Unlocking Carbon Savings with Plastic Insulation Materials

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PLASTIC INSULATION IS typically composed of a plastic polymer, such as polyurethanes or polystyrenes, a blowing agent, such as chlorofluorocarbons (CFCs), a surfactant, and other flame retardants or additives. The application of insulation in homes evolved from hay to fiberglass in the 1930s, followed by the shift to plastic insulation in the 1970s.[1, 2]

The method of determining the environmental impact of plastic insulation materials is through a life-cycle assessment (LCA), which is the quantified analysis of the material and energy inventories and potential environmental impacts of a product through the various stages of that product's life. An LCA consists of four phases: goal and scope, life-cycle inventory, life-cycle impact assessment, and interpretation of the results. In the building sector, the life-cycle of insulation products is typically depicted in an environmental product declaration (EPD) that communicates the verifiable results of an LCA. The life-cycle of an insulation product includes four stages: product manufacture, construction, use, and end of life. A fifth stage, depicted by Module D in Figure 1, quantifies potential benefits and impacts beyond the building's system boundary and is often excluded from the scope of EPDs. The life-cycle stages are divided further into substages called modules shown in **Fig. 1** module A1 through module C4. Figure 1 also depicts the four more-common types of life-cycle scopes: cradle-to-gate, cradle-to-site, cradle-to-grave, and cradle-to-cradle.

EPDs for insulation products report various environmental impact categories, including the embodied carbon of the insulation material, which is calculated as the global warming potential (GWP) and expressed as kg CO_2e or kilograms of carbon dioxide equivalent. This article focuses on the embodied carbon of four insulation types: expanded polystyrene (EPS), extruded polystyrene (XPS), spray foam (SPF), and polyisocyanurate (PIR). EPS is made up of closed-cell foam plastic beads molded into a rigid board. XPS is an extruded closed cell insulation product that comes in the form of boards. SPF is foamed in place at the job site; it comes in open cell and closed cell material types which expands when its two components react when combined in a spray gun. PIR or polyiso, is a closed-cell rigid foam board insulation consisting of a foam core typically between two facers. The functional unit is m^2 of insulation based on an RSI value of 1 based on a service life of 75 years for each of the four insulation types. RSI is variable used in the International System of Units (SI) for thermal resistance. RSI can be converted to *R*-value, the Imperial Units (IP) variable, by multiplying the RSI value by 5.678. Thus, all analyzed environmental impacts are reported based on this functional unit. For example, the GWP is reported kg CO_2e/m^2 of insulation based on an RSI value of 1 based on a service life of 75 years. Data were collected from primary sources, EPDs from various years and product category rules (PCRs), and peer-reviewed reports. The embodied carbon data points were then grouped by their formulation; the most recent formulation of each material from a producer was used.

Over the last several decades, plastic insulation has included blowing agents from chlorofluorocarbons (CFCs), to hydrochlorofluorocarbons (HCFCs), to hydrofluorocarbons (HFCs), and

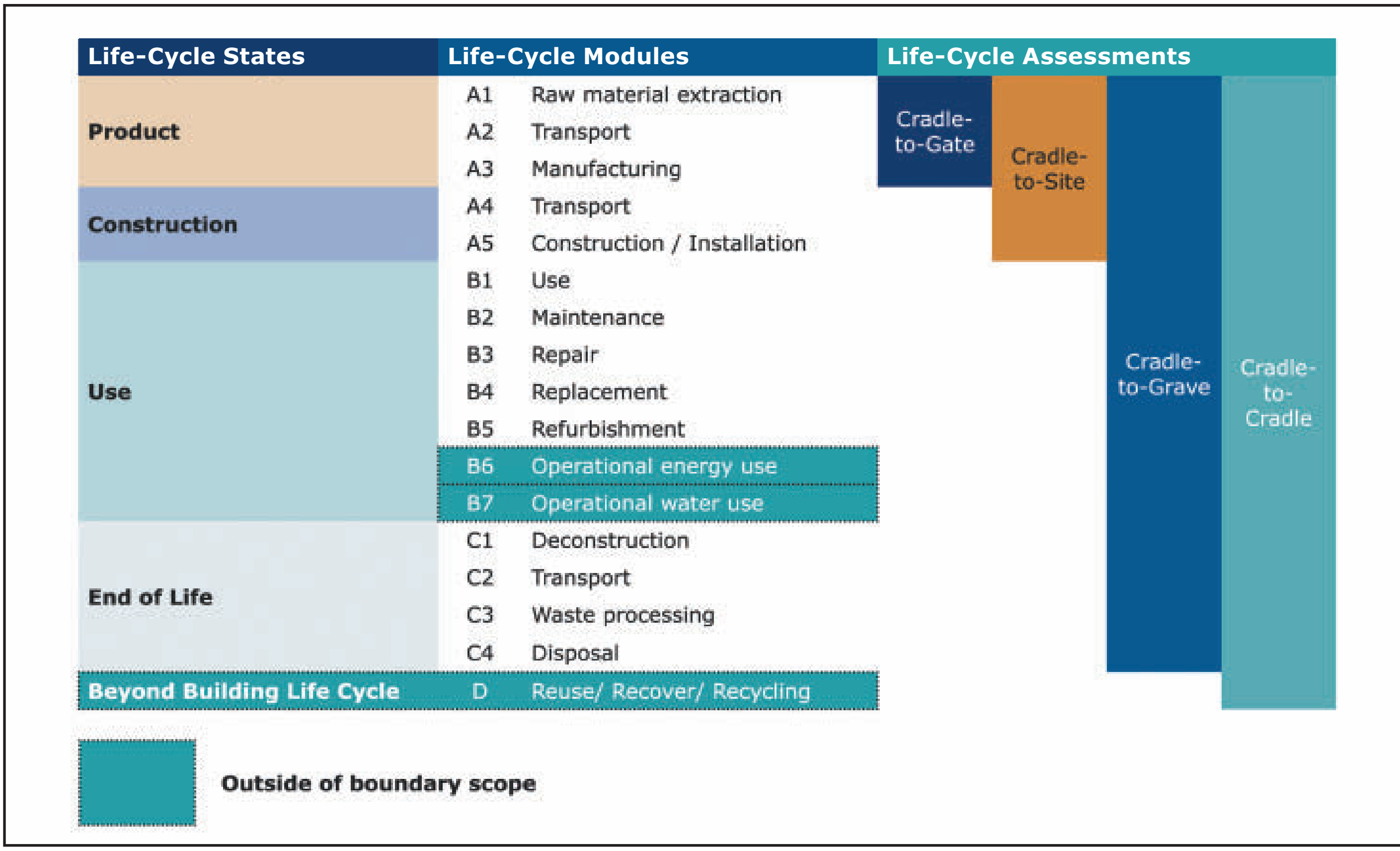

Figure 1. *Displays the life-cycle modules for each life-cycle stage of the insulation and common scopes of life-cycle assessment.*

hydrofluoroolefins (HFOs). Part I of the "Results and Discussion" section describes the shift to blowing agents with lower greenhouse gas (GHG) emissions and ultimately lower embodied carbon. The decreasing embodied carbon of plastic insulation materials was the result of product reformulations driven by global concern regarding the environmental impact of blowing agents. Despite the globally publicized phase out of blowing agents with high GWPs, plastic insulation continues to be scrutinized for its supposed high embodied carbon and related impacts. The limited understanding of embodied carbon improvements inhibits the ability of the plastics insulation industry to inform GWP-related policy and develop solutions surrounding decisions on the sustainability of plastic insulation. Additionally, there are insufficient data on the total carbon impacts of insulation, including the embodied carbon of insulation material and the carbon benefits of these materials. Here, total carbon impact is defined as the net impact of the embodied carbon investment and the operational carbon savings associated with a material, as shown in **Fig. 2**.[3] Therefore, this two-part report aims to A) highlight the historical reductions in the embodied carbon of four insulation types and B) evaluate the life-cycle energy and GHG savings attributed to the application of plastic insulation materials in both residential and commercial building enclosures. Figure 2 demonstrates the inputs required to calculate the total carbon of a material, which is the sum of the embodied carbon of a material and the operational carbon savings of the same material.

EXPERIMENTAL

Part I

The embodied carbon of each insulation type is determined by calculating the GWP of the insulation products in accordance with the *Product Category Rules (PCR) Guidance for Building Related Products and Services Part B: Building Envelope Thermal Insulation EPD Requirements* UL 10010-1.[4] The PCR includes modules A1-A5, B1-B5, and C1-C4 (Fig. 1). Impacts of other modules can be voluntarily included in the EPD but are not included for the purposes of our analysis. The EPDs are typically conducted by an insulation association or insulation manufacturer with the assistance of a third-party consultant or LCA expert. Although several potential environmental impacts are included in a product's EPD, this report focuses on GHGs. GHGs are gases that absorb and trap

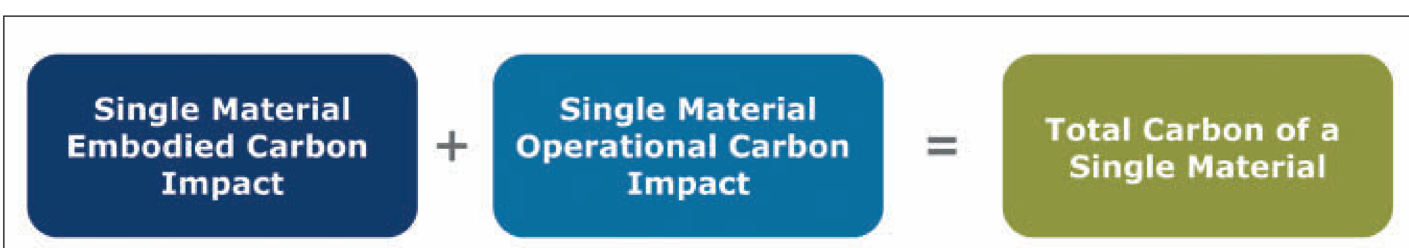

Figure 2. *Total carbon of a material evaluates the net greenhouse gas emissions from a product or material's embodied carbon and emissions savings attributed to the operational carbon benefits realized after installation and during the building's use.*

heat in the atmosphere; the most common GHGs include carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O). The GHGs are measured in a metric called global warming potential (GWP). GWP is used to measure the impact of different gases on one shared scale, due to gases having different effects on global warming. The two main ways GHGs have variable effects on global warming are their abilities to absorb energy and the amount of time they stay in the atmosphere. GWP measures the amount of energy one ton of a gas will absorb over a certain amount of time compared to the amount of energy one ton of CO_2 will absorb over the same amount of time. As mentioned previously, GWP is measured as kilograms (kg) of CO_2 equivalent, which allows different GHGs to be compared on the same scale.

