THERMAL BRIDGING PLAYBOOK

Prepared by
EVOKE
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OVERVIEW

THERMAL BRIDGING

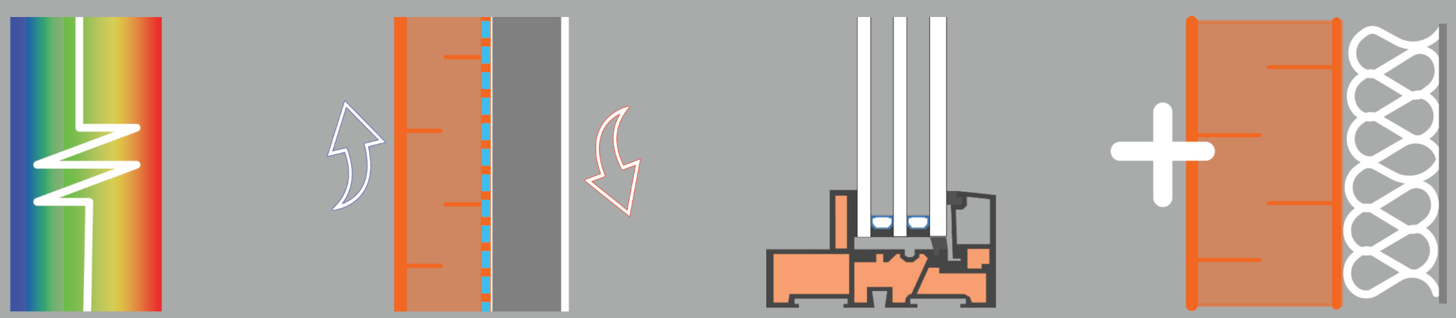
When codes have high targets for all the building envelope energy efficiency measures, then not addressing any one of the building envelope related measures in a meaningful way and relying on trade-offs using the performance compliance path will result in non-optimal solutions.

Examples of non-optimal solutions involving trade-offs are smaller window-to-wall ratios, limits to architecture, increased wall thickness, and more expensive or inefficient HVAC systems.

In the context of low-carbon buildings, codes are transitioning to net-zero energy ready (NZER) by 2030 in Canada for new construction and are increasingly introducing higher expectations for all energy efficiency measures. New requirements will make it more difficult to rely on simple trade-offs, such as enabling poor thermal building envelopes with high-efficiency HVAC systems. Moreover, the emerging policy is directed at retrofitting existing buildings, and looking beyond energy efficiency measures aimed at reducing operational energy to also address the carbon for the entire building life cycle. This includes embodied carbon during construction.

This playbook highlights how insulation can be utilized more effectively on projects with a focus on achieving high levels of thermal performance and balancing a multitude of objectives. For example, more materials and some systems might be good for energy efficiency and controlling moisture accumulation but might not be the best or most cost-effective option for reducing carbon emissions, sound transmission, and meeting fire protection requirements. This playbook provides examples of the process that is necessary to arrive at optimal outcomes from a holistic perspective for large commercial and residential (Part 3) buildings in Canada.

High-performance buildings require more insulation, mitigation of thermal bridging, increased airtightness, and better windows and glass than is required for conventional construction.



Thermal bridging in codes and standards

This playbook focuses on high-level design considerations and the process for mitigating the impact of thermal bridging. A basic understanding of thermal transmittances related to clear field assemblies and interface details is assumed. Refer to the Owens Corning Thermal Guide, Building Envelope Thermal Bridging (BETB) Guide, and ThermalEnvelope.ca for more data and information related to thermal bridging calculations.

Consideration of thermal bridging at the interface between building envelope components is a requirement in recent versions of energy code and standards[1] regardless of the path to code compliance (prescriptive, trade-off, performance). However, to effectively mitigate thermal bridging, attain optimal wall designs (cost, wall thickness, reduction in material use), and enable design flexibility requires attention to the details beyond what can be effectively done with prescriptive compliance that relies solely on checking boxes.

Comprehensive calculations lead to more consistent outcomes for large commercial and residential net-zero energy ready buildings because both the quality and quantity of details matter and one-size fits all generally does not work well to deliver optimal solutions. Figure 2 provides the motivation to tackle the thermal quality of interface details when the expectations for the overall R-value of the walls are set high. This figure shows how both more insulation and higher thermal quality details are required to meet targets that are becoming more common as the industry transitions to NZER buildings. For example, interface details that average 0.05 W/m K, when weighted by linear length, can achieve R-30 overall when used in conjunction with an R-50 clear field wall assembly. In contrast, an R-30 target is not rational for interface details averaging 0.1 W/m K or higher.

