We will be starting soon!

Thanks for joining us

Practical Ways to Address Embodied Carbon

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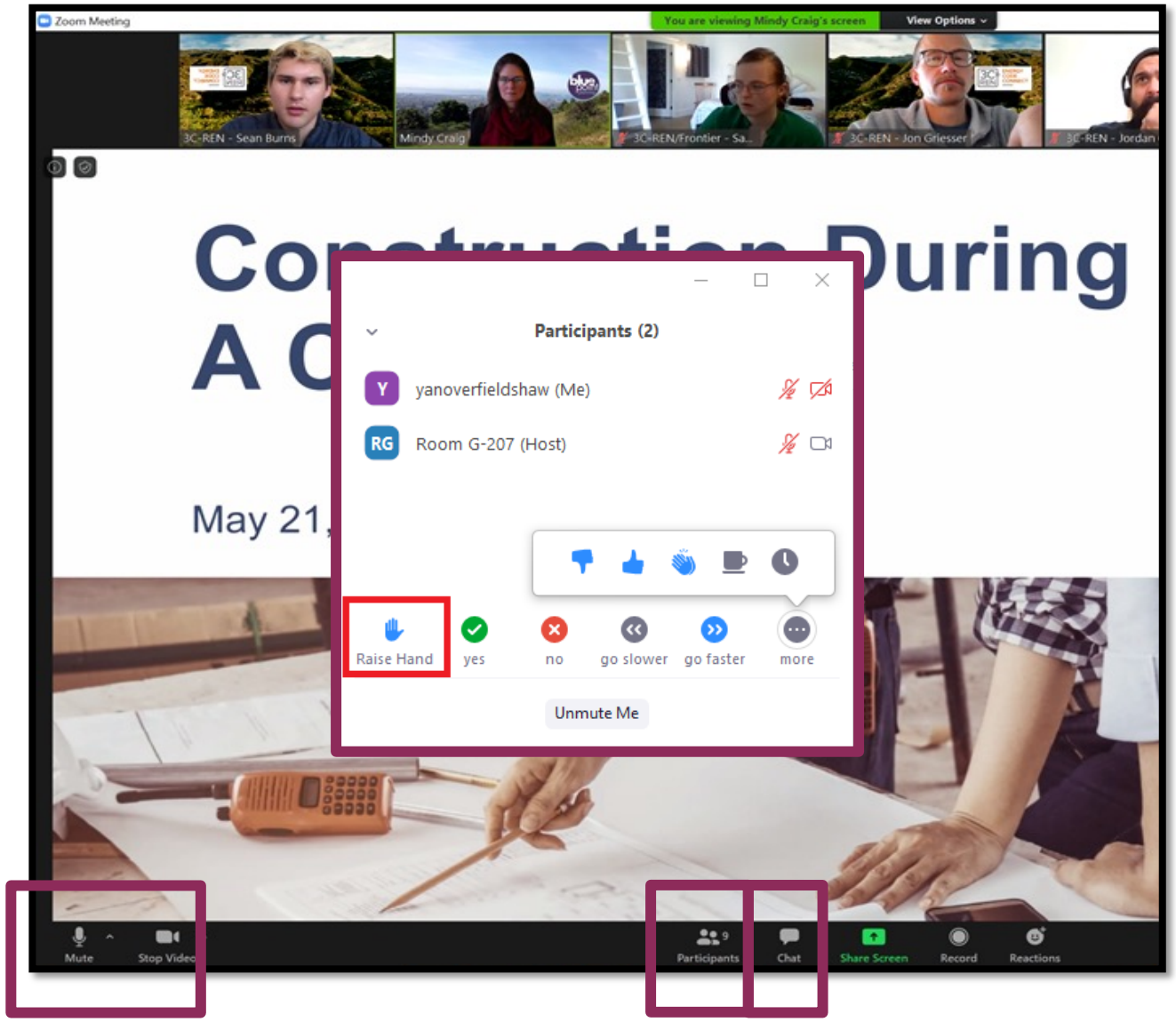
February 20, 2024

Zoom Orientation

- Please be sure your full name is displayed
- Please mute upon joining
- Use "Chat“ box to share questions or comments
- Under "Participant" select "Raise Hand" to share a question or comment verbally
- The session may be recorded and posted to 3C-REN's on-demand page. Feel free to ask questions via the chat and keep video off if you want to remain anonymous in the recording.



3C-REN: Tri-County Regional Energy Network

- Three counties working together to improve energy efficiency in the region
- Services for –
  - **Building Professionals:** industry events, training, and energy code compliance support
  - **Households:** free and discounted home upgrades
- Funded by ratepayer dollars that 3C-REN returns to the region

3C REN ENERGY CODE CONNECT

3C REN BUILDING PERFORMANCE TRAINING

3C REN HOME ENERGY SAVINGS

3C REN ENERGY CODE CONNECT

- Serves all building professionals
- Three services –
  - **Energy Code Coach**
  - **Training and Support**
  - **Regional Forums**
- Makes the Energy Code easy to follow

Energy Code Coach:
3c-ren.org/codes
805.781.1201

Event Registration:
3c-ren.org/events

BUILDING PERFORMANCE TRAINING

- Serves current and prospective building professionals
- Expert instruction:
  - **Technical skills**
  - **Soft skills**
- Helps workers to thrive in an evolving industry

Event Registration:
3c-ren.org/events

3C REN HOME ENERGY SAVINGS

Multifamily (5+ units)

- No cost technical assistance
- Rebates up to $750/apartment plus additional rebates for specialty measures like heat pumps

Single Family (up to 4 units)

- Sign up to participate!
- Get paid for the metered energy savings of your customers

Enrollment:
3C-REN.org/contractor-participation

Practical Ways to Address Embodied Carbon

February 20, 2024

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In This Presentation

- Operating vs Embodied Carbon – and other terms
- Why Care about Embodied Carbon?
- Embodied Carbon in the Construction Process – Understanding Relative Impacts
- Practical steps (and shortcuts) for Reducing EC
- 3 Methods for CALGreen Compliance
- Storing Carbon into the Future

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Differentiating Types of Carbon

Skanska

- **Embodied carbon (EC)** refers to the greenhouse gas emissions arising from the manufacturing, transportation, installation, maintenance, and disposal of building materials.
- **Kg CO2e** is often used as proxy measure for embodied carbon (valid across CO2, methane, etc.)

- **Operational carbon** refers to the greenhouse gas emissions due to building energy consumption.

