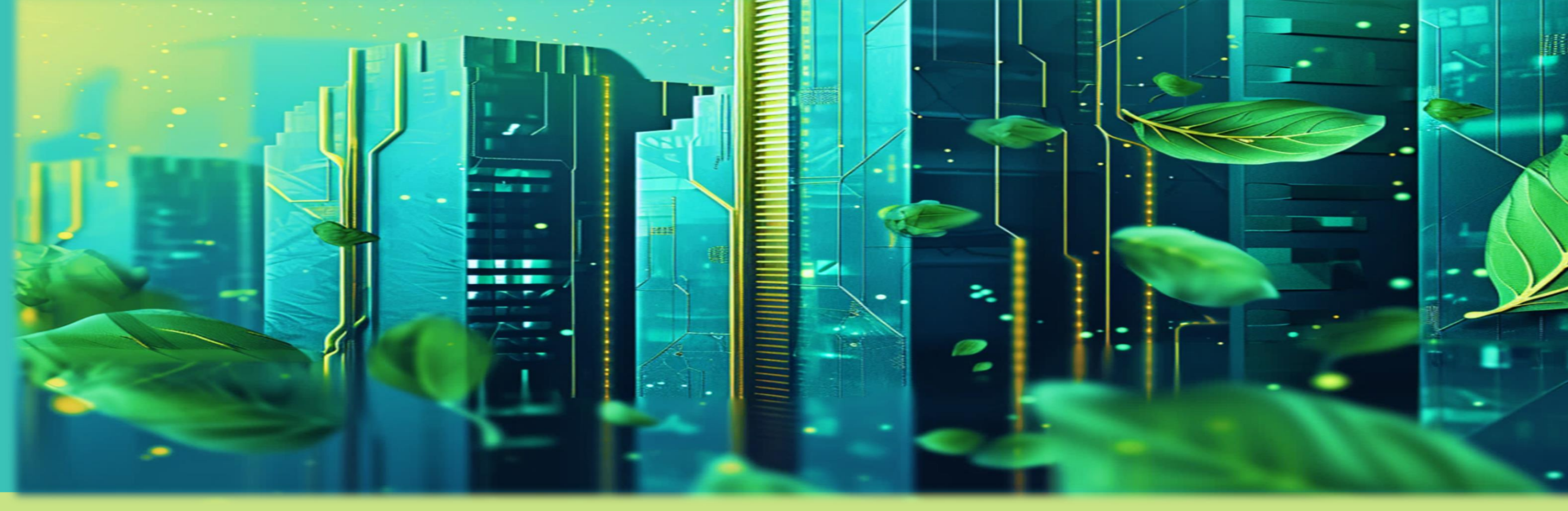
Advancing Sustainable Construction: Bio-based Insulation Materials for Eco-friendly Building Envelopes, Canada



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Abstract

Mitigating the life-cycle carbon emissions of building materials is key to reducing the construction industry's environmental impact, one of the highest-emitting sectors. While enhancing operational efficiency often increases the demand for fossil fuel-derived insulation, achieving net-zero buildings requires addressing both operational and embodied carbon emissions. In Canada, carbon storage insulation presents a promising sustainable option. This study conducts a comparative life cycle assessment (LCA) of three insulation materials for a hypothetical Calgary office building using One Click LCA, focusing on hemp fibre insulation's greenhouse gas (GHG) emissions relative to commonly used materials. The research also explores policy strategies for calculating embodied carbon to improve early design decisions, emphasizing the importance of harmonizing Product Category Rules (PCRs) and standardizing Environmental Product Declarations (EPDs) to enhance the reliability of LCA results.

Purpose of the Study

Objective 1: Investigate the result and methodology of comparative life cycle assessments of insulations. Determine if bio-based insulation materials generally show superior environmental benefits compared to conventional options based on the reviewed LCAs. Identify knowledge gaps and challenges.

Objective 2 Explore available Environmental Product Declarations (EPDs) for insulation products in North America to identify bio-based insulation currently used in commercial buildings in Canada.

Objective 3: Conduct an LCA for some selected insulation materials using One Click LCA, and after that identify challenges in assessing their environmental life cycle, highlighting the key roles of harmonized EPDs in ensuring accurate environmental evaluation.

Objective 4: Identify the policy role in encouraging greater adoption of lower-impact materials by promoting life cycle thinking in the construction sector.