To compare the changes in the GWP of the four plastic insulation types, data were collected from primary sources through a survey. Insulation manufacturers were requested to provide current and historical life-cycle data, specifically embodied carbon data along with its associated PCR version as applicable and any notable changes that may have caused the change in embodied carbon from one PCR or product formulation to the next. Additional information was collected from industry and producer EPDs available on the Building Transparency EC3 database.[5] Data from peer-reviewed sources were also incorporated where applicable to maintain the parameters of the study for North American applications.

Part II

To develop new data and gain a more current perspective on the net, or total carbon impacts of plastic insulation materials, specifically XPS, EPS, SPF, and PIR, a modeling project was conducted by ICF International Inc. This project, "Determination of Total Carbon Impact of Plastic Insulation Materials," examined the energy and operational carbon impacts associated with these four plastic insulation materials throughout their useful life using conservative assumptions, including thermal resistance properties, climate zones, building types, and grid makeup.[6] The model results were compared to the embodied carbon investment of the insulation materials in the prototype buildings to establish an understanding of the total carbon payback and total carbon avoidance (embodied carbon investment to operational carbon savings).

A case study by Franklin Associates, "Plastic Energy and Greenhouse Gas Savings Using Rigid Foam Sheathing Applied to Exterior Walls of Single-Family Residential Housing in the U.S. and Canada," found favorable energy and carbon payback time frames.[7] While this study used different modeling assumptions than the recent ICF study and was conducted nearly two decades prior, the results were consistent. The Franklin study showed that by adding an additional ⅝ in (16 mm) of exterior rigid foam insulation to a home with a service life of 50 years, a GHG payback ranging from 12.5 years in the US to 3 years in Canada could be achieved, despite the higher embodied carbon of insulation materials at that time.

Another research report in the *Journal of Industrial Ecology* (JIE), "Life Cycle Greenhouse Gas Emissions Reduction from Rigid Thermal Insulation Use in Buildings," published in 2011, found an average GHG savings to embodied carbon ratio of 48:1.[8] As with the Franklin study, this study used different modeling assumptions than the ICF study but found comparable significant total carbon benefits of plastic insulation materials when considering the full life-cycle of the building. It's important to note the GHG emissions data per functional unit in the 2011 study were not subjected to the same third-party analysis or PCR as with the ICF study.

There are a handful of other industry-wide and manufacturer-specific LCAs that model total carbon benefits, but the majority are limited to a single insulation type or building application, further emphasizing the need for recent, and more extensive studies on the total carbon benefits of plastic insulation.

The ICF study, included current plastic insulation embodied carbon data, projected grid emissions data based on the National Renewable Energy Lab (NREL) Cambium scenarios, Climate Zones 3 and 5, and Department of Energy (DOE) residential two-story home and medium office building prototypes.[9] ICF utilized DOE's Energy Plus software to model the energy data. ICF also calculated the total carbon impacts of the insulation materials in the modeled buildings and used current and projected grid emissions data to determine the GWP impacts. Using the data, ICF calculated the plastic insulation material GWP payback and GWP avoidance ratios using Cambium High, Medium, and Low Cost of Conversion to Renewable Energy grid projections. The data were then compared to the embodied carbon investment in these materials in prototype buildings so that an understanding of GWP payback and GWP avoidance could be established.

The US is segmented into eight different climate zones, represented by a number 1-8, and three categories based on moisture levels, denoted by letters A, B, and C.[11] Climate Zones 3 and 5 were selected for the study because they are conservatively representative of heating and a cooling dominated regions of the U.S. (**Table 1**). These climate zones are also home to a large segment of the population and the representative cities are all found in the top 11 states for housing starts in 2022 according to the US Census Bureau Building Permits Survey.[10]

Representative thermo-physical properties were established in (**Table 2**). These values do not reflect all available or proprietary insulation properties. They are conservative representations of materials readily available in the US.

Table 1. Representative Climate Zones 3 and 5 Modeling Assumptions

Climate Zone	Representative City	Weather Location	HDD65	CDD65
3A	Atlanta, Georgia	Atlanta/Hartsfield Jackson International Airport, Georgia	2,498	2,099
3B	El Paso, Texas	El Paso International Airport, Texas	2,012	2,972
3C	San Diego, California	San Diego/Brown Field Municipal Airport, California	1,377	763
5A	Buffalo, New York	Buffalo Niagara International Airport, New York	6,242	769
5B	Denver, Colorado	Denver/Aurora/Buckley AFB, Colorado	5,737	832
5C	Port Angeles, Washington	Port Angeles/William R Fairchild International Airport, Washington	5,488	20

Note: HDD65 = Heating Degree Days below 65°F (18°C); CDD65 = Cooling Degree Days above 65°F (18°C).

Table 2. Representative Thermo-physical Properties of Plastic Insulation Materials

Insulation Material	*R*-value per inch thickness	Thermal Conductivity Btu/h·ft·°F (W/m·K)	Density lb/ft³ (kg/m³)	Specific Heat Btu/lb·°F (J/kg·K)
XPS	5.00	0.01667 (0.02885)	1.56 (25)	0.36 (1500)
EPS	4.00	0.02083 (0.03606)	1.56 (25)	0.36 (1500)
Closed cell-SPF	6.50	0.01282 (0.02219)	2.18 (35)	0.35 (1450)
Open cell-SPF	3.50	0.02381 (0.04121)	2.18 (35)	0.35 (1450)
Polyisocyanurate	5.80	0.01437 (0.02487)	1.56 (25)	0.36 (1500)

Note: EPS = expanded polystyrene; SPF = spray foam; XPS = extruded polystyrene.

Table 3. Simulated Scenarios for Residential Prototype

Scenario	Description
R0	No Insulation (Baseline)
R1	Basement + Attic Insulation (No Wall Insulation)
R2	Wall + Attic Insulation (No Basement Insulation)
R3	Wall + Basement Insulation (No Attic Insulation)
R4	Whole Home Insulation

Table 4. Simulated Scenarios for Commercial Prototype

Scenario	Description
C0	No Insulation (Baseline)
C1	Slab + Roof Insulation (No Wall Insulation)
C2	Wall + Roof Insulation (No Slab Insulation)
C3	Wall + Slab Insulation (No Roof Insulation)
C4	Whole Office Insulation

Table 5. 2021 *International Energy Conservation Code* (IECC) Minimum Insulation *R* -values and Enclosure Components.[13]

Location	Climate Zone	
	3	5
Above-Grade Exterior Wall Insulation	*R*-13 oc-SPF/cc-SPF blend 50/50 in cavity, *R*-5ci XPS/EPS foam sheathing blend 50/50	*R*-13 oc-SPF/cc-SPF blend 50/50 in cavity, *R*-10ci XPS/EPS foam sheathing blend 50/50
Basement Exterior Wall Insulation	*R*-5ci exterior XPS	*R*-10ci exterior XPS, *R*-5ci interior XPS/EPS foam sheathing blend 50/50
Unvented Attic Insulation (Roof and Gable End Wall)		
Roof Insulation	*R*-38 cc-SPF, as allowed by IECC Section R402.2.1, assuming that insulation is applied to full *R*-value and over the top plate at the eaves.	*R*-49 cc-SPF, as allowed by IECC Section R402.2.1, assuming that insulation is applied to full *R*-value and over the top plate at the eaves
Gable End Wall Insulation	*R*-13 oc-SPF/cc-SPF blend 50/50 in cavity, *R*-5ci XPS/EPS foam sheathing blend 50/50	*R*-13 oc-SPF/cc-SPF blend 50/50 in cavity, *R*-10ci XPS/EPS foam sheathing blend 50/50

Note: cc = closed cell; ci = continuous insulation; EPS = expanded polystyrene; oc = open cell; SPF = spray foam; XPS = extruded polystyrene.

Table 6. ASHRAE 90.1-2019 Minimum Insulation *R*-values and Enclosure Components.[14]

Location	Climate Zone	
	3	5
Above-Grade Wall Insulation	Steel framed, *R*-13 cc-SPF in cavity, *R*-5ci PIR sheathing	Steel framed, *R*-13 cc-SPF in cavity, *R*-10ci PIR sheathing
Slab Insulation	None	*R*-15ci XPS foam sheathing for 24″ deep from top of slab down
Roof Insulation (Entirely Above Deck)	*R*-25ci PIR sheathing	*R*-30ci PIR sheathing

Note: cc = closed cell; ci = continuous insulation; PIR = polyisocyanurate; SPF = spray foam; XPS = extruded polystyrene.

