Carbon Leadership Forum Vancouver

Diana Lopez
Research Manager
UBC Sustainability Initiative

Oriana Vanderfleet, PhD
UBC Sustainability Scholar
McMaster University

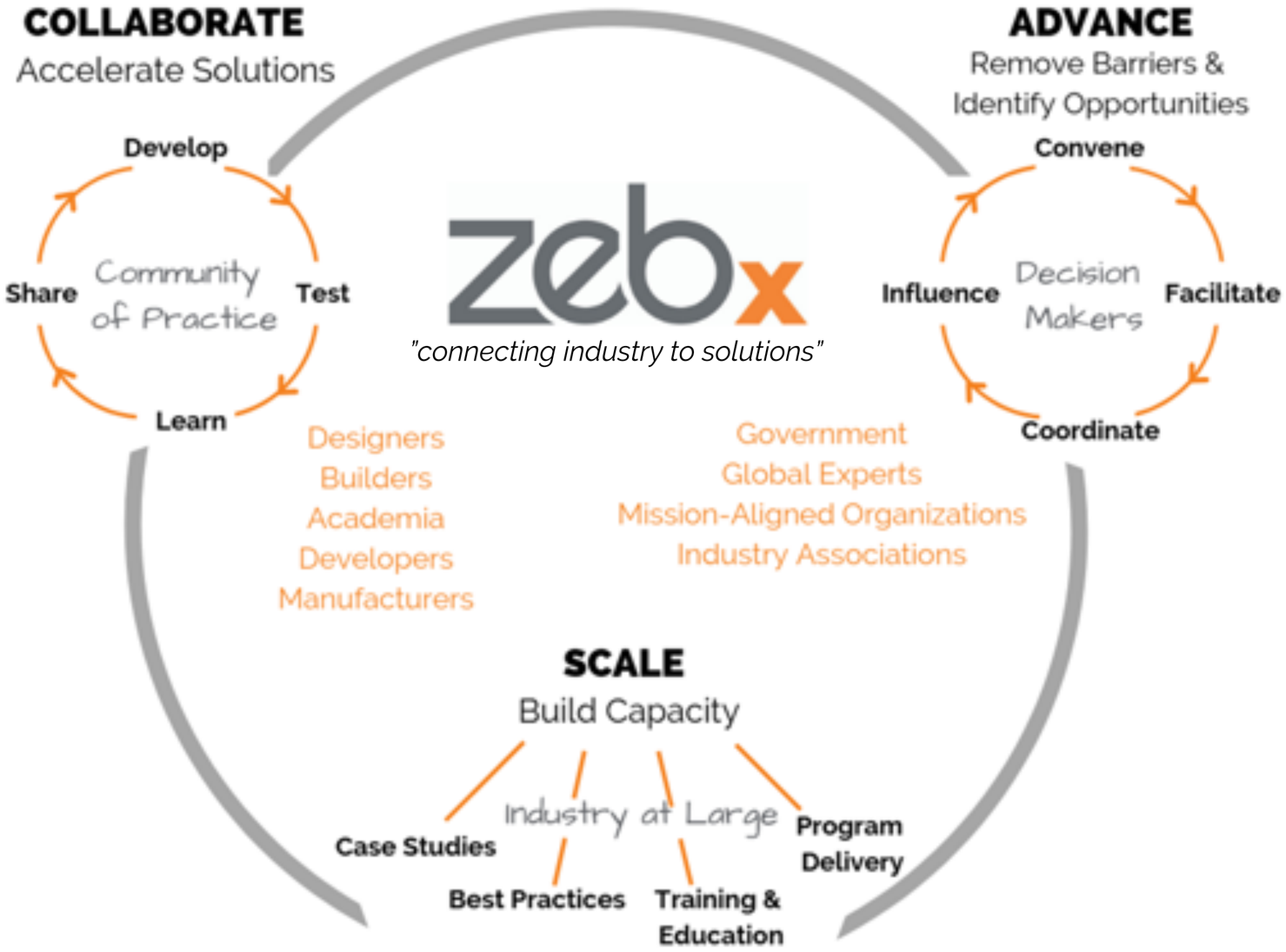
Quantifying Embodied Carbon for Buildings of the Future

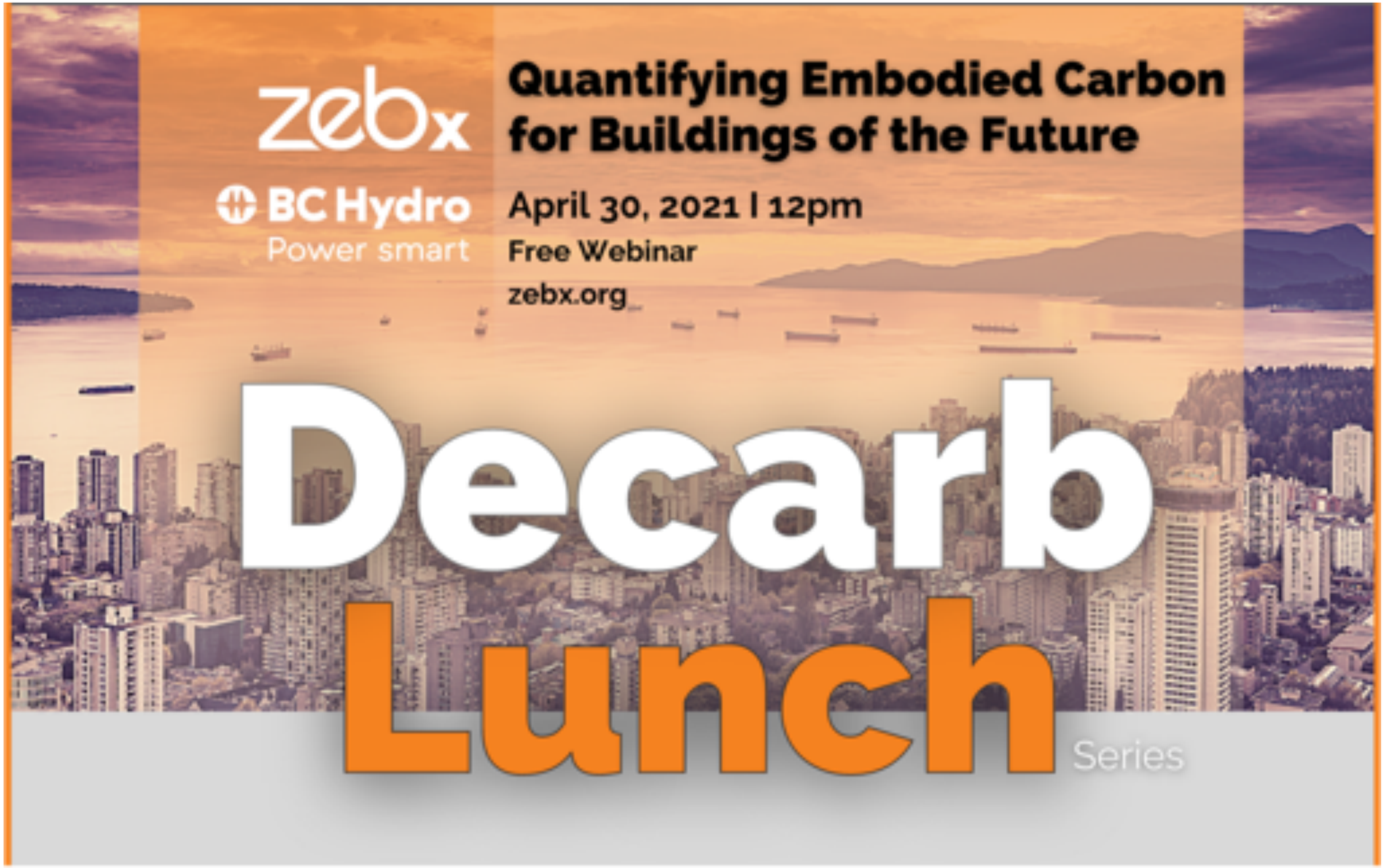
April 30, 2021 at 12-1pm PST

zebx

WELCOME!

ROBERTO PECORA, DIRECTOR OF PROGRAMS


COLLABORATE
Accelerate Solutions
Develop
Test
Learn
Share
Community of Practice
ADVANCE
Remove Barriers & Identify Opportunities
Convene
Facilitate
Coordinate
Influence
Decision Makers
zebx
"connecting industry to solutions"
Designers
Builders
Academia
Developers
Manufacturers
Government
Global Experts
Mission-Aligned Organizations
Industry Associations
SCALE
Build Capacity
Industry at Large
Case Studies
Best Practices
Training & Education
Program Delivery


zebx
BC Hydro
Power smart
Quantifying Embodied Carbon for Buildings of the Future
April 30, 2021 | 12pm
Free Webinar
zebx.org
Decarb
Lunch
Series

cleanBC
BETTER BUILDINGS

THE NARROWS

CLEANBC NET-ZERO ENERGY-READY CHALLENGE

Supporting, promoting and celebrating the design and construction of net-zero energy-ready buildings

