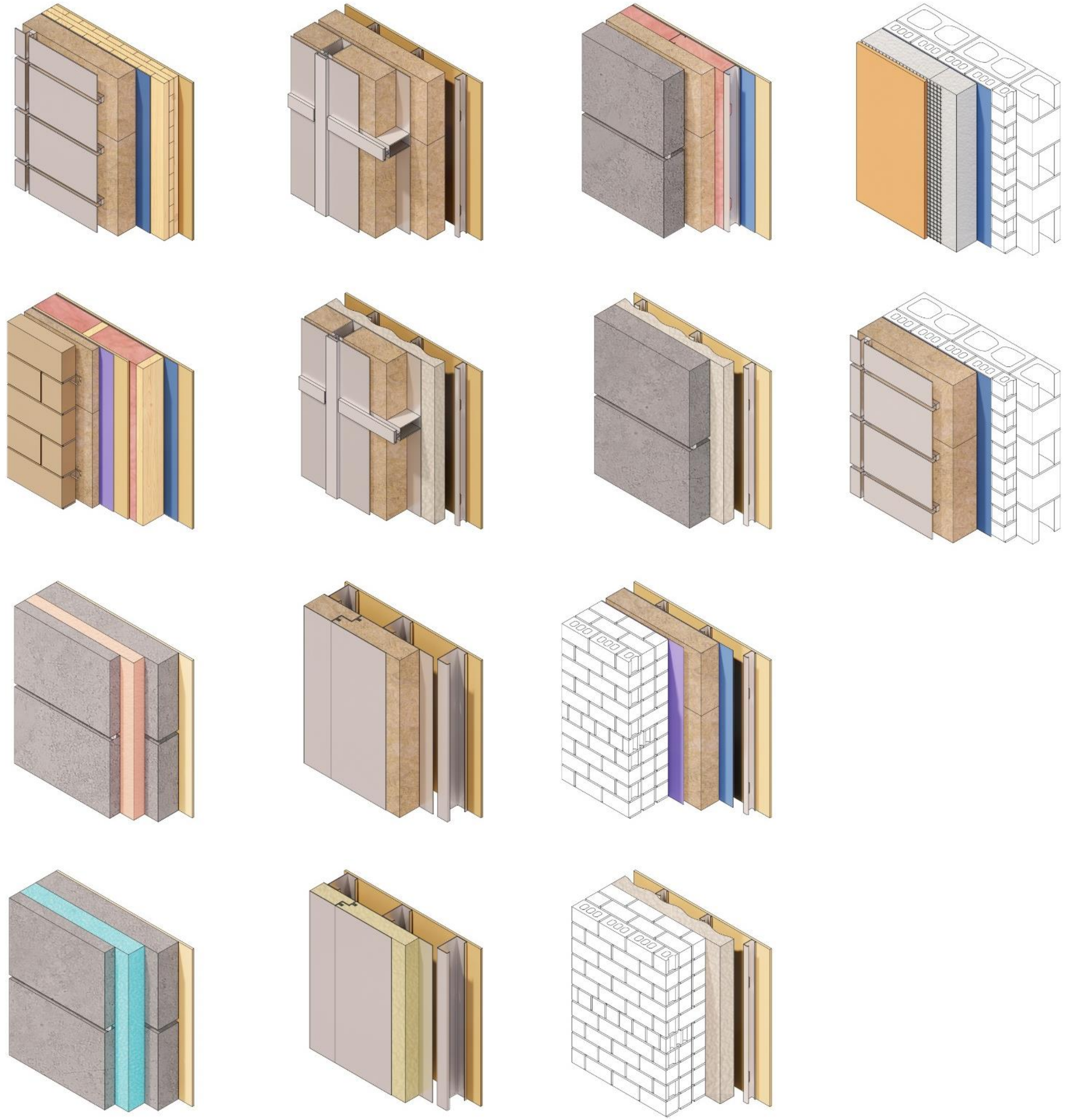


New Design Resources for Embodied Carbon Targets

November 28, 2023

CLEAN AIR PARTNERSHIP

Kelsey Saunders, Senior Building Science Consultant

Rehanna Devraj-Kizuk, Passive House Project Manager

TAF Toronto Metropolitan University RDH

TODAY'S AGENDA

WELCOME TO OUR SESSION!

Kelsey Saunders
Senior Building Science Consultant
RDH Toronto

Rehanna Devraj-Kizuk
Passive House Project Manager
RDH Toronto

01 | Whole Building Life Cycle

WHY DOES THIS MATTER?

We are in a climate crisis.
How do we act as an industry?

CLIMATE CHANGE MITIGATION

- Reduce operational carbon emissions
- Reduce embodied carbon emissions

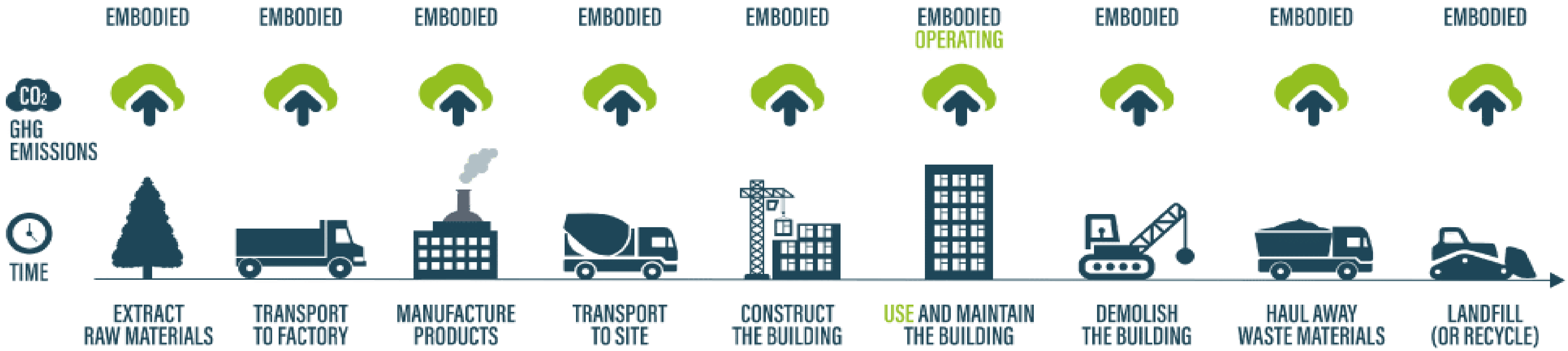
CLIMATE CHANGE ADAPTATION

- Consider future environmental loads
- Consider extremes

WHY DOES THIS MATTER?

The buildings and construction industry represent around **37% of global operational energy and process-related CO2 emissions** (UNEP 2022).

In Canada, between 2023 and 2050, **embodied carbon could represent over 90%** of a new building's carbon emissions (CAGBC 2022).



1 Understanding the **true and complete** impact of buildings

2 Mitigate and Adapt.

CLIMATE CHANGE MITIGATION FOR BUILDINGS

- Reduce operating emissions
- Use low or zero carbon fuel sources
- Reduce emissions associated with building materials


Brock Commons
Source: Naturally Wood

- **Reduce operating emissions**
- **Use low or zero carbon fuel sources**
- Reduce emissions associated with building materials

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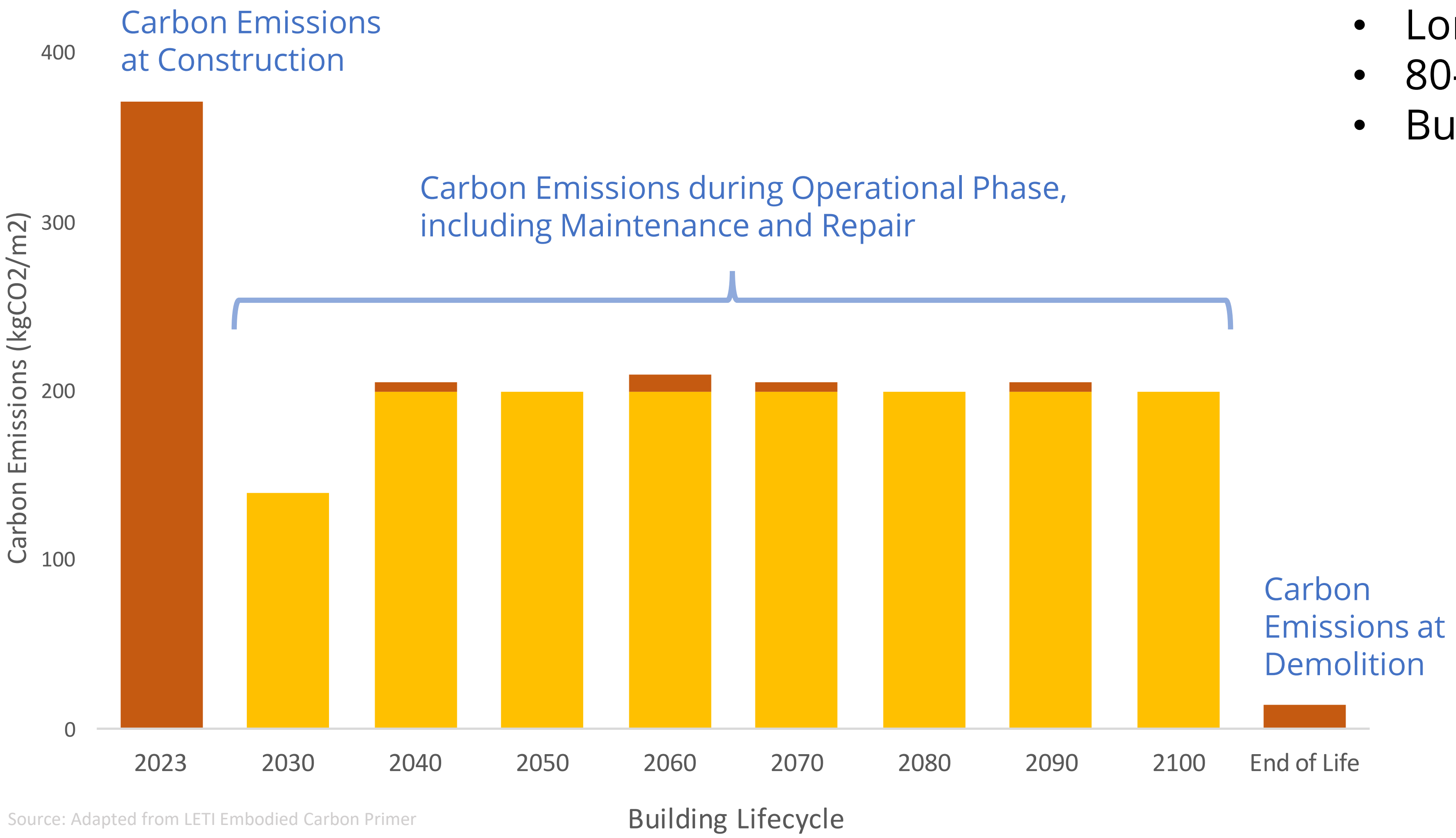
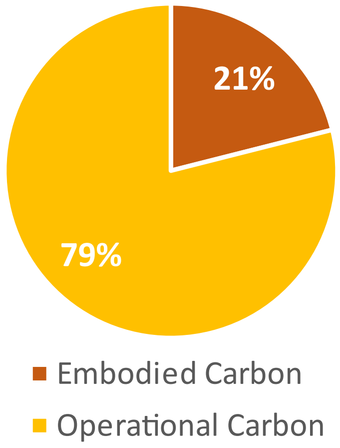
EMBODIED CARBON VS. OPERATIONAL CARBON

