

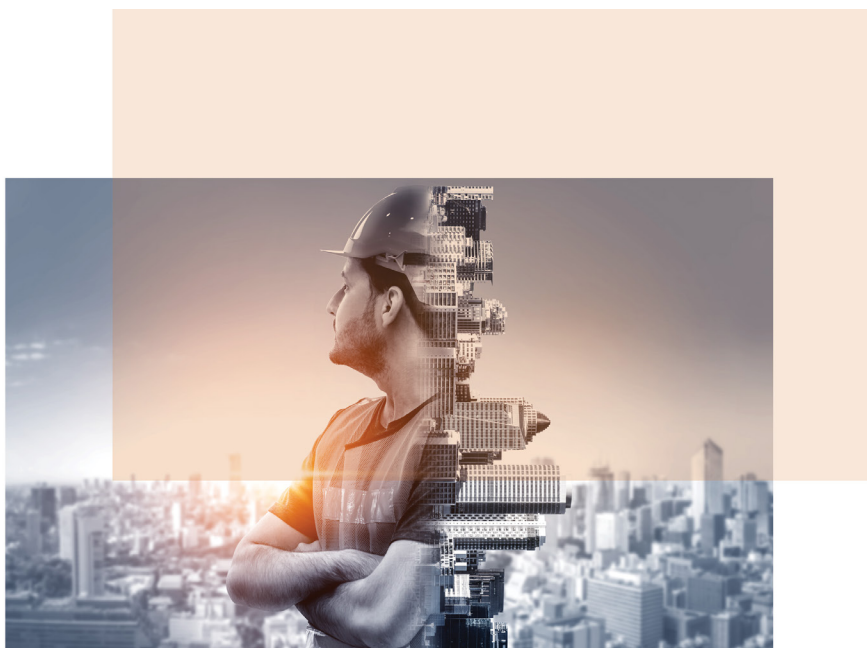
# The Cost of Building Enclosures

A Comparative Analysis of Life Cycle Costs and Energy Use of Common Building Enclosure Systems



# 2020

Technical Series



# Comparative Life Cycle Analysis of Building Enclosures



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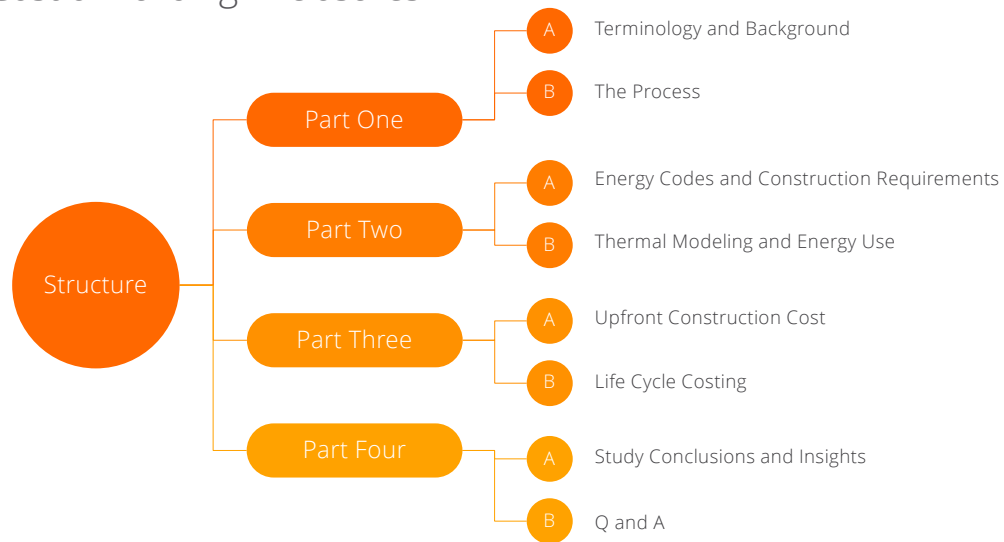
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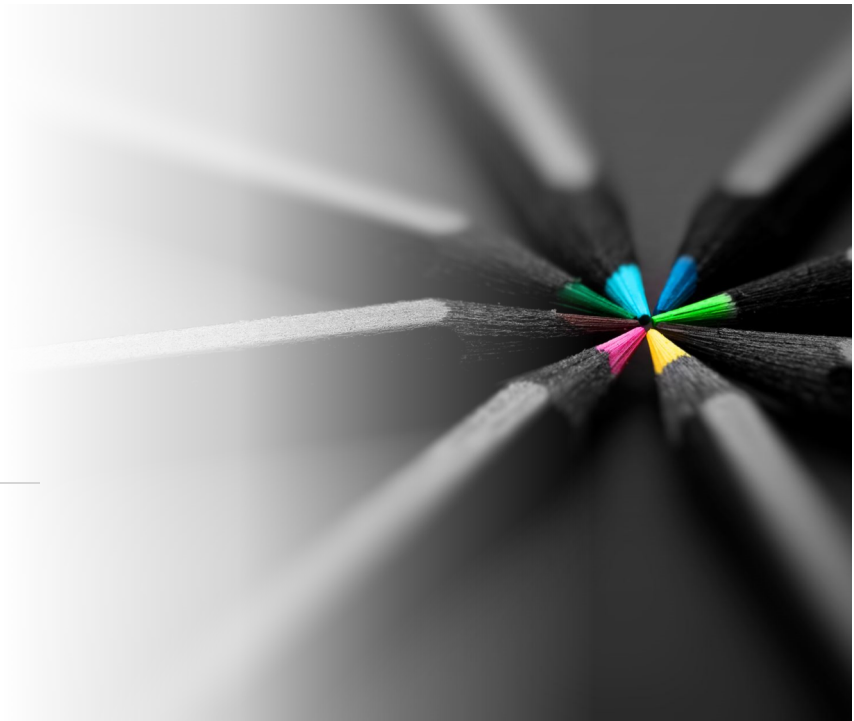


## The Cost of Building Enclosures



### Part One

Terminology and Study  
Background





## Language of the Energy Study

### R-value

is a quantitative measure of an assembly or material resistance to heat flow for a unit temperature difference and a unit area. It is the reciprocal of the U-factor. As R-value increases, conduction through an assembly or material decreases for the same temperature difference.

### Nominal R-value ( $R_{Nom}$ )

is simply the rated R-value of the insulation products in their installed condition. The contribution of other materials is ignored. Initial thermal resistances typically measured using the ASTM C518 standard are often used but it is preferred to use Long Term Thermal Resistance (LTTR) measured through standards such as CAN/ULC-S770-03.

### Clear Wall R-value ( $R_{CW}$ )

accounts for the thermal resistance of the assembly layers (Assembly R-value) and also includes the two-dimensional effect of standard repetitive framing (e.g. steel studs and tracks). Minimum  $R_{CW}$  values are currently the common metric (referred to as Assembly Thermal Resistance in ASHRAE 90.1 or its inverse, Maximum Thermal Transmittance, in NECB).

### U-factor or U-value

is the thermal transmittance of a material or assembly. It is a quantitative measure of the ease of heat flow expressed as an equivalent conductance per unit area and per unit temperature difference, the reciprocal of R-value. Where used in the NECB, a weighted calculation is used that includes the accounting for thermal bridging by elements representing  $\geq 2\%$  of the wall's cross-sectional area.

### Thermal Bridging

is a material with higher thermal conductivity transferring heat through an assembly with substantially lower thermal conductivity. For example, a steel stud in a wall will transfer more heat than the surrounding insulation, reducing the overall thermal control of the system.

### Continuous Insulation

is defined by ASHRAE 90.1 as "insulation that is continuous across all structural members without thermal bridges other than fasteners and service openings. It is installed on the interior, exterior, or is integral to any opaque surface of the building envelope." Continuous Insulation is often referred to as "ci".





## Language of the Energy Study

### Mechanical Attachment Losses

are losses due to cladding attachment materials, that typically penetrating exterior continuous insulation and in addition to those captured in clear wall R-value calculations. A number of mechanical attachments for cladding systems are included in the drawings of the various wall assemblies including brick ties, galvanized screws through battens, and fiberglass clips.

### Whole Wall R-value ( $R_{ww}$ )

includes the clear wall R-value (RCW) plus the thermal impact of conductive penetrations (e.g. floors, balconies) and any additional framing or fasteners at openings (e.g. windows and doors), and the effects of thermal bridges at changes in plane and other interfaces (e.g. foundation-to-above-grade-wall, wall-to-roof, balconies, etc.) but excludes window area.

### High-R Wall

is a term used in this presentation to identify walls with a  $R_{ww}$  of at least 7.0 RSI (R-40).

### Linear Thermal Transmittance ( $\psi$ )

is defined in ISO 7345 as "heat flow rate in the steady state divided by length and by the temperature difference between the surroundings on each side of a system." When  $\psi$  is used to characterize linear thermal bridges in the building envelope,  $\psi$  is not the total but the additional heat transfer due to the thermal bridge.

### Point Thermal Transmittance ( $\chi$ )

is a material with higher thermal conductivity transferring heat through an assembly with substantially lower thermal conductivity. For example, a steel stud in a wall will transfer more heat than the surrounding insulation, reducing the overall thermal control of the system.

### Window Flanking Loss

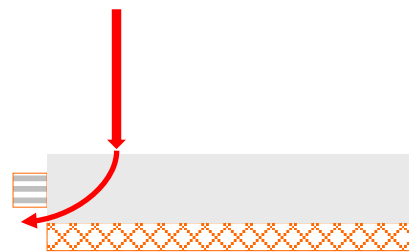
are losses around the window, typically through the structural components the window is installed in. They are losses additional to those captured by clear wall R-value for the opaque wall and the U-Value of the window system.



### Window Flanking Loss



Minimal Window Flanking Losses

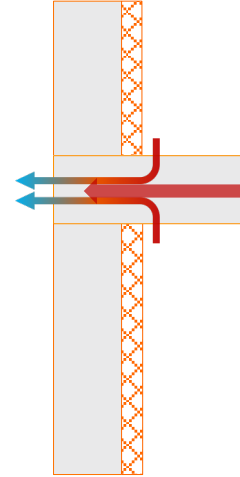
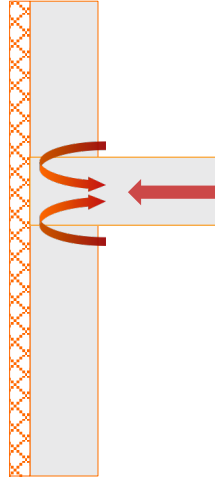


Significant Window Flanking Losses



## Floor-to-Wall Interface Losses

are losses due to floor slab assemblies penetrating wall assemblies, which may include stud wall assemblies or the entire exterior wall assembly. These losses may also include through-wall flashing and cladding mounting systems (e.g. shelf angles for masonry) that are located at these interfaces.



## Language of the Cost Study

### Life-Cycle Cost Analysis (LCCA)

a technique of economic evaluation that sums the costs of an investment decision over a given study period, expressed in present or annual value terms, including the costs of initial investment (less resale value), replacements, operations (including energy use), and maintenance and repair.

### Initial Costs (IC) or *first costs*

defined in ASTM E631 as costs incurred in placing a building or building subsystem into service, including, but not limited to, costs of planning, design, engineering, site acquisition and preparation, construction, purchase, installation, property taxes and interest during the construction period and construction-related fees. For this study, the initial costs were determined by Quantity Surveyors/Cost Consultants - Finnegan Marshall.

### Energy Costs

a component of operating costs and in this study capture the building's energy usage associated with the impacts of the opaque wall system thermal performance.



## Language of the Cost Study

### Maintenance and Repair Costs

defined in ASTM E631 as the total of labour, material, and other related costs incurred in conducting corrective and preventative maintenance and repair on a building, or on its systems and components, or both.

### Present Value (PV)

defined in ASTM E631 as the value of a benefit or cost found by discounting future cash flows to the base time. Within the study PV includes initial cost (taken from the Finnegan Marshall report), annual energy costs, and wall system repair and maintenance costs recurring at varying frequencies over an assumed 50-year cladding system service life. The analysis includes an assumed interest rate and cost escalation rate(s), which are factored into the analysis as modified uniform present values, following ASTM E917. As it is difficult to directly assign energy usage to wall areas, the difference between baseline building energy and that for the same building with the high-R wall option was assigned as an energy cost to the baseline wall system operating cost.