Two prototype buildings were selected for the study, one residential and one commercial. Again, conservative prototypes were selected. The residential prototype selected was the DOE two-story home.[12] This is typically more conservative than the one-story home prototype due to its smaller square footage and area of thermal loss through the ceiling/roof. The commercial prototype selected was the medium office building. This prototype is typically more conservative than other larger, more energy intensive, buildings like schools and hospitals.

Four base modeling scenarios were developed for both residential and commercial. These scenarios are shown in **Tables 3** and **4**.

Plastic insulation types that are commonly used in these applications were used in the model. In some scenarios where one of two materials are typically used, their data were averaged ($^{50}/_{50}$ blend). The representative insulation types selected are shown in **Table 5** for residential and **Table 6** for commercial. For the residential model, the insulation configurations for both the roof deck and on the gable ends was defined. The insulation types specified for modeling purposes in this study are not representative of all potential plastic insulation materials that can be used in these applications.

These assumptions were used to inform the assembly thermal resistance values used in the EnergyPlus model.

A few changes were made to the EnergyPlus model to better represent the configuration of enclosure layers and the location of insulation elements. For example, the modeling of residential insulation at the roof deck versus the attic floor was used to simulate an unvented attic. These adjustments are described in detail in the ICF report.[6]

A 75-year useful life was assumed, which is the same service life assumption that is included in the PCR for thermal insulation materials.

There were 147 simulations modeled: 120 for residential and 27 for commercial. There were more simulations run for the residential model due to the 4 different heating systems (electric resistance, gas furnace, oil furnace, and heat pump) in the EnergyPlus model. Additional simulation details can be found in the ICF report.[6]

RESULTS AND DISCUSSION

Part I

While there are many factors that have led to reductions in the embodied carbon of insulation products, using lower GHG blowing agents are attributed to the most significant improvements. CFCs were first synthesized in the 1920s in a combined effort by Frigidaire, General Motors, and DuPont to replace less desirable substances with refrigerant qualities.[15] CFCs were utilized as blowing agents in foam insulation materials where they formed air-filled pockets that restricted heat transfer and reduced the density of the foam insulation. In 1974, scientists discovered the risk CFCs posed to the deterioration of the ozone layer upon their release. The depletion of ozone, a gas with ultraviolet radiation absorption properties, could increase the amount of radiation that reaches the earth's surface, subsequently heating the planet. Like the ozone-depleting characteristics of CFCs, these gases were determined to have a significant embodied carbon demonstrated by their high GWP. According to a study of the GHG emissions of rigid thermal insulation, a formulation of XPS (principle blowing agent CFC-12) used in North America from 1971-1989, had an embodied carbon of more than 900 kg CO_2e/m^2.[7]

As a result of rising concerns associated with the ozone-depleting nature of CFCs, a global environmental treaty, the *Montreal Protocol to Reduce Substances that Deplete the Ozone Layer*, was adopted in 1987.[16] The treaty outlined a plan to phase out several ozone depleting substances, including CFCs, by placing controls on the production and consumption of these substances. In the absence of CFCs two new classes of substances were created with similar insulating properties,

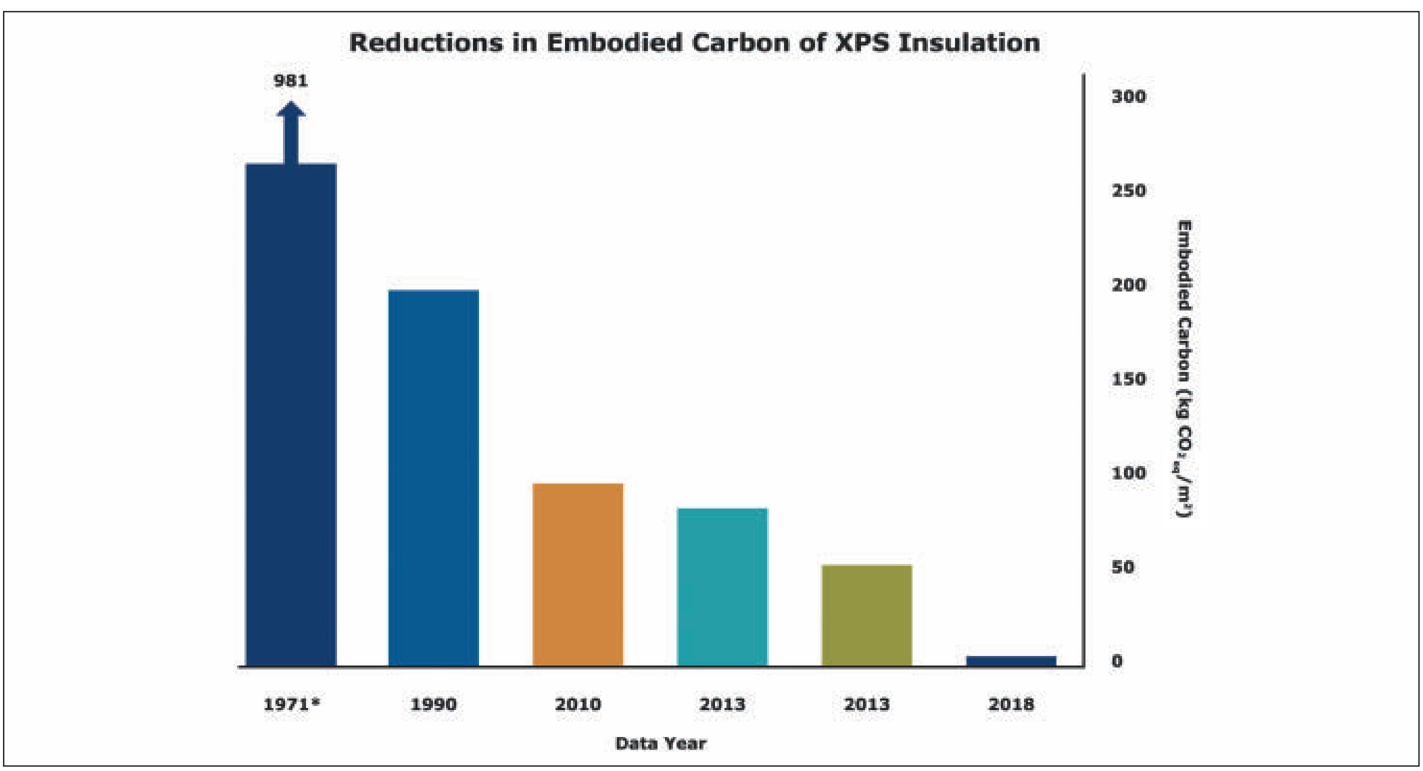

Figure 3. *Reductions in embodied carbon of extruded polystyrene (XPS) insulation based on formulations in 1971, 1990, 2010, 2013, and 2018. *The X-axis cuts-off at 300 kg CO_2e/m^2 to accommodate the more recent embodied carbon metrics that are significantly below 100 kg CO_2e/m^2. However, the actual embodied carbon for XPS in 1971 is shown within the data bar as 981 kg CO_2e/m^2.*

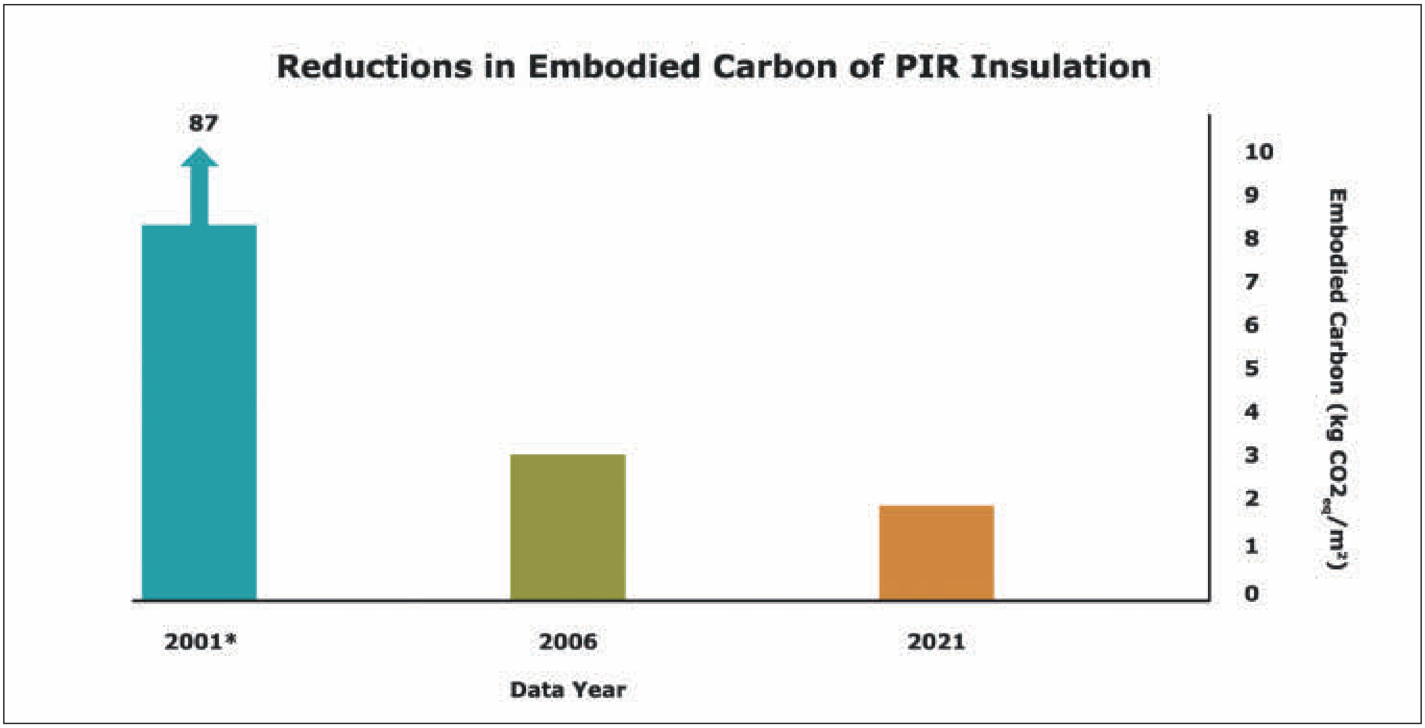

Figure 4. *Reductions in embodied carbon of polyisocyanurate (PIR) insulation based on formulations in 2001, 2006, and 2021. *The YX-axis cuts-off at 10 kg CO_2e/m^2 to accommodate the more recent embodied carbon metrics that are significantly below 10 kg CO_2e/m^2. However, the actual embodied carbon for PIR in 2001 is shown within the data bar as 87 kg CO_2e/m^2.*

HCFCs and HFCs. HCFCs proved to be beneficial substitutes with a significantly lower GWP than CFCs, as demonstrated by the 1990 formulation of XPS (principle blowing agent HCFC-142b) with a GWP of less than 230 kg CO_2e/m^2.