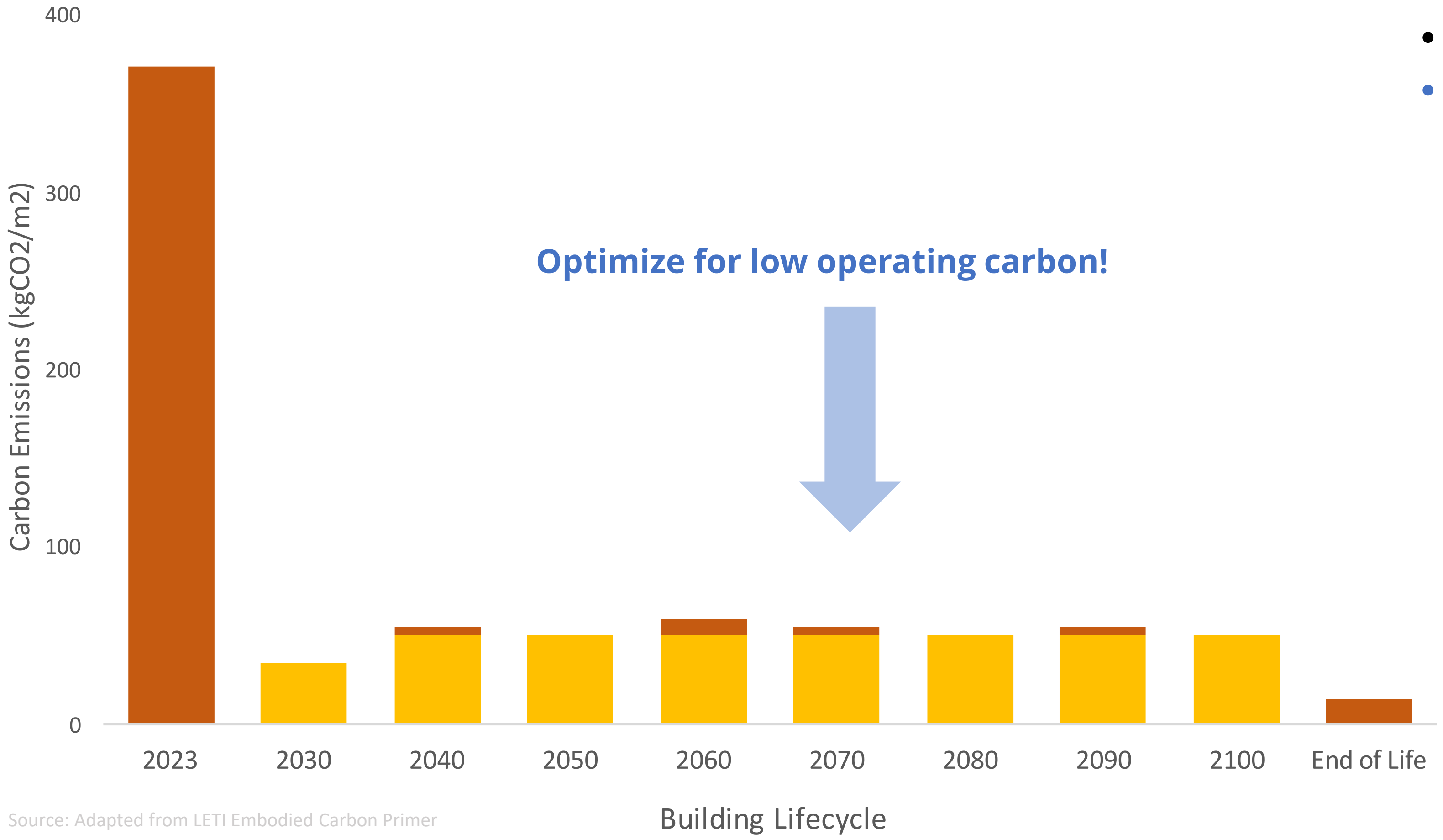


Source: Adapted from LETI Embodied Carbon Primer

- Long Term care facility
- 80-year service life
- Built to code

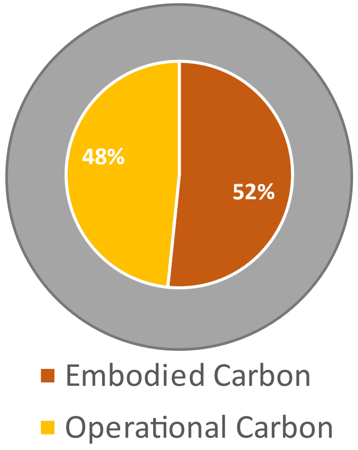


EMBODIED CARBON VS. OPERATIONAL CARBON



Source: Adapted from LETI Embodied Carbon Primer

- Long Term care facility
- 80-year service life
- Low energy and zero fossil fuels



CLIMATE CHANGE MITIGATION FOR BUILDINGS

- Reduce operating emissions
- Use low or zero carbon fuel sources
- **Reduce emissions associated with building materials**