## Process and Learning Objectives

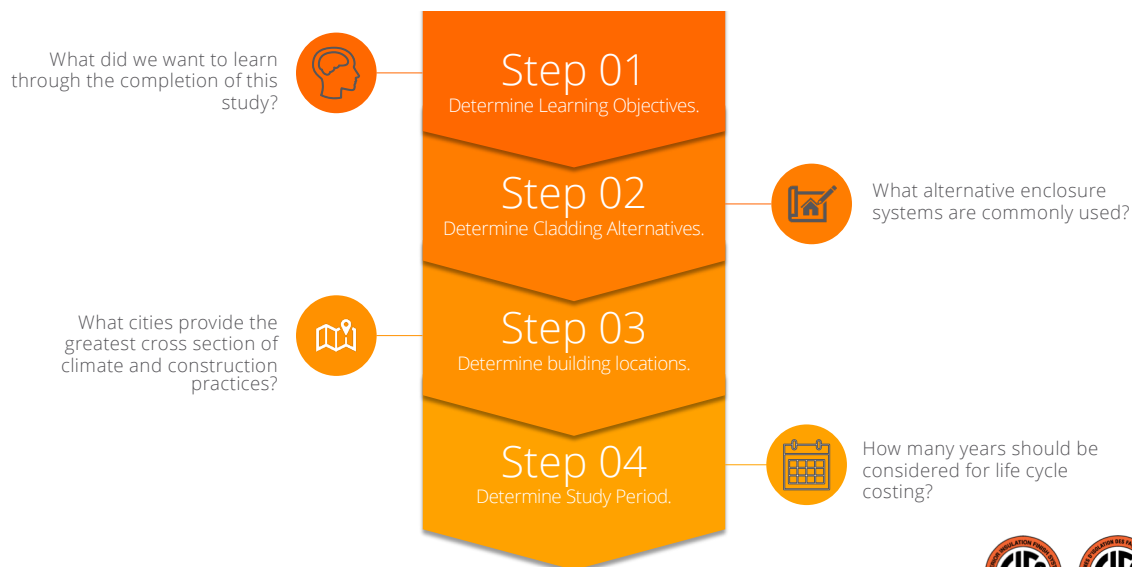


## Study Scope and Approach

- The study is unique in that compares both initial and life cycle costs for assemblies designed and constructed to provide the same overall thermal transmittance value as delivered by Exterior Insulation and Finish Systems.
  - Previous studies have compared EIFS' performance relative to alternative wall assemblies when using like amounts of insulation. When compared to other assemblies and the influence of thermal bridging, studies have shown that EIFS provide for a more effective delivery of thermal resistance and have lower heat-energy loss.
  - In this study, where impacted by heat loss through thermal bridging, the construction method has been enhanced and additional amounts of insulation added so that all assemblies achieve near equal overall thermal transmittance value.
- This approach allows for a true apples to apples comparison of the total economic implications (capital and operating) of typical enclosure strategies designed to meet prescriptive envelope efficiency requirements of Canada's energy codes.
- The study also revealed that new energy efficiency requirements bring about constructability challenges for alternative claddings and enclosure strategies.



## Process



# Learning Objectives

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Information for architects, builders, and municipalities on the comparative performance of EIFS and other cladding options over the life of new and retrofitted buildings.

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Thermal performance calculations that can be used by designers and energy modellers.

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Service life data for wall cladding systems for use in future environmental life cycle analysis reporting.

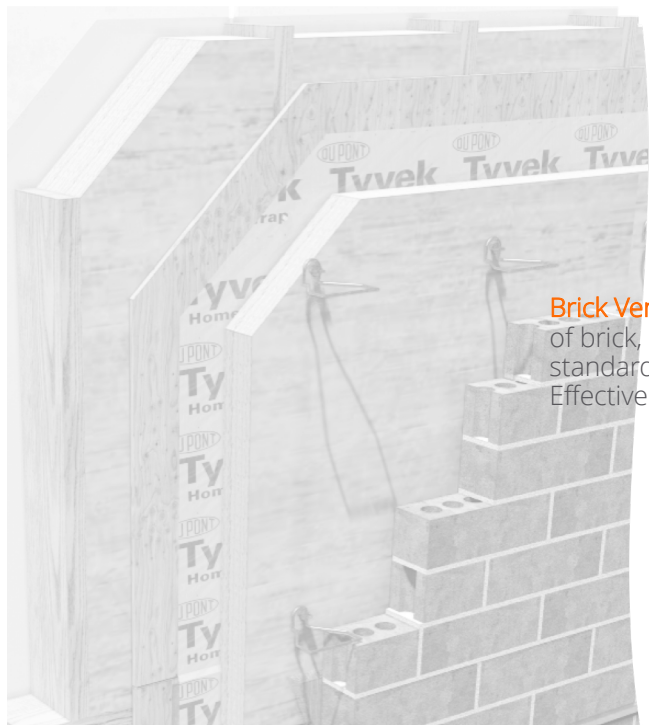
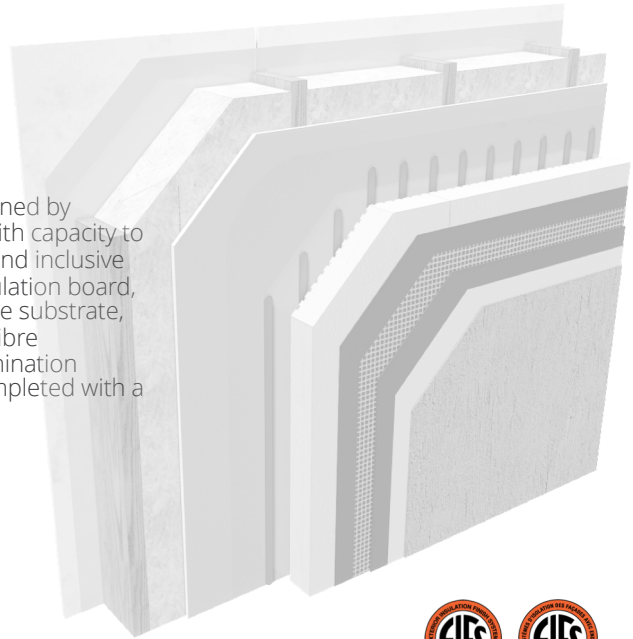


## Wall Types

- Exterior wall assemblies are configured to meet:
  - Respective Energy Code Requirements
  - Building Code Requirements
  - Material and/or System Standards (e.g. CAN/ULC-S716.1), as applicable
- To the greatest degree possible, common construction practices where used.
  - In some cases, enhanced measures were required to achieve the Effective Whole Wall R-Value target
    - e.g. offset shelf angles, intermittent fiberglass wall brackets, etc. See Constructability Section
- 40% glazing was seen as commonly utilized/desired window-to-wall ratio in multi-unit residential buildings. This ratio was also applied to commercial buildings for study consistency and minimizing of variables.

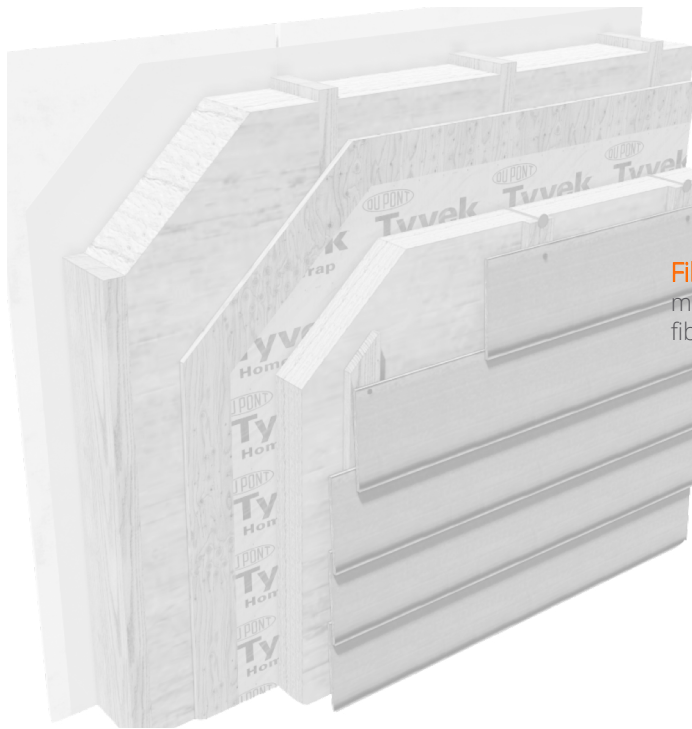


**Exterior Insulation and Finish System (EIFS)** is defined by CAN/ULC-S716.1-19 as “an exterior wall system with capacity to provide heat, air and moisture control functions and inclusive of a water resistive barrier assembly, thermal insulation board, attachment method for securing the system to the substrate, and protected by a base coat material and glass fibre reinforcing mesh (installed over the face and termination surfaces of the thermal insulation board) and completed with a finish material.”



**Brick Veneer** consists of a single non-structural external layer of brick, installed as per code and masonry installation standard with enhancements to achieve target Whole Wall Effective R-Value.

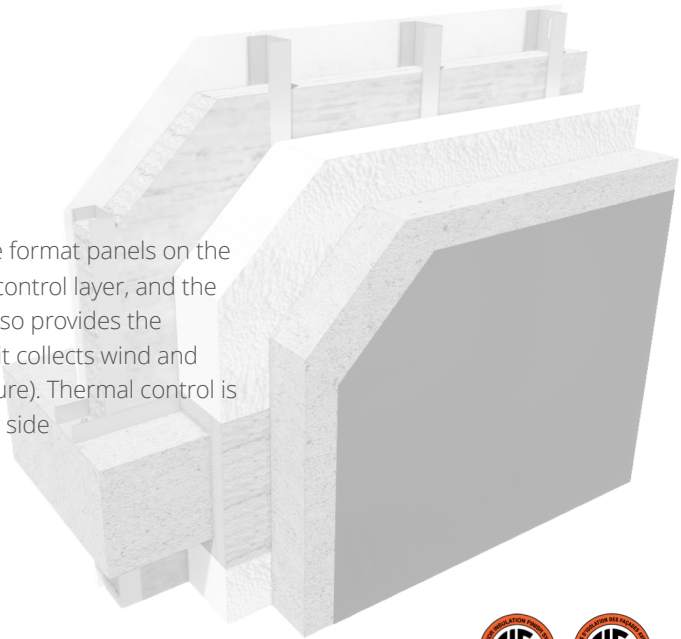


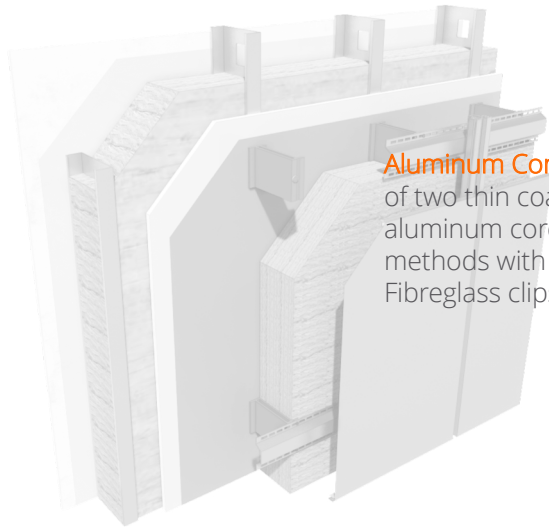


**Fibre Cement Cladding** is a composite board material made of cement reinforced with cellulose fibres and covered with a paint coating.



**Architectural Precast Panels** - concrete in large format panels on the exterior as the exterior finish, the primary air-control layer, and the rainwater management. The concrete panel also provides the enclosure structural support function (that is, it collects wind and self-load and transfers it to the primary structure). Thermal control is provided by insulation installed on the interior side of the panel.

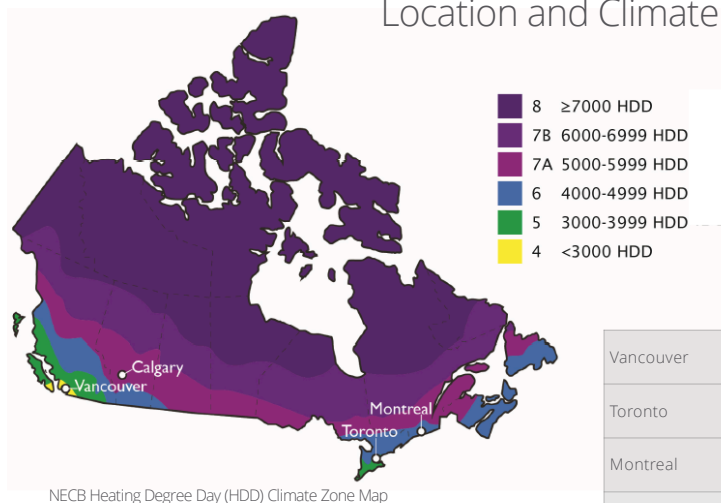




**Aluminum Composite Panels (ACP)** are flat panels consisting of two thin coated aluminum sheets bonded to a non-aluminum core. The study considers cladding attachment methods with minimal thermal bridging (4-9% degradation). Fibreglass clips with stainless steel screws.



