Accounting for Thermal Bridging at Interface Details

A Methodology for De-Rating Prescriptive Opaque Envelope Requirements in Energy Codes

April 29, 2015

Report Prepared by:

Morrison Hershfield

1. INTRODUCTION

Based on the research conducted for the Building Envelope Thermal Bridging Guide (BETBG), BC Hydro requested that Morrison Hershfield develop a methodology for "de- rating" the base building or prescriptive U-values found in energy codes, based on inclusion of thermal bridging at interface details. These recommendations are expected to form part of the new requirements for BC Hydro's New Construction Program.

The BETBG research has shown that thermal bridging at interface details, such as slabs, parapets and glazing transitions, can be sources of significant heat flow through the building envelope that previously were not accounted for in envelope heat loss calculations. It is widely accepted in industry that the current prescriptive opaque envelope U-values in many energy codes, including ASHRAE 90.1-2010 and NECB do not include the additional heat loss from these interface details. As such, if an energy modeler were to include the heat loss from these details in the proposed building, they would be unfairly penalized when their proposed values are compared to the base building.

The purpose of this report is to propose an alternate approach for determining base building U-values that account for interface details that can then be applied to whole building simulations in performance based programs.

2. METHODOLOGY

It is widely accepted that ASHRAE 90.1-2010 prescriptive U-values do not include the additional heat loss occurring at interface details, such as slabs, parapets, window transitions, corners, etc. The same is true for the NECB 2011, which also has specific exclusions for some thermal bridging. However, the reality of construction is that there is always some level of thermal bridging occurring in these areas. Therefore, in order to encourage a project team to consider and mitigate the heat loss at these interface details in their design, they should be compared to a suitable base building that reflects the realities of construction, and not one that assumes zero heat loss through these details.

One of the challenges with redefining the base building U-value requirements is to come up with a standard of performance for these interface details that is commensurate with the U-value requirements for the assemblies. That is, the performance of the interface details should reflect the same difficulty as other requirements in the standard relative to current construction practice. However, since ASHRAE 90.1-2010 and the NECB 2011 have not fully addressed the issue of thermal bridging at interface details, it is not clear what performance level would be suitable as a baseline. The analysis that follows considers a multitude of options leading to recommended values supported by data from the BETBG.

2.1 Thermal Bridging Overview

The BETBG breaks down opaque envelope heat loss requirements into three components: clear wall, linear, and point. Clear wall heat loss refers to the heat loss associated with the assembly, away from transitions and interfaces with major components. The linear heat loss elements are interface details whose additional heat losses have been quantified per unit length. This includes elements such as slabs, parapets, corners, glazing transitions, etc. Point transmittances are interface details whose additional heat losses have been quantified per occurrence, such as a beam or mechanical penetration. The sum of all three heat loss components can then be converted into an equivalent opaque envelope U-value, as per the equation below. Please refer to the BETBG for more detailed background information.

$$\begin{matrix}\text{Total Heat flow per area}\\ \text{through the overall assembly}\end{matrix} = \frac{\begin{matrix}\text{Heat flow through}\\ \text{linear transmittances}\end{matrix} + \begin{matrix}\text{Heat flow through}\\ \text{point transmittances}\end{matrix}}{\text{Total Area of assembly}} + \begin{matrix}\text{Heat flow per area through}\\ \text{clear field assembly}\end{matrix}$$

When considering adjustments to the base building U-values of energy codes, the assumption is that the clear wall assembly would remain equal to the assembly U-value prescribed in the standard. Beyond the clear wall heat loss, linear heat loss elements present the largest additional heat flow to be considered. These linear heat loss elements can add anywhere between 30% to 500% additional heat loss (based on sample buildings), depending on building type, clear wall U-value (based on climate zone and assembly type) and performance of those linear details.

