damaged must be protected.	6.2.2.1-4
Service water heating equipment, other than hot water storage tanks, must be installed in conditioned space.	6.2.2.2
Controls	
Service water heating systems with storage tanks must have automatic temperature controls capable of setting temperatures between the lowest and highest acceptable temperatures for the intended use.	6.2.4.1
Except for systems in which the storage capacity is less than 100 L, each service water heating system must have a readily accessible and clearly labeled device to allow shutdown.	6.2.4.2
Electric heat trace elements installed along service water pipes must have automatic controls to maintain the hot water temperature within the required range.	6.2.4.3
Water Conservation	
Individual showerheads, used for reasons other than safety, must limit the maximum water discharge to 9.5 L/min.	6.2.6.1-1
Where multiple shower heads are served by one temperature control, each showerhead must have an automatic control device that shuts off the flow of water when the shower is not in use.	6.2.6.1-2
Except in dwelling units, lavatory faucets must limit the maximum water discharge to 8.3 L/min.	6.2.6.2-1
Each lavatory in a public access washroom of an assembly occupancy building must have a device capable of automatically shutting off the flow of water when the lavatory is not in use.	6.2.6.2-2
Piping	
All hot service water piping in circulating systems, non-circulating systems without heat traps, and non-circulating systems with electric heat-tracing elements along the pipes must be insulated in accordance with MNECB.	Table 6.2.3.1 and Sentences 6.2.3.1 (2) to (4).
Systems With More Than One End-Use Design Temperature	
When less than 50% of the total design flow of a service water heating system has a design discharge temperature higher than 60°C, separate remote heaters or booster heaters are required for those portions of the system with a design temperature higher than 60°C.	6.2.5.1
Swimming Pools	

Pool heaters must be equipped with a readily accessible and clearly labeled device to start and stop the heater without adjusting the thermostat setting and, where applicable, without relighting the pilot light.	6.2.7.1-1
Except for pumps required by public health standards to operate continuously and pumps required to operate solar or waste heat recovery pool heating systems, swimming pool heaters must have time switches or other controls that can be set to automatically turn off pumps and heaters when their operation is not required.	6.2.7.1-2
Except for pools deriving more than 60% of their pool-heating energy from site-recovered energy or site solar energy, heated outdoor and indoor swimming pools must be equipped with pool covers. In the case of pool temperatures above 32°C, the cover must have an RSI-value of at least 2.1.	6.2.7.2-1/3
LIGHTING	
Lighting Design Intent	
Lighting design documentation conforms to Clause 4.2.6.1.	4.2.6.1
Exterior Lighting	
Exterior entrances/exits, unless high-risk security areas, must meet the requirements of MNECB Table 4.2.1.2. Blending of power for all entrance/exits is permitted.	4.2.1.2-2
Façade lighting power must be less than 2.4 W/m2 of face area.	4.2.1.3-1
Other exterior lighting, unless exempt, must have a luminous efficacy greater than 60 lm/W.	4.2.1.1
Exterior Lighting Controls	
Except for exterior lighting for 24-hour use, or outdoor sports facilities, exterior lighting must be controlled by programmable schedule controllers or photocells.	4.2.2.1-1
Interior Lighting	
Exit sign power must be less than 22W.	4.2.3.1
Interior Lighting Controls	
Controls are required to provide lower lighting levels at night for office spaces with the following characteristics:	4.2.4.2-1
… Area greater than 40 m2.	
… Enclosed wall or ceiling-height partitions.	
… Where connected lighting exceeds 12 W/m2.	
The required night light fixtures must meet the following:	4.2.4.2-3
… Not more than one fixture per 40 m2.	
… An average lighting level greater than 10 lx.	
… At least one fixture controlled separately from the remaining fixtures.	
Unless continuously lit, each space enclosed by walls or	4.2.4.1-3