## Location and Climate Zones



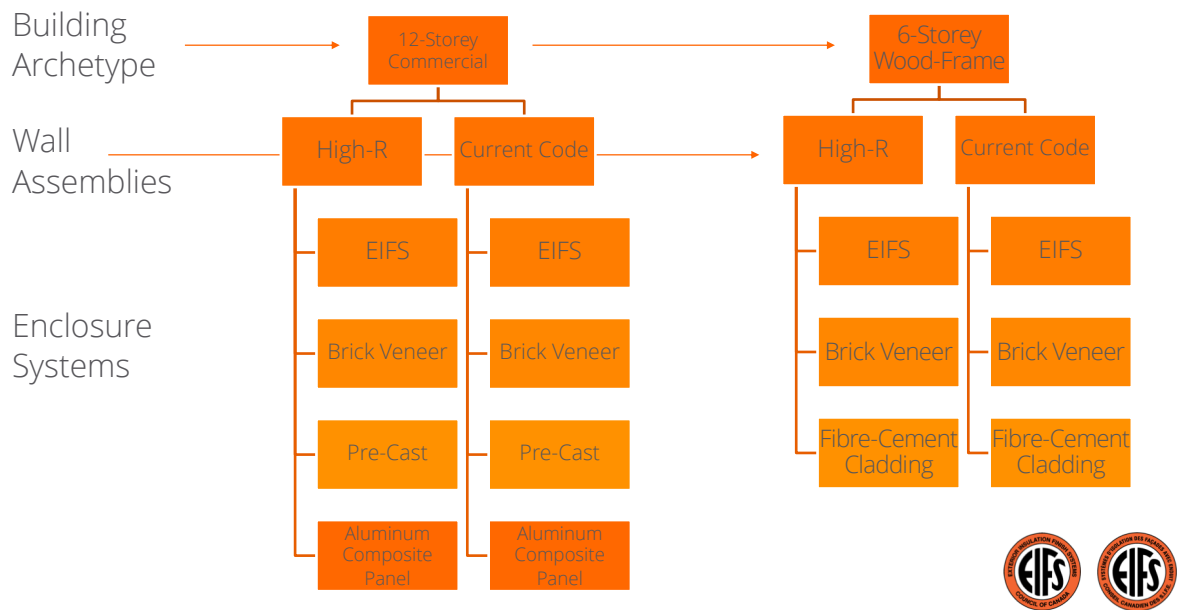
	Energy Code	NECB Climate Zone
Vancouver	2019 Vancouver Building By-Law	4
Toronto	Toronto Green Standard/SB-10/NECB 2015	5
Montreal	Quebec Construction Code	6
Calgary	NECB 2017	7A



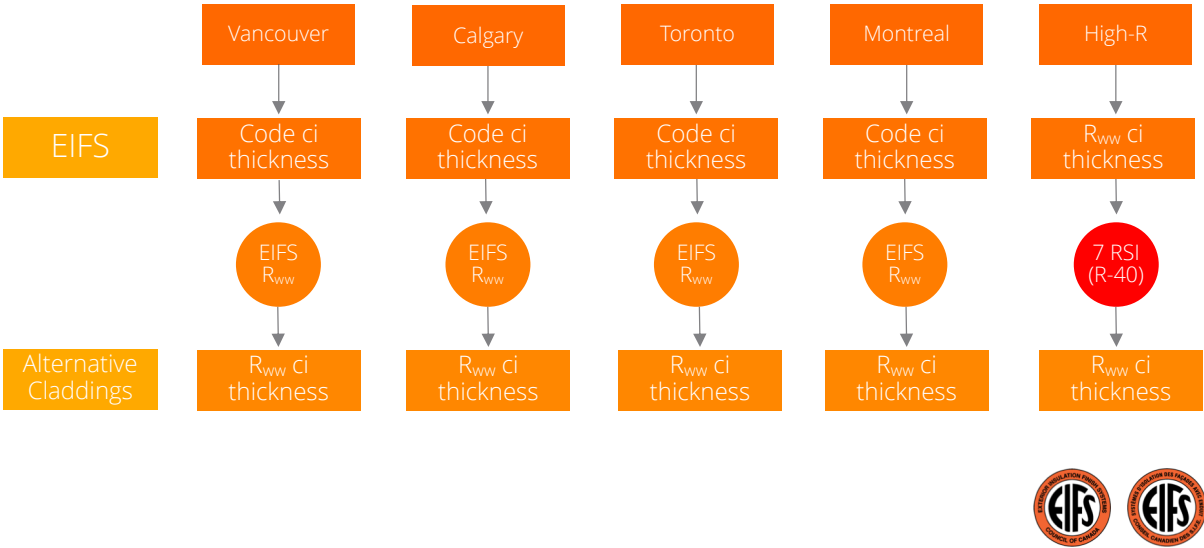


## 50 Year Study Period

### Study Framework



# Thermal Analysis Framework



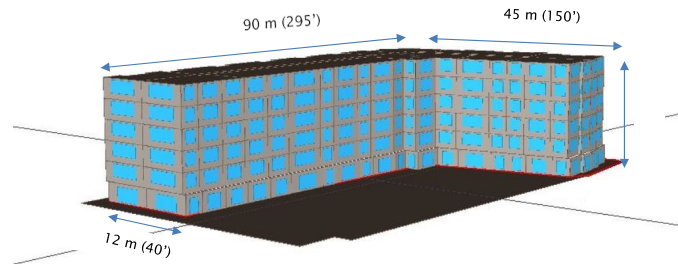
## Part Two

Energy Codes and Construction Requirements

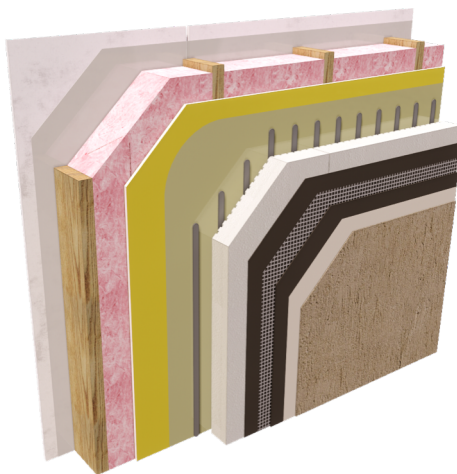


## Building Typology – Residential

- eQuest Model 6– Storey Residential Wood-Frame



## Wall Construction



### From Interior to Exterior

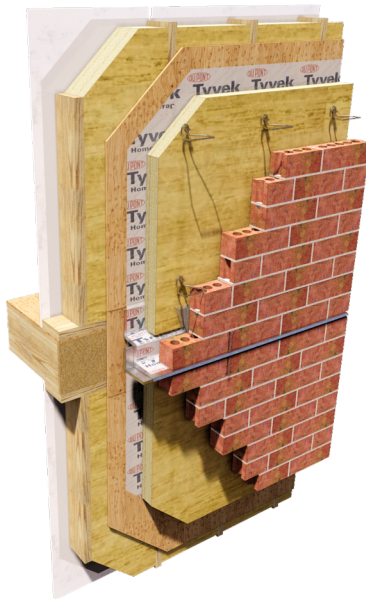
- 5/8" painted drywall
- Polyethylene vapour barrier
- 16" on-center 2x6 stud wall with R21 fibreglass batts
- ½" fibre glass reinforced sheathing board
- Vapour permeable liquid-applied air barrier (AB) and water-resistive barrier (WRB) by EIFS manufacturer
- Trowel applied adhesive (no mechanical fasteners)
- Profiled EPS insulation board meeting CAN/ULC-S701 (R3.75/in) to thicknesses as required (3" shown)
- Base coat, standard mesh, and finish coat
- Expansion joints at every floor
- Designed as per CAN/ULC-S716.3. I EIFS Design Standard
- Installation as per CAN/ULC 716.2 -12 Standard for Exterior Insulation and Finish Systems.



6-STOREY RESIDENTIAL (WOOD FRAMED W/2X6 R-21 BATT) EIFS WALLS					
	Vancouver	Calgary	Toronto	Montreal	High-R
Requirement	R <sub>cw</sub>	R <sub>cw</sub>	R <sub>cw</sub>	R <sub>Nom</sub>	R <sub>ww</sub>
	3.8 RSI (R-21.6)	4.8 RSI (R-27)	3.5 RSI (R-20)	3.3 RSI (R-19)	7.0 RSI (R-40)
ci Thickness	51 mm (2")	76 mm (3")	51 mm (2")	51 mm (2")	165 mm (6.5")
ci R-value	1.3 RSI (R-7.5)	2.0 RSI (R-11.3)	1.3 RSI (R-7.5)	1.3 RSI (R-7.5)	4.3 RSI (R-24.4)
R <sub>ww</sub>	2.6 RSI (R-14.5)	2.8 RSI (R-15.8)	2.6 RSI (R-14.5)	2.6 RSI (R-14.5)	7.2 RSI (R-40.8)



## Wall Construction

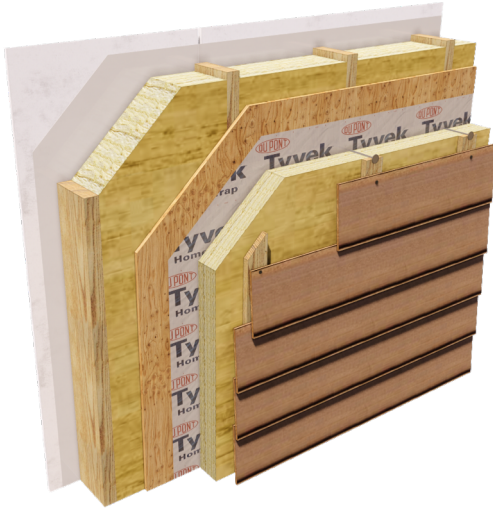


### Interior to Exterior

- 5/8" painted drywall
- Polyethylene vapour barrier
- 16" on-center 2x6 stud wall with R21 mineral wool batt
- 1/2" exterior-grade plywood sheathing
- Mechanically attached vapour permeable housewrap (Tyvek or Tytar) with approved tape
- **Thermally optimized screw brick ties with stainless-steel hooks** spaced 16" on center horizontally and 24" on center vertically
- Expansion joints 25 feet apart (horizontally) at occupied space
- Exterior mineral wool insulation board (semi-rigid) to thicknesses as required (3" shown)
- 1 1/2" drainage air space
- Mortar mesh and insect screen for weeps (spacing) at base courses
- Standard brick and mortar
- **Standoff galvanized steel lintels and shelf angles** to support brick veneer at every floor



## Wall Construction

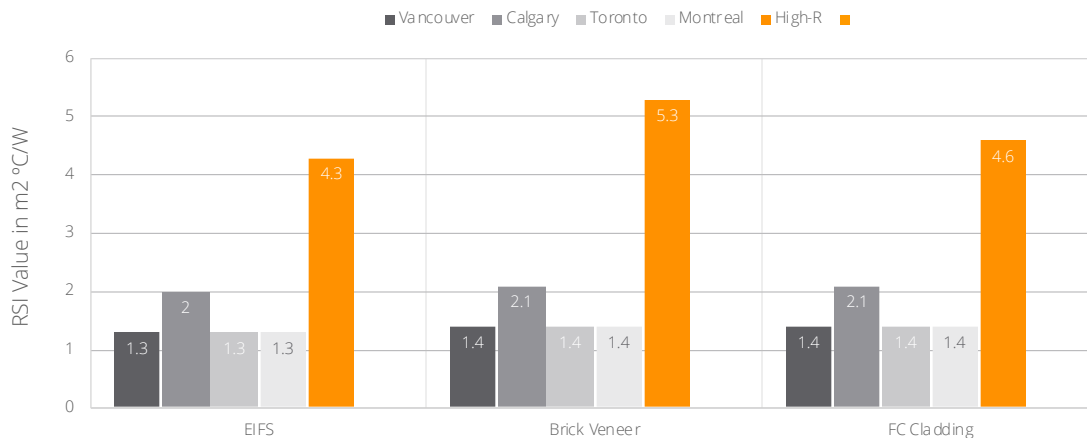


### Interior to Exterior

- 5/8" painted drywall
- Polyethylene vapour barrier
- 16" on-center 2x6 stud wall with R21 mineral wool batt
- 1/2" exterior-grade plywood sheathing
- Taped mechanically fastened housewrap (Tyvek)
- Mineral wool insulation board to thicknesses as required (3" shown)
- Fibre cement cladding panels
  - Pre-primed on all surfaces and cut edges not already primed from factory with alkali resistant primer approved by supplier
  - Mounted on 3" wide 3/4" exterior-grade plywood battens attached with #12 galvanized steel screws minimum 1" into studs and spaced vertically every 16" for 1 to 4" continuous insulation and every 12" for >4" to 8" continuous insulation.

