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Material use and embodied GHG in renovation, retrofit, refurbishment, and adaptive reuse of existing buildings

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Summary

This study investigates material use, material intensity (MI), and embodied greenhouse gas (GHG) emissions in five real refurbishment, renovation, and adaptive reuse projects in Canada and the U.S. Unlike most existing research, which focuses on new construction or energy efficiency retrofits, this work quantifies detailed material flows: demolished, retained, and newly added for renovation/refurbishments of existing buildings. Across the five projects, 60–98% of original structural mass was retained, demonstrating the significance of existing buildings as material reservoirs. New additions generally used lighter assemblies, with some projects reducing whole-building MI by up to 42%. Expansions required substantial new inputs, while conversions with minimal structural work (e.g., office to residential) involved almost no net mass increase. Structural components dominated material mass and embodied GHG across all cases, while interior finishes contributed comparatively little.

Despite strong material retention, all final buildings exhibited higher embodied GHG emissions than their original states, with increases ranging from 1% to 60%. This reflects the carbon intensity of new materials - especially insulation, openings, and concrete - despite their varying mass contributions. The study provides a first-of-its-kind dataset for understanding material flows into existing buildings and highlights the need for broader research on this aspect of the AEC sector.

Key Takeaways:

Material retention is consistently high, making refurbishment an effective strategy for conserving structural mass. Even in major expansions, more than half of existing material stock remained in place, highlighting the resource-efficiency proposition of upgrading existing structures

Material intensity does not necessarily rise with increased floor area. In several cases, expansions used lighter, more efficient assemblies, reducing overall MI despite added mass.

Embodied GHG emissions almost always increase, even when MI decreases. Lightweight materials such as insulation, windows, and moisture-protection systems often carry high carbon intensities, meaning even these smaller quantities create significant carbon inputs. As a result, all refurbished buildings ended with higher embodied GHG than the originals.

Renovation impacts vary widely, shaped by building type, age, scope of intervention, and structural system. Conversions with little structural work required minimal material additions, whereas structural rehabilitations or expansions generated substantial new material demand.

Collectively, these insights highlight that refurbishment is materially efficient but not automatically low carbon, underscoring the need for careful material selection, consideration of functional changes, and attention to long-term durability. Detailed attention is needed to better understand the heterogeneity of material inputs into existing buildings.

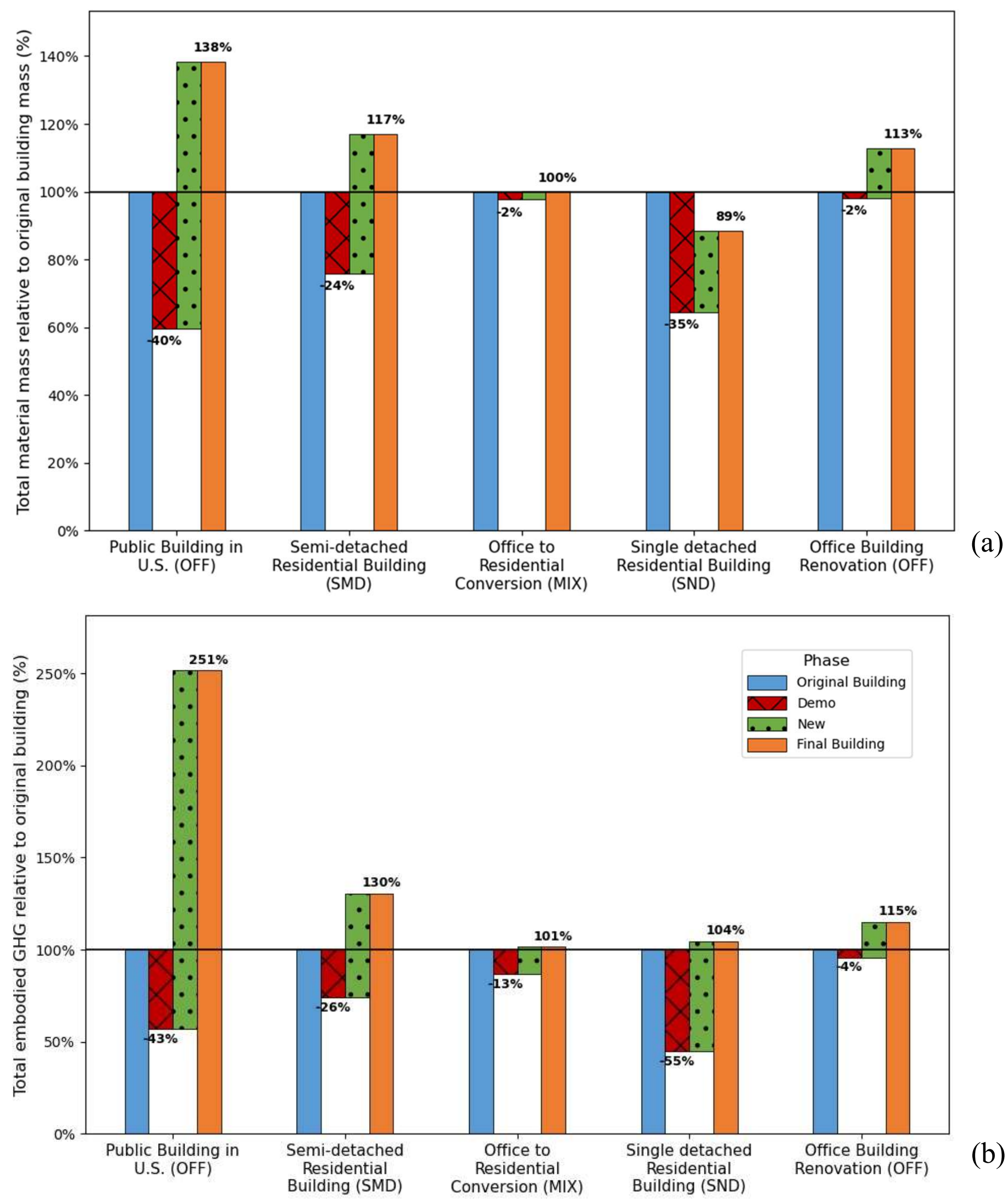

Figure 1. (a) Relative material use, and **(b)** Relative embodied GHG by phase across five case studies (original mass = 100%). Phases: Original (reference), Demolition (negative), New (positive), Final (resulting total).