However, HCFCs had similar potential to CFCs to deplete the ozone layer, prompting an amendment to the Montreal Protocol outlining their planned phase out too. This precipitated the substitution of HCFCs with HFCs. While HFCs do not have ozone depleting properties, they have significant embodied carbon or GWPs that resulted in the adoption of the Kigali Amendment in 2016. This amendment outlines the plan to phase out HFCs before 2050, due to the high GWPs ranging from 12 to 14,800.[17] These substances will be replaced by lower GWP blowing agents, such as HFOs or pentanes.

Figure 3 showcases the reductions in embodied carbon of XPS insulation materials over the last several decades. The years indicated on the X-axis correlate to the year a new generation of XPS was introduced. The embodied carbon of XPS has been significantly reduced since 1971, primarily as a result of innovations in new blowing agents and polymers, production efficiencies, and material sourcing. While some product generations may overlap, the higher GWP materials are continuing to be phased out as the industry trends shift towards greater sustainability. Although the most recent formulation was introduced in 2018, more recent XPS products with EPDs published in 2021 and beyond, show a continual downward trend in the embodied carbon.

Similarly, **Figure 4** displays the reductions in embodied carbon of PIR insulation materials over the last several decades. The years indicated on the X-axis correlate to the year a new generation of PIR was produced. The embodied carbon of PIR has been reduced significantly since 2001, resulting from innovations in new blowing agents and polymers, production efficiencies, and material sourcing. While some product generations may overlap, the higher GWP materials are continuing to be phased out as the industry trends shift toward greater sustainability. Although the most recent formulation was introduced in 2006, more recent PIR products with EPDs published in 2021 and beyond, show a continual downward trend in the embodied carbon.

The scope of Part I included the embodied carbon of four types of plastic insulation. However, there was limited data publicly available that met the parameters of the study, including the functional unit and geographical location. Plastic insulation produced, transported, installed, and disposed of in other countries or regions, such as Europe, may have varying GWP results compared to plastic insulation materials produced in the US. This is because of potential differences in the grid's fuel sources, since some energy sources have higher emissions than others when combusted. Furthermore, expired EPDs are removed from databases and other building resources to ensure that only current data on the contents and embodied carbon of plastic insulation materials are communicated. While beneficial in reducing the communication of outdated metrics, this presents a challenge in collecting historical information. Additionally, the tracking of plastic insulation's embodied carbon through EPDs is a more recent process, further adding to the limited data available. However, it's important to recognize that other plastic insulation materials, including SPF and EPS, were not previously produced with high GWP components, such as CFCs, HCFCs, or HFCs. Moreover, the current EPDs for both EPS and SPF showcase embodied carbons comparable to most recent formulations of XPS and PIR. This emphasizes the continual trend for plastic insulation products to have low embodied carbon throughout their life-cycles.

Part II: Determination of Total Carbon Impacts

To determine the total carbon impacts associated with plastic insulation materials, the embodied carbon of the insulation materials, and the operational carbon savings associated with the modeled buildings were summed.

The operational energy consumption and savings were determined through the modeling for the various scenarios. Modeling was done using current heating and cooling system energy mixes and to simulate a future 100% heat pump conversion.

The total site energy use for each of the scenarios utilizing the current heating systems can be found in the ICF report.[6] From this consumption data, the energy savings of the insulation elements associated with each scenario were determined and summarized in **Table 7** (residential) and **Table 8** (commercial).

The ICF report noted, consistent with anomalies experienced with EnergyPlus, that the software seems to undervalue slab insulation contributions.[6] Although these values were expected to be much lower than other insulation elements, there is more investigation needed to understand the potential shortcomings of the existing EnergyPlus capabilities for this element. Additional details about this phenomenon are available in the ICF report.

The modeling to simulate a future 100% conversion to electric heat pumps was done to understand how the results may differ if the goal of 100% electrification is achieved. The

Table 7. Impact of Insulation on Total Site Energy Savings by End Use and Climate Zone for the Case with Current Heating Systems Mix (residential)

Climate Zone	Scenario	Total Site Energy Savings [kBtu]
3	Whole Home Insulation Impact	71,468
	Wall Insulation Impact	39,203
	Basement Insulation Impact	6,040
	Attic Insulation Impact	26,927
5	Whole Home Insulation Impact	257,647
	Wall Insulation Impact	137,697
	Basement Insulation Impact	29,940
	Attic Insulation Impact	100,420

Table 8. Impact of Insulation on Total Site Energy Savings by End Use and Climate Zone for the Case with Natural Gas Heating (commercial)

Climate Zone	Scenario	Total Site Energy Savings [kBtu]
3	Whole Office Insulation Impact	472,512
	Wall Insulation Impact	142,056
	Slab Insulation Impact	—
	Roof Insulation Impact	309,987
5	Whole Home Insulation Impact	969,178
	Wall Insulation Impact	327,591
	Slab Insulation Impact	2,594
	Roof Insulation Impact	622,109

Table 9. Embodied Carbon Per Functional Unit of Plastic Insulation Materials

Insulation Material	Embodied Carbon (kg CO_2e/m^2)
XPS	5.63
EPS	3.78
PIR (Wall)	3.49
PIR (Roof)	3.46
cc-SPF	4.21
oc-SPF	1.68
50/50 XPS/EPS	4.71
50/50 cc-SPF/oc-SPF	2.95

Note: cc = closed cell; EPS = expanded polystyrene; oc = open cell; PIR = polyisocyanurate; SPF = spray foam; XPS = extruded polystyrene.

energy savings associated with this assumption can be found in the ICF report.

To determine the embodied carbon of the insulation materials for each of the scenarios, representative emissions values of the materials were used. The representative values include materials that are available today and for the foreseeable future. It is important to note that there are values of materials currently available that were not used due to known material and blowing agent phase out programs.

Embodied carbon values for each of the material types were taken from public sources. Embodied carbon is reported per functional unit as specified in the *UL Product Category Rule for Building Envelope Thermal Insulation Requirements*.[3] In some cases, industry-averaged EPD was used and in some cases, manufacturer-averaged EPD data were used. A summary of the embodied carbon per functional unit used in this study can be found in **Table 9**.

Using the building prototypes, the total embodied carbon investment in the buildings for each of the enclosure elements was calculated. This data were used to calculate the carbon payback and carbon avoidance ratios in the report. The total embodied carbon values are summarized in **Table 10** (residential) and **Table 11** (commercial):

In addition to modeling scenarios that include a 100% conversion to heat pumps, several different future-looking grid scenarios were used to understand the carbon payback and the carbon avoidance ratios associated with the use of plastic insulation materials.

Table 10. Total Embodied Carbon for Different Enclosure Elements Insulation for Climate Zone 3 and Climate Zone 5 (residential)

Scenario	Embodied Carbon [metric tons CO_2e]	
	Climate Zone 3	Climate Zone 5
Wall Insulation	1.74	2.53
Basement Insulation	0.51	1.46
Attic Insulation	3.13	4.11
Whole Home Insulation	5.39	8.09

Table 11. Total Embodied Carbon for Different Enclosure Elements Insulation for Climate Zone 3 and Climate Zone 5 (commercial)

Scenario	Embodied Carbon [metric tons CO_2e]	
	Climate Zone 3	Climate Zone 5
Wall Insulation	15.6	19.6
Slab Insulation	—	1.51
Roof Insulation	25.3	30.4
Whole Office Insulation	40.9	51.5

Table 12. Electricity Emission Rates for Low RE Cost, Medium RE Cost, and High RE Cost

Year	Electricity Emission Rate (kg CO_2e/MWh)		
	Low RE Cost	Medium RE Cost	High RE Cost
2024	327.0	302.7	255.0
2026	342.4	266.7	234.0
2028	330.5	211.6	176.1
2030	324.1	188.7	97.9
2035	325.0	132.1	40.8
2040	313.2	87.8	25.2
2045	315.8	63.7	39.6
2050	282.6	57.6	34.9

Note: RE = renewable energy.