Conventional Prescriptive Approach

- ▶Window U-value
- ▶Opaque U-value
- ▶Glazing Ratio
- ▶Equipment Efficiency
- ▶Airtightness

Figure 1. Prescriptive Approach Compliance through a prescriptive approach seems ideal. Checking boxes is easy for everyone. However, getting to net-zero is problematic when thermal bridging must be addressed for large buildings. Thermal bridging calculations allow for more design flexibility, reduction of material use, and optimization of the building envelope.

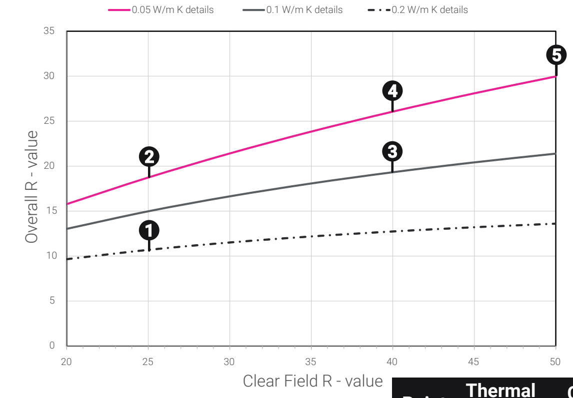


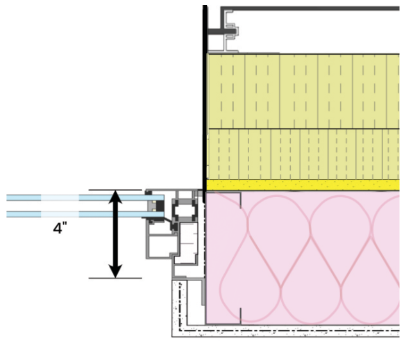
Figure 2. Thermal Quality of Details and Assembly Effective R-value Average thermal quality of the interface details and clear field R-value to meet overall R-value target[2]

Point	Thermal Quality	Clear Field	Overall
1	0.2	R-25	10.7
2	0.05	R-25	18.7
3	0.1	R-40	19.3
4	0.05	R-40	26.1
5	0.05	R-50	30.0

[1] BC Step Code, Toronto Green Standard, Quebec Construction Code, Chapter I.1 - Energy efficiency of buildings
[2] This example is specific to the archetype building and the quantity of details in relation to the overall wall opaque area

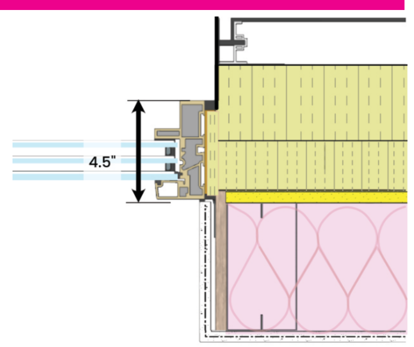
EXPECTATIONS FOR THE THERMAL QUALITY OF INTERFACE DETAILS

Unmitigated Thermal Bridging with Conventional Windows



- Double glazed aluminium framed window with thermal break attached by metal angles
- Partial insulation in window frame
- 4" (102 mm) frame depth
- 5" (127 mm) of Thermafiber® RainBarrier® 45 semi-rigid insulation
- Window within the steel-framed wall assembly
- 6" (152 mm) studs (16 gauge) at 16" (406 mm) o.c. with R-20 PINK NEXT GEN™ FIBERGLAS® insulation in stud cavity

Fully Mitigated Thermal Bridging with High-Performance Windows



- Triple glazed fibreglass framed window with thermal break attached by strap anchors
- Fully insulation in window frame
- 4.5" (114 mm) frame depth
- 5" (127 mm) of Thermafiber® RainBarrier® 45 semi-rigid insulation
- Window within the exterior insulation
- 6" (152 mm) studs (16 gauge) at 16" (406 mm) o.c. with R-20 PINK NEXT GEN™ FIBERGLAS® insulation in stud cavity

Conventional construction often includes interface details that are considered poor to moderate thermal quality with linear transmittances greater than 0.2 W/m K (0.12 BTU/hr ft F). Mitigating thermal bridging below this threshold has been considered good enough in the past. However, experience on projects that are targeting an overall effective R-value greater than R-20 has highlighted that more mitigation is necessary going forward.

Pay special attention to the window-to-wall interfaces when targeting an overall effective R-value greater than R-20. Often a target of less than 0.05 W/m K is one of the most sensible ways to minimize the wall insulation and optimize the bundle of energy efficiency measures. The difference between a window-to-wall interface that is marginally mitigated compared to a fully mitigated detail is illustrated to the left.