Source: https://carbonleadershipforum.org/embodied-carbon-101/

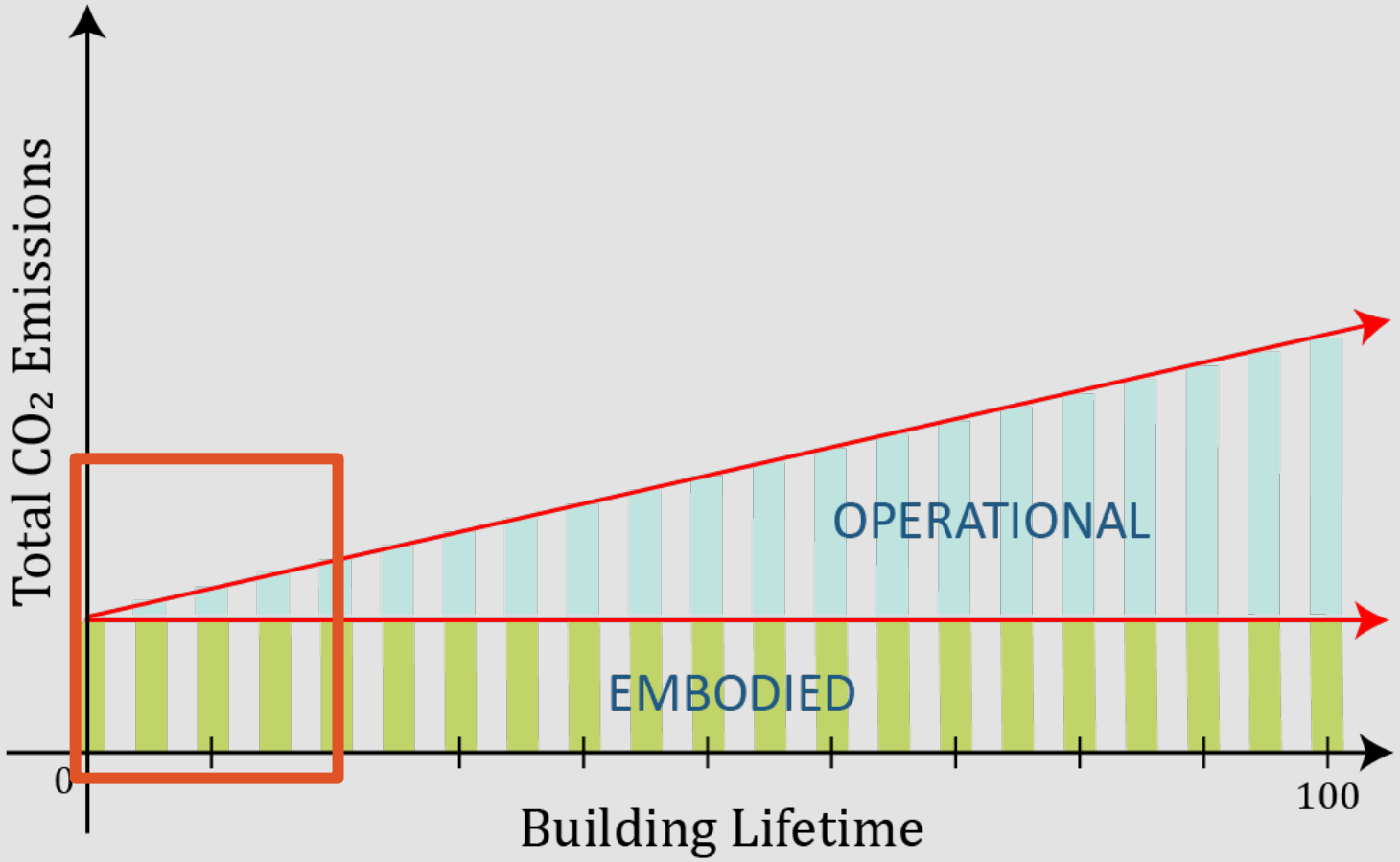
Other Terms

- **GWP – Global Warming Potential (in kg CO2e) -** A proxy for Embodied Carbon
- **EPD – Environmental Product Declarations** *(env. Impacts including GWP)*
- **HPDs – Health Product Declaration** *(health impacts such as pollutants/toxins)*
- **LCA – Life Cycle Analysis –** A systematic analysis of environmental impact of a product, material, process, etc.
- **WBLCA – Whole Building Life Cycle Assessment –** An evaluation of the environmental impact of a building's systems and materials
- **For reference:**
  - **MT/t (metric tonne)** = 1000kg or 2204.62lbs
  - **Ton –** 2000 lbs

Why Care about EC?

Time value of carbon

Embodied carbon makes up the majority of carbon associated with a building in the first 20 years.



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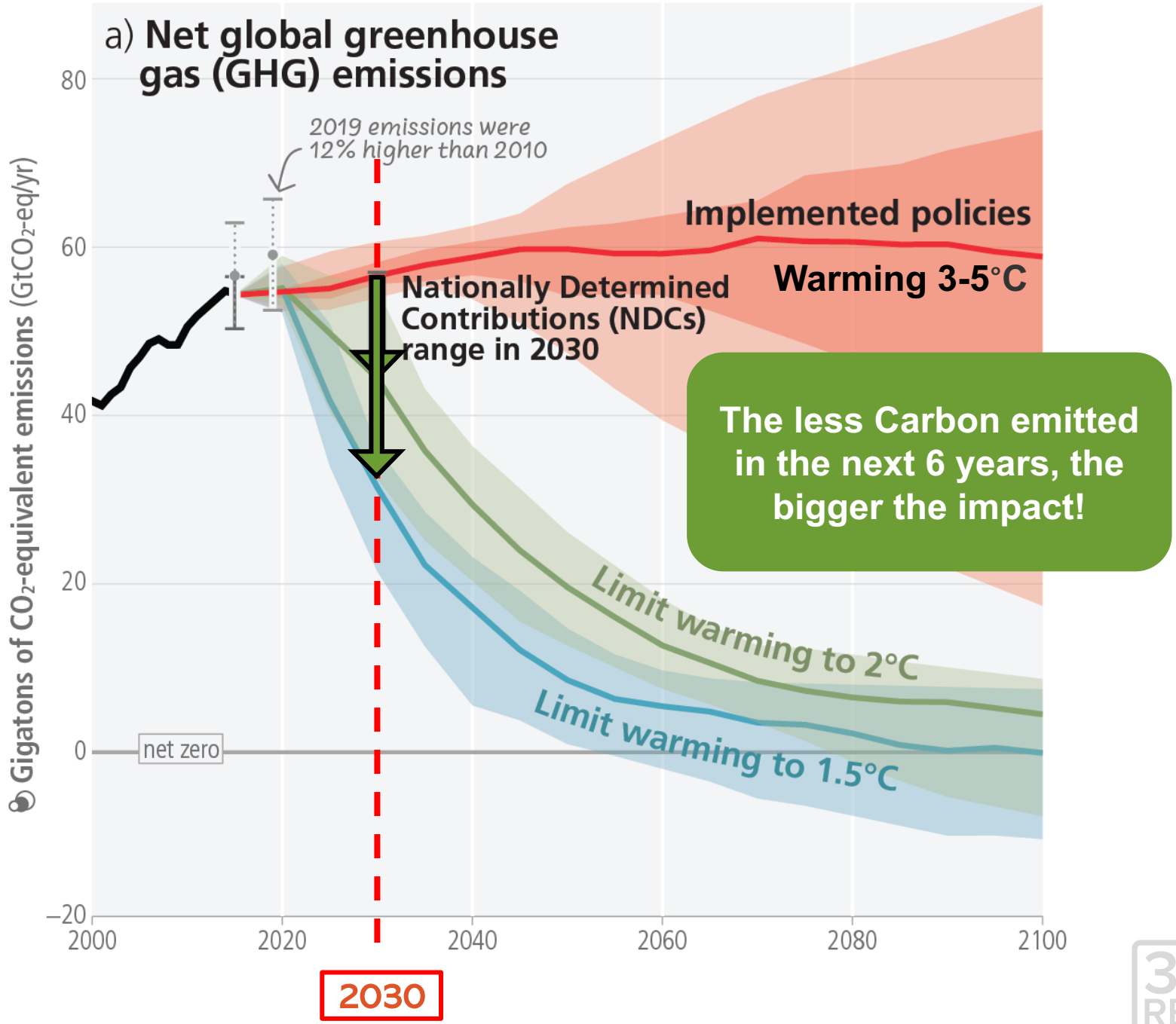
Why Care about EC?

Time value of carbon



The less Carbon emitted in the next 6 years, the bigger the impact!

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Another Curve

- "To approach zero emissions by 2050, however, we must immediately **pick the low-hanging fruit everywhere** possible and simultaneously accelerate the embodied carbon learning curve to advance our knowledge beyond the easy reductions, uncover further decarbonization strategies, and **turn buildings into climate solutions with carbon-storing materials."**

  - RMI, "Driving Action on Embodied Carbon in Buildings"

