PART 3
SIGNIFICANCE, INSIGHTS AND NEXT STEPS

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3.1 OVERVIEW

With the abundance of information provided in Part 1 and 2, and related appendices, the question may arise "So what?" and "What do we do now?" Part 3 of this guide responds to these questions.

First in Section 3.2, Significance and Insights, the question of "So what?" is answered by highlighting the important stories and insights that follow from the analysis covered by this guide. Then the question of "What do we do now?" is covered in section 3.3, Next Steps.

Part 3 has insights and next steps for all the stakeholders. A focus of Part 3 is on market transformation, but there are also insights relevant to current design practice.

3.2 SIGNIFICANCE AND INSIGHTS

The significance of the body of work that supports this guide and insights are not simply summarized by mirroring Parts 1 and 2. Insights are presented by different viewpoints that are organized by high level themes. These themes present individual stories that are intended to create an informed impression without getting lost in the details.

Many of the themes presented below are suitable for future technical bulletins, which is discussed in section 3.3.

3.2.1 WOOD-FRAME BUILDINGS (TYPICALLY) HAVE BETTER BUILDING ENVELOPE THERMAL PERFORMANCE

With the spirit of "Wood First" in BC, the first theme to address is the ranking of wood-frame construction compared to other types of construction.

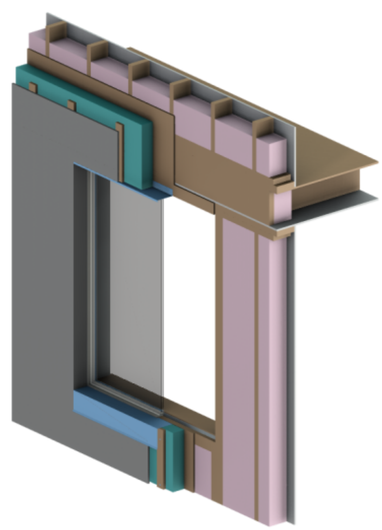


Figure 3.1: Wood-Frame Construction

Wood-frame construction is inherently more thermally efficient due to the lower conductivity of wood compared to concrete, steel-frame, and masonry construction. As a result, the impact of thermal bridges caused by wood framing is less than materials typically used in non-combustible construction. The low conductivity of wood also makes it easier to account for thermal bridging in calculations because lateral heat flow is less of an issue and assumptions of parallel path heat flow are more valid for most wood-frame details. Moreover, since it is more easily determined, energy standards account for more thermal bridging in wood-frame construction than for other types of construction. For example, assumptions in ASHRAE 90.1, Appendix A, include extra framing such as plates, sills, and headers, for wood-framed walls. In contrast, steel framed walls do not account for any extra framing around openings. Nevertheless, not all thermal bridges are addressed. There can be a significant difference between the U-values assumed by ASHRAE 90.1, Appendix A and the overall U-value determined by the procedures put forward in Part 1 of this guide. Figure 3.2 compares the prescriptive requirements for thermal transmittance in the applicable BC energy codes and standards to the U-values contained in ASHRAE 90.1 Appendix A or by using the procedures outlined in Part 1 (BETA Calculation Method). The BETA values are part of the calculation for the Low-rise MURB scenarios contained in Appendix E.

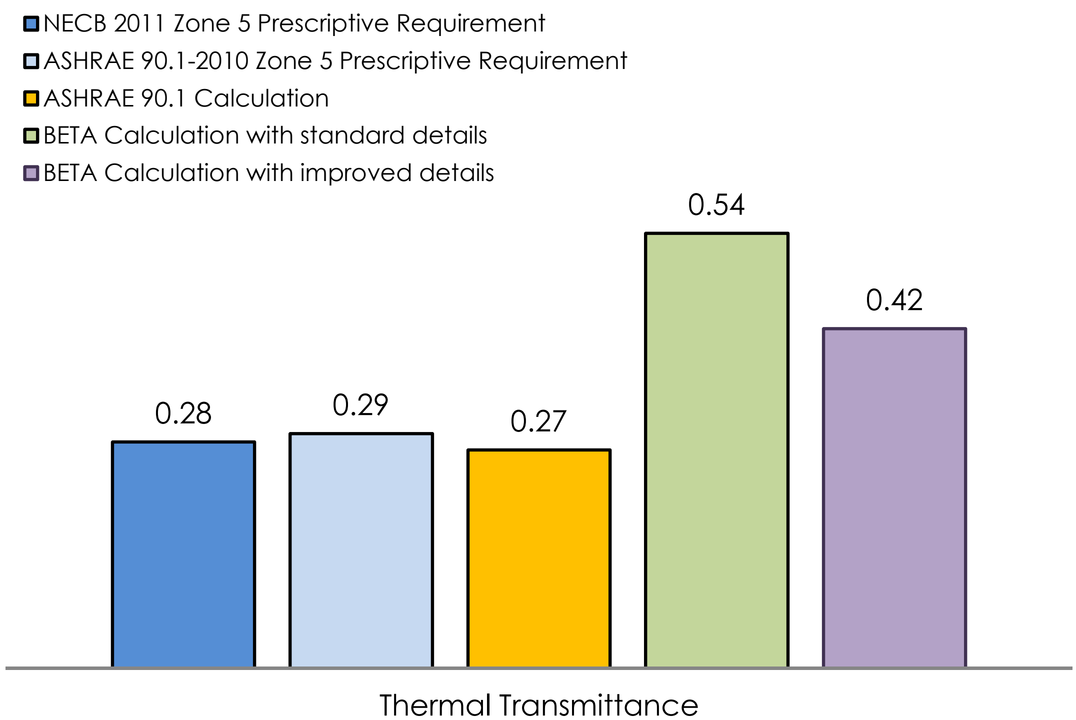


Figure 3.2: Comparison of the Thermal Transmittance (W/m^{2}K) of ASHRAE 90.1 and BETA Calculation Methods for a Wood-Frame Wall Assembly with R-19 Batt Insulation in the Stud Cavity and R-5 Exterior Insulation

There are a limited number of wood-frame details covered by this guide, but generally the transmittances for the wood-frame details are low. Even the highest linear transmittance values for the wood-frame interface details with flashing are lower in comparison to similar details for other construction types. Nevertheless, the relative contribution of the interface details to the overall heat flow for wood-frame construction can add up to be more than the clear wall heat flow. This is largely because of how little heat flows through thermally efficient clear field wood-frame walls. For example, for a low-rise wood-frame building with 30% glazing, the contribution of the interface between an aluminum window and the adjacent wood framed wall ranged from 30% to 40% of the total heat flow through the opaque elements. The window interface contribution to the overall heat flow dropped by half with a vinyl window with similar positioning and detailing. Figure 3.3 compares wood-frame construction to steel-framed and concrete construction for regular details for the 30% glazing low-rise MURB building. The heat flow associated with the clear field assembly is broken out from the heat flow associated with the interface details to show the relative contribution to the effective thermal resistance for the different types of construction.

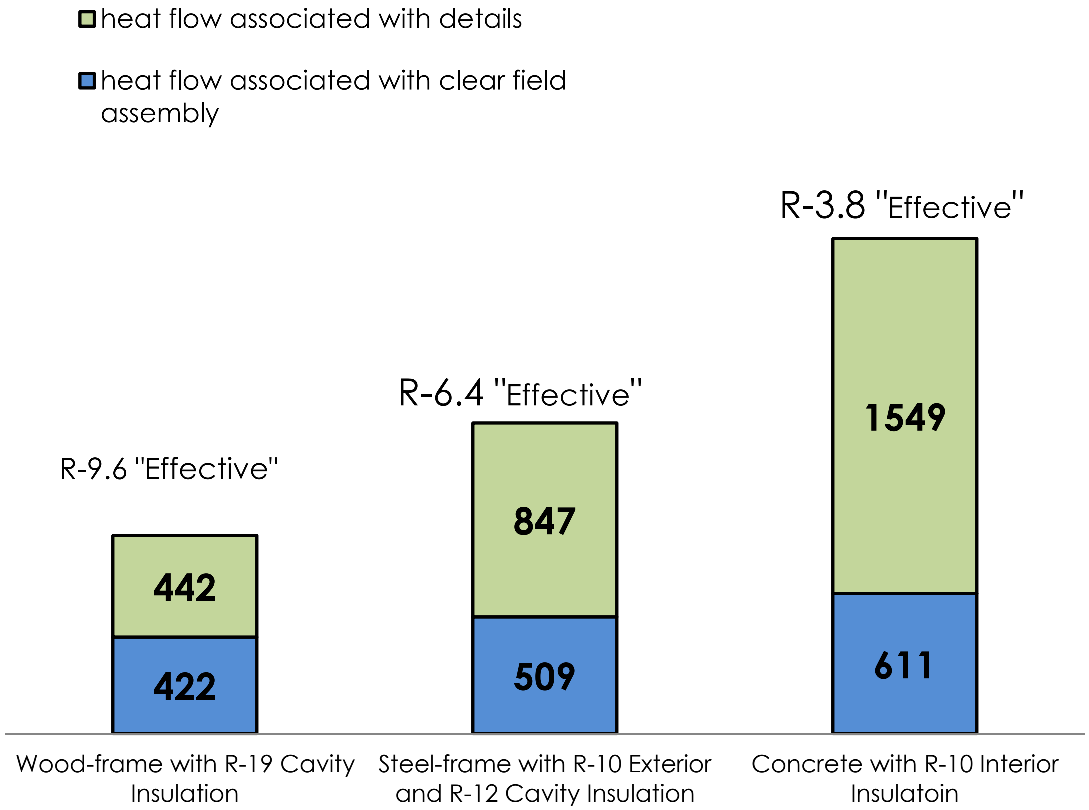


Figure 3.3: Comparison of Relative Contribution of Heat Flow (W/K) to the Effective Thermal Resistance (ºF ft2 hr/BTU) for Various Construction Types

Prescriptive requirements in energy codes and standards referenced by the BCBC for larger buildings (NECB 2011 and ASHRAE 90.1-2010) strongly encourage exterior insulation for wood-frame assemblies. As more insulation is added to the exterior of wood-frame walls, the improvement to energy savings become negligible due to the law of diminishing returns and the bypassing of insulation by thermal bridging. The impact of the heat flow at window interfaces can be significant, sometimes even exceeding the heat flow through the clear field of the well-insulated walls. Accordingly, improvements to the selection, design, and installation of windows for wood-frame construction will be increasingly more critical and cost effective than adding more exterior installation.