Table 13. Global Warming Potential (GWP) Payback Period Using Different Electricity Rates for Scenario 1: Current Heating Systems Mix (residential)

Scenario	GWP Payback Period [months]					
	Climate Zone 3			Climate Zone 5		
	High RE Cost	Med RE Cost	Low RE Cost	High RE Cost	Med RE Cost	Low RE Cost
Wall Insulation Impact	2.8	3.0	3.5	2.2	2.3	2.5
Basement Insulation Impact	5.5	5.9	6.8	6.3	6.5	7.0
Attic Insulation Impact	7.5	8.1	9.3	5.0	5.2	5.6
Whole Home Insulation Impact	4.8	5.2	6.0	3.8	4.0	4.3

Table 14. Global Warming Potential (GWP) Payback Period Using Different Electricity Rates for Scenario 2: 100% Heat Pump Systems (residential)

Scenario	GWP Payback Period [months]					
	Climate Zone 3			Climate Zone 5		
	High RE Cost	Med RE Cost	Low RE Cost	High RE Cost	Med RE Cost	Low RE Cost
Wall Insulation Impact	2.7	2.9	3.5	1.4	1.5	1.8
Basement insulation Impact	5.3	5.8	6.8	3.2	3.4	4.1
Attic Insulation Impact	7.4	8.0	9.4	3.0	3.3	3.9
Whole Home Insulation Impact	4.7	5.1	6.1	2.3	2.5	3.0

Table 15. Global Warming Potential (GWP) Payback Period Using Different Electricity Rates for Scenario 1: Current Heating System Mix (commercial)

Scenario	GWP Payback Period [months]					
	Climate Zone 3			Climate Zone 5		
	High RE Cost	Med RE Cost	Low RE Cost	High RE Cost	Med RE Cost	Low RE Cost
Wall Insulation Impact	4.9	5.3	6.3	2.8	3.1	3.6
Slab Insulation Impact	—	—	—	72.5	84.6	93.8
Roof Insulation Impact	3.7	4.0	4.8	2.6	2.8	3.2
Whole Office Insulation Impact	3.9	4.2	5.0	2.7	2.9	3.4

Table 16. Global Warming Potential (GWP) Payback Period Using Different Electricity Rates for Scenario 2: 100% Heat Pump Systems (commercial)

Scenario	GWP Payback Period [months]					
	Climate Zone 3			Climate Zone 5		
	High RE Cost	Med RE Cost	Low RE Cost	High RE Cost	Med RE Cost	Low RE Cost
Wall Insulation Impact	10.1	10.9	13.0	6.0	6.5	7.7
Slab Insulation Impact	—	—	—	NA*	NA	NA
Roof Insulation Impact	7.5	8.1	9.6	4.4	4.8	5.7
Whole Office Insulation Impact	7.9	8.6	10.2	4.9	5.3	6.3

*NA indicates that negative savings result in infinite payback period. Recall that negative savings were primarily due to the fact that insulation is only applied to the perimeter of the slab in addition to inherent limitations on the F-factor method modeling assumptions.

Table 17. Global Warming Potential (GWP) Avoidance Ratio Using Different Electricity Emissions Rates for Scenario 1: Current Heating Systems Mix (residential)

Scenario	GWP Avoidance Ratio [-]					
	Climate Zone 3			Climate Zone 5		
	High RE Cost	Med RE Cost	Low RE Cost	High RE Cost	Med RE Cost	Low RE Cost
Wall Insulation Impact	295	114	84	386	251	229
Basement Insulation Impact	149	59	44	137	94	87
Attic Insulation Impact	109	43	32	171	112	103
Whole Home Insulation Impact	171	67	50	222	146	134

Table 18. Global Warming Potential (GWP) Avoidance Ratio Using Different Electricity Emissions Rates for Scenario 2: 100% Heat Pump Systems (residential)

Scenario	GWP Avoidance Ratio [-]					
	Climate Zone 3			Climate Zone 5		
	High RE Cost	Med RE Cost	Low RE Cost	High RE Cost	Med RE Cost	Low RE Cost
Wall Insulation Impact	299	87	52	590	171	103
Basement Insulation Impact	152	44	26	255	74	44
Attic Insulation Impact	110	32	19	270	78	47
Whole Home Insulation Impact	172	50	30	348	101	60

Table 19. Global Warming Potential (GWP) Avoidance Ratio Using Different Electricity Emission Rates for Scenario 1: Current Heating System Mix (commercial)

Scenario	GWP Avoidance Ratio [-]					
	Climate Zone 3			Climate Zone 5		
	High RE Cost	Med RE Cost	Low RE Cost	High RE Cost	Med RE Cost	Low RE Cost
Wall Insulation Impact	166	50	31	287	90	58
Slab Insulation Impact	—	—	—	12	8	7
Roof Insulation Impact	218	67	42	319	108	73
Whole Office Insulation Impact	208	63	39	305	100	66

Table 20. Global Warming Potential (GWP) Avoidance Ratio Using Different Electricity Emission Rates for Scenario 2: 100% Heat Pump System Mix (commercial)

Scenario	GWP Avoidance Ratio [-]					
	Climate Zone 3			Climate Zone 5		
	High RE Cost	Med RE Cost	Low RE Cost	High RE Cost	Med RE Cost	Low RE Cost
Wall Insulation Impact	80	23	14	136	39	24
Slab Insulation Impact	—	—	—	NA*	NA	NA
Roof Insulation Impact	109	32	19	183	53	32
Whole Office Insulation Impact	103	30	18	164	48	29

*NA indicates that negative savings result in infinite payback period. Recall that negative savings were primarily due to the fact that insulation is only applied to the perimeter of the slab in addition to inherent limitations on the F-factor method modeling assumptions.

The National Renewable Energy Lab (NREL) Cambium Database low-, medium-, and high-cost predictions of grid conversion to renewable energy for Georgia were selected. Since Cambium only estimates grid emissions rates up to 2050 it was assumed that 2050 rates prevailed for the remainder of the building life-cycle. The emission rates used from the Cambium database are found in **Table 12**.

Utilizing the background data described in the above tables, the GWP payback of plastic insulation materials was calculated assuming current heating system and 100% heat pump scenarios. All insulation elements had a GWP payback under one year except for commercial Climate Zone 3 Low Renewable Energy (RE) Cost of conversion walls with 100% heat pumps and Climate Zone 5 slab insulation scenarios. As described previously, it is suspected to be hampered by the current capabilities of EnergyPlus modeling software. This is the case even if the grid rapidly converts to renewable energy and when 100% of heating systems are converted to heat pumps. Residential wall insulation in Climate Zone 5, assuming 100% heat pump conversion and a High RE Cost of grid conversion, had the most rapid payback at 1.4 months. The carbon payback in months for the residential prototype are found in **Table 13** (current heating system mix) and **Table 14** (100% heat pumps).

The carbon payback in months for the commercial prototype are found in **Table 15** (current heating system mix) and **Table 16** (100% heat pumps).

The lifetime GWP savings and the GWP avoidance ratios attributed to plastic insulation were also calculated. Except for the slab insulation, which is limited by modeling capabilities, it was found that plastic insulation in all other applications had net carbon savings over its useful life. Excepting slab insulation, plastic insulation saves between 14 times and 590 times its embodied carbon during its useful life. The residential GWP avoidance ratios for all scenarios are found in **Table 17** (current heating system mix) and **Table 18** (100% heat pump mix) below.

The GWP avoidance ratios for all commercial scenarios are found in **Table 19** (current heating system mix) and **Table 20** (100% heat pump mix) below.

CONCLUSION

This report concludes that plastic insulation manufacturers, through their own product stewardship and sustainability goals, have made steady improvements to their manufacturing processes and product formulations of plastic insulation materials. These improvements have resulted in significant embodied carbon reductions of insulation materials in the market. Improvements to embodied carbon are likely to continue as production technology improves and the energy sources transition to lower GHG options.

Additionally, the report concludes that the investment of embodied carbon in plastic insulation materials is trumped by its GHG savings benefits during its useful life in buildings. This is true for our current energy grid GHG intensity and the projected grid transition to a cleaner mix even at aggressive conversion speeds. Furthermore, the report shows that the embodied carbon invested in plastic insulation materials has rapid payback times of under one year in nearly all scenarios even when it is assumed that all buildings are converted to heat pump systems.

Outside the building enclosure, insulation also can support global efforts to reach a point of drawdown, where GHGs in the atmosphere stop increasing and decline through many carbon mitigation strategies. This analysis, called Project Drawdown, cites building insulation as one of the climate solutions needed to reach this turning point, further underscoring the benefits of plastic insulation in a low carbon economy.[18] Project drawdown indicates that a steady implementation of low-embodied-carbon insulation materials could lead to more than 15 gigatons of avoided GHG emissions.

Insulation LCA and EPD data should be used in the context of whole building LCA or in combination with total carbon benefit data for insulation materials that includes the use-phase carbon benefits to make smart policy, design, and product selection decisions for the building sector. Evidence shows that including embodied carbon impacts of insulation without considering total carbon analysis would be counterproductive to our global and national carbon reduction goals. Policies, building specifications, industry tools and other resources that include or aim to set maximum embodied carbon limits for insulation or deselect/disincentivize insulation materials based on embodied carbon content alone is misguided and are not recommended in our opinion.

It should be noted that the carbon savings attributed to eliminating the additional air or water resistive barrier were not factored into the carbon savings in this report. These savings can be significant and should be considered by design professionals when making material selections. Furthermore, there can often be cost savings associated when an additional air or water barrier can be eliminated through the sealing of foam insulation. In many cases, the energy savings can lead to the l downsizing of HVAC and renewable energy equipment due to the reduced heating and cooling loads. Further study would need to be done to quantify these benefits.