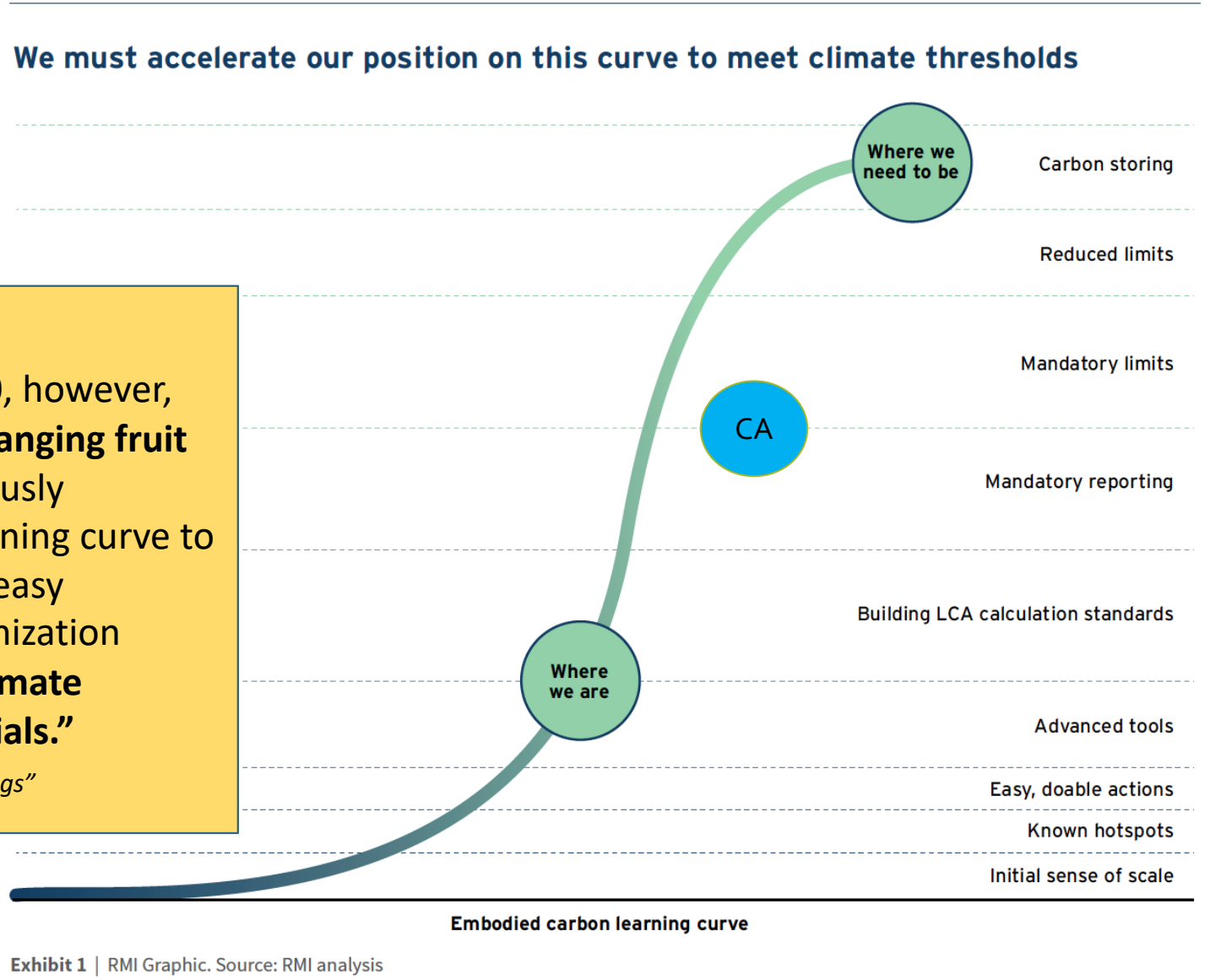

Exhibit 1 | RMI Graphic. Source: RMI analysis

Will decrease to 50,000 SF Jan. 1, 2026!

Why Care about EC?

You'll soon have to….

CALGreen Intervening Code Cycle Update – Effective July 1, 2024

Threshold: All Non-Res Commercial projects over 100,000 SF and schools under jurisdiction of DSA over 50,000 SF.

Building Reuse **Section 5.105, Deconstruction and Reuse of Existing Structures**	Life Cycle Analysis **Section 5.409, Life Cycle Assessment**	Prescriptive Path **Section 5.409.3, Product GWP Compliance**
Components: Existing primary structural elements, enclosure, (roof framing, wall framing, and exterior finishes). **Exceptions:** Additions 2x the area or more of the existing building. **Exclude:** Window assemblies, insulation, portions structurally unsound or hazardous, and hazardous materials that are remediated as part of the project shall not be included in the calculation.	**Scope:** 60-year cradle-to-grave WB LCA (ISO 14044), excluding operating energy. Show GWP analysis. **Components:** Primary and secondary structural members, glazing, insulation, exterior finishes.	**Components:** Structural steel, rebar, flat glass, light and heavy-duty mineral wool insulation, and ready mix concrete. **Exception:** Concrete mixes can use a weighted average for all mixes.
Mandatory 45% of the structure and enclosure to be reused	**Mandatory** 10% reduction from baseline	**Mandatory** 175% of IW-EPD GWP Limits
Tier 1 75% of the structure and enclosure to be reused	**Tier 1** 15% reduction from baseline	**Tier 1** 150% of IW-EPD GWP Limits
Tier 2 75% of the structure and enclosure to be reused AND 30% of interior non-structural elements to be reused	**Tier 2** 20% reduction from baseline	**Tier 2** IW-EPD GWP Limits

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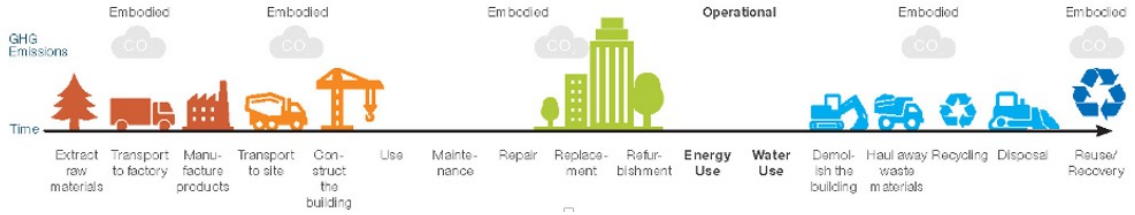
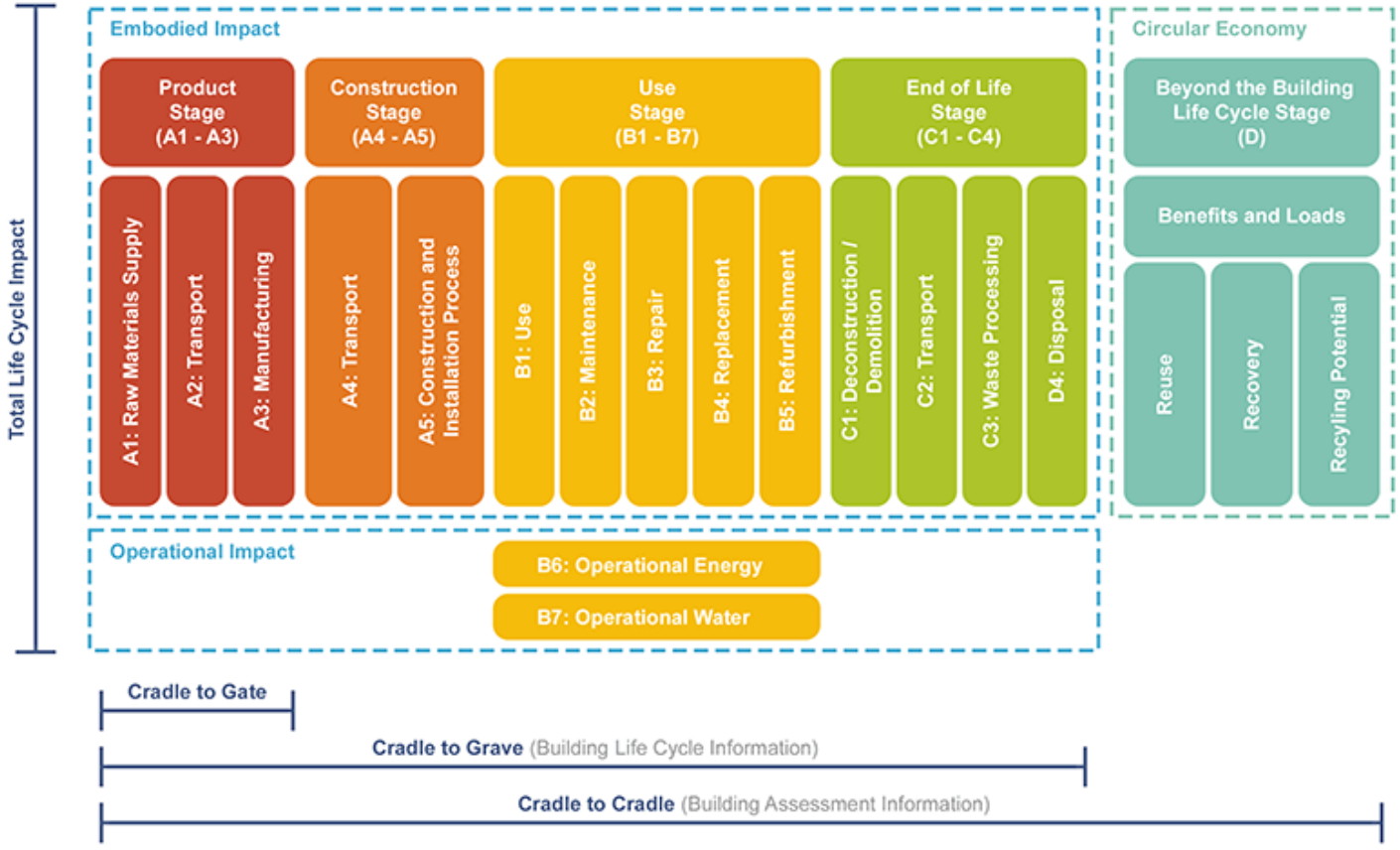
Embodied Carbon in the Construction Process

