

Implications of Envelope Backstops in Recent Energy Codes

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ENERGY CONSUMPTION WITHIN the residential and commercial sector accounts for 40% of energy utilization in the United States.¹ Among the various energy uses, space heating and cooling activities are responsible for more than 50% of this energy consumption.² Canada also faces a similar concern, prompting regulatory authorities to explore alternative approaches. To mitigate energy consumption, both the US and Canada are increasingly turning to more rigorous energy standards at the state and provincial levels, respectively. These energy codes have progressively become more stringent over the past few years. The underlying principle is that nationwide regulation will ultimately support each country in achieving its national sustainability targets. However, some jurisdictions are moving ahead of national standards in pursuit of higher performance.

Many western and northeastern states have already adopted the latest energy codes, emphasizing their commitment to sustainability and environmental preservation. Notably in the Northwest, Washington and British Columbia have implemented some of the most rigorous energy building codes. These jurisdictions, along with others such as Massachusetts, Vermont, Rhode Island, New York, and the City of Toronto, have gone one step further and implemented a strict requirement known as an “envelope backstop.” The type of restriction imposed by each jurisdiction varies based on their respective targets, but the ultimate goal remains the same: to construct resilient and sustainable enclosures.

The envelope backstop requirement restricts a design team’s ability to substitute energy efficiencies from internal systems (such as HVAC, hot water, lighting) against enclosure energy-efficiency shortfalls within the performance path to compliance. The traditional performance-path methods based

on whole-building energy modeling have provided designers with considerably greater flexibility compared with the prescriptive path, as they permit the utilization of certain components that may not independently satisfy the prescriptive requirements. This allowance is permissible due to the requirement for other components to exhibit higher performance levels, resulting in a building that performs as well as or better than one designed using the prescriptive approach for each component. It is worth noting that the terminology associated with these requirements may vary across states and can be used interchangeably. However, this trade-off approach has often been used to justify lower-performing enclosures.

The following section briefly contrasts two approaches taken by Washington State in the US and British Columbia in Canada, focusing on how these individual jurisdictions have implemented additional limitations on enclosure performance trade-offs to accelerate progress toward their sustainable building goals.

A CLOSER LOOK AT JURISDICTIONAL APPROACHES

The 2018 *Washington State Energy Code*,³ which took effect on Feb. 1, 2021, introduced envelope backstop as part of its energy performance path to compliance alongside

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traditional compliance methods and the prescriptive path (including prescriptive method and enclosure component trade-off method). This new requirement imposes a limitation on the building enclosure's total heat loss coefficient UA calculated through the building enclosure trade-off method. Per the *Washington State Energy Code*, the calculated UA must not exceed 20% higher than the level specified in the prescriptive code for Washington State. The City of Seattle, which has its own version of the *Washington State Energy Code*, has adopted a more stringent threshold set at 10%. The UA approach to envelope backstop is also found in other jurisdictions, such as Massachusetts and New York City.

In contrast, the British Columbia Energy Step Code⁴ compliance path requires new constructions to meet higher energy-efficiency standards beyond the requirements of the previous British Columbia building code, with the aim of transitioning to net-zero energy-ready buildings by 2032. For instance, under step 3 of the Step Code, which came into effect on May 1, 2023, all new buildings must achieve a 20% improvement in energy efficiency compared to the previous code minimum.⁴ The Step Code introduced new energy performance targets through a new performance metric, thermal energy demand intensity (TEDI), in combination with the traditional energy use intensity (EUI). TEDI focuses on enhancing building enclosure and space conditioning equipment performance, while EUI targets the overall energy consumption of all building systems. TEDI quantifies the annual heating load per unit of floor area, taking into account factors such as exterior surface area, thermal transmittance of building enclosure components, airtightness, solar radiation, internal gains, heat recovery, and ventilation. However, TEDI does not include factors such as lighting and domestic hot water, despite their interaction with the building systems. In essence, TEDI can be perceived as a subset of EUI, and their combined application offers a comprehensive representation of overall building energy usage (Fig. 1).⁵

Both the UA and TEDI approaches exemplify distinct envelope backstop trade-off paths established by jurisdictions to pursue sustainable goals. The UA approach exclusively concentrates on the building enclosure itself, excluding other building parameters that could potentially compensate for deficiencies in the building enclosure such as mechanical systems. Conversely, the TEDI approach offers greater flexibility compared with the UA approach, permitting the offset