cleanBC
BETTER BUILDINGS

WINNING PROJECTS


CORVETTE LANDING


THE NARROWS


3279 VANNESS AVENUE


OSO


825 PACIFIC STREET


UVIC STUDENT HOUSING


SKEENA RESIDENCE

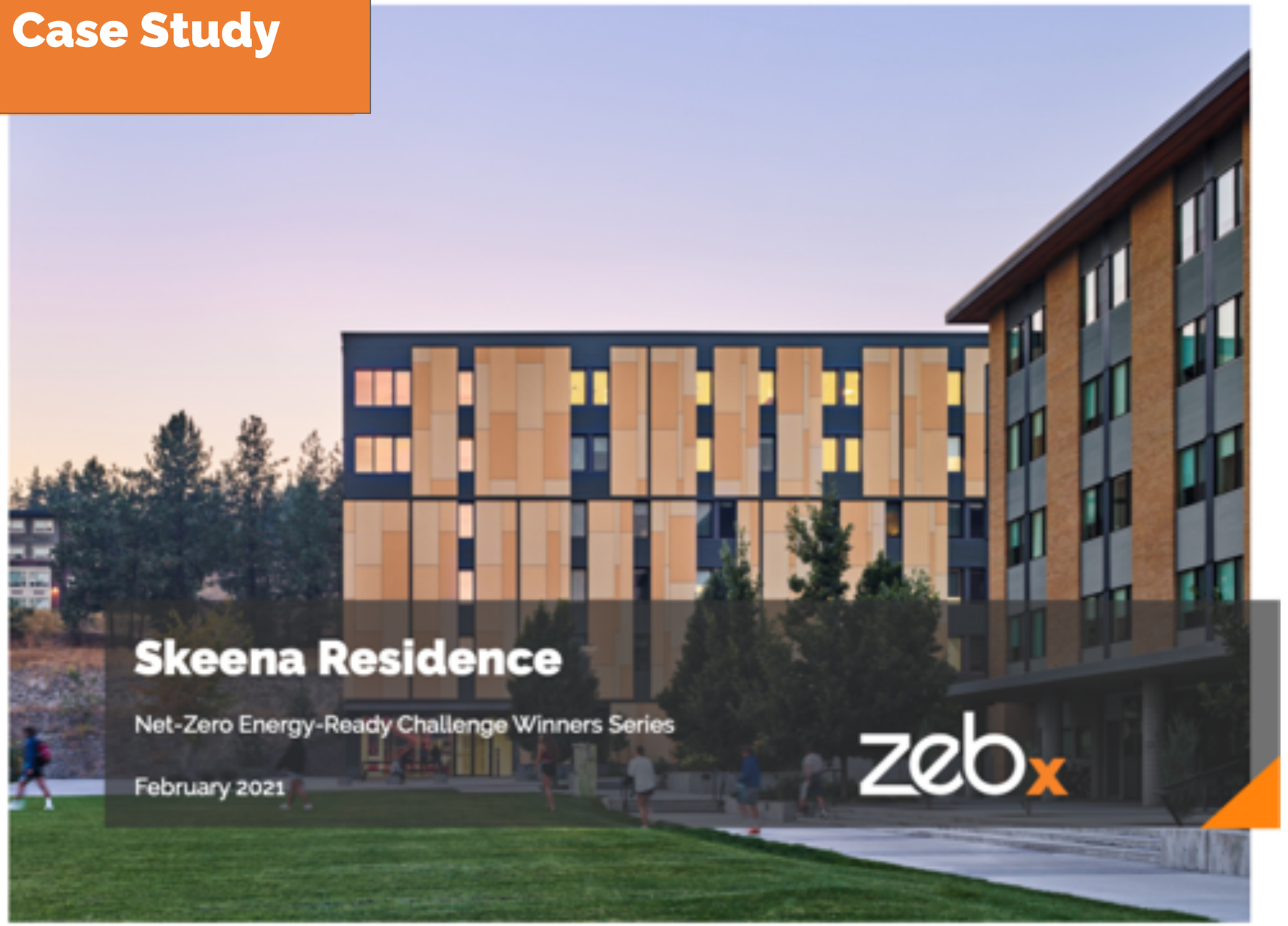

SFU PARCEL 21


2150 KEITH DRIVE


PEATT COMMONS PHASE 2


CARRINGTON VIEW – BUILDING A

Case Study



CLEANBC NET-ZERO ENERGY-READY CHALLENGE

WINNER

New case studies:
zebx.org / resources

PLAYBOOK

Ventilation Strategies for High-Performance Multi-Unit Residential Buildings

From ZEBx's Net-Zero Energy-Ready Playbook Series

March 2021

Follow the details on zebx.org to apply

Tell us about yourself

POLL

About CLF Vancouver

Carbon Leadership Forum Vancouver

Join our Mailing List at:

clfvancouver.com

Jeremy Field

Organizing Team at **CLF Vancouver**

Senior Sustainability Advisor at **Integral Group**

Carbon Leadership Forum Vancouver

Upcoming Part 2

Improving How We Baseline Embodied Carbon

A Facilitated Technical Discussion

May 20, 2021 at 4pm-5pm PST

Lifecycle thinking

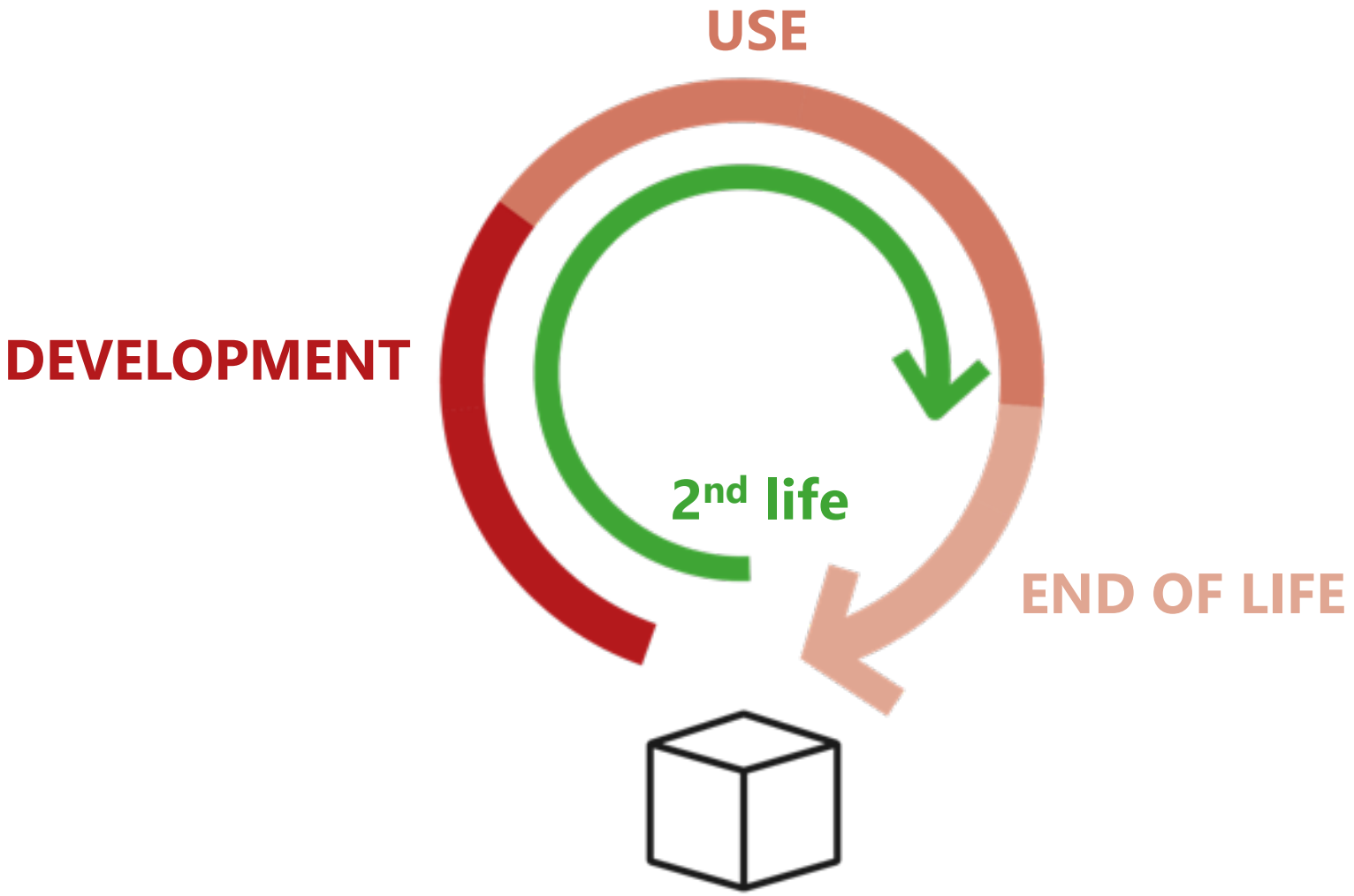
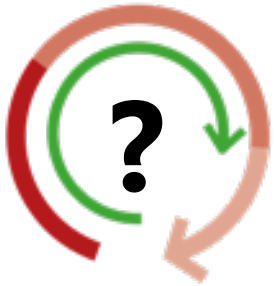


Image Source: Integral

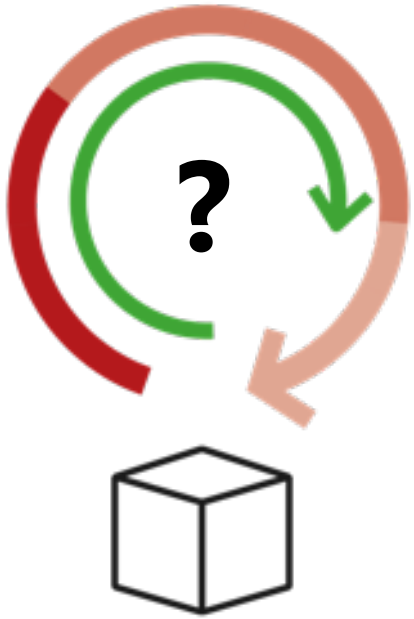
Lifecycle assessment at a high level



Inventory	x	Impacts	=	Total
Estimate of quantities of material and processes in the built asset		Estimate of environmental impacts for each material and process		Estimate of total environmental impact of the built asset

Image Source: Integral

Lifecycle assessment (LCA)



Example of impact categories evaluated by LCA:

Climate change

Ozone depletion

Acidification

Eutrophication

Abiotic depletion

Water use

Image Source: Integral

Link to carbon

kgCO2e

Evaluation of the **Global Warming Potential (GWP)** in kgCO2e of a built asset throughout its life cycle