This research project's goal & objective align with the UN Sustainable Development Goals

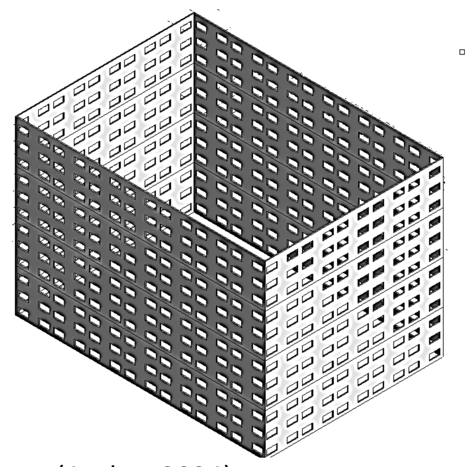
Research Questions

1. What factors are involved in considering an insulation, environmentally friendly?
2. What bio-based insulation materials have been used in commercial buildings in Canada?
3. What are the main challenges in evaluating the environmental impacts of bio-based insulation materials in North America?
4. What are the roles of Environmental Product Declarations (EPDs) in effectively conducting comparison life cycle assessment?
5. What role do policies play in informing material choices, and how can awareness of bio-based insulation materials in building envelopes be increased?

Methods

This LCA study compares CO2 emissions from three mineral-based and fossil fuel-based insulation materials (glass wool, stone wool, EPS, and PIR) with plant-based hemp fibre insulation. The comparison is for a typical commercial wall in a hypothetical office building with a steel frame and a 20% window-to-wall ratio over a 60-year service life. The building is assumed to have a gross floor area of 42,000 m^2 in Alberta's Zone 7A. The assessment will be performed using One Click LCA software, adhering to standards EN 15978, EN 15804, ISO 14040, ISO 14044, and ISO 21929. The system boundary covers stages A1-A5 (production and construction) and stages C1-C4 (end-of-life). Data is sourced from the One Click LCA database, with the functional unit defined as 1 kg.

Note. A modular 10 x 4 m² wall is considered and it is assumed that the ratio of window to wall is considered 20%.



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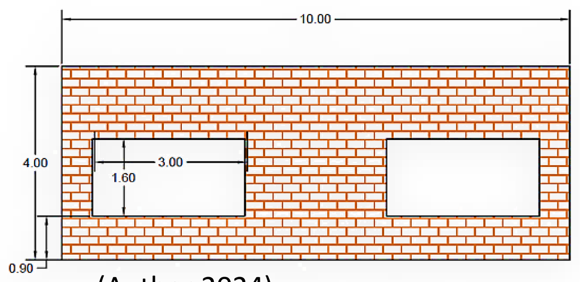

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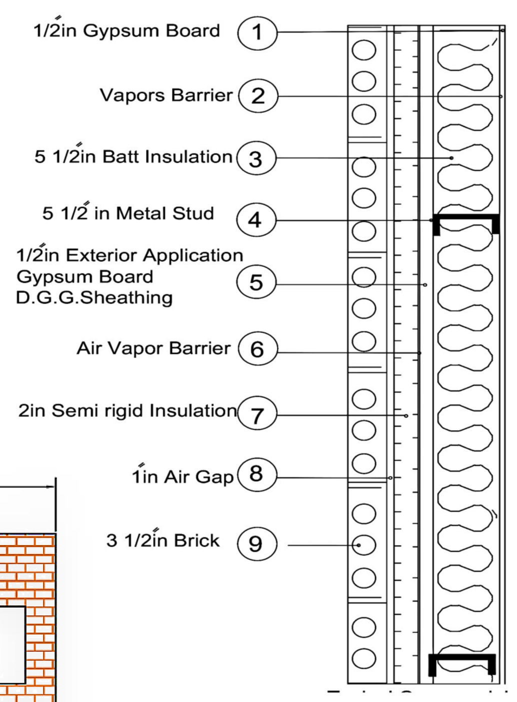


(Zahed,2024)