Credit: Skanska

Life-Cycle Analysis: Stages and Scopes





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Embodied Carbon Emissions by life cycle stage

The majority of building product embodied emissions occur up front

Breakdown of product life-cycle, not including building operational emissions

50%-85%
PRODUCT STAGE
(A1-A3)

3%-10%
CONSTRUCTION
(A4-A5)

6%-22%
USE
(B1-B5)

1%-15%
END OF LIFE
(C1-C4)

Exhibit 2 | RMI Graphic. Source: See endnote 7

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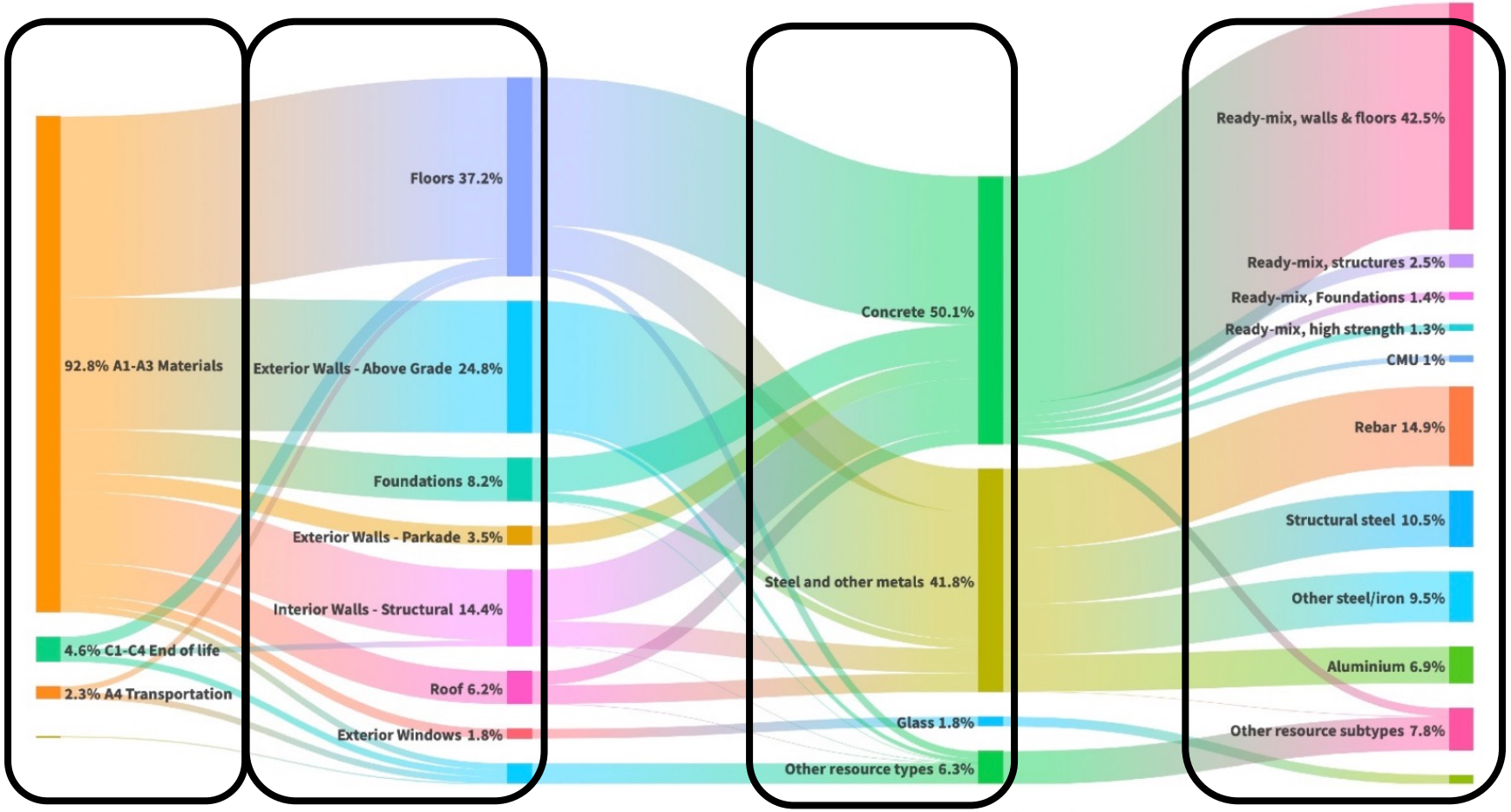
Embodied Carbon emissions by materials



An LCA evaluation by Priopta looks at the embodied carbon, or Global Warming Potential (GWP), of the materials used in a building.

Source: https://www.canadianarchitect.com/embodied-carbon-key-considerations-for-key-materials/

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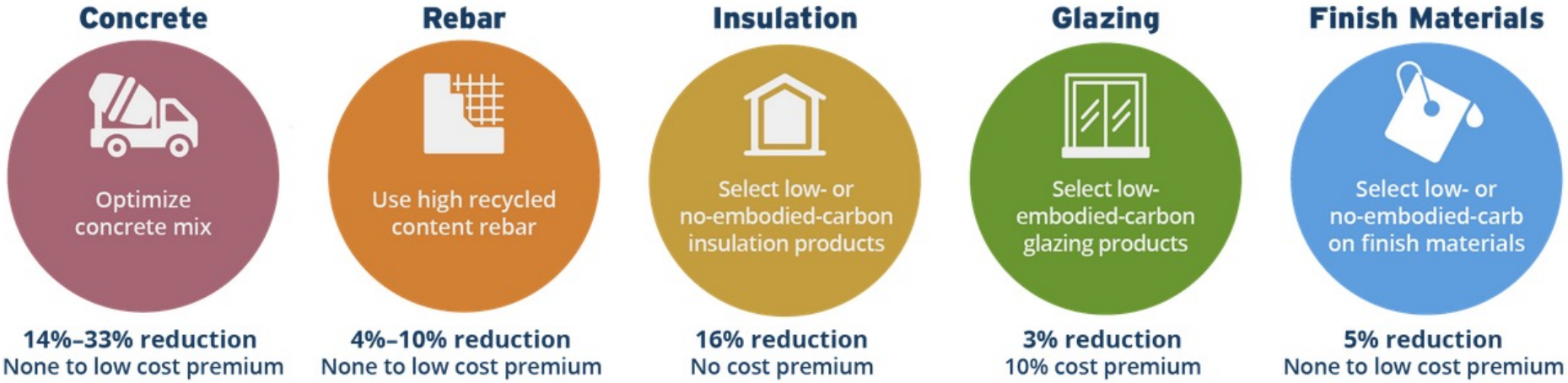
Cost-effective, Low-Carbon Product Selection

Source: https://rmi.org/embodied-carbon-101/



Concrete

Actions to Reduce Carbon

Substitute cement with alternative cementitious materials (ACMs). Choose recycled aggregate. Select structural shapes and sizes that use less material while keeping the same structural integrity.

Structural Steel

Actions to Reduce Carbon

Specify CA or U.S.-made steel and steel with high recycled content. Prioritize electric arc furnace (EAF) production over basic oxygen furnace (BOF) production.

Rebar

Actions to Reduce Carbon

Use 97% or higher recycled content rebar. Select a structural concrete design that uses less material while keeping the same structural integrity.

Insulation

Actions to Reduce Carbon

Replace foam (especially XPS) with lower-carbon materials, like cellulose and mineral wool batt.

Glazing

Actions to Reduce Carbon

Select low-carbon window frame materials. Specify no more than two panes of glazing.

Finish Materials

Actions to Reduce Carbon

Select low-carbon and durable finish materials. Reuse materials and design for deconstruction and reuse for future tenant improvements.

Source: Embodied Carbon and CALGreen Embodied Carbon Requirements, California Energy Codes & Standards, 2024

Practical Steps for Reducing EC

Top design interventions for embodied carbon reduction

1 Reuse

Reuse an entire building and/or components of a deconstructed building. Limit the scope of renovations to what is needed. Prioritize salvaged materials over new production.

2 Right-size

Optimize building size by using space more intensively and minimizing excess space. Design with better scheduling or dual-use spaces to decrease the building size.

3 Dematerialize

Expose structure instead of applying finishes. Optimize structural system to minimize excess material. Consider reducing overdesign by evaluating conservative load assumptions.

4 Carbon storing materials

Carbon storing materials can speed transition to zero embodied emissions. Building projects can ask for responsibly produced biobased and concrete materials that can store carbon durably.

5 Product substitutions

Make substitutions for the highest impact materials informed by a whole-building integrated approach or by low-material GWP limits when you cannot do an LCA.