Tables 1.3-1.6 in Part 1 of The Building Envelope Thermal Bridging Guide summarize the range of performances of linear heat loss elements. The tables have been recreated below for reference. The ranges have been categorized by performance category as Poor, Regular, Improved, and Efficient. In general, the values shown represent the lower performing end of values found in the Guide. For example, an efficient floor slab detail has a value of 0.12 Btu/hr-ft-°F in Table 1.3. There are several floor slab details in the “Efficient” performance category below this value (i.e. more efficient details are possible). A large scale parametric analysis was conducted using these wide ranging performance values to understand how the range of performances impacts the overall U-value. The information was then used to make a recommendation for new, de-rated base building U-values.

Table 1.3: Performance Categories and Default Transmittances for Floor and Balcony Slabs

	Performance Category		Description and Examples	Linear Transmittance	
				Btu / hr ft F	W / m K
FLOOR AND BALCONY SLABS		Efficient	**Fully insulated with only small conductive bypasses** Examples: exterior insulated wall and floor slab.	0.12	0.2
		Improved	**Thermally broken and intermittent structural connections** Examples: structural thermal breaks, stand-off shelf angles.	0.20	0.35
		Regular	**Under-insulated and continuous structural connections** Examples: partial insulated floor (i.e. firestop), shelf angles attached directly to the floor slab.	0.29	0.5
		Poor	**Un-insulated and major conductive bypasses** Examples: un-insulated balconies and exposed floor slabs.	0.58	1.0

Table 1.4: Performance Categories and Default Transmittances for Glazing Transitions

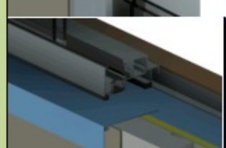
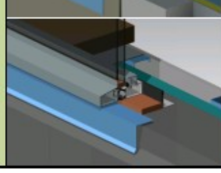
	Performance Category		Description and Examples	Linear Transmittance	
				Btu / hr ft F	W / m K
GLAZING TRANSITIONS		Efficient	**Well aligned glazing without conductive bypasses** Examples: wall insulation is aligned with the glazing thermal break. Flashing does not bypass the thermal break.	0.12	0.2
		Regular	**Misaligned glazing and minor conductive bypasses** Examples: wall insulation is not continuous to thermal break and framing bypasses the thermal insulation at glazing interface.	0.20	0.35
		Poor	**Un-insulated and conductive bypasses** Examples: metal closures connected to structural framing. Un-insulated concrete opening (wall insulation ends at edge of opening).	0.29	0.5

Table 1.5: Performance Categories and Default Transmittances for Parapets

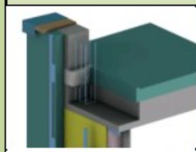
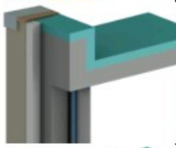
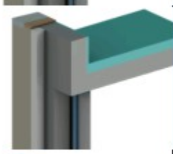
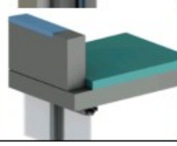
	Performance Category		Description and Examples	Linear Transmittance Btu / hr ft F	Linear Transmittance W / m K
PARAPETS		Efficient	**Roof and Wall Insulation Meet at the Roof Deck** Examples: structural thermal break at roof deck, wood-frame parapet.	0.12	0.2
		Improved	**Fully Insulated Parapet** Examples: insulation wraps around the parapet to the same insulation level as the roof and wall.	0.17	0.3
		Regular	**Under-insulated Parapets** Examples: concrete parapet is partially insulated (less than roof insulation), insulated steel framed parapet, concrete block parapet.	0.26	0.45
		Poor	**Un-insulated and major conductive bypasses** Examples: exposed parapet and roof deck.	0.46	0.8

Figure 1 – Ranges of Performance for Linear Heat Loss Elements from BETBG

2.2 Parametric Analysis

To understand the broad impact of different interface details on the overall U-value, we took the 8 archetype buildings that were analyzed in the BETBG (high and low-rise MURBs, Institutional, School, Retail, Recreation Centre, Office, Hotel) and assigned them various interface details at slabs, parapets and glazing transitions ranging from poor to efficient. Details on the archetype buildings can be found in Appendix C of the BETBG and take-off quantities for interface details can be found in Appendix E of the BETBG.