The impact of the interface details is not as dramatic for wood-frame construction and generally the energy use is less for buildings with wood-frame construction than for other types of construction. Nevertheless, other types of construction with exterior insulation and improved details can achieve the same over-all U-value as wood-framed construction. However, more attention is required to the details to achieve the same level of performance. For example, the cost benefit analysis in Appendix E shows how a low-rise MURB with a concrete structure and exterior insulated steel stud infill can meet the same U-value requirements as wood-frame construction, but requires thermally broken balconies and parapets and costs more (compare Case 1A to Case 2A of the Low-rise MURB with 30% glazing).

3.2.2 INTERFACE DETAILS ARE SIGNIFICANT IRRESPECTIVE OF CROSS SECTIONAL AREA

The cost-benefit analysis completed for this guide makes it clear that if reductions in energy use in our building stock is a real goal in society (and in codes) then thermal bridging at interface details cannot be ignored.

"For highly insulated walls, the U-values determined by the BETA method, with common details, is as high as **three to four** times the clear field U-value"

For larger buildings, there is currently a wide gap between the building envelope thermal performance that our energy code and standards assume and what is actually being built. Our analysis of archetype buildings, with concrete walls insulated on the inside with ASHRAE 90.1-2010 prescriptive insulation levels and common details, show the effective U value of the opaque walls are two to three times the prescriptive assembly U-value. The gap widens to as much as three to four times for wall assemblies that are insulated per NECB 2011 prescriptive levels.

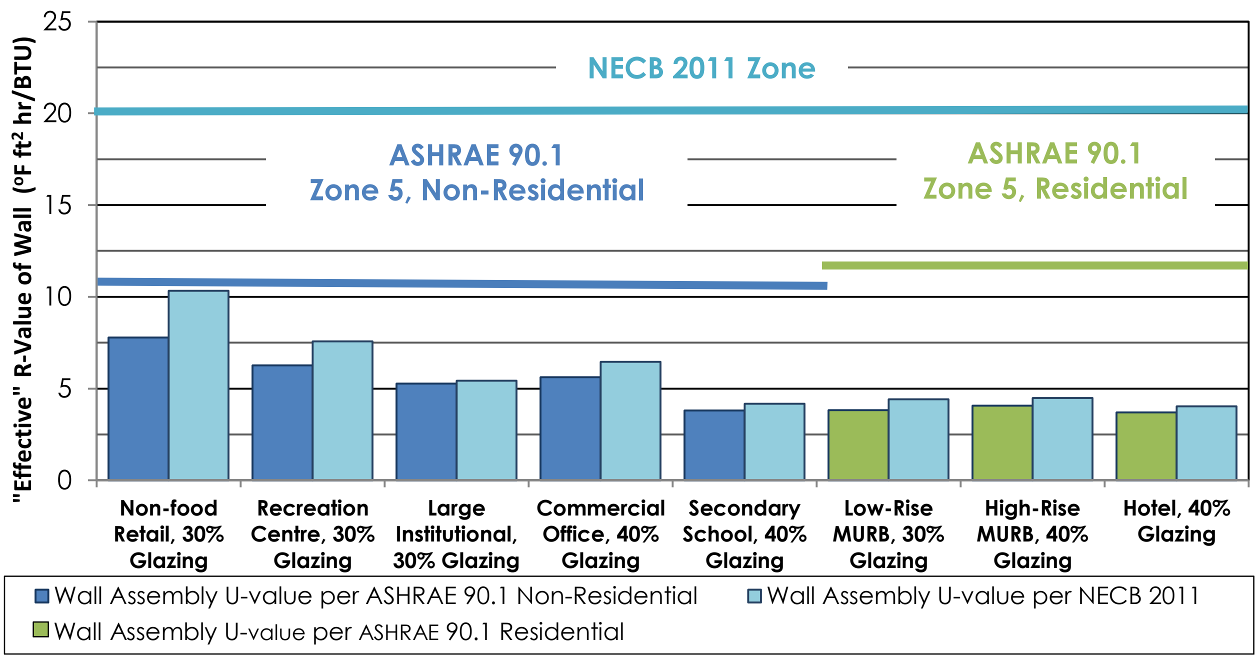


Figure 3.4: "Effective" R-value for the 30% to 40% Glazing Archetype Buildings with Concrete Walls and Common Details

For higher glazing ratios the gap between the assembly U-value and the overall U-value that includes interface details is higher, approximately 25% to 50% higher. This has implications for achieving code compliance using the performance path (i.e. whole building energy modeling) in energy codes and standards. Often the performance path is the desirable path for designers and developers looking to maximize the percentage of glazing. Clearly, with more glazing there will be more interface details per opaque area and the difference between the assembly U-value and U-value that includes details will be amplified. The following figure and table illustrates this concept for strip glazing, where the linear length of the glazing interface is constant. Note for punched windows, the linear length of the interface detail will increase with increasing glazing ratios and the difference will be larger.

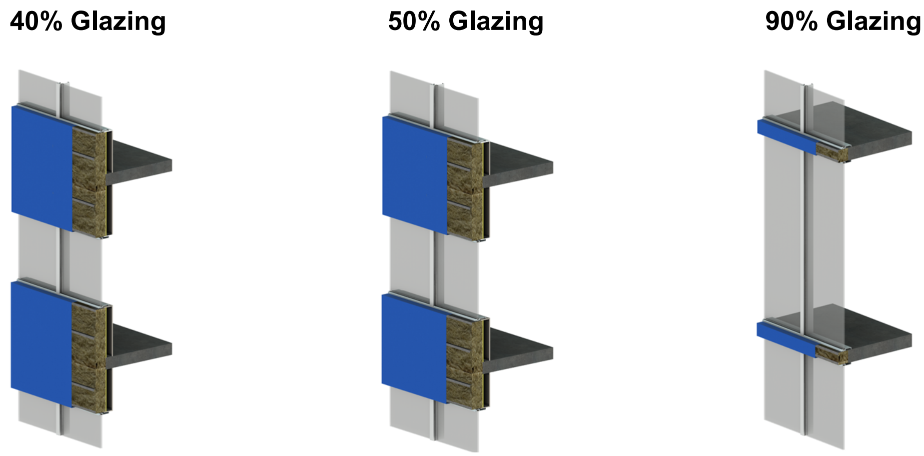


Table 3.1: Impact of Interface Details for Increasing Glazing Percentage

% Glazing	**Glazing Area** Conventional Curtain-wall with vertical mullions spaced at 5 feet (1.5 m) o.c.		**Opaque Area** Steel Stud Wall with Intermittent Clips spaced at 24 inch (610 mm), o.c. vertically and 16 inch (406 mm), o.c. horizontally		% Reduction in "Effective" R-value
	$U_{glazing}$ BTU/hr ft² °F (W/ m² K)	$R_{glazing}$ hr ft² °F/BTU (m² K/W)	U_{opaque} BTU/hr ft² °F (W/ m² K)	R_{opaque} hr ft² °F/BTU (m² K/W)	
40%	0.42 (2.36)	R-2.4 (0.42)	0.059 (0.34)	**R-16.8 (2.96)**	-
50%	0.42 (2.37)	R-2.4 (0.42)	0.061 (0.35)	**R-16.4 (2.89)**	2%
90%	0.39 (2.2)	R-2.6 (0.45)	0.101 (0.57)	**R-9.9 (1.74)**	41%

The archetype buildings are relatively simple in form, incorporating only a modest length of linear interface details. For more articulated architecture, interface details will have an even bigger impact (See section 3.2.3 for more discussion of the impact of articulated architecture).

It is clear that for future iterations of energy codes and standards requiring improvement of interface details will likely have a much more significant impact than requiring additional insulation. Moreover, improving interface details or devoting more attention to avoiding large thermal bridges is generally more cost effective than solely adding insulation. See section 3.2.4 for more discussion on the cost effectiveness of adding more insulation and the impact of mitigating thermal bridging combined with higher insulation levels.

The U-value gap due to interface details translates to as much as a 36 ekWh/m^2 difference in total annual energy. Tables 3.2 and 3.3 summarize the impact of interface details, in terms of annual energy use, for common concrete construction with either 30% or 40% glazing (Scenario 2, Case 1 in Appendix E). Note that 28% of the opaque area is glazing spandrel, in addition to concrete walls, for the commercial office building and 9% of the opaque area of the large institutional building is glazing spandrel.

Table 3.2: Comparison of Energy-Use related to ASHARE 90.1-2010, Zone 5, U-Values to BETA Method U-values for Common Concrete Construction

Building Type	ASHRAE 90.1-2010 Zone 5 U-Value W/m²K	BETA Calculation Value W/m²K	% Incr. U-Value	Total Energy Difference ekWh/m²	Energy Cost Difference $/m²
Commercial Office	0.51	0.97	91	8	$ 0.29
High-Rise MURB	0.45	1.39	210	11	$ 1.03
Hotel	0.45	1.54	242	20	$ 0.57
Large Institutional	0.51	1.10	115	16	$ 0.39
Low-Rise MURB	0.45	1.48	230	14	$ 1.24
Non-Food Retail	0.51	0.73	62	10	$ 0.30
Recreation Centre	0.51	0.91	77	6	$ 0.18
Secondary School	0.51	1.08	112	10	$ 0.34

Table 3.3: Comparison of Energy-Use related to NECB 2011, Zone 5, U-Values to BETA Method U-values for Common Concrete Construction

Building Type	NECB 2011 Zone 5 U-Value W/m²K	BETA Calculation Value W/m²K	% Incr. U-Value	Total Energy Difference ekWh/m²	Energy Cost Difference $/m²
Commercial Office	0.28	0.88	215	11	$ 0.41
High-Rise MURB	0.28	1.27	352	12	$ 1.08
Hotel	0.28	1.41	402	21	$ 0.62
Large Institutional	0.28	1.07	285	36	$ 1.20
Low-Rise MURB	0.28	1.29	359	13	$ 1.21
Non-Food Retail	0.28	0.55	96	12	$ 0.34
Recreation Centre	0.28	0.75	170	8	$ 0.35
Secondary School	0.28	1.36	389	14	$ 0.48

Moving beyond code compliance to voluntary ratings programs, such as LEED, developers and architects need to understand that there are different set of rules for modeling building envelope thermal performance than for simple code compliance. One difference is that interface details, such as projecting balconies, perimeter edges of intermediate floor slabs, concrete floor beams over parking garages and roof parapets, are often required to be accounted for in the proposed design building. Developers or building owners should expect that a competent energy modeler will account for these interface details for rating programs that follow these sets of rules. Moreover, if the building envelope design has major thermal bridges (i.e. cantilevered balcony floor slabs) it should be expected that this can be a major hurdle for getting energy related points for LEED or an equivalent program.