= Embodied Carbon

Image Source: Integral

Life cycle of a building

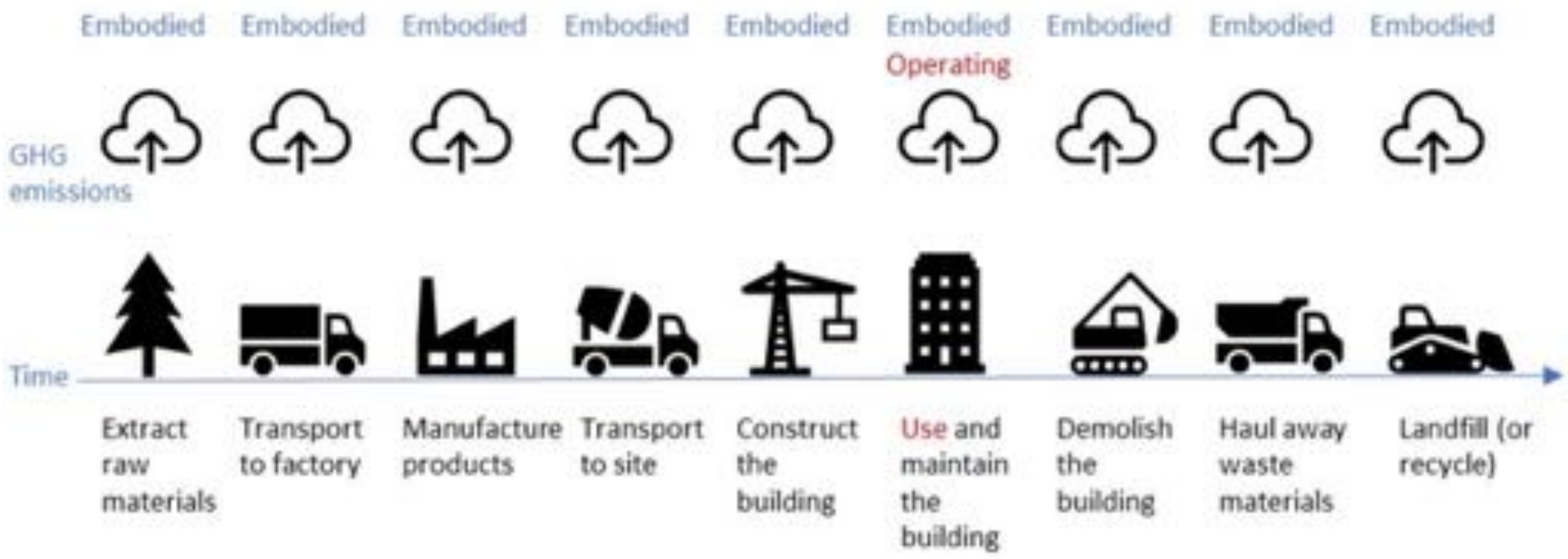
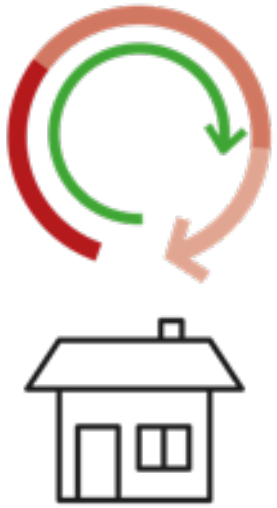


Image Source: Embodied Carbon of Buildings and Infrastructure – International Policy Review (Sept 2017)

Formal stages of a building life cycle assessment (LCA)



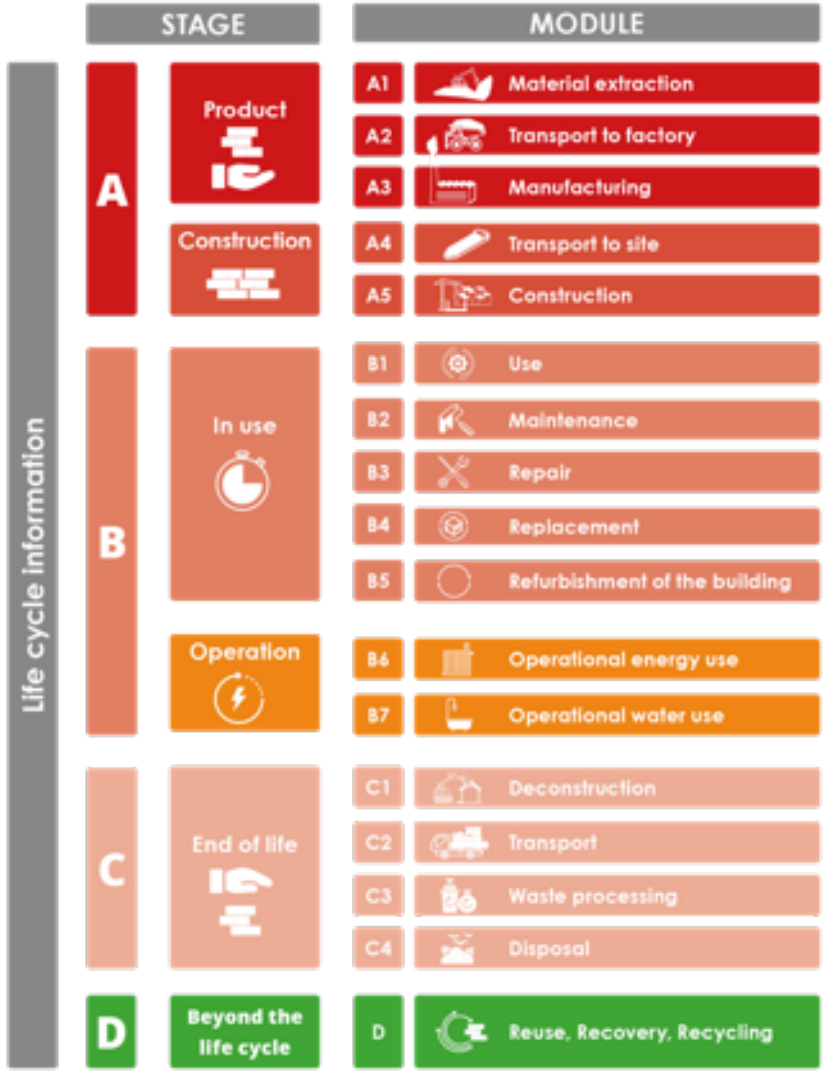
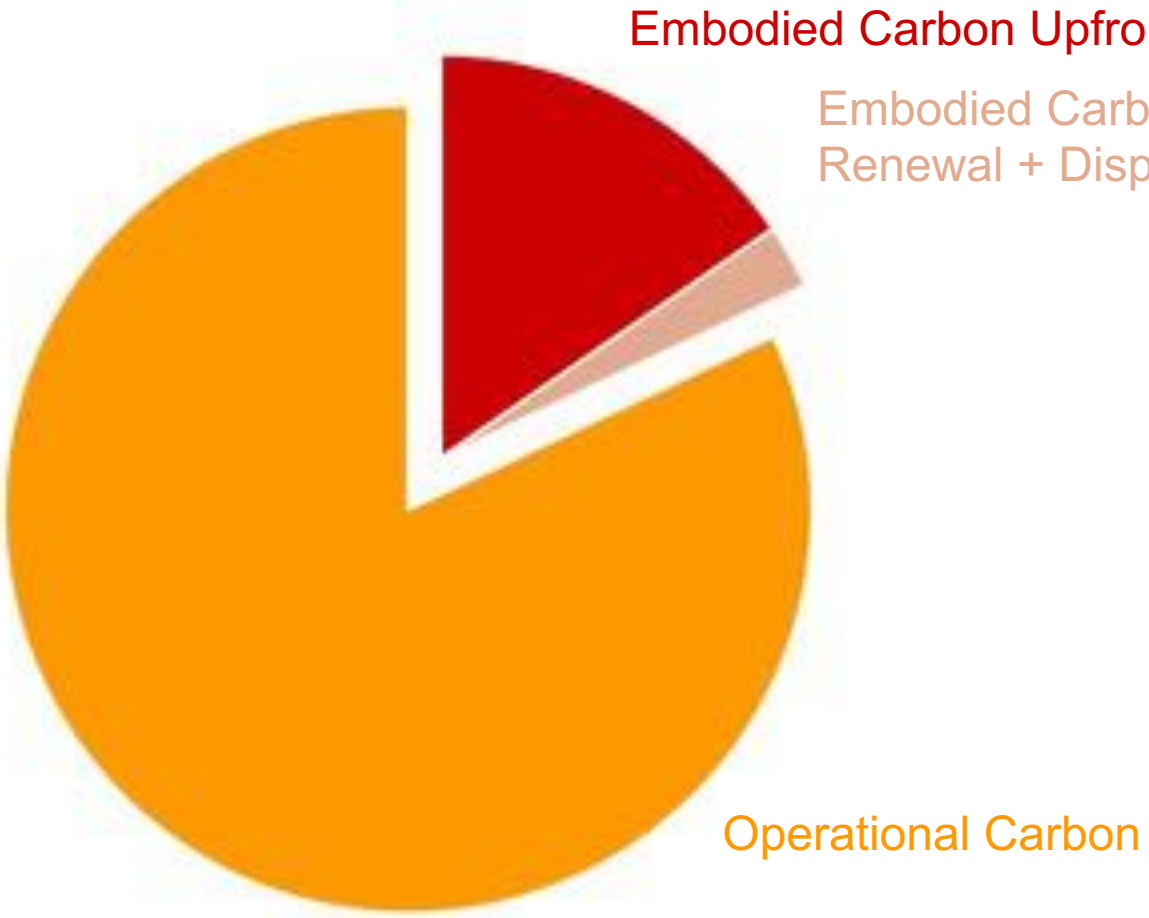
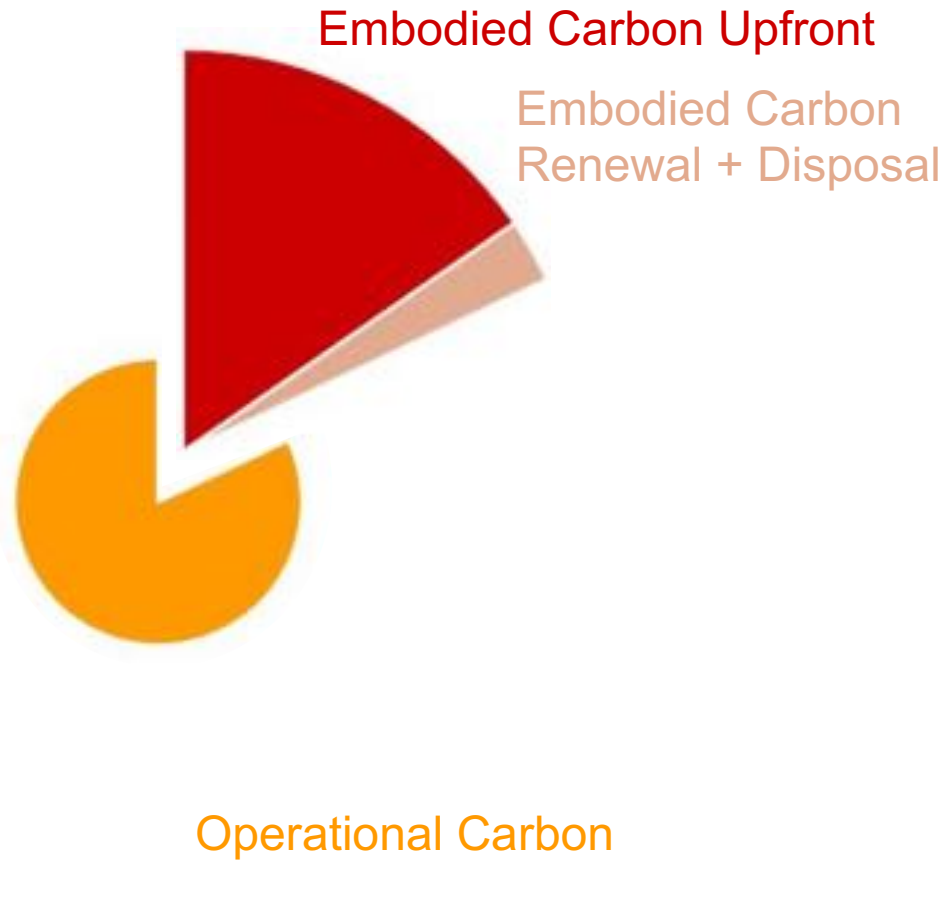


