abaa2025 building enclosure conference

Air Barrier Embodied Carbon: A Critical Review

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abaa EDUCATION

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Air Barrier Embodied Carbon: A Critical Review

Randy Van Straaten P.Eng

President and Building Science Specialist at Building Enclosure Labs Inc. (BELi) in London, Ontario. He has conducted embodied carbon analysis for building envelopes and whole buildings for architects and certification along with systems and products for contractors and manufacturers.

Adam Broderick

Research and Development Scientist with 10 years experience applying material science principles and building science fundamentals to drive towards innovative building envelope products and applications (plus another couple of years as a lab coat polymer chemist / material scientist).

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Learning Objectives

1. Identify the embodied carbon impact stages for air barrier.

1. Determine Clear Field vs Linear Impacts.

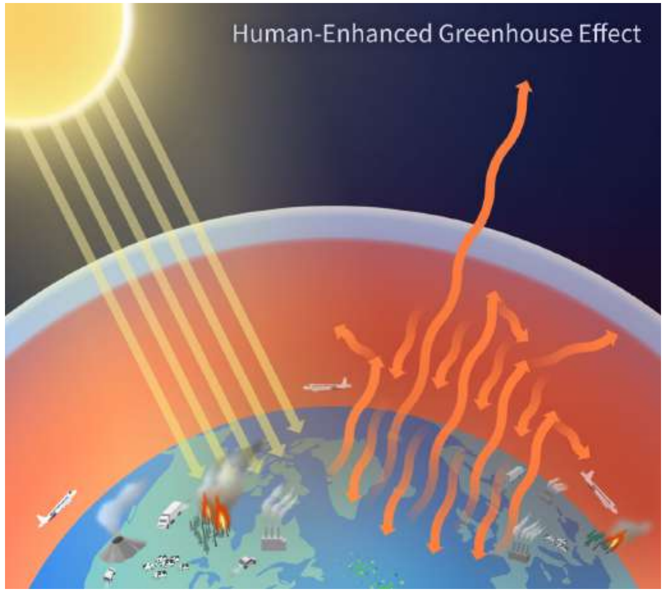
1. Illustrate the impact of air barrier on the embodied carbon of building envelope assemblies.

1. Identify the impacts of common air barrier strategy selections.

What's the Data on Global Warming?

#science

The world is heating up because carbon dioxide (CO_2) and other GHGs are accumulating in the atmosphere, meaning less heat can escape to space



Refs:
https://www.climate.gov/media/16408
https://wmo.int/sites/default/files/2025-03/WMO-1368-2024_en.pdf

- A few of the many factoids:
  - Global CO_2 levels now at their highest in the last 800,000+ years
  - 2024 was the warmest year on record
  - Oceans are hottest on record

Atmospheric CO_2

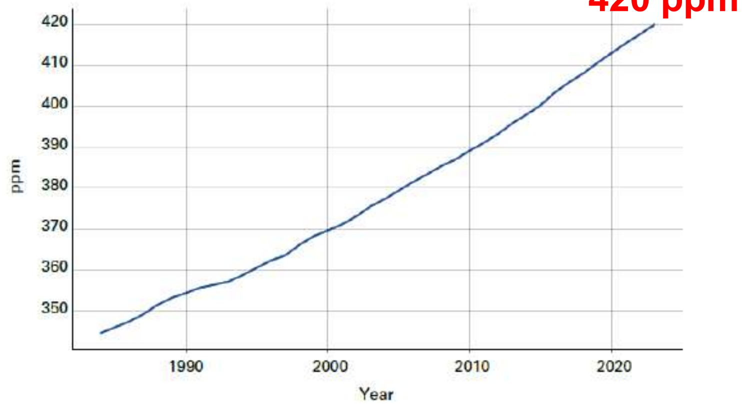


Figure 1. Annual mean globally averaged atmospheric mole fraction of carbon dioxide from 1984 to 2023 in parts per million (ppm)
Source: Data are from the World Data Centre for Greenhouse Gases (WDCGG). See Datasets and methods.

Global Mean Surface Temperature

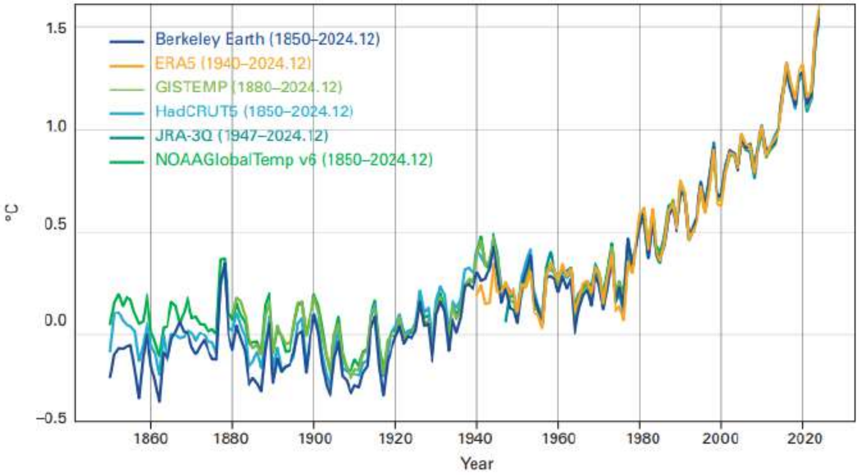


Figure 2. Annual global mean temperature anomalies relative to a pre-industrial (1850–1900) baseline shown from 1850 to 2024
Source: Data are from the six datasets indicated in the legend. For details see Datasets and methods.

Ocean Heat Content

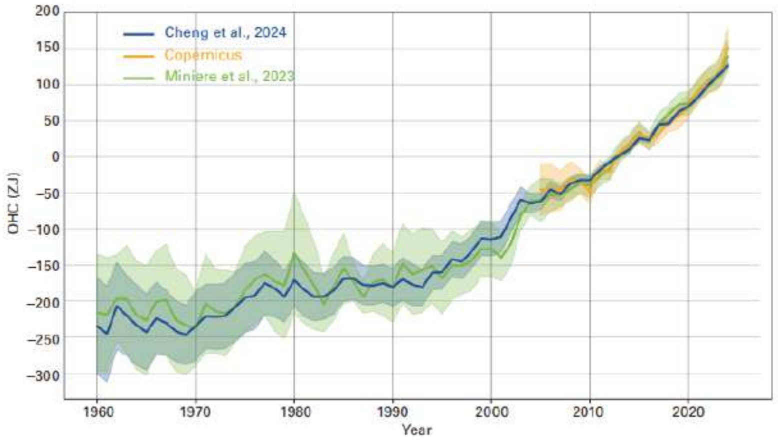
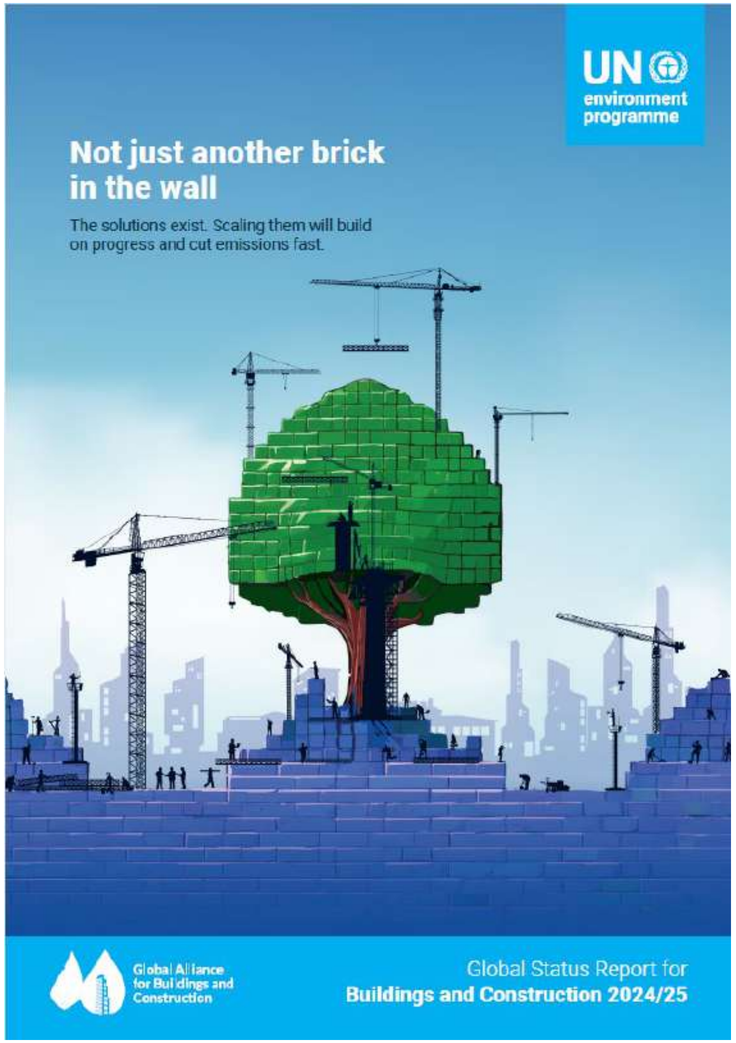
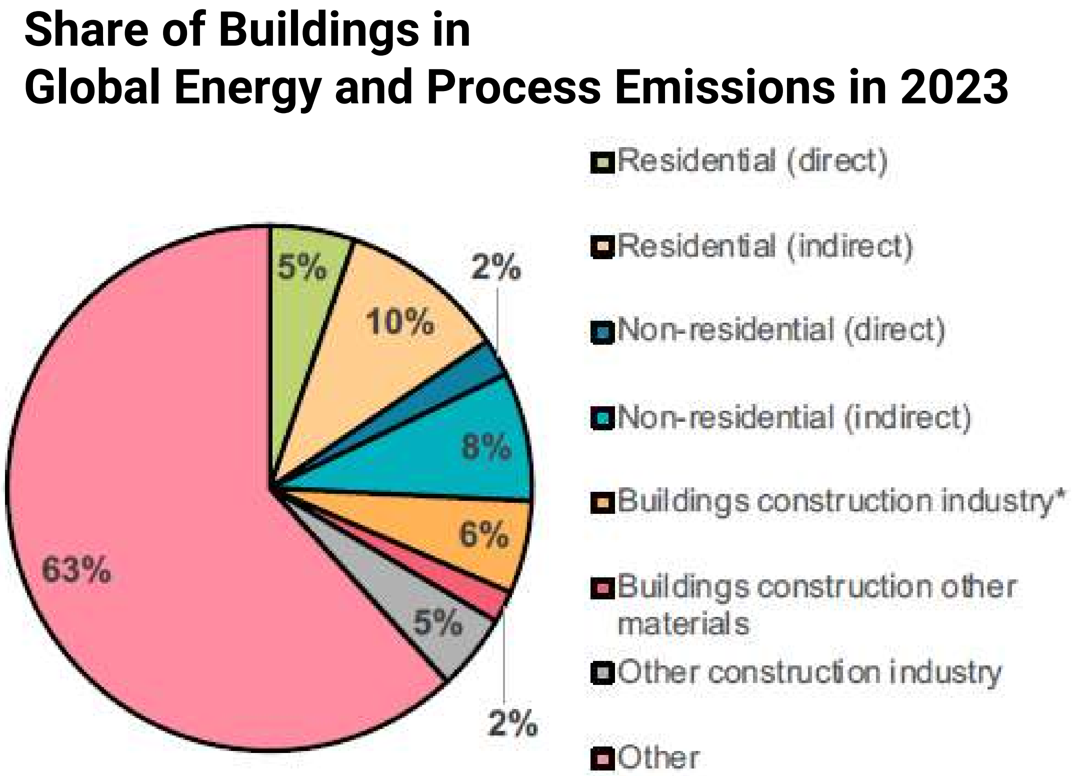


Figure 3. Annual global ocean heat content down to 2000 m depth for the period 1960–2024, in zettajoules (10^{21} J). The shaded area indicates the 2-sigma uncertainty range on each estimate. For details see Datasets and methods.

Buildings account for roughly 34% of global GHG emissions





Notes: "Buildings construction industry" and "Other construction industry" refers to concrete, steel and aluminum for buildings and infrastructure construction. The boundaries of the emissions (energy and process) account for construction materials including from raw materials preparation and processing and the different steps to produce the materials. For example, for cement this includes the entire manufacturing process, from obtaining raw materials and preparing the fuel through to grinding and milling.
The numbers in the pie chart are rounded values and therefore do not necessarily sum to the total value for a given sector.

Life cycle thinking for Buildings and associated GHG emissions: defining Embodied and Operational Carbon

Embodied Carbon

GHGs

Building Materials Production

Operational Carbon

GHGs

Purchased energy used to operate the building

GHGs

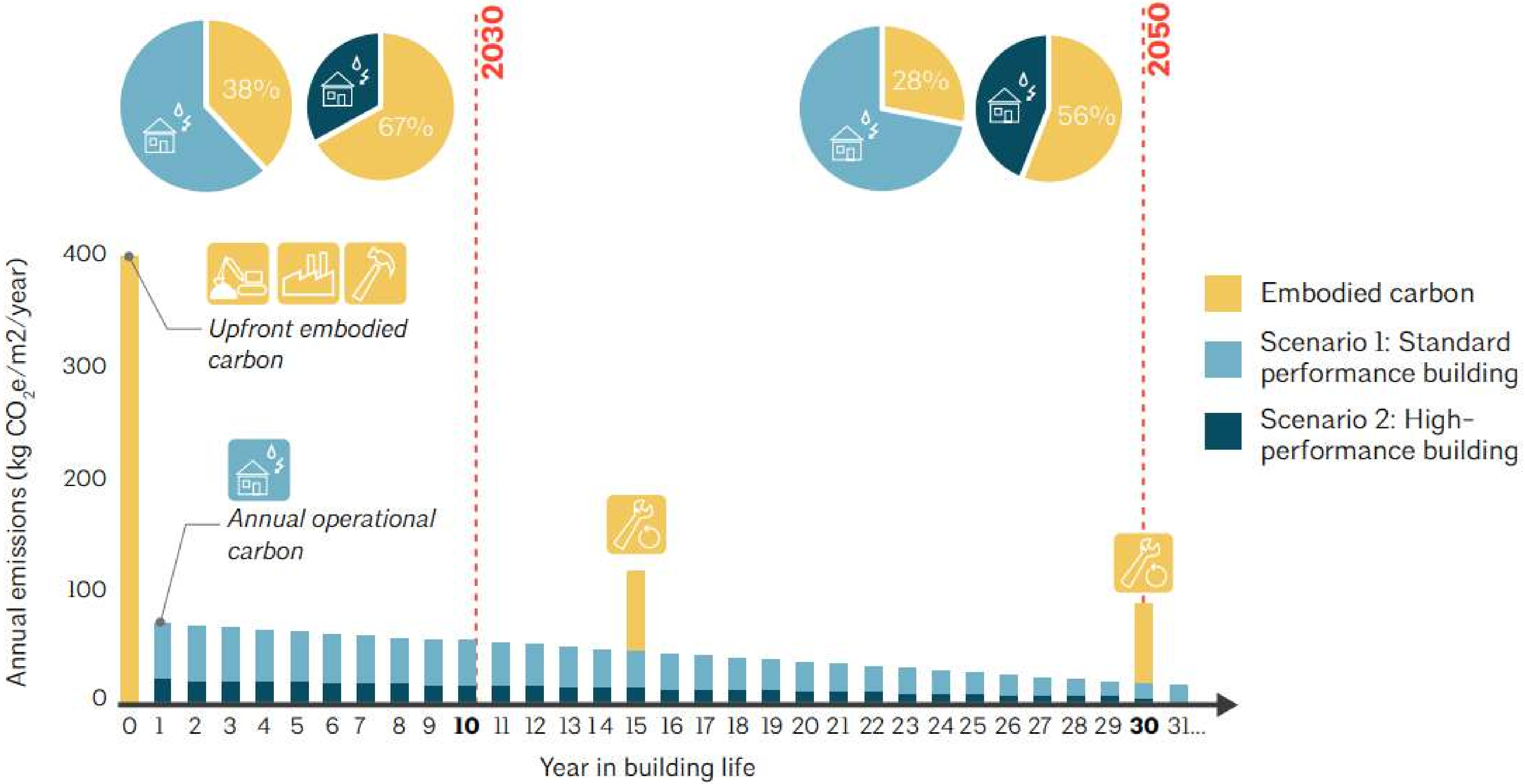
Direct emissions from building operation

Embodied Carbon

GHGs

Building Materials End of Life

A Building Life Cycle Look at Embodied and Operational Carbon



Embodied Carbon Lifetime Emissions

Reference: AIA-CLF Embodied Carbon Toolkit for Architects
Data Sources: Embodied Carbon Benchmark Study and Commercial Buildings Energy Consumption Survey (CBECS), assuming a medium-sized commercial office building. Assumes gradual grid decarbonization to zero by 2050.