Meeting LEED requirements is even more difficult when you consider that energy "points" are achieved by comparing the energy use of the "proposed design building" to a baseline building that does not include an allowance for heat loss at interface details (i.e. the U-values are based on the prescriptive assembly maximum U-factors).

Figure 3.5: An example of thermal bridging at the interface between assemblies. This is NOT captured by wall schedules but reduces the insulation effectiveness

Good design considers the impact of interface details, not simply to comply with code, but because there is often additional advantages. Often (but not always) more thermally efficient building envelope details reduce the risk of condensation. Architects have a responsibility for coordinating the design team (i.e. mechanical designer, energy modeler, contractor) and that requires an awareness of the potential impact of design and construction of interface details.

With regard to accounting for the heat flow in the mechanical design, the buck stops with the mechanical designer. Good practice for load analysis requires a mechanical designer to accurately account for the heat loss through the envelope based on the architectural drawings. Gross assumptions or an inappropriate factor of safety can sometimes lead to operational inefficiencies related to under or over sizing of equipment. Good practice requires a quantity takeoff for each zone. An example of gross assumptions is reliance on a single U-value for the entire opaque building envelope based on wall schedules and ignoring the impact of interface details. This does not reflect the reality of construction. The good news is that this guide provides information to make detailed heat loss calculations easier for mechanical designers.

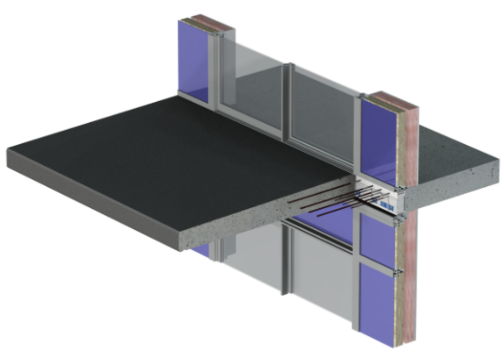


Figure 3.6: A thermally broken floor slab at a balcony and sliding door

An important consideration for everyone is that the cross sectional area is not a key indicator for evaluating the impact of thermal bridges. For example, steel studs have a small cross sectional area that bypasses any thermal insulation in the stud cavity and reduces the effectiveness of the insulation by 40% to 60% depending if there is exterior insulation and the stud spacing. There is well documented information to the expected performance of framed walls, and generally industry accepts that thermal bridging related to framing like studs must be considered.

For less frequent spaced thermal bridges, like balcony slabs or shelf angles, the impact is not often considered in practice. Justifications for this include that these penetrations are needed for structural purposes, the thermal impact is difficult to assess, they are a small proportion of the envelope area, or they can be considered negligible if the insulation is installed tight to the penetration (paraphrased from NECB 2011). The information in this guide should put these assumptions to rest.

The impact of these penetrations can be significant. For example, the high-rise multi-unit residential buildings covered by the cost benefit analysis included cantilevered balconies that are approximately 2.7% of the total opaque wall area. However, approximately 15% to 30% of the heat flow through the wall area is associated with the balconies. The relative impact depends on the efficiency of the wall assembly and other interface details.

"The cantilevered balconies are approximately 2.7% of the total opaque wall area but 15 to 30% of the heat flow through the opaque wall area is associated with the balconies"

For the high-rise MURB with 40% glazing with EIFS on concrete (Scenario 2, Base Case 2 in Appendix E), the heat flow associated with the balconies and exposed floor slabs accounted for approximately 40% of the heat flow. For the case with thermally broken balconies and improved EIFS details (Scenario 2, Case 2A in Appendix E), the heat flow dropped to only approximately 20% of the heat flow. The EIFS with improved details is a 59% improvement in U-value compared to the common interior insulated case (Scenario 2, Base Case 1 in Appendix E) and translates to 10 ekW/m^2 in electricity savings compared to the base case.

EIFS on concrete with improved details is an example where the U-value determined by the BETA method is close to the prescriptive requirements for Zone 5 of ASHRAE 90.1-2010. However, EIFS outboard of concrete, thermally broken balconies, and insulated parapets costs a lot more than what is currently common practice for interior insulated poured-in-place concrete walls.

These extra costs raise the question of what is an appropriate baseline for any economic analysis, which includes the impact of details that were previously overlooked. Some extra costs are expected to address thermal bridging at interface details compared to current practice. However, the magnitude of extra costs is debatable and depends on the reference point or how high the bar is set. If the bar stays set high (i.e. U-value requirements remain the same but interface details become part of U-value calculations) then some types of common construction, such as interior insulated poured-in-place architectural concrete, will be put under pressure from a cost perspective and alternative forms of construction will be much more attractive. If the bar is set low, reflective of what is currently built to meet code minimums, and then improving the building envelope by better details is very cost effective.

Regardless where the bar is set, improving interface details is likely to be more cost effective than adding more insulation or upgrading to triple glazing. Figure 3.7 illustrates the cost effectiveness of improving interface details for concrete framed construction with steel stud infill (Scenario 1, Case 1 in Appendix E) compared to adding more insulation and upgrading to triple glazing (Scenario 1, Case 4 in Appendix E) for the high-rise MURB with 40% glazing in Vancouver.

Where the bar should be set is an important consideration for energy code and standards when looking at addressing thermal bridging interfaces. More insights into the role of energy codes and standards can be found in section 3.2.6.

The question of what is an appropriate baseline is also an important consideration for utility incentive programs that require energy savings be demonstrated by energy modeling. These programs might set the bar low to reflect current practice and encourage better practice, then steadily raise the bar as thermal bridging is more effectively addressed in practice.

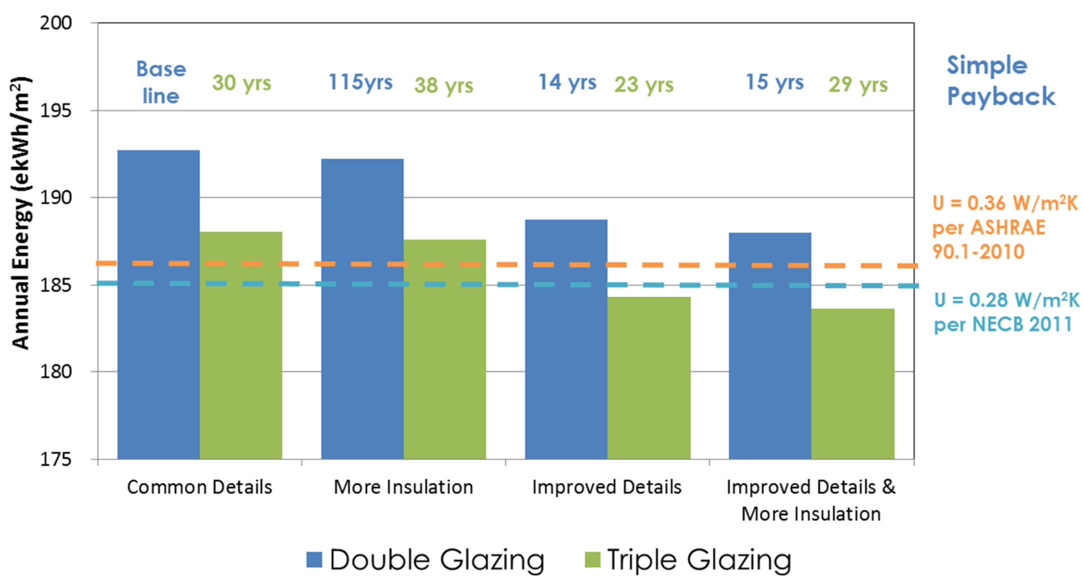


Figure 3.7: Comparison of Annual Energy Use and Simple Payback for High-Rise MURB with 40% Glazing in Vancouver

3.2.3 ARCHITECTURE

Design decisions made by architects can have a big impact on the overall building thermal performance. Decisions that lead to more interface details, will typically lead to additional heat flow. Examples include articulating architecture, glazing broken up by small areas of opaque walls, and glazing orientation. Some thermal bridges can be completely avoided or substantially decreased, such as concrete shear walls or eyebrows.

The quantity of interface details in the archetype buildings used for the cost-benefit analysis is modest compared to some new construction. A straightforward approach to encouraging less energy intensive design is to require that the energy impact of the interface details be included in U-factor calculations for code compliance and voluntary performance programs.

Figure 3.8: A common form for a residential tower in BC with many thermal bridges at interface details

For example, the impact of a concrete shear wall intersecting with interior insulated concrete walls between the units of a high-rise residential building was considered in the cost-benefit analysis (Scenario 2, Case 1B in Appendix E). Simply avoiding the concrete shear walls coming to the exterior, results in a 1.4 to 2.1 eKWh/m^2 in electrical savings, for all the climates.

Assembly selection far outweighs the costs related to mitigating thermal bridges at interface details. Some assemblies inherently have less thermal bridging at interface details. Therefore, it is rational to compare between competing assemblies. However, the incremental costs between competing assemblies overshadow even the most expensive upgrades to specific interface details.