Image Source: Integral

Why it matters – historical vs future life cycle carbon



Current Buildings



Future Buildings

Image Source: Integral

Carbon Leadership Forum Vancouver

Oriana Vanderfleet, PhD

UBC Sustainability Scholar

McMaster University

Quantifying embodied carbon for buildings of the future

Embodied carbon in *Passive House* part 9 buildings

By: Oriana Vanderfleet

Embodied carbon in *Passive House* part 9 buildings

1 HOW DO WE QUANTIFY EMBODIED CARBON?

2 HOW DO WE REDUCE EMBODIED CARBON?

Understanding carbon; image by: Stacy Smedley/Skanska

Methodology

3 PASSIVE HOUSE PART 9 BUILDINGS IN VANCOUVER

MATERIAL TAKEOFFS & MANUFACTURER-SPECIFIC EPDs

Athena Impact Estimator for Buildings

BUILDING EMISSIONS ACCOUNTING FOR MATERIALS

COMPARE EMBODIED CARBON & ANALYZE TRENDS

Methodology

Our interest: **cradle-to-gate** assessment of building materials' global warming potential (GWP)

Product / Manufacture Stage [A1-A3]			Construction Process Stage [A4-A5]		Use [B1-B7]							End-of-Life Stage [C1-C4]				Benefits & Loads Beyond [D]
					Building Fabric					Operation of the Building						
Raw Material Extract / Process / Supply	Transport	Manufacture	Transport to the Site	Assembly / Install in the building	Use / Application of Installed Products	Maintenance	Repair	Replacement	Refurbishment	Operational Energy Use	Operational Water Use	Deconstruction / Demolition	Transport to Waste Process	Reuse-Recovery-Recycle	Disposal	Reuse-Recovery-Recycle Potential
A1	A2	A3	A4	A5	B1	B2	B3	B4	B5	B6	B7	C1	C2	C3	C4	D
Cradle-to-Gate			Gate-to-Grave													
Cradle-to-Grave																
Cradle-to-Cradle																
System Boundaries																

Can Köseci, Firat. (2018). *Integrated Life Cycle Assessment to Building Information Modelling.* [Master's thesis, KTH Royal Institute of Technology].

Material takeoffs & manufacturer-specific EPDs

MATERIAL TAKEOFFS (USING BLUEBEAM REVU)

MANUFACTURER SPECIFIC EPDs (WHENEVER POSSIBLE)

INCLUSIONS	EXCLUSIONS
Foundation & footings	Doors
Interior walls	Staircases
Exterior walls	Cabinets/millwork
Cladding	Plumbing
Floors & flooring	Electrical
Ceiling	HVAC
Roof	Gutters & fascia
Windows	Paint
Drywall	Garage

Athena *Impact Estimator*

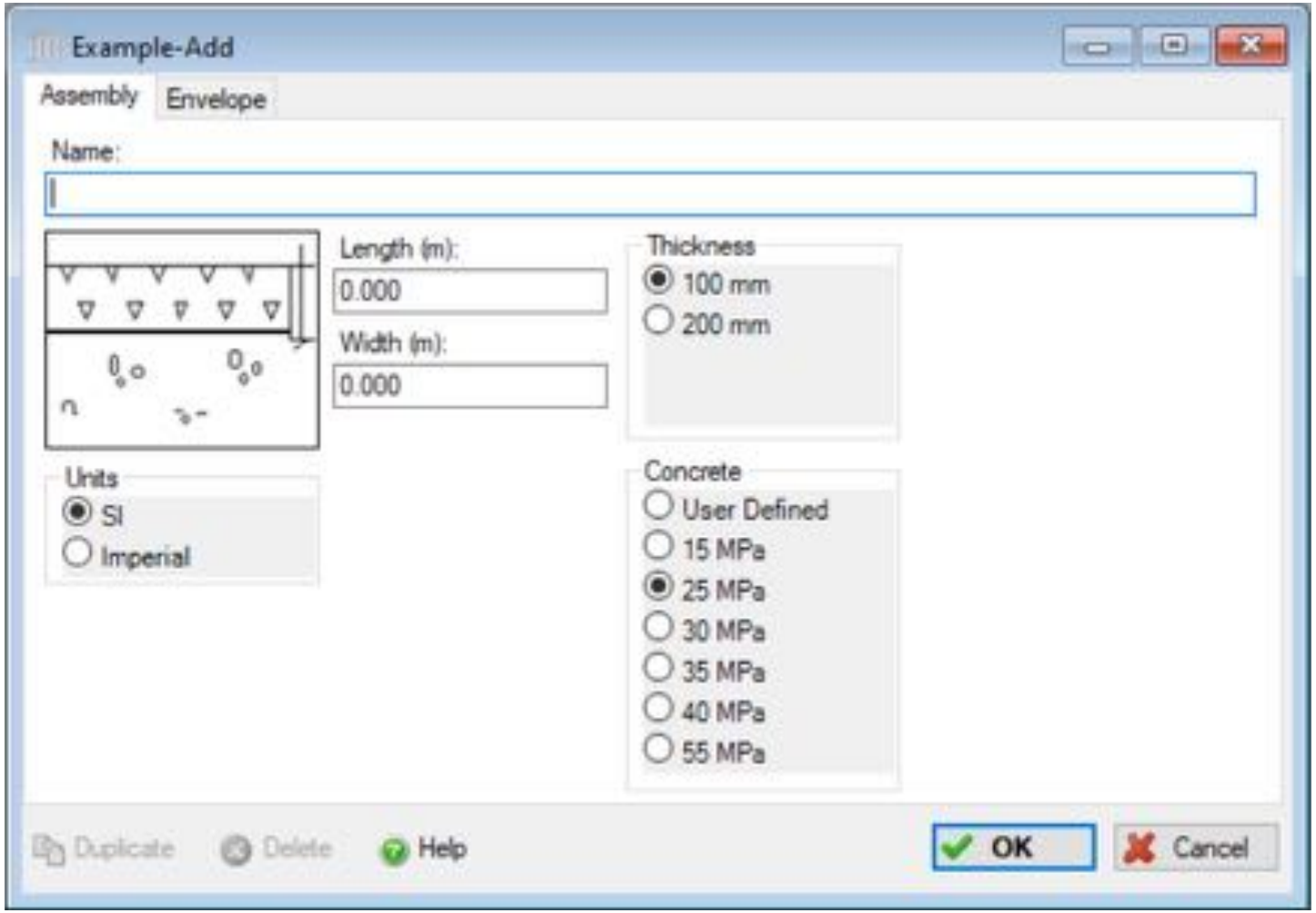
INPUT GEOGRAPHICAL LOCATION & BUILDING INFO

↓

ADD ASSEMBLIES (FOUNDATION, WALLS, ROOFS, FLOORS, COLUMNS/BEAMS)

↓

INPUT DIMENSIONS & SELECT MATERIALS FROM LIST



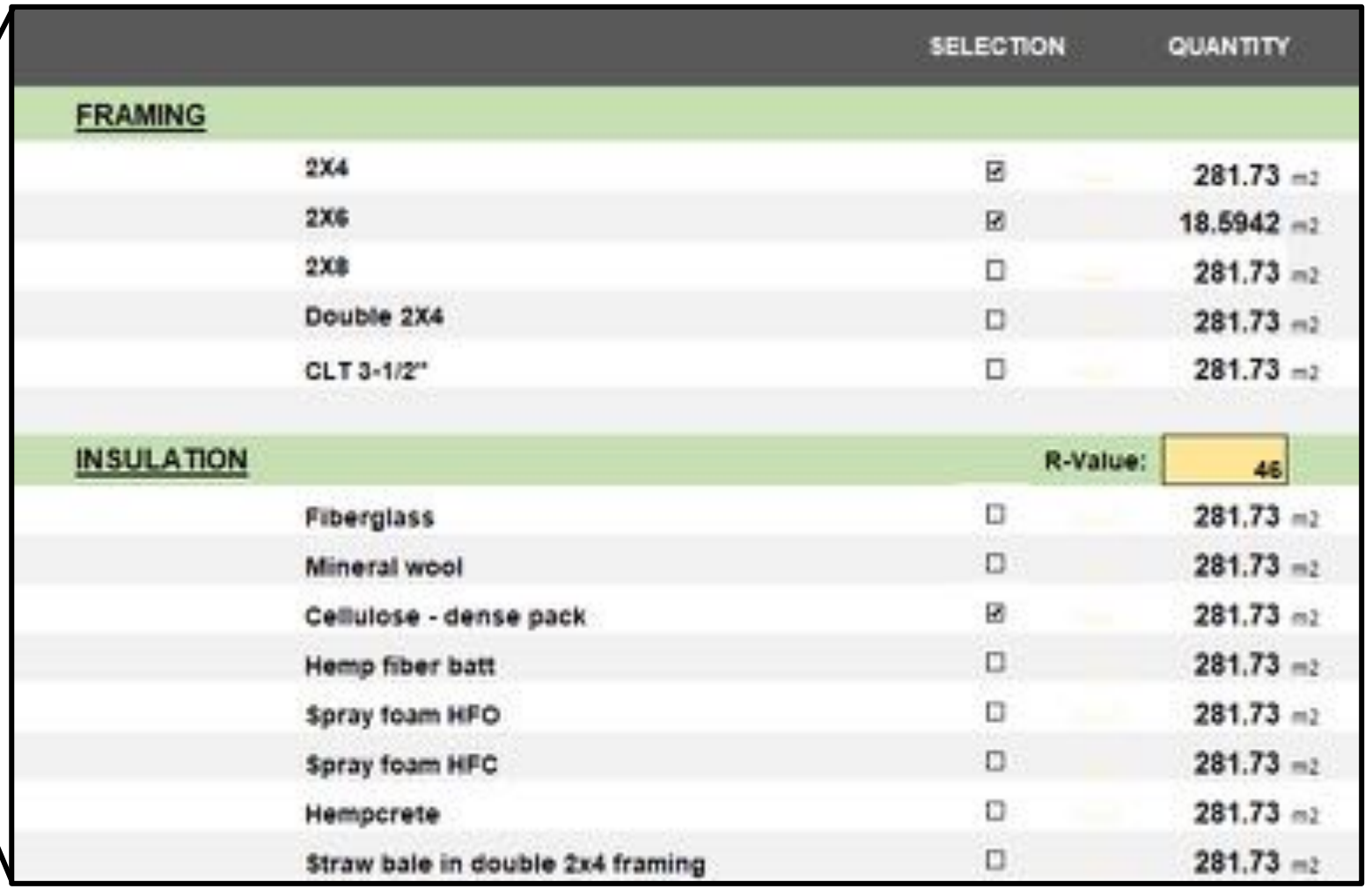
BEAM (Building Emissions Accounting for Materials)