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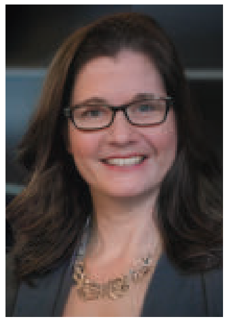

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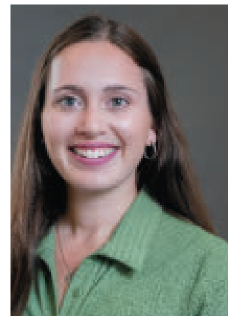

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Online Exclusive

Lessons Learned from Building Enclosure Delegated Design Disasters

By Fan Feng, REWO, RRO, PE, CDT; and Amy Peevey, REWC, RRO, PE, CDT

This paper was presented at the 2023 IIBEC Building Enclosure Symposium.

INTRODUCTION

As a means of achieving higher quality control, expedited installation, and adapting buildings for their next phase of use, more and more building enclosure systems are prefabricated and consolidated, and their designs require higher performance than ever before. Simply put, the building enclosure is no longer simply keeping water (liquid and vapor) out and achieving the overall exterior aesthetic while other systems manage the thermal, structural, and hygrothermal aspects of the overall building performance. The modern building enclosure has evolved into a complex design that not only manages and transfers structural loads while accommodating the permanent and dynamic main frame structural and thermal movements. The enclosure systems are also controlling the transfer of water vapor, managing liquid water, achieving the thermal performance to ensure occupant safety and comfort, all whilst providing an aesthetically beautiful, sustainable, and durable building enclosure.

For complex building enclosure systems, their overall design is often delegated to trades with specialized expertise and is typically performed under the trade responsible for their installation.[2] Common delegated-design systems include architectural precast panels, curtainwall systems, dimension stone cladding, metal or composite wall panels, fabric membrane roof systems, panelized roof systems, green/blue/purpose roof systems, etc. As the delegated design is independent from the coordinated building design that is performed under the supervision of the Designer-of-Record (DOR), the DOR does not assume the responsibility of the proper integration of the system's design with other systems of the building. Therefore, the system's delegated design is responsible for the integration with the other building systems. In most jurisdictions, only a portion of the actual delegated design requires a licensed design professional. As a result, an engineer contracted under the specialty trade typically provides structural design, which includes thermal and other movement accommodations. However, the other performance requirements, such as water-penetration and air-infiltration management, hurricane resistance, and specialty performance (such as fire, flood, and blast protection), are not the responsibility of a licensed professional. Instead, system performance testing (manufacturer or project specific) is compared to the performance requirements established by the building's DOR, and if it meets or exceeds them, then the system is accepted for incorporation into the building design.[3]

Herein lies a fatal flaw. Ultimately, the system's delegated design does not have a licensed professional responsible for its overall performance. The delegated design engineer is typically only responsible for a portion of the system's design; however, the entire system's performance is critical to the health and safety of the occupants and the public.[4] In addition, the trade responsible for efficient and effective system installation to achieve the project cost and schedule is also responsible for the system's design, resulting in a conflict of interest and requiring additional design coordination. Further, modification of a tested standard system or customization of a tested fabrication/installation that deviates from the standard means and methods must be vetted to understand possible impact on the system's previously tested performance. If

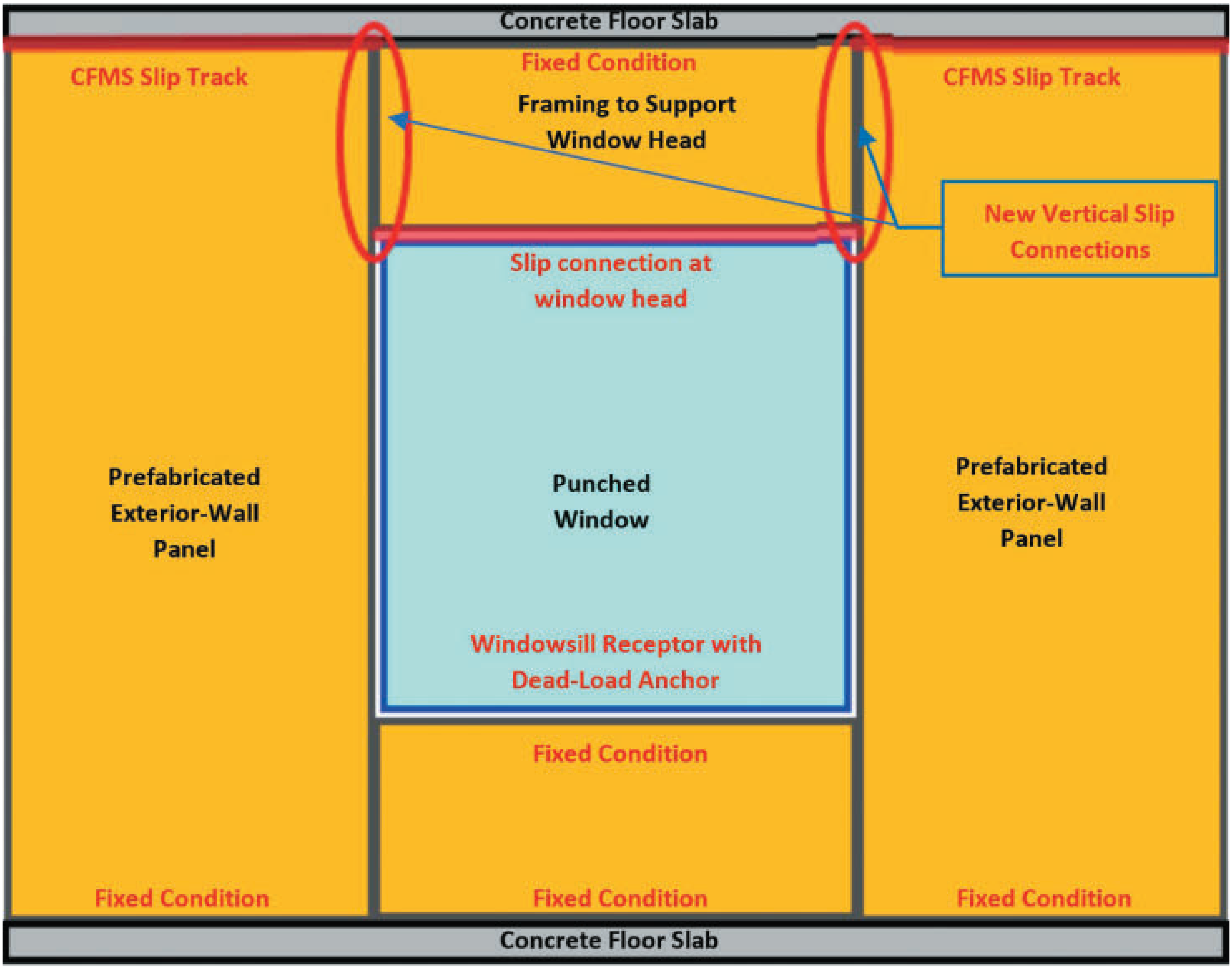

Figure 1. *Configuration of typical premanufactured exterior wall framing panel and punched window between floor lines with resulting unresolved vertical differential movements (circled).*

system customizations and modified means and methods are not integrated within the delegated design, then there can be significant consequences, the direst of which are structurally unstable systems or systems that don't meet the DOR's design requirements. This article discusses the complexity of modern building enclosure design and the possible problems resulting from complex delegated designs and their increased expectations for installation and performance through a series of case studies from the authors' personal experience.

CASE STUDY 1

Located in Texas, this building is a 32-story luxury residential high-rise with a concrete-framed structure containing 274 apartments. To meet an accelerated project schedule, prefabrication was considered for the building cladding and fenestration systems. As it was not feasible to prefabricate the traditional brick cavity wall veneer required for construction in the historic district where the building was located, the decision was made to prefabricate the exterior cold-formed metal stud (CFMS) framed walls, exterior sheathing, and air barrier, as well as the punched windows and window-wall systems. Therefore, once the prefabricated exterior backup walls and fenestrations were in place, the building would be dried in to accelerate the finish-out process.[5] However, as the delegated design of each prefabricated system was left to its respective team (the curtainwall contractor and the framing contractor), there was a lack of coordination that resulted in conflicts related to system performance and ultimately caused schedule delays for the project. Both the prefabricated exterior walls and fenestration systems were designed to accommodate movement as well as construction installation tolerance with movement joints along each floor line. The premanufactured framed exterior-wall panels (**Fig. 1**) were designed to fit between the floor lines with allowance for movement and construction tolerance at the head condition. For the punched windows, the same provisions were provided at the window heads. As the premanufactured components were submitted as two separate submittals, it was not apparent that the provisions for each conflicted with one another and resulted in a design issue that was not discovered until installation was underway. Specifically, it became apparent that to achieve proper load transfer from the punched windows, the