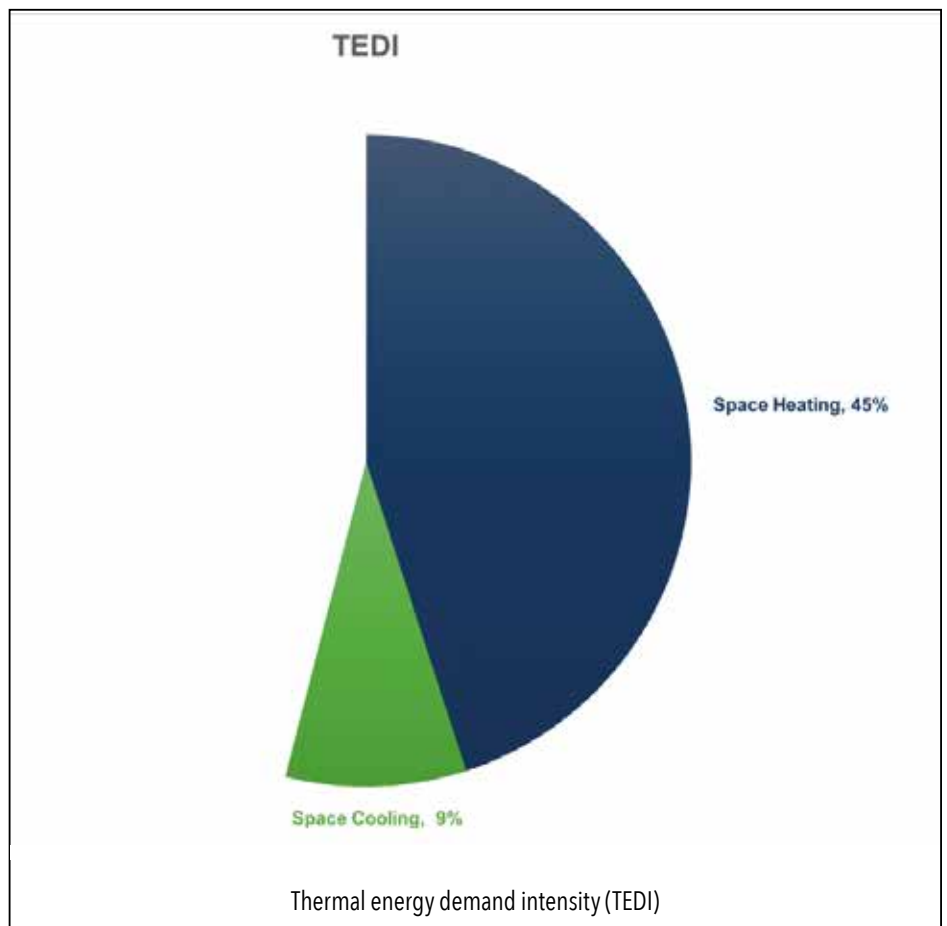
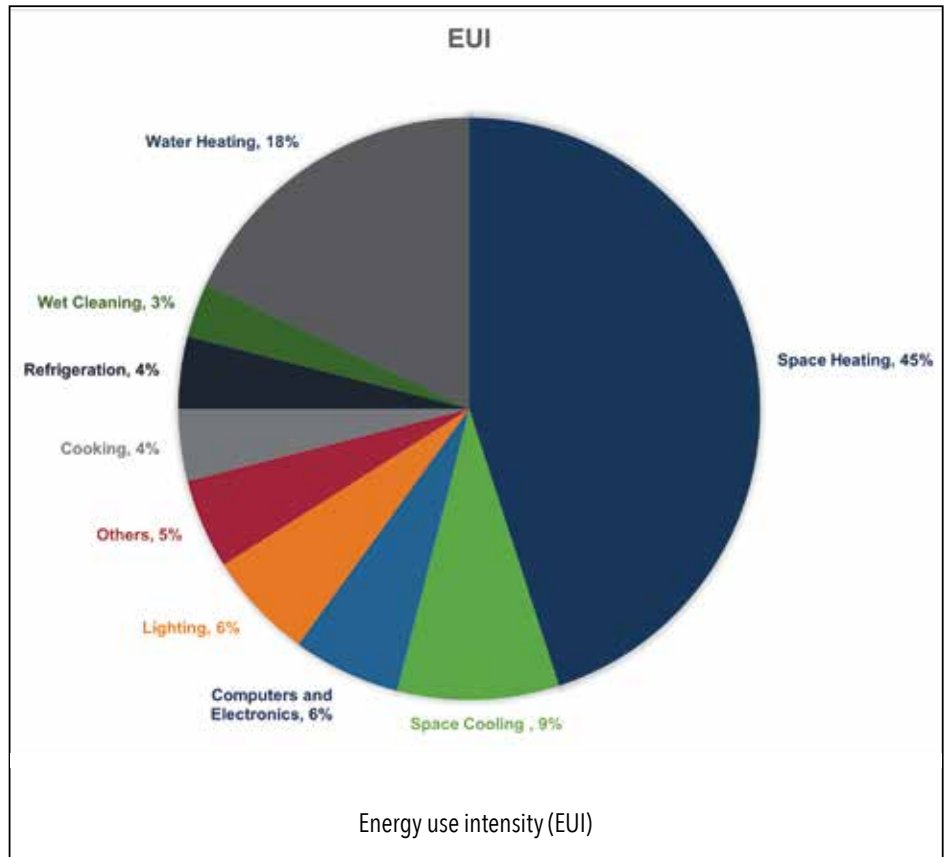


Figure 1. TEDI can be perceived as a subset of EUI.

of any *U*-factor shortcomings in the building enclosure by employing efficient mechanical systems. This mitigates the burden on the enclosure to fulfill the entire energy-reduction requirement. However, it is important to note that the TEDI approach incorporates more rigorous measures in building enclosure thermal bridging calculations, accounting for thermal transmittance through interface details such as wall-to-roof interfaces, intermediate floors, at-grade to below-grade parking garages, and other similar elements. This level of meticulousness is not extensively considered in the UA approach, which predominantly focuses on thermal bridges within the assembly itself.