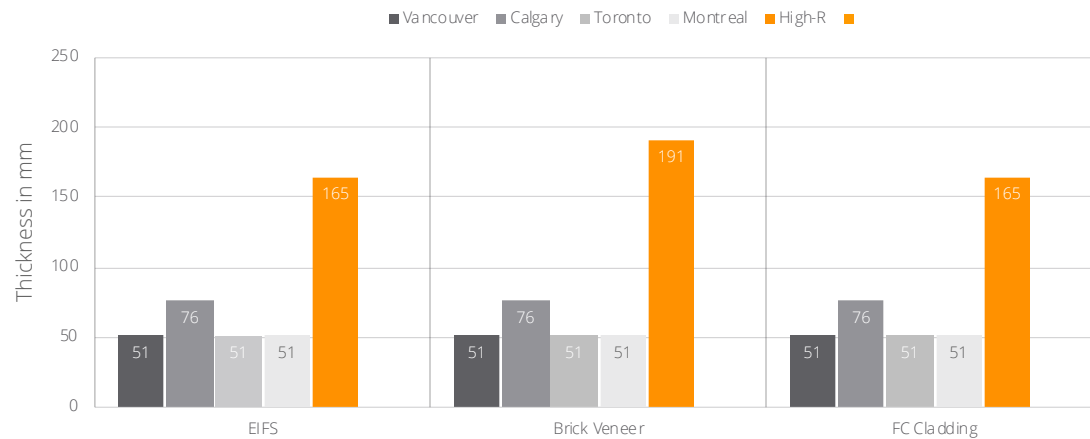


## Continuous Insulation for Residential Assemblies





## Continuous Insulation for Residential Assemblies



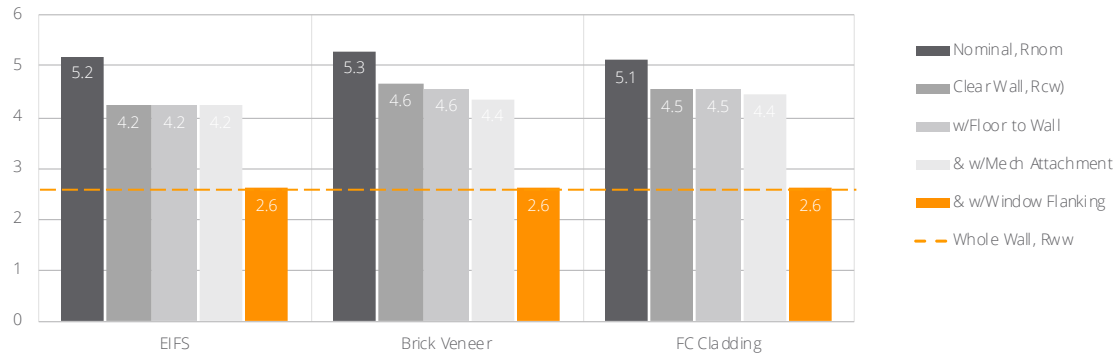
## Thermal Resistance Residential

Thermal resistances for the wall assemblies are plotted over the next series of slides. The plots include nominal, clear wall, and adjusted clear wall values (degraded for floor-to-wall interface thermal bridging, mechanical penetrations, and window flanking, accumulatively).

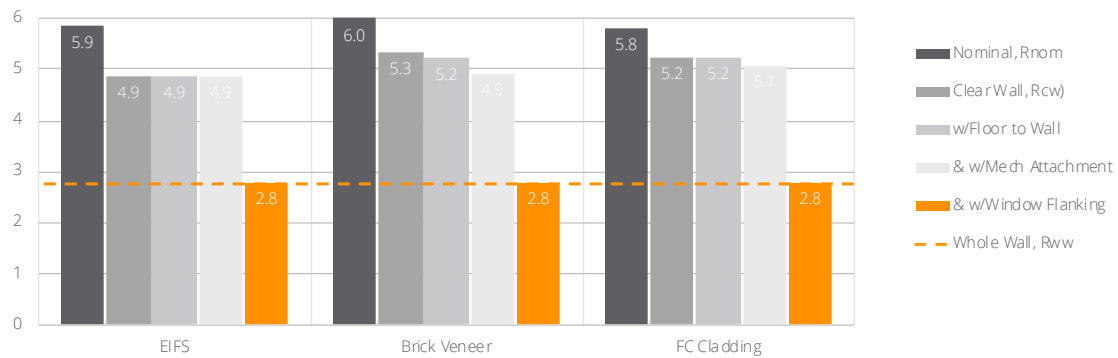


## Thermal Resistance Values Vancouver Residential Wall Assemblies

Thermal Resistance Value ( $\text{m}^2 \text{ }^\circ\text{C/W}$ )

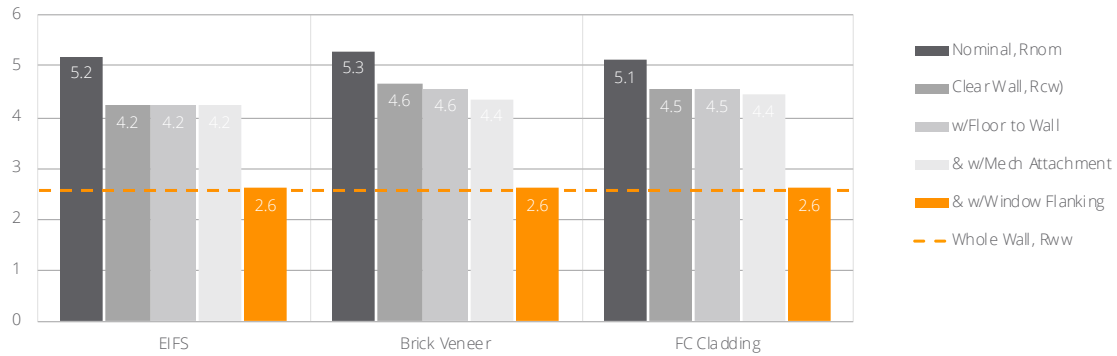


## Thermal Resistance Values Calgary Residential Wall Assemblies



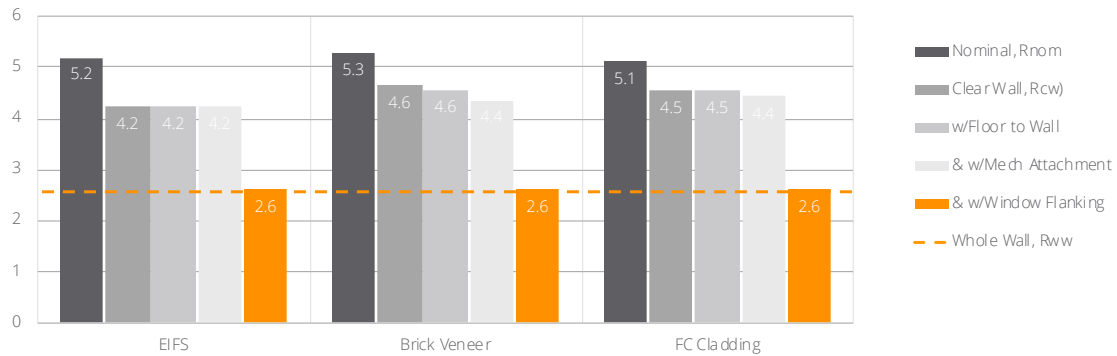
## Thermal Resistance Values Toronto Residential Wall Assemblies

Thermal Resistance Value ( $\text{m}^2 \text{ }^\circ\text{C/W}$ )



## Thermal Resistance Values Montreal Residential Wall Assemblies

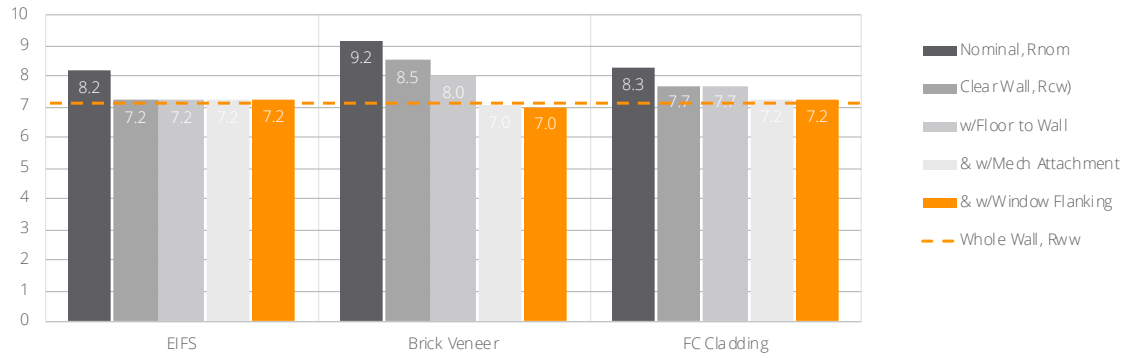
Thermal Resistance Value ( $\text{m}^2 \text{ }^\circ\text{C/W}$ )





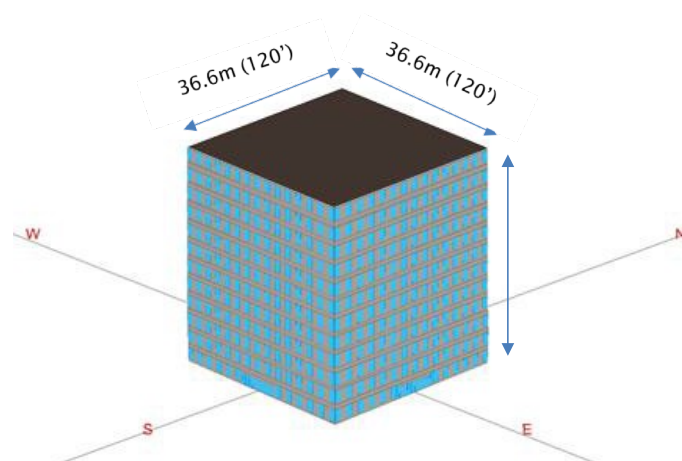
## Thermal Resistance Values High-R Residential

Thermal Resistance Value ( $\text{m}^2 \text{ } ^\circ\text{C/W}$ )

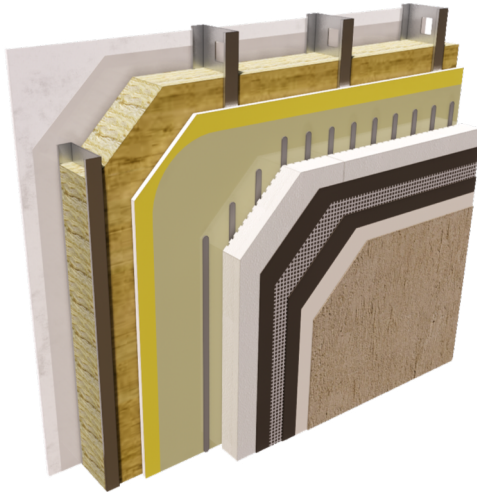


## Building Typology – Commercial

- eQuest Model 12 – Storey Commercial  
- Concrete with Steel Frame infill



## Wall Construction



### From Interior to Exterior

- 5/8" painted drywall
- Polyethylene vapour barrier
- Panelized EIFS
  - 6" deep 18-gauge steel studs every 16" with R14 cavity batt insulation
    - 1/240 deflection limit
  - 5/8" fibreglass reinforced gypsum board
  - Liquid-applied water-resistive barrier (WRB) from EIFS manufacturer
  - Trowel applied adhesive (no mechanical fasteners)
  - Profiled EPS meeting CAN/ULC-S701 (R3.75/in). Thickness as required.
  - Base coat, standard mesh, and finish coat
  - Expansion joint at every floor
  - Installed per ULC 716 -12 Standard for Exterior Insulation and Finish Systems.