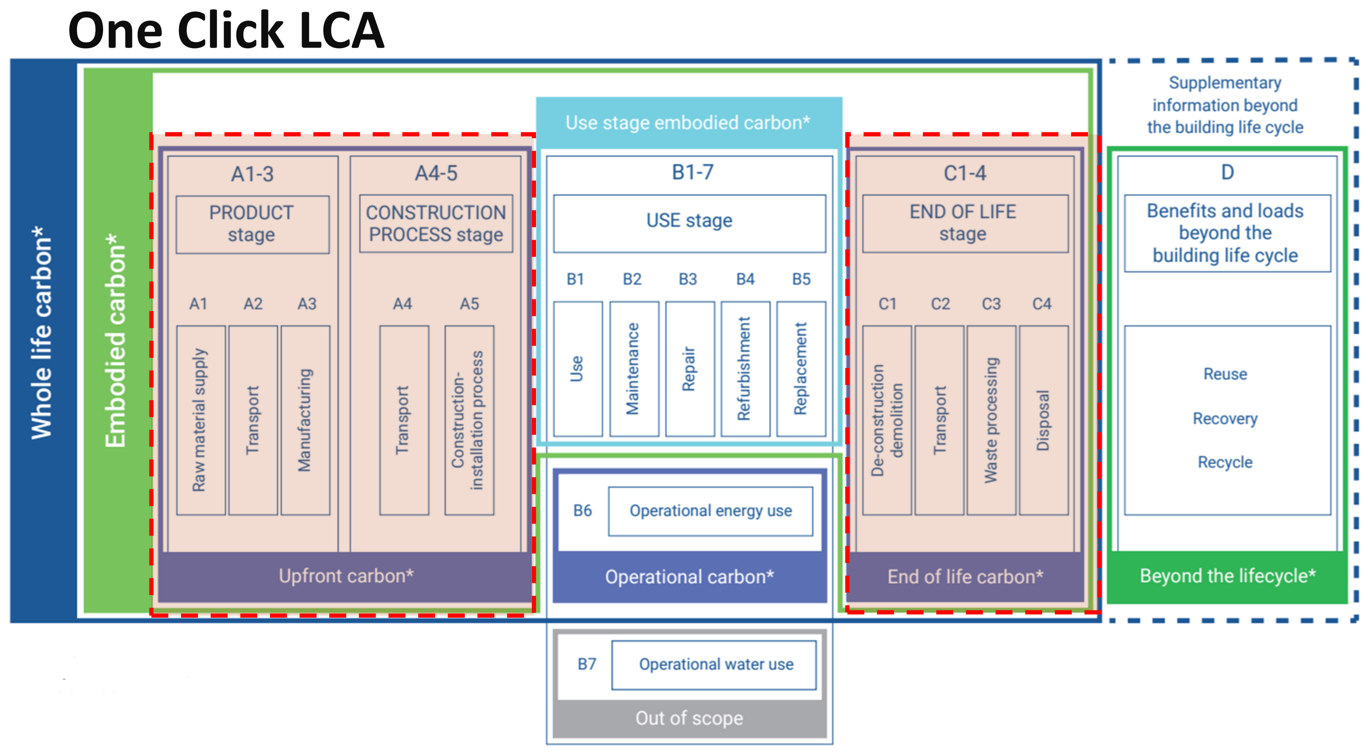
- **Assessing the thermal characteristic of each insulation in the typical commercial wall assembly**

	R-Value (m2·K)/W) in 100mm Thickness	Max U value for walls: 0.215 Zone7A:(2) 5000 to 5999
Option 1 (Glass Wool)	2.94	≈0.199
Option2 (Stone Wool)	3.33	≈0.18
Option3 (EPS)	2.70	≈0.20
Option4 (Hemp Fibre)	2.56	≈0.215
Option 5 (PIR)	4.54	≈0.15

Polyisocyanurate (PIR): Best thermal resistance and lowest heat transfer rate.

Hemp Fibre: Slightly less effective in thermal performance. Still, it can meet the U-Values requirement for Zone 7A.

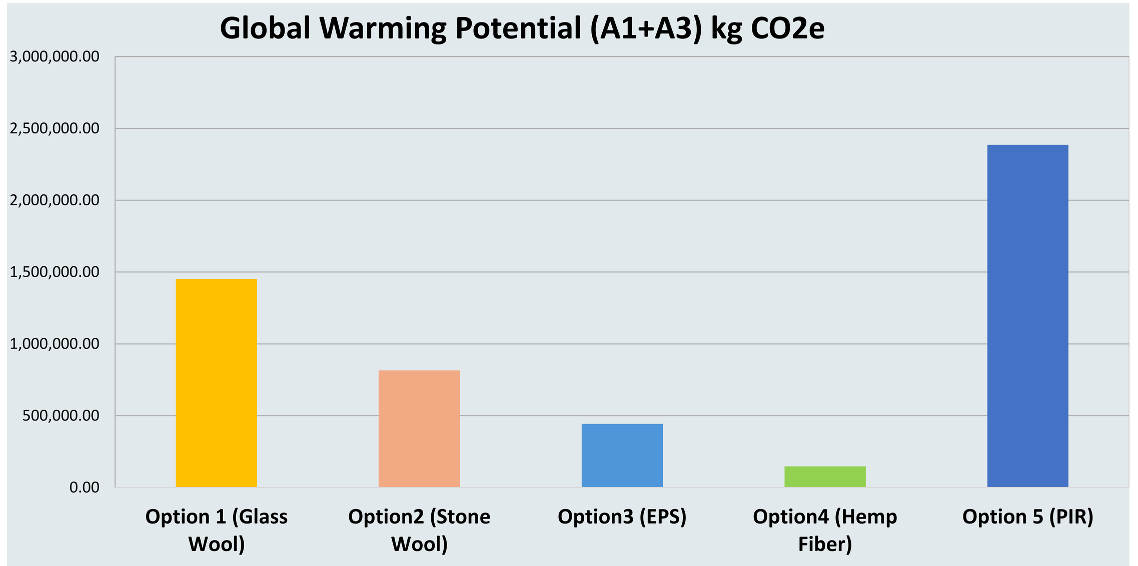
- **Assessing the Global Warming Potential with One Click LCA**