Brock Commons
Source: Naturally Wood

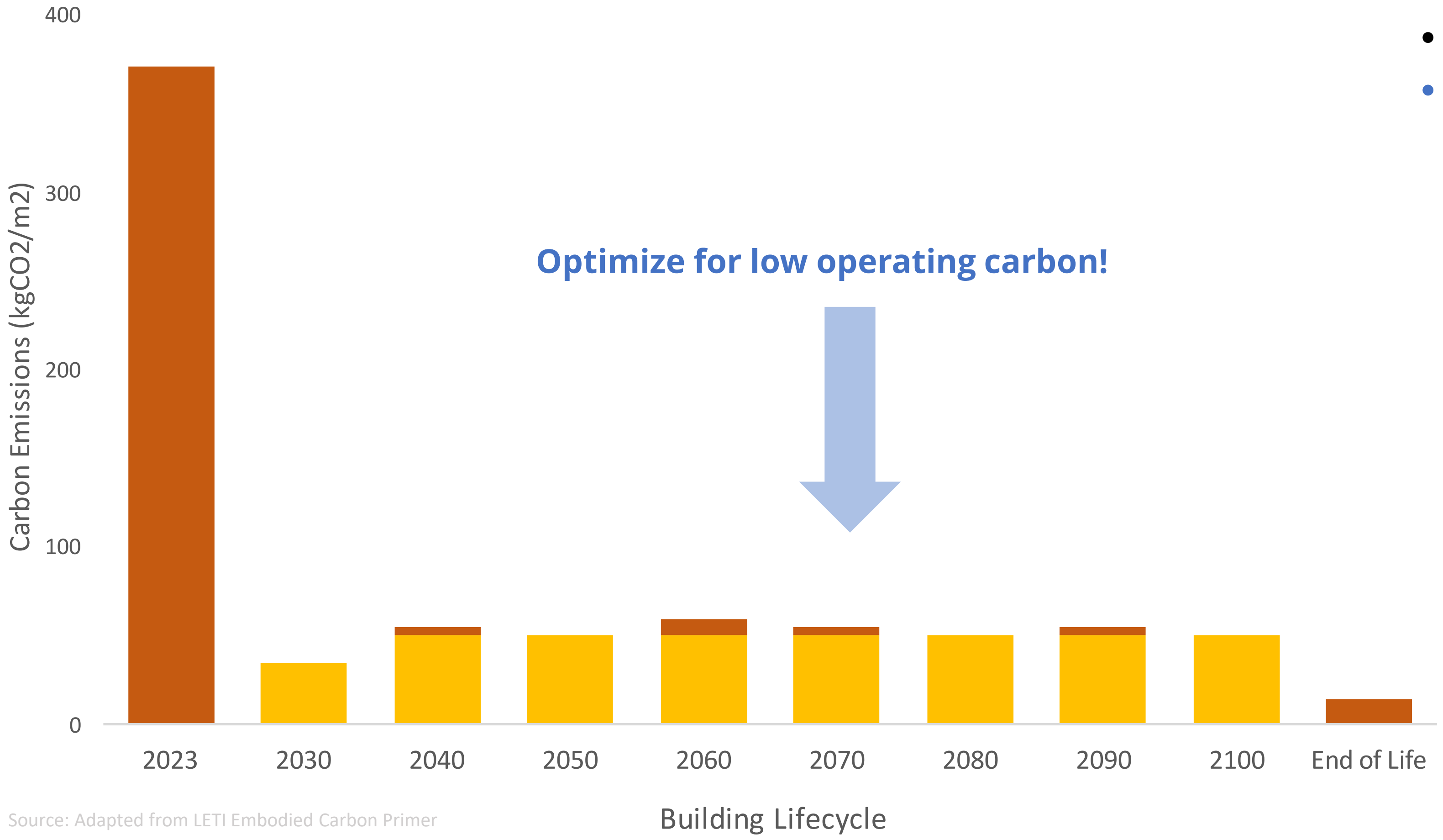
CLIMATE CHANGE MITIGATION FOR BUILDINGS

- Reduce operating emissions
- Use low or zero carbon fuel sources
- **Reduce emissions associated with building materials**
  - Use fewer materials
  - Use materials with lower GHG-intensity
  - Make the materials last as long as possible!


Brock Commons
Source: Naturally Wood

EMBODIED CARBON VS. OPERATIONAL CARBON

- Long Term care facility
- 80-year service life
- Low energy and zero fossil fuels



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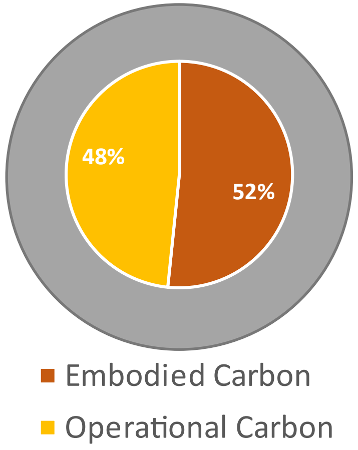

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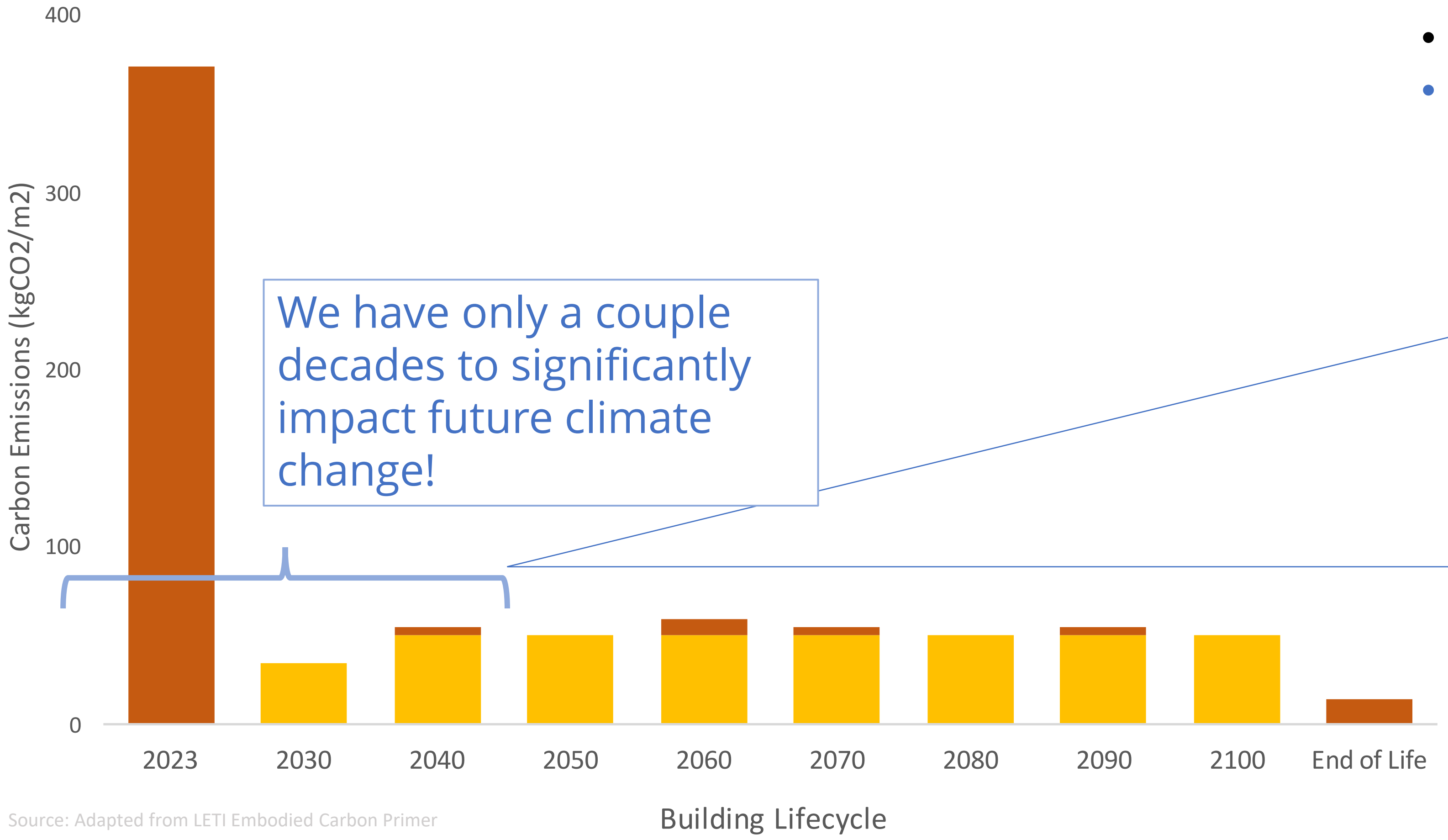