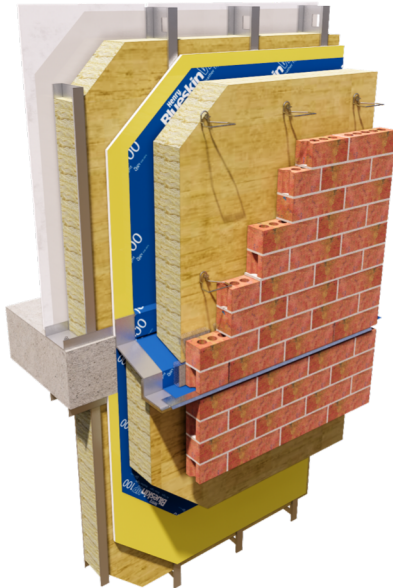


## Wall Construction

12-Storey Commercial - Panelized EIFS (6" Deep 18-guage metal framing)					
	Vancouver	Calgary	Toronto	Montreal	High-R
Requirement	R <sub>cw</sub>	R <sub>cw</sub>	R <sub>cw</sub>	R <sub>Nom</sub>	R <sub>ww</sub>
	3.2 RSI (R-18)	4.8 RSI (R-27)	3.5 RSI (R-20)	3.3 RSI (R-19)	7.0 RSI (R-40)
ci Thickness	76 mm (3")	127 mm (5")	89 mm (3.5")	51 mm (2")	229 mm (9")
ci R-value	2.0 RSI (R-11.3)	3.3 RSI (R-18.8)	2.3 RSI (R13.1)	1.3 RSI (R-7.5)	5.9 RSI (r-34)
R <sub>ww</sub>	2.1 RSI (R-12.1)	2.8 RSI (R-15.9)	2.3 RSI (R-13.1)	1.8 RSI (R-10.3)	7.3 RSI (R-41.4)



## Wall Construction

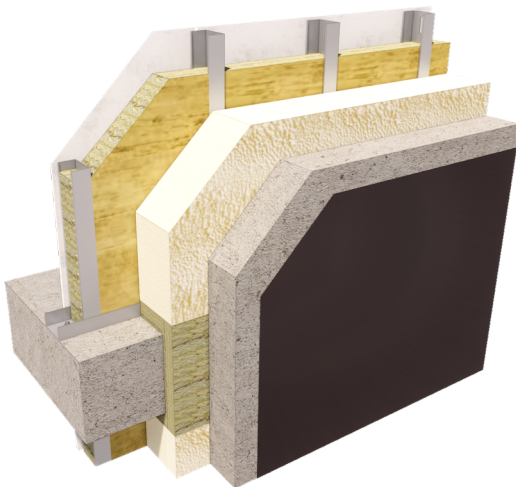


### Interior to Exterior

- 5/8" painted drywall
- Polyethylene vapour barrier
- 6" deep 16-gauge steel studs with R14 mineral wool cavity batt insulation
- 5/8" fibreglass reinforced gypsum board
- **Thermally optimized screw brick ties with stainless-steel hooks** spaced 16" on center horizontally and 24" on center vertically
- Peel-and-stick membrane over primer (e.g. Blueskin)
- Mineral wool insulation board to required thickness (6.5" shown)
- Standard brick and mortar
- Mortar mesh and insect screen for weeps (spacing)
- **Standoff galvanized steel lintels and shelf angles to support brick veneer at every second floor**



## Wall Construction

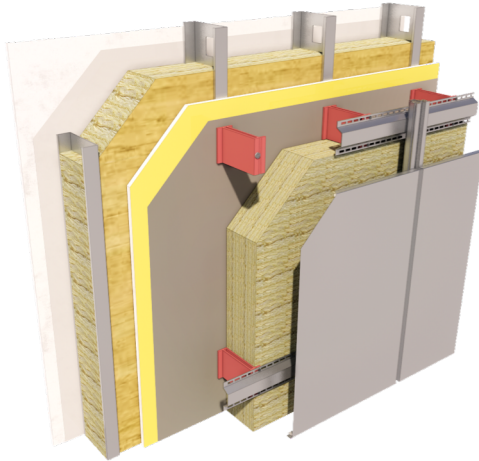


### Interior to Exterior

- 5/8" painted drywall
- 3.5" deep 20-gauge steel studs with R14 cavity batt insulation
- Field applied closed-cell spray foam on interior surface of panel to thicknesses as required.
- Painted 5" thick architectural precast
  - Drained two-stage joints
  - Plain smooth paint finish
  - 8 ft wide by 26 ft tall panels
- Anchoring and insulation at floor intersections
  - Field applied closed-cell spray foam on interior surface of panel
  - 2" of firestop mineral wool insulation
- Precast panels run over floor slabs
- 10" floor slab thickness
- 2" rigid mineral wool between back of precast panel and floor slab with fire proofing at top



## Wall Construction

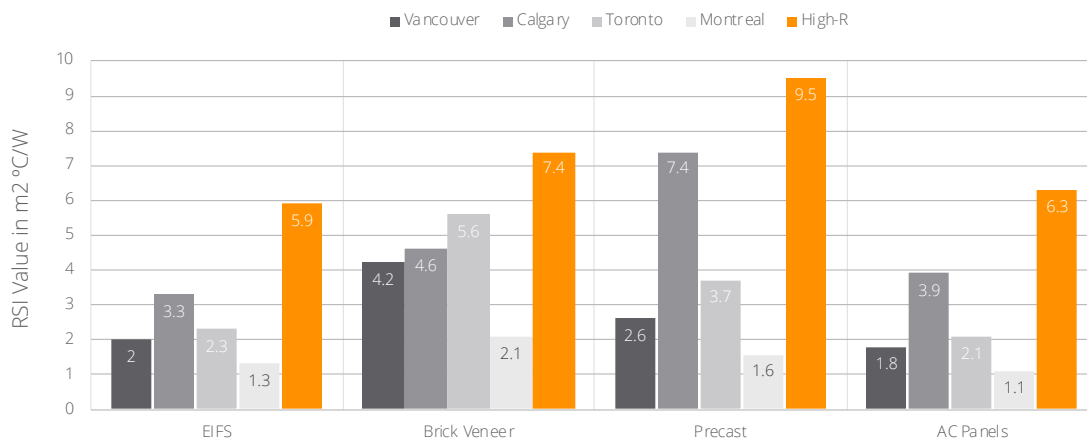


### Interior to Exterior Construction

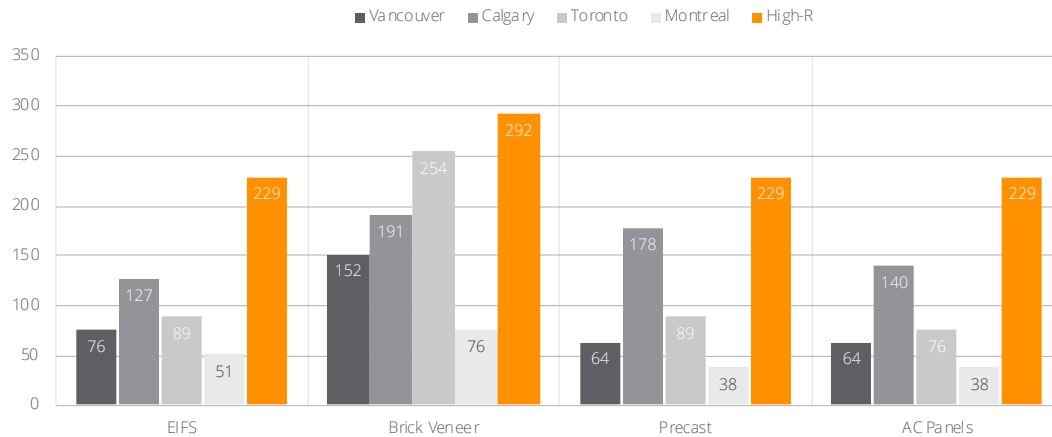
- 5/8" painted drywall
- Polyethylene vapour barrier
- 6" deep 18-gauge steel studs
  - Batt insulation filled steel studs
  - 1/175 or 3/4 (whichever is less) deflection per Alucobond Specification
- 5/8" fiberglass reinforced gypsum board
- Mineral wool insulation board to thicknesses as required
- 1.5m x 2.5m Alucobond Plus panels mounted on a horizontal hat-track on **fibreglass clips (thermally broken with galvanized steel fasteners) spaced every 16" horizontally and 36" vertically** in all assemblies
- At aluminum composite panel assemblies, install insulation boards on outer surface of self-adhesive air barrier of wall cavity with Cascadia clips. When required, provide stick pins screwed directly to the stud wall framing at a maximum spacing of 12" x 16". Provide sealant at penetration of screw through self-adhered membrane
- Expansion joints not needed



## Continuous Insulation for Commercial Assemblies



## Continuous Insulation for Commercial Assemblies



## Thermal Resistance Commercial

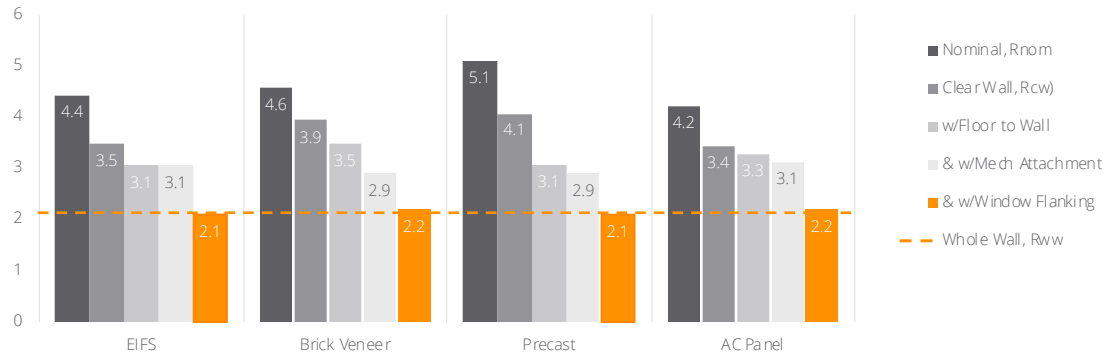
Thermal resistances for the wall assemblies are plotted over the next series of slides. The plots include nominal, clear wall, and adjusted clear wall values (degraded for floor-to-wall interface thermal bridging, mechanical penetrations, and window flanking, accumulatively).



## Thermal Resistance Values

### Vancouver Commercial Wall Assemblies

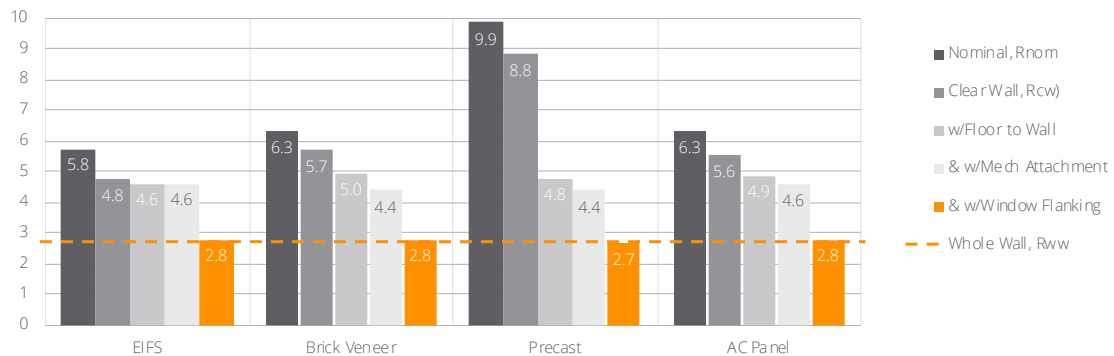
Thermal Resistance Value ( $\text{m}^2 \text{ } ^\circ\text{C/W}$ )



## Thermal Resistance Values

### Calgary Commercial Wall Assemblies

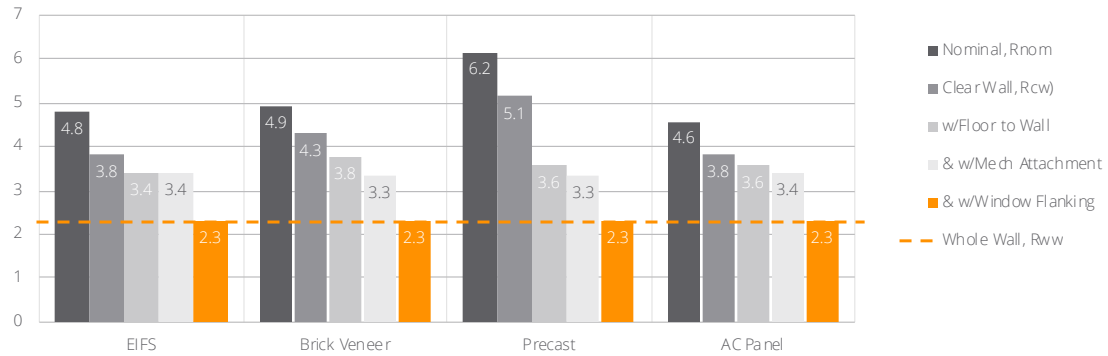
Thermal Resistance Value ( $\text{m}^2 \text{ } ^\circ\text{C/W}$ )