The implementation of building envelope backstop requirements has the potential to significantly impact building enclosure design. Addressing the design challenges in low-rise buildings with a low ratio of vertical enclosure area to horizontal enclosure area is easier to achieve, enabling the potential offset of UA shortfalls through the use of high-performance roofing systems. Low-rise construction also lends itself to a wider range

of high-performance exterior opaque wall assemblies.

However, challenges arise when transitioning to high-rise buildings, where the ratio of vertical enclosure area greatly exceeds the horizontal area. This renders it impractical to compensate for UA shortfalls through increased performance of the roof assemblies. In such cases, the primary focus lies in increasing the efficiency of the vertical enclosure, including both opaque walls and fenestrations. Furthermore, solely increasing the *R*-value of fenestrations does not significantly enhance overall performance. For instance, upgrading from double-glazing fenestration to a triple-glazing system would result in an increase of only two to four *R*-value units, which fails to compensate for the shortfall in the 70% opaque wall coverage of the building enclosure.⁶ While high-performance opaque wall options, such as insulated sandwich wall panels or stud walls with continuous exterior insulation, are viable options, they are not as popular as unitized glazing systems for taller buildings due to cost, speed of construction, and

logistical constraints. To address the speed and cost challenges associated with high-rise construction, unitized panelized systems have become the dominant approach. However, the spandrel assemblies in these unitized systems often fall short of the target *U*-factor for the opaque walls. Traditionally, mechanical systems have been employed to compensate for this shortcoming, but the envelope backstop limits the flexibility of such trade-offs.

In the context of high-rise towers with panelized glazing systems, opaque assemblies are often glazed spandrel assemblies integrated into aluminum-framed, panelized construction. The amended energy code in Washington State started including default *U*-factors for spandrel assemblies for various types of insulation thicknesses and the configuration of the spandrel system in Table C303.1.5.³ The table of default spandrel *U*-factors originates from California Title 24, Appendix JA4-42, Table 4.3.8.⁷ The default *U*-factors are mandated to be used, unless the designer can demonstrate the thermal performance of the proposed spandrel

Table 1. Default *U*-factors for spandrel systems (Table C303.1.5 of the 2018 *Washington State Energy Code*)

			Rated <i>R</i> -value of insulation between framing members							
			None	<i>R</i> -4	<i>R</i> -7	<i>R</i> -10	<i>R</i> -15	<i>R</i> -20	<i>R</i> -25	<i>R</i> -30
Frame type	Spandrel panel		A	B	C	D	E	F	G	H
Aluminum without thermal break	Single glass pane, stone or metal panel	1	0.360	0.242	0.222	0.212	0.203	0.198	0.195	0.193
	Double glass with no low-e coatings	2	0.297	0.233	0.218	0.209	0.202	0.197	0.194	0.192
	Triple or low-e glass	3	0.267	0.226	0.214	0.207	0.200	0.196	0.194	0.192
Aluminum with thermal break	Single glass pane, stone or metal panel	4	0.350	0.211	0.186	0.173	0.162	0.155	0.151	0.149
	Double glass with no low-e coatings	5	0.278	0.200	0.180	0.170	0.160	0.154	0.151	0.148
	Triple or low-e glass	6	0.241	0.191	0.176	0.167	0.159	0.153	0.150	0.148
Structural glazing	Single glass pane, stone or metal panel	7	0.354	0.195	0.163	0.147	0.132	0.123	0.118	0.114
	Double glass with no low-e coatings	8	0.274	0.180	0.156	0.142	0.129	0.122	0.117	0.114
	Triple or low-e glass	9	0.231	0.169	0.150	0.138	0.127	0.121	0.116	0.113
No framing, or insulation is continuous	Single glass pane, stone or metal panel	10	0.360	0.148	0.102	0.078	0.056	0.044	0.036	0.031
	Double glass with no low-e coatings	11	0.297	0.136	0.097	0.075	0.054	0.043	0.035	0.030
	Triple or low-e glass	12	0.267	0.129	0.093	0.073	0.053	0.042	0.035	0.030

Table 2. Comparison of guarded hotbox test results with two- and three-dimensional thermal modeling results, 2018