Life Cycle Analysis (LCA)

- LCA is the calculation and evaluation of the potential environmental impacts associated with all the stages of the life cycle of a commercial product, process, or service.
- Goal & Scope Definition

  What is the goal of the study? What is the functional unit? What are the product system boundaries?

Inventory analysis

  Life Cycle Inventory (LCI): What are the flows from and to nature (ecosphere) for a product system? Environmental inputs and outputs refer to the demand for natural resources and to the emissions and solid waste.

- Impact Assesment

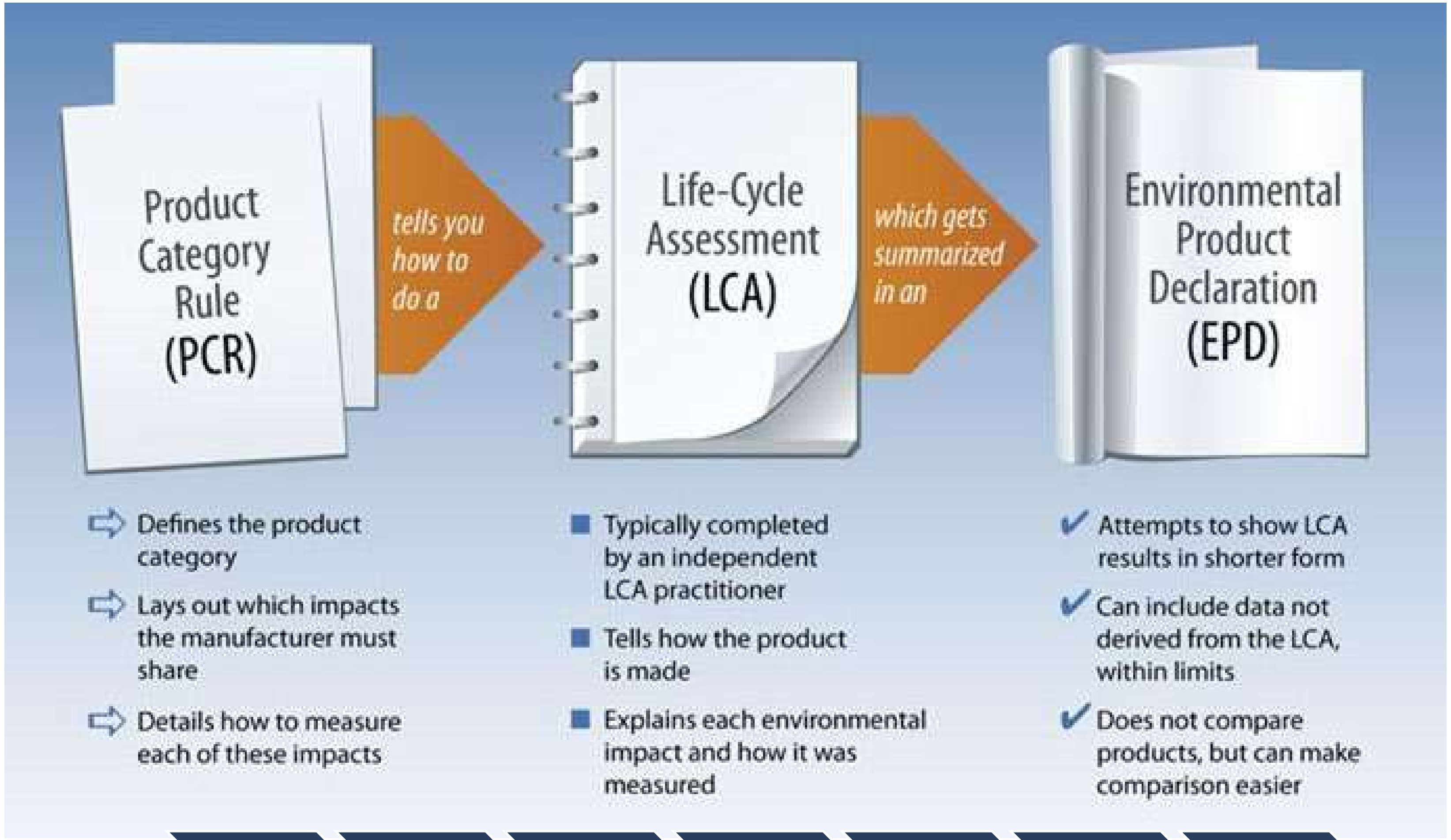
  What are the potential environmental and human health impacts resulting from the flows determined in the LCI?

- Interpretation

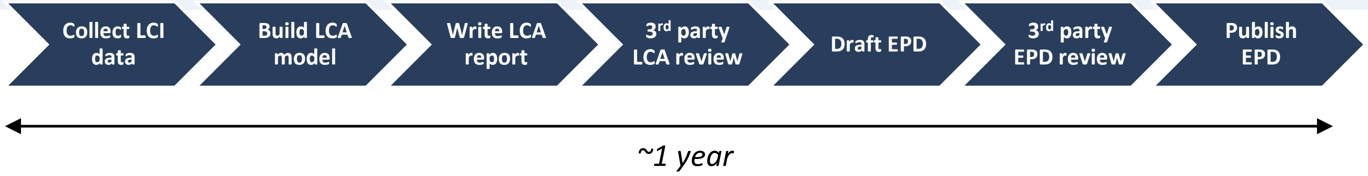
  What significant issues are identified from the study? How complete, sensitive, and consistent is the study? Conclusions, limitations, and recommendations are stated.

Welcome to the wonderful world of EPDs!

a reasonably good representation of PCR, LCA, and EPD from Building Green:



overview of the process:



Embodied Carbon and life cycle stages

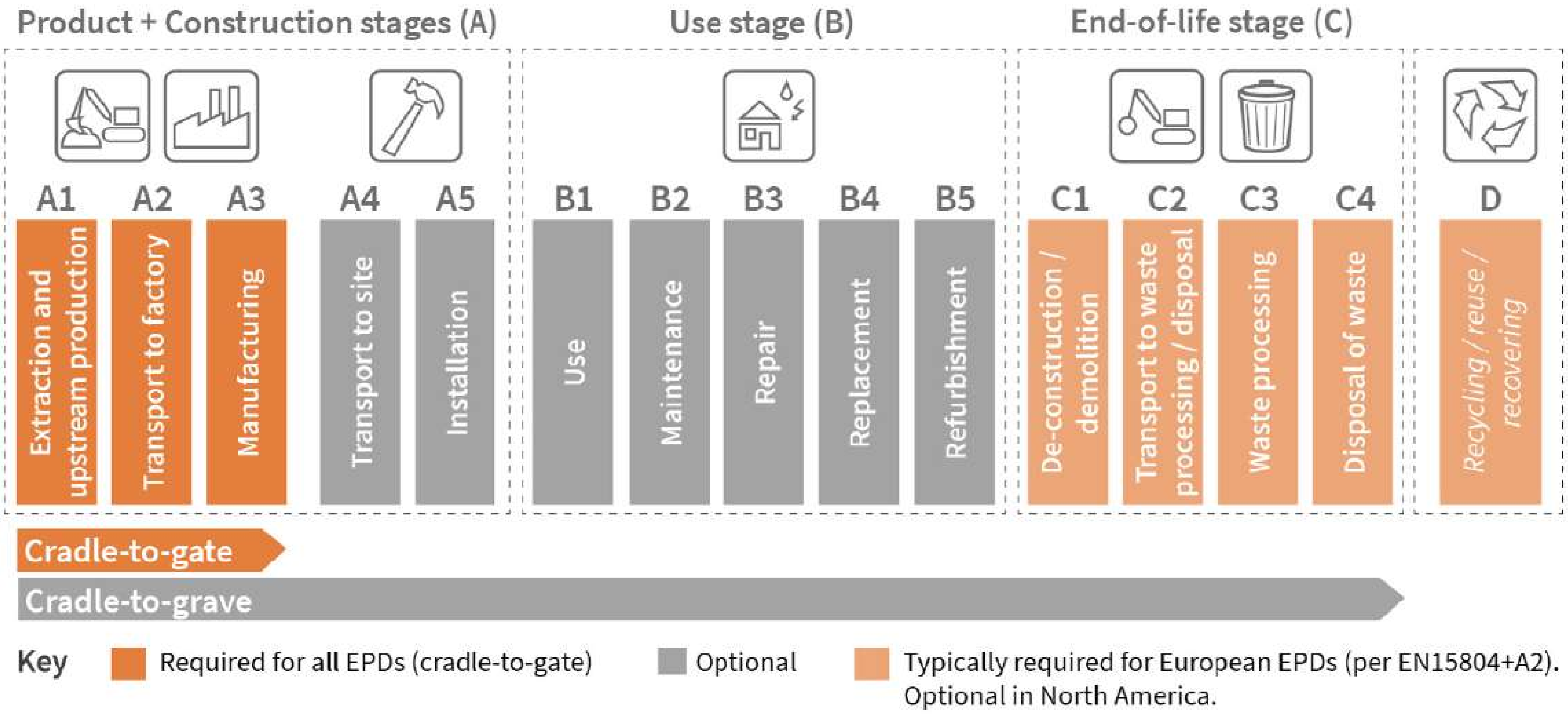


Figure 1. Life cycle stages typically included in North American EPDs. Module names are in accordance with ISO 21930. Product category rules (PCRs) dictate which life cycle stages are required, excluded, or optional.

- Taken from Carbon Leadership Forum 2 - EPD 101: Embodied Carbon Accounting for Materials - Carbon Leadership Forum

What it looks like: the numbers and where to find them

Styrofoam EPD
published in 2021


ENVIRONMENTAL PRODUCT DECLARATION
STYROFOAM™ BRAND ST-100 PRODUCTS

DuPont™ Styrofoam™ Brand ST-100 XPS insulation products offer high, long-term thermal resistance, moisture resistance, and a wide variety of sizes and edge treatments for both residential and commercial applications.

The biggest sustainability problems can't be solved without big contributions from the building and construction industry. Solving these problems calls for sweeping transformation in today's building practices. At DuPont Performance Building Solutions, we're up to the challenge, and have charted a course to help make sustainability a reality in the building industry over the next decade. Inspired by the United Nations' Sustainable Development Goals (UN SDGs), and in support of the DuPont 2030 sustainability Goals, we are committed to deliver solutions that help solve climate change, drive the circular economy, deliver safer solutions and help communities thrive.

Our Product Stewardship commitment drives us toward a vision that every product we bring to the market is safe for use across its life cycle, compliant, risk-managed, trusted, and contributing to a sustainable society. As part of this vision, we recognize the stakeholder need regarding product transparency beyond the Safety Data Sheet and are committed to providing transparency documents for products in our portfolio.

For additional details on our sustainability journey, please see:
https://www.dupont.com/building/sustainability.html

4. Life Cycle Assessment Results

Table 10: Description of the system boundary modules

	PRODUCT STAGE			CONSTRUCTION PROCESS STAGE		USE STAGE							END OF LIFE STAGE				BENEFITS AND LOADS BEYOND THE SYSTEM BOUNDARY
	A1	A2	A3	A4	A5	B1	B2	B3	B4	B5	B6	B7	C1	C2	C3	C4	D
	Raw material supply	Transport	Manufacturing	Transport from gate to site	Assembly/Install	Use	Maintenance	Repair	Replacement	Refurbishment	Building Operational Energy Use During Product Use	Building Operational Water Use During Product Use	Deconstruction	Transport	Waste processing	Disposal	Reuse, Recovery, Recycling Potential
EPD Type Cradle to Grave	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	MND

4.1. Life Cycle Impact Assessment Results

All results are given per functional unit, which is 1 m^2 of insulation material with a thickness that gives an average thermal resistance RSI = 1 m^2K/W over 75 years.

Table 11: North American Impact Assessment Results

TRACI v2.1	A1-A3	A4	A5	B1	B2	B3	B4	B5	B6	B7	C1	C2	C3	C4
GWP 100 [kg CO_2 eq]	3.51E+00	6.95E-02	5.50E-02	1.16E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	7.58E-03	0.00E+00	1.44E+00

EPDs can (should!) change over time

ENVIRONMENTAL PRODUCT DECLARATION

STYROFOAM™ BRAND XPS PRODUCTS

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Styrofoam™ Brand XPS Insulation in 2020

Sustainable Innovation

ENVIRONMENTAL PRODUCT DECLARATION

STYROFOAM™ BRAND PRODUCTS

DuPont™ Styrofoam™ Brand XPS Insulation products offer high, long-term thermal resistance, moisture resistance, and a wide variety of sizes and edge treatments for both residential and commercial applications.

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Styrofoam™ Brand XPS Insulation in 2023

Embodied Carbon* =

100

kg CO_2eq/(m^2K/W)

94% reduction in Embodied Carbon

Embodied Carbon* =

6.2

kg CO_2eq/(m^2K/W)

*Sum of A1-C4 as reported in the EPD

A few tips for comparing EPDs!

Make sure that the EPDs are actually comparable

- Need to follow the same PCR
- Ensure the products deliver the same function
- Should use the same software/background datasets

Make sure you are looking at the most recent EPD

- Current EPDs must be accessible from the 3rd-party Program Operator (e.g. UL, ASTM, NSF, SCS)
- When in doubt reach out to the product manufacturer

If you have comparable EPDs, follow a good LCA rule of thumb: embodied carbon differences of < 5-10% may not be meaningful

- Keep in mind we're not actually measuring anything, we're attempting to model a very complex concept

If understanding the impact of your product choices on carbon is really important, seek professional LCA help

- LCA expertise is available to help you draw sound conclusions when comparing product options
- Best option: avoid comparing product EPDs, instead conduct a building-level LCA

DISCLAIMER

Required language* that must be stated in EPDs:

"EPDs regularly rely on estimations of impacts; the level of accuracy in estimation of effect differs for any particular product line and reported impact.

EPDs from different programs may not be comparable.

Full conformance with a PCR allows EPD comparability only when all stages of a life cycle have been considered.

However, variations and deviations are possible.