Previously Builders for Climate Action Material Emissions Calculator

INPUT DIMENSIONS FOR EACH COMPONENT

SELECT MATERIALS USED (& R-VALUE)

GWP IS CALCULATED BASED ON AVERAGE OF MULTIPLE EPDs



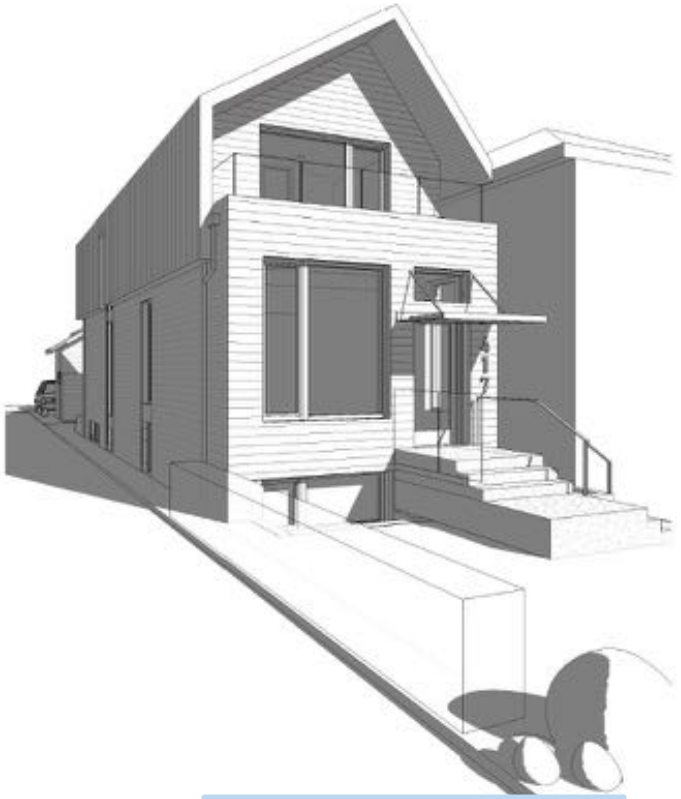
	SELECTION	QUANTITY
FRAMING		
2X4	☑	281.73 m2
2X6	☑	18.5942 m2
2X8	☐	281.73 m2
Double 2X4	☐	281.73 m2
CLT 3-1/2"	☐	281.73 m2
INSULATION	R-Value:	46
Fiberglass	☐	281.73 m2
Mineral wool	☐	281.73 m2
Cellulose - dense pack	☑	281.73 m2
Hemp fiber batt	☐	281.73 m2
Spray foam HFO	☐	281.73 m2
Spray foam HFC	☐	281.73 m2
Hempcrete	☐	281.73 m2
Straw bale in double 2x4 framing	☐	281.73 m2

https://www.buildersforclimateaction.org/beam-calculator.html

Case studies

KHOTSO HOUSE

ART + SCIENCE HOUSE



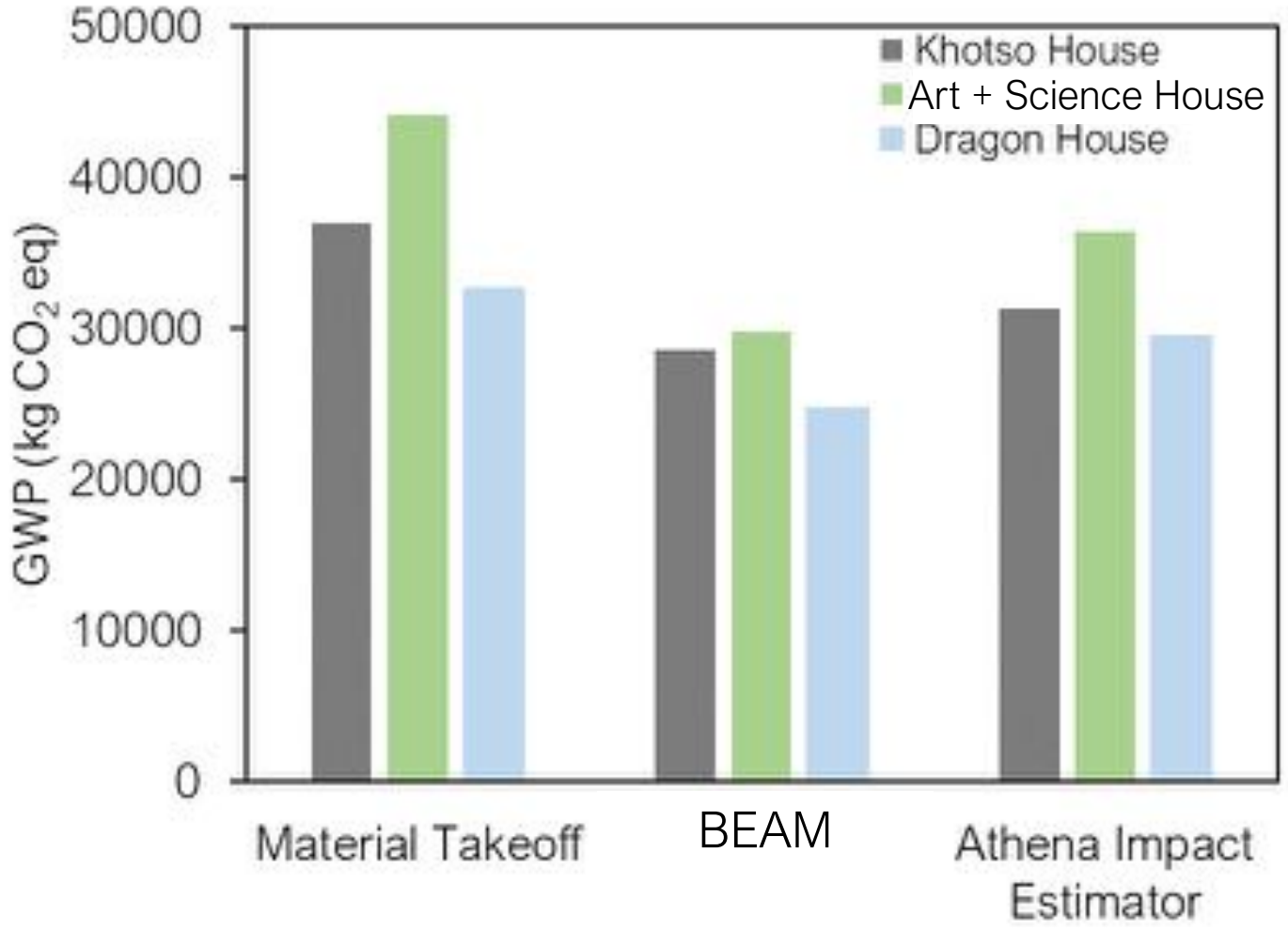
DRAGON HOUSE

- All designed by *ONE SEED Architecture + Interiors*
- *Passive House* certified with conscientious material selection
  - (e.g., cellulose insulation)

Similarities & differences

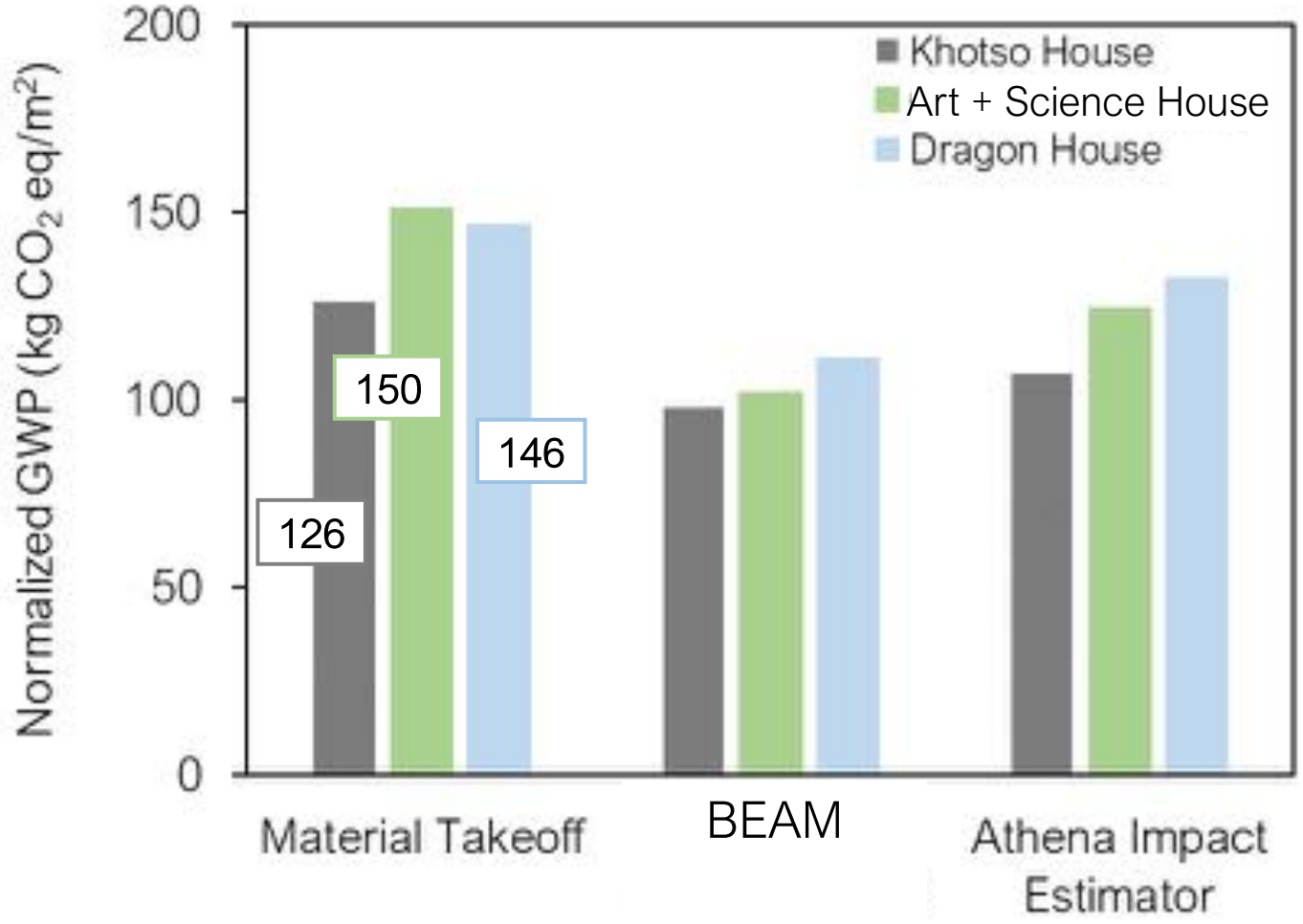
	Khotso	Art + Science	Dragon
Gross floor area (m^2)	293	316	223
Building height (m)	11	8.6	9.5
Number of levels	4	3	3
Main roof type	Flat	Flat	Gabled
Roof Insulation	Polyiso & mineral wool	Polyiso & mineral wool	Mineral wool
Exterior wall structure	TJI joists & 2x4 studs	TJI joists & 2x4 studs	TJI joists & 2x4 studs
Exterior wall insulation	Cellulose & mineral wool	Cellulose & mineral wool	Cellulose & mineral wool
Foundation insulation	EPS	EPS	EPS
Foundation type	Footing wall	Footing wall	Grade beam with 25 % SCM
Window frames	Wood & aluminum	Fiberglass	Fiberglass
Cladding	Metal & fibre cement	Metal & fibre cement	Metal