6 Sourcing

Ensure products are coming from legal and sustainable or regenerative sources. Prioritize local materials when data reveals they have reduced impacts associated with transport.

7 Circular design

Reduce the impact over the building's life cycle and enable low-embodied-carbon future construction by prioritizing reusability, recyclability, design for disassembly, and durability.

Source: RMI, Driving Action on Embodied Carbon Reduction, pg 20.

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Three Methods for CALGreen Compliance

	Building Reuse	Whole Building LCA	Prescriptive Approach
Mandatory*	**45% REUSE** of structure and enclosure	**10% REDUCTION** from baseline building	Limit Materials to **175%** of GWP limits
Tier 1	**75% REUSE** of structure and enclosure	**15% REDUCTION** from baseline building	Limit Materials to **150%** of GWP limits
Tier 2	**75% REUSE** of structure and enclosure **AND** **30% REUSE** of interior non-structural	**20% REDUCTION** from baseline building	Limit Materials to **100%** of GWP limits

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CALGreen: Reuse

- 5.105.2 Reuse of existing building. An alteration or addition to an existing building shall maintain at a minimum 45 percent combined of the existing building's primary structural elements (foundations; columns, beams, walls, and floors; and lateral elements) and existing building enclosure (roof framing, wall framing and exterior finishes). Window assemblies, insulation, portions of buildings deemed structurally unsound or hazardous, and hazardous materials that are remediated as part of the project shall not be included in the calculation.

- Exception [BSC-CG, DSA-SS]: Combined addition(s) to existing building(s) of two times the area or more of the existing building(s) is not eligible to meet compliance with Section 5.105.2.

Case Study: Reuse

Total SF > 100,000 SF?

No

	Existing Building SF	Addition SF	Total SF	Total > 100k SF?	Addition is 2x or more of Existing?	CALGreen Documentation Method
Building A	45,000 SF	50,000 SF	90,000 SF	No		Does not trigger EC compliance req.
Building B	45,000 SF	80,000 SF	105,000 SF	Yes	No	Reuse documentation
Building C	45,000 SF	100,000 SF	145,000 SF	Yes	Yes	WBLCA or Prescriptive

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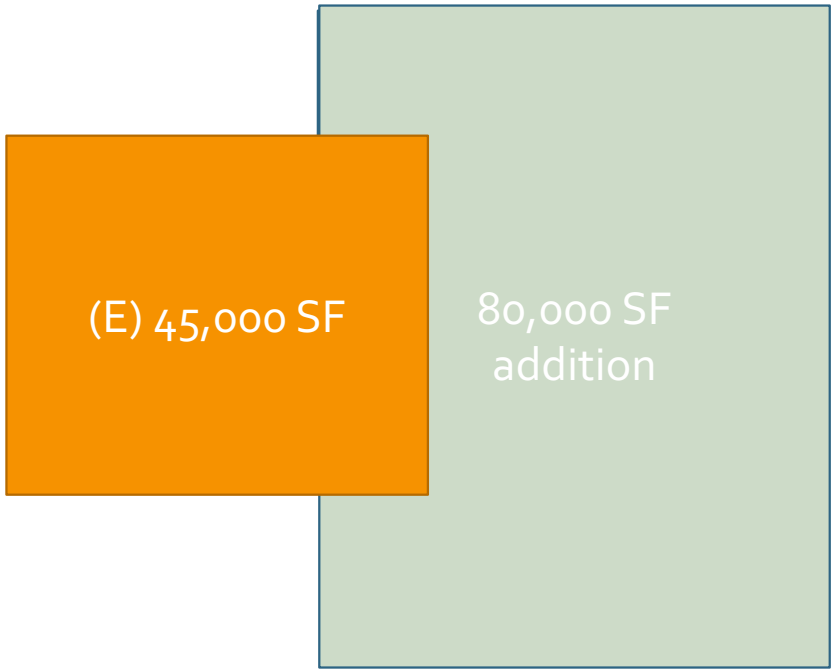
Case Study: Reuse



Total SF > 100,000 SF?

Yes

Addition > 2x Existing SF?

No

	Existing Building SF	Addition SF	Total SF	Total > 100k SF?	Addition is 2x or more of Existing?	CALGreen Documentation Method
Building A	45,000 SF	50,000 SF	90,000 SF	No		Does not trigger EC compliance req.
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Case Study: Reuse

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Yes

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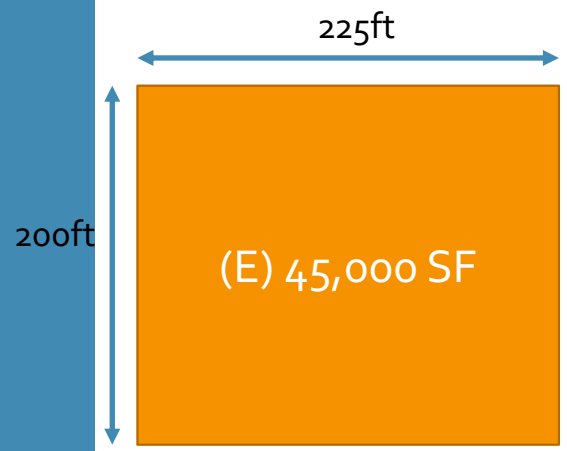
Documenting Reuse



- Primary structural elements (foundations; columns, beams, walls, and floors; and lateral elements)
- Existing building enclosure (roof framing, wall framing and exterior finishes)
- Exclude windows, insulation, hazardous

Primary Structure					
			Existing SF	Retained SF	
	perimeter foundation		2550	2550	
	concrete floor		45,000	45,000	
	CMU walls		8500	4250	
	lateral beams		900	0	
	excl windows		50	0	
		subtotal	*57000*	*51800*	*90.88 %*
Existing enclosure					
	roof framing		45000	0	
	wall framing		n/a	n/a	
	exterior finishes		8450	8450	
		subtotal	*53450*	*8450*	*15.81 %*
Total			**110,350**	**60,250**	**54.60 %**

WORKSHEET (WS-3)
5.105.2 BUILDING REUSE

DOCUMENTATION OF COMPLIANCE OF EXISTING BUILDING REUSE

Area of Existing Building(s) 45,000 **SF**

Area of Aggregate Addition(s) (if applicable) 80,000 **SF**

	EXISTING TOTAL AREA (A)	RETAINED TOTAL AREA (B)	% OF RETAINED STRUCTURE (B)/(A)
Primary Structural Elements of Existing Building(s) (foundations; columns, beams, walls, and floors; and lateral elements)	57,000 SF	51,800 SF	90.88 % SF
Building Enclosure of Existing Building(s) (roof framing, wall framing and exterior finishes only)	53,450 SF	8450 SF	15.81 % SF

Total % Reuse of Required Elements ≥ 45% 54.60 %

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CALGreen: WBLCA

5.409.2 Whole building life cycle assessment. Projects shall conduct a cradle-to-grave whole building life cycle assessment performed in accordance with ISO 14040 and ISO14044, excluding operating energy, and demonstrating a minimum 10-percent reduction in global warming potential (GWP) as compared to a reference baseline building of similar size, function, complexity, type of construction, material specification, and location that meets the requirements of the California Energy Code currently in effect.

5.409.2.1 Building components. Building enclosure components included in the assessment shall be limited to glazing assemblies, insulation, and exterior finishes. Primary and secondary structural members included in the assessment shall be limited to footings and foundations, and structural columns, beams, walls, roofs, and floors.

ASTM E2921-22 **Reference building** shall have the same location, orientation, size, function and space conditioning as the proposed building. Materials shall be based on typical design or construction practices for the area in which the site is located.

CALGreen WBLCA Scope

Exhibit 2 Typical high-embodied-carbon structural elements, building envelope materials, and finish materials

Source: Mithun

Documenting WBLCA

- A summary of the GWP analysis produced by the software and Worksheet WS-4 signed by the design professional of record shall be provided in the construction documents as documentation of compliance.

WORKSHEET (WS-4)
Section 5.409.2 WHOLE BUILDING LIFE CYCLE ASSESSMENT

Responsible Designer's Declaration Statement:
I attest that the Whole Building Life Cycle Analysis has been performed according to the requirements of Section 5.409.2 and has met the minimum 10 percent reduction in global warming potential as compared to a reference baseline building of similar size, function, complexity, type of construction, material specification, and location that meets the requirements of the *California Energy Code* currently in effect. Furthermore, I will ensure during construction that the material specifications will be reviewed for substantial conformance with the life cycle assessment indicated on the approved plans so at the close of construction the minimum 10 percent reduction in global warming potential is thereby secured.