Example of variations: Different LCA software and background LCI datasets may lead to different results"

*Required by UL Part A Product Category Rules for Building Products

Early Embodied Carbon

Harvey, L. D. (2007). Net climatic impact of solid foam insulation produced with halocarbon and non-halocarbon blowing agents. *Building and Environment*, *42*(8), 2860-2879

- Estimated payback for insulation energy savings to offset GHG from blowing agents
- Found that high insulation thicknesses do not pay off in terms of direct energy saving

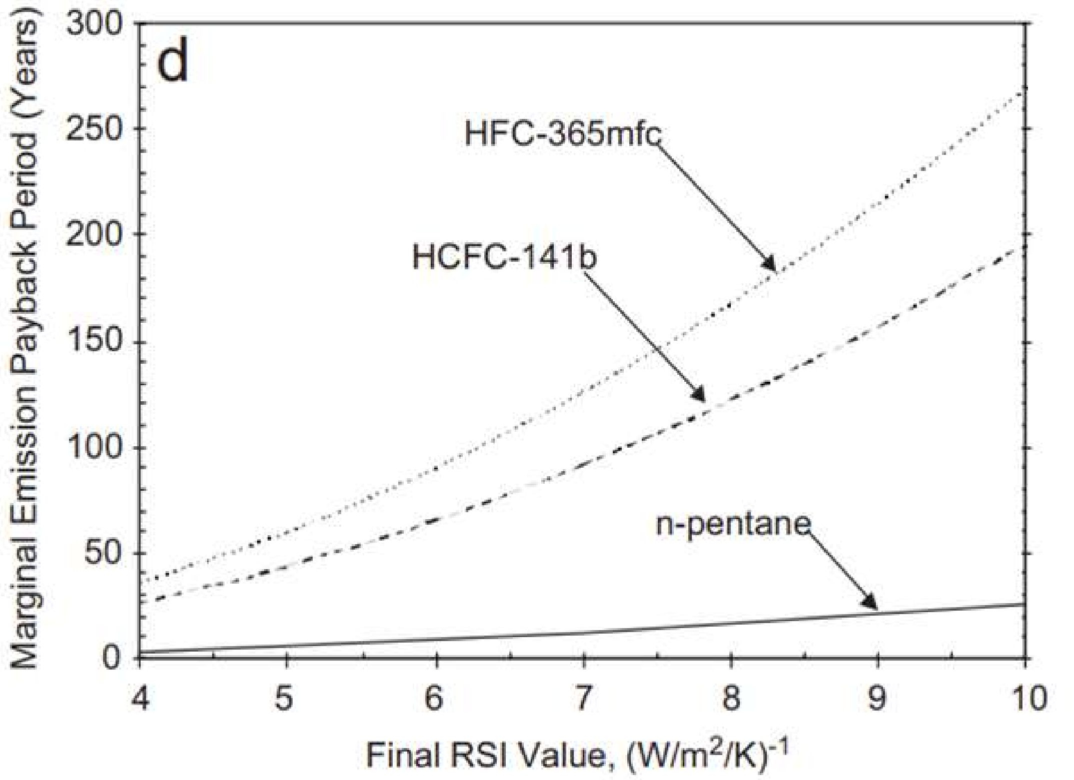


Fig. 5. (d)Variation in the marginal emission payback time when the RSI-value is increased by 1.0 to the indicated final value. Emission payback times are for polyurethane insulation using either HCFC-141b, HFC-365mfc, or *n*-pentane as blowing agents, for a climate with 4000 HDD, for a heating system efficiency of 0.9, 8% leakage at the time of manufacture, 0.5%/year leakage during use, and ~~no~~ release of the blowing agent remaining at the time of disposal

Embodied Carbon comes to LEED v4

LEED BD+C: New Construction · v4 - LEED v4

Building product disclosure and optimization - environmental product declarations

Materials and Resources

Possible 2 Points

- **Option 1. Environmental product declaration (EPD)**
- Option 2. Multi-attribute optimization

LEED BD+C: New Construction · v4 - LEED v4

Building life-cycle impact reduction

Materials and Resources

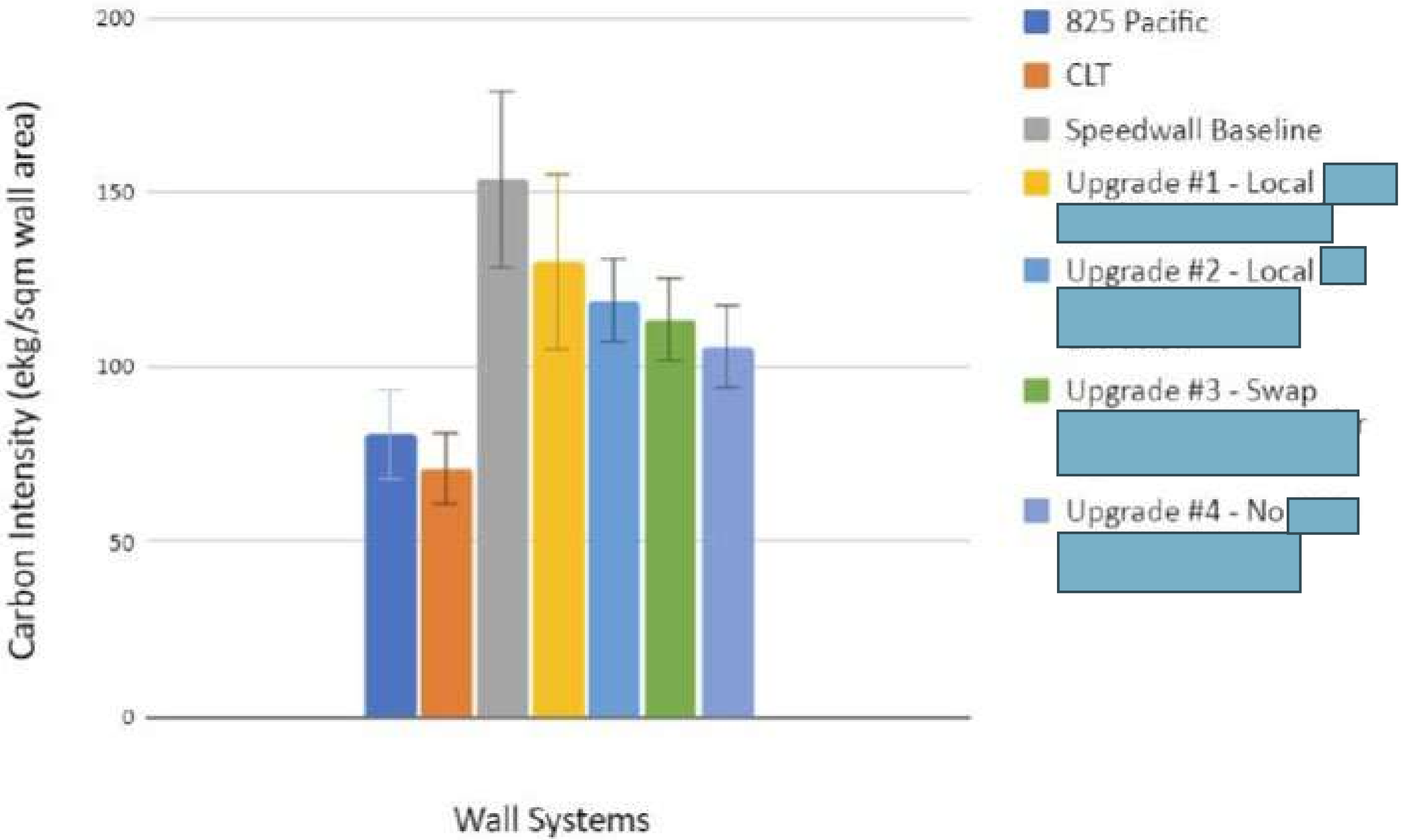
Possible 5 Points

- Option 1. historic building reuse (5 points)
- Option 2. renovation of abandoned or blighted building (5 points)
- Option 3. building and material reuse (2–4 points)
- **Option 4. whole-building life-cycle assessment (3 points)**

CaGBC Zero Carbon Standard v4

- **Embodied Carbon Path 1 (for most buildings): max 450 kg $C0_2e/m^2$**
- **Embodied Carbon Path 2: 10% less than a baseline**

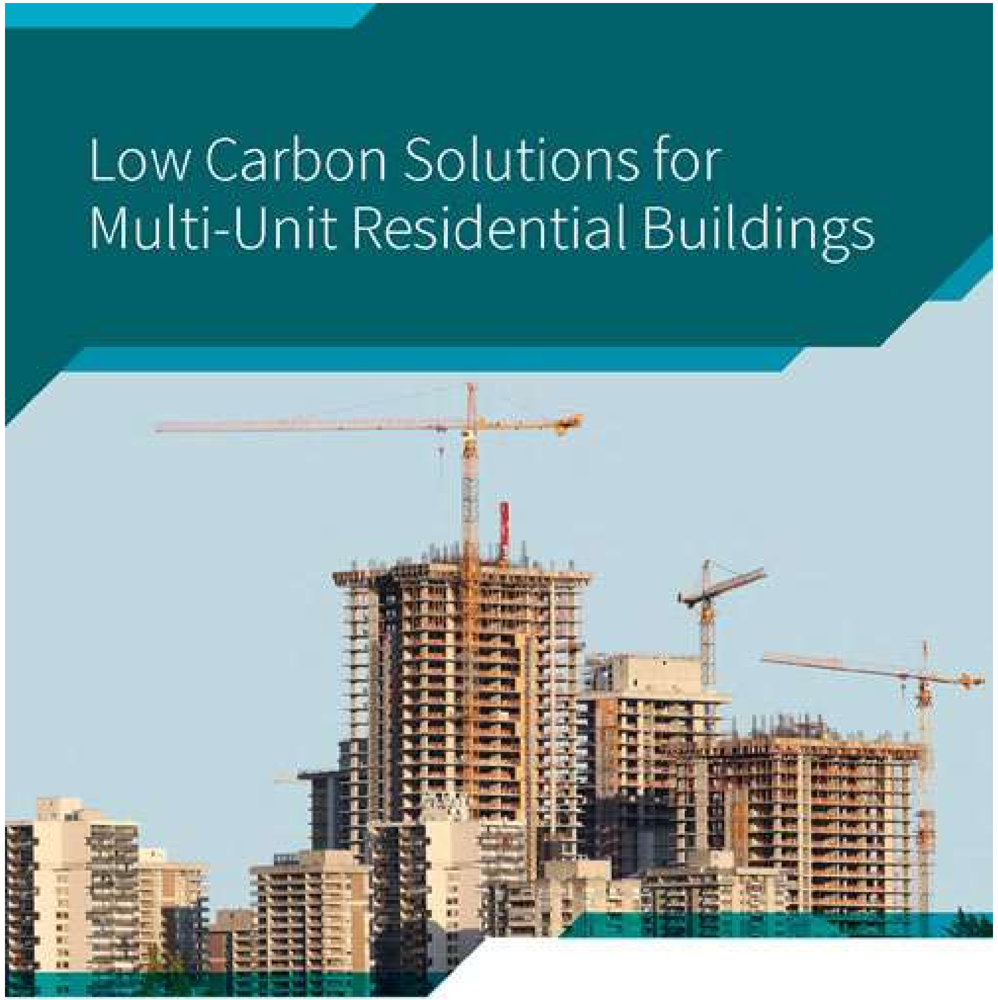
Façade Contractor Support



BC Housing Study

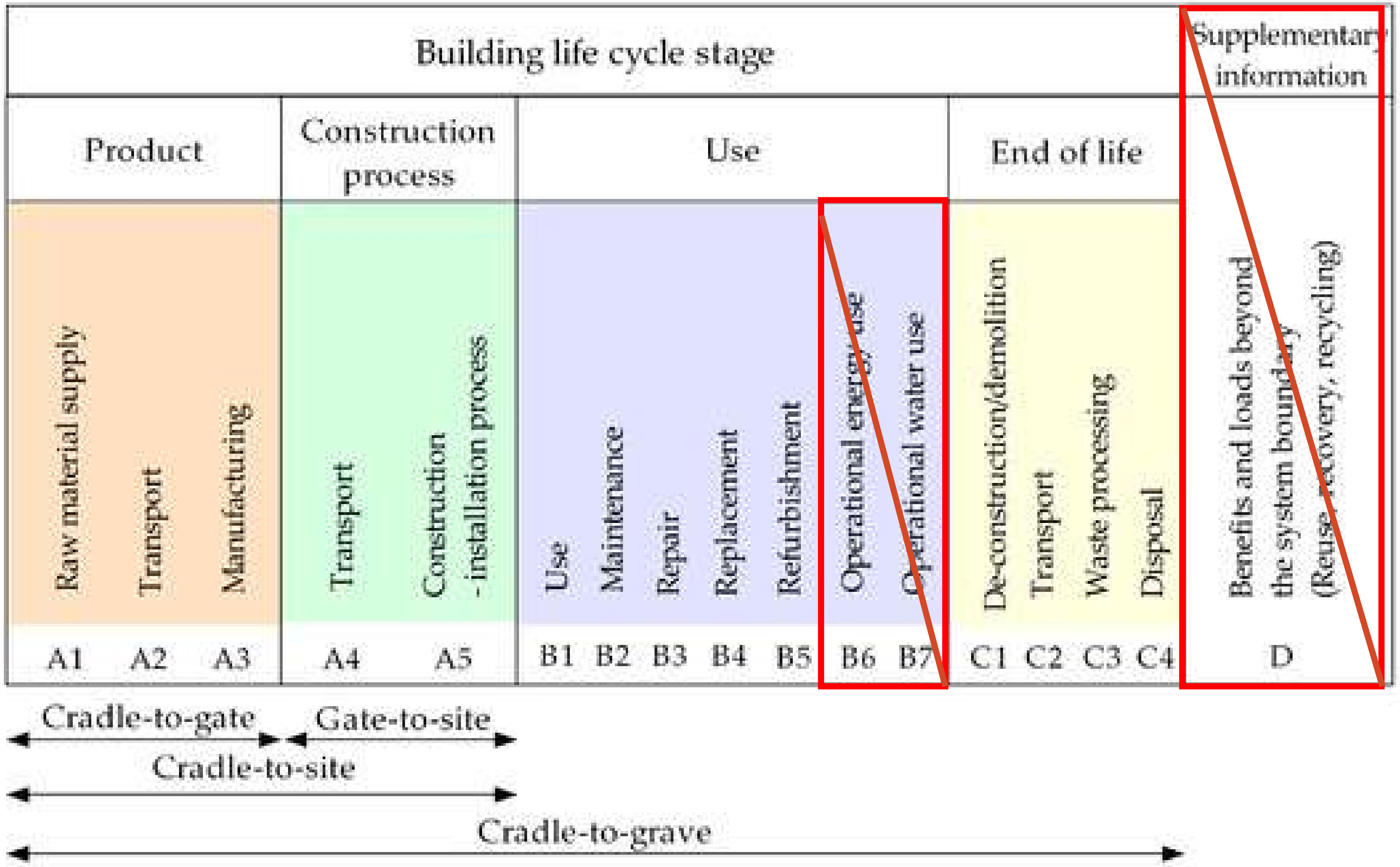
Objectives:

1. The optimal strategies to capture maximum energy efficiency gains and overall carbon emission reductions during manufacturing, construction, operation, and deconstruction,
2. **How to reduce embodied carbon of the building envelope, and**
3. **How to accurately determine building embodied carbon in an efficient and consistent manner.**



BC HOUSING
RESEARCH CENTRE

www.bchousing.org/sites/default/files/media/documents/Low-Carbon-Solutions-for-Multi-Unit-Residential-Buildings.pdf


Building life cycle stage
Supplementary information
Product
Construction process
Use
End of life
Raw material supply
Transport
Manufacturing
Transport
Construction -installation process
Use
Maintenance
Repair
Replacement
Refurbishment
Operational energy use
Operational water use
De-construction/demolition
Transport
Waste processing
Disposal
Benefits and loads beyond the system boundary (Reuse, recovery, recycling)
A1 A2 A3
A4 A5
B1 B2 B3 B4 B5 B6 B7
C1 C2 C3 C4
D
Cradle-to-gate
Gate-to-site
Cradle-to-site
Cradle-to-grave

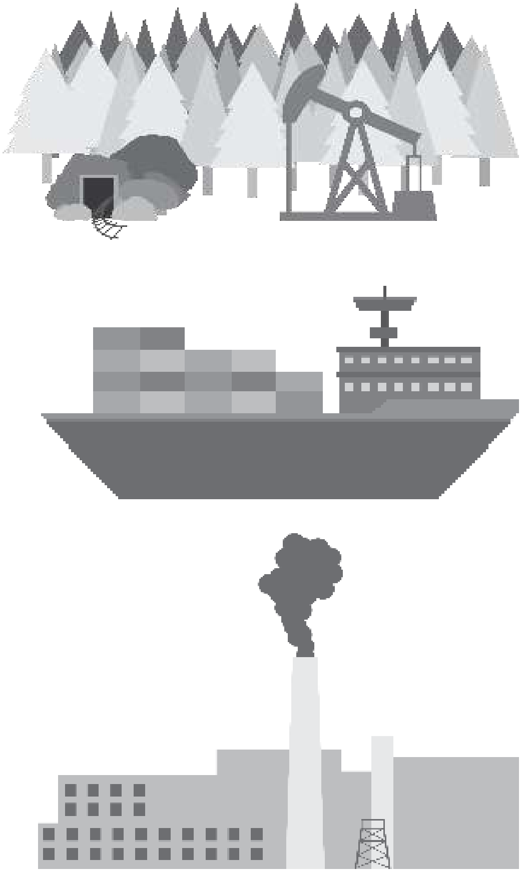
Methodology

A1-A3 Raw Materials, Transport, Manufacturing

- Plant specific data typically not available
- Too many comparisons of functionally different materials
- Industry averages vs product data

Recommendations

- BC Support plant specific EPD for regional manufacturers
- Encourage projects to consider suitable materials and specific products with low GWP



Methodology

A4 Transportation to Site

- Burdensome and inconsistent calculations within tools
- Significant impact for many materials in BC projects

Recommendations

- Offer default regional source per kg assumptions (Below fo BC based on UK approach)

Location	Distance Travelled by Road (km)	Distance Travelled by Sea (km)	GWP Intensity (kg eCO_2/kg)
Local	100	N/A	0.005
BC, Alberta, Washington	1000		0.053
Eastern North America, Mexico	5000		0.267
Overseas direct to Vancouver	1000	10,000	0.429
Overseas through East Coast ports	5000	10,000	0.643

