Feature

Advancing Sustainable Roof Restoration: Enhancing Roof Re-Covers with Embodied Carbon Analysis and Innovative Material Choices

By Milirsan Pugalendiran, RRO, PEng, and Michelle Christopherson, DipT, ENV SP

WHILE THE BUILDING industry's sustainability discourse has increasingly focused on new construction, a significant opportunity lies quietly in the vast inventory of existing buildings. Roof re-covering—which focuses on membrane replacement rather than full-system tear-off and replacement—is a well-established strategy for extending roof life and reducing waste. The authors aimed to take this approach further by integrating detailed embodied carbon calculations and optimizing material selection to maximize environmental and economic benefits.

Large-scale industrial or warehouse buildings were prime candidates (**Fig. 1**) to explore optimized roof re-covering strategies. These roof-centric assets have long service lives, but their roofs have relatively short service lives, with roof replacements or renewals required roughly every 20 years (depending on the membrane system). Traditional practices often default to full-roof replacement, resulting in disposal of large volumes of otherwise serviceable insulation and cover board materials, and the associated environmental impact. The enhanced roof re-covering methodology challenges this assumption by focusing on membrane renewal and selective replacement, supported by condition assessments and life-cycle assessments focused on embodied carbon reduction.

What makes this approach both technically robust and replicable is its reliance on conventional materials and assemblies, which ensures contractor familiarity, competitive bidding, and long-term membrane performance. Beyond sustainability, this approach can also align with owners' financial and operational goals. Restoration projects typically yield construction cost savings of 20 to 25% and schedule reductions of up to 50 weeks, often with minimal disruption to continuous building

Figure 1. *Existing industrial building built-up roof system.*

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operations—a crucial consideration in industrial facilities that typically operate 24 hours a day, 7 days a week.

The process begins with a comprehensive feasibility study, including a drone infrared thermography scan, targeted test cuts, and on-site moisture meter readings. These diagnostics determine the salvageability of concealed components, allowing us to identify saturated or deteriorated areas for localized replacement. In these cases, the insulation and substrate remain largely intact, existing components are retained, and a new membrane (that is, a two-ply modified bitumen membrane) is installed. Roof re-cover may not be feasible if the roof was not reasonably maintained and substantial amounts of wet components were identified.

Key engineering concerns are carefully managed throughout the design process. Air and vapor barrier discontinuities at penetrations, perimeters, and expansion joints are addressed through localized roof replacement to tie in a new air and vapour barrier. In Canada, roof systems that consist of new roofing components must be tested to CSA 123.21[1] for uplift resistance; however, roof re-cover systems incorporate both old and new roof components with an assembly composition that may not match pretested systems. Engineering judgement, by a qualified engineer, may be required to determine appropriate mechanical fastener and adhesive spacing for wind uplift. As part of the design, existing roofing components are all mechanically fastened so as to not rely on the existing securement system that may be compromised while removing the existing membrane. Fastener lengths and underdeck conduit mapping are specified to avoid contact with conduits beneath steel decks—a critical consideration in active industrial environments. Test openings are created at thermal anomaly locations to measure moisture content (>5%) for future replacement (**Fig. 2**) and to also review the underlying steel decks for repairs as necessary.

The environmental benefits of roof re-covering are quantifiable. To assist with embodied carbon calculations, an Excel-based calculator was created with available manufacturer-specific environmental product declarations (EPDs). At one of our past roof re-cover projects, a building with 74,322 m^2 (800,000 ft^2) of roof area achieved an estimated 310 tonnes (~342 tons) of carbon dioxide–equivalent (CO_2 eq) savings and diverted approximately 400 tonnes (441 tons) of material from landfills, based on an assumed 60-year study period. We completed a total of approximately 195,096 m^2 (2.1 million ft^2) of roof re-cover projects to date, with each project executed under this enhanced roof re-cover model demonstrating embodied carbon reductions of 28% or more compared to full replacements. Based on extrapolation, we estimate that our roof re-cover projects have saved over 1,800 tonnes (~1,984 ton) of CO_2 eq emissions and diverted nearly 2,000 tonnes (2,205 tons) of waste.

Figure 2. *Existing built-up roof membrane removed and localized "wet" insulation being replaced.*

CASE STUDY: QUANTIFYING IMPACT ON A LARGE INDUSTRIAL WAREHOUSE

To further validate and refine these principles, we undertook a comprehensive embodied carbon study for a significant project: a large, one-story industrial warehouse facility with an approximate roof area of 99,964 m^2 (1,076,000 ft^2). The existing conventional built-up roof system was at the end of its service life. The cradle-to-grave embodied carbon assessment aligned with the National Research Council Canada's *National Whole-Building Life Cycle Assessment Practitioner's Guide*[2] and primarily leveraged product-specific EPDs. The study evaluated three distinct roofing restoration scenarios over a 60-year study period:

- **Scenario 1 (Roof Replacement [Baseline]):** This represented a typical full-roof-system replacement with a new two-ply modified bitumen system, including new insulation and an air and vapor barrier. This scenario assumed two additional full replacements over the 60-year study period.
- **Scenario 2 (Roof Re-Cover/Renewal):** This involved removing only the existing multi-ply membrane while retaining the existing overlay fiberboard, insulation, and vapor retarder. The existing membrane is to be removed and replaced with a two-ply modified bitumen membrane and two new 6.35 mm (0.25 in.) asphaltic overlay boards—the first layer mechanically fastened to separate the new and old system and the second adhered to reduce risks with fastener backout below the membrane. Crucially, this scenario incorporated a "resurfacing" strategy for subsequent roof renewal cycles, where only a one-ply cap sheet membrane would be installed at 20-year cycles, with no further material removal, significantly reducing future impacts. One initial roof re-cover and two resurfacings were assumed over 60 years. It should be noted warranty options are available with select manufacturers.

TABLE 1. Embodied carbon calculation summary from the 60-year case study (Note: CO_2 eq = carbon dioxide equivalent)

	Roof replacement (baseline)	Roof re-covering/ renewal	Roof re-covering/ renewal V.2
Up-front embodied carbon emissions (life-cycle modules A1–A5)			
Embodied carbon intensity—~kg CO_2 eq/m² (~lb CO_2 eq)	20.5 (45)	19 (42)	15.5 (34)
Embodied carbon—~kg CO_2 eq (~lb CO_2 eq)	~2,020,000 (~4,450,000)	~1,880,000 (~4,140,000)	~1,520,000 (~3,350,000)
Embodied carbon savings compared to roof replacement—~%	N/A	7%	24%
Full-life-cycle embodied carbon emissions (life-cycle stages A–C)			
Embodied carbon intensity—~kg CO_2 eq/m² (~lb CO_2 eq)	61 (134)	27.5 (61)	24 (53)
Embodied carbon—~kg CO_2 eq (~lb CO_2 eq)	~6,060,000 (~13,360,000)	~2,720,000 (~6,000,000)	~2,360,000 (~5,200,000)
Embodied carbon savings compared to roof replacement—~%	N/A	55%	61%

- **Scenario 3 (Roof Re-Cover/Renewal V.2 [Embodied Carbon Optimized]):** Similar to Scenario 2 in its re-cover approach, this scenario specifically selected lower-embodied-carbon materials. Instead of two layers of asphaltic board, it specified a base sheet membrane panel (a membrane laminated onto an asphaltic board) and a 6.35 mm (0.25 in.) gypsum overlay board. This scenario also assumed one initial re-cover with optimized materials and two subsequent resurfacings over 60 years. Similar to Scenario 2, warranty options are available with select manufacturers.

The results from this large industrial warehouse study provided powerful validation.

Embodied Carbon and Waste Reduction: Compared to the baseline full-roof replacement (Scenario 1), the roof re-cover options demonstrated significant embodied carbon savings (also see **Table 1**):

- **Up-Front (Initial Restoration) Carbon Savings:**
  Scenario 2 (Roof Re-Cover/Renewal): A **7%** reduction in up-front (life-cycle modules A1–A5) embodied carbon (from ~2,020,000 kg CO_2 eq [4,453,338 lb CO_2 eq] to ~1,880,000 kg CO_2 eq (4,144,691 lb CO_2 eq]). Notably, the study revealed that these initial savings were not as high as initially expected, primarily due to the relatively high embodied carbon content of the multiple asphaltic overlay boards.
  Scenario 3 (Optimized Roof Re-Cover/ Renewal V.2): A **24%** reduction in up-front (life-cycle modules A1–A5) embodied carbon (to ~1,520,000 kg CO_2 eq [3,351,026 lb CO_2 eq]). Most of the up-front embodied carbon savings (~90%) was from the base sheet panel, with the gypsum board providing lower embodied carbon savings (~10%).
- **Full-Life-Cycle (60-Year Study Period) Carbon Savings:**
  Scenario 2 achieved a **55%** reduction in embodied carbon (from ~6,060,000 kg CO_2 eq [13,360,012 lb CO_2 eq] to ~2,720,000 kg CO_2 eq [5,996,574 lb CO_2 eq]).
  Scenario 3, with its optimized material choices, delivered an even greater **61%** reduction (to ~2,360,000 kg CO_2 eq [5,202,909 lb CO_2 eq]). This was largely driven by the "resurfacing" strategy for future cycles, which resulted in a **75%** embodied carbon intensity reduction compared to repeated full replacements.
- **Avoided Waste:** Both re-cover scenarios (2 and 3) diverted approximately **480 tonnes** (529 tons) of up-front construction waste from landfills. Over the full 60-year life cycle, this figure soared to an estimated 4,200 tonnes (4,630 tons) of waste diverted.

Unexpected Cost Savings: Taking these principles further, we applied embodied carbon optimization on a large industrial warehouse roof by developing an alternate design that prioritized lower-embodied-carbon materials with EPDs. Instead of the typical two layers of asphaltic board, the design specified a base sheet panel—a membrane laminated onto an asphaltic board—for the first layer and roof-grade gypsum board replacing the second asphaltic board layer (scenario 3). The base sheet panel and gypsum board both have a higher material cost compared to their base sheet membrane and asphaltic board counterparts.