Signature:	.
Company:	Date:
Address:	License:
City/State/Zip:	Phone:

Project Name	Unit	Foundations	Walls	Columns and Beams	Floors	Roofs	Project Extra Materials	Total
Baseline -- SB Fire Dispatch	kg CO2 eq	7.54E+04	9.93E+04	1.19E+04	0.00E+00	8.11E+04	0.00E+00	2.68E+05
Proposed -- SB Fire Dispatch	kg CO2 eq	7.26E+04	3.71E+04	-3.24E+03	0.00E+00	7.92E+04	0.00E+00	1.86E+05
Total	kg CO2 eq	1.48E+05	1.36E+05	8.69E+03	0.00E+00	1.60E+05	0.00E+00	4.53E+05

- A copy of the whole building life cycle assessment which includes the GWP analysis produced by the software, in addition to the maintenance and training information, shall be included in the O&M manual.

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Tools for modeling WBLCA

Free software:

Athena Sustainable Materials Institute

One Click LCA

Planetary

Paid software:

sphera®

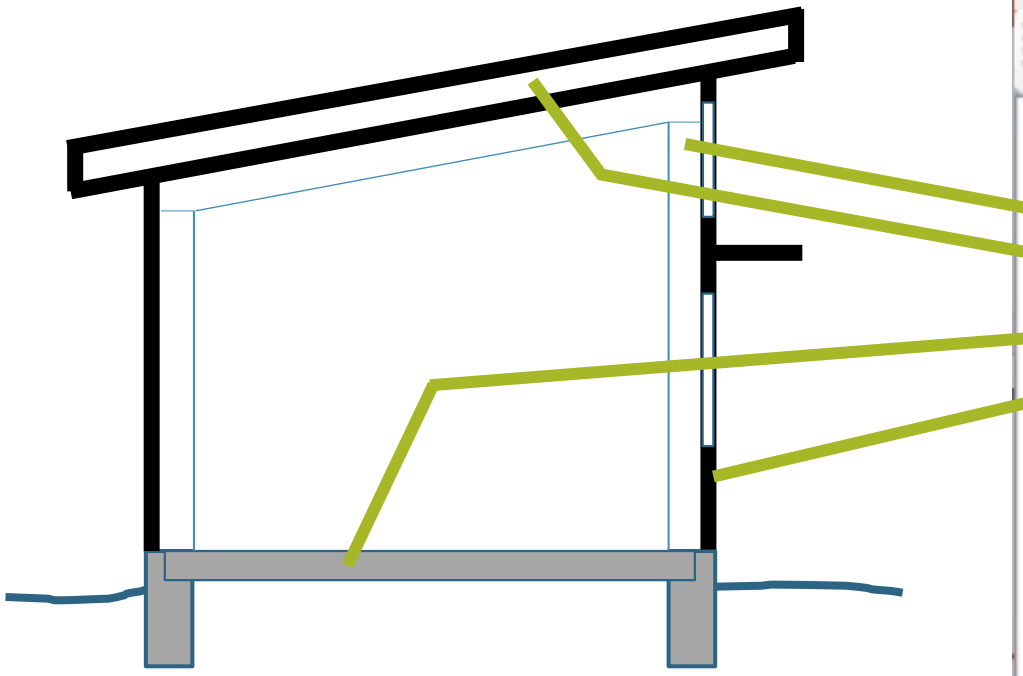
(fka GaBi)

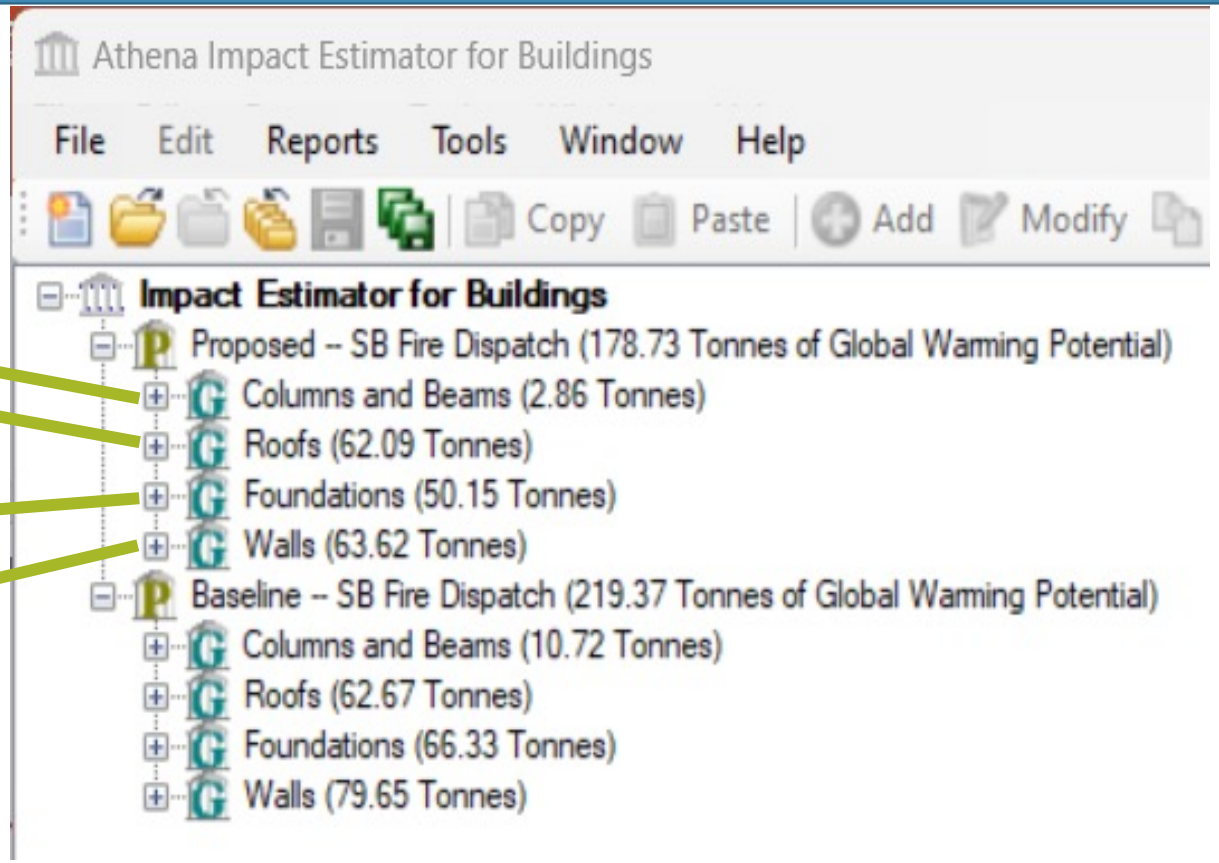
SimaPro

tally®

(Revit plug-in)