Methodology

A5c Installation Emissions

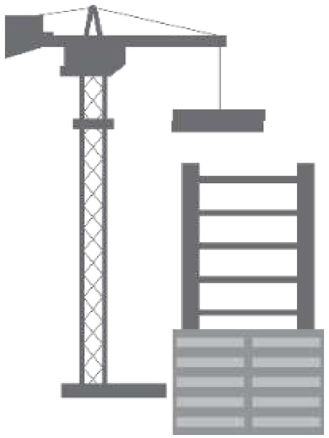
- Big impact for heat/flame applied roofing
- Impact for off gassing products

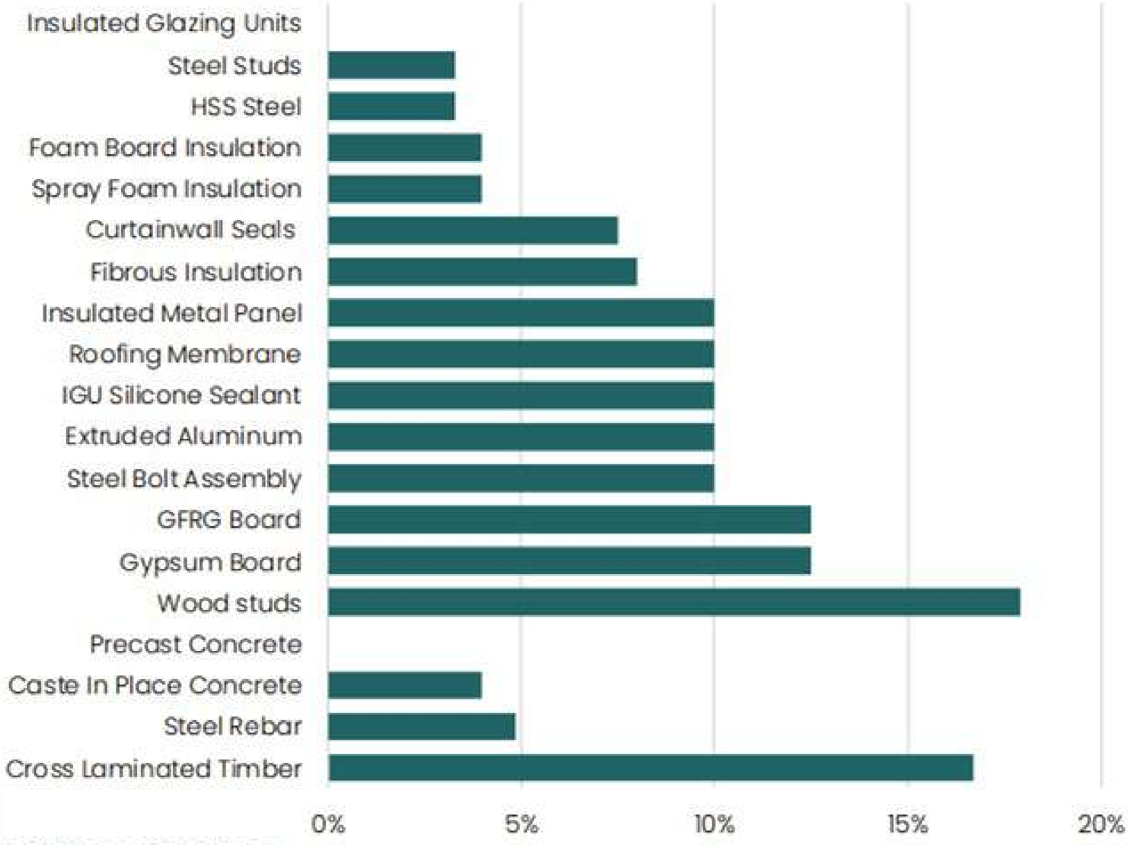
A5w Construction Waste

- Inconsistent assumptions used in industry
- Big impact for most materials

Recommendations

- Provide list of materials where A5c emissions cannot be ignored
- Provide standard industry wastage rate assumptions (now available in City of Vancouver standard)





Vancouver Embodied Carbon Guidelines

Default A5 Construction Site Material Wastage Rates

Methodology

B1, B2, & B3 – Use, Maintaince, & Repair

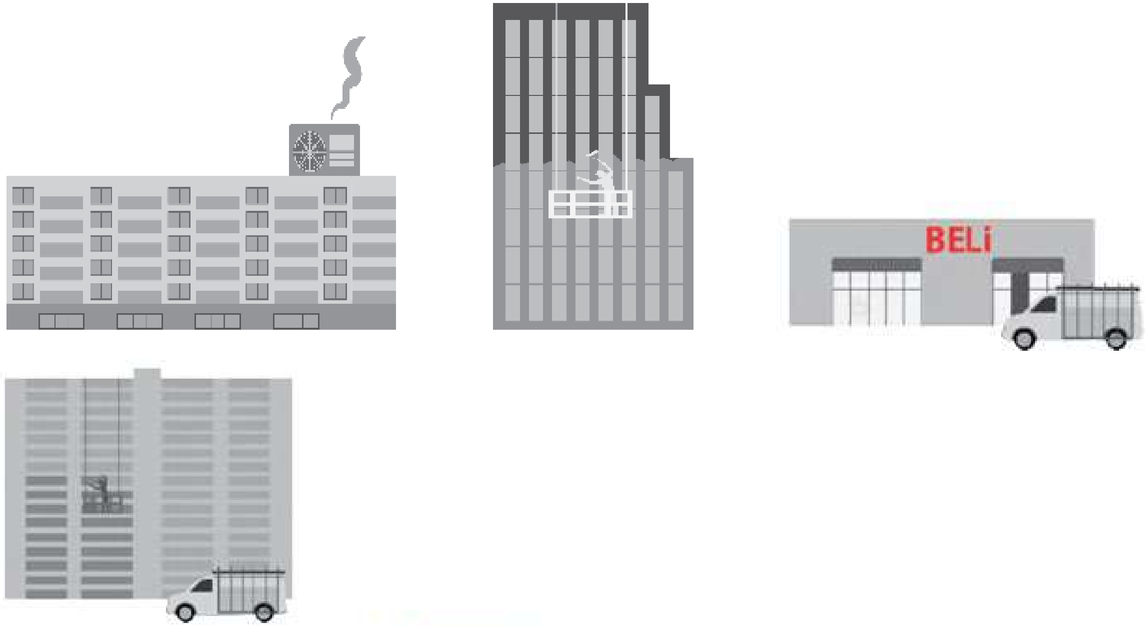
- Inconsistent assumptions used in industry
- Small impacts

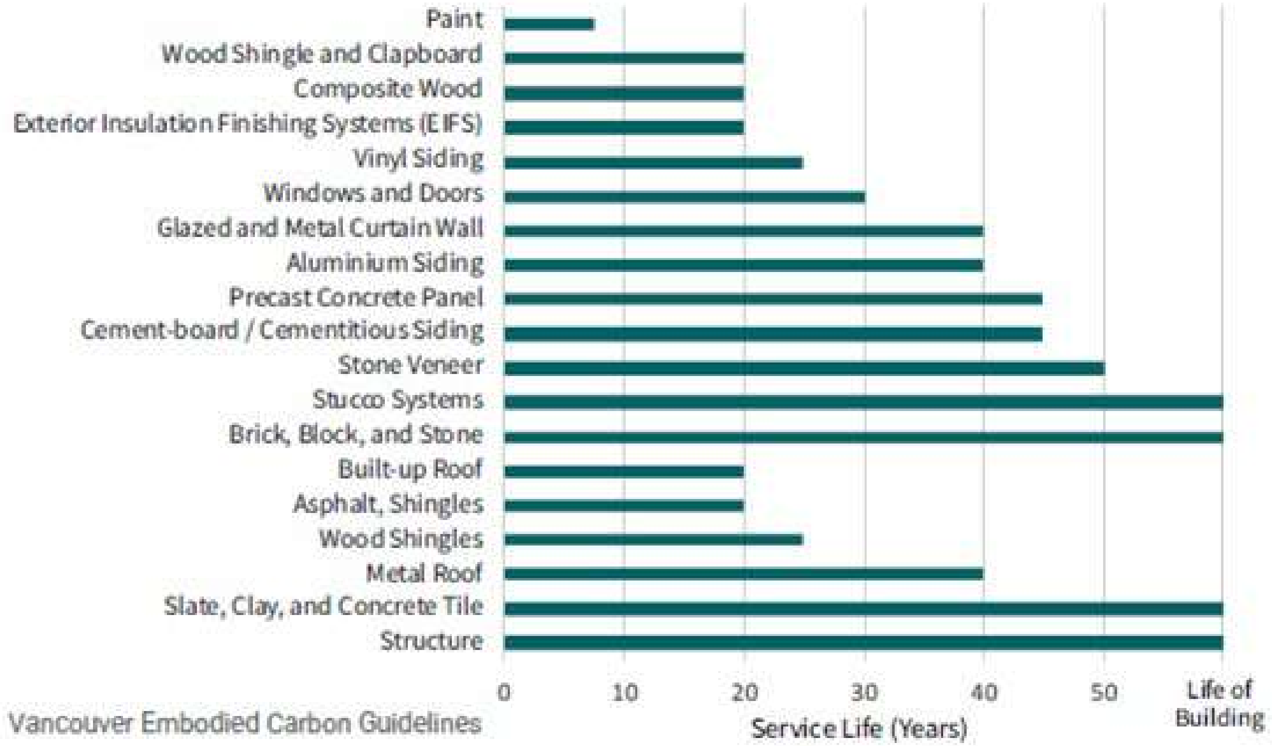
B4 & B5 – Refurbishment and Replacements

- Limited users service live knowledge

Recommendations

- Provide simple per kg assumption for B1-B3
- Provide default component service life values
- Provide incentive and analysis method for more durable design, construction, and maintenance





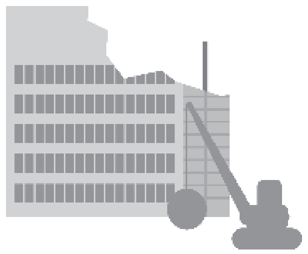
Methodology

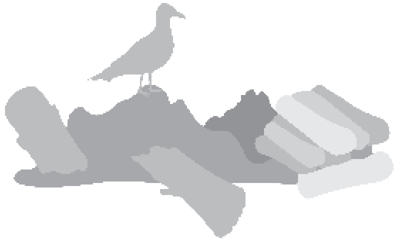
C1-C4 Demolition, Transportation, Waste Processing, & Landfill

- Complicate and inconsistent assumptions used in industry
- Small impacts = limited incentives

Recommendations

- Provide simple default per kg assumptions
- Conduct baseline and best practice studies to understand impacts and incentivize improvements





Environmental Product Declarations (EPDs)

Randy's EPD Gripes:

1. Provide current EPDs
2. Don't make users register with some third party to download an EPD
3. Keep expired EPDs available as users often need them to supplement missing data points
4. Provide adequate product details – more product variations the better within an EPD
5. Provide the kg weight for product with per m^3, per m^2 and per RSI m^2 reporting

HIGH PERFORMANCE SCENARIO

TRACI 2.1		
Parameter	**Unit**	**A1-A3**
GWP	[kg CO_2 eq]	9.43E-01

LOW RISE SCENARIO

TRACI 2.1		
Parameter	**Unit**	**A1-A3**
GWP	[kg CO_2 eq]	4.97E-01

ENVIRONMENTAL PRODUCT DECLARATION

MECHANICALLY FASTENED AIR AND WATER BARRIER SYSTEM

Mechanically Fastened Air and Water Barrier Systems offer outstanding protection for gypsum, CMU, and many common sheathing substrat

DuPont Protection Solutions is a strategic business unit of DuPont, bringing dynamic science to the discovery and development of innovative products and services for commercial and residential construction. DuPont Protection Solutions is committed to increasing the performance of building systems and creating energy efficient and durable structures. DuPont is the only manufacturer to offer both Mechanically Fastened and mechanically fastened building wrap air and water barrier systems. DuPont™ Tyvek® commercial air and water barrier systems help effectively seal the building envelope. When you choose DuPont products for your next project, you get products that meet the highest performance standards and are backed by industry-leading building science and unrivaled industry support provided by the DuPont™ Tyvek® Specialists Network and the DuPont™ Building Knowledge Center.

CERTIFIED ENVIRONMENTAL PRODUCT DECLARATION

ENVIRONMENTAL PRODUCT DECLARATION

MECHANICALLY FASTENED WEATHER BARRIER SYSTEMS
AIR BARRIER FOR COMMERCIAL CONSTRUCTION

According to ISO 14025

This declaration is an environmental product declaration (EPD) in accordance with ISO 14025. EPDs rely on Life Cycle Assessment (LCA) to provide information on a number of environmental impacts of products over their life cycle. Exclusions: EPDs do not indicate that any environmental or social performance benchmarks are met, and there may be impacts that they do not encompass. LCAs do not typically address the site-specific environmental impacts of raw material extraction, nor are they meant to assess human health toxicity. EPDs can complement but cannot replace tools and certifications that are designed to address these impacts and/or set performance thresholds – e.g. Type 1 certifications, health assessments and declarations, environmental impact assessments, etc. Accuracy of Results: EPDs regularly rely on estimations of impacts, and the level of accuracy in estimation of effect differs for any particular product line and reported impact. Comparability: EPDs are not comparative assertions and are either not comparable or have limited comparability when they cover different life cycle stages, are based on different product category rules or are missing relevant environmental impacts. EPDs from different programs may not be comparable.

PROGRAM OPERATOR	UL Environment	
DECLARATION HOLDER		
DECLARATION NUMBER	4787059050.102	
DECLARED PRODUCT	Tyvek® Mechanically Fastened Air and Water Barrier Systems	
REFERENCE PCR	IBU Part B: Plastic and elastomer roofing and sealing sheet systems. With UL part A and part B addendum	
DATE OF ISSUE	June 21, 2017	
PERIOD OF VALIDITY	5 Years	
CONTENTS OF THE DECLARATION	Product definition and information about building physics Information about basic material and the material's origin Description of the product's manufacture Indication of product processing Information about the in-use conditions Life cycle assessment results Testing results and verifications	
The PCR review was conducted by:		Institut und Umwelt e.V. Independent Expert Committee info@ibu-epd.com
This declaration was independently verified in accordance with ISO 14025 by Underwriters Laboratories ☐ INTERNAL ☒ EXTERNAL		Wade Stout, UL Environment
This life cycle assessment was independently verified in accordance with ISO 14044 and the reference PCR by:		Thomas P. Gloria, Industrial Ecology Consultants

June 21, 2017
5 Years

ENVIRONMENTAL PRODUCT DECLARATION

MECHANICALLY FASTENED AIR AND WATER BARRIER SYSTEM
AIR AND WATER BARRIER FOR COMMERCIAL CONSTRUCTION

According to ISO 14025

Life Cycle Assessment Results

Results for 1 m^2 of installed Tyvek® Mechanically Fastened Air and Water Barrier Systems are presented below.