Performance-based compliance

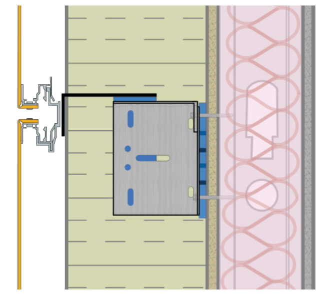
The introduction of comprehensive thermal bridging calculations is not the only significant change that has occurred in recent years in preparation for the transition to NZER buildings. The requirement for comprehensive thermal bridging calculations combined with absolute targets and mandatory energy modeling has encouraged design teams to pay more attention to the building envelope and look beyond only providing high efficiency HVAC systems to meet code requirements.

The shift to performance-based compliance with absolute targets is not without challenges. More integration between all team members is necessary to effectively deliver. Sometimes it may seem like there are endless options to consider because every decision impacts something else. Nevertheless, this novel approach invites optimization when following a process that involves conversations that start during schematic design and is informed by data.

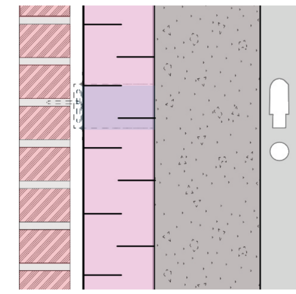
BUILDING DETAILS

This playbook utilizes a 17-story high-rise multi-unit residential building (MURB) with concrete structure. The window-to-wall ratio is 40% and the balconies comprise approximately 35% of the above-grade intermediate floor perimeter for the upper floors.

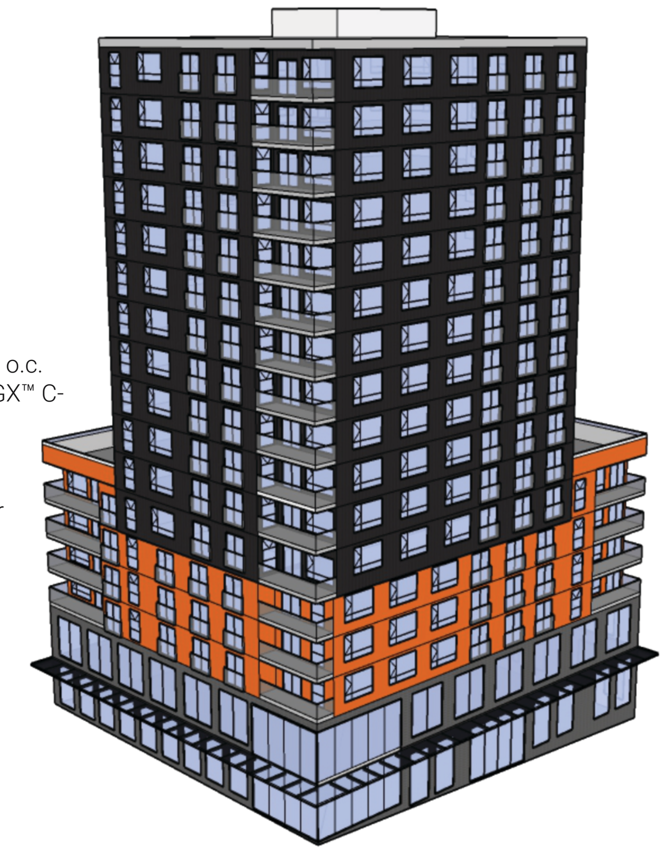
The lower two floors are brick veneer on concrete and the upper floors have metal panels on steel-framed walls.



- Rain-screen aluminum composite panel
- Thermally broken steel clip spaced at 32" (813 mm) horizontally (every other stud) and 36" 914 mm) o.c. Vertically with 16 GA 1.5" x 3" (38 mm x 76 mm) horizontal L-angle
- 5" (127 mm) Thermafiber® RainBarrier® 45 semi-rigid insulation
- Exterior sheathing with air and moisture barrier membrane
- 6" (152 mm) studs (16 gauge) at 16" (406 mm) o.c. with R-20 PINK NEXT GEN™ FIBERGLAS® insulation in stud cavity
- Interior drywall with vapour control



- Brick veneer
- Masonry ties at 16" (406 mm) o.c.
- 4" (102 mm) FOAMULAR® NGX™ C-200 extruded polystyrene (XPS) rigid insulation
- 8" (203 mm) cast-in-place concrete with moisture barrier
- 1 5/8" (42 mm) steel studs
- Interior drywall



CASE STUDY EXAMPLE

Thermal mitigation

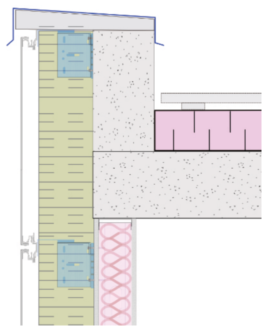
Building envelope trade-offs are more difficult when the underlying assumptions in energy codes and standards include high-performance windows and glass, thermal bridging mitigation, increased airtightness, and more insulation.