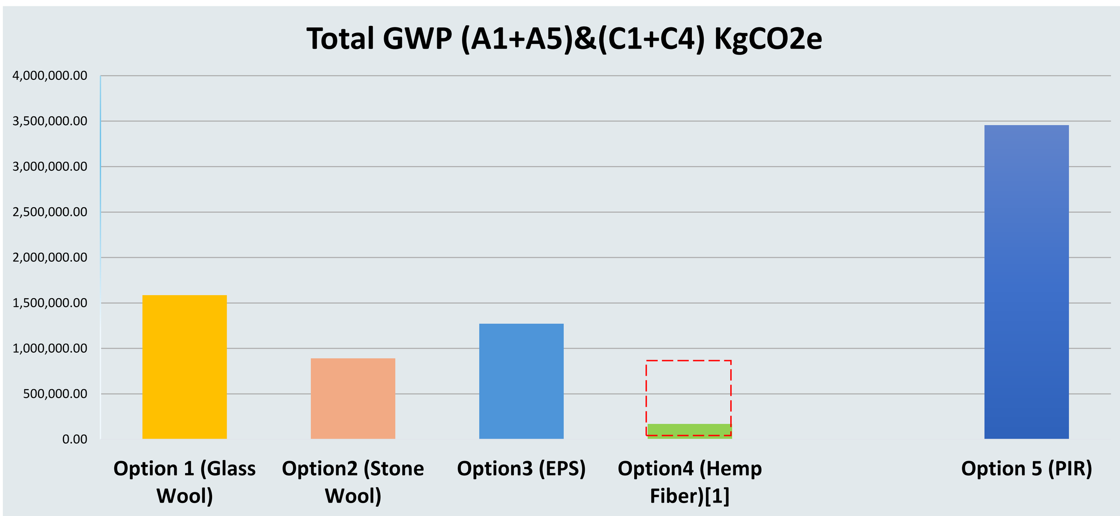


Life Cycle Stages (Eleuterio, 2023)

Options	GWP(A1+A3) kg CO2e	GWP(A4) kg CO2e	GWP(A5) kg CO2e	GWP(C1-C4) kg CO2e	Biogenic Carbon kg CO2e	Total GWP kg CO2e
Option 1 (Glass Wool)	1,452,701.1	10,762.46	117,513.5	5,459.62	-	1,613,846.1
Option2 (Stone Wool)	814,220.63	6,848.86	65,963.5	3,474.31	-	890,507.3
Option3 (EPS)	442,567.97	2,568.32	84,921.14	743,333.12	-	1,273,390.56
Option4 (Hemp Fibre)	146,371.38	9,424.34	12,602.74	1,738.48	432,953.58	170,136.94
Option 5 (PIR)	2,385,182.33		255,957.27	814,283.53	-	3,455,423.12

(Adopted from One Click LCA Assessment,2024)





Recommendations for Zone 7A:

Stone wool, glass wool, and hemp fibre are more balanced material choices for Zone 7A, offering sufficient thermal performance with reduced environmental footprints compared to PIR and EPS.

The study advocates for a transition from carbon-intensive building materials to carbon-storing alternatives. It is important to consider both operational emissions, which are linked to the energy consumption during the building's lifecycle, and embodied emissions, associated with the production, transportation, installation, and disposal of materials. Enhancing the energy efficiency of bio-based insulation can help reduce the global warming potential of buildings.

Future Research

Harmonization of PCRs within insulation material EPDs
Integration of Circular Economy Principles
Development of Data Banks
Multi-Criteria Decision Analysis
Coupling Energy Modeling with LCA

References

Eleuterio, A. (2023, March 1). What is embodied carbon in the real estate sector and why does it matter? GRESB. https://www.gresb.com/nl-en/what-is-embodied-carbon-in-the-real-estate-sector-and-why-does-it-matter/

Phillips, R., Troup, L., Fannon, D., & Eckelman, M. J. (2020). Triple bottom line sustainability assessment of window-to-wall ratio in US office buildings. Building and Environment, 182, 107057. https://doi.org/10.1016/j.buildenv.2020.10705

United Nations. (n.d.). THE 17 GOALS | Sustainable Development. https://sdgs.un.org/goals