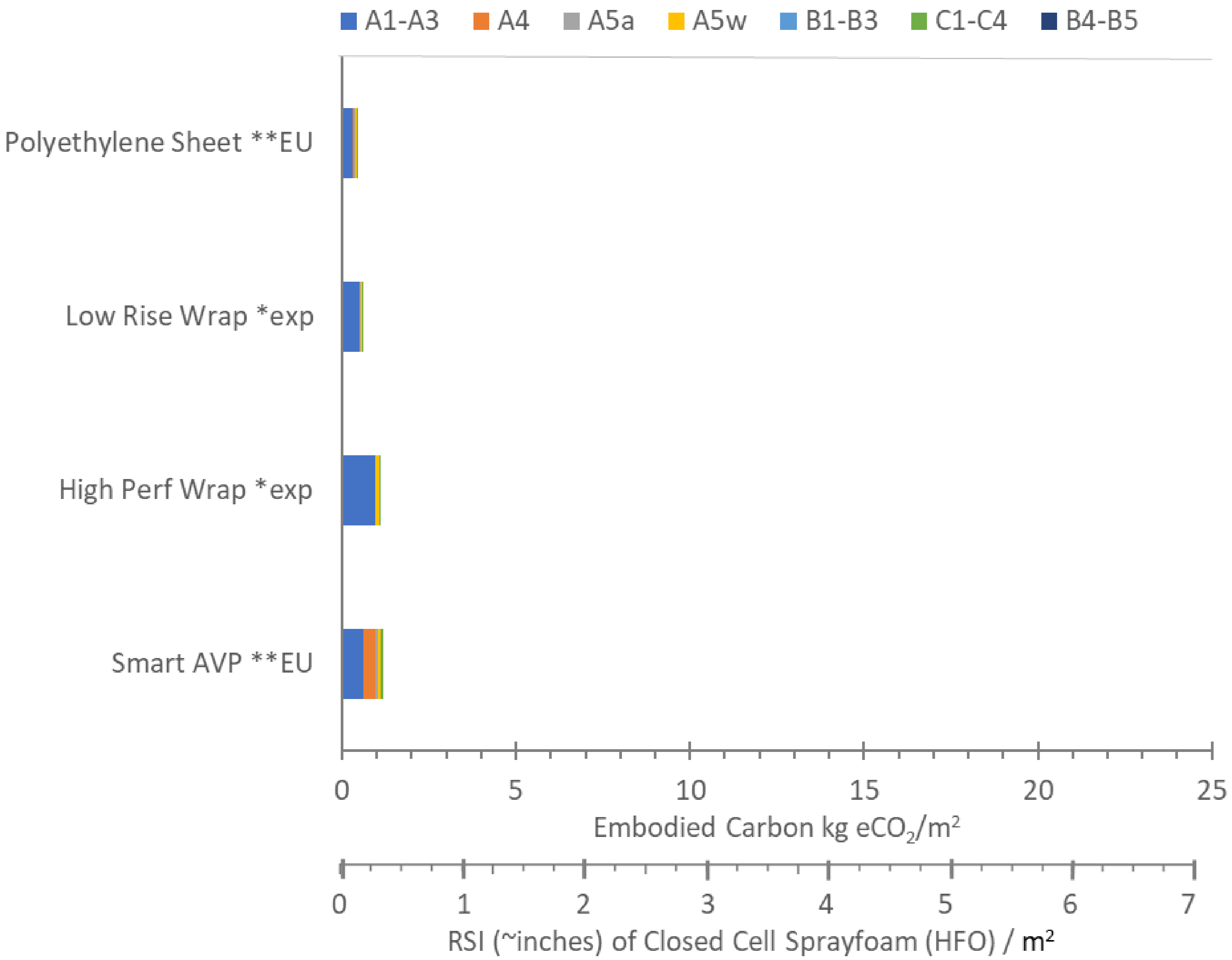
ENVIRONMENTAL IMPACTS: LOW RISE SCENARIO							
CML 2001 (Apr 2013)							
Parameter	**Unit**	**A1-A3**	**A4**	**A5**	**C2**	**C4**	**D**
GWP	[kg CO_2 eq.]	4.97E-01	7.02E-03	[illegible]	2.68E-04	4.93E-03	-3.44E-04
ODP	[kg CFC-11 eq.]	1.18E-06	5.78E-14	[illegible]	2.20E-15	9.43E-14	-1.04E-13
AP	[kg SO_2 eq.]	1.32E-03	2.60E-05	7.91E-05	9.91E-07	2.13E-05	-9.29E-07
EP	[kg PO_4^{3} eq.]	1.25E-04	6.71E-06	9.78E-06	2.56E-07	2.72E-06	-5.62E-08
POCP	[kg C_2H_4 eq.]	2.68E-04	3.10E-06	1.68E-05	1.18E-07	2.16E-06	-6.02E-08
ADPE	[kg Sb eq.]	2.48E-07	[illegible]	1.26E-08	4.00E-11	1.89E-09	-7.85E-11
ADPF	[MJ]	[illegible]	[illegible]	5.60E-01	3.76E-03	7.45E-02	-4.18E-03
TRACI 2.1							
Parameter	**Unit**	**A1-A3**	**A4**	**A5**	**C2**	**C4**	**D**
GWP	[kg CO_2 eq]	4.97E-01	7.02E-03	2.90E-02	2.68E-04	4.93E-03	-3.44E-04
ODP	[kg CFC-11 eq]	1.17E-06	6.15E-14	5.88E-08	2.34E-15	1.00E-13	-1.11E-13
AP	[kg SO_2 eq]	1.31E-03	3.41E-05	8.31E-05	1.30E-06	2.30E-05	-8.83E-07
EP	[kg N eq]	6.32E-05	3.17E-06	5.37E-06	1.21E-07	1.28E-06	-3.75E-08
SFP	[kg O_3 eq]	1.83E-02	1.08E-03	1.04E-03	4.13E-05	4.47E-04	-8.46E-06

ENVIRONMENTAL IMPACTS: HIGH PERFORMANCE SCENARIO							
CML 2001 (Apr 2013)							
Parameter	**Unit**	**A1-A3**	**A4**	**A5**	**C2**	**C4**	**D**
GWP	[kg CO_2 eq.]	9.42E-01	1.39E-02	5.41E-02	5.35E-04	9.86E-03	-5.70E-04
ODP	[kg CFC-11 eq.]	3.54E-06	1.15E-13	1.77E-07	4.41E-15	1.89E-13	-1.72E-13
AP	[kg SO_2 eq.]	[illegible]	5.16E-05	1.49E-04	1.98E-06	4.27E-05	-1.54E-06
EP	[kg PO_4^{3} eq.]	[illegible]	1.33E-05	1.84E-05	5.11E-07	5.45E-06	-9.30E-08
POCP	[kg C_2H_4 eq.]	[illegible]	6.15E-06	3.76E-05	2.36E-07	4.33E-06	-9.97E-08
ADPE	[kg Sb eq.]	1.72E-06	2.08E-09	8.64E-08	8.00E-11	3.78E-09	-1.30E-10
ADPF	[MJ]	[illegible]	1.96E-01	1.07E+00	7.52E-03	1.49E-01	-6.93E-03
TRACI 2.1							
Parameter	**Unit**	**A1-A3**	**A4**	**A5**	**C2**	**C4**	**D**
GWP	[kg CO_2 eq]	9.43E-01	1.39E-02	5.41E-02	5.35E-04	9.86E-03	-5.70E-04
ODP	[kg CFC-11 eq]	3.55E-06	1.22E-13	1.77E-07	4.69E-15	2.01E-13	-1.83E-13
AP	[kg SO_2 eq]	2.51E-03	6.77E-05	1.56E-04	2.60E-06	4.60E-05	-1.46E-06
EP	[kg N eq]	1.22E-04	6.29E-06	9.92E-06	2.42E-07	2.56E-06	-6.21E-08
SFP	[kg O_3 eq]	3.61E-02	2.15E-03	2.03E-03	8.26E-05	8.94E-04	-1.40E-05

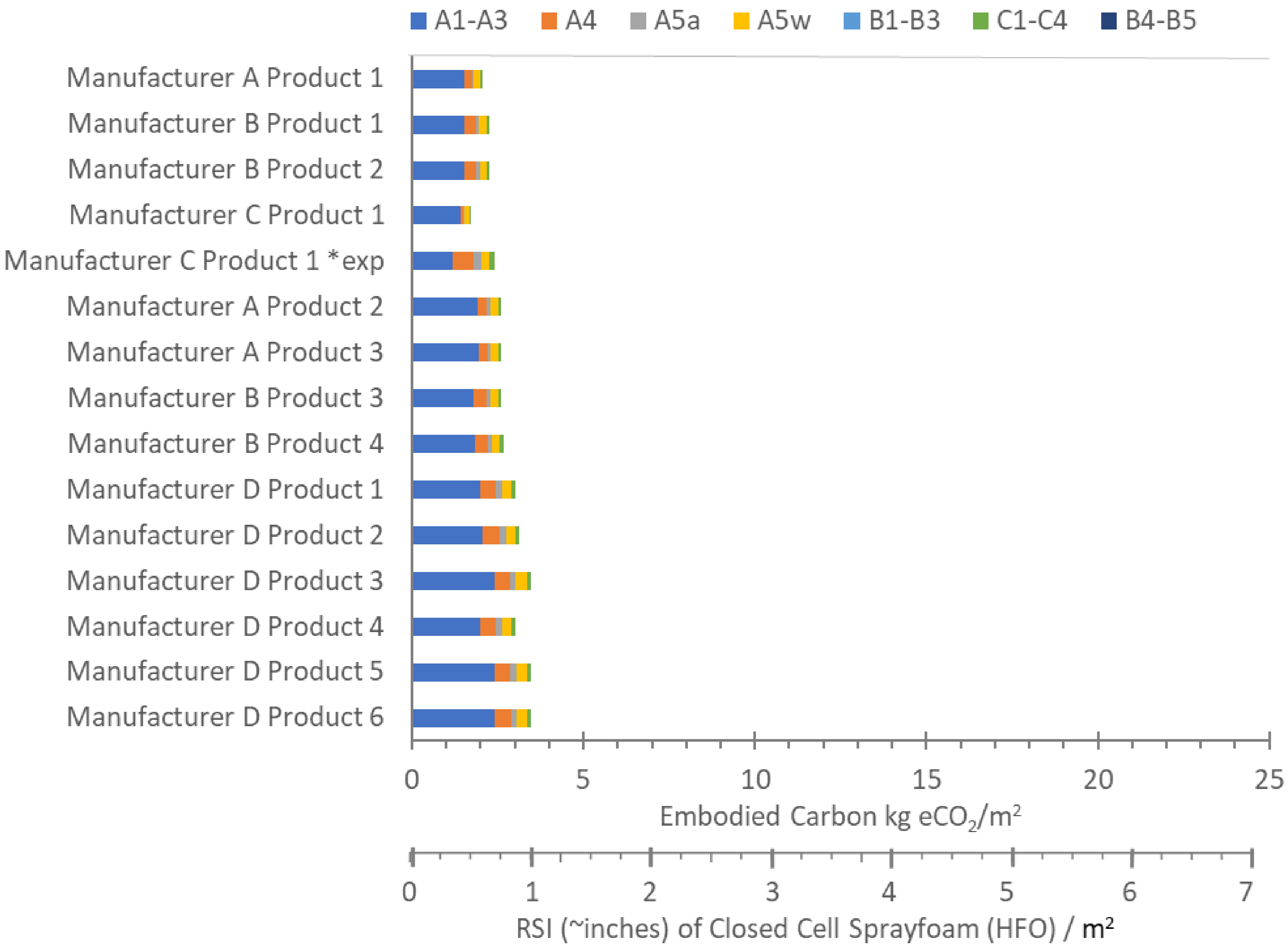
GWP = Global warming potential; ODP = Depletion potential of the stratospheric ozone layer; AP = Acidification potential of land and water; EP = Eutrophication potential; POCP = Formation potential of tropospheric ozone photochemical oxidants; ADPE = Abiotic depletion potential for non-fossil resources; ADPF = Abiotic depletion potential for fossil resources; SFP = Smog formation potential

RESOURCE USE: LOW RISE SCENARIO							
Parameter	**Unit**	**A1-A3**	**A4**	**A5**	**C2**	**C4**	**D**
PERE	[MJ]	1.76E-01	1.64E-03	9.16E-03	6.25E-05	4.84E-03	-4.47E-04
PERM	[MJ]	8.26E-02	–	4.13E-03	–	–	–
PERT	[MJ]	2.59E-01	1.64E-03	1.33E-02	6.25E-05	4.84E-03	-4.47E-04
PENRE	[MJ]	7.20E+00	9.92E-02	3.69E-01	3.78E-03	7.65E-02	-5.11E-03
PENRM	[MJ]	4.44E+00	–	2.22E-01	–	–	–
PENRT	[MJ]	1.16E+01	9.92E-02	5.91E-01	3.78E-03	7.65E-02	-5.11E-03
SM	[kg]	–	–	–	–	–	–
RSF	[MJ]	–	–	–	–	–	–
NRSF	[MJ]	–	–	–	–	–	–
FW	[m^3]	1.75E-03	2.01E-05	9.00E-05	7.66E-07	1.18E-05	-1.62E-06