		IGU with air	IGU with argon	Combined IGU with VIP	VIP unit	VIP without backpan insulation
Hotbox test results	Total U (W/m ² K)	0.89	0.87	0.56	0.50	0.60
	Total U (Btu/h ft ² °F)	0.156	0.153	0.097	0.088	0.105
	Total R (h ft ² °F/Btu)	6.40	6.52	10.23	11.36	9.52
2-D thermal modeling—NFRC 100 approach	Total U (W/m ² K)	0.65	0.63	0.43	0.34	0.47
	Total U (Btu/h ft ² °F)	0.114	0.111	0.076	0.059	0.082
	Total R (h ft ² °F/Btu)	8.74	8.98	13.08	16.96	12.14
	Delta R	-2.34	-2.46	-2.85	-5.6	-2.62
	Delta %	-26.77%	-27.39%	-21.79%	-33.02%	-21.59%
3-D thermal modeling	Total U (W/m ² K)	0.90	0.87	0.57	0.51	0.59
	Total U (Btu/h ft ² °F)	0.158	0.153	0.101	0.089	0.103
	Total R (h ft ² °F/Btu)	6.40	6.54	9.94	11.20	9.68
	Delta R	0	-0.02	0.29	0.16	-0.16
	Delta %	0%	-0.31%	2.92%	1.43%	-1.65%

Note: 2-D = two-dimensional; 3-D = three-dimensional; IGU = insulating glass unit; VIP = vacuum-insulated panel.

assembly with either thermal modeling or guarded hot-box testing. Of these default U -factors, the only spandrel configuration that meets the prescriptive thermal performance in colder climate zones requiring R -15 performance is a system without any framing member, which is generally not feasible in most unitized glazing systems (Table 1). This characteristic makes it necessary for a truly continuous insulation to be provided either inboard or outboard of the facade system, uninterrupted by framing members. The typical industry practice to address this has been to introduce insulation inboard of the glazing system. This approach, however, presents a significant risk in colder climates. By insulating inboard of the glazing system, the dewpoint is moved inward, increasing the risk of condensation inboard of the now-colder framing.

It is also important to recognize the existing methods of determining thermal performance of such spandrel systems. Traditionally, NFRC 100, *Procedure for Determining Fenestration Product U-Factors*,⁸ included a two-dimensional, area-weighted modeling approach to assess thermal performance of glazed systems, including opaque spandrel systems. The modeling

approach as per NFRC 100 is intended mostly for glazed fenestrations and allows for insulated spandrels to be assessed the same way. However, it was later found that the same approach, when used for spandrel systems, lacks accuracy when verified against guarded hot-box test results.⁸ In comparison, two-dimensional modeling of insulated spandrel systems results in higher R -values, with a margin of error as high as 33%. It has been found that three-dimensional modeling is the most accurate in simulating the effective thermal performance of spandrel systems. The three-dimensional modeling results are verified to be accurate, with minimal discrepancy from the guarded hot-box test results (Table 2). NFRC has been developing a proposed methodology specific to the modeling of spandrel assemblies that better accounts for these discrepancies.

In a typical unitized curtainwall system, the vertical mullions would typically be a singular extrusion that spans between the vision glass and spandrels. The added insulation on the spandrels makes the mullions colder, but because the concealed mullion is a singular component that is also exposed on the vision portion of the panel, a significant amount of heat flows along these vertical members. As

the frame components are typically highly conductive materials such as aluminum, it creates a vertical thermal bridging effect. The intermediate horizontal mullions between the vision and the spandrel also experience increased heat loss across the mullion with the added insulation. This issue takes place by the same mechanism that makes the internal of the spandrel colder, leading to additional heat flow into the spandrel assembly. In general, aluminum extrusions are more susceptible to this risk, as aluminum is a highly conductive material. When insulated inboard, the mullions start to form a grid of thermal bridges, further negating the effectiveness of the continuous insulation. This reinforces the importance of continuity of thermal insulation. As an example, a unitized curtainwall system with R -17 backpan insulation and nominal assembly R -20.5 yields effective R -7.7 (62% derating). An addition of R -11.5 continuous insulation inboard of the curtainwall increases the nominal assembly R -value to R -32.5, but it only improves the effective R -value of the system by R -1.2, which equates to R -8.9 effective (73% derating), as per Fig. 2.¹⁰

The 2021 *International Energy Conservation Code* (IECC) as adopted by Washington State and the City of Seattle under Commercial Energy

Efficiency takes this one step further by including section C402.2.9, which requires alignment of the thermal break of vertical fenestration to be positioned within 2 in. (51 mm) laterally of either face of the continuous insulation.¹⁰ In the context of recent trends with unitized glazing systems in the industry, this new provision will create challenges to using the interior layer of continuous insulation as a way to improve the thermal performance of aluminum-framed unitized glazing systems. In order to meet this new requirement, the industry will need to revisit the design of thermal-barrier continuity

within curtainwall systems for greater efficiency. A similar requirement is proposed for adoption in the upcoming 2024 IECC.