## Thermal Resistance Values

### Toronto Commercial Wall Assemblies

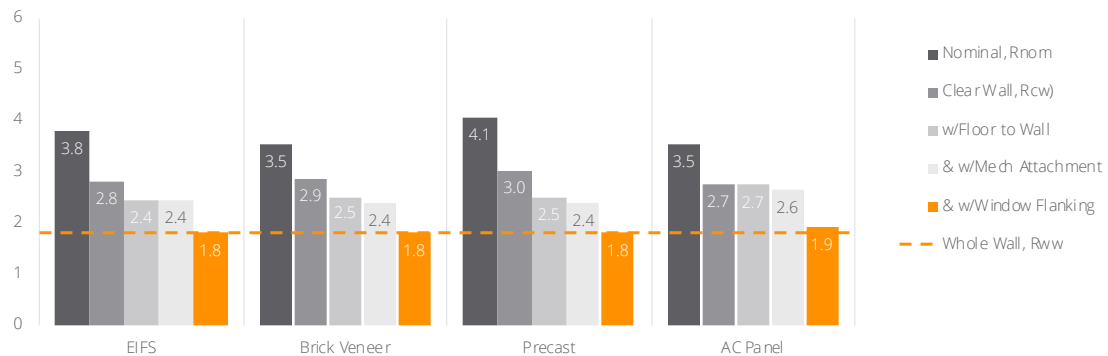
Thermal Resistance Value ( $\text{m}^2 \text{ } ^\circ\text{C/W}$ )



## Thermal Resistance Values

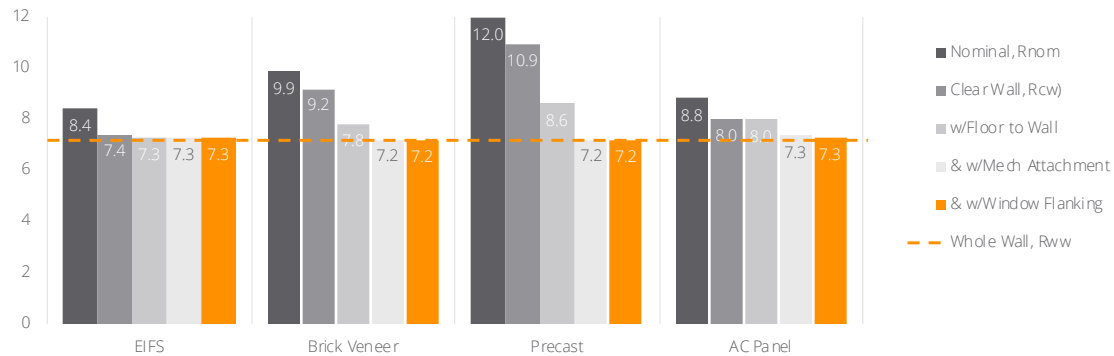
### Montreal Commercial Wall Assemblies

Thermal Resistance Value ( $\text{m}^2 \text{ } ^\circ\text{C/W}$ )



## Thermal Resistance Values

Thermal Resistance Value ( $\text{m}^2 \text{ } ^\circ\text{C/W}$ )



## Thermal Resistance

### Conclusions and Discussion

- It is important to appreciate that in conducting thermal analyses, the EIFS wall cladding system does not deviate from the requirements set out in the current CAN/ULC-S716 set of standards. The resulting thermal performance for EIFS represents details and practices that are typically delivered today across all building types.
- By contrast, the alternative wall cladding systems deploy measures that do not represent standard industry practice and often go far beyond what is typically installed today.
- This is a critical distinction because the constructability challenges associated with some of the measures needed to achieve whole wall thermal resistance values have not been accounted for in the costing. It is also possible that some of the overall whole wall thermal resistance values may prove very challenging to achieve for some of the alternative wall cladding systems.





## Thermal Resistance

### Conclusions and Discussion

- For the residential wood framed walls, the EIFS and fibre cement clad walls showed significantly better thermal performance than the brick veneer clad wall, due to the additional heat loss through brick shelf angles and brick ties.
- For the commercial steel stud walls, the EIFS and aluminum composite panel clad wall showed significantly better thermal performance than the brick veneer and architectural precast concrete walls. Challenges for brick veneer clad walls and for architectural precast concrete walls in achieving high thermal performance are due to the losses at brick shelf angles, brick ties, floor-to-precast-panel-wall interfaces and panel anchors.



## Thermal Resistance

### Conclusions and Discussion

- The analysis demonstrates that a number of thermal bridges occur in common wall assemblies that have a larger impact on performance than the studs in batt-filled spaces. These results support efforts to capture these effects in energy codes.
- As building codes incorporate better accounting of thermal bridging, the effects of window flanking will be very important for all types of wall assemblies. For the high-R walls, it is assumed that designers will implement effective window installation detailing currently common in passive house projects, reducing window flanking effect to negligible or even positive impacts on thermal performance.



# Energy Use Analysis



## Energy Use Analysis

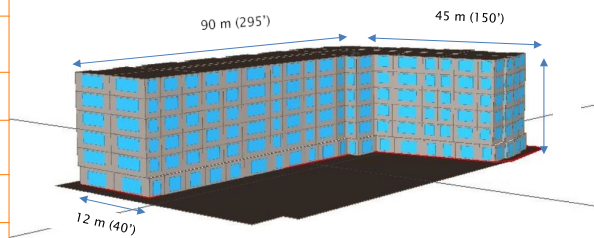
### Approach

- The energy analysis is based on hourly whole-building annual simulations for each city, building type, and wall construction combination. This approach was chosen over modelling only a portion (i.e. 100 m<sup>2</sup>) of each wall assembly for the following reasons:
  - It provides a better comparison for code compliance and adherence to certain standards like the Toronto Green Standard V3 and the City of Vancouver Energy Modelling Guidelines.
  - Hourly whole-building modelling is the current industry “state of the art” approach and has the sophistication to address internal heat gains (based on building type/usage) and other considerations.
- The simulation software used was eQuest 3-64. The energy models were based on existing models from previous RDH projects for purposes of efficiency.
- Energy use associated with the baseline scenario (EIFS  $R_{ww}$ ), and High-R walls were calculated as the difference in energy usage between the baseline wall and a wall assembly with negligible heat transfer (i.e. 35 RSI (R-200 walls)



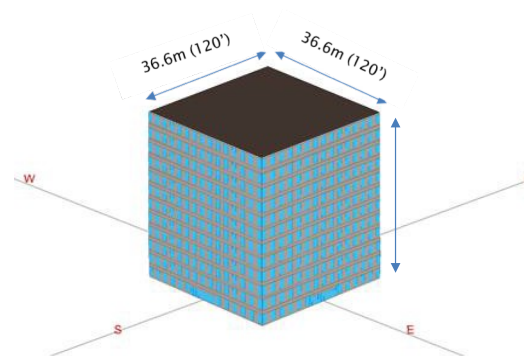
## Building Typology - 6-Storey Wood-frame

Parameter	Model Input
Wall	$R_{ww}$ values baseline wall
Roof	Flat roof, nominal 7.9 RSI (R-45)
Floor Slab	Floor insulated to $R_{eff}$ 3.52 RSI (R-20)
Windows	Double-glazed U-1.59 W/m <sup>2</sup> K (0.28 Btu/h·ft <sup>2</sup> ·°F); SHGC 0.31
Window to wall ratio	40%
Infiltration	0.2 L/s/m <sup>2</sup> (0.04 cfm/ft <sup>2</sup> ) at 5 Pa
Floor-to-Floor Height	3.3 m (10.8 ft)
Building Footprint	1,467 m <sup>2</sup> (15,888 ft <sup>2</sup> )



## Building Typology - 12-Storey Commercial

Parameter	Model Input
Wall	$R_{ww}$ values baseline wall
Roof	Flat roof, nominal 5.28 RSI (R-30)
Floor Slab	Floor insulated to $R_{eff}$ 3.52 RSI (R-20)
Windows	Double-glazed U-2.24 W/m <sup>2</sup> K (0.40 Btu/h·ft <sup>2</sup> ·°F); SHGC 0.34
Window to wall ratio	40%
Infiltration	0.2 L/s/m <sup>2</sup> (0.04 cfm/ft <sup>2</sup> ) at 5 Pa
Floor-to-Floor Height	4.0 m (13 ft)
Building Footprint	1,338 m <sup>2</sup> (14,400 ft <sup>2</sup> )



# Additional Model Inputs



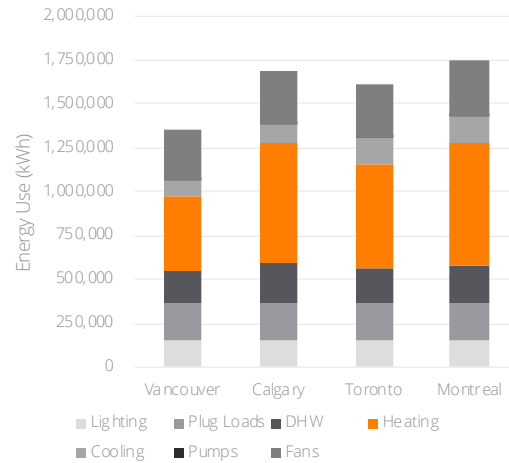
## Mechanical and Electrical Inputs

Parameter	Model Input Residential	Model Input Commercial
Domestic Hot Water (DHW)	Flow rate is per NECB default flows and schedule Natural Gas - 96% efficient condensing storage type natural gas heater	Central DHW heating via heat exchange from hydronic gas-fired boiler (93% efficient)
Space Heating and Cooling	Natural Gas Heating - Napoleon heating/cooling unit coupled with Kanaire ERV 93% heating efficiency - 9.0 EER cooling efficiency	Condensing hydronic gas-fired boiler (93% efficient) and central water-cooled centrifugal chiller (COP 3.9) serving hydronic coils in air handling unit (AHU).  Uses available free cooling from outdoor air (economizer)
Ventilation	In-suite ERVs sized to outdoor air requirements ERV sensible efficiency: 65% average ERV latent efficiency: 55% average	Central air handling unit with hydronic heating and cooling coils serving terminal VAV boxes with hydronic reheat coils (60% enthalpy recovery)
Corridor Ventilation	100% outdoor air provided by rooftop unit Natural Gas Heating - Furnace with 92% heating efficiency, 12.8 EER cooling efficiency	N/A
Interior Lighting Power Density	Dwelling Units - 7.3 W/m <sup>2</sup> (0.68 W/ft <sup>2</sup> ) Other Spaces - 5.4 W/m <sup>2</sup> (0.5 W/ft <sup>2</sup> )	7 W/m <sup>2</sup> (0.65 W/ft <sup>2</sup> )
Receptacle Loads	Dwelling Units - 5.4 W/m <sup>2</sup> (0.5 W/ft <sup>2</sup> ) Other Spaces - 1 W/m <sup>2</sup> (0.1 W/ft <sup>2</sup> )	Units - 5.4 W/m <sup>2</sup> (0.5 W/ft <sup>2</sup> )

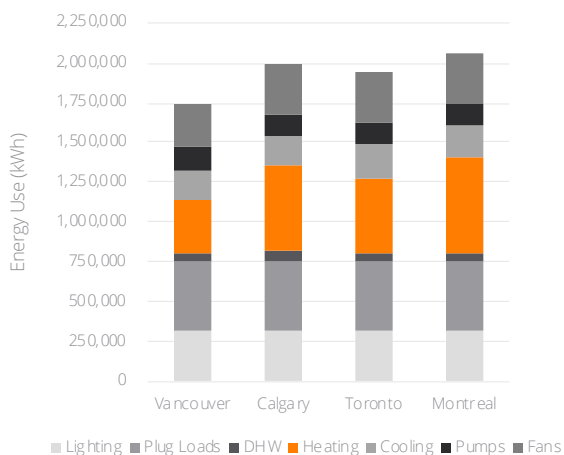


## 6-Storey Wood-Frame Residential

- The results show that heating accounts for the largest use of energy at 30% to 41% of total energy.
- The energy models captured minor differences in fan energy use related to in heating vs. cooling.
- The remaining energy use, including domestic hot water (DHW), plug loads, and lighting, was the same in all residential building scenarios.