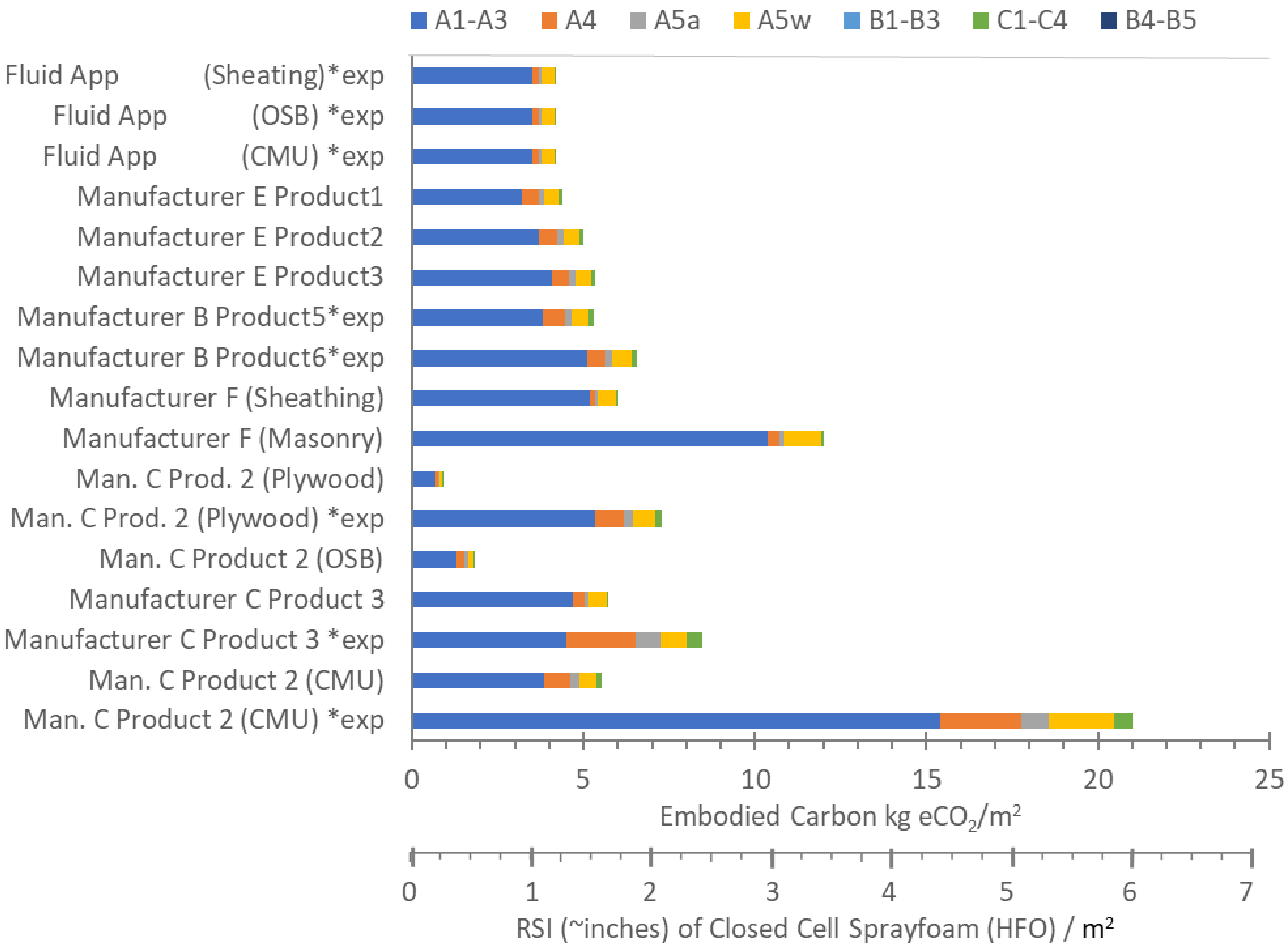
Loose Sheet Air Barriers



Fully Adhered Air Barriers



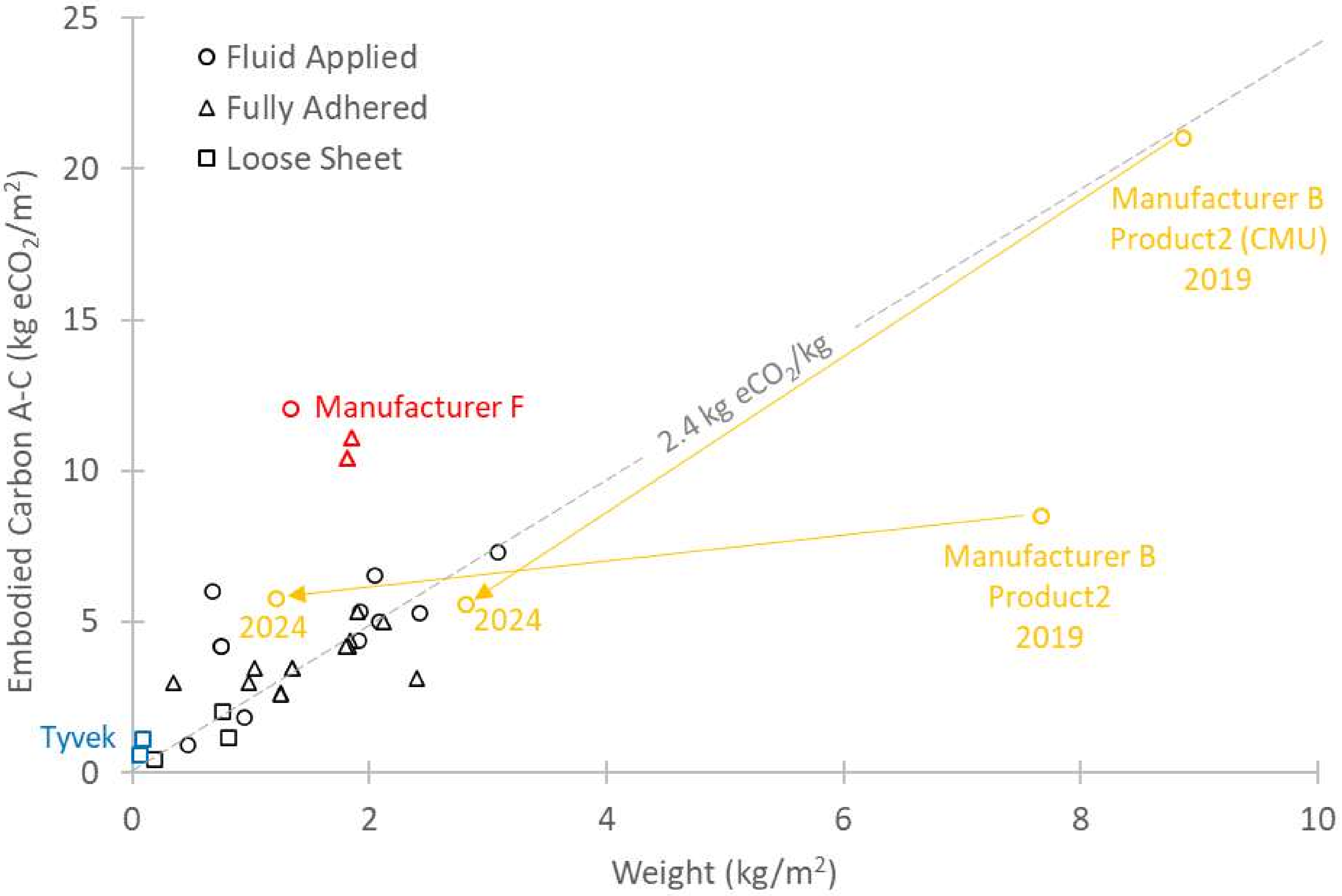
Liquid Applied Air Barriers



All

Air Barriers

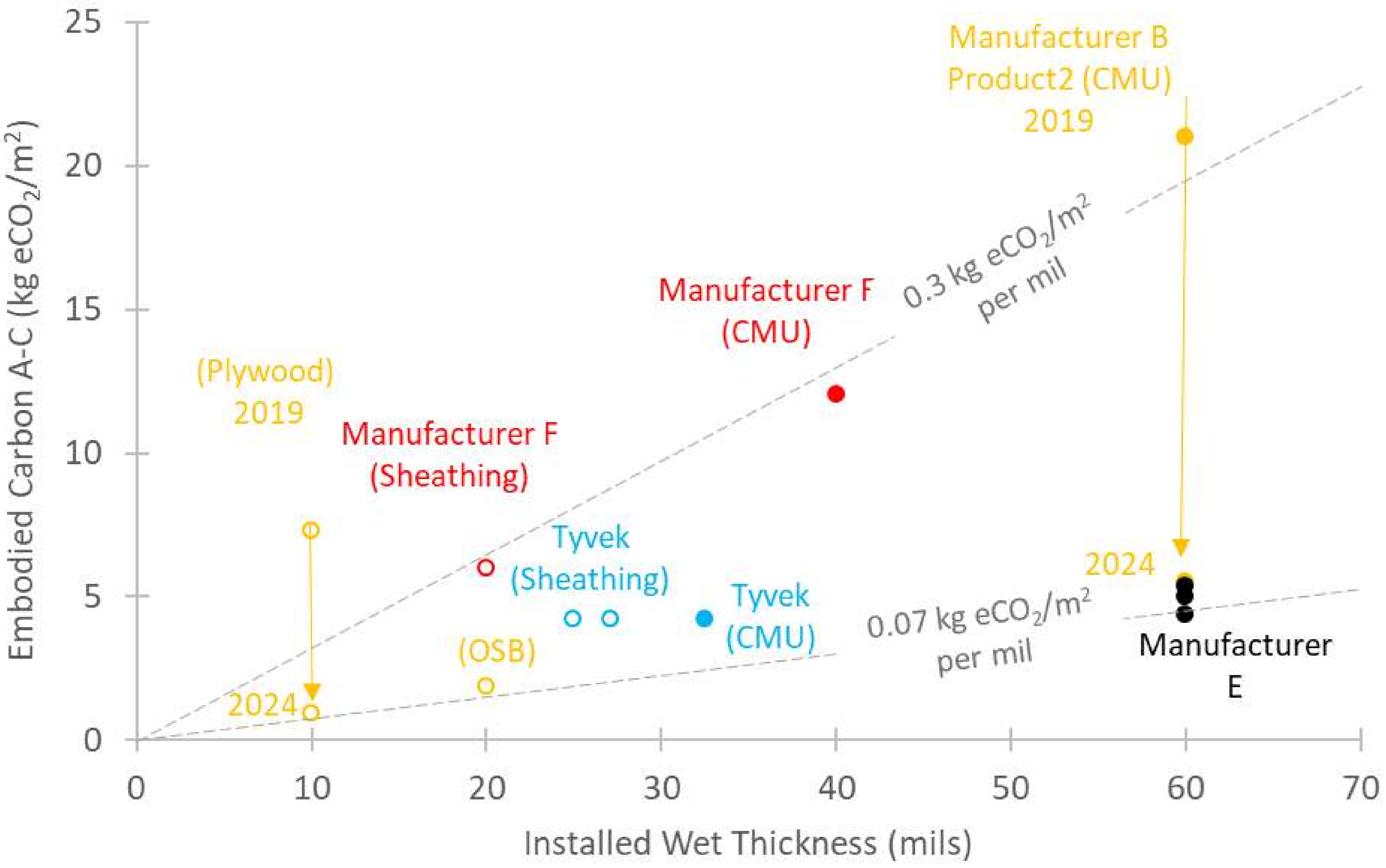
Average Impact
2.4 kg eCO_2/kg



Liquid Applied Air Barriers

Lower Impact
0.30 kg eCO_2/m^2 per mil

Higher Impact
0.07 kg eCO_2/m^2 per mil



Clear Field (Wall) Analysis

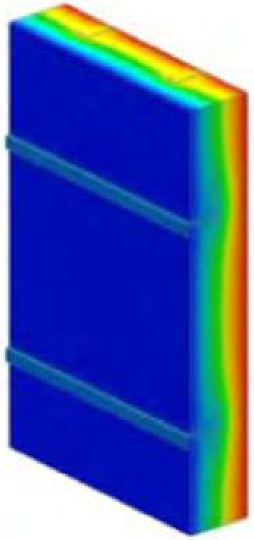
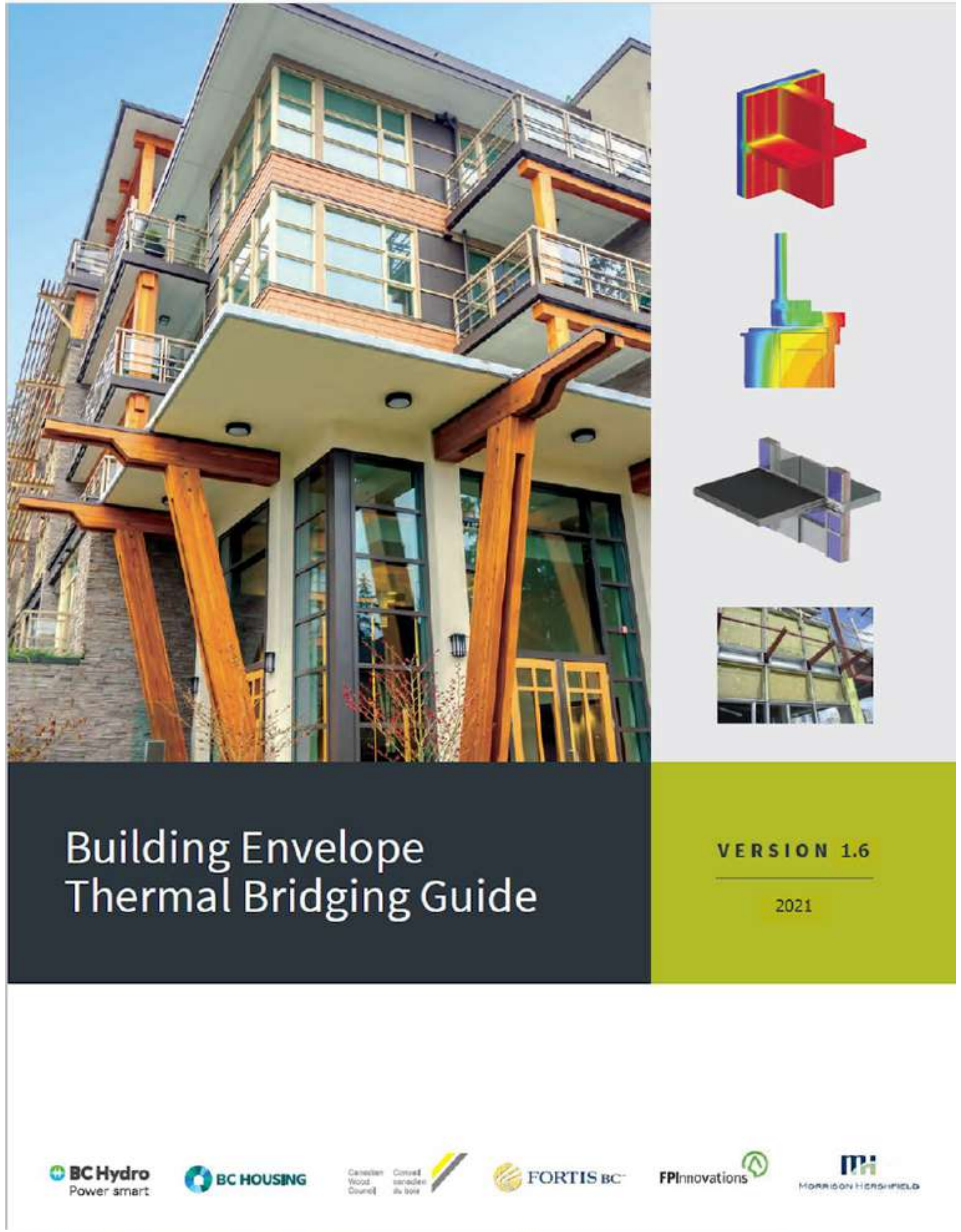
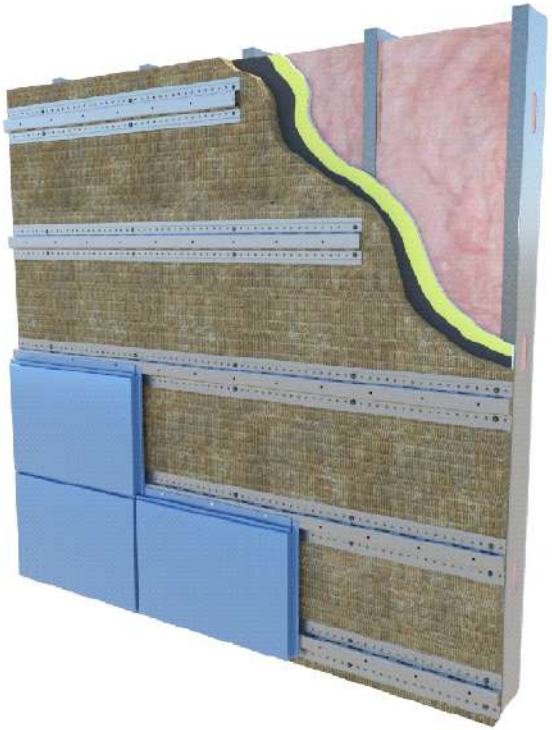


Figure 6: Example clear field assembly



The “Average Wall” for Zone 5 (London Ontario)

ASSEMBLY



ASSEMBLY COMPONENTS	WIDTH	R-VALUE	DENSITY	CARBON
	mm	h°F ft²/Btu	kg/m²	kg eCO₂/m²
Outdoor Air Film (Ventilated Cladding)		0.7		
Cladding: Galvanized Steel (1/3 replaced)	1	0.0	7.8	28.8
Ventilated Cavity w metal tracks	12	0.0	2.3	6.5
Heavy density Mineral Board	100	16.5	10.0	25.8
Screws		-4.1	1.3	3.6
AWB Membrane	1	0.0	1.4	2.5
Glas-Mat Reinforced Gypsum Board	13	0.5	10.2	6.4
Mineral Wool Batt Insulation	150	22	5.7	9.4
Steel Studs 6" deep 16" OC		-14.5	4.3	11.1
6 mil poly	0	0	0.2	0.4
Gypsum Board	13	0	10.4	4.5
Paint and Primer	0	0	0.6	0.6
Indoor Air Film (Wall)		0.7		
CLEAR FIELD R-VALUE	290	**22.5**	54.1	
EMBODIED CARBON (kg eCO2/m²)				**100**

Guidelines

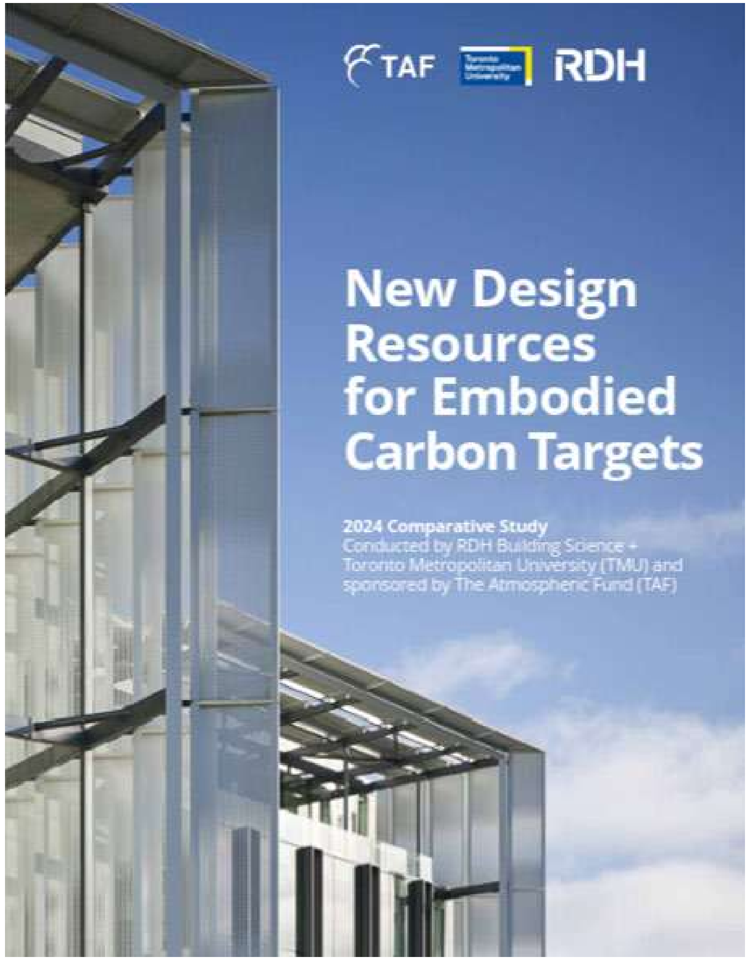
Embodied Carbon Guidelines

Version 1.0

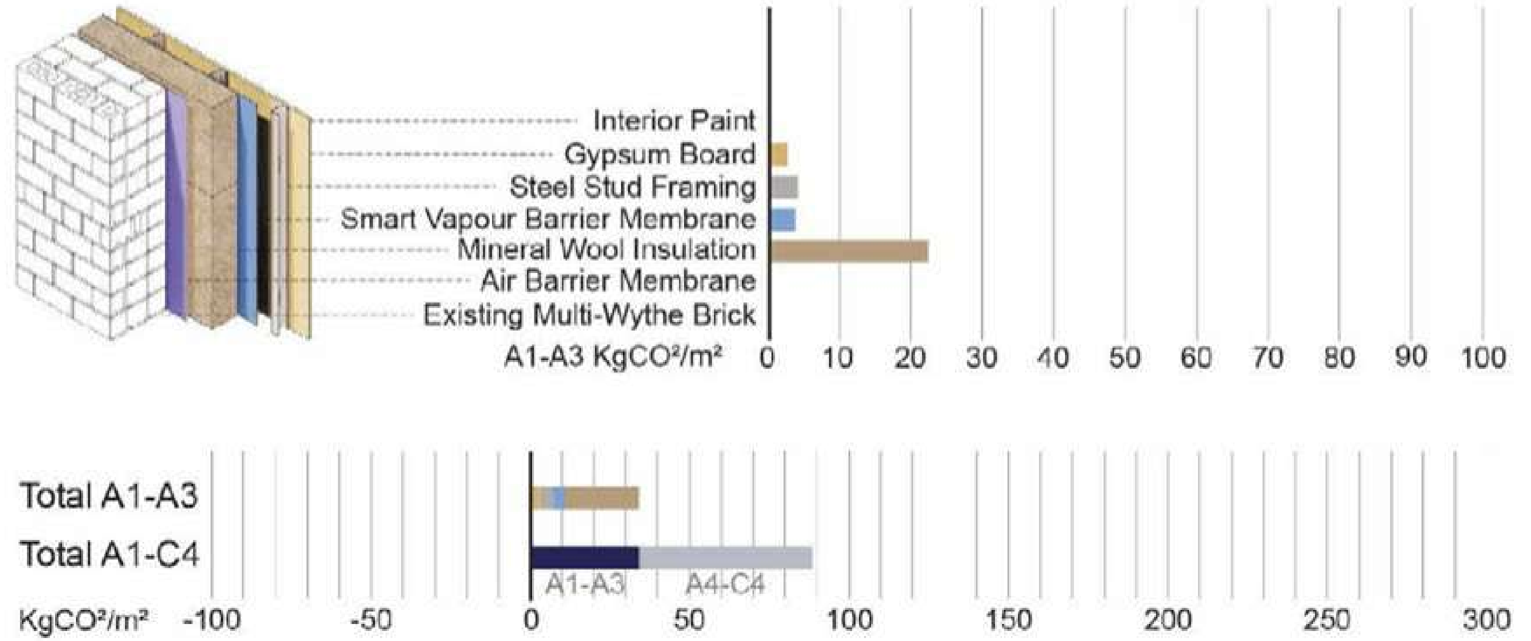
Approved by Chief Building Official on October, 2023