One emerging design solution to overcome this challenge is the vacuum-insulated panel (VIP). These high-density insulation panels provide a high R-value, which makes them an ideal material for use in typical aluminum-framed glazing systems, as insulating capacity is limited to the depth of the facade system. The thinness of the VIP also makes it possible to place the insulation in the same plane as the thermal break of the framing

member, which is a better placement of insulation in aluminum-framed unitized glazing systems, potentially eliminating the need for standard backpan insulation other than for fire staffing at the floor line. VIP can be integrated into a unitized curtainwall system either skinned with finished sheet metal or in an insulating glass unit (IGU) assembly replacing the air cavity. The former system with 1 in. (25 mm) VIP with nominal assembly R-value of 39.1 can yield R-16.6/U-0.060 effective (58% derating), whereas the latter system with glass does not perform as effectively due to the need for a traditional IGU spacer along the perimeter, as per Fig. 3.^{10,12} Although this modeled configuration still does not comply with the minimum prescriptive code requirement, it is a significant improvement in the effectiveness of metal-framed facade systems.¹²

The optimal continuous insulation placement in a unitized glazing system is the exterior of the framing, which also complies with the aforementioned IECC requirement (Fig. 4). More recently developed glazing systems offer the possibility of maintaining continuous thermal insulation exterior to the framing system. This type of system is founded upon the same design principles of fully glazed facade systems, where the frame members are utilized as the carrier/chassis on which continuous insulation panels can be placed. Transparent glazing components also no longer have to be integrated into the mullions, but rather can be installed as an independent window system where the thermal break and the insulated glass units can be placed in the same plane as the continuous insulation panels. As an example of this type of system, a facade system that allows for 6 in. (152 mm) thick insulated metal panel installed over the mullions with nominal system R-value of 52.6 can yield an effective R-value of 45.7 (derating of 13%), as per Fig. 5.¹⁰

CONCLUSION

The implementation of envelope backstop requirements in energy codes has the potential to significantly impact enclosure design, especially for high-rise buildings. These new requirements place increased focus on building enclosure thermal performance, necessitating innovative solutions. Incorporating continuous exterior insulation within unitized glazing systems is a promising alternative, but it adds complexities depending on the placement relative to the facade systems. With the newly updated energy code, this will require the continuous insulation outboard of the facade systems. The strict energy code drives innovation, leading to more resilient and