Too much deviation from the underlying assumptions will often lead to suboptimal outcomes. Striving for optimal solutions for the walls and using insulation efficiently has the following many benefits:

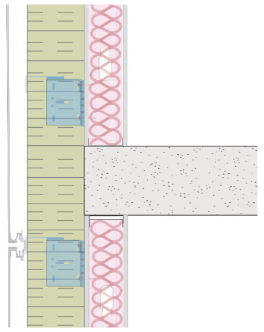
- Reduce embodied carbon,
- Reduce costs,
- Minimize wall thickness,
- Maximize glazing ratio,
- Enable affordable glazing options, and
- Enable affordable HVAC options that take up less space.

The following examples highlight the process of how to arrive at optimal solutions for the walls using the case study building that is outlined above.

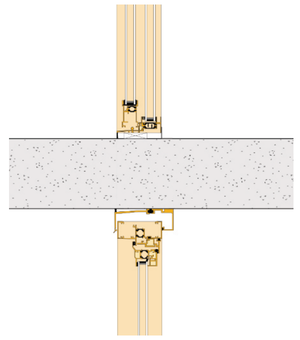
Scenario 1: Unmitigated thermal bridging at the interface details with 5 inches (127 mm) of Thermafiber® RainBarrier® 45 semi-rigid insulation and R-20 PINK NEXT GEN™ FIBERGLAS® insulation steel-framed wall.



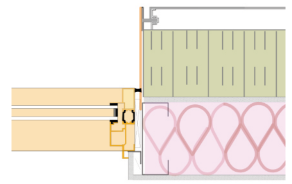
Roof to Wall



Intermediate Floor

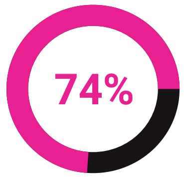


Cantilevered Balcony



Window to Wall

Linear Transmittance	0.67 W/ m K	0.07 W/ m K	1.78 W/ m K	0.18 to 0.53 W/ m K
Length	195 m	591 m	338 m	3275 m
% Contribution to Overall Heat Flow	6%	2%	22%	44%



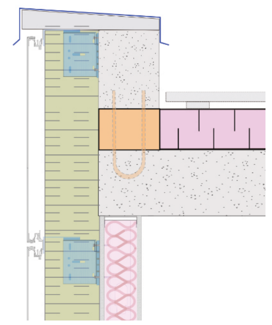
Proportion of heat flow related to interface details

Effective R-Value

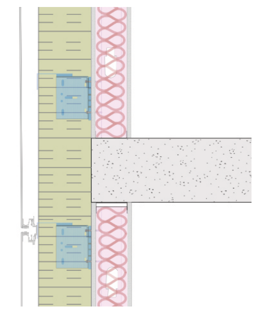
Clear Field Wall Assembly R-30.4

Overall R-7.8

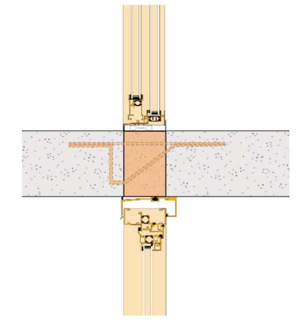
Scenario 2: Mitigated thermal bridging at the interface details with 5 inches (127 mm) of Thermafiber® RainBarrier® 45 semi-rigid insulation and R-20 PINK NEXT GEN™ FIBERGLAS® insulation steel-framed wall.



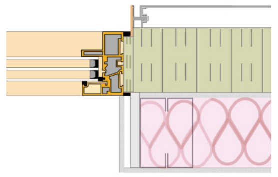
Roof to Wall



Intermediate Floor

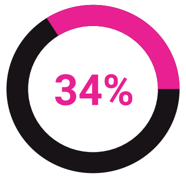


Cantilevered Balcony



Window to Wall

Linear Transmittance	0.21 W/ m K	0.07 W/ m K	0.33 W/ m K	0.02 to 0.03 W/ m K
Length	195 m	591 m	338 m	3275 m
% Contribution to Overall Heat Flow	5%	5%	14%	11%



Proportion of heat flow related to interface details

Effective R-Value

Clear Field Wall Assembly R-30.4

Overall R-20.1

MITIGATION BY DESIGN

Evaluation of the impact and benefit of thermal bridging mitigation takes a three-step process as follows:

1. Identify and make estimates for the clear field, linear, and point transmittances.
2. Perform a quantity takeoff of the thermal transmittances.
3. Determine how much each interface detail contributes to the overall thermal transmittance.