Embodied carbon (A1-A3)



- EC correlates with building size:
  - Dragon PH (smallest house) has the lowest EC
  - Art + Science PH (largest house) has the highest EC
- Both Athena & Builders for Climate Action report lower EC values (likely due to limited selections)

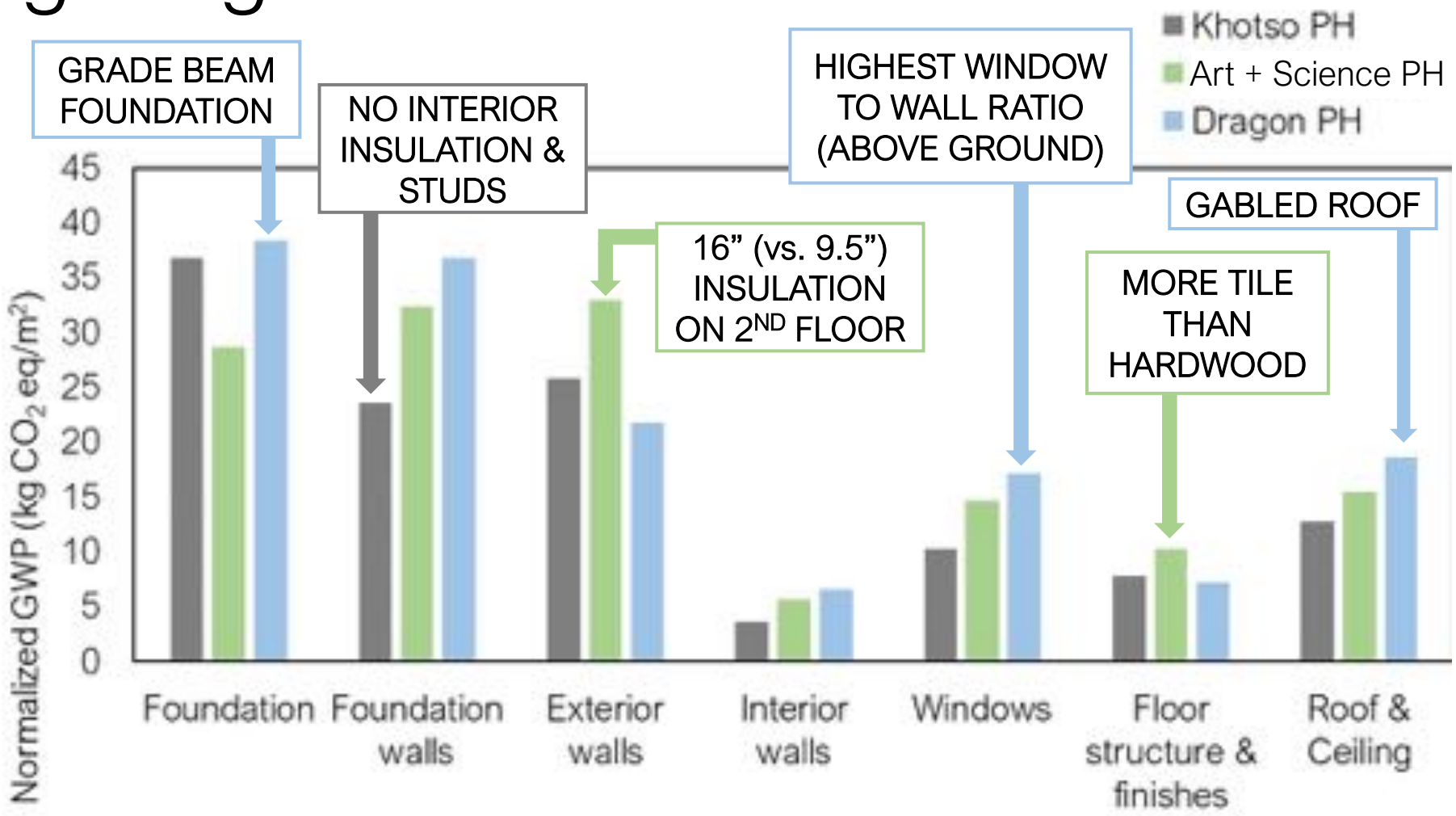
Embodied carbon (A1-A3)



- Normalize GWP with gross floor area
- Khotso PH has the lowest normalized EC for all 3 methods

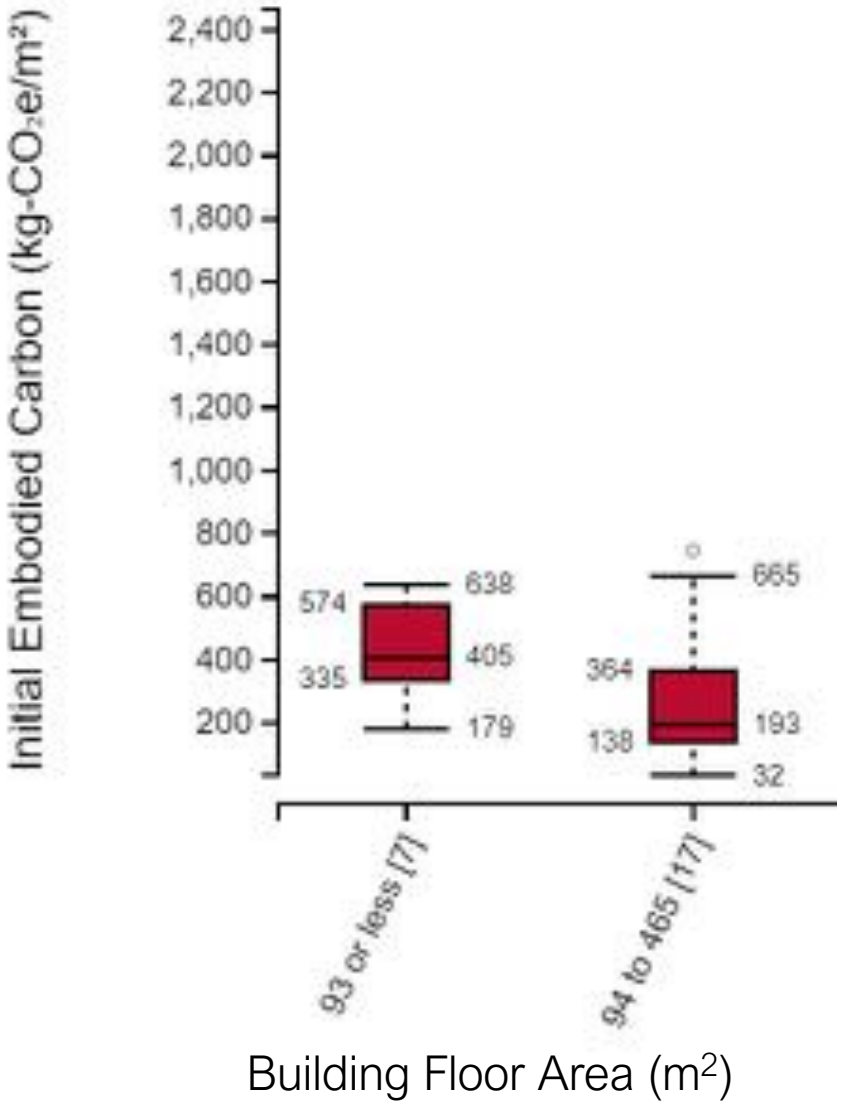
WHY?

Investigating assemblies



Available comparisons

- Database includes buildings from studies which vary in scope, LCA method and data/EPDs used
- Includes structure, foundation, enclosures, and interiors
- Buildings with floor area of 94-465 m^2: 32-665 kg CO_2 eq/m^2 (avg= 193)
  - Khotso (126 kg CO_2 eq/m^2) , Art + Science (150 kg CO_2 eq/m^2), and Dragon (146 kg CO_2 eq/m^2) fall in this range



Embodied Carbon Benchmark Study (2017), The Carbon Leadership Forum, Department of Architecture, University of Washington.

Embodied carbon (A-C)

- Athena *Impact Estimator* allows for cradle-to-grave analysis
  - EPDs generally report cradle-to-gate (must use lowest common denominator)

- Cradle-to-gate (A1-A3) accounts for 70-75% of cradle-to-grave (A-C) emissions

	Khotso	Art + Science	Dragon
A1-A3 GWP in Athena (kg CO_2 eq)	31,300	36,400	29,500
A-C GWP in Athena (kg CO_2 eq)	43,700	49,300	42,100
% of GWP in A1-A3 stages	72%	74%	70%

Findings

- 3 homes in this study have low EC due to conscientious material selection
- 3 EC calculation methods reported similar results; material takeoff is most tedious, but likely most accurate
- Size is the governing factor in total EC (bigger house = more emissions)
  - Best way to report? (i.e., normalize to area or occupants)
- Normalizing EC to floor area gives insights on the carbon toll of certain structural features
  - Grade beam foundation had higher EC
  - Gabled roof had higher EC
  - On a /m^2 basis, windows have higher EC than wood-frame wall assemblies

Thank you!

QUESTIONS?