The results that were generated represent all of the possible U-values that could result for each permutation of archetype building, interface detail type, and detail performance category, combined with a number of clear wall U-values from ASHRAE 90.1-2010. An illustration of the results is shown in Figure 2.

A separate analysis was done for the low and high-rise MURB to assess the impact of balconies independently of non-balcony floor slab details. This approach was taken due to the reality that some level of balconies exists in most MURBs. For high-rise MURBs, a balcony slab allowance of 25% of the perimeter floor plate yielded similar values for increase in heat loss as the other archetypes. For low-rise, wood-frame MURBs, the balcony details are similar in performance to efficient non-balcony floor slab details. As such, no adjustments for balconies were required for low-rise MURBs.

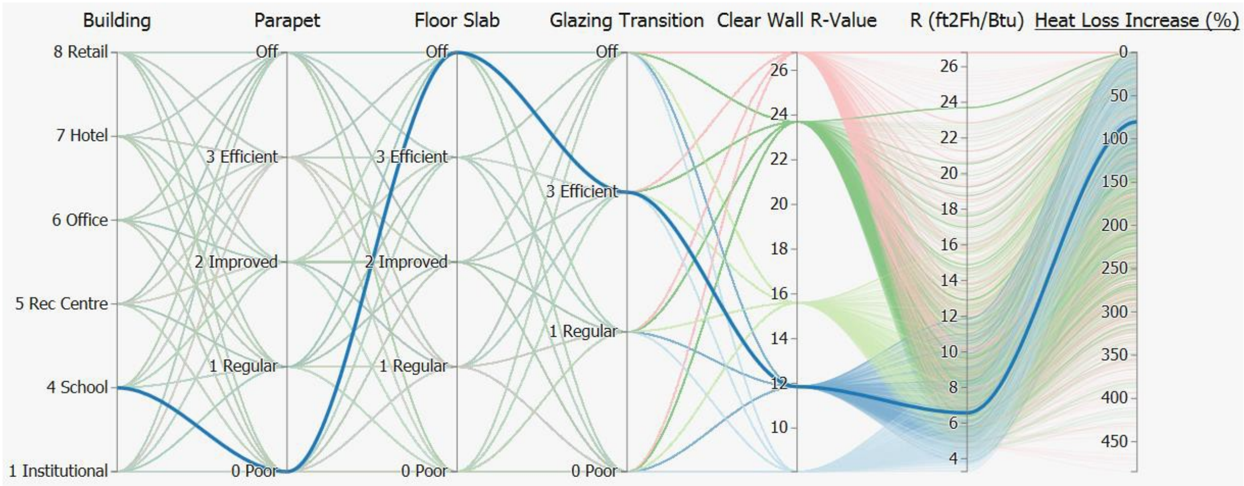


Figure 2 – Parametric Analysis of Base Building U-Value Impacted by Thermal Bridging

Figure 2 is a screenshot of the thousands of iterations that were performed. The image shows a data representation using parallel coordinates, which is a technique that assists with analyzing large data sets to find trends and patterns. The first 5 coordinates are inputs in the U-value calculation, with the last two coordinates represent outputs. The R-value output represents the effective R-value taking into account all the details, and the final coordinate shows the % increase in heat loss for each individual scenario compared to the clear wall value.

From Figure 2, the large range in increased heat loss due to interface details is evident. Another pattern that was seen was that building type was not a major driver of heat loss increase, but rather clear wall U-value and interface detail performance was. Figures 3 and 4 are example screenshots that illustrate these points.