ceiling-height partitions must have controls (at least one per circuit) capable of turning off hard-wired lights in the space.	
Controls may be centralized if:	4.2.4.3-2
… Controls are automatic or programmable.	
… For safety reasons, lights are under control of staff or building management.	
Such controls, except in dwelling units, must have identification showing the lighted areas controlled.	4.2.4.3
Task lighting (not in the ceiling) must have a switch near the work station.	4.2.4.3-3
Hotel guest rooms must be provided with a master switch at the entrance to the room for all permanently wired lighting fixtures and receptacles, except those in the bathroom.	4.2.4.4
ELECTRICAL	
Electrical Distribution System Monitoring	
Unless exempted, dwelling units and suites having all electrical loads supplied by a feeder to only that suite must be individually metered to billing accuracy.	7.2.1.1-1
Electrical distribution systems with load carrying capacity of greater than 250 kV A must be designed to facilitate the installation of a system to monitor the electrical consumption of (Clause 7.2.1.2-1/2):	7.2.1.2-1/2
… Tenants with connected loads greater than 100 kV A.	
… Services, appliances, or equipment serving storeys greater than 1000 m^2 and intended to be used as office space.	
… Electrical power feeders for hard-wired lighting, HVAC systems and equipment serving multiple tenants, service water heating, elevators, and any special equipment or systems of more than 20 kW.	
Power Receptacles	
Where exterior power receptacles are provided, at least one must be controlled from indoors.	7.2.2.1-1
Where power receptacles are provided for indoor/outdoor parking and are supplied through a panel board serving a suite, they must be controlled by switches or timers accessible only to the tenants of the suite.	7.2.2.1-2
Transformers	
Transformers and their power loss characteristics must comply with the relevant appliance or equipment efficiency act, or CAN/CSA-C802 if the transformer falls within the scope of that standard.	7.2.3.1
Electrical Motors	
Permanently wired polyphase motors must comply with the	7.2.4.2-1

relevant appliance or equipment efficiency act, or CAN/CSA-C390 clause 4.10.	
Nameplates must list the nominal full-load motor efficiency.	7.2.4.2-3

Appendix 2: Pricing Data

RESIDENTIAL CAPITAL COSTS

City Number 0

130% Yellowknife relative labor cost vs Vancouver — Yellowknife SD

Code	Frame No.	Insul. No.	Insul. No.	Attics Description	Shaded cells are base cases Type	nom. RSI (m2C/W)	Regional framing ($/m2)	Regional insulation ($/m2)	Regional insulation ($/m2)	Regional Total w/tax ($/m2)
A4	148	256		Raised heel truss (12")	Blown cell.., attic, R40	7.00	2.09	17.02		20.44
A5		312		Conventional truss @24 OC	fg batt, R40, 15"	7.04		20.53		21.96
A6	148	257		Raised heel truss (12")	Blown cell.., attic, R44	7.75	2.09	18.72		22.26
A7	148	258		Raised heel truss (12")	Blown cell.., attic, R50	8.81	2.09	21.27		24.99
A8	148	259		Raised heel truss (12")	Blown cell.., attic, R60	10.57	2.09	20.53		24.20

Code	Frame No.	Insul. No.	Insul. No.	Joist-Type Roofs Description	Minimum 2" space above insulation Shaded cells are base cases Type	nom. RSI (m2C/W)	Regional framing ($/m2)	Regional insulation ($/m2)	Regional insulation ($/m2)	Regional Total w/tax ($/m2)
J2	143	310		Conv., 2x10 @ 16" OC, 2x4 strapped	fg batt, R28, 15"	4.93	94.57	11.09		113.05
J3	143	315		Conv., 2x10 @ 16" OC, 2x4 strapped	fg batt, R31.8, 15"	5.60	94.57	12.71		114.79
J4	141	315		Conv., 11.5" comp. @ 16" OC, strapped	fg batt, R31.8, 15"	5.60	89.72	12.71		109.61
J5	141	312		Conv., 11.5" comp. @ 16" OC, strapped	fg batt, R40, 15"	7.04	89.72	20.53		117.97
J6	108	312	302	Conv., 16" open web @ 16" OC	fg batt, R40, 15" + fg batt, R12, 15"	9.16	95.92	20.53	6.03	131.05