Knowing how much each interface detail contributes to the overall thermal transmittance identifies the details that should be targeted for mitigation. What details and how to best mitigate the thermal bridging is informed by this relative impact, but ultimate decisions are made based on many other factors, such as cost and constructability.

A set of tools to help with this process is available at ThermalEnvelope.ca. The Thermal Envelope web application has a large database that includes detailed data of specific Owens Corning insulation products that is helpful for evaluating the impact of different insulation types and applications.

Database

Extrapolation

Thermal Calculator

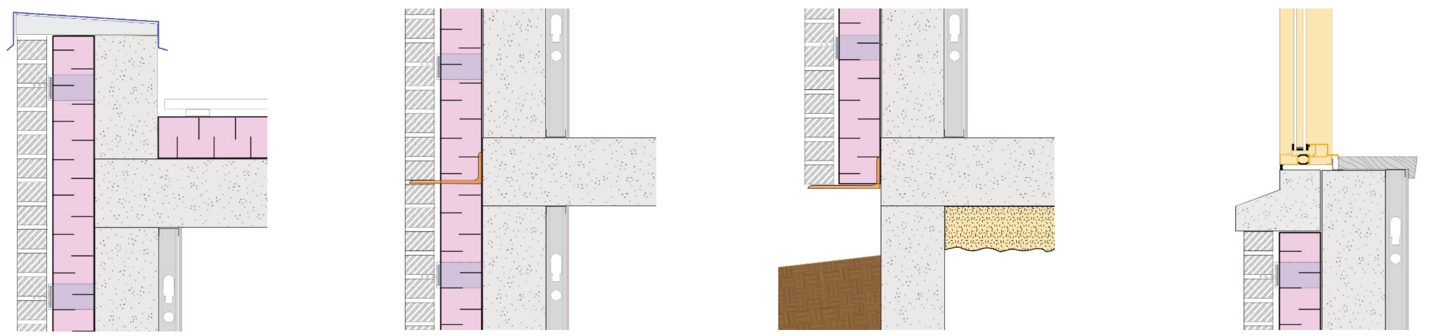
Reporting

Education

The Thermal Envelope web application is an integrated platform designed to make thermal bridging calculations require less effort, more consistent, and more transparent in practice.

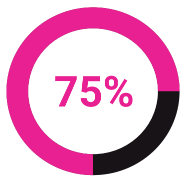
ThermalEnvelope.ca

Scenario 3: Unmitigated thermal bridging at the interface details with 4 inches (102 mm) of FOAMULAR® NGX™ C-200 extruded polystyrene (XPS) rigid insulation within a mass masonry wall.



Roof to Wall | **Intermediate Floor** | **At-Grade** | **Window to Wall**

Linear Transmittance	0.50 W/ m K	0.50 W/ m K	0.56 W/ m K	0.13 to 0.63 W/ m K
Length	40 m	97 m	71 m	596 m
% Contribution to Overall Heat Flow	5%	13%	10%	42%

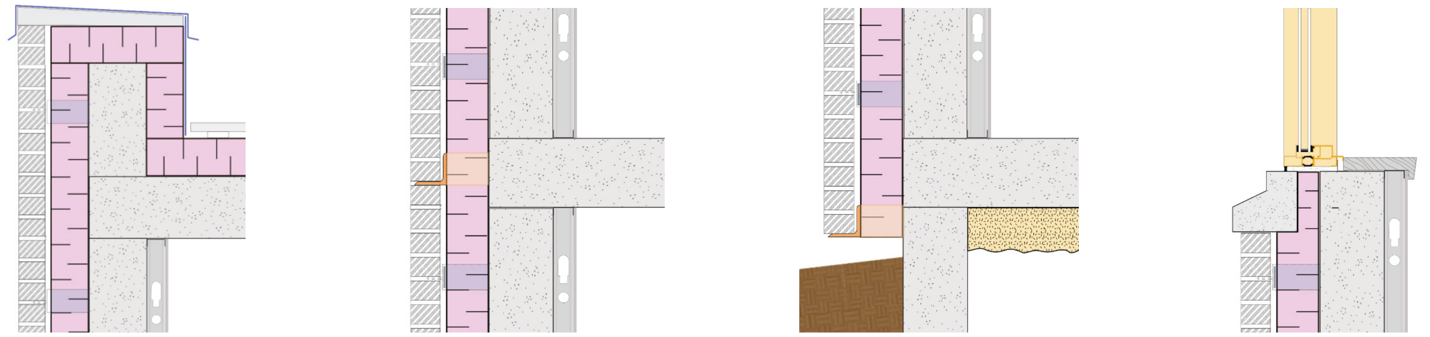


Proportion of heat flow related to interface details

Effective R-Value

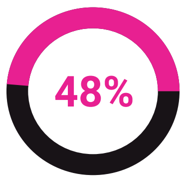
Clear Field Wall Assembly	R-20.0
Overall	R-5.1

Scenario 4: Mitigated thermal bridging at the interface details with 4 inches (102 mm) of FOAMULAR® NGX™ C-200 extruded polystyrene (XPS) rigid insulation within a mass masonry wall.