Figure 3.9: A concrete shear wall bypasses the thermal insulation (seen from the interior). The blue material is insulation, is on both sides of the concrete wall. The concrete wall is part of the suite separation.

Table 3.4 demonstrates this concept by comparing the costs and performance of two exterior insulated steel stud assemblies, metal panel (Scenario 1, Case 1 in Appendix E) and EIFS (Scenario 1, Case 2 in Appendix E). The EIFS assembly has slightly better performance than the metal panel assembly for the same level of exterior insulation (R-15), but cost less. The difference in cost between the assemblies is far more than the cost to provide thermally broken balconies and parapets.

These decisions are not just made by architects; entire design teams and owners will need to get onboard to improve practice related to building envelope performance. This circles back to the importance of the codes and standards to set the bar so that industry is on a level playing field. More discussion about energy codes and standards related to encouraging improved designed practice is covered in section 3.2.6.

Table 3.4: Cost and Performance Comparison of Two Types of Steel Stud Assemblies

Type of Steel Stud Wall Assembly	Interface Detail Scenario	U-Value (W/m^2K)	Incremental Costs	Energy Cost Savings	Payback
Metal Panel	Common	0.95	-	-	-
	Improved	0.60	$149,394	$10,019	14
EIFS	Common	0.92	$(2,136,608)	$965	0
	Improved	0.51	$ (1,692,257)	$11,489	0

3.2.4 THE EFFECTIVENESS OF ADDING MORE INSULATION

Analysis summarized in Appendix E shows that adding more insulation to already highly insulated wall assemblies, with common interface details, has little impact on building energy use. This is true for wood-frame and non-combustible construction. Adding more insulation to wall assemblies has diminishing returns regardless of the interface details, but these diminishing returns are amplified by the presence of significant thermal bridges.

The payback for adding more insulation to assemblies that are already highly insulated is high, because of the minimal reduction in energy use. This is true even if the impact of the details are not considered. Table 3.5 summarizes the payback for exterior insulated steel stud assemblies with metal panel with an "effective" R-value of R-15.6 (ASHRAE 90.1-2010 prescriptive requirement for Zone 5) compared to R-20 (NECB 2011 prescriptive requirement for Zone 5) for the buildings with 30% or 40% glazing (Scenario 1 of Appendix E). The construction costs and energy savings presented in table 3.5 do not consider thermal bridging at interface details.

Table 3.5: Cost and Performance Comparison of Adding More Insulation to Steel Stud Assemblies to go from an "Effective" R-value of R-15.6 to R-20

Building Type	Incremental Construction Cost	Energy Cost Savings	Payback (years)
Commercial Office	$ 94,825	$ 1,116	85
High-Rise MURB	$ 153,222	$ 2,542	60
Hotel	$ 64,650	$ 543	119
Large Institutional	$ 150,375	$ 1,833	82
Non-Food Retail	$ 24,192	$ 461	53
Recreation Centre	$ 28,400	$ 263	108
Secondary School	$ 36,325	$ 306	119

The costs for adding more insulation is quite high when compared to the energy savings.

Simple no cost changes, such as avoiding bringing shear walls to the exterior walls of interior insulated concrete walls (Scenario 2, Case 1B for High-Rise MURBS in Appendix E), can achieve energy savings of a similar magnitude as to adding insulation.

Even some “expensive” options look attractive when compared to the cost effectiveness of added insulation. The cost to upgrade to thermally broken balconies and parapets for the high-rise MURB with 40% glazing (Scenario 1, Case 1 in Appendix E) may be three times the cost of increasing the effective wall assembly R-value from R-15.6 to R-20. The resultant savings, however, is more than seven times as much. Better details AND adding insulation translates to the most energy savings and the best payback period.

Adding insulation to interior insulated concrete assemblies (Scenario 2 in Appendix E) did show paybacks that were 30% - 40% lower than the above example with exterior insulated steel stud walls, but only if you assumed that there are no extra costs associated with thicker walls. If there are costs associated with thicker walls, due to FSR constraints, then adding insulation to interior insulated walls would be very expensive.

The implication highlighted by these examples is that increasing insulation requirements to assemblies without considering the impact of interface details will in some cases cost industry more money but will not result in any significant energy savings. Conversely, adding more insulation and improving details can result in real energy savings.

Notwithstanding the general message that paying attention to interface details pays off more than adding insulation, more insulation is sometimes a good solution. For example, adding insulation outboard the metal framing of glazing spandrel sections can result in appreciable reductions in U-value and energy use. Glazing spandrel performance can be improved by incorporating vacuum insulation panels into double glazed sealed units (referred to as AIM or Architectural Insulated Modules in the thermal performance catalogue) or adding spray-foam behind the metal back pan. Improving glazing spandrel sections is discussed under new and innovative technologies in section 3.2.8.

3.2.5 RANKING OF OPAQUE AND GLAZING THERMAL PERFORMANCE

Regulators and designers are starting to realize that they need to focus on improving glazing performance because glazing U-values are assumed to be so much higher than what is assumed will be provided by the opaque building envelope. Unfortunately, analysis in Appendix E shows that when interface details are taken into account, the overall U-value of the opaque building envelope may not be that much higher than the vision areas. Also, the opaque areas do not have the potential of providing solar heat gain in the winter or daylighting. Upgrading windows may be important but not at the expense of ignoring the performance of opaque elements.

Cases with triple glazing were evaluated for the commercial and the high-rise multi-unit residential buildings to benchmark the cost effectiveness and energy savings of the opaque building envelope (Case 2 for Commercial and Case 4 for High-rise MURB in Appendix E). The triple glazing scenarios resulted in some of the lowest energy use, but the same savings could be achieved by modifications to the opaque elements. For example, the multi-unit residential building with 40% glazing, the case with EIFS and thermally broken balconies has more energy savings than triple glazing with standard details.

Table 3.6: Cost and Performance Comparison of Opaque Building Envelope to Triple Glazing for High-Rise MURB with 40% Glazing

Wall Assembly	Glazing Assembly	Interface Detail Scenario	U-Value (W/m^{2}K)	Incremental Costs	Energy Cost Savings	Pay Back
Baseline: R-10 Exterior and R-12 Interior Insulated Steel Stud Assembly	Double Glazing	Common	0.95	-	-	-
R-7.6 EIFS and R-12 Interior Insulated Steel Stud Assembly	Double Glazing	Common	0.92	$(2,136,608)	$965	0
R-15 EIFS Steel Stud Assembly	Double Glazing	Improved	0.51	$(1,692,257)	$11,489	0
R-10 Exterior and R-12 Interior Insulated Steel Stud Assembly	Triple Glazing	Common	0.95	$346,125	$11,678	30
R-15 Exterior Insulated Steel Stud Assembly	Triple Glazing	Improved	0.60	$496,995	$21,053	23

From a payback perspective, the triple glazing scenarios are generally on par with the "more insulation" cases. However, the triple glazing scenarios are amongst the most expensive cases. Regulations in BC are trending towards more expensive glazing systems to reduce energy use in buildings. The fact that there are opaque envelope solutions that provide similar gains in terms of reducing energy consumption, but cost less, should provide more incentive for codes to address thermal bridging at interface details. Addressing the interface details and improving the glazing together have the potential to make the biggest reductions in energy use.

3.2.6 The Role of Energy Codes and Standards

This guide places a lot of attention on how market buildings are affected by codes and standards, because the simple action of requiring consideration of thermal bridging at interface details will be the catalyst for market transformation.

A more holistic attitude to evaluating the impact of thermal bridging, as outlined by this guide, is needed for assessing the economics of current insulation requirements and methods. The cost-benefit analysis underlined the significance of interface details and that past economic analysis based on assembly insulation levels are likely not completely valid.

This guide highlights that there are many approaches to reducing energy through improvements to the building envelope performance. These improvements have a wide range of associated costs. Once designers are forced by code to consider the impact of interface details then thermal bridging will simply become another factor that must be considered to comply with code.

The market will gravitate to the optimum and most cost effective solutions, because there are not a lot of opportunities to market the attractiveness of thermally efficient details. Architecture and assembly selection have far more impact on costs than even the most expensive detail improvements. Furthermore, changes to the code to address thermal bridging at interface details will likely make technology-driven improvements more cost effective because new technologies will become common as industry is expected to respond with more innovation.

We first need to move past the idea that the only thing a designer or authority having jurisdiction needs to think and check is how much insulation is provided, if consistent outcomes will be realized for large buildings. This is largely an issue with ASHRAE 90.-2010 and not NECB 2011. NECB 2011 has already moved beyond this line of thinking and is based exclusively on effective U-values. Even if "continuous" insulation, (i.e. insulation that is only interrupted by service openings) existed in practice, such as EIFS without flashing, then parapets and balcony slabs would have to be wrapped with insulation. This is possible for exterior insulated steel stud assemblies, but this is not reality for interior insulated poured-in-place architectural concrete walls that are ubiquitous in BC construction. This is not a reality because floor slabs bypass the thermal insulation for this type of construction, and actual continuous insulation cannot be achieved. Despite the intent of the continuous insulation concept, to make it simple and not require calculations, this approach has created confusion in industry and enforcement challenges.

When heat transfer at interface details become part of the equation, for U-value calculations in energy codes and standards, then U-value requirements might need to be relaxed for the interim. The justification would be an acknowledgement that a gap exists between the clear field or assembly U-values and the reality of what is achieved in practice when interface details become part of the equation. The BETA approach makes it straightforward to set baselines based on any assumed common detail or target performance level. Moreover, getting industry to accept the concept of the BETA approach might be easy in comparison to making the changes to energy codes and standards. Reaching acceptance of the finer details and assumptions will take some work, but with some optimism, the methodology and data presented in this guide will lead the way to constructive changes.