Code	Frame No.	Insul. No.	Insul. No.	Description	Type	nom. RSI (m2C/W)	Regional framing ($/m2)	Regional insulation ($/m2)	Regional insulation ($/m2)	Regional Total w/tax ($/m2)
				Wood frame walls	Using thicker gyproc with 24"OC walls?	**Yes**				
					Shaded cells are base cases					
W0	005	307		Conv., 2x6 @ 16" OC	fg batt, R20, 15"	3.52	41.99	8.63		54.17
W2	007	307	219	Conv., 2x6 @ 24" OC clad	fg batt, R20, 15" + EPS, R5.77	4.54	38.22	8.63	10.71	61.59
W3	002	302	219	Conv., 2x4 @ 16" OC clad	fg batt, R12, 15" + EPS, R5.77	3.13	36.60	6.03	10.71	57.08
W4	007	309	210	Conv., 2x6 @ 24" OC clad	fg batt, R22 + XPS, R7.5	5.20	38.22	12.50	16.00	71.38
W5	009	309	210	Adv., 2x6 @ 24" OC clad	fg batt, R22 + XPS, R7.5	5.20	35.46	12.50	16.00	68.43
W6	008	357		Adv., 2x6 @ 24" OC	mw batt, R22, 23"	3.87	33.73	11.12		47.99
W7	009	308	210	Adv., 2x6 @ 24" OC clad	fg batt, R20, 23" + XPS, R7.5	4.84	35.46	8.87	16.00	64.54
W8	006	357		Conv., 2x6 @ 24" OC	mw batt, R22, 23"	3.87	36.49	11.12		50.94
W9	014	311	303	Conv. 2x4 @ 24" OC double 12"	fg batt, R28, 23" + fg batt, R12, 23"	7.04	70.22	10.87	6.07	93.26

Code	Frame No.	Insul. No.	Insul. No.	Description		nom. RSI (m2C/W)	Regional framing ($/m2)	Regional insulation ($/m2)	Regional insulation ($/m2)	Regional Total w/tax ($/m2)
				Wood Crawlspace frame walls	Shaded cells are base cases					
C0		217		no framing	XPS HD, R12.5	2.20		25.58		27.37
C1		213		no framing	XPS HD, R15	2.64		29.48		31.54
C2	005	307		Conv., 2x6 @ 16" OC	fg batt, R20, 15"	3.52	41.99	8.63		54.17
C3	002	302	210	Conv., 2x4 @ 16" OC clad	fg batt, R12, 15" + XPS, R7.5	3.43	36.60	6.03	16.00	62.73
C4	008	309		Adv., 2x6 @ 24" OC	fg batt, R22	3.87	33.73	12.50		49.47
C5	005	309	210	Conv., 2x6 @ 16" OC	fg batt, R22 + XPS, R7.5	5.20	41.99	12.50	16.00	75.42
C6	009	309	210	Adv., 2x6 @ 24" OC clad	fg batt, R22 + XPS, R7.5	5.20	35.46	12.50	16.00	68.43

Code	Frame No.	Insul. No.	Insul. No.	Basement walls Description	Shaded cells are base cases Type	nom. RSI (m2C/W)	Regional framing ($/m2)	Regional insulation ($/m2)	Regional insulation ($/m2)	Regional Total w/tax ($/m2)
B0	003	302		Conv., 2x4 @ 24" OC	fg batt, R12, 15"	2.11	31.99	6.03		40.68
B1		291		no framing	fg bsmt. batt, R12	2.11		12.83		13.72
B2		210	210	no framing	XPS, R7.5 + XPS, R7.5	2.64		16.00	16.00	34.23
B3	001	302		Conv., 2x4 @ 16" OC	fg batt, R12, 15"	2.11	34.88	6.03		43.77
B4	003	303		Conv., 2x4 @ 24" OC	fg batt, R12, 23"	2.11	31.99	6.07		40.72
B5	003	303	303	Conv., 2x4 @ 24" OC	fg batt, R12, 23" + fg batt, R12, 23"	4.23	31.99	6.07	6.07	47.22
B6	004	304	304	Adv., 2x4 @ 24" OC	fg batt, R14 + fg batt, R14	4.93	29.63	8.14	8.14	49.13

Code	Frame No.	Insul. No.	Insul. No.	On-Ground Floors Description	Shaded cells are base cases Output Desc.	nom. RSI (m2C/W)	Regional framing ($/m2)	Regional insulation ($/m2)	Regional insulation ($/m2)	Regional Total w/tax ($/m2)
S0		212		perimeter	XPS, R5	0.88		11.93		12.76
S1		210			XPS, R7.5	1.32		16.00		17.12
S2		211		perimeter	XPS, R10	1.76		19.18		20.52
S3		222			EPS HD, R4	0.70		9.38		10.04
S4		223		perimeter	EPS HD, R6	1.06		11.37		12.17
S5		224		perimeter	EPS HD, R8	1.41		13.42		14.36
S6		213		full slab	XPS HD, R15	2.64		29.48		31.54