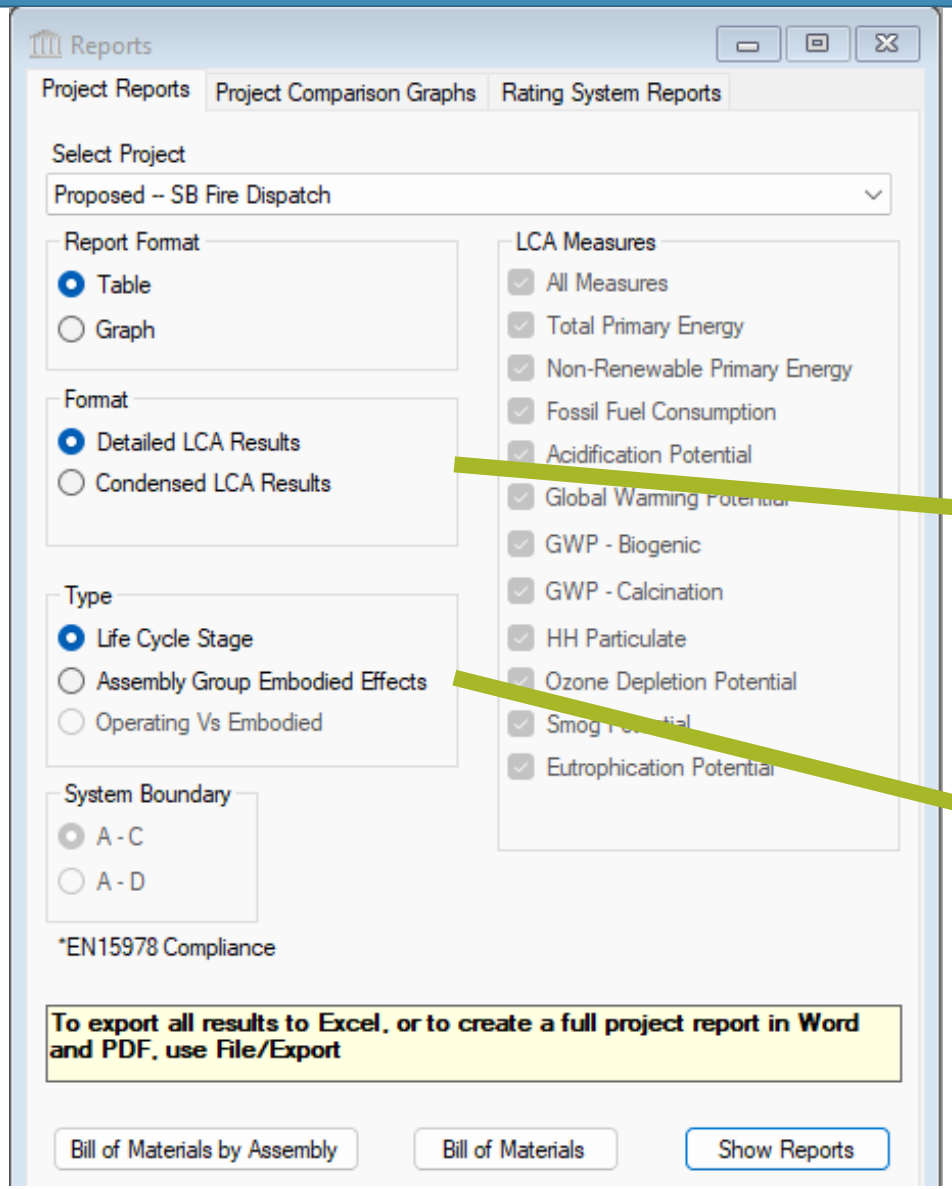
Athena – Building Tree Organization





The user can build a **Baseline** model and a **Proposed** model for comparison.
The user can define the wall and roof assemblies.
The wall assemblies include "openings" for basic window inputs.
The foundation can include slab, footings, grade beams, pad footings and rebar.

Athena – Excerpt from Project Reports: Data for CALGreen Reporting



Note:
Reports to be run for Proposed and Baseline projects for comparison

Detailed LCA Results

Life Cycle Stage

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Athena: Summary Comparison Report (Data for CALGreen Reporting)

		PRODUCT (A1 to A3)			CONSTRUCTION PROCESS (A4 & A5)			USE (B2, B4 & B6)				END OF LIFE (C1 to C4)			TOTAL EFFECTS	
LCA Measures	**Unit**	Manufacturing	Transport	**Total**	Construction-Installation Process	Transport	**Total**	Replacement Manufacturing	Replacement Transport	Operational Energy Use Total	**Total**	De-construction, Demolition, Disposal & Waste Processing	Transport	**Total**	**A to C**	**A to D**
Global Warming Potential	kg CO2 eq	7.24E+04	5.06E+02	**7.29E+04**	1.05E+04	4.36E+04	**5.41E+04**	1.58E+04	1.77E+03	0.00E+00	**1.76E+04**	3.90E+04	2.13E+03	**4.12E+04**	**1.86E+05**	**1.85E+05**
GWP - Biogenic	kg CO2 eq	-8.42E+04	0.00E+00	**-8.42E+04**	-2.54E+03	0.00E+00	**-2.54E+03**	0.00E+00	0.00E+00	0.00E+00	**0.00E+00**	3.27E+04	0.00E+00	**3.27E+04**	**-5.40E+04**	**-5.40E+04**
GWP - Calcination	kg CO2 eq	1.45E+04	0.00E+00	**1.45E+04**	7.26E+02	0.00E+00	**7.26E+02**	0.00E+00	0.00E+00	0.00E+00	**0.00E+00**	0.00E+00	0.00E+00	**0.00E+00**	**1.52E+04**	**1.52E+04**
Acidification Potential	kg SO2 eq	5.80E+02	5.07E+00	**5.85E+02**	8.42E+01	4.93E+02	**5.77E+02**	1.03E+02	1.95E+01	0.00E+00	**1.22E+02**	7.66E+01	2.05E+01	**9.71E+01**	**1.38E+03**	**1.33E+03**
HH Particulate	kg PM2.5 eq	9.71E+01	2.70E-01	**9.74E+01**	9.51E+00	2.40E+01	**3.35E+01**	3.81E+01	9.86E-01	0.00E+00	**3.91E+01**	3.20E+01	1.14E+00	**3.31E+01**	**2.03E+02**	**1.97E+02**
Eutrophication Potential	kg N eq	1.89E+02	3.15E-01	**1.89E+02**	1.67E+01	3.05E+01	**4.72E+01**	1.73E+01	1.21E+00	0.00E+00	**1.85E+01**	6.16E+00	1.27E+00	**7.44E+00**	**2.62E+02**	**2.62E+02**
Ozone Depletion Potential	kg CFC-11 eq	4.04E-02	1.81E-08	**4.04E-02**	2.13E-03	1.71E-06	**2.13E-03**	4.42E-04	6.96E-08	0.00E+00	**4.42E-04**	2.43E-04	7.44E-08	**2.43E-04**	**4.32E-02**	**4.32E-02**
Smog Potential	kg O3 eq	1.14E+04	1.61E+02	**1.15E+04**	2.30E+03	1.57E+04	**1.80E+04**	9.00E+02	6.21E+02	0.00E+00	**1.52E+03**	2.39E+03	6.47E+02	**3.04E+03**	**3.41E+04**	**3.38E+04**
Total Primary Energy	MJ	1.67E+06	7.37E+03	**1.68E+06**	1.29E+05	6.29E+05	**7.58E+05**	3.03E+05	2.56E+04	0.00E+00	**3.28E+05**	9.33E+04	3.11E+04	**1.24E+05**	**2.89E+06**	**2.89E+06**
Non-Renewable Energy	MJ	1.28E+06	7.37E+03	**1.29E+06**	1.07E+05	6.28E+05	**7.36E+05**	2.92E+05	2.56E+04	0.00E+00	**3.18E+05**	9.28E+04	3.11E+04	**1.24E+05**	**2.47E+06**	**2.47E+06**
Fossil Fuel Consumption	MJ	1.21E+06	7.35E+03	**1.22E+06**	1.03E+05	6.27E+05	**7.30E+05**	2.65E+05	2.55E+04	0.00E+00	**2.91E+05**	9.06E+04	3.10E+04	**1.22E+05**	**2.36E+06**	**2.38E+06**

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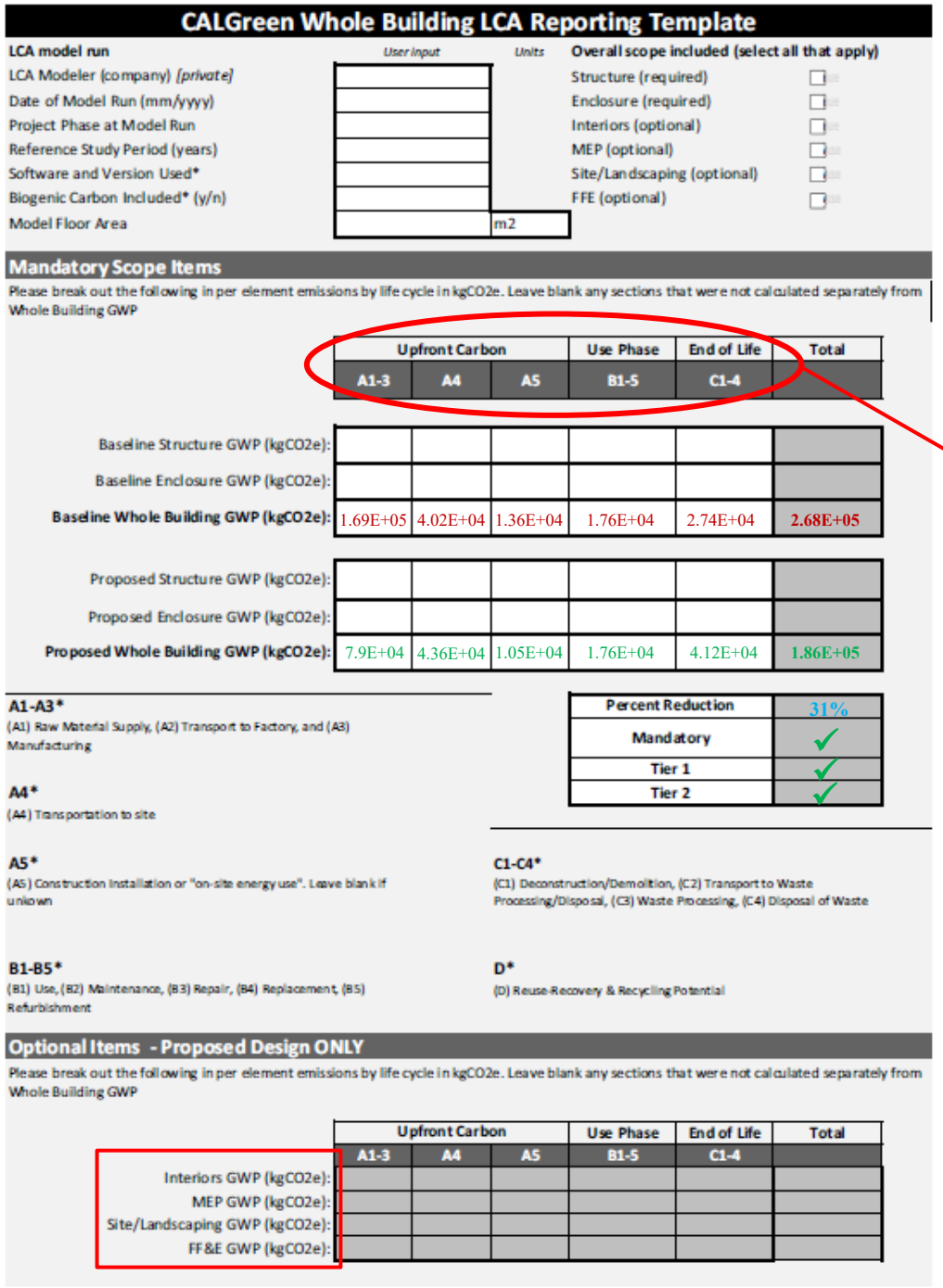
Documenting WBLCA