All three design scenarios were tendered (bid) to six contractors across three warehouse buildings, including the building reviewed for the aforementioned embodied carbon calculations. Contrary to the initial expectation that these lower-embodied-carbon materials might increase overall construction cost, contractor bids collectively reflected significant project cost savings compared to the base design. Tender results of the project are summarized below and in **Table 2:**

- **Scenario 2 (Roof Re-Cover/Renewal):** Achieved approximately **22 to 23%** project cost savings compared to full replacement.
- **Scenario 3 (Roof Re-Cover/Renewal V.2 [Embodied Carbon Optimized]):** Delivered even greater savings, ranging from **23 to 25%.**

Discussions with contractors provided key insights into these unexpected overall savings passed on to the client:

- **Economies of Scale:** The vast roof area enabled contractors to secure more competitive pricing from manufacturers and suppliers due to large material quantities.
- **Material Dimensions and Labor Efficiency:** The larger dimensions of the base sheet membrane panels (3 ft × 8 ft) and gypsum boards (4 ft × 8 ft) compared to

TABLE 2. Tender (bid) results summary

	Building 1	Building 2	Building 3
Roof area m² (ft²)	39,019 (420,000)	50,725 (546,000)	99,964 1,076,000
Roof re-covering project cost savings compared to roof replacement (~%)	22%	22.7%	22%
Roof re-covering V.2 project cost savings compared to roof replacement (~%)	24%	23.2%	25%

standard 4 ft × 5 ft asphaltic overlay boards significantly reduced labor time, especially on a largely unobstructed roof with a low number of penetrations. This enhanced labor efficiency proved to be the primary factor contributing to the reduced total project cost, effectively offsetting any higher per-unit material costs.

The tender results highlight the importance of considering both material and labor cost when making material substitutions related to embodied carbon or other reasons. Substitutions for lower-embodied-carbon results may result in a material cost increase; however, there may be labor cost savings that are not being recognized. The owner decided to proceed with Scenario 3 for the embodied carbon, schedule, and cost savings with Phase 1 of construction wrapping up for November 2025 (**Fig. 3**).

This experience underscores that including sustainability objectives into design and procurement can deliver environmental benefits without increasing total project costs. It challenges the perception that lower-embodied-carbon materials necessarily entail premium pricing, reaffirming roof re-cover as a practical and impactful strategy for embodied carbon reduction.

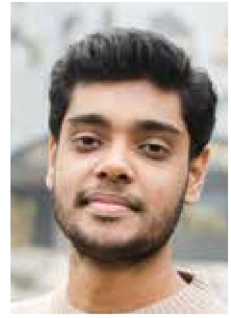
The case for roof renewal is well-established and growing. The analysis shows that embodied carbon savings in retrofit roof re-covering can rival those promoted in new construction. This project/study provides a gateway for consultants to run carbon calculations on other roofing systems, explore how adding insulation may affect results, or expand the study to life-cycle assessment modules not included in this study. As policy focus eventually shifts towards existing buildings, strategies like these will be central to meeting carbon targets. The industry would do well to recognize that improving and restoring existing roofs offers one of the most meaningful opportunities for sustainable progress.

REFERENCES

1. CSA Group. 2020. *Standard Test Method for the Dynamic Wind Uplift Resistance of Membrane-Roofing Systems.* CSA A123.21:20. Ottawa, ON: CSA Group.
2. National Research Council Canada (NRCC). 2024. *National Whole-Building Life Cycle Assessment Practitioner's Guide.* Ottawa, ON: NRCC.

Figure 3. *New roof re-cover system installed.*

ABOUT THE AUTHORS



MILIRSAN PUGALENDIRAN, RRO, PENG

Milirsan Pugalendiran *is a project manager and building envelope engineer with WSP Canada Inc. He specializes in the investigation, design, and rehabilitation of building enclosure systems with a focus on sustainable renewal strategies that balance performance, durability, and embodied carbon considerations. Pugalendiran is a licensed professional engineer in multiple Canadian provinces and a Registered Roof Observer. He is actively involved in industry development and currently serves on IIBEC's Region VII Education Committee and Canadian Sub-Advocacy Committee, as well as on the Building Science Association of Ontario's Codes and Standards Committee.*

MICHELLE CHRISTOPHERSON, DIPT, ENV SP

Michelle Christopherson *is the national lead for embodied carbon at WSP Canada Inc. With a background in building science and sustainable design and infrastructure, she leads initiatives that integrate embodied carbon reduction strategies across WSP's buildings and infrastructure projects nationwide. Christopherson is passionate about advancing low-carbon practices and demonstrating the long-term environmental and economic value of both new construction and restoration projects in the built environment. She currently serves on the Embodied Carbon Technical Advisory Group for the Canada Green Building Council (CAGBC) and contributed to the development of CAGBC's new Zero Carbon Building—Design Standard.*

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