Last amended October 18, 2023

Clear Field (Wall) Analysis Example

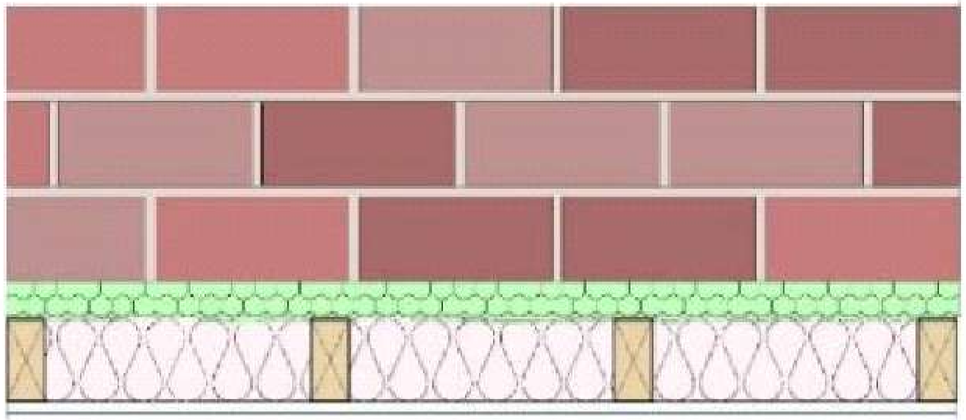


Metrics	Results
Description	**Existing Masonry with Interior Mineral Wool Insulation**
Effective R-value	RSI-4.2 m^2K/W | R-24.0 $ft^2 \cdot °F \cdot h/BTU$
Embodied Carbon per m^2 of Enclosure (A1-A3)	33.7 $kgCO_2/m^2$
Biogenic Carbon per m^2 of Enclosure	0 $kgCO_2/m^2$



Clear Wall Heavy Masonry Interior Retrofit (A-C)

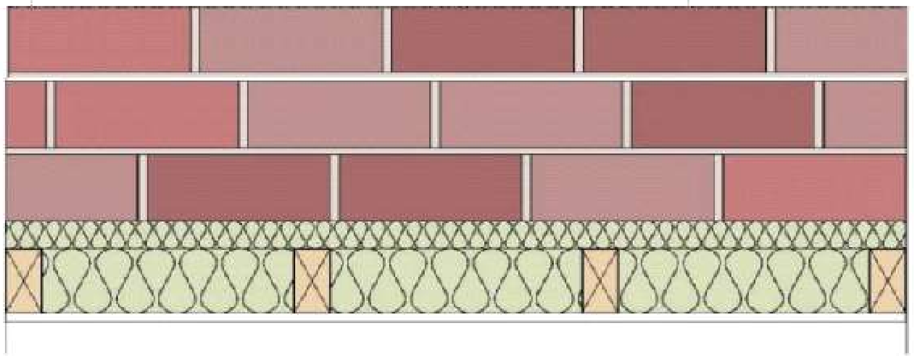
Option 1a: Spray foam (wood studs)



ASSEMBLY COMPONENTS	WIDTH (mm)	R-VALUE (h°F ft²/Btu)	REF	DENSITY (kg/m²)	CARBON (kg eCO_2/m^2)
Outdoor Air Film (Moving Air)		0.2	4		
2 to 4 wythe brick masonry	400	2.8	14		-
Spray polyurethane foam insulation	75	16.1	19	2.4	9.9
3 1/2" Rockwool Comforbatt insulation	88.9	14.0	18	3.2	3.9
wood studs	25%	-5.2	3	10.2	2.4
1/2" drywall	13	0.5	4	9.9	3.6
Paint and Primer	1	0.0		1.5	5.5
Indoor Air Film (Wall)		0.7	4		
CLEAR FIELD R-VALUE	578	**29.1**		27.2	
EMBODIED CARBON (kg eCO2/m²)					**25.2**

Clear Wall Heavy Masonry Interior Retrofit (A-C)

Option 2a: Mineral Wool (wood studs)



ASSEMBLY COMPONENTS	WIDTH mm	R-VALUE h°F ft²/Btu	REF	DENSITY kg/m²	CARBON kg eCO_2/m^2
Outdoor Air Film (Moving Air)		0.2	4		
2 to 4 wythe brick masonry	400	2.8	14		-
liquid applied AWB	1	0.0		0.7	5.9
Rockwool CavityRock	76	12.8	18	4.4	2.4
3 1/2" Rockwool Comforbatt insulation	88.9	14.0	18	3.2	3.9
wood studs	25%	-5.2	3	10.2	2.4
Smart vapour barrier	1	0.0		0.8	2.0
1/2" drywall	13	0.5	4	9.9	3.6
Paint and Primer	1	0.0		1.5	5.5
Indoor Air Film (Wall)		0.7	4		
CLEAR FIELD R-VALUE	581	**25.8**		30.6	
EMBODIED CARBON (kg eCO2/m²)					**25.6**

Clear Field (Wall) Analysis

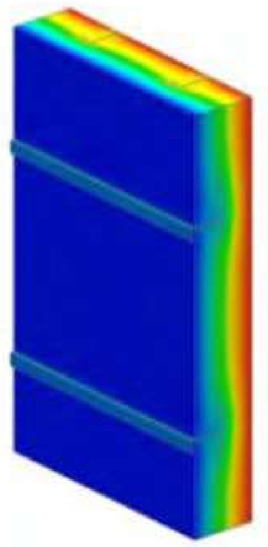


Figure 6: Example clear field assembly

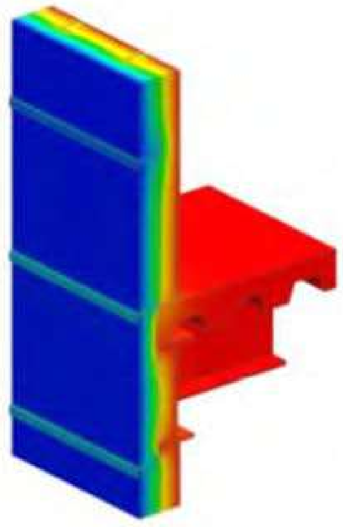
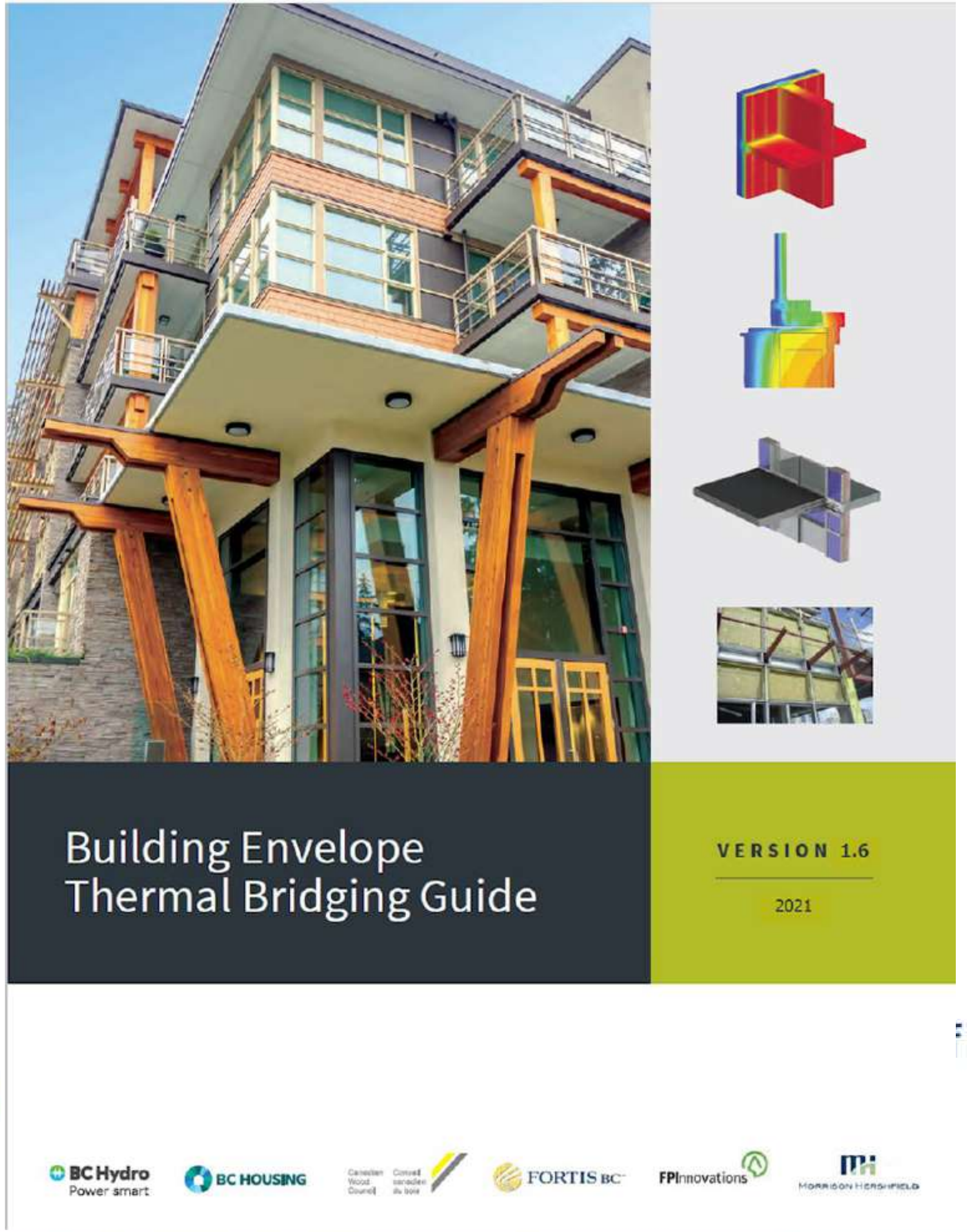
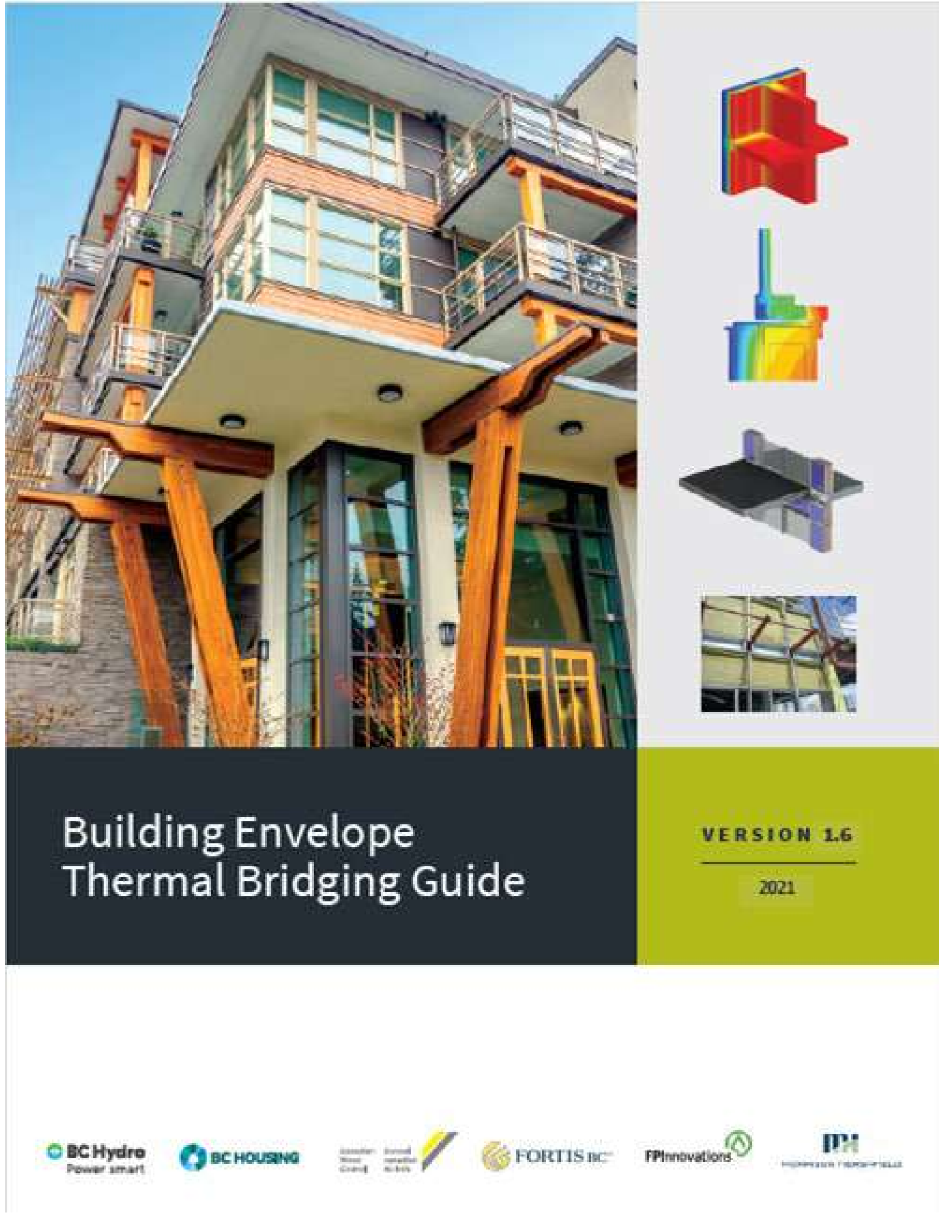
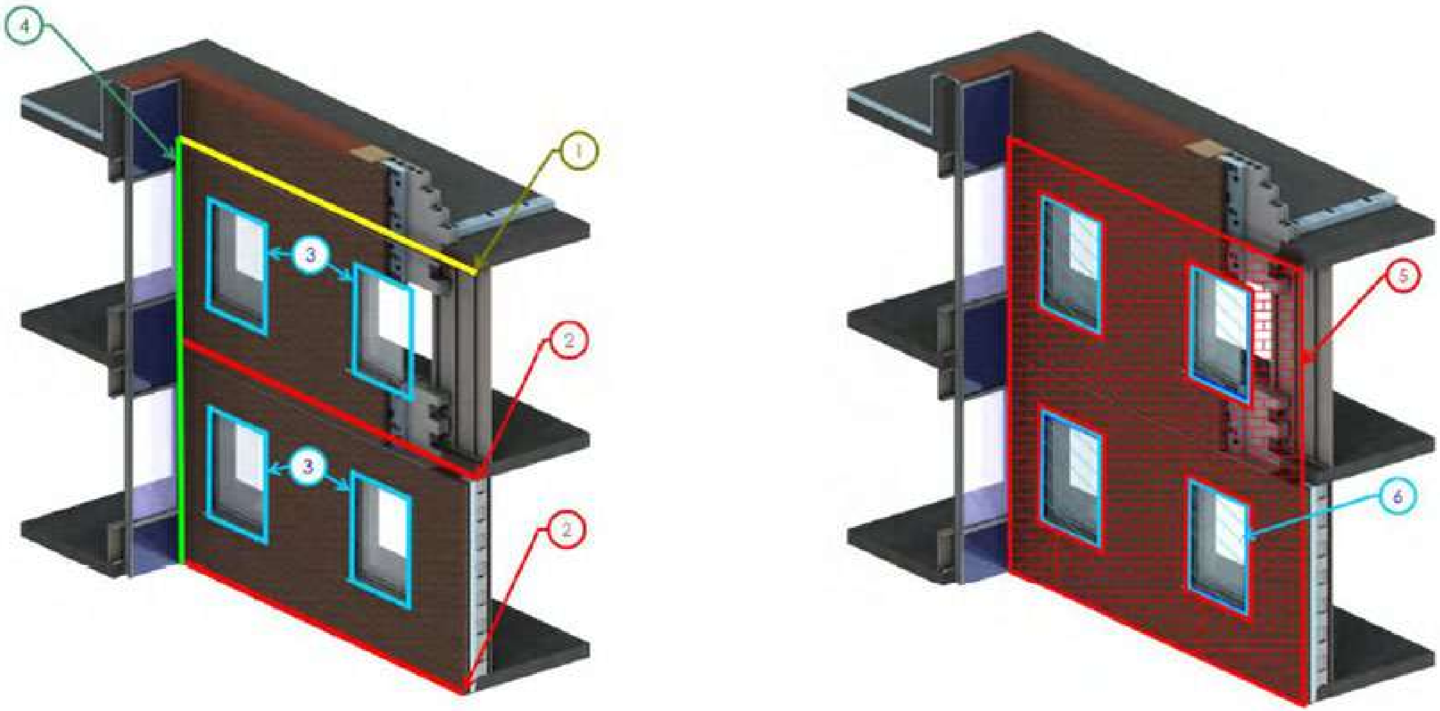