## 12-Storey Commercial Construction



- The results show that heating accounts for the largest amount of energy use at 19% to 29% of total energy.
- There is greater opportunity for cost saving through High-R wall construction in commercial buildings relative to residential archetype.
  - Although the heating demand is less for commercial buildings, the whole wall thermal performance of baseline commercial walls is much worse than baseline walls in residential, providing greater potential for savings.
  - Heating cost can be reduced 13 – 20%





## Life Cycle Cost Analysis

- Life-cycle cost analysis (LCCA) attempts to monetize various alternatives to compare their cost effectiveness. Present value calculations are used in the analysis to determine the amount of money paid upfront to cover the initial costs and then the operating, maintenance, and repair costs over a 50-year life cycle period
- The scope of costs captured in the analysis for this study included:
  - Capital construction costs based on the wall assembly specifications to achieve Effective Whole Wall R-value,
  - Annual energy costs associated with opaque wall area as estimated through energy modelling by RDH (and
  - Expected enclosure system maintenance and repairs
  - Building operation costs.





# Construction Costs



## Cost of Construction Residential

	Vancouver	Calgary	Toronto	Montreal
EIFS Walls				
Baseline Wall Cost (\$/sf)	\$24.00	\$25.00	\$24.00	\$24.00
High-R Wall Cost (\$/sf)	\$28.50	\$28.50	\$28.50	\$28.50
Brick Veneer Walls				
Baseline Wall Cost (\$/sf)	\$59.00	\$56.50	\$69.50	\$51.00
High-R Wall Cost (\$/sf)	\$67.03	\$61.53	\$77.53	\$59.03
Fibre Cement Board Walls				
Baseline Wall Cost (\$/sf)	\$34.00	\$34.00	\$39.00	\$51.50
High-R Wall Cost (\$/sf)	\$38.50	\$37.50	\$43.50	\$56.00



## Cost of Construction Commercial

	Vancouver	Calgary	Toronto	Montreal
Panelized EIFS				
Baseline Wall Cost (\$/sf)	\$35.50	\$37.00	\$36.00	\$34.50
High-R Wall Cost (\$/sf)	\$41.50	\$41.00	\$41.50	\$41.50
Brick Veneer				
Baseline Wall Cost (\$/sf)	\$61.50	\$57.50	\$69.50	\$50.00
High-R Wall Cost (\$/sf)	\$70.53	\$65.03	\$77.03	\$60.53
Architectural Precast Panels				
Baseline Wall Cost (\$/sf)	\$96.60	\$76.60	\$61.60	\$51.60
High-R Wall Cost (\$/sf)	\$103.10	\$78.60	\$67.10	\$59.10
Aluminum Composite Panels				
Baseline Wall Cost (\$/sf)	\$86.00	\$63.50	\$47.50	\$46.50
High-R Wall Cost (\$/sf)	\$92.50	\$67.00	\$53.50	\$54.00



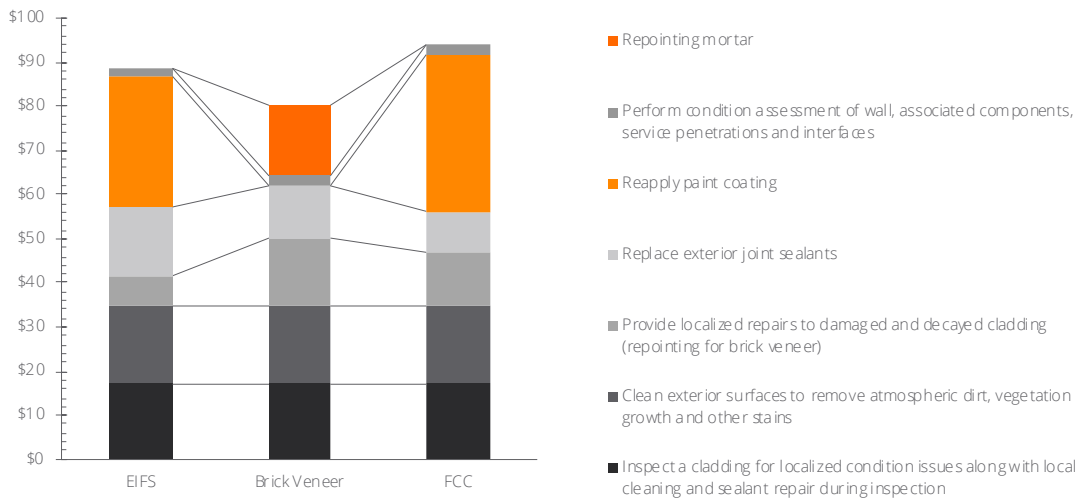
## Repairs and Maintenance



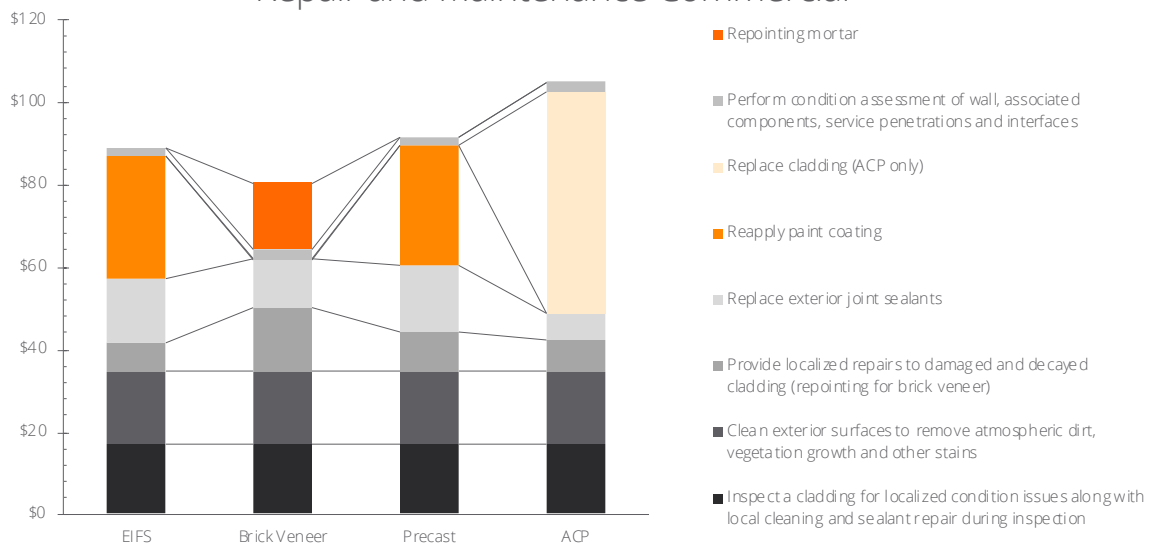
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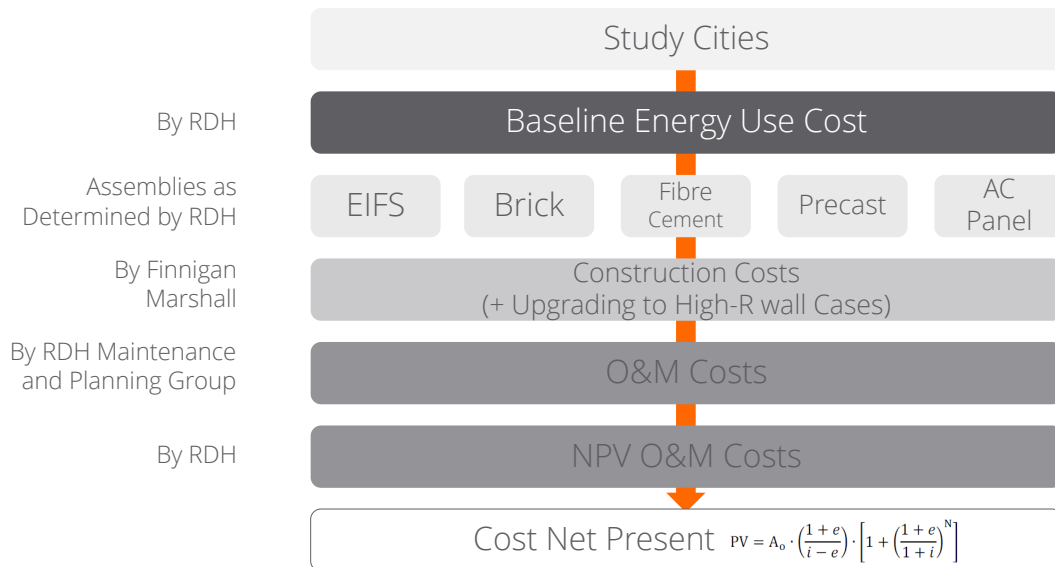
## Repair and Maintenance Residential



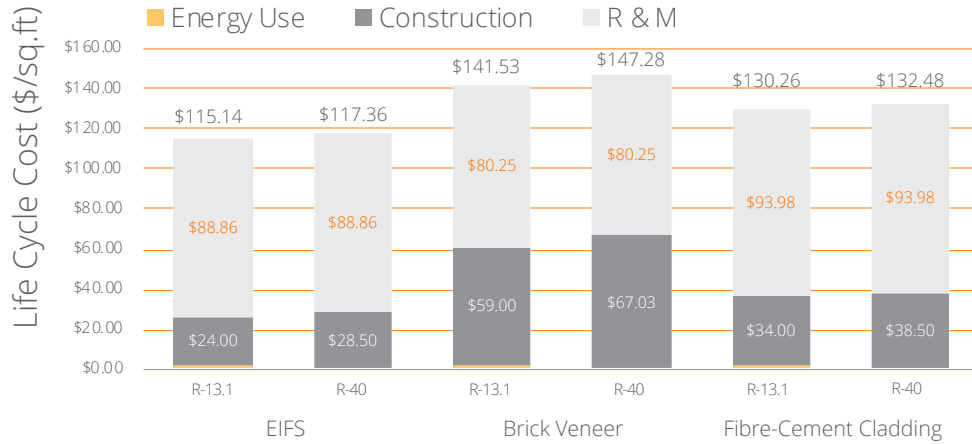
## Repair and Maintenance Commercial



# Life Cycle Cost Analysis



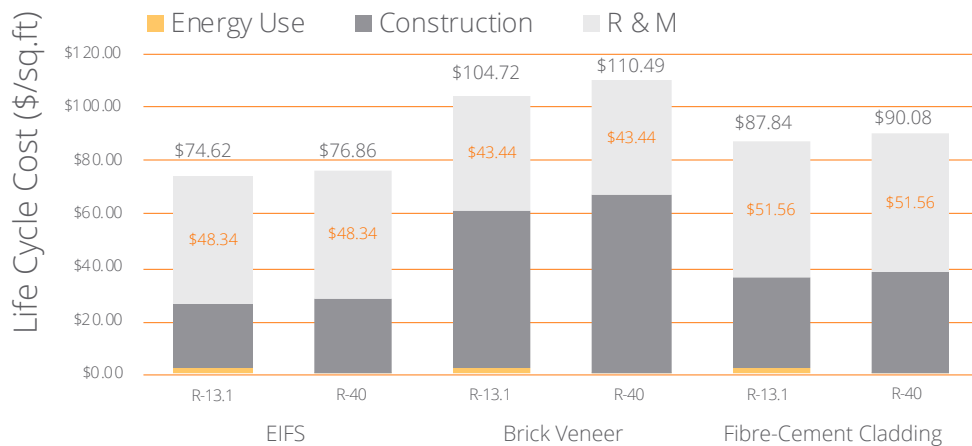
## Residential Life Cycle Cost – Vancouver



2% Discount Rate, 4% Escalation



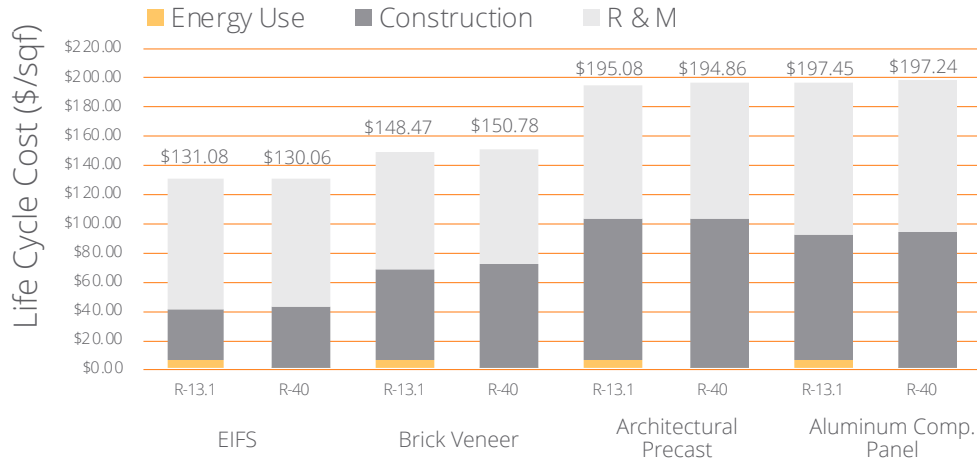
## Residential Life Cycle Cost – Vancouver