Figure 3 illustrates that the resultant effective R-value is not greatly impacted by the archetype, resulting in an R-value difference of about 1. The effective R-value difference between archetypes is slightly higher at higher clear wall R-value, but never greater than R1.5. Conversely, it's slightly lower at lower clear wall R-values. As such, no adjustments to the base building U-value are recommended by archetype. Figure 4, on the other hand, shows how percent increases in heat loss are very sensitive to the clear wall value. As such, the de-rated base building U-value should be depending on the clear wall.

Figure 3 – Impact of Archetype on Base Building Effective R-value

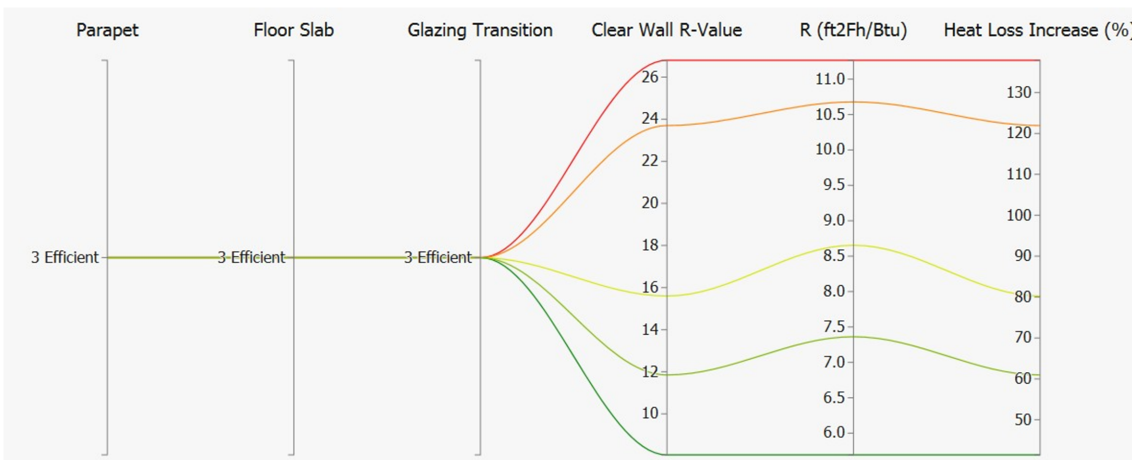


Figure 4 – Impact of Clear Wall on Heat Loss Increase over Base Building

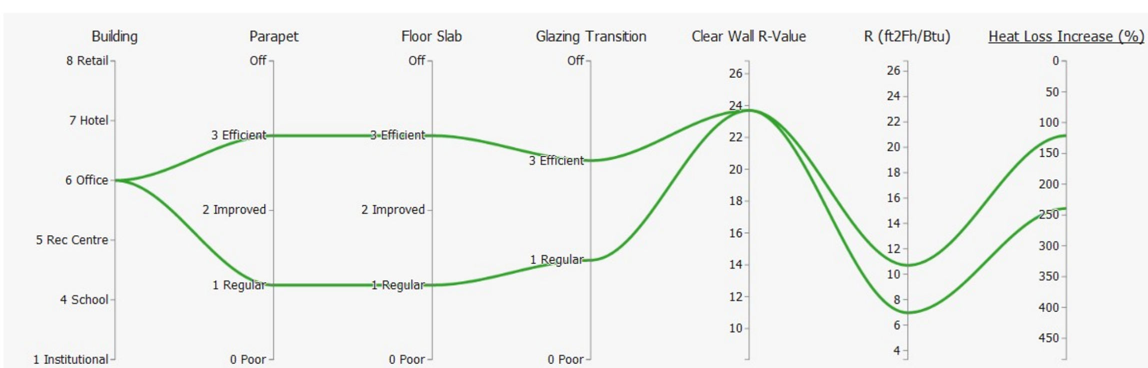


Figure 5 – Impact of Performance Category on Heat Loss Increase

In looking at the overall data using the parametric analysis tool, it became clear that the base building should have “Efficient” transition details. With “Efficient” details, the de-rating of the base building clear wall U-value is anywhere from 35% to 140%, depending on the clear wall value. Using a lower performance class would result in at least twice that amount of increased heat loss, making the base building overall U-value much higher and impractical for promoting high performance buildings. Also, the ability to implement efficient details in all building types except high rise MURBs is not prohibitive, based on the payback analysis shown in Appendix E of the BETBG.