Figure 7: Example linear transmittance of a floor slab detail







1. Parapet Length
2. Slab Lengths
3. Wall to Window Transition Lengths
4. Corner Length
5. Opaque Brick Wall Area
6. Glazing Area

Figure 9: Example building length and area takeoffs

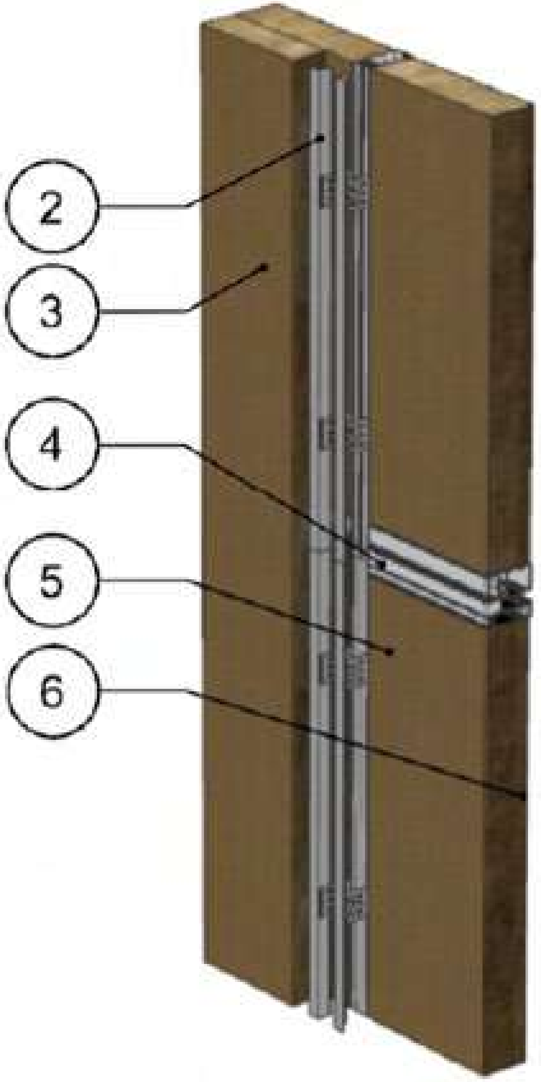
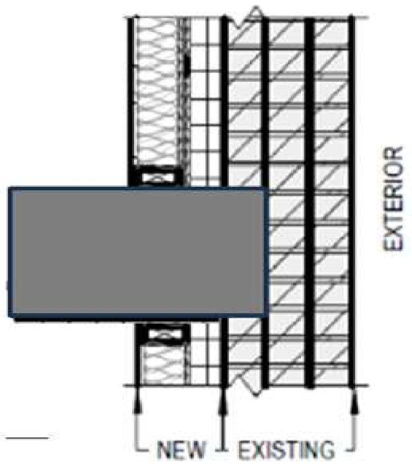
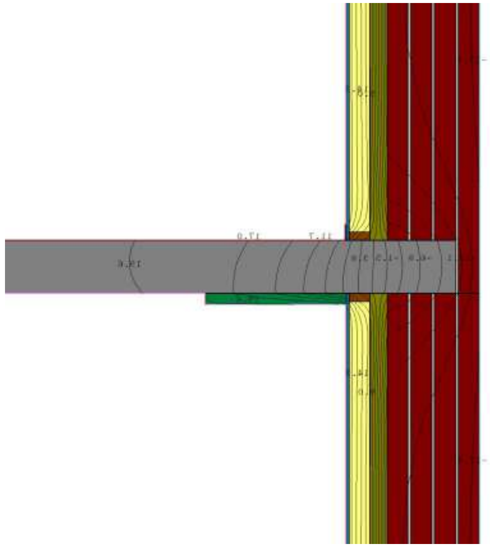


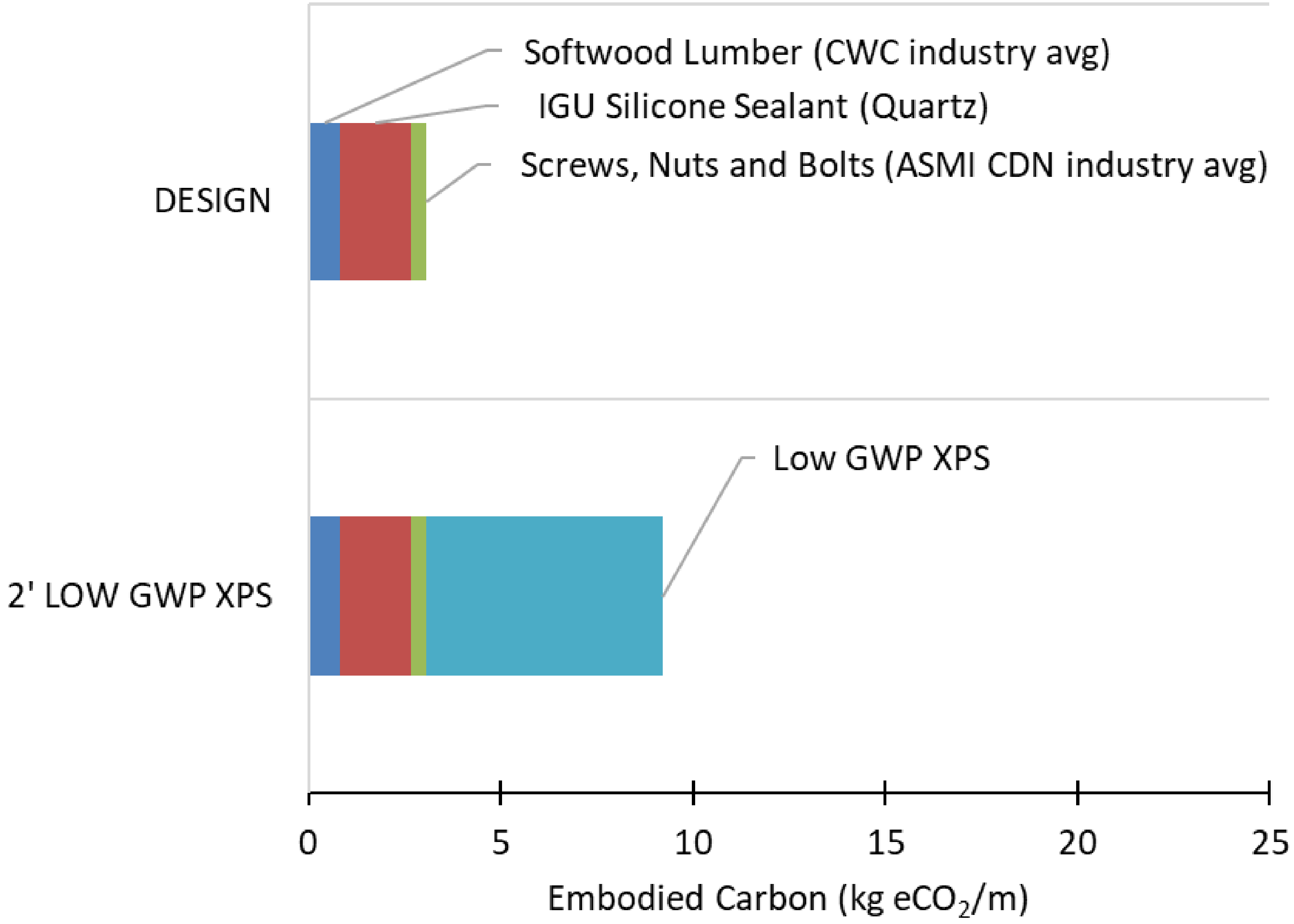
Table 9. Increase in Emissions (kg/CO_2e/m^2) for Alternative Facade Systems[6]

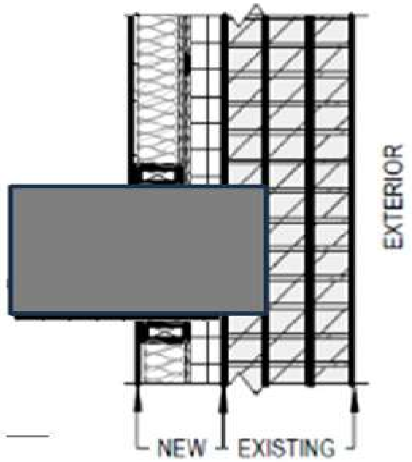
Wall System	Exterior Insulation	Emissions - 30% Glazing			Emissions - 50% Glazing		
		Using Clear Field Quantities	Using Detailed Quantity Take-off	Increase	Using Detailed Quantity Take-off	Emissions using Clear Field Quantities	Increase
Steel-framed walls with vertical clip system and aluminum framed windows	4″ (102 mm)	67	72	5	79	85	6
	6″ (152 mm)	70	75		81	87	
	8″ (203 mm)	73	77		83	89	
	10″ (254 mm)	76	80		86	91	
Exterior Insulated Unitized Curtain-Wall with clip system	4″ (102 mm)	124	223	99	138	193	54
	6″ (152 mm)	127	226		141	195	
	8″ (203 mm)	129	229		144	198	
	10″ (254 mm)	132	232		146	200	

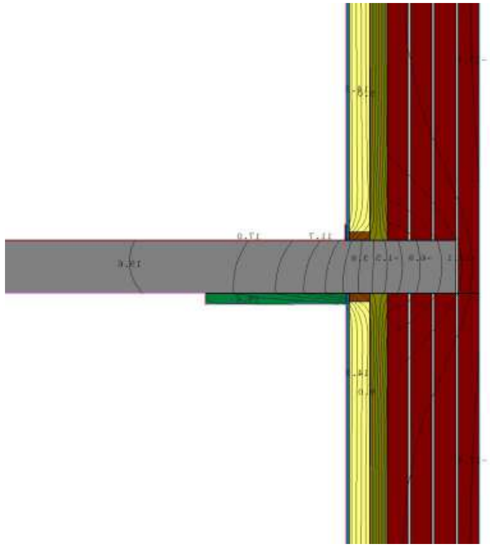
www.bchousing.org/sites/default/files/media/documents/Low-Carbon-Solutions-for-Multi-Unit-Residential-Buildings.pdf


EXTERIOR
NEW
EXISTING

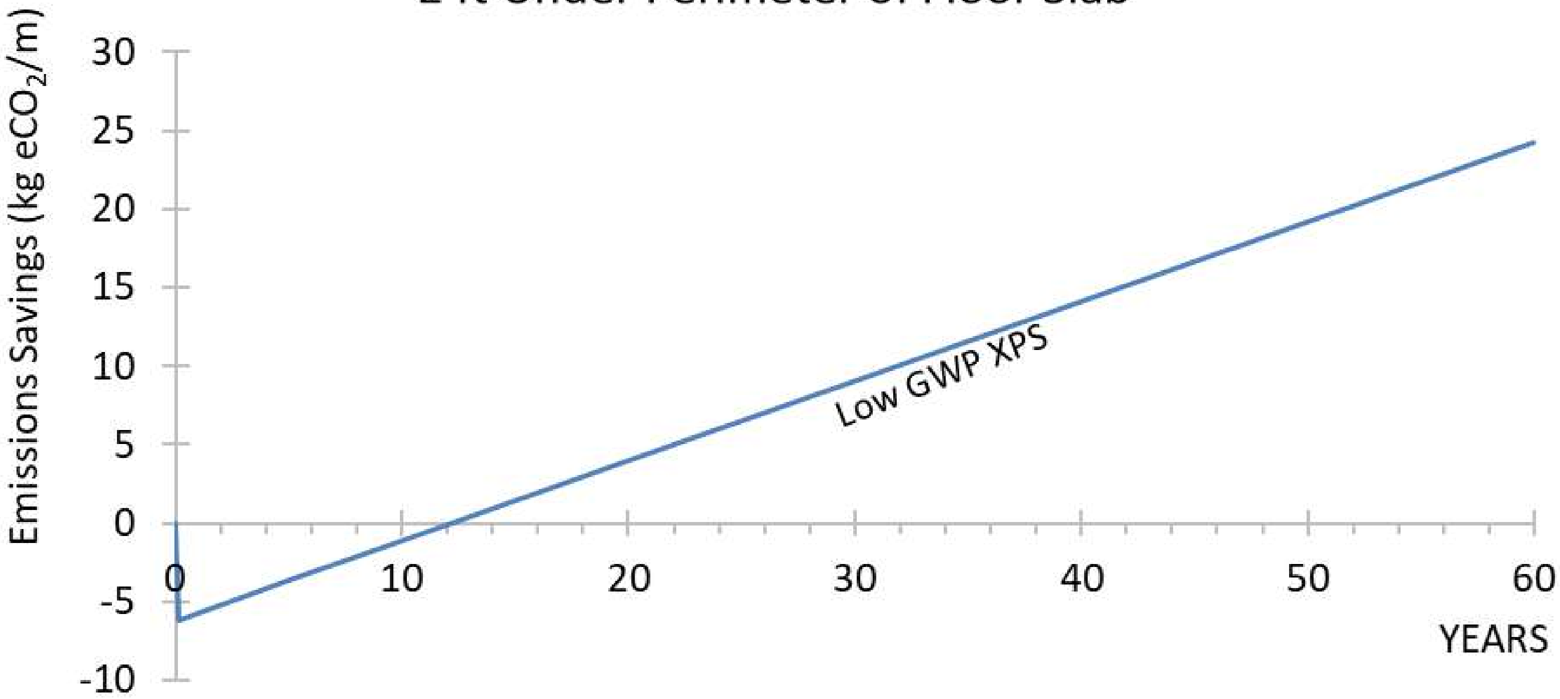



Softwood Lumber (CWC industry avg)
IGU Silicone Sealant (Quartz)
Screws, Nuts and Bolts (ASMI CDN industry avg)
DESIGN
Low GWP XPS
2' LOW GWP XPS
0
5
10
15
20
25
Embodied Carbon (kg eCO_2/m)





Carbon Emissions Savings for 2" Low GWP XPS Insulation run 2 ft Under Perimeter of Floor Slab



* London, Ontario in building with 90% efficient NG heating

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Presenter Name 2