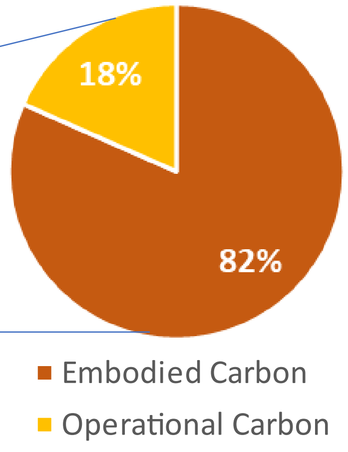

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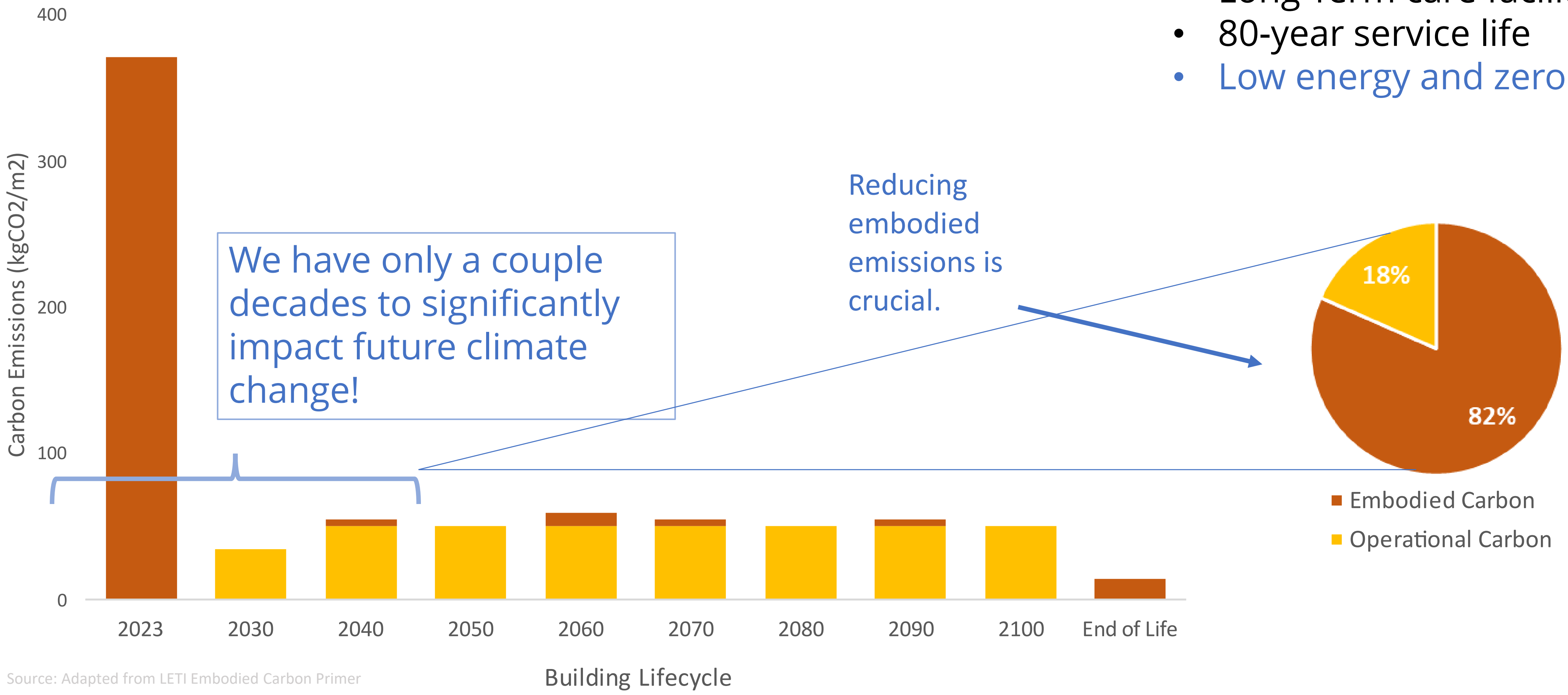
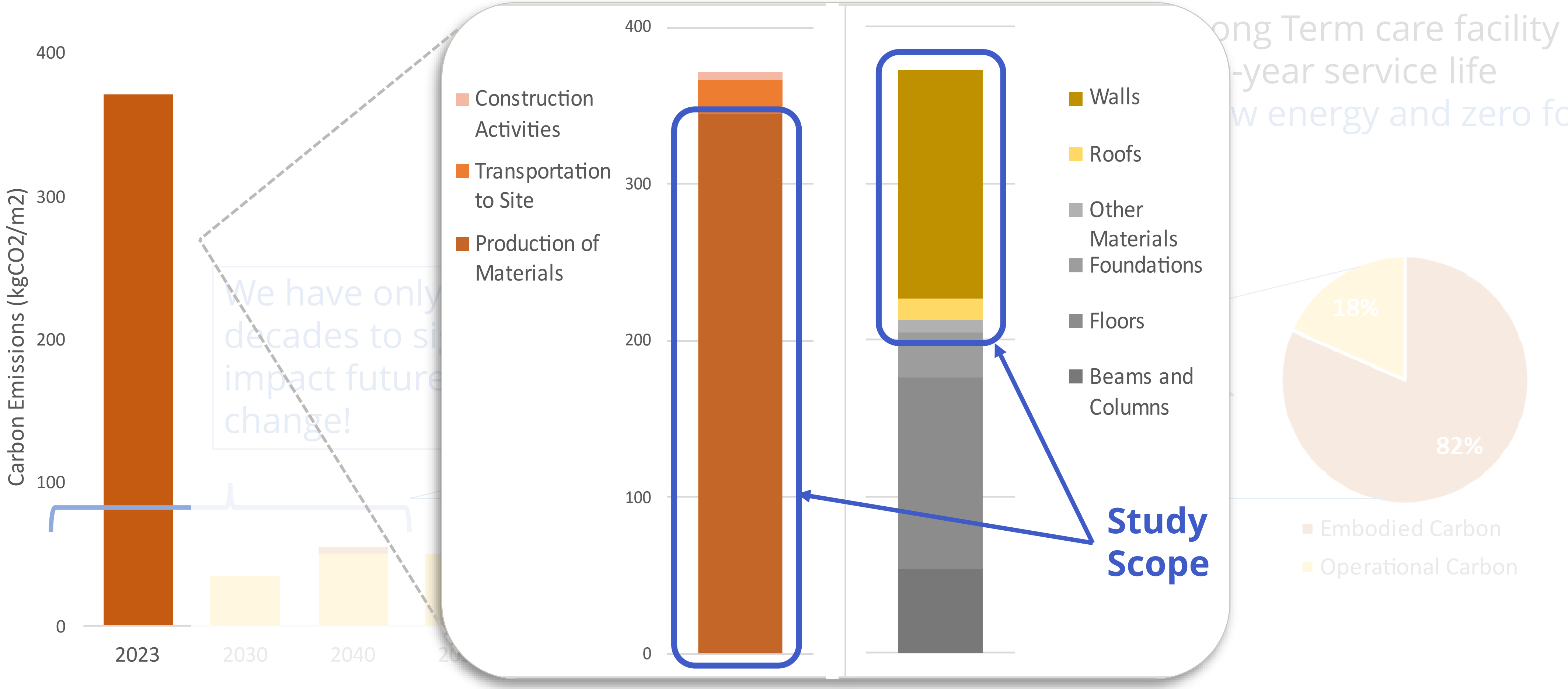


Source: Adapted from LETI Embodied Carbon Primer

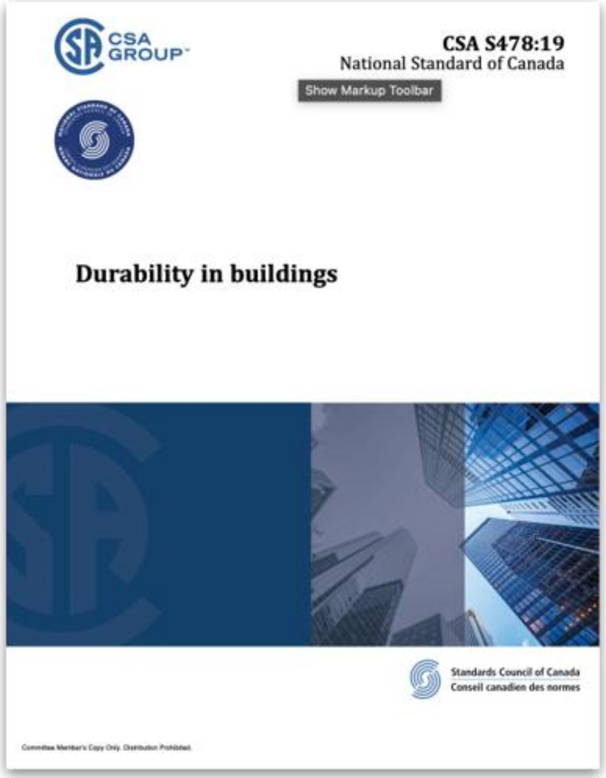
SCOPE OF THE STUDY – UPFRONT CARBON



Source: Adapted from LETI Embodied Carbon Primer

NOD TO DURABILITY IN BUILDINGS

- Durable materials last – ideally for the service life of the building
- Durable details prevent premature failure of components and assemblies
- Designing for durability minimizes material use over a buildings life cycle, and with that life cycle carbon emissions



New standards and codes are coming into effect:

- CaGBC Zero Carbon Building Standard – in place, voluntary
- Toronto Green Standard – Version 5 is coming soon in ~2025
- National Building Codes 9.36 and NECB – Embodied carbon is coming in 2030
- Proposed ASHRAE Standard 240P (tbd)
- City of Toronto targets all existing buildings retrofitted to net-zero by 2050

02 | RDH x TMU

RDH + TMU spent the better part of 2022 and 2023 working hard to launch a comprehensive study of more than 25 wall and roof assemblies.

- RDH approached TMU to partner on this study in 2021 and kicked off with TAF funding in early 2022.
- Fit well with already approved and ongoing studies at TAF
- Use case: tool for early design stage life cycle assessment to inform decision making at a project and a policy level.
- Final guidance document and website resource now live! LINK

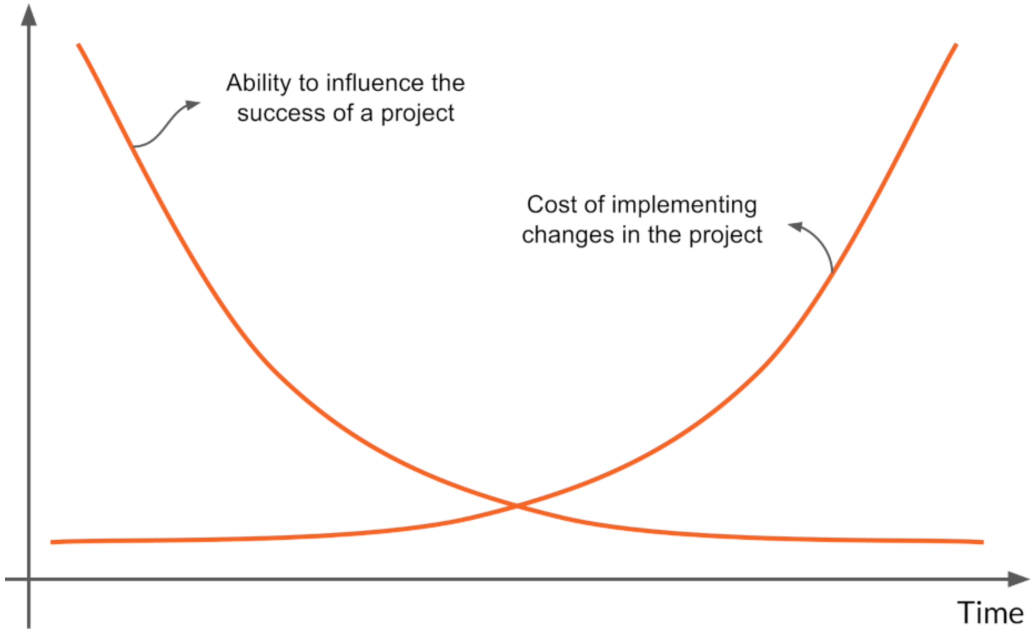
TAF The Atmospheric Fund

Toronto Metropolitan University

RDH Making Buildings Better™

RESPONDING TO A CALL FOR ACTION

- “Carbon” is the new “Energy”
- Decisions made early in design have a major impact on the whole life cycle carbon of a building.
- Current standards addressing embodied carbon in buildings are a “report card.”
- The industry needs accessible (read “simple”) resources that support **early stage enclosure design** decisions to reduce upfront carbon
- The industry need more benchmark data to inform policies addressing the **whole life cycle carbon balance point**



Balance between Operational Energy Reductions & Embodied Carbon Emissions

03 | Embodied Carbon Study

a. Project Overview

Key Objectives

1. Define a **standard methodology** to calculate embodied carbon for enclosure assemblies

2. Establish the **embodied carbon metrics** for 26 enclosures

3. Develop **design support guidance**

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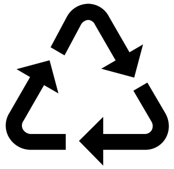
Outcomes and Deliverables

- **Open-source database** of results
- **Cut sheets** for each assembly, including
  - R values
  - Quantity Takeoffs
  - Embodied Carbon and Environmental Impact
- **Guidance Document**, detailing:
  - Applicable use cases
  - Comparative study of key enclosure materials
  - Key takeaways and lessons learned

STUDY USE CASES

- Provide designers with **early-stage design information** regarding the LCA impact of enclosure assembly type and the material within.