Roof to Wall | **Intermediate Floor** | **At-Grade** | **Window to Wall**

Linear Transmittance	0.21 W/ m K	0.09 W/ m K	0.42 W/ m K	0.026 to 0.1 W/ m K
Length	40 m	97 m	71 m	596 m
% Contribution to Overall Heat Flow	4%	5%	16%	21%



Proportion of heat flow related to interface details

Effective R-Value

Clear Field Wall Assembly	R-20.0
Overall	R-11.4

How much mitigation is good enough?

A key question that arises when looking for opportunities to mitigate thermal bridging is when to stop. Not all thermal bridging can be eliminated and trying to eliminate all thermal bridging is a futile endeavour. Limiting the contribution of the interface details to 20 to 30% of the overall thermal transmittance is a reasonable target for mid and high-rise construction. Comparisons between scenarios 1 and 2 show how critical the window-to-wall interface is to good overall performance and the type of details that are required to get thermal bridging at interface details down to 30%.

Scenarios 3 and 4 highlight how mitigation of thermal bridging at the interface details beyond 50% can be challenging for a low-rise building when a detail is not easy to fully mitigate. To mitigate beyond what is outlined in scenario 4 requires the building structural loads to be transferred to a structural beam at the parking garage perimeter to accommodate a thermal break on top of the parking garage foundation wall. Introducing a thermal break at this location will bump up the overall R-value to R-14.6 and bring down the contribution of the interface details to less than 30%.

A preliminary stretch target of 30% is a reasonable starting point for most Part 3 buildings that encourages the optimization between the insulation levels and mitigation of thermal bridging at the interface details.

What about "The Perfect Wall"?

Putting all the insulation and control layers on the exterior of the structure is part of the sometimes coveted concept of "The Perfect Wall" (BSI-001 2010), where the structure is kept warm and dry. An attraction to the "Perfect Wall" is that it is difficult to mess up and works in all climates. Moreover, adding insulation to a steel-framed wall cavity is viewed as an unnecessary moisture-related risk that is not justified by the incremental benefit of a higher effective R-value. This risk-reward evaluation is based on conventional sensibilities of construction and expected thermal performance.

Designers are now often tasked with meeting targets that require an overall opaque wall to be R-20 effective or higher, which requires more exterior insulation than was deemed sensible in the past. Products are also now available that make higher levels of exterior insulation more feasible, such as proprietary cladding attachment systems, and reduce the risk of moisture issues for split insulated assemblies, such as vapour permeable self-adhered sheathing membranes.

Trying to meet an R-20 effective overall with more than 5 inches of exterior insulation is about the point where a designer should start questioning if all the insulation outboard of the structure is the best or "perfect" solution. More factors that need to be taken into account, including acoustics, wall thickness, cladding attachment, cost, embodied carbon, and constructability.

For example, to meet the same level of performance as scenario 2 requires at least 8 inches of Thermafiber® RainBarrier® 45 insulation for a fully exterior insulated wall. Not only does this increase the wall thickness by 3 inches, but also limits the available options for cladding attachment and is not the best solution when considering the balance of objectives.

Owens Corning has resources available to evaluate split-insulated assemblies and determine the level of exterior insulation needed to keep the structure warm enough to balance a multitude of project objectives.

Multi-unit residential building.