However, for high rise MURBs, applying efficient details is not typically common place and can require more effort and cost, depending on the construction. As such, the base building standard for high rise MURB would be based on improved and regular performing details rather than efficient. This approach was determined in consultation with BC Hydro to reflect conditions closer to current market practice.

Based on the above trends, and additional data found in Appendix E of the BETBG, a correlation was made between clear wall (code prescriptive) U-value and overall effective. Two correlations are presented – high rise MURBs and all other building types. The results are shown in Figure 6. Essentially, the “de-rating” of the clear wall U-value due to the impact of thermal bridging at interface details is greater at higher clear wall values and at lower performance categories.

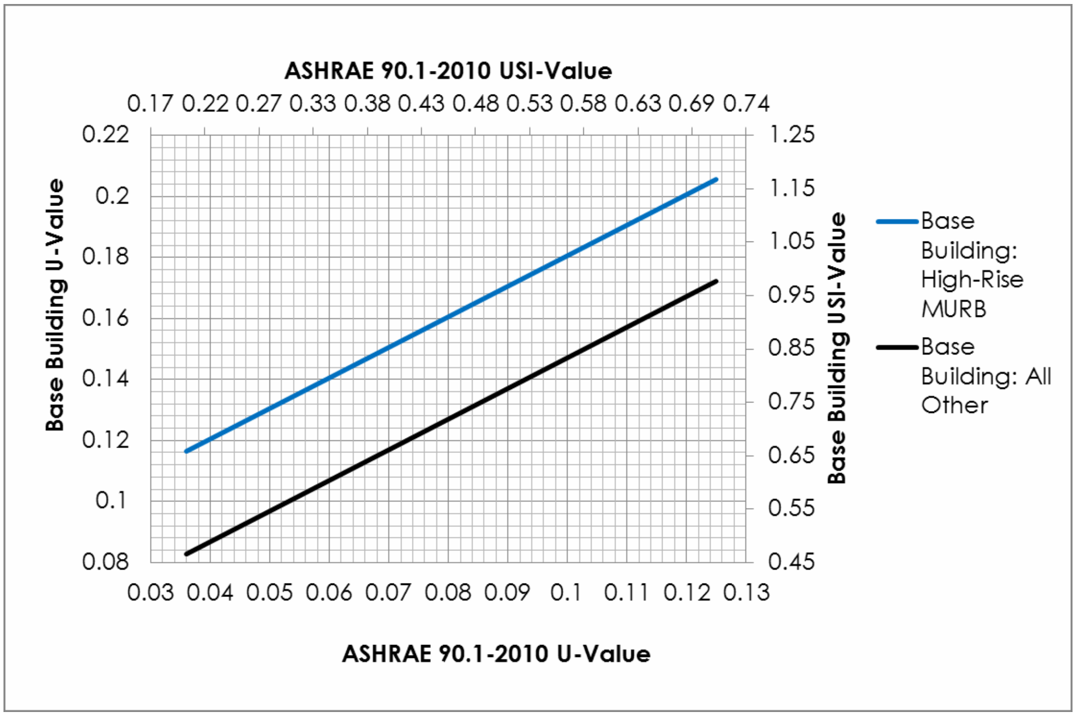


Figure 6 – Effective U-value Accounting for Linear Heat Losses for Varying Clear Wall U-vaues

Tables for all BC climates zones (Zones 4 through 8) have been developed using the correlations in Figure 6 and are shown below in Tables 1 through 5.