STUDY USE CASES

- Provide designers with **early-stage design information** regarding the LCA impact of enclosure assembly type and the material within.

- Assist in the development of embodied carbon **targets for codes and standards** development and/or references (baseline).

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- Allow **manufacturers to develop an understanding of context** for their product, including meeting ever evolving demands for low carbon design choices.

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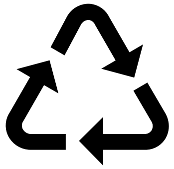

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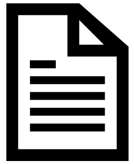
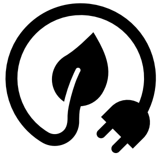
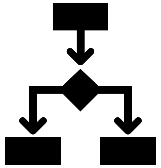


- Allow **manufacturers to develop an understanding of context** for their product, including meeting ever evolving demands for low carbon design choices.



- Encourage manufacturers to **develop their product specific EPDs** that will allow designers to have greater choices of materials for their enclosure assemblies.



b. Methodology

Building Enclosures are "Environmental Separators"

- choices affect both operating and embodied emissions
- long-term performance must be considered

Building Enclosure embodied emissions are complex

- there are many material choices, many reasons to choose them
- great variation between different building enclosure assembly options.

ASSEMBLY SELECTION METHODOLOGY

1. Set performance targets
2. Develop typical enclosure assemblies list based on industry experience
3. Build out assemblies based on clear wall effective R-value calculation

1. **Set performance targets**
2. Develop typical enclosure assemblies list based on industry experience
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Performance Targets

- Walls R-25 (RSI-4.4)
- Roofs R-30 (RSI-5.3)
- Floors R-25 (RSI-4.4)

Nominal R-value

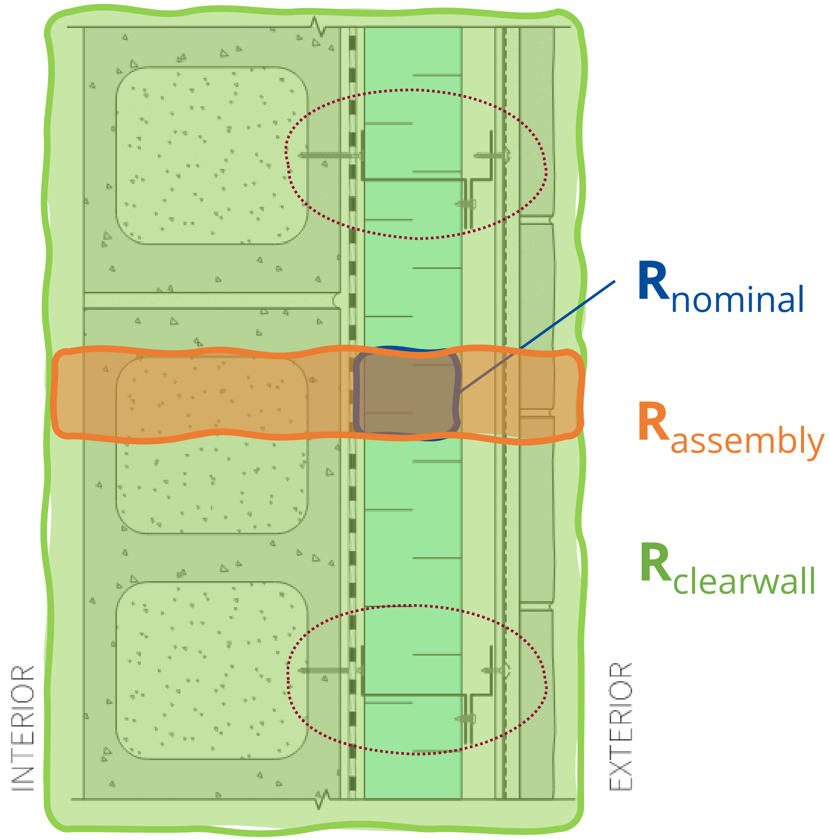
- Rated R-value of insulation layer only

Assembly R-value

- Nominal R-value + thermal resistance of other layers , assuming the assembly is 1D

Clear-wall R-value (Effective)

- Assembly R-value + two-dimensional effect of standard repetitive thermal bridging (steel, studs, cladding attachments…)



1. Set performance targets
2. **Develop typical enclosure assemblies list based on industry experience**
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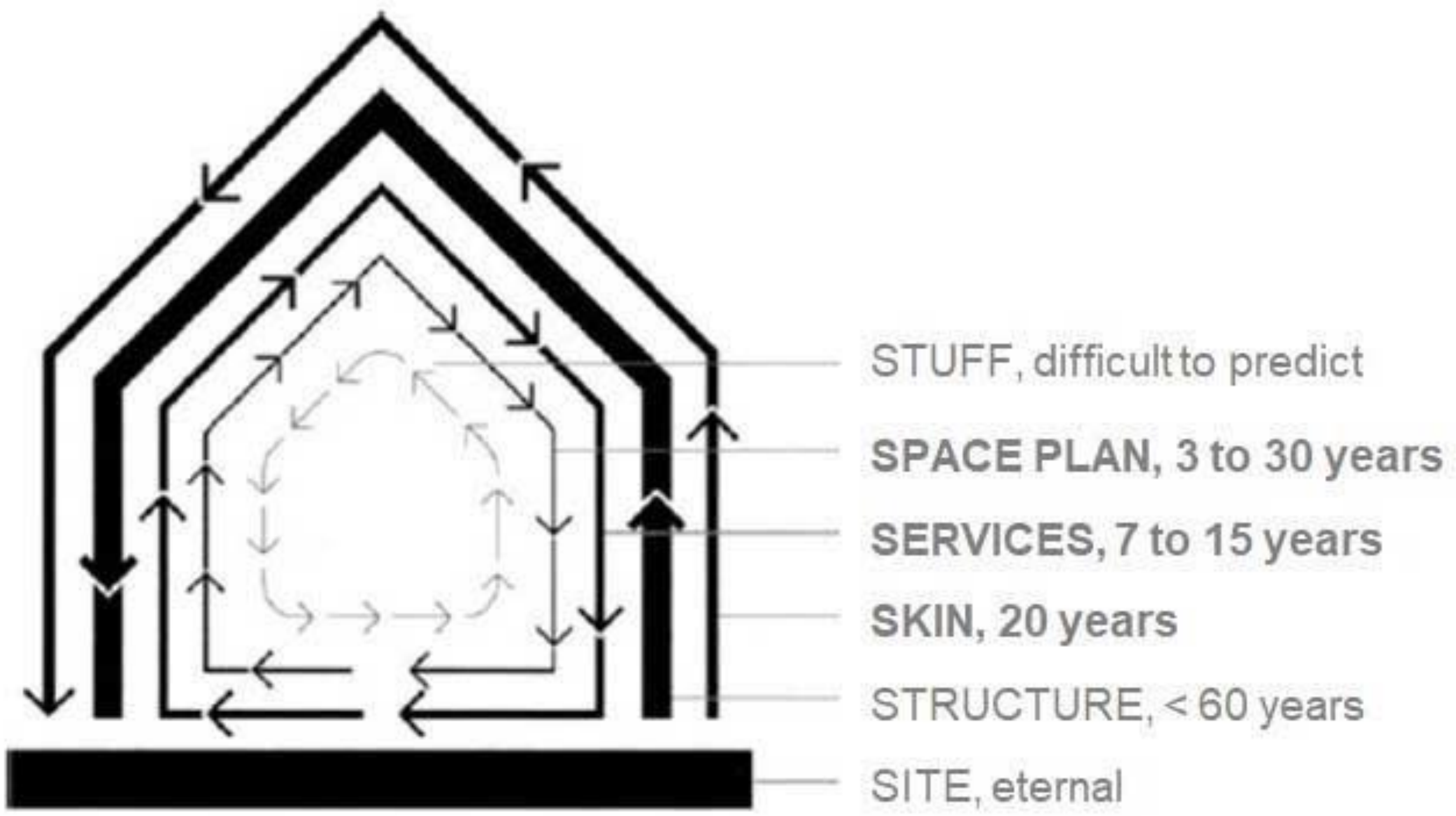
Performance Targets

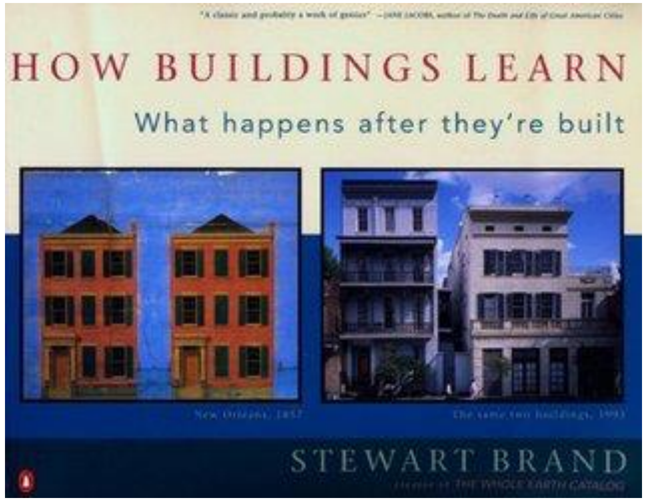
- Walls R-25 (RSI-4.4)
- Roofs R-30 (RSI-5.3)
- Floors R-25 (RSI-4.4)