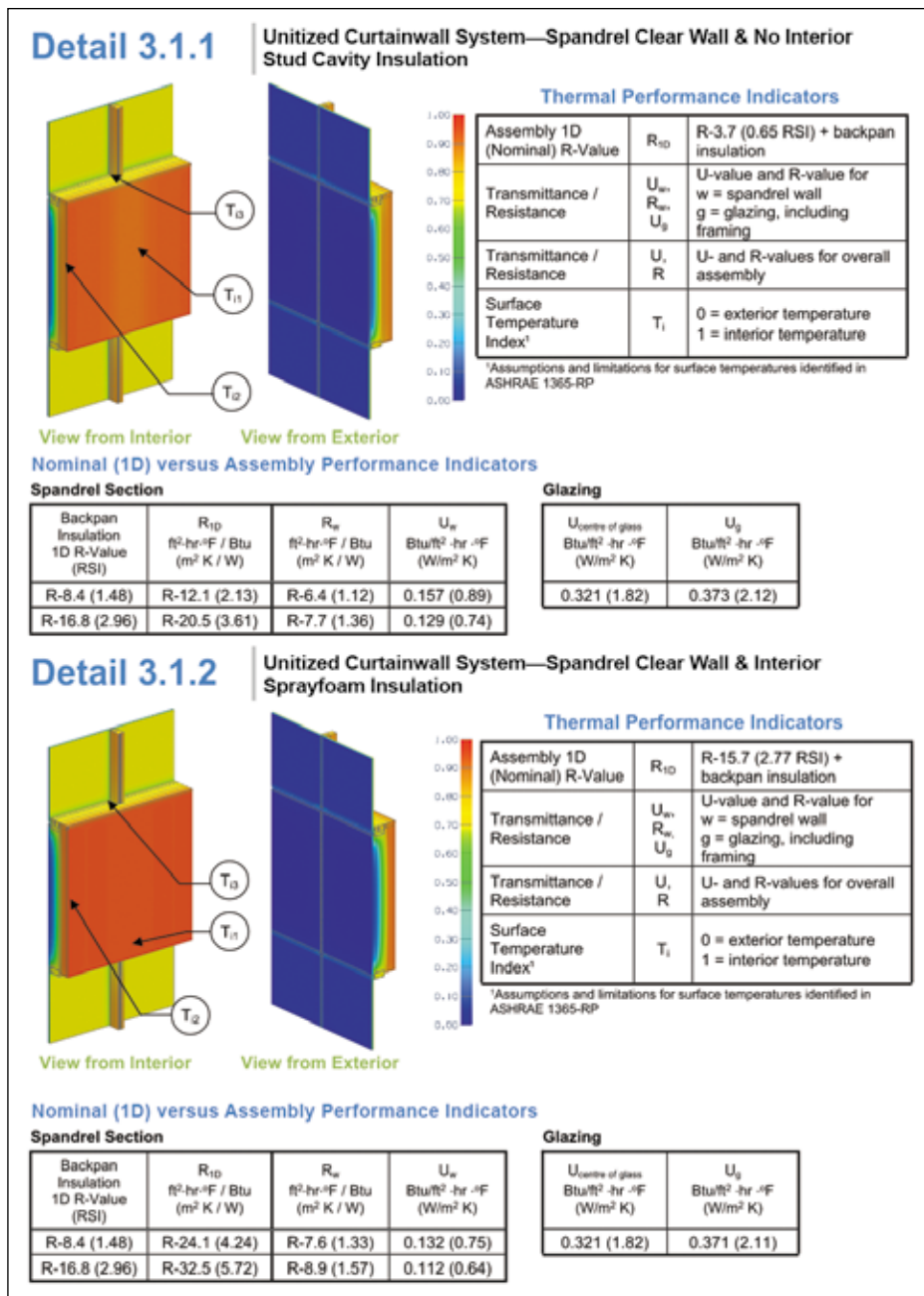



Figure 2. Comparison of thermal performance of unitized curtainwall system with and without interior insulation. Data reproduced from Morrison Hershfield Ltd. (2014).

sustainable building enclosure designs. Ongoing efforts to refine these requirements will shape the future of energy-efficient building practices, reducing energy consumption and promoting environmental sustainability. 

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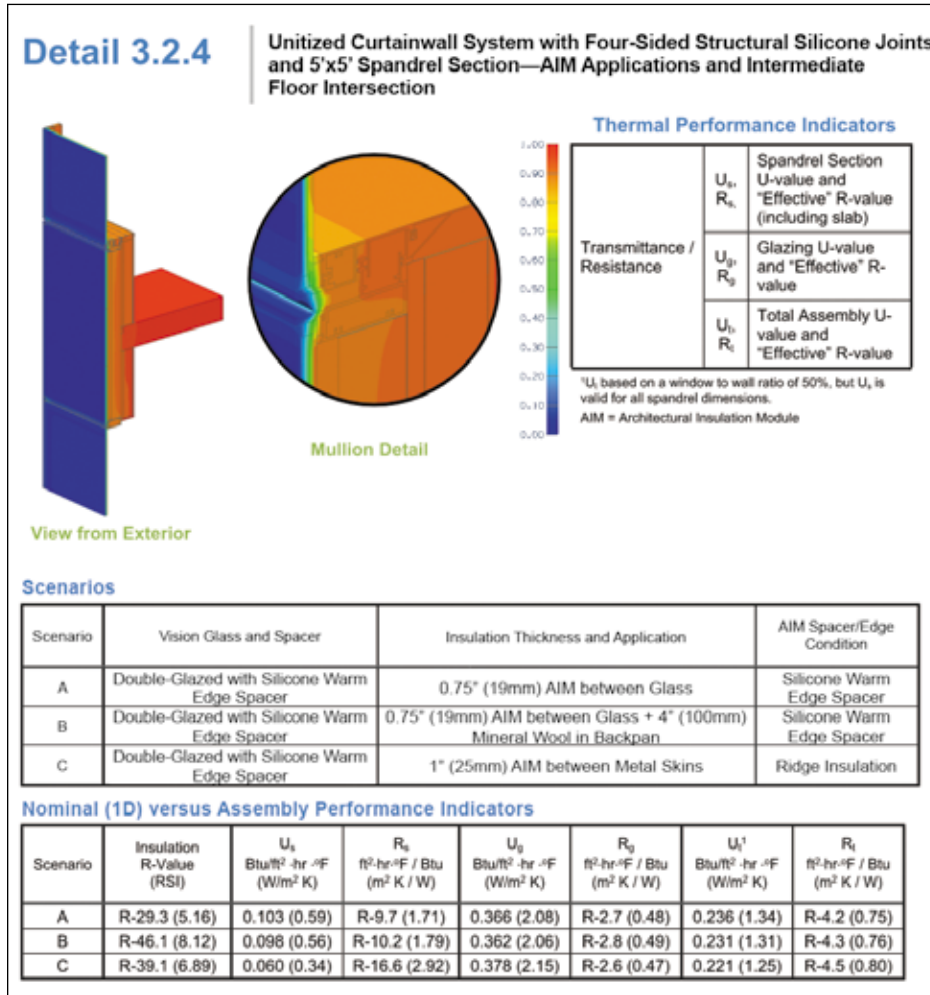


Figure 3. Three-dimensional modeling results of unitized curtainwall with architectural insulation module (vacuum-insulated panel). Data reproduced from Morrison Hershfield Ltd. (2014).