Code	Frame No.	Insul. No.	Insul. No.	Above-Ground Floors Description	Shaded are base cases Output Desc.	nom. RSI (m2C/W)	Regional framing ($/m2)	Regional insulation ($/m2)	Regional insulation ($/m2)	Regional Total w/tax ($/m2)
F0	101	313		Conv., 2x10 @ 16" OC	fg batt, R25, 15"	4.40	84.21	10.63		101.48
F1	100	313		Conv., 2x8 @ 16" OC	fg batt, R25, 15"	4.40	72.01	10.63		88.42
F2	106	310		Conv., 12" open web @ 16" OC	fg batt, R28, 15"	4.93	83.96	11.09		101.70
F3										0.00
F4	101	315		Conv., 2x10 @ 16" OC	fg batt, R31.8, 15"	5.60	84.21	12.71		103.71
F5	106	312		Conv., 12" open web @ 16" OC	fg batt, R40, 15"	7.04	83.96	20.53		111.80
F6	108	312	307	Conv., 16" open web @ 16" OC	fg batt, R40, 15" + fg batt, R20, 15"	10.57	95.92	20.53	8.63	133.84
F7	108	312	309	Conv., 16" open web @ 16" OC	fg batt, R40, 15" + fg batt, R22	10.92	95.92	20.53	12.50	137.98

Life: 20 yrs Code	Window No.		20	Windows - Fixed yr replacement Description	Shaded are base cases Output Desc.	nom. RSI (m2C/W)	Regional Cost ($/m2)	Replacement Cost (1)* ($/m2)		Regional Total w/tax ($/m2)
P0	400			DG, picture, vinyl		0.35	228.18	104.14		355.57
P1	401			DG lowE, Argon, picture, vinyl		0.58	257.37	117.46		401.07
P2	402			TG, picture, vinyl		0.58	260.72	118.99		406.29
P3	403			TG, 1 low E, Argon, insul. spacer, vinyl		0.66	316.12	144.27		492.62
P4	404			TG, 2 low E, Argon, insul. spacer, vinyl		0.75	343.93	156.97		535.96
P5										0.00
P6										0.00
P7										0.00
P8										0.00
P9										0.00

* One replacement at 20 years (inflated at 2%/yr, and discounted back to present at 6%/yr)

Life:	15	yrs		Windows - Operable			Regional	Replacement		Regional
Code	**Window**				shaded are base cases	nom. RSI	Cost	Cost (1)*		Total w/tax
	No.			Description	Output Desc.	(m2C/W)	($/m2)	($/m2)		($/m2)
G2	431			DG lowE, Argon, casement, vinyl		0.58	666.58	370.13		1109.27
G3	432			TG, casement, vinyl		0.58	671.32	372.76		1117.17
G4	433			TG, 2 low E, Argon, insul. spacer, vinyl		0.75	781.81	434.11		1301.04
G5	434			DG, casement, HM SC75, Krypton		1.04	800.64	444.57		1332.38
G6	435			DG, low E, casement, HM SC75, Krypton		0.81	822.16	456.52		1368.19
G7	436			DG, casement, HM TC88, Air		0.73	773.74	429.63		1287.61
G8	437			DG, casement, HM TC88, Argon		0.93	781.81	434.11		1301.04
G9	438			DG, casement, HM TC88, Krypton		1.35	800.64	444.57		1332.38

Appendix 3: Financial Aggregation

Units by period 24.5units per building

740	104	185	451	70	10
715	100	179	436	70	10
575	81	144	351	70	10
575	81	144	351	70	10
total	365	651	1589	280	40

Buildings per period

Period	Stick	Modular	MURB	Office	Big Box
2005 - 2009	104	185	18	70	10
2010 - 2014	100	179	18	70	10
2015 - 2019	81	144	14	70	10
2020 - 2024	81	144	14	70	10
total	365	651	65	280	40

Cumulative Buildings

Period	Stick	Modular	MURB	Office	Big Box
2005 - 2009	104	185	18	70	10
2010 - 2014	204	364	36	140	20
2015 - 2019	284	508	51	210	30
2020 - 2024	365	651	65	280	40

Energy savings [mj/unit/year]

Electricity	57	298	8,000	10,000	35,000
Oil	59,834	43,263	1,526,000	397,000	962,000

Energy price ($/mj)

Electricity	0.637	0.637	0.4748	0.4748	0.4747
Oil	0.023	0.023	0.023	0.023	0.023

Energy Inflation 2.50%

Energy Operating Costs

	Stick	Modular	MURB	Office	Big Box
2005 - 2009	$ 1,412	$ 1,185	$ 38,896	$ 13,879	$ 38,741
2010 - 2014	$ 1,598	$ 1,341	$ 44,008	$ 15,703	$ 43,831
2015 - 2019	$ 1,808	$ 1,517	$ 49,791	$ 17,766	$ 49,591
2020 - 2024	$ 2,046	$ 1,716	$ 56,334	$ 20,101	$ 56,108