Table 1: Zone 4 Base Building Values (IP)

Wall Type	ASHRAE 90.1 U-Value	Base Building U-value: High Rise MURB	Base Building U-Value: All Other
Non Residential			
Mass	0.104	-	0.151
Metal Building	0.084	-	0.131
Steel-Framed	0.064	-	0.111
Wood-Framed & Other	0.089	-	0.136
Residential			
Mass	0.090	0.171	0.137
Metal Building	0.084	-	0.131
Steel-Framed	0.064	0.144	0.111
Wood-Framed & Other	0.064	-	0.111

Table 2: Zone 5 Base Building Values (IP)

Wall Type	ASHRAE 90.1 U-Value	Base Building U-value: High Rise MURB	Base Building U-Value: All Other
Non Residential			
Mass	0.090	-	0.137
Metal Building	0.069	-	0.116
Steel-Framed	0.064	-	0.111
Wood-Framed &Other	0.064	-	0.111
Residential			
Mass	0.080	0.161	0.127
Metal Building	0.069	-	0.116
Steel-Framed	0.064	0.144	0.111
Wood-Framed & Other	0.051	-	0.098

Table 3: Zone 6 Base Building Values (IP)

Wall Type	ASHRAE 90.1 U-Value	Base Building U-value: High Rise MURB	Base Building U-Value: All Other
Non Residential			
Mass	0.080	-	0.127
Metal Building	0.069	-	0.116
Steel-Framed	0.064	-	0.111
Wood-Framed and Other	0.051	-	0.098
Residential			
Mass	0.071	0.152	0.118
Metal Building	0.069	-	0.116
Steel-Framed	0.064	0.144	0.111
Wood-Framed and Other	0.051	-	0.098

Table 4: Zone 7 Base Building Values (IP)

Wall Type	ASHRAE 90.1 U-Value	Base Building U-value: High Rise MURB	Base Building U-Value: All Other
Non Residential			
Mass	0.071	-	0.118
Metal Building	0.057	-	0.104
Steel-Framed	0.064	-	0.111
Wood-Framed & Other	0.051	-	0.098
Residential			
Mass	0.071	0.152	0.118
Metal Building	0.057	-	0.104
Steel-Framed	0.042	0.122	0.089
Wood-Framed & Other	0.051	-	0.098

Table 5: Zone 8 Base Building Values (IP)

Wall Type	ASHRAE 90.1 U-Value	Base Building U-value: High Rise MURB	Base Building U-Value: All Other
Non Residential			
Mass	0.071	-	0.118
Metal Building	0.057	-	0.104
Steel-Framed	0.064	-	0.111
Wood-Framed &Other	0.036	-	0.083
Residential			
Mass	0.052	0.132	0.099
Metal Building	0.057	-	0.104
Steel-Framed	0.037	0.117	0.084
Wood-Framed & Other	0.036	-	0.083

2.3 Other Heat Loss Elements

The above analysis only considers linear heat loss elements and only for some areas of the building. The added heat loss from other types of interface details (e.g. corners or point transmittances) typically represents a smaller fraction of heat flow. Adding these variables to the analysis would significantly increase the amount of data and would likely show similar conclusions. Our recommendation of how to implement these types of heat loss elements into the program are discussed below.

3. RECOMMENDATIONS

In our view, there are two primary paths to implementing modified base building U-values into BC Hydro's New Construction Program. They are described in further detail below.

3.1 Method 1: Simplified Approach - Recommended

The first approach is simple and involves using one of the correlation lines in Figure 6 to equate energy code clear wall U-values to the de-rated U-value to be used in the program. This approach is simple and does not require the use of base building calculations. As the values were derived from archetype buildings with average amounts of interface details, it allows room for projects to improve in effective U-value not only by having better performing interface details, but also by having less of them.

3.2 Method 2: Base Building Calculations Approach – Secondary Recommendation

The second approach would involve base building calculations. The base building would use the same quantity take-offs as the proposed, but the performance values for the linear interface details would be prescribed. The recommended prescribed values would be based on the efficient performance category for all building types except MURBs or 0.12 Btu/h ft F. The downside with this approach is that it does not incent reducing the amount of interface details. A design that has little additional heat loss because it limits the quantity of interface details would not see a significant benefit over the base building, since the base building would also have few interface details. It also does not put a cap on base building heat loss for designs that have excessive articulating architecture (i.e. large quantity of interface details).