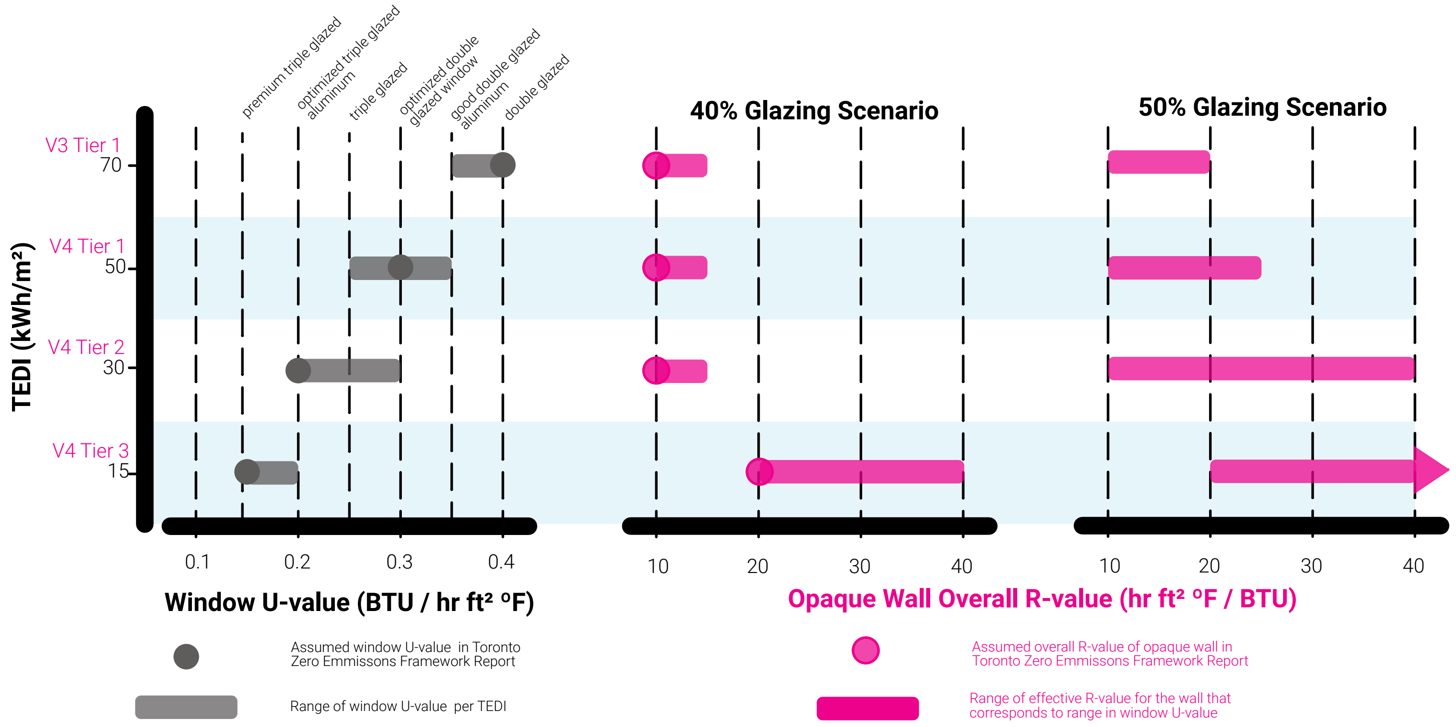


Figure 3. Optimization of the Vertical Facade A range of glazing and opaque performance will meet each tier or step for a multi-unit residential building with a complex shape for performance-based standards such as the Toronto Green Standard.[3,4]

Part 3 buildings often comply with energy efficiency codes and standards by following a performance path that utilizes energy modelling. This method evaluates energy use for the whole building and all the building systems.