3.2.7 TACKLING THERMAL BRIDGING AT WINDOW TRANSITIONS

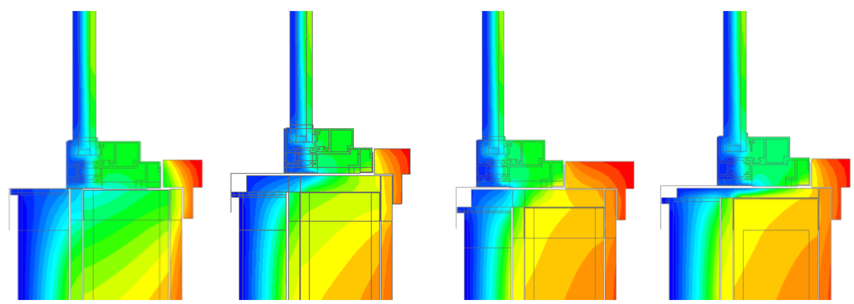
The work covered by Parts1 and 2 of this guide underscored the significant impact that thermal bridging at glazing interfaces can have on overall U-values and energy consumption.

Appendices A and B only scratch the surface to the amount of work and attention that is warranted for this subject given the significance, range of different window and wall construction, and possible improvements. More analysis is warranted on the impact of thermally efficient flashing, placement of windows, bringing insulation into window openings, and alignment of insulation.

ISO 14683-2007 provides broad order of magnitude assumptions for linear transmittance values of window and door openings for:

- Different placement of windows and discontinuous thermal insulation at openings
- Bringing the thermal insulation into openings
- Large conductive paths around the perimeter of openings.

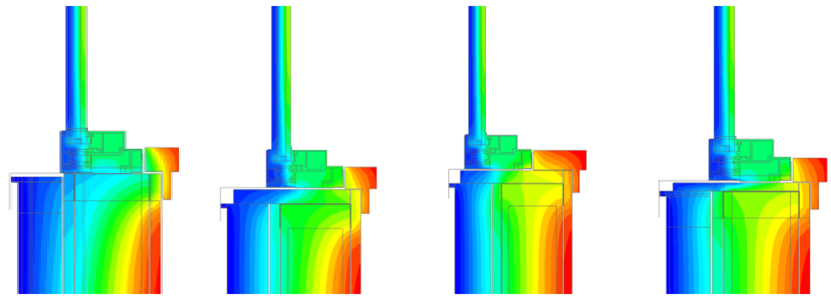
However, these values do not account for the complex heat flow resulting from flashings, thermal breaks from wood liners, different window types (frame material, spacer and thermal break), the interface of the window with framing of the wall assembly, and placement of windows in relation to the thermal insulation. Small differences can impact the heat flow, and consequently linear transmittance, which can be significant for the quantity of window glazing interfaces there are for buildings. This complex interaction is not only relevant to heat loss, but also is an important consideration for evaluating the risk of condensation. The following example highlights the relative impact of introducing a wood liner, moving the window position, and insulating the window opening for an aluminum framed window in a punched steel stud opening with exterior insulation. For this analysis, only the sill was considered.



	Base Case	**Plywood Liner**	**Plywood Liner with Window at Exterior**	**R-4 Insulation Wrapped into Opening**
Linear Transmittance (W/m K)	0.41	0.24	0.21	0.21
Glass Temperature Index at Edge (-)	0.465	0.464	0.460	0.456
Frame Temperature Index (-)	0.503	0.505	0.499	0.485

A difference in linear transmittance between the base case and R-4 wrapped into the opening has notable impact on energy consumption. For example, when comparing the base case to the R-4 insulation wrapped into the opening, **for the entire window interface**, the linear transmittances are 0.32 and 0.19 respectively. For the high-rise MURB with 40% glazing for the EIFS with improved details scenario (Scenario 1, Case 2A in Appendix E), the difference between these two interface details translates to an "Effective" R-value of 9 versus 11 and a difference in electricity energy savings of approximately $2,900. This amount of energy savings is more than the difference between the base case with common details, U-value of 0.35 W/m^{2}K (ASHRAE 90.1-2010 prescriptive requirement for zone 5) and an assembly with an additional R-10 exterior insulation or U-value of 0.28 W/m^{2}K (NECB 2011 prescriptive requirement for zone 5).

Interestingly, the linear transmittances for the same interface details, but with R-12 batt insulation in the stud cavity, are less. The difference is explained by the fact that the insulation in the stud cavity provides resistance to heat flow short circuiting the window thermal break for poorly positioned windows. Nevertheless, significant improvements can still be made for split insulated assemblies as summarized below.



	Base Case	Plywood Liner	Plywood Liner with Window at Exterior	R-4 Insulation Wrapped into Opening
Linear Transmittance (W/m K)	0.23	0.11	0.10	0.09
Glass Temperature Index at Edge (-)	0.465	0.457	0.456	0.453
Frame Temperature Index (-)	0.503	0.492	0.491	0.490

3.2.8 New and Innovative Technologies

This guide includes a few new emerging technologies and applications that have been recently evaluated for manufacturers. These include:

- Vacuum insulated panels (VIP) in insulated glazed units for glazing spandrel sections called Architectural Insulated Module (AIM) manufactured by Dow Corning. AIM applications included spandrel sections for window-wall, conventional curtain-wall, high performance curtain-wall, and unitized curtain-wall.
- Structural thermal breaks manufactured by Schöck for several applications, including cantilevered concrete balconies, concrete parapets, interior insulated poured-in-place concrete walls, concrete to steel connections (like balconies), and steel to steel beam penetrations.
- Cladding attachments incorporating thermal breaks and innovative materials for various manufacturers.

The following sections discuss the significance of these technologies.

3.2.8.1 Evaluating and Improving Glazing Spandrel Sections

Spandrel sections are common in BC construction for window-wall and curtain-wall. There are two questions that industry is faced with:

1. What is the real performance of spandrel sections that fully accounts for lateral heat flow?
2. How can we improve the performance of spandrel sections?

Industry is increasingly recognizing that the performance of glazing spandrel sections is not adequately addressed by standard industry calculation methods. Two-dimensional procedures for determining the thermal transmittance of vision areas are not adequate for spandrel sections due to the much larger and variable edge effects. With a lot of work, better estimates of glazing spandrel sections can be found using two-dimensional computer modeling. Three-dimensional modeling overcomes this hurdle. This guide covers benchmarks for what should be expected for glazing spandrel sections for generic sections. Nevertheless, a lot of work can still be done for cataloguing the performance for generic systems and components.

This guide has made significant strides with regards to evaluating solutions to improve spandrel sections. One of these solutions is the inclusion of AIM in spandrel sections.

The costs associated with spandrel sections with AIM spandrel sections are similar to adding medium density spray applied polyurethane foam (spray foam) inboard of the metal back pan of spandrel sections. However, the costs provided by the general contractor for this guide for adding spray foam inboard the back pan of conventional curtain-wall appear to be on the high side, thus making the AIM spandrel sections appear very cost effective.

Regardless of the real costs that will be realized on a project, the AIM spandrel panels have similar improvements to performance as adding spray foam inboard of the metal back pan. However, AIM has some additional benefits that were not likely fully captured by the construction cost estimates that include:

- Easier sequencing and less construction time than insulating after the curtain-wall is installed (unitized approach).
- Potential architectural benefits and cost savings of not needing to finish inboard of the spandrel section.

The construction cost estimates also likely did not include any special measures for fire protection other than typical drywall. Combining AIM with four sided unitized curtain-wall and triple glazing vision sections for the commercial building with 70% glazing resulted in 21 to 33 ekWh/m^2 gas savings and payback of 23 to 44 years, depending on climate, compared to commonly insulated unitized curtain-wall spandrel sections (Scenario 1, Case 2 in Appendix E). This payback is reasonable considering the current low price of natural gas in BC ($7/GJ or $0.025/ekWh). Tables 3.7 and 3.8 show the U-value reduction and payback for upgrading from double glazing to triple glazing for base assemblies compared to AIM applications.

Table 3.7: Opaque U-values and Incremental Construction Costs for an Office Building with 70% Glazing and Unitized Curtain-wall with and without AIM

Assembly Scenario	Interface Detail Scenario	Glazing	Opaque U-Value BTU/hr ft² °F (W/m²K)	% Reduction in U-Value	Incremental Construction Costs
Base Assemblies	Common	Double	0.259 (1.47)	-	-
	Common	Triple	0.224 (1.36)	7%	$333,366
AIM Applications	Common	Double	0.125 (0.71)	52%	$149,104
	Common	Triple	0.095 (0.54)	63%	$482,622
	Improved	Triple	0.092 (0.52)	65%	$496,473

Table 3.8: Energy Savings and Payback for an Office Building with 70% Glazing and Unitized Curtain-wall with and without AIM

Assembly Scenario	Interface Detail Scenario	Glazing	Lower Mainland (Zone 5C, Cool-Marine)		Okanagan (Zone 5B, Cool-Dry)		Prince George (Zone 7, Very Cold)	
			Energy Cost Savings	Pay Back	Energy Cost Savings	Pay Back	Energy Cost Savings	Pay Back
Base Assemblies	Common	Double	-	-	-	-	-	-
	Common	Triple	$6,619	50	$7,462	45	$10,870	31
AIM Applications	Common	Double	$5,904	25	$5,779	26	$6,542	23
	Common	Triple	$11,205	43	$12,745	38	$17,566	27
	Improved	Triple	$11,362	44	$12,930	38	$17,787	28

From these tables it can be seen that for this case, using AIM results in a shorter payback period than simply upgrading to triple glazing and can significantly decrease the U-values for the curtain-wall system. This showcases the potential to reduce heating energy significantly below the code minimum while still having high percentage glazing.

Even in buildings with lower glazing percentages and less curtain-wall, these types of AIM systems will have more of an impact compared to simply adding more cavity insulation. Figure 3.12 shows the relative paybacks for a variety of scenarios for a commercial building with 40% glazing.