4% Discount Rate, 4% Escalation



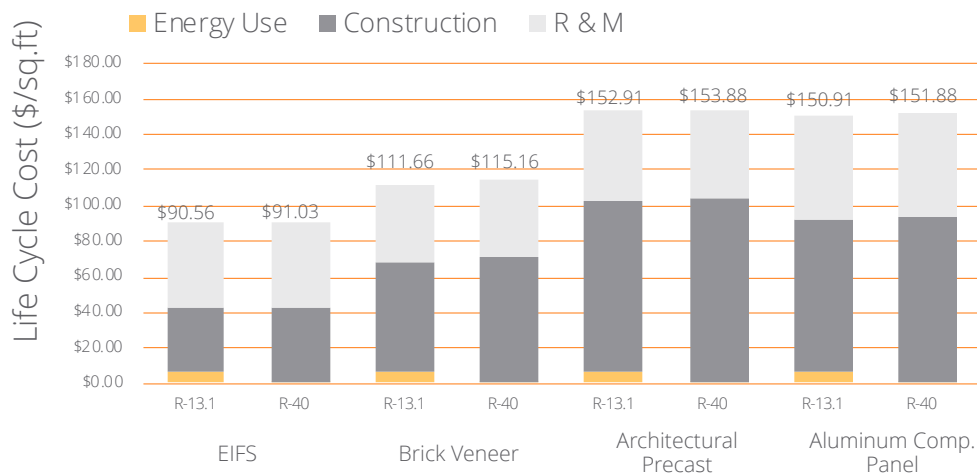
## Commercial Life Cycle Cost – Vancouver



2% Discount Rate, 4% Escalation



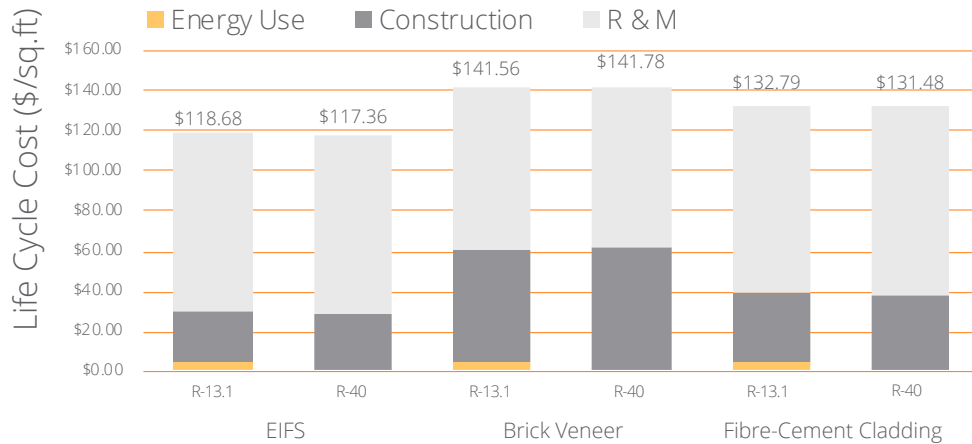
## Commercial Life Cycle Cost – Vancouver



4% Discount Rate, 4% Escalation



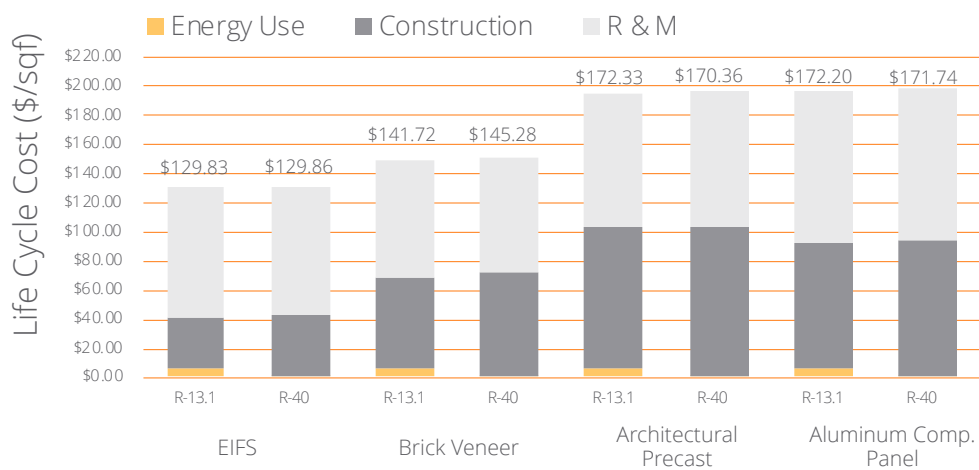
## Residential Life Cycle Cost – Calgary



2% Discount Rate, 4% Escalation



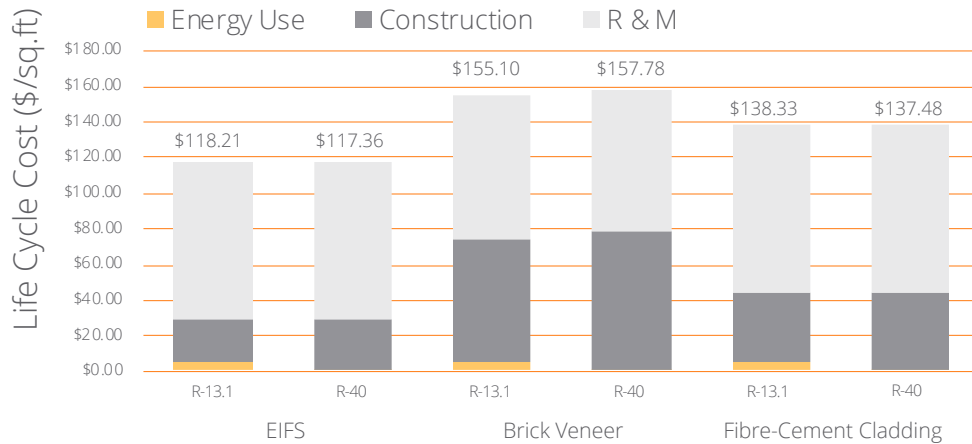
## Commercial Life Cycle Cost – Calgary



2% Discount Rate, 4% Escalation



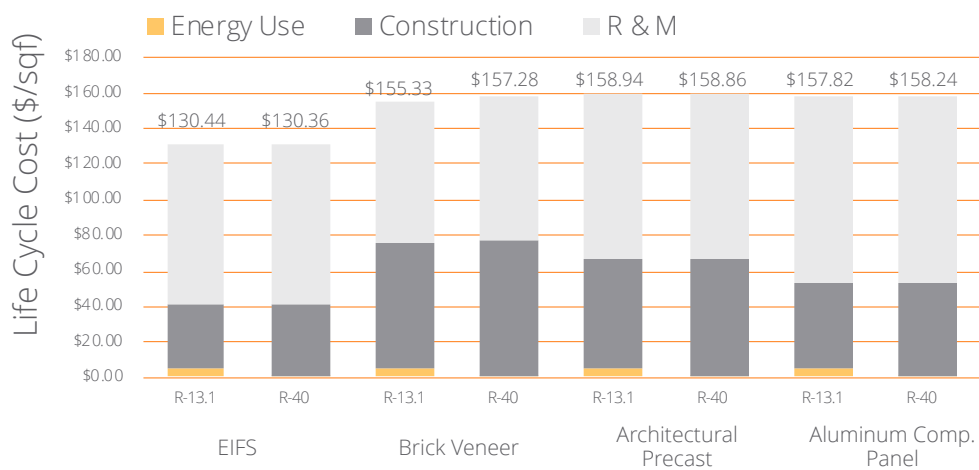
## Residential Life Cycle Cost – Toronto



2% Discount Rate, 4% Escalation



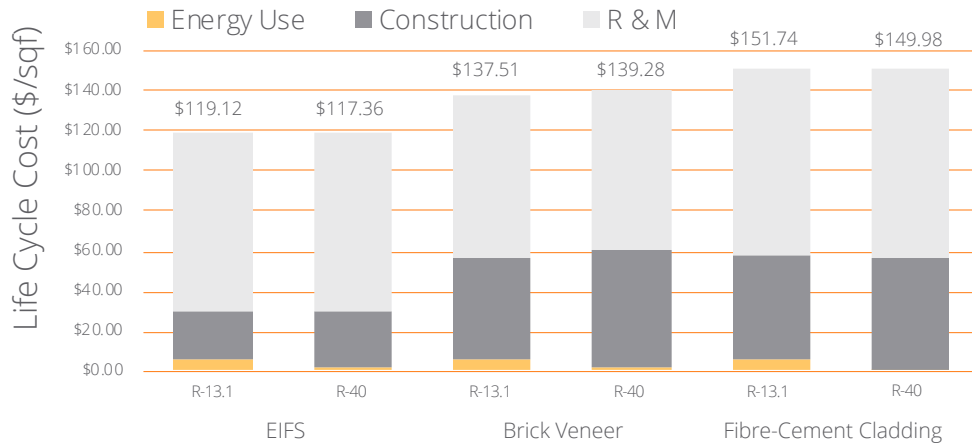
## Commercial Life Cycle Cost – Toronto



2% Discount Rate, 4% Escalation



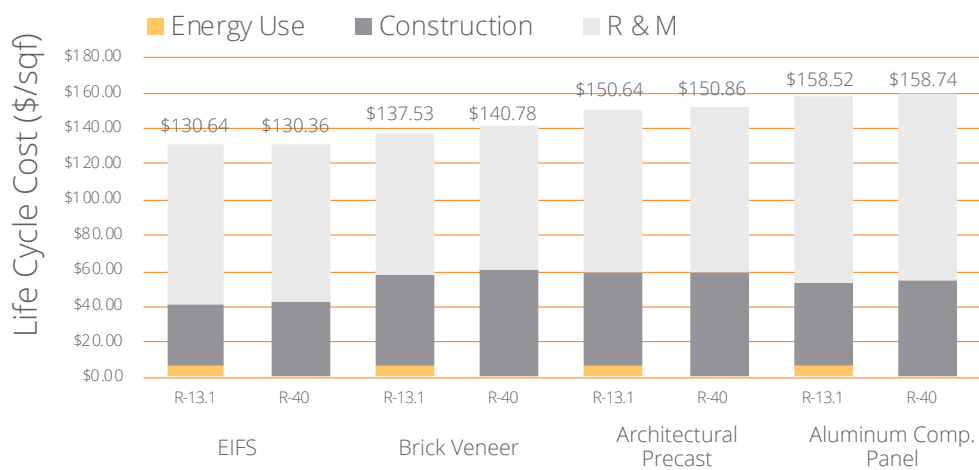
## Residential Life Cycle Cost – Montreal



2% Discount Rate, 4% Escalation



## Commercial Life Cycle Cost – Montreal



2% Discount Rate, 4% Escalation



## Part 4

### Conclusions and Insights



## Overall Insights and Conclusions

- The major advantage of EIFS is lower construction cost (partly due to more effective thermal performance) and similar or lower life cycle costs when built and operated with a high level of design, construction, and maintenance quality
- At current natural gas costs the LCCA impact of construction, repair, and maintenance are much greater than related energy use
- A number of construction assumptions were made which could be argued are conservative toward EIFS (no special provisions), while beneficent toward alternatives
  - (e.g. use of >6 in. of exterior insulation in masonry veneer in conjunction with stand-off shelf angles and thermally optimized brick ties).
- Life Cycle Analysis values highly dependent on interest and price escalation rates but still show advantages of EIFS



## Overall Insights and Conclusions

- The analysis results show a lower construction and life cycle cost for EIFS in residential and commercial buildings when compared to other cladding options for 6-storey wood framed residential and 12-storey concrete commercial buildings in major cities in Canada.
- This EIFS advantage is sustained across the various climate zones and differences in energy code requirements
- Estimating construction costs for alternative assemblies across Canada should not be used for budgeting of projects.
- Range of costs for alternatives, reflects the very limited data-pool for building constructed to meet the target effective R-value when utilizing the comparative materials.
- Insulation thicknesses used for EIFS does not trigger special application requirements.

## Additional Insights

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Construction cost range is likely to lessen as energy codes tighten and greater experience constructing more energy efficient buildings is gained

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Alternative technologies for precast, such as sandwich panels may improve constructability, but are also likely to have higher upfront cost

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EIFS represents both the most cost effective and greatest known quantity based on standardized construction practices and their ability to achieve High-R enclosures without special or untried provisions