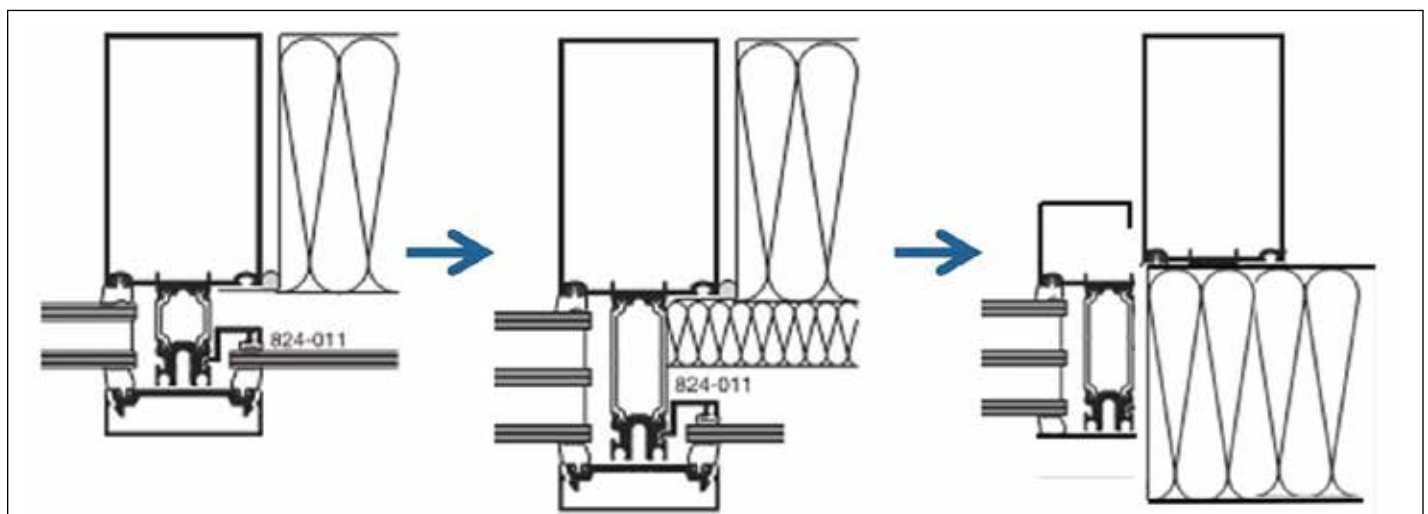
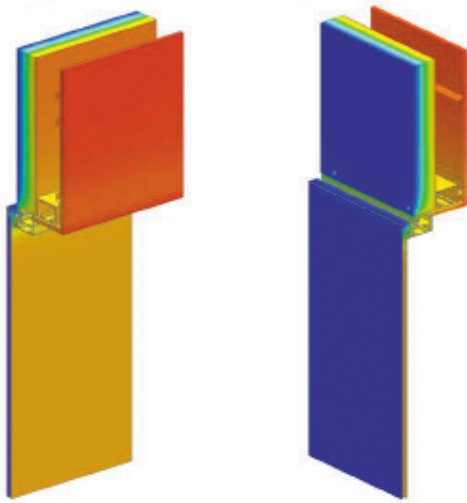
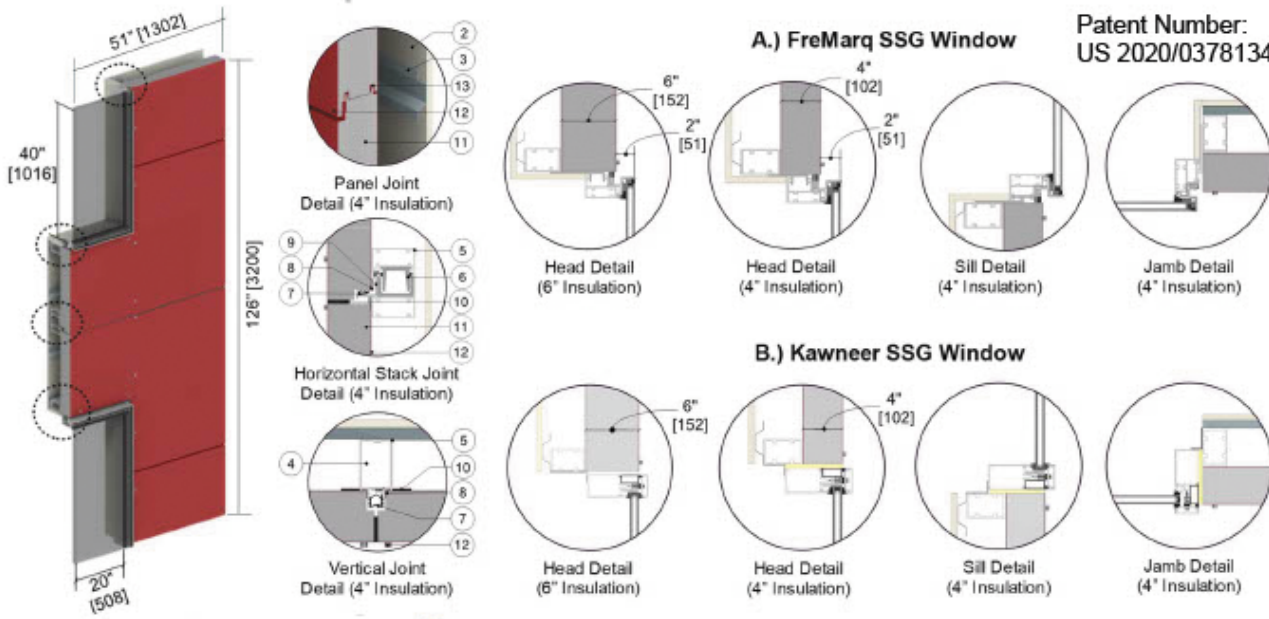


Figure 4. Evolution of insulation placement in unitized curtainwall system.