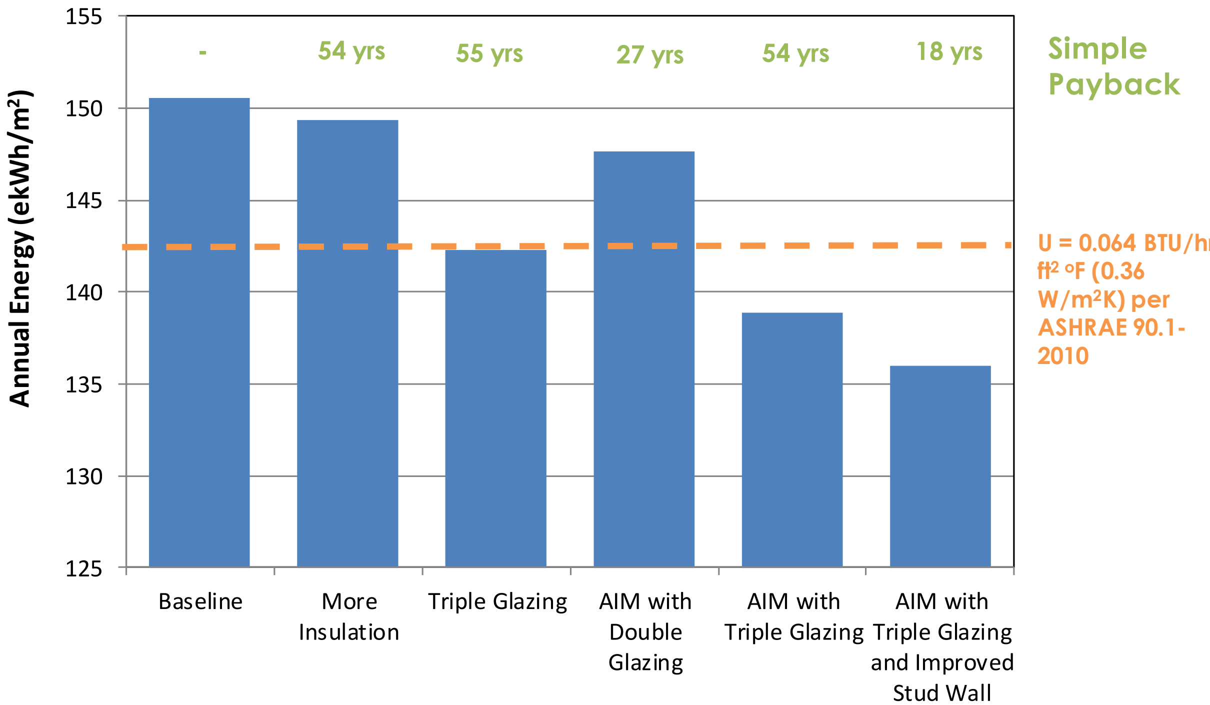


Figure 3.10: Energy Consumption and Payback for AIM Applications to other Envelope Improvements for the Commercial Building with 40% Glazing

3.2.8.2 Manufactured Structural Thermal Breaks

As outlined in section 2.3, new technologies from Schöck appear to be priced at a premium. These products address thermal bridging at details that have not been a concern in the past, which come at a cost. However, these manufactured solutions are not that costly compared to wrapping continuous insulation around parapets and balconies like some suggest is required to meet prescriptive requirements in ASHRAE 90.1. Moreover, these products combined with efficient wall assemblies have the potential for real energy savings.

From a cost perspective, you can look at these new technologies from two quite different perspectives.

1. Assume what we are doing is now is acceptable. Compare the cost of manufactured structural thermal breaks to common practice where unmitigated and overlooked thermal bridges are the norm.

2. Assume what we are doing now is not acceptable, we need to account for these significant thermal bridges, and compare to alternatives.

If you look at structural thermal breaks compared to what we are doing now, then the payback period is significant, but the energy savings are real. In comparison to adding more insulation, the payback is still less and the energy savings are considerably more. Therefore from a code perspective and consumer benefit, there is an economic argument for introducing changes that prescribe, or at least assume, thermally broken parapets and balconies in baseline buildings for performance paths to demonstrate code compliance.

Structural thermal breaks are also more cost effective than alternatives such as wrapping insulation around parapets and balconies. Despite manufactured thermal breaks not being free of thermal bridging, these technologies are more effective in reducing thermal bridging than wrapping parapets or balconies.

For example, the heat loss is reduced by more than 85% compared to common practice for the thermally broken parapet (Detail 5.5.12 in Appendix A) compared to approximately 60% reduction for wrapping insulation around the parapet (Detail 5.5.4 in Appendix A). The parapet with wrapped insulation does not deal with the geometric thermal bridge, additional heat flow due to geometry, which is a result of heat flowing to the parapet and the increased surface area exposed to the exterior. The following graphics illustrate the difference between a thermally broken concrete parapet and a fully insulated parapet. Note the clear wall assemblies are slightly different, but the insulation levels are identical and the clear field thermal transmittances are essentially the same.

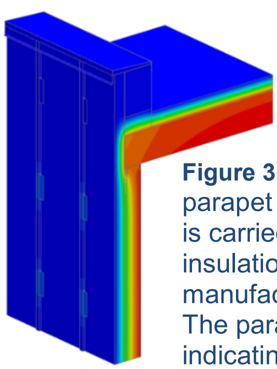


Figure 3.11: A thermally broken parapet where the roof insulation is carried to the exterior insulation at the same level via a manufactured thermal break. The parapet is cold (blue), indicating less heat flow and a more efficient system.

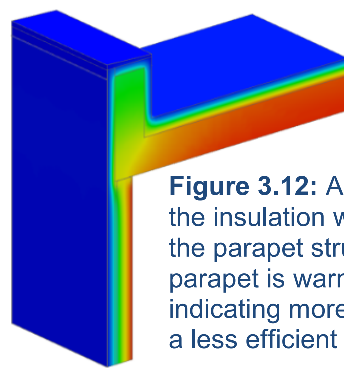


Figure 3.12: A parapet with the insulation wrapped around the parapet structure. The parapet is warm (green), indicating more heat flow and a less efficient system.

This example highlights a scenario where a new and innovative technology is more cost effective than the prescriptive requirements that energy standards might adopt if thermal bridging will be thoroughly addressed. If energy standards assume insulation wrapped around a parapet as the baseline, then there will be a significant incentive for designers to consider cost effective solutions such as structural thermally broken parapets.

3.2.8.3 Cladding Attachments

Many new methods for the structural attachment of claddings have been recently developed in response to code changes in BC and Ontario after more stringent energy standards were adopted. These innovations highlight the ability of the construction industry to effectively respond to more stringent energy standards and innovate.

Thermally efficient methods for attaching claddings make fully exterior insulated steel stud wall assemblies with high levels of effective thermal resistance more cost effective. Moreover, designers now have better options to provide high levels of effective thermal resistance without introducing additional risk, from a moisture management perspective, by adding additional insulation to the stud cavity.

Thermal performance data for many proprietary systems for the structural attachment of claddings are presented alongside generic systems in Appendices A and B of this guide. This information provides the foundation and opportunity for designers to develop performance based specifications for projects.

Structural analysis, thermal analysis and feedback from installers of these systems provide some reasons why project specific performance specifications should be considered:

- Every system will have different maximum spacing of structural members for a given design wind load. The spacing for these systems is often a function of the stiffness of the outer girt, the capacity of structural members, and the method of fastening members together and to the wall.
- The thermal performance of a wall assembly is affected by the spacing, or grid pattern, of structural members that go through the thermal insulation.
- Specifications can be set by the expected structural and thermal performance.
- Installers want a system that is adjustable at the rain-screen cavity. Sub-trades might charge a premium or resist a system that is unforgiving and difficult to install.

Figure 3.16 shows the effective thermal resistance for an exterior insulated steel stud assembly (with no cavity insulation) with various intermittent cladding attachments. The structural members penetrating the thermal insulation are attached to steel studs spaced at 16 inch o.c. and are spaced vertically at 24 inch o.c. Figure 3.15 illustrates the generic horizontal steel clip and sub-girt scenario. The other cladding structural attachments outlined in figure 3.16 are variations of this wall assembly. Detailed information about the specific components for each type of structural attachment can be found in section 5 of Appendix A.

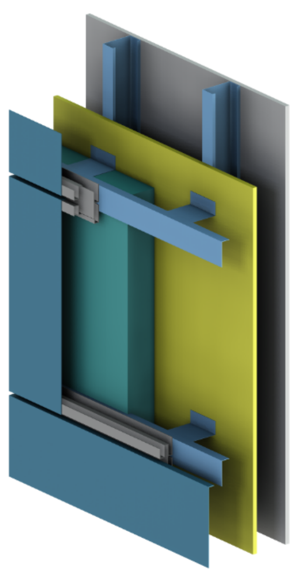


Figure 3.13: Exterior Insulated Steel Stud Assembly with the Generic Horizontal Steel Clip and Sub-girt