Assembly selection

- Commonly used assemblies (GTHA)
- Variety of materials
- New construction and existing building retrofits

BUILDING ELEMENTS





[Image from: How Buildings Learn, Stewart Brand, Penguin Books 1994]

1. Set performance targets
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Assembly selection

- Commonly used assemblies (GTHA)
- Variety of materials
- New construction and existing building retrofits

26 Assemblies Built

- 17 Walls
- 5 Roofs
- 4 Floors

WALL ASSEMBLIES

W01
Exterior Insulated CMU with Brick Veneer

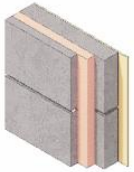
W02
Split Insulated Steel Frame with Lightweight Cladding

W03
Split Insulated Steel Frame with EIFS (EPS)

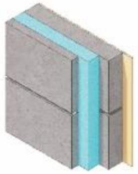
W04
Exterior Insulated CLT wall panel with Aluminum Panel Cladding

W05
Split Insulated Wood Frame with Mineral Wool and Stone Veneer Cladding

W06
Double Wythe Insulated Precast with Kooltherm



W07
Doubly Wythe Insulated Precast with XPS Insulation



W08
Spandrel Panel with 3" Mineral Wool Backpan, Interior Insulated with Mineral Wool

W09
Spandrel Panel with 3" Mineral Wool Backpan, Interior Insulated with Sprayfoam

W10
Insulated Metal Panel with Mineral Wool Insulation

W11
Insulated Metal Panel with Polyisocyanurate Insulation

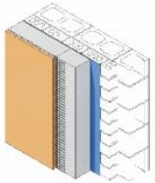
W12
Architectural Precast with Mineral Wool Interior Insulation

W13
Architectural Precast with Spray Foam Interior Insulation

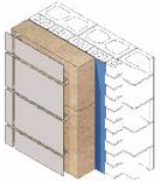
W14
Existing Masonry with Interior Mineral Wool Insulation

W15
Existing Masonry with Interior Spray Foam Insulation

W16
Existing Masonry with Exterior EIFS Overcladding

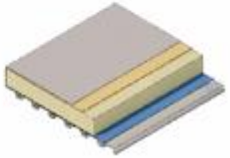


W17
Existing Masonry with Exterior Aluminum Panel Overcladding

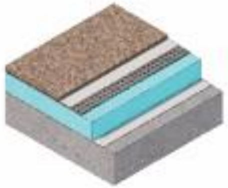


ROOF ASSEMBLIES

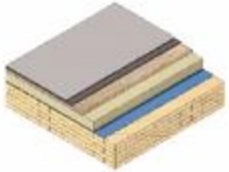
R01
Conventional Roof with Polyiso on Metal Deck



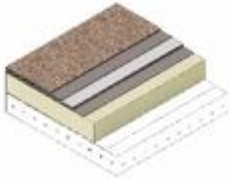
R02
Protected Membrane Roof with XPS on Concrete Deck



R03
Conventional Modified Bitumen Roof with Hybrid Insulation on CLT Deck



R04
Existing BUR Roof Replacement over Polyisocyanurate Insulation



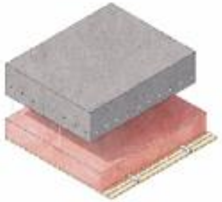
R05
Sloped Metal Roof Assembly

FLOOR ASSEMBLIES

F01
Parking Garage Concrete Ceiling with Vinyl-faced Mineral Wool

F02
Parking Garage Concrete Ceiling with Fire Resistant Spray Insulation

F03
Parking Garage Insulated Dropped Ceiling (Heated Plenum)



F04
Insulated Soffit with Mineral Wool

EMBODIED CARBON CALCULATION METHODOLOGY

1. Tool Selection
2. Quantity Takeoffs
3. Life Cycle Assessment (LCA)

1. **Tool Selection**
2. Quantity Takeoffs
3. Life Cycle Assessment (LCA)

OneClick LCA

- User interface
- EPD availability
- Comprehensiveness of LCA results

LCA DATABASES AND SOFTWARE

Life Cycle Inventory Databases

- EPD database: Environmental Product Declarations (constantly being updated)
  - Specific material produced by a specific manufacturer
- Generic Database:
  - Material data is based on industry averages

To use any of these tools:

- Project/building specific data required
  - Depends on software used and design phase (concept design vs construction documents).

1. Tool Selection
2. **Quantity Takeoffs**
3. Life Cycle Assessment (LCA)

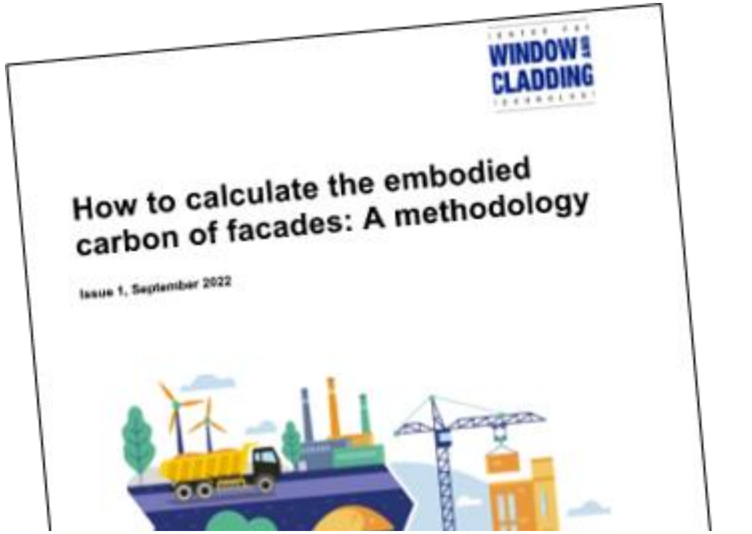
OneClick LCA

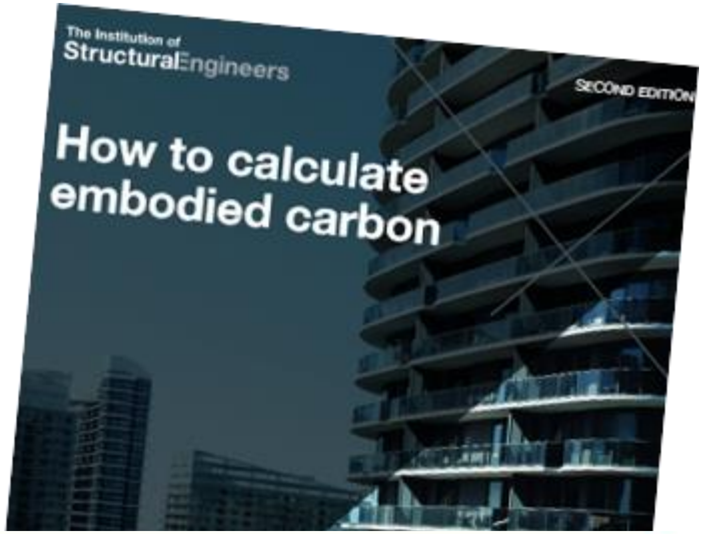
- User interface
- EPD availability
- Comprehensiveness of LCA results

Quantity Takeoffs

- Volume of materials for each component
- Function unit of 9 square meters of enclosure area

GUIDELINES FOR WHOLE BUILDING CALCULATIONS



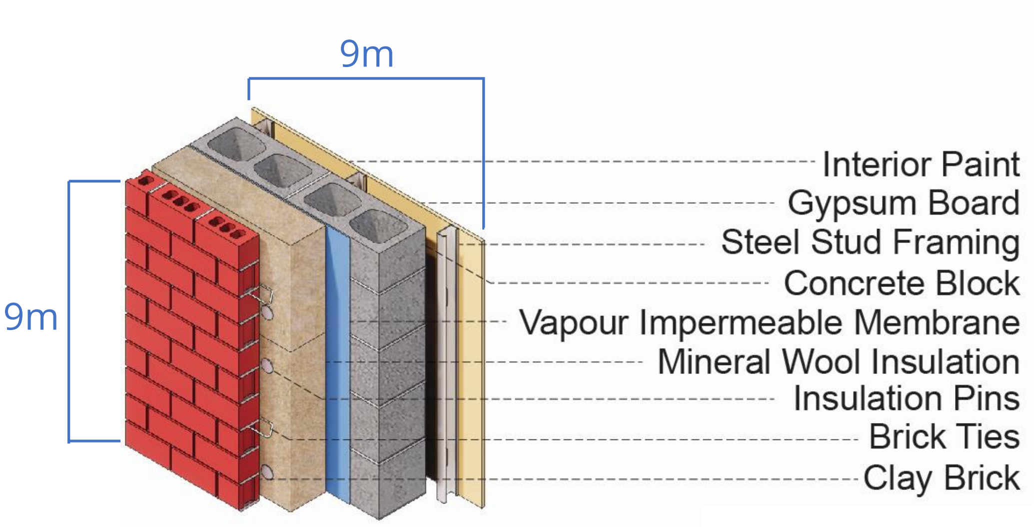


The fundamental principle of an embodied carbon calculation is to multiply the quantity of each material by a carbon factor for the life cycle modules being considered†:

$$\text{material quantity (kg)} \times \text{carbon factor (kgCO}_2\text{e/kg)} = \text{embodied carbon (kgCO}_2\text{e)}$$

VOLUME OF MATERIALS CALCULATIONS

W01



Calculate by material volume, or by material area

Category	Material (RDH specification)	Description (from EPD)	Thickness (mm)	Volume of material (m3)
Finish	Interior Paint	Eggshell acrylic paint, 1294.29 kg/m3		0.0014
Finish	Interior gypsum board	Gypsum plaster board, regular, generic, 6.5-25 mm, 10.7 kg/m2, (for 12.5 mm), 858 kg/m3	12.7 (0.5")	0.114
Interior finish support	Steel Stud Framing	Steel stud framing for drywall/gypsum plasterboard per sq. meter of wall area (incl. air gaps per m3); 63.5 mm x 30.5 mm, gauge 25	63.5 (2.5")	*
Back-up structure	Reinforced Concrete Block Masonry	Concrete masonry unit (CMU), normal weight, 2250 kg/m3 (Canadian Concrete Masonry Producers Association)	203.2 (8")	1.8
Exterior membrane	Vapour Impermeable Membrane	Latex-based membrane, vapor impermeable, fluid-applied, 40 mils (1mm), 1.15 kg/L, Perm-A-Barrier® NPL 10	1 (0.04")	0.009
Exterior insulation	Exterior Insulation Mineral Wool (Semi-rigid)	Heavy density mineral wool board, Industry average US (NAIMA), 1 m2K/W, 34 mm (1.3"), 4.2 kg/m2, 123.52 kg/m3	152.4 (6")	1.35
Exterior insulation	Insulation Pins	5 insulation pins per panel - 169 pins in total - Hot-dipped galvanised steel; 80% recycled content - 0.28 kg/m2	-	0.000302
Cladding anchorage	Stainless Steel Brick Ties	Assumed 4-foot spacing for angle support - 17 anchors in total - Composed from hot-dipped galvanized cold-formed steel, USA industry average, 7769 - 7849 kg/m3 (SFIA)	-	0.001
Cladding	Clay brick	Clay brick (Acme Brick Company, Belden Brick Company, etc.) 2120 kg/m3	90 (3.5")	0.81

1. Tool Selection
2. Quantity Takeoffs
3. **Life Cycle Assessment (LCA)**

OneClick LCA

- User interface
- EPD availability
- Comprehensiveness of LCA results

Quantity Takeoffs

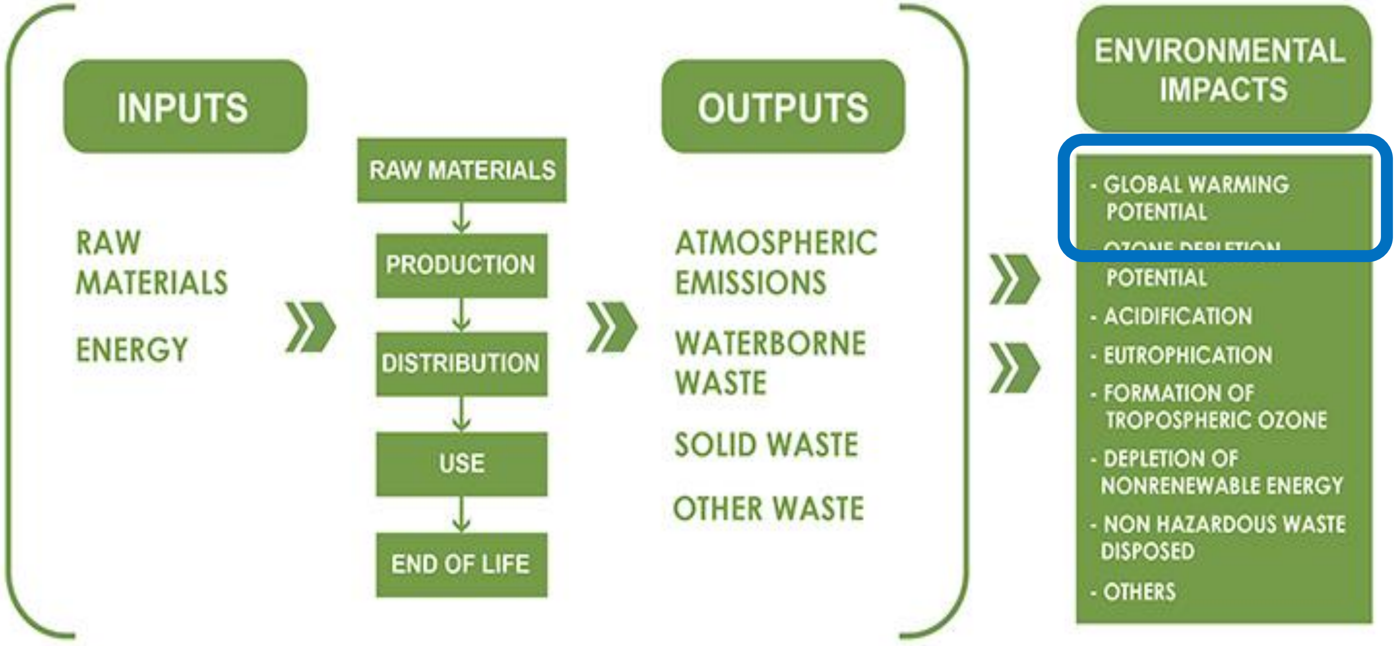
- Volume of materials for each component
- Function unit of 9 square metres of enclosure area

LCA

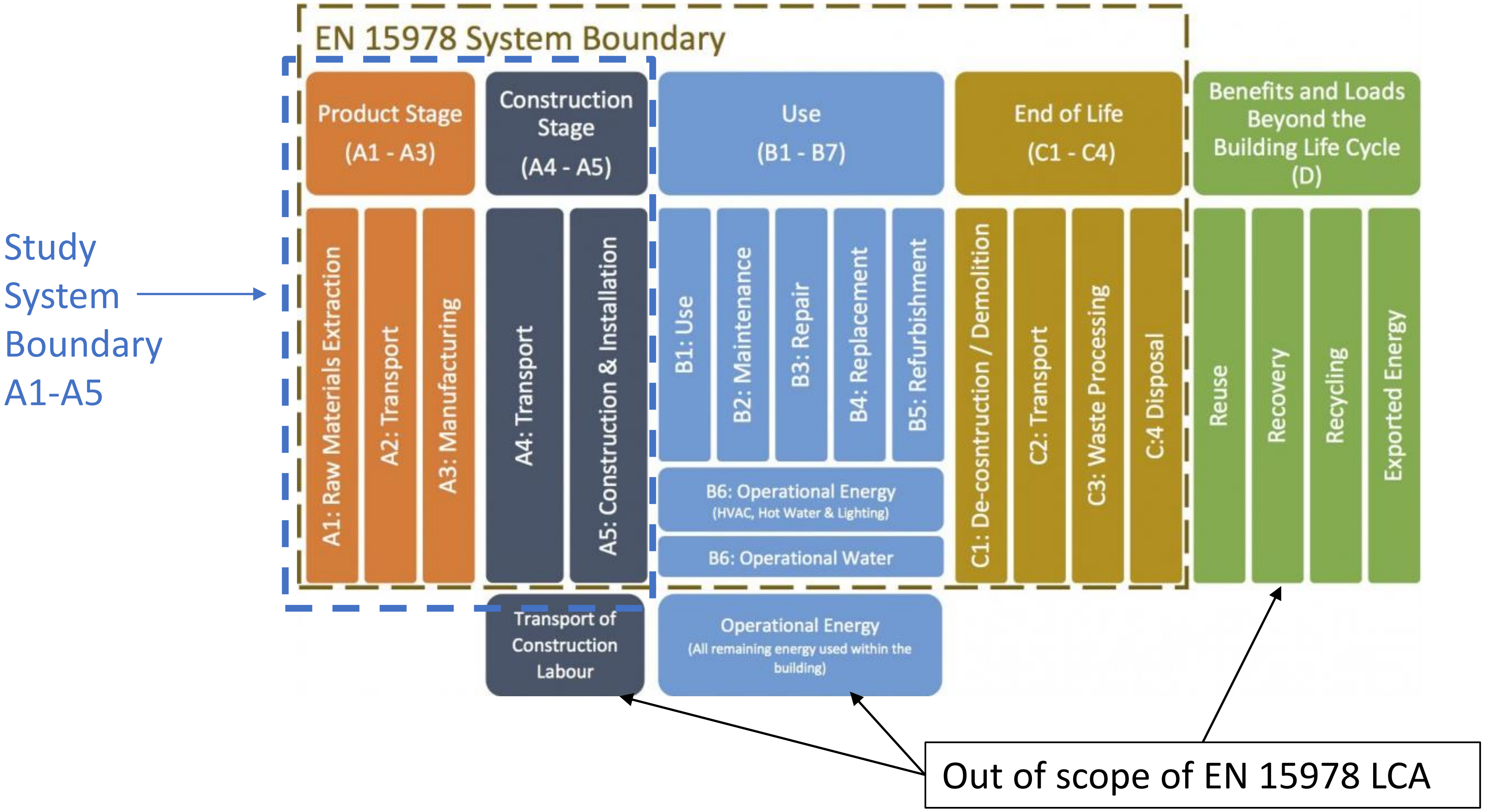
- A1 - A3 lifecycle stages for a 60 year lifespan
- Generic and product-specific EPDs

LIFE CYCLE ASSESSMENTS

- Building Life Cycle Assessment is a standardized scientific methodology – it is not a set scope.
- Results are dependent on boundaries conditions - No two LCAs are the same.
- Embodied Carbon is typically calculated within an LCA - Global Warming impact category = Carbon Footprint



LCA BOUNDARY CONDITIONS



c. Results

ONLINE DATABASE

Making Buildings Better™

CONTACT LOCATIONS

WHAT WE DO LEARN ABOUT CAREERS BLOG

https://www.rdh.com/blog/embodied-carbon-resources-for-building-enclosures/

03 | Key Takeaways

LIMITATIONS AND CHALLENGES

- During this study:
    - Lack of centralized life cycle inventory across platforms
    - Generic EPDs are sometimes unavailable
    - EPD's in general are difficult to source
    - Product specific information doesn't reflect a regional average

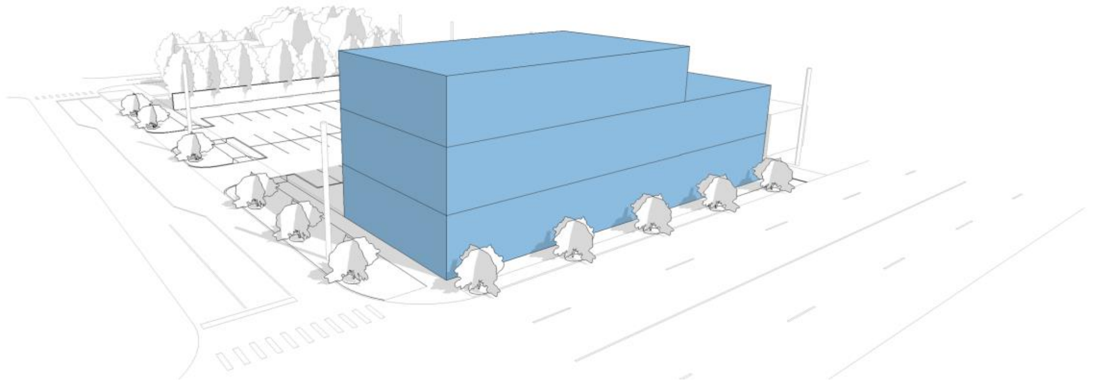
- Note on applicability:
    - EPDs represent the energy that went into manufacturing, very regionally specific!
    - Electrical grid in Ontario is clean, this is not the case everywhere.
        - Products where a significant portion of their energy used in manufacturing is electricity will be heavily grid dependent.

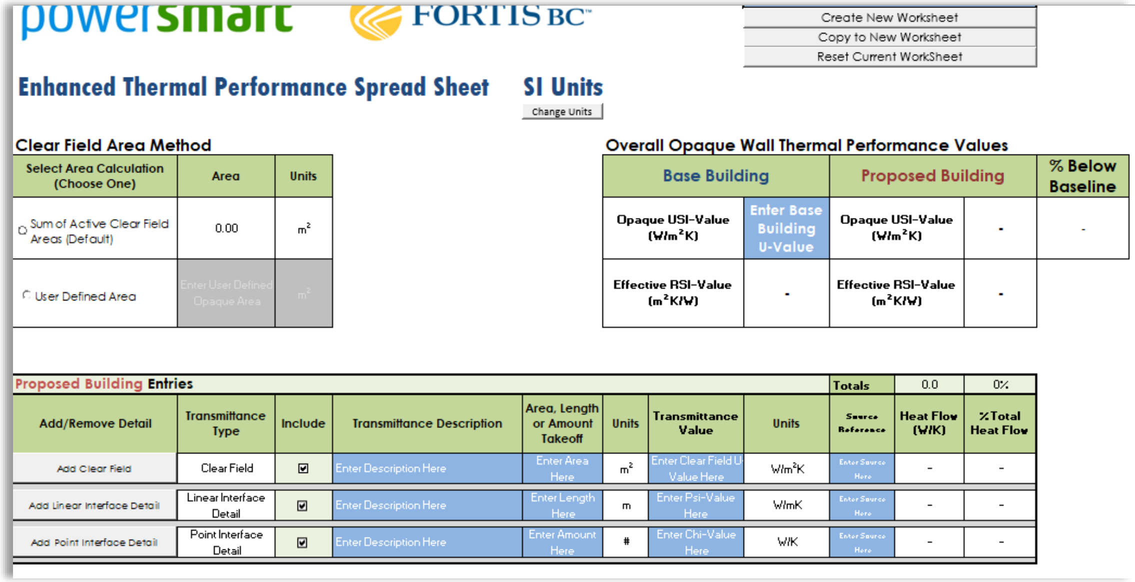
KEY TAKEAWAYS

- Industry need to rethink how we look at whole life cycle impact of buildings, balancing upfront and operational impacts – **find the whole life carbon "balance point"**
- Considerations are most effective when included in early design development, and must be influenced by local policies and standards
- Consider material durability and lifespan as part of whole life cycle carbon. This includes the durability impact of architectural details to mitigate future emissions for replacement and repair.
- Use less material and select materials with lower GHG-intensity.
- Simple form, lower glazing ratio and other important passive design strategies also tend to lend to lower life cycle emissions.

PUTTING THE STUDY TO USE

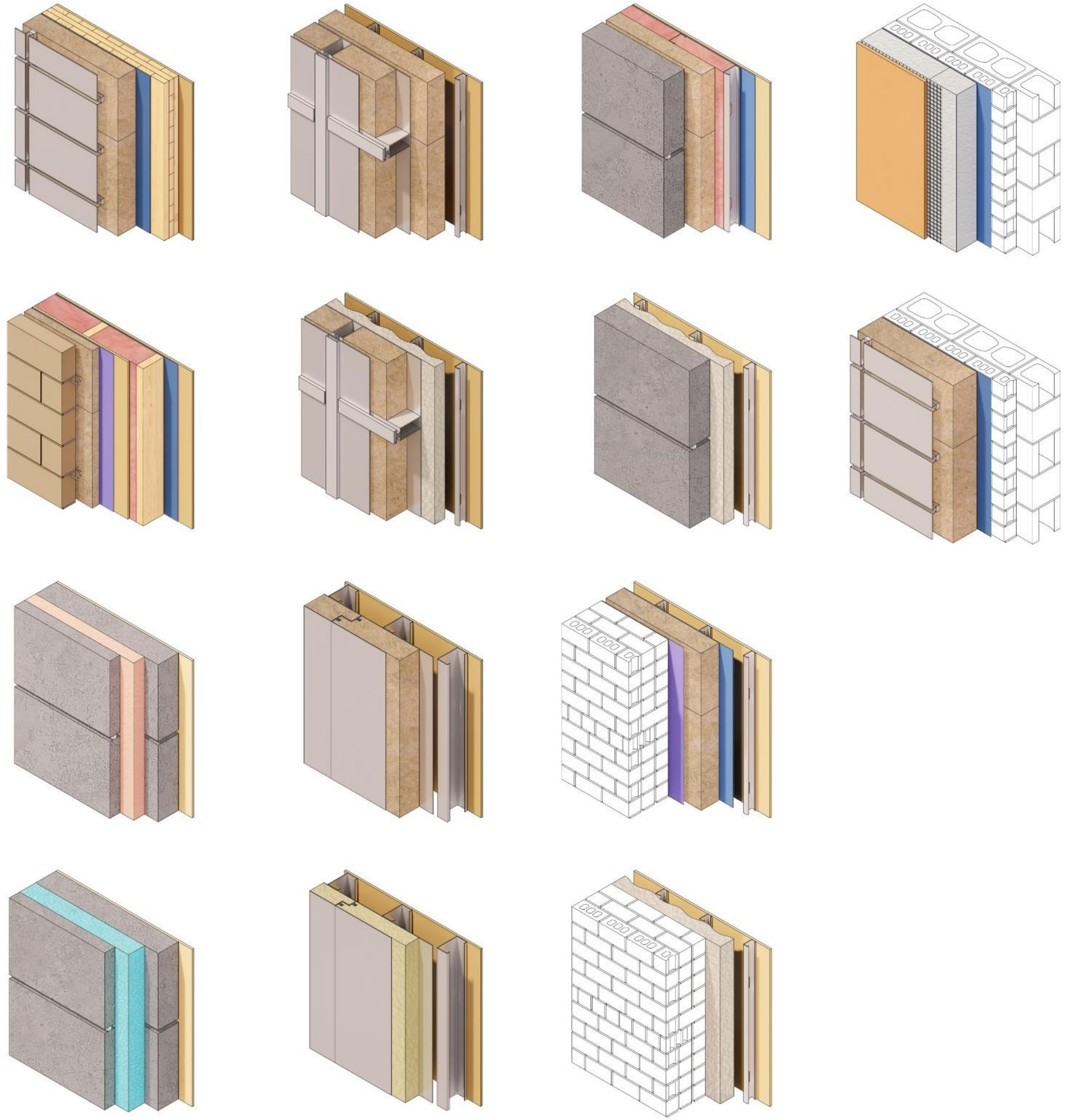
- Reference the data in the study and adapt it to your own use case
- Volume calculations and quantity takeoffs may be of most value
- Inform schematic level estimates of enclosure-related embodied emissions early in decision making
- EPDs and later stage emissions will be project specific.
  - New EPD development
  - Specific products, specific locations
- Check out our new tool and provide feedback!
  - Is it useful to you?
  - If not, what is your use case and how can the tool be adapted to suit it?





FUTURE WORK

- Inclusion of common glazing assemblies
- More attention given to retrofits
- Sensitivity analysis comparing options within each component type (insulation, cladding, back up structure, etc.)
- Impact of additional material at transitions (window perimeters, parapets, etc.)
- Optimization of whole building carbon reductions for electrified buildings **– as thermal enclosure performance improves, so does embodied carbon!**



THANK YOU!
Questions?
Let’s talk.

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