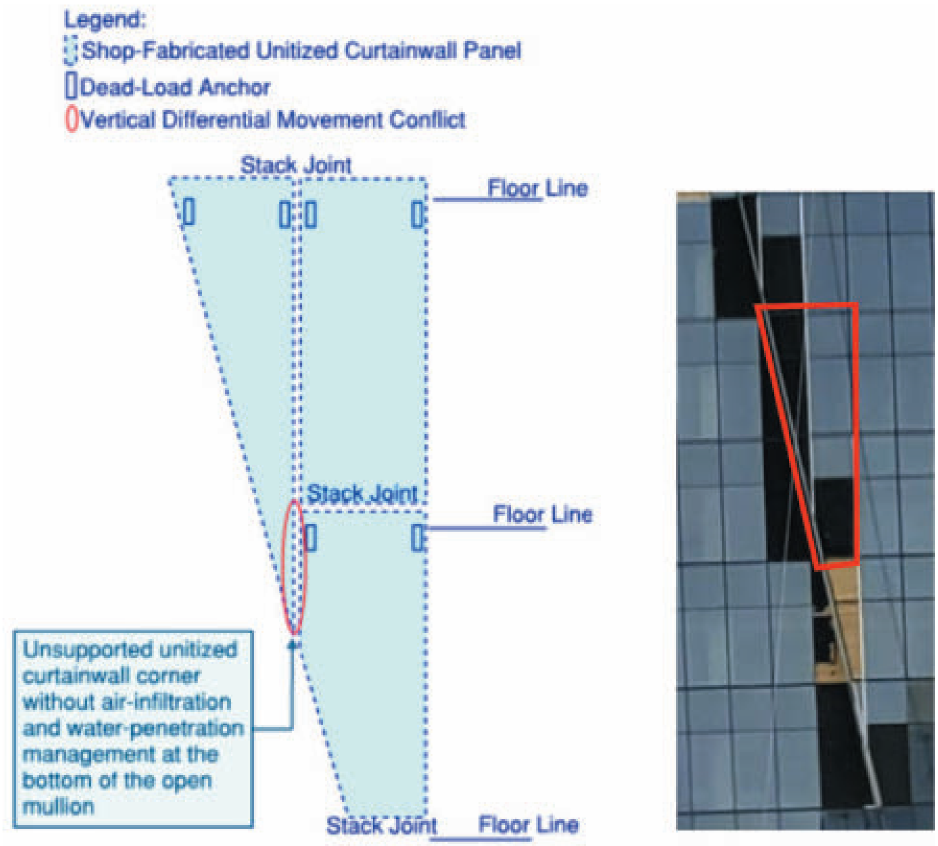

Figure 2. *Unitized curtainwall panelization layout on the left showing a triangular panel bypassing the floor line where the typical panel stack joint accommodates the installation tolerance and movements (see the resulting movement conflict along the two-part mullion circled). Photograph of the missing bypass panel on the right.*

framing supporting the window head required anchorage to the base of the overlying slab. However, the adjacent exterior-wall framing at each side was supported at the slab below. As a result, there was no provision for movement between the prefabrication framed panels and the framing supporting the window heads. To address the resulting movement between the two locations within each level, a new vertical slip joint at each side of the window head framing was required (circled in Fig. 1). The resulting redesign and rework to accommodate the coordination oversight between the adjacent systems caused increased project costs and schedule delays. This first case study provides an example of how independent delegated designs require proper integration to ensure the overall building enclosure performance.

CASE STUDY 2

This is a 19-story Class A office building in Texas, constructed as a part of a master-planned business district which includes aluminum and glass curtainwalls, metal panels, and architectural precast-concrete cladding systems with a signature angled feature on each building. The new tower consists of a concrete-frame structure clad with a unitized curtainwall system and metal wall panel accents, with an attached parking garage clad with architectural precast-concrete panels. The signature angled accents on three elevations are outset from the building face and supported by concrete framing and supplemental steel. The unitized curtainwall was a standard system by a large manufacturer that was customized to achieve the angled accent features and was modified by the installer for field-erection means and methods. The design was delegated to the curtainwall installer who retained an engineer to perform the structural design for the system. The engineer reviewed the curtainwall system shop drawings produced by the curtainwall installer to provide the associated framing and connection design. No fabrication or erection drawings were provided to the engineer. However, the curtainwall installer intended to splice adjacent units together side by side and across floor lines to achieve their desired panel erection layout. The result was unsupported/discontinuous triangular units that were omitted from the delegated design and were not coordinated with the adjacent components, supporting structure, building movements, and thermal expansion/contraction (**Fig. 2**) to achieve the project requirements. In addition, twin-span units were fabricated under the direction of the curtainwall installer to address constructability issues but were also omitted from the delegated design. Finally, the building design included entrance canopies, balconies, a garden roof plaza, and other horizontally intersecting features through the curtainwall. Like Case Study 1, floor-to-floor movements and thermal expansion/contraction changed between adjacent floor slabs at and adjacent to these features, resulting in conflicts for the continuity of vertical displacement between floor lines.

Other consequences resulted from the separation of the delegated design from the design team to that of the installer. The triangular glass units along the angled building features were not coordinated with the glass manufacturer's minimum dimensional production requirements. As a result, metal panels were utilized in lieu of glazing, which significantly impacted the overall building aesthetic along the signature angled features of the building facade. Also, the cut framing elements at the triangular units resulted in open and discontinuous framing intersections that did not conform to the manufacturer's tested curtainwall assembly for air-infiltration and water-penetration management of the standard curtainwall system.

Finally, where the triangular panels were spliced to panels at the overlying or underlying floor, the triangular panel was laterally unsupported and obstructed the adjacent continuous stack joint's movement and drainage above the floor line. Finally, the engineering requirements for the maximum framing spans, cantilevered framing distances, connection requirements, and fastener requirements were not coordinated between the engineered calculations and the field installation. As a result, following curtainwall installation, every framing span/cantilever, connection, and anchor required inspection for the entire project. Subsequently, many conditions were outside of the tolerance of the engineering requirements and required field modifications.

The delegated-design engineer was solely focused on the structural performance of the curtainwall without an understanding

Figure 3. *Excessive deflection of twin-span unitized curtainwall during erection.*

of the unit fabrication and erection layout, building features, and the corresponding structural movements and thermal expansion/contraction. Additionally, because the installer failed to coordinate between the installation and engineering requirements, field conditions did not meet the engineering requirements. Extensive repair design and field alterations were required to remediate the curtainwall system, which led to significant project cost and schedule overruns. This resulted in an unvetted, custom system that no longer resembled the standardized manufacturer system (that met the project requirements), and the curtainwall aesthetics did not meet the architect's and owner's desired intent for an integrated aesthetic of the master-planned business district. This case study serves as an example that delegated designers are responsible for the overall system design. The lack of coordination between the installer and its delegated designer can result in design deficiencies and construction defects that fail to meet the design intent.

SAMPLE STUDY 1: TRANSPORT AND INSTALLATION

In addition to design considerations for shop fabrication and field installation, the process of transportation, handling, and erection may also impact the delegated design of prefabricated building enclosure systems. For example, twin-span precast unitized curtainwall undergoes significant loading during transport and erection (**Fig. 3**). These loads can result in excessive deflections that can cause permanent deformation or breakage of the unit's components.

For architectural precast concrete and other large, unitized components (such as mega panels), the engineered panel size and layout must be coordinated with the erection methods, including crane capacity. Crane weight limitations may limit panel shapes and sizes, which can impact the overall aesthetic; therefore, coordination is necessary before the finalization of the delegated design. Another aspect commonly requiring delegated-design coordination is for installation of other adjacent systems. For example, large structural elements such as continuous concrete shear walls that bypass several floor and column lines will obstruct access for installation of the interior continuous-insulation and air-barrier systems. Also, the placement of panel structural connections should undergo review prior to finalizing the delegated design. Often, the delegated designer is more focused on the constructability and structural performance of the system and less concerned with the impact on the air- and water-management performance. Therefore, if not coordinated properly, flashing or integration between systems may be negatively impacted. A common example is with perimeter dual-joint sealants that are obstructed or discontinuous as a result of structural embed or connection placement. These examples illustrate that while delegate designers are not part of the design team, their designs still require coordination with the overall design.

SAMPLE STUDY 2: ROOF DECKS

During standard planned reroofing operations of a major hospital campus in the Texas Medical Center, review of the existing roof deck confirmed that while the new roof system was a manufacturer-tested assembly complying with the latest code-required wind-uplift pressures, the existing roof deck, which had been in place for over 50 years, was unable to meet the same requirements. Further engineering review confirmed that the metal roof decks throughout the campus required significant modification to accommodate the increased uplift capacity of modern codes; however, many of the roofs had already undergone replacement in the recent past. As a result, retrofit of the existing roofs at metal roof deck locations was required to enhance the roof deck capacity at corner and sometimes perimeter zones. On another Texas Medical Center reroof project, an evaluation for the removal of abandoned rooftop equipment confirmed that the incorporation of so many rooftop penetrations had compromised the shear diaphragm capacity of the roof deck. The evaluation also revealed significant areas of roof deck corrosion requiring replacement. The result was complete roof deck replacement and additional support at corner and perimeter zones, significantly impacting the overall project scope, budget, schedule, and hospital operations. These projects serve as a lesson learned that routine maintenance should include an engineer review to ensure that the roof deck or components supporting the roof system are able to meet the increased demands of modern building codes (and insurance requirements).

RECOMMENDATIONS

The following provisions, when properly coordinated and integrated with the project scope, have proven successful to mitigating delegated-design disasters.

1. Include building enclosure commissioning within the project scope from the conceptual design phase forward.
2. Incorporate specialty engineering design peer review for complex building enclosure delegated designs.
3. Perform third-party special inspections at the fabrication facility and in the field to support installer quality control and quality assurance (if not already required by the authority having jurisdiction).