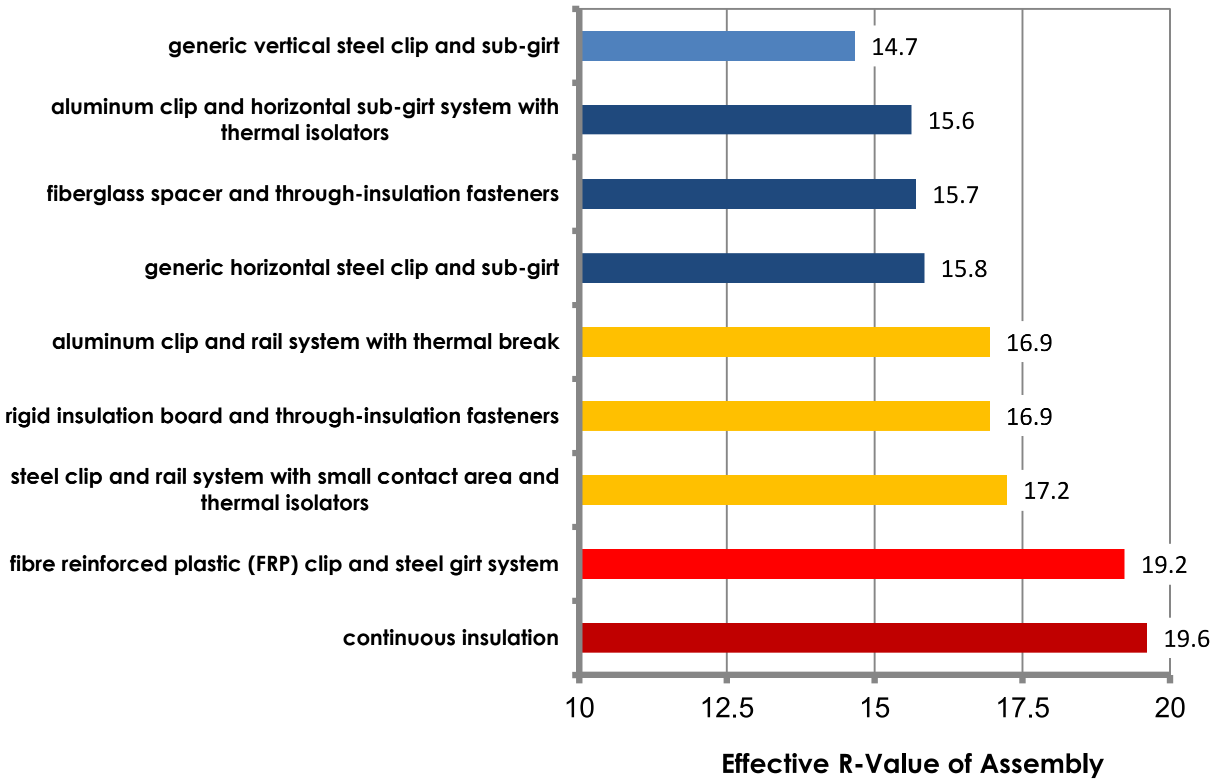


Figure 3.14: Comparison of Various Intermittent Attachment Methods for R-16.8 Exterior Insulation with the Attachment Member at 24 inches o.c. Vertically and 16 inches o.c. Horizontally

An important takeaway from figure 3.16 is that the differences between the systems cannot be explained solely by the material conductivity and cross sectional area of the members penetrating the insulation. These systems have complex heat flow paths. Thermal performance is also impacted by the contact area between components, the type and location of thermal breaks and isolators, and how far the structural components penetrate the thermal insulation. As a result, prescribing acceptable alternatives based on broad characteristics, such as cross sectional area, could be problematic if there is little acceptance, from designers, for variances in the thermal performance of installed walls.

Performance specifications based on the required U-value for the structural design loads of a project provide flexibility to sub-contractors to choose the system that is most cost effective to them, while ensuring that the thermal performance expectations will be met. Both the thermal and structural performance should be considered concurrently for design specifications because the grid pattern of structural members can have a big impact on the thermal performance. Figure 3.17 compares the effective thermal resistance of the structural attachments at a vertical spacing at 24 inch o.c. and at the spacing of the structural attachments that is required for a common wind load of 40 psf. Often a vertical spacing of 24 inches o.c. is reported and used to compare the thermal performance of various intermittent structural attachments for cladding. However, the thermal performance of some proprietary systems might appear to be more thermally efficient than others if the structural performance is not factored into decision making, but are not better in reality if project specific design loads are considered. In some cases, the installed wall assembly might even fall well below expectations.

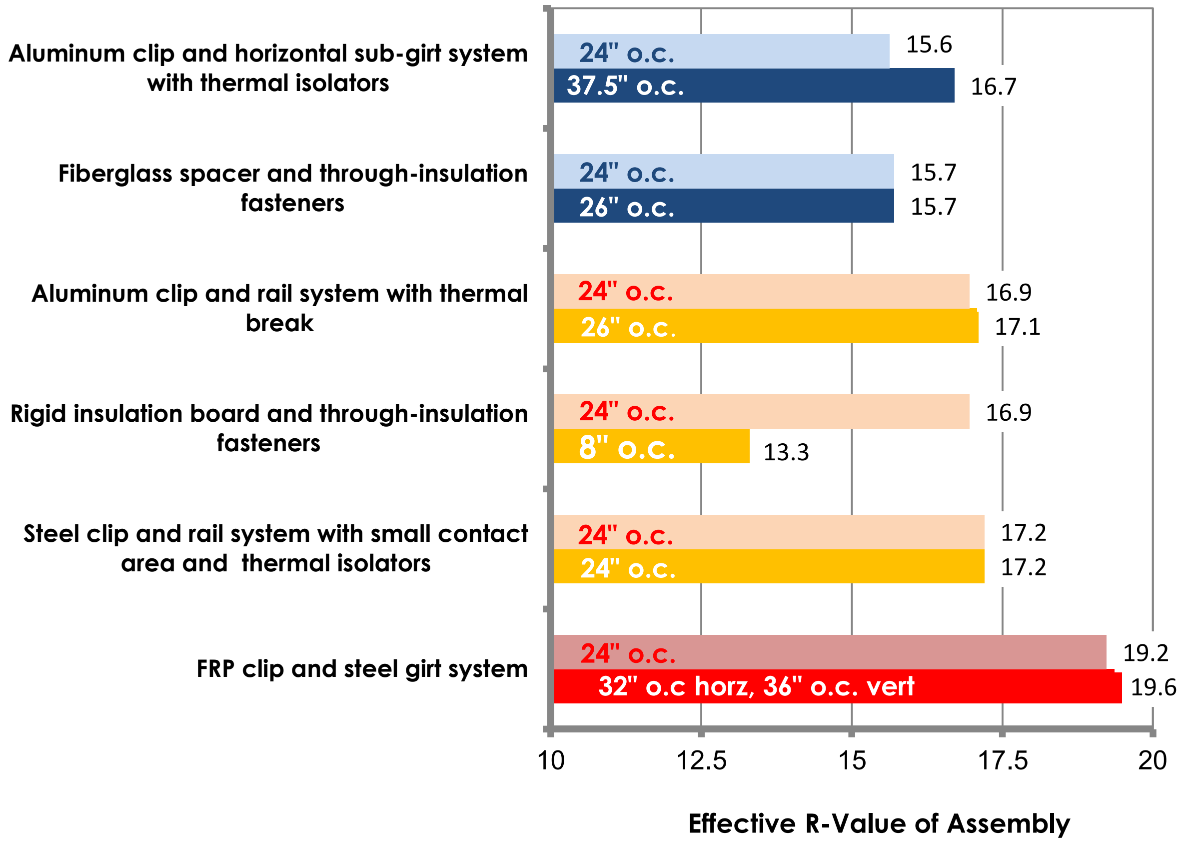


Figure 3.15: Comparison of Various Intermittent Attachment Methods with Attachment Members Spaced per the Structural Requirements Based on a Design Wind Load of 40 PSF[1]

3.2.9 Exterior Insulation Finish Systems (EIFS)

In the past, EIFS was more commonly installed in BC because this type of system is inexpensive and provides thermally efficient wall assemblies; however, it has fallen out of favour in the past two decades. EIFS systems have evolved since then to be more durable yet still offer a cost effective and thermally efficient alternative to other types of claddings. In many respects, EIFS is the only wall assembly that is close to the notion of continuous insulation many in the building industry believe is important. However, even though it is often referred to as a "continuous insulation" system, EIFS systems are not immune to thermal bridging at interface details, such as misaligned windows discussed in section 3.2.7.

For poured-in-place concrete construction, EIFS can significantly improve performance compared to interior insulation. Reiterating from section 3.2.2, a savings of 10 ekW/m^2 in electricity energy was determined for the high-rise MURB with 40% glazing with EIFS on concrete and thermally broken balconies compared to common construction

[1] Based on the design guides provided by manufacturers for proprietary systems or fasteners for rigid insulation board and through-insulation fasteners (NTA engineering evaluation report: TRU 110910-21). Lightweight cladding (5 psf) and 18 guage steel studs was assumed in this analysis.

(Scenario 2, Case 2A in Appendix E). However, there is currently no immediate incentive to realize these savings during design because continuous insulation is installed inboard of poured-in-place concrete walls and are deemed to comply with code. Installing insulation inboard of the concrete is made ineffective because it is bypassed by concrete floor slabs. This highlights the need for industry to move past the idea that a designer or authority having jurisdiction only needs to determine how much insulation is required, if real energy savings through improved the building envelope thermal performance is to be realized. This is largely an issue with ASHRAE 90.1 -2010 and not NECB 2011. NECB 2011 has already moved beyond this line of thinking and is based exclusively on effective U-values.

In terms of the thermal performance of EIFS details and common construction, Figure 3.18 illustrates the gap between standard concrete constructions with interior insulation to EIFS on concrete for all the 30% to 40% glazing archetype buildings. While the difference is significant, there is still room for improvement. The increase in energy savings mainly comes from the ability of EIFS to cover the exposed slab edges, while interior insulated concrete systems do not. However, both systems are still greatly affected by exposed balconies that, in this analysis, do not include synergies from using thermally broken balconies. This example also did not include other improvements at the parapet, window transitions, and spandrel sections and at-grade transitions.