Carbon Leadership Forum Vancouver

Diana Lopez

Research Manager

UBC Sustainability Initiative

UBC EMBODIED CARBON PILOT

& UBCO Skeena Residence Case Study

DIANA LOPEZ
RESEARCH MANAGER, UBC SUSTAINABILITY INITIATIVE

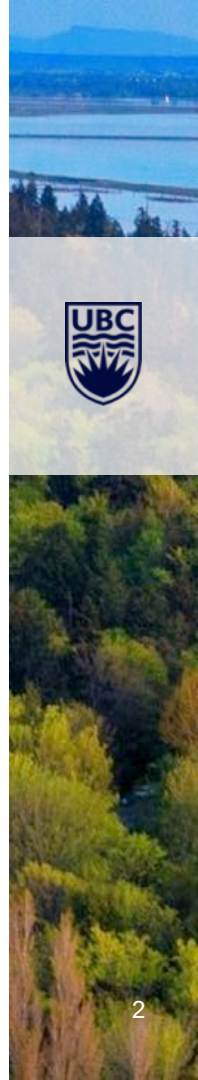
EMBODIED CARBON PILOT

Objectives

- Address early steps towards establishing embodied carbon benchmarks and performance targets for buildings
- Inform the development of policy on embodied carbon performance in buildings
- Identify procedural challenges and barriers for the adoption and streamline of LCAs as a tool to assess embodied carbon performance in buildings

Methodology

- Explore the process of conducting LCAs by conducting pilot assessments on buildings of different typologies in BC employing different data sources and software tools.
- Focus on the creation of the building's bill of materials using different methods.



EMBODIED CARBON PILOT

Phase I

- 9 LCAs on 3 buildings (UBC Campus)
- 7 LCAs on Campus Energy Centre
- Data sources: project drawings, cost estimates, BIM model.
- Tools: Athena IE4B, One Click LCA + EC3

Campus Energy Center (CEC)
Infrastructure (utility) – UBC Vancouver
Mass timber hybrid structure

Key focus

- Factors that affect consistency, reliability and variability of results:
  - Project data sources
  - Building components (object of assessment)
  - Method to generate the bill of materials
  - Life cycle stages (system boundary)
  - LCA tool

Full report: https://sustain.ubc.ca/research/research-collections/sustainable-building-materials

EMBODIED CARBON PILOT

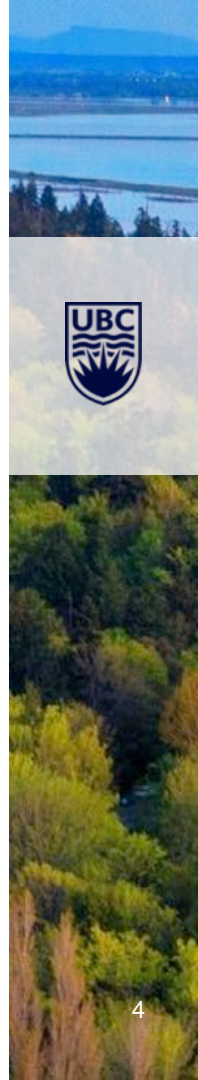
Phase II

- 9 LCAs on 7 buildings (NZERC +UBC)
- Focus on high-performance buildings
- Building typologies:
  - Residential
  - Commercial (office)
  - Institutional
- Data sources: focus on BIM models + cost estimates
- Tools: Athena IE4B, Tally, One Click LCA

Key focus

- BoM Generation Methodology for WBLCA
  - Process used to conduct whole-building LCAs during Phase 1 and 2
  - Focused on data preparation process for bill of materials-based LCAs
  - Provide high-level guidance on the data preparation and calculation process

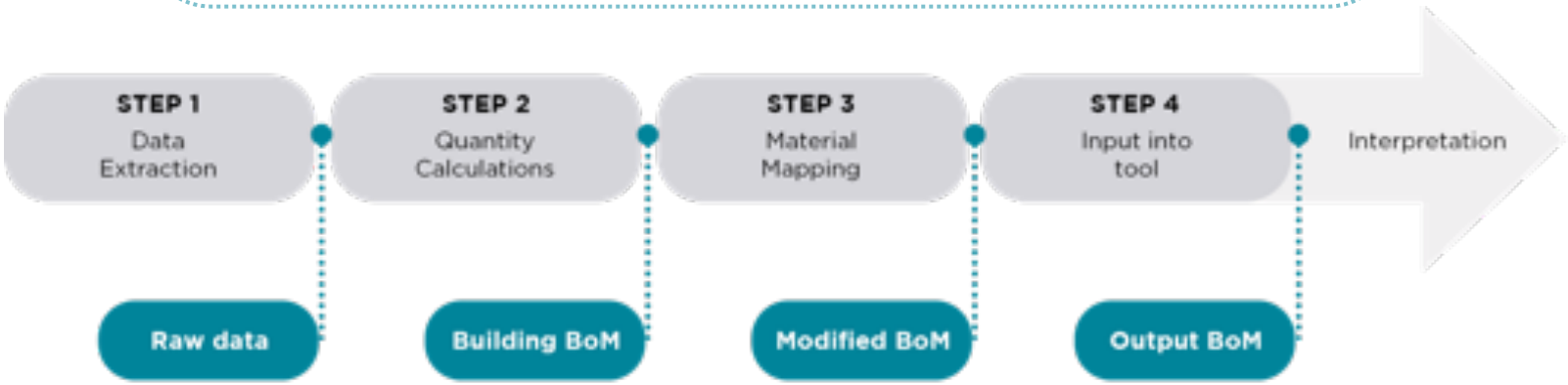
Methodology paper: https://sustain.ubc.ca/research/research-collections/sustainable-building-materials



BOM GENERATION METHODOLOGY

LCA PARAMETERS

- LCA goal + assessment timing
- LCA Scope
  - Building components
  - Life cycle stages
  - Reference study period
- Building data sources
- Assessment tools
  - Life cycle scope
  - Data input methods
  - Results format
  - Tool database



UBC OKANAGAN SKEENA RESIDENCE

ARCHITECT | **Public Design**

STRUCTURAL ENGINEER | **Bush, Bohlman & Partners**

YEAR COMPLETED | **2020**

LOCATION | **UBC Okanagan Campus, BC**

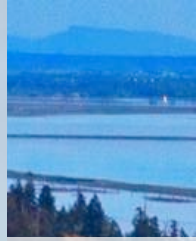
USE | **Student residence**

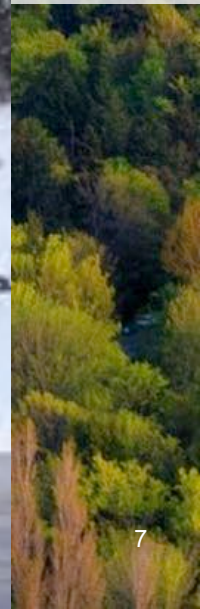
GFA | **6,744 m²**

TOTAL STORIES | **6**

HEIGHT | **20.6**

PRIMARY STRUCTURE | **Concrete GF + Wood frame (2-6)**

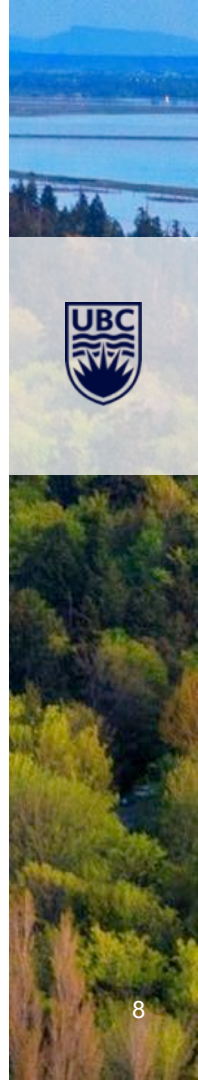




SKEENA RESIDENCE PILOT LCAS

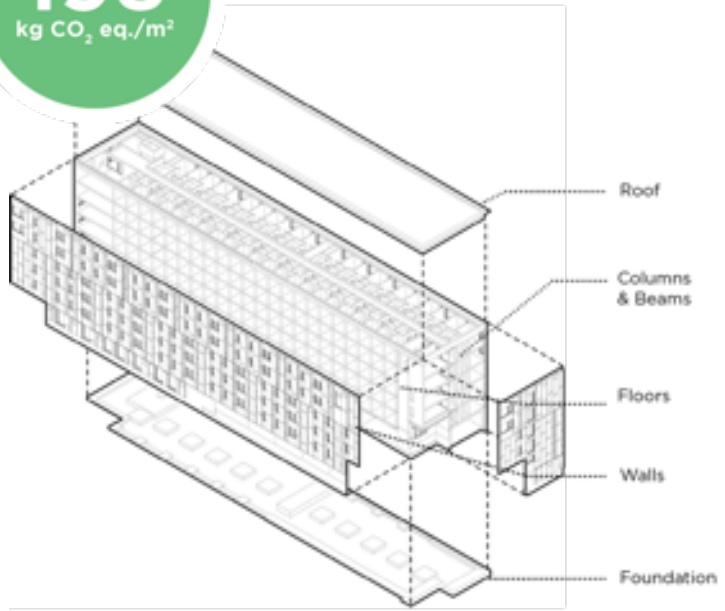
LCA PARAMETERS

LCA goal + assessment timing:	Pilot LCA, near project completion	
LCA Scope		
• **Building components:**	Foundation, structure, enclosure, interiors	
• **Life cycle stages:**	Product, construction process, use, end of life	
• **Reference study period:**	60 years	
Building data sources:	BIM model	
Assessment tools:	Athena IE4B	Tally
• **Life cycle scope:**	A1-A5, B2, B4, C1-C2, C4	A1-A4, B2-B5, C2-C4
• **Data input methods:**	BoM input method	BIM-integrated
• **Results format:**	Excel + pdf report	Excel + pdf report
• **Tool database:**	Proprietary	Proprietary + EPDs