Incorporate the following project requirements to ensure that the delegated

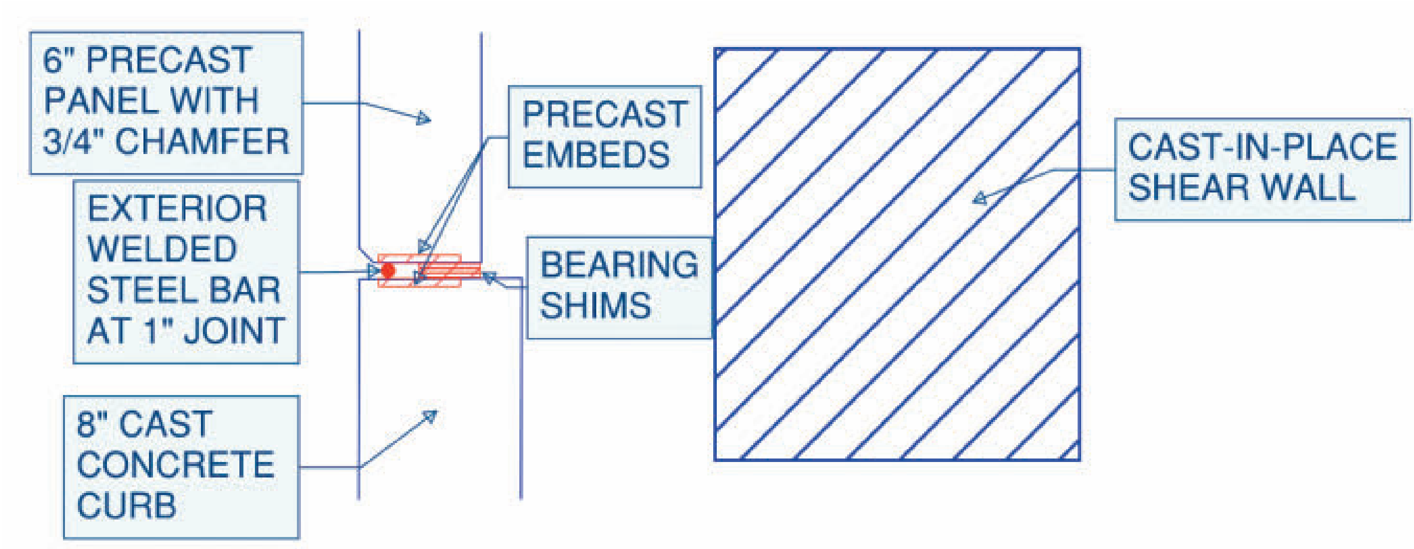

Figure 4. *Excessive deflection of twin-span unitized curtainwall during erection.*

design is comprehensive and coordinated with the other project requirements.

1. Loads: In addition to dead, wind, seismic, and other project-in-service loads, include the following:
    a. Transport- and erection-load analysis reflecting dynamic transport and erection methods
    b. Maintenance loads including at intermittent stabilization anchors and along horizontal projecting elements (such as sunshades)
    c. Sufficient load transfer and accommodation of movement across movement/expansion joints
    d. Inclusion of associated requirements, such as those for supplemental framing
2. Delegated-design engineering package: Professional engineer–sealed, coordinated, and comprehensive set, including structural calculations (framing, glazing, and structural-sealant glazing), shop-fabrication drawings and instruction, and field-elevation panelized layout and installation instructions. The field-elevation panelized layout should include the outline of each panel (single span, twin span, spliced-multiple wide units, etc.), dead-load and live-load anchor locations, clear indication for each starter and stack joint locations, etc.).
3. Delegated-design requirements: Coordination with other performance requirements, including but not limited to the following:
    a. Structural-engineering movements (creep, dead loads, live loads, etc.)
    b. Structural-engineering or wind-tunnel components and cladding pressures
    c. Review of complete and final delegated design to ensure system meets specified requirements (water management, air management, thermal, energy, fire, sound, etc.).
    d. For existing buildings, confirmation of as-built construction with updated code-required loads and associated requirements (area of openings, projectile risk, increased loads/pressures, etc.)
4. Manufacturer's certification letter: Project-specific letter from the manufacturer (framing, glazing/infill system, structural-sealant glazing, etc.) certifying their review of the delegated-design engineering package to ensure that the system will meet the specified project requirements.
5. Site-inspection requirements for existing buildings:
    a. Confirmation of as-built construction
    b. Confirmation of existing conditions (distress, damage, etc.)
    c. Evaluation of as-built, existing capacity and coordination with requirements (including additional requirements such as shear diaphragm, shear walls, etc.)

Finally, during construction, include the following provisions.

1. Delegated-design meeting(s): Between the delegated-design team (specialty trade/installer and their engineer), owner, general contractor, structural engineer, architect, building enclosure consultant (prior to fabrication), and related manufacturers.
2. Field-erection set: Provide a set of field-installation/erection drawings that include the actual layout, dimensions, spans, anchor types, anchor requirements. The set should include the following:
    a. Maximum spans and cantilever framing lengths (anchor to stack/parapet/soffit hang-down, etc.) per system type/component type
    b. Connection requirements, including maximum eccentricity (of anchors/hooks), maximum shim depth/height, etc., for each connection and/or anchor (embedded versus field installed) type
    c. Fastener requirements, including minimum edge distances, minimum embedment depths, required torque, minimum thread engagement, etc.
    d. Allowable field modifications (such as cutting of lifting lugs) to accommodate setting of units
3. Quality control and quality assurance: Pre-fabrication laboratory performance mockup testing for custom or modified standard systems:
    a. Shop-fabrication inspections, including compliance with manufacturer's requirements
    b. Field verification of structural dimensions prior to installation (spans, embed locations, etc.)
    c Pre-setting inspection of units (for proper unit fabrication and confirming no damage)

  d Post-setting inspection of units (for proper integration between units, stack/starter seal installation, etc.)
  e. Fastener inspections to ensure compliance with requirements
  f. Field air-infiltration and water-penetration testing
4. As-built set: Provide as-built record set, including all field fixes and supporting documents.

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Credentials: No Free Rides

Editor's Note: This column from IIBEC Past President Richard Canon originally appeared in the June 1987 issue of IIBEC Interface. *It shows the organization's historical commitment to its credentialing programs. While much of IIBEC's history is roofing-centric—this article emphasizes IIBEC's (then RCI's) first certification, the Certified Roof Consultant, now called the Registered Roof Consultant (RRC®)—a key part of the group's expansion of its mission to encompass the full building enclosure has extended to IIBEC's numerous credential programs spanning exterior walls, waterproofing, and building enclosure commissioning. The CBECxP®, or Certified Building Enclosure Commissioning Provider, is IIBEC's newest certification program. (In May of 2023 IIBEC celebrated its first class of CBECxP certifications.) Canon's column is a reminder that credentials continue to be a key component in increasing IIBEC's visibility and respect among the building enclosure industry.*

By Richard P. Canon, PE
RCI Past President (1985-1986)

WHEN I WAS about 11 years old my brother and I were given a Soap Box Derby car—one of those classic stream-lined kinds from the 1940s and '50s. We called it the Silver Streak. It had been built by a man named Herbert Yates, who worked for my dad. We used to push that heavy contraption up Granny Smith T's Hill in Opelika, Alabama, jump aboard, and ride that little wooden car down the hill like a bat out of hell—until we ran out of hill. Back up we would go, huffing and puffing until we reached the top again, and then back down.

We worked mighty hard pushing the Silver Streak up hills. Nobody could ride the Silver Streak unless they did their share of the work. Work your tum or just watch with envy as the Silver Streak cut the air racing down Granny Smith T's Hill. There were no free rides on the Streak.

YOU HAVE TO EARN IT

I learned in the years that followed that you did not wear an eagle on your Scout uniform unless you *earned* 21 merit badges. You did not get to wear the Scout's Mile Swim Badge unless you had fought the 5,208 feet (or 74,360 inches) of water, one stroke at a time. You did not get a degree from college or registration as an engineer or architect until you served your time, learned from others, made some mistakes, and passed some tests. Then and only then could you carry the title of professional engineer or registered architect.

And then I woke up one morning, many years later, after a lot of experience in highway

Richard Canon

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construction, the military service, and structural engineering and found that my new job title was not downhill racer, Eagle Scout, mile swimmer, college graduate, or structural engineer.

I was a roof consultant!

This new title—roof consultant—did not always represent what one would call an elite group. We were a mixture of "ex"es: ex-roof material salesmen; ex-roof material distributors; ex-construction specifiers; ex-structural, mechanical, chemical, electrical, and industrial engineers; ex-architects; and dozens of other varieties.

We also had a group of "still are but gonna diversify"ers and a final group who represented what I'll call "sigmas," a Greek word sometimes meaning "the summation," or in Latin, "et al.," meaning "and everybody else who wants in on the action."

THE CERTIFIED ROOF CONSULTANT

The problem with all of this is that although there is a profession called roof consulting, there is no distinction between "one who is" and "one who ain't." Which is to say, in the past there was no distinction, but there soon will be! And this, my friends, brings us to the Certified Roof Consultant.

From the first meeting of the Roof Consultants Institute (RCI) to this day, a common complaint among bona fide, experienced, and qualified roof consultants has been that there is no distinction between a fast-talking charlatan or crooked snake oil salesman and the legitimate professional roof consultant. What can be done to protect the honest consultant? Where will this profession wind up if something is not done to curb the runaway misuse of the title of roof consultant?

I am pleased to report to you that the first examination for certification of roof consultants was administered by RCI at its annual convention in Orlando, Florida, on March 23, 1987.

To recap the procedure, only Qualified Professional and Industry Members may sit for the closed-book exam. This examination is the second part of a two-part certification program. The first part is documentation of the applicant's education and/or work experience. This documentation procedure was presented at the 1987 convention for a vote during the annual meeting.

All-in-all, we have come a very long way in a relatively brief period of time. We still have years of work ahead of us to implement recognition of the certification program by governmental agencies and in the private sector. But to become a Certified Roof Consultant will require work. Just like riding the Silver Streak, you can only enjoy the pleasure and benefits if you exert personal effort, work, and labor. There will be no free rides to certification, no grandfathering, no giveaways.

We need your support in this endeavor. Please be a positive force in helping us to help you. There are enough negative forces out there against us now. You too can make *the difference*. Become a Certified Roof Consultant.

They *are* the difference.