Stock Operating Cost (undiscounted) [$/yr]

	Stick	Modular	MURB	Office	Big Box	total
2005 - 2009	$ 146,334	$ 219,202	$ 716,646	$ 971,530	$ 387,405	$ 2,441,117
2010 - 2014	$ 325,534	$ 487,635	$ 1,594,247	$ 2,198,394	$ 876,626	$ 5,482,436
2015 - 2019	$ 513,864	$ 769,746	$ 2,516,563	$ 3,730,922	$ 1,487,733	$ 9,018,828
2020 - 2024	$ 746,070	$ 1,117,579	$ 3,653,750	$ 5,628,260	$ 2,244,312	$ 13,389,971
total	$ 1,731,802	$ 2,594,162	$ 8,481,206	$ 12,529,106	$ 4,996,077	**$ 30,332,353**

Incremental Investment

	Stick	Modular	MURB	Office	Big Box	total
	$ 11,764	$ 8,064	$ 135,000	$ 51,000	$ 66,490	
2005 - 2009	$ 1,218,750	$ 1,491,840	$ 2,487,306	$ 3,570,000	$ 664,900	$ 9,432,797
2010 - 2014	$ 1,177,576	$ 1,441,440	$ 2,403,276	$ 3,570,000	$ 664,900	$ 9,257,192
2015 - 2019	$ 947,002	$ 1,159,200	$ 1,932,704	$ 3,570,000	$ 664,900	$ 8,273,806
2020 - 2024	$ 947,002	$ 1,159,200	$ 1,932,704	$ 3,570,000	$ 664,900	$ 8,273,806
total	$ 4,290,331	$ 5,251,680	$ 8,755,990	$ 14,280,000	$ 2,659,600	**$ 35,237,601**

	8.3	6.8	3.5	3.7	1.7

NPV of energy savings in time period

	Stick	Modular	MURB	Office	Big Box
2005 - 2009	$ 8,395	$ 6,700	$ 312,871	$ 110,341	$ 381,745
2010 - 2014	$ 6,144	$ 4,903	$ 228,967	$ 80,750	$ 279,371
2015 - 2019	$ 4,461	$ 3,561	$ 166,269	$ 58,639	$ 202,871
2020 - 2024	$ 3,204	$ 2,557	$ 119,418	$ 42,115	$ 145,706

Electricity [GJ/yr]

	Stick	Modular	MURB	Office	Big Box	total
2005 - 2009	6	55	147	700	350	1,258
2010 - 2014	6	53	142	700	350	1,251
2015 - 2019	5	43	115	700	350	1,212
2020 - 2024	5	43	115	700	350	1,212
Total						4,934

Oil [GJ/yr]

	Stick	Modular	MURB	Office	Big Box	total
2005 - 2009	6,199	8,004	28,116	27,790	9,620	79,728
2010 - 2014	5,989	7,733	27,166	27,790	9,620	78,299
2015 - 2019	4,817	6,219	21,847	27,790	9,620	70,292
2020 - 2024	4,817	6,219	21,847	27,790	9,620	70,292
total						298,612

GHG Emission Factors

Electricity	Oil		
0.04	0.26	Kg	GHG benefit [$/Tonne]
11	72	KG/GJ	$ -

GHG Impact Tonnes

2005 - 2009	14	5,758	5,772	$0.00
2010 - 2014	28	11,413	11,441	$0.00
2015 - 2019	41	16,490	16,531	$0.00
2020 - 2024	55	21,566	21,621	$0.00
total			0	

NPV

	Stick	Modular	MURB	Office	Big Box	Total
2005 - 2009	$ 869,722	$ 1,239,500	$ 5,764,489	$ 7,723,870	$ 3,817,450	$ 19,415,031
2010 - 2014	$ 614,982	$ 876,453	$ 4,076,082	$ 5,652,528	$ 2,793,709	$ 14,013,754
2015 - 2019	$ 359,139	$ 511,834	$ 2,380,365	$ 4,104,701	$ 2,028,710	$ 9,384,749
2020 - 2024	$ 257,941	$ 367,609	$ 1,709,623	$ 2,948,075	$ 1,457,058	$ 6,740,306
	$ 2,101,785	$ 2,995,396	$13,930,558	$ 20,429,174	$ 10,096,927	$ 49,553,840

benefit cost ratio 1.41