Detail 6.3.3

Exterior Insulated QuadCore Speedwall™ Panel Wall Assembly Supported by Curtainwall Framing (60" o.c.), Finished with 1. 5/8" Steel Stud and 1/2" Gypsum—Double-Glazed Aluminum Window-to-Wall Transition

Patent Number:
US 2020/0378134 A1



Thermal Performance Indicators

Assembly 1D (Nominal) R-Value	R_{1D}	R-4.5 (0.80 RSI) + exterior insulation
Transmittance / Resistance without Anomaly	U_o, U_{cog}, R_o	"clear wall" U- and R-value with panel joints and window
Transmittance / Resistance	U_w, R_w, U_g	U- and R-values for: w = wall with stack joints g = glazing
Transmittance/Resistance	U, R	U- and R-values for overall assembly
Linear Transmittance	Ψ	Incremental increase in transmittance per linear length of slab

Scenario

Scenario	Window Type
A	Double-Glazed, FreeMarq SSG Window
B	Double-Glazed, Kawneer SSG Window

Nominal (1D) versus Assembly Performance Indicators

Base Assembly – Clear Wall

Exterior Insulation 1D R-Value (RSI)	R_{1D} ft ² ·hr·°F / Btu (m ² K / W)	R_o ft ² ·hr·°F / Btu (m ² K / W)	U_o Btu/ft ² ·hr·°F (W/m ² K)
R-32.0 (5.64)	R-36.5 (6.43)	R-31.2 (5.49)	0.032 (0.18)
R-48.0 (8.45)	R-52.5 (9.25)	R-45.7 (8.05)	0.022 (0.12)

Base Assembly – Glazing

Scenario	$U_{centre\ of\ glass}$ Btu/ft ² ·hr·°F (W/m ² K)	U_g Btu/ft ² ·hr·°F (W/m ² K)
A	0.212 (1.205)	0.225 (1.276)
B	0.212 (1.205)	0.279 (1.585)

Figure 5. Example of exterior insulated facade system. Data reproduced from Morrison Hershfield Ltd. (2014).

ABOUT THE AUTHORS



SADAF MANSOUR

Sadaf Mansour is a building science specialist with a passion for building enclosure design and energy-saving solutions. She holds a Bachelor of Architecture and a Master of Building Science degree from Ryerson University in

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Jaydon Chun is a building science consultant with Morrison Hershfield's Seattle office. Jaydon's Bachelor of Architectural Science degree is from Toronto Metropolitan University (formerly Ryerson University). With a diverse

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Special interest

Is There Profit in Mandating In-Person Work? Survey Says 'No.'

THE DATA FROM post-pandemic work trends keeps coming in, and the results don't always vindicate employers that want workers back in the office.

In the case of a University of Pittsburgh Katz Graduate School of Business survey of 457 firms and 4,455 quarterly financial observations between June 2019 and January 2023, the results indicate no profitability increase for companies that called workers back to in-person work.

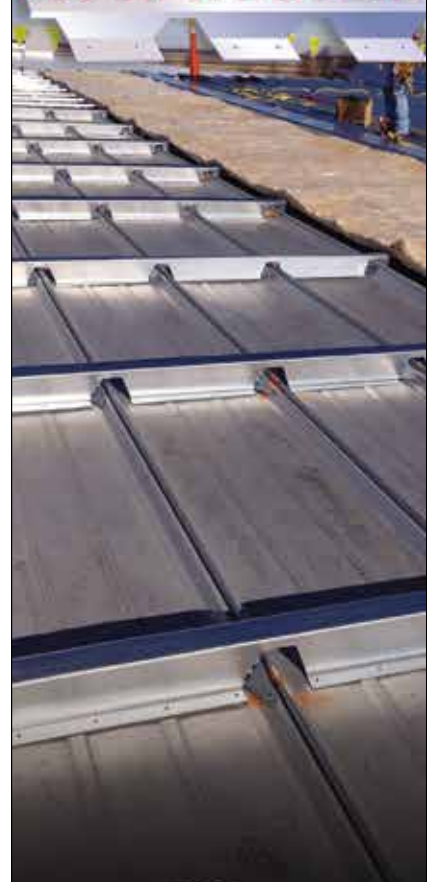
The study analyzed the quarterly results and company stock price of S&P 500 companies that

had office mandates versus similar companies that did not. "Firms with mandates did not experience financial boosts compared with those without," wrote Danielle Abril in the *Washington Post*.

On top of that, the research suggests that office mandates, while not helping companies' financial performances, "can make workers less satisfied with their jobs and work-life balance."

Study coauthor and Katz Graduate School of Business associate professor Mark Ma said mandates make workers less happy, less productive, and more likely to look for a new job.

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