CALGreen Whole Building LCA Reporting Template

LCA model run	User input	Units
LCA Modeler (company) *(private)*		
Date of Model Run (mm/yyyy)		
Project Phase at Model Run		
Reference Study Period (years)		
Software and Version Used*		
Biogenic Carbon Included* (y/n)		
Model Floor Area		m2

Overall scope included (select all that apply)
- Structure (required)
- Enclosure (required)
- Interiors (optional)
- MEP (optional)
- Site/Landscaping (optional)
- FFE (optional)

Mandatory Scope Items

Please break out the following in per element emissions by life cycle in kgCO2e. Leave blank any sections that were not calculated separately from Whole Building GWP

	Upfront Carbon			Use Phase	End of Life	Total
	A1-3	A4	A5	B1-5	C1-4	
Baseline Structure GWP (kgCO2e):						
Baseline Enclosure GWP (kgCO2e):						
Baseline Whole Building GWP (kgCO2e):	1.69E+05	4.02E+04	1.36E+04	1.76E+04	2.74E+04	**2.68E+05**
Proposed Structure GWP (kgCO2e):						
Proposed Enclosure GWP (kgCO2e):						
Proposed Whole Building GWP (kgCO2e):	7.9E+04	4.36E+04	1.05E+04	1.76E+04	4.12E+04	**1.86E+05**

Percent Reduction	31%
Mandatory	✓
Tier 1	✓
Tier 2	✓

A1-A3* (A1) Raw Material Supply, (A2) Transport to Factory, and (A3) Manufacturing

A4* (A4) Transportation to site

A5* (A5) Construction Installation or "on-site energy use". Leave blank if unkown

B1-B5* (B1) Use, (B2) Maintenance, (B3) Repair, (B4) Replacement, (B5) Refurbishment

C1-C4* (C1) Deconstruction/Demolition, (C2) Transport to Waste Processing/Disposal, (C3) Waste Processing, (C4) Disposal of Waste

D* (D) Reuse-Recovery & Recycling Potential

Optional Items - Proposed Design ONLY

Please break out the following in per element emissions by life cycle in kgCO2e. Leave blank any sections that were not calculated separately from Whole Building GWP

	Upfront Carbon			Use Phase	End of Life	Total
	A1-3	A4	A5	B1-5	C1-4	
Interiors GWP (kgCO2e):						
MEP GWP (kgCO2e):						
Site/Landscaping GWP (kgCO2e):						
FF&E GWP (kgCO2e):						

- In addition, the enforcing entity may require Worksheet WS-9 to demonstrate compliance with the requirements.
- Cradle-to-Grave
- Consult ASTM E2921-22 for standard practice guidelines for baseline
- Mandatory measure targets a 10% reduction from baseline; 15% for Tier 1; 20% for Tier 2

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CALGreen: Prescriptive Path

- 5.409.3 Product GWP compliance—prescriptive path. Each product that is permanently installed and listed in Table 5.409.3 shall have a Type III environmental product declaration (EPD), either product-specific or factory-specific.
  - 5.409.3.1 Products shall not exceed the maximum GWP value specified in Table 5.409.3.

- Exception: Concrete may be considered one product category to meet compliance with this section. A weighted average of the maximum GWP for all concrete mixes installed in the project shall be less than the weighted average maximum GWP allowed per Table 5.409.3. For the purposes of this exception, industry-wide EPDs are acceptable.

Table 5.409.3 GWP Limits

Only certain steel, glass and insulation…

…. and concrete. Allowed GWP keyed to strength and type of ready-mix

TABLE 5.409.3
PRODUCT GWP LIMITS

BUY CLEAN CALIFORNIA MATERIALS PRODUCT CATEGORY[1]	MAXIMUM ACCEPTABLE GWP VALUE (unfabricated) ($GWP_{allowed}$)	UNIT OF MEASUREMENT
Hot-rolled structural steel sections	1.77	MT CO_2e/MT
Hollow structural sections	3.00	MT CO_2e/MT
Steel plate	2.61	MT CO_2e/MT
Concrete reinforcing steel	1.56	MT CO_2e/MT
Flat glass	2.50	kg CO_2e/MT
Light-density mineral wool board insulation	5.83	kg CO_2e/1 m^2
Heavy-density mineral wool board insulation	14.28	kg CO_2e/1 m^2
Concrete, Ready-Mixed[2, 3]		
CONCRETE PRODUCT CATEGORY	**MAXIMUM GWP ALLOWED VALUE ($GWP_{allowed}$)**	**UNIT OF MEASUREMENT**
up to 2499 psi	450	kg CO_2e/m^3
2500–3499 psi	489	kg CO_2e/m^3
3500–4499 psi	566	kg CO_2e/m^3
4500–5499 psi	661	kg CO_2e/m^3
5500–6499 psi	701	kg CO_2e/m^3
6500 psi and greater	799	kg CO_2e/m^3
Concrete, Lightweight Ready-Mixed[2]		
CONCRETE PRODUCT CATEGORY	**MAXIMUM GWP ALLOWED VALUE ($GWP_{allowed}$)**	**UNIT OF MEASUREMENT**
up to 2499 psi	875	kg CO_2e/m^3
2500–3499 psi	956	kg CO_2e/m^3
3500–4499 psi	1039	kg CO_2e/m^3

Note: Units for steel are MT or metric tonne. Often noted in EPDs as t.

GWP data will be found on EPDs

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Environmental Product Declarations (EPDs)

- Standardized document with information about environmental impact of products – including GWP
- Type III EPDs are third-party verified
- May represent:
  - Product-specific data
  - Factory-specific data
  - Industry average – one product across several manufacturers

ENVIRONMENTAL PRODUCT DECLARATION

FABRICATED HOT-ROLLED STRUCTURAL STEEL SECTIONS

NUCOR CORPORATION

COVER PAGE

NUCOR®

Nucor Corporation operates two ISO 14001-certified structural steel mills, Nucor-Yamato Steel and Nucor Steel Berkeley, that have the capacity to annually produce up to 3,250,000 tons of wide-flange steel beams, pilings and heavy structural steel products for fabricators, construction companies, manufacturers and steel service centers.

Nucor Corporation is North America's largest recycler, turning approximately 20 million net tons of scrap steel in 2019 into new steel. Nucor uses Electric Arc Furnace (EAF) technology at each of its 25 steel recycling facilities. EAFs use post-consumer scrap as its major feedstock, unlike traditional blast furnace steelmaking, which produces more than 70% of the world's steel using mined iron ore and metallurgical coal as feedstock.

Through its use of EAFs, Nucor's steelmaking CO2 emissions are one-half of the global average on a per ton basis, and Nucor's energy intensity is approximately one-quarter the global average.

UL CERTIFIED ENVIRONMENTAL PRODUCT DECLARATION ULCOM/EPD

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