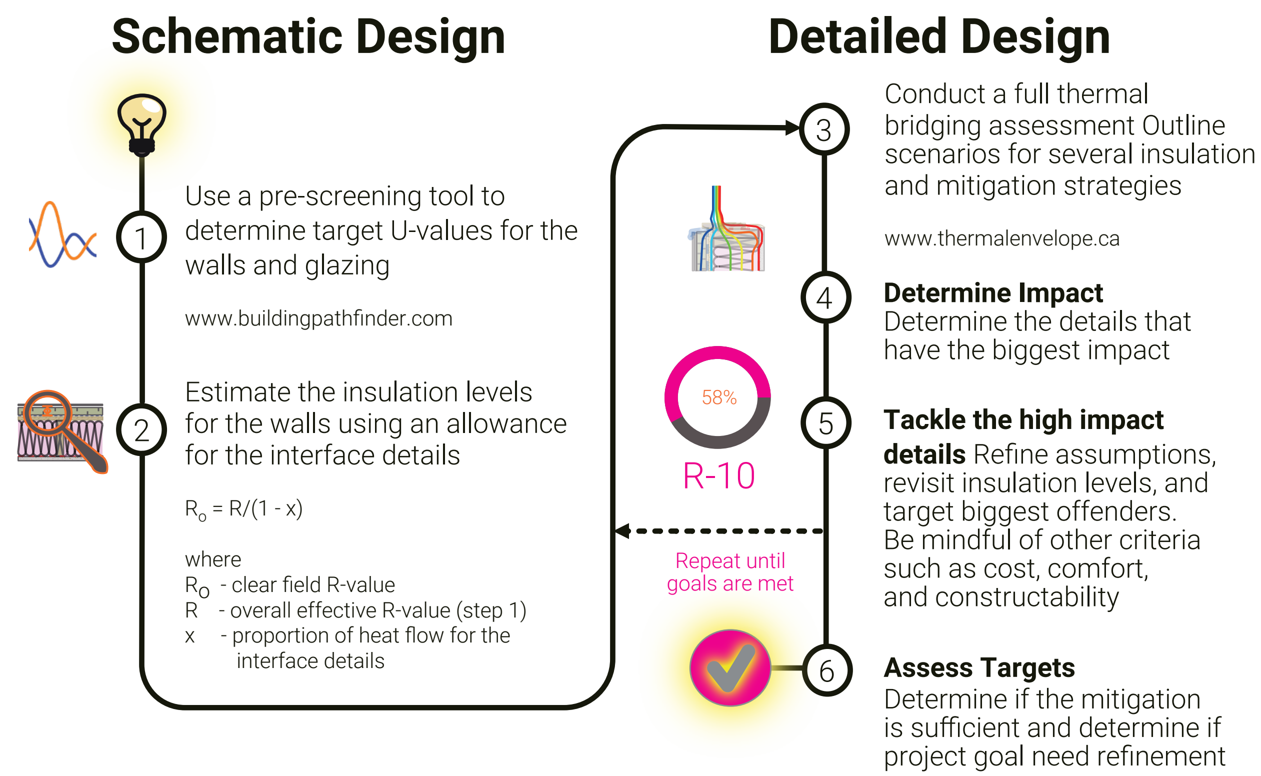
One of the key drivers for voluntarily utilizing a performance path is to enable more affordable glazing options or take advantage of different glazing options. In addition, standards that utilize absolute energy targets, such as the BC Step Code or Toronto Green Standard, only have a performance path that requires energy modelling for determining compliance.

The net result is that setting expectations for wall performance is not as simple as in the past. There are now more possibilities, but someone needs to crunch the numbers. This is a great thing for design teams that relish design freedom and are inclined to optimize designs. However, getting started on the right path and working towards consensus can sometimes be a challenge, even for the most seasoned team, when everything is up for consideration.

This is where tools such as Building PathFinder play a critical role in decision-making during early design. Figure 3 was developed using Building Pathfinder for a complex building in climate zone 5. More details on the assumptions are found at the end of this document in the end notes.

Putting it all together in practice.

Thermal bridging calculations are one of the many building envelope requirements. Remember to keep looking for details where mitigation will have the largest impact, not only from the perspective of thermal efficiency, but also other important factors, such as durability, constructability, and costs. This is an iterative process until targets are met as illustrated at the bottom right.



For NZER buildings the biggest bang for your buck is to get over the R-20 effective threshold. There is less of an impact on the overall design for R-25 to R-30 and so on, but higher insulation levels may be justified to unlock some more options. Using tools and resources such as Thermal Envelope, Building Pathfinder, and Owens Corning's BETB data can help teams optimize the building designs and know when more refinement will not lead to more informed decisions.

Key Insights:
- At 40% glazing, there is a wide range of glazing options for modest wall R-values for TEDI 30 or higher.
- Higher levels of wall R-value are needed for 50% glazing to support more affordable glazing options.
- At TEDI 15, the glazing has to be quite good to support rational levels of insulation and increasing the glazing ratio is difficult. At this level, there is less room to optimize, but the potential payback in cost-effectiveness and constructability can be significant

End Notes:
[3]Figure 3 highlights the most likely ranges of glazing performance and opaque wall overall R-value for each TEDI target in the Toronto Green Standard
[4]Figure 3 Assumptions in Building Pathfinder:
- 0.7 vertical surface to floor area ratio
- 0.3 SHGC
- 65% for TEDI 70. 75% for TEDI 50, 80% TEDI 30. 90% for TEDI 15 heat recovery efficiency
- R-20 roof for TEDI 50 and 70, R-40 roof for TEDI 15 and 30
- 2 L/s m^2 at 75 Pa for TEDI 50 and 70, 0.8 L/s m^2 at 75 Pa for TEDI 15 and 30

[5]TEDI is the annual heating load. TEDI depends on the walls, windows, airtightness, building shape, heat recovery, etc.

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Owens Corning. 2019. Enclosures Solutions Thermal Bridging Guide. Owens Corning. 2022. Split Insulation Wall Assembly Guide.

This publication was prepared by

EVOKE

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DISCLAIMER

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OWENS CORNING CANADA LP
3450 McNicoll Avenue
Scarborough, Ontario M1V 1Z5

1-800-GET-PINK®
www.owenscorning.ca

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