Although the analysis above only considered the major interface details, this approach would include all interface details, each with a base building value of 0.12 Btu/h ft F. High rise MURBs would use 0.20 Btu/hr ft F for slabs and glazing, 0.17 Btu/hr ft F for parapets and 0.26 Btu/hr ft F for everything else. Balconies in base building high-rise MURBs shall have the same number of balconies and performance as the proposed, up to 25% of the building perimeter per floor. Point transmittances shall have a base building value of 0.3 Btu/h F for all scenarios.

3.3 Implementation

It's typical industry practice for energy simulators to separate wall constructions in an energy model by wall type, with similar performing wall types of similar mass grouped together. This approach would not change with the incorporation of linear heat loss elements and interface details. However, sometimes it may be difficult to assign heat loss from linear interface details to a construction. For example, the interface between a curtain wall and a concrete wall can have its additional heat loss assigned to either assembly. This decision is arbitrary and would be left up to the energy simulator. If implementing Method 2, the same delineation of wall type would occur in the base building.

4. VALIDATION

Method 1 and Method 2 were tested on 3 sample projects that Morrison Hershfield has worked on recently. Two of the projects are high rise residential towers, one with interior insulated concrete as the main opaque wall assembly and one with mostly window wall spandrel panels. The third project was a community centre with a mix of curtain wall spandrel, interior insulated concrete, and exterior insulated cladding. Table 1 below summarizes the results for Method 1 and Method 2.

Table 1 – Case Studies of Base Building Methodology

Case Study	Method 1	Method 2
Project 1 - Concrete High Rise MURB (Zone 5)		N/A
Proposed	5.5	
Proposed No Details (except balconies)	10.8	
Proposed if Clear Wall met Baseline Clear Wall	5.5	
Baseline Clear Wall	11.1	
Baseline Effective U-Value	6.3	6.4
Project 2 - Window Wall High Rise MURB (Zone 7)		N/A
Proposed	3.8	
Proposed No Details (except balconies)	3.8	
Proposed if Clear Wall met Baseline Clear Wall	6.0	
Baseline Clear Wall	23.8	
Baseline Effective U-Value	8.2	9.8
Project 3 - Community Centre (Zone 5)		N/A
Proposed	8.3	
Proposed No Details (except balconies)	14.9	
Proposed if Clear Wall met Baseline Clear Wall	6.3	
Baseline Clear Wall	13.0	
Baseline Effective U-Value	8.1	8.9

Table 1 illustrates that details have a significant impact on both the proposed and base building, with slightly more impact to the proposed building. However, interface details have not been optimized for these buildings, so there is room for improvement. Also, in project 3, the proposed has a similar R-value as the base building due to a higher clear wall. With improved details, project 3 could easily exceed the base building U-values.

Project 1 does not meet the base building U-value, but it is an interior insulated concrete building with poor interface details at glazing, floor slabs and parapets. This type of construction inherently has high heat loss unless significant measures are taken. Project 2 is all window wall with wrap around balconies. It is also inherently inefficient due to extensive use of balconies and poor clear wall values in the spandrel panels. We believe the base building effective U-value (or R-value) that has been de-rated provided an achievable target for all building types, however, we do not recommend lowering it further to accommodate designs similar to Project 1 and 2. These designs are inefficient and there are readily available industry methods to improve their performance.

5. CLOSING

The above outlines a methodology for reducing the prescriptive U-value requirements of energy codes to account for thermal bridging at interface details. This “de-rating” of the base building U-values provides a more achievable target for design teams that consider all heat loss elements of the building. By including all of the heat loss elements, design teams will be able to focus in on poor performing areas and improve their performance towards overall better energy efficiency.