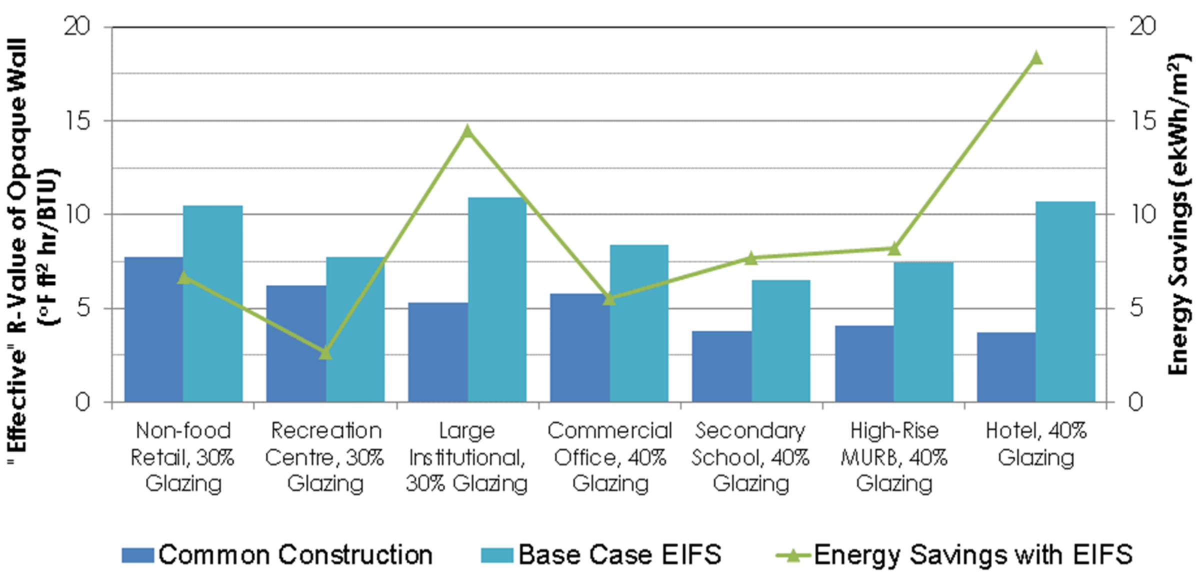


Figure 3.16: Comparison of Poured-in-place Concrete Walls with "Continuous" Insulation to the Base Case EIFS Wall Assemblies for all the Archetype Buildings for Vancouver (Except Low-Rise MURB)

In comparison to exterior insulated steel assemblies, illustrated in figure 3.19, EIFS does not have a significant advantage in terms of thermal performance and energy savings because large thermal bridges can be insulated with any exterior insulated assembly. The advantage comes more from the construction costs savings with EIFS compared to exterior insulated assemblies with cladding. Therefore, the costs to improve the overall performance, such as addressing balconies and spandrel sections, can be more than offset by the savings related to a cost effective assembly such as EIFS. Again, other improvements are still possible that were not considered in this particular analysis.

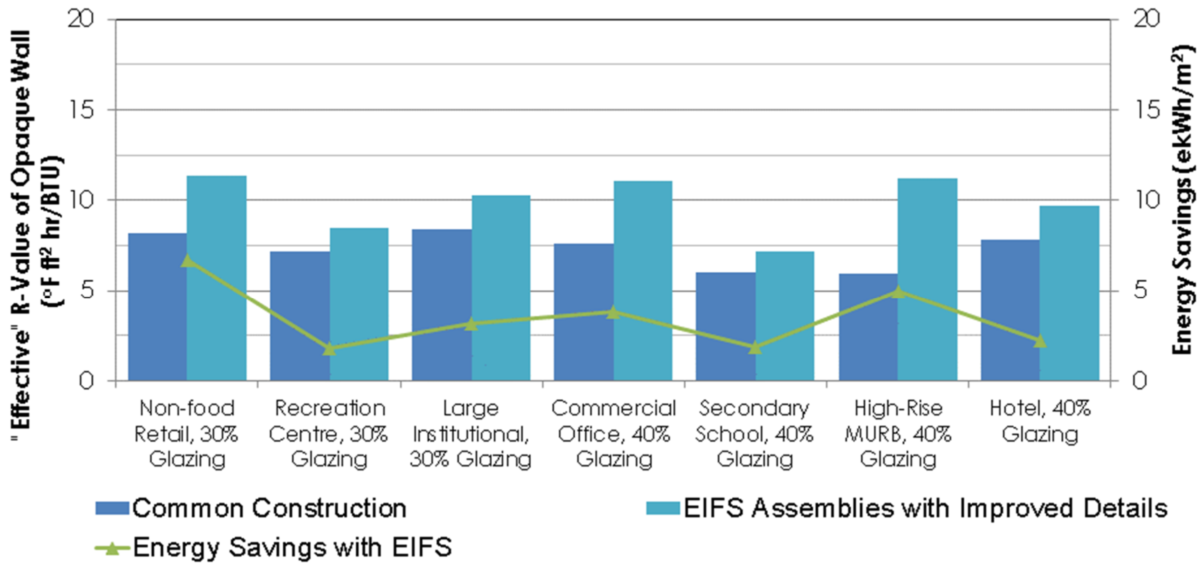


Figure 3.17: Comparison of Common Exterior Insulated Steel Stud Walls to the EIFS Wall Assemblies with Improved Details for all the Archetype Buildings for Vancouver (Except Low-Rise MURB)

3.2.10 THE BOTTOM LINE

Key lessons or significance that can be gleamed from the cost-benefit analysis that is not covered in the sections above include:

- Split and interior insulated assemblies are not only inefficient from an assembly perspective, but are shown to be even more inefficient when the impact of interface details is included in determining an overall U-value. More energy savings can be realized with exterior insulated assemblies than compared to split insulated assemblies. (For results, refer to Scenario 1, compare between base Case 1 and Case 1B, in Appendix E).
- Sometimes a small amount of insulation in a gap makes a difference. For the thermally broken balconies, insulating the curb has an impact that requires attention. (For results compare details 5.2.11 to 5.2.16).
- The key finding that more attention needs to be paid to interface details is a recommendation that applies to all the building sectors. The interface details had more of an impact on some types of buildings and less on others, but the impact is significant for all the buildings.
- Ground heat flow is important for low-rise buildings, which is a large percentage of buildings. Ground heat flow is highly transient and questions remain how prevailing methods relate to reality. Only a few details were evaluated for this guide, but thermal bridging the at-grade transition can significantly impact the overall U-value for low-rise buildings.
- More work could be done to evaluate the impact of thermal mass for our climate with respect to 3D heat flow and the impact on peak loads (Refer to Appendix C for discussion on the impact of thermal mass).

- Not all building types have been thoroughly addressed by this study. One type of building to be more thoroughly addressed is metal buildings and particularly the impact of the roof to wall and wall base interfaces.
- A focus of this guide was on codes and energy standards and how they relate to new-construction. The same methodology and data can be applied to existing buildings to mitigate thermal bridging. For existing buildings, different factors affect costs than for new construction that will need to be evaluated. The concept of payback is also more appropriate for existing buildings than for new construction.
- The details categorized as regular or poor are ubiquitous in BC construction. Some details and assemblies are more common for certain types of buildings (such as balconies and window-wall), and primarily apply to residential buildings and hotels; whereas, conventional curtain-wall applies more to large institutional buildings, recreation centres, and commercial offices. A summary of the use of the assemblies in the different building sectors is shown in Table 3.9.

Table 3.9: Common BC Assemblies and Elements

Catalogue Index	Assembly / Element	Common Building Type	Relative Use in BC
1.	Window-Wall	Hotel, Mid- and High-Rise MURB’s	high
2.	Conventional Curtain-Wall and Structural Beam Penetrations	Large Institutional Buildings, Recreation Centres, Commercial Office	high
3.	Unitized Curtain-Wall	Commercial Office, Mid- and High-Rise MURB’s	medium
4.	High Performance Curtain-Wall	Large Institutional Buildings, Commercial Office, Hotel	low
5.	Steel Framed Walls with Metal Panel	Large Institutional Buildings, Schools, Recreation Centres, Commercial Office, Hotel, Mid- And High-Rise MURB’s	high
5.	Steel Framed Walls with Stucco	Schools, Recreation Centres, Hotel, Mid- and High-Rise MURB’s	high
6.	Poured-In-Place Concrete Walls	Large Institutional Buildings, Recreation Centres, Hotel, Mid- and High-Rise MURB’s	high
6.	Precast Concrete	Large Institutional Buildings, Schools, Recreation Centres, Commercial Office, Hotel, Mid- and High-Rise MURB’s	medium
7.	Wood-Frame Construction	Wood-Frame MURB’s	high
8.	Concrete Balconies	Hotel, Mid- and High-Rise MURB’s	high
9.	Sloped Metal Roofs	Schools, Recreation Centres, Hotel, Mid- and High-Rise MURB’s	medium

3.3 NEXT STEPS

Current energy standards adopted by jurisdictions need to evolve or risk being dropped by those jurisdictions and replaced with competing energy codes and standards that are more effective in meeting their energy goals. Regulators have to recognize that prescriptive requirements based solely on providing the required insulation R-values and corresponding assumed assembly U-value is not enough for non-combustible buildings. Market transformation will lead from the development and adoption of code requirements that require thermal bridging at interface details to be considered during design. Enforcement will be the key for ensuring that any new code requirements are adopted by industry as accepted practice. The objective of changes to the codes should be:

- Improve the ability to enforce the code and level the playing field by adding clarity.
- Adopt requirements that make sense for our climate and construction practice.
- Replace "exceptions" based on wall areas with metrics that represent heat flow like linear transmittance or remove all exceptions.
- Create incentives and reward improved details when practical.
- Encourage good practice and a holistic design approach.
- Use this guide to help policy and authorities implement programs that are more enforceable.

Once adopted, it will be the responsibility of many of the leading stakeholders to get the information out to the wider industry. This includes government and policy makers, engineering/architectural associations and utility companies. This could be done through:

- Technical bulletins on specific and targeted areas of interest.
- Increase awareness through presentations and publications.
- Training and workshops based on the process set forth in this guide.

Even with the publication of this extensive guide, further work is needed to better the industry's understanding of the effects of thermal bridging. This can include:

- Extending this work to other climates and jurisdictions to support development of national codes and standards.
- Revise current methodologies and standard procedures for evaluating spandrel panels.
- Create local interpretation bodies for the enforcement of energy standards.
- Implement methodology and information into energy modeling software. This is key to the ease of implementation into current practice.

For utility companies, there are many opportunities to incentivize good practice if it means a more efficient use of energy. Utilities can:

- Implement programs to incentivize upgrades for existing buildings during major retrofits or rehabs or for new construction.
- Target specific sectors where the envelope matters most (residential, low-rise commercial buildings).
- Create design guides for projects following utility incentive programs.

For the design teams, accounting for thermal bridges, if not done already, should be on the radar of every member. For those team members whose work can be directly affected by thermal bridging:

- Become a more integrated part of the design team by increased awareness of the impact of thermal bridging on the building envelope thermal performance.
- Use this guide to provide information to the design team. This may include thermal performance, but it can also be used to help clarify roles and responsibilities on a project.