SKEENA RESIDENCE – ATHENA

198
kg CO_2 eq./m²

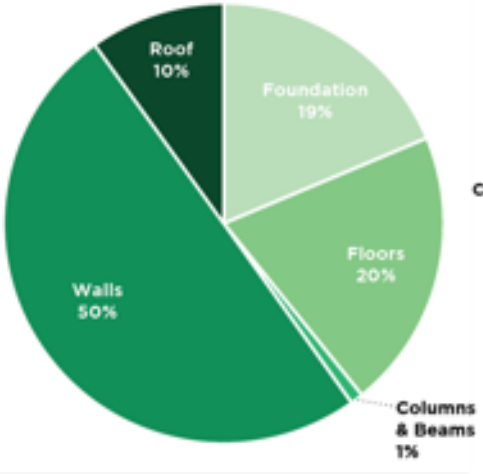


TOTAL GWP
1,338,625
kg CO_2 eq

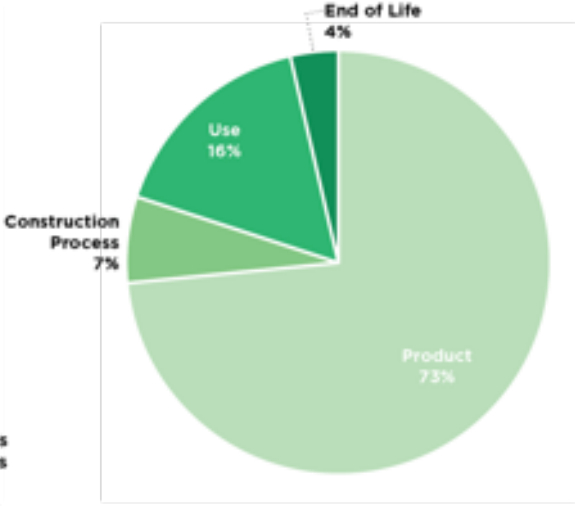
HIGHEST IMPACT BUILDING ASSEMBLY
WALLS

HIGHEST IMPACT LIFE CYCLE MODULE
A - PRODUCT

HIGHEST IMPACT BUILDING MATERIAL
INSULATION



GWP BY BUILDING ELEMENT



GWP BY LIFE CYCLE STAGE

SKEENA RESIDENCE – TALLY

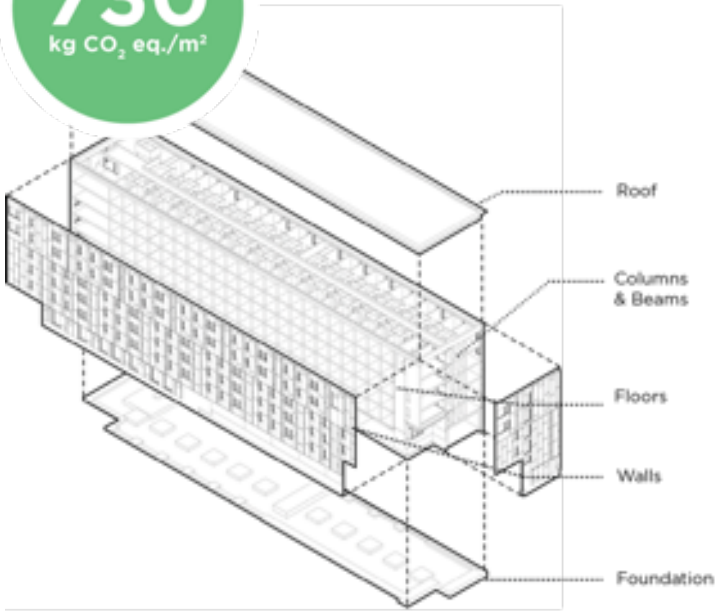
TOTAL GWP
4,923,868
kg CO_2 eq

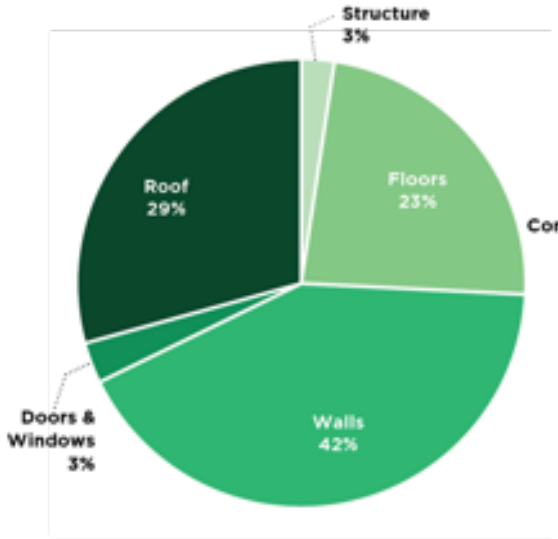
HIGHEST IMPACT BUILDING ASSEMBLY
WALLS

HIGHEST IMPACT LIFE CYCLE MODULE
A - PRODUCT

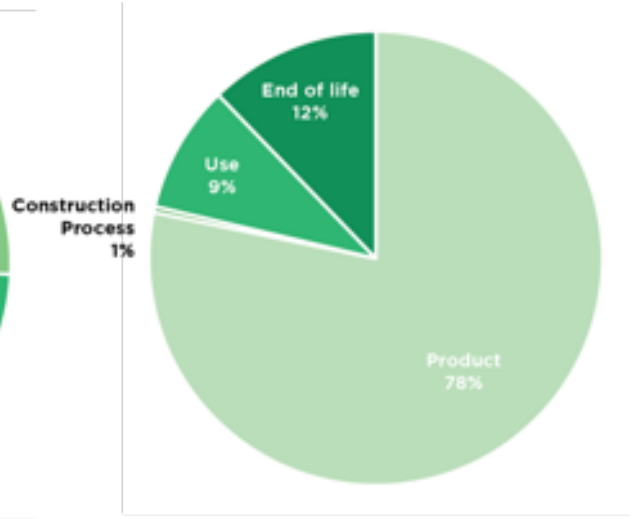
HIGHEST IMPACT BUILDING MATERIAL
INSULATION

730
kg CO_2 eq./m²





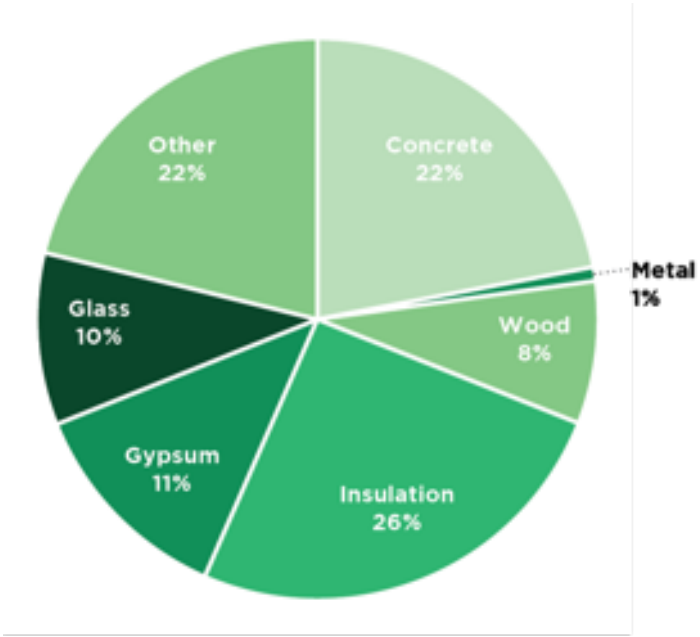
GWP BY BUILDING ELEMENT



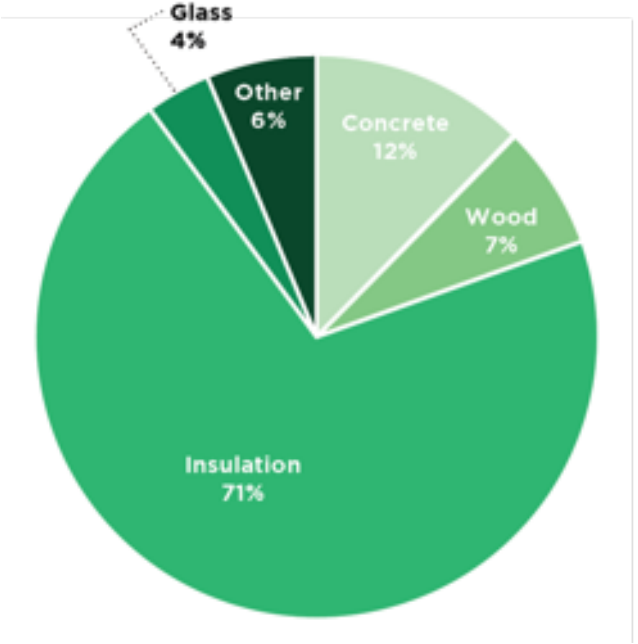
GWP BY LIFE CYCLE STAGE

SKEENA RESIDENCE - GWP BY BUILDING MATERIAL

Athena Impact Estimator

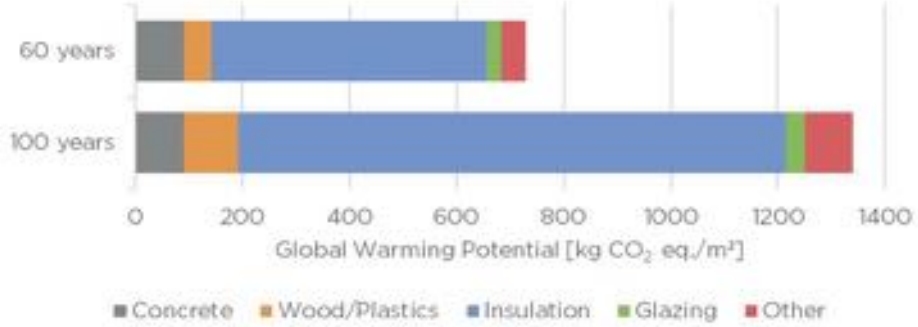


Tally



SKEENA RESIDENCE – ANALYSIS

Variation of GWP by material for different reference study periods - Tally



Proportion of GWP from building envelope

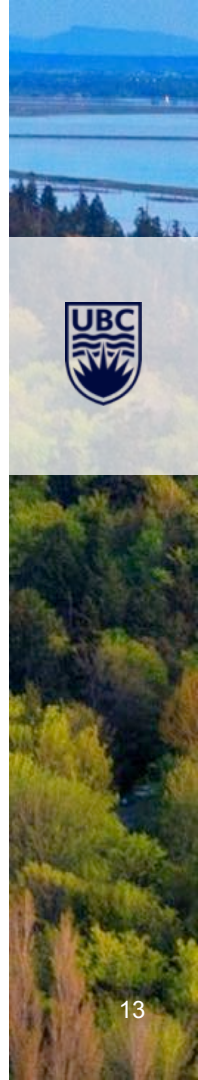
KEY TAKEAWAYS + FUTURE RESEARCH

- Envelope + insulation contribution to GWP in high-performance buildings
  - LCA tools material database and impact data limitations
  - Reference study period impact due to replacement cycles

- Benefits and limitations of BIM model as a data source

- Variation of materials in the BoMs throughout the LCA process

- Embodied carbon benchmarking and reduction targets
  - Inform policy




THE UNIVERSITY OF BRITISH COLUMBIA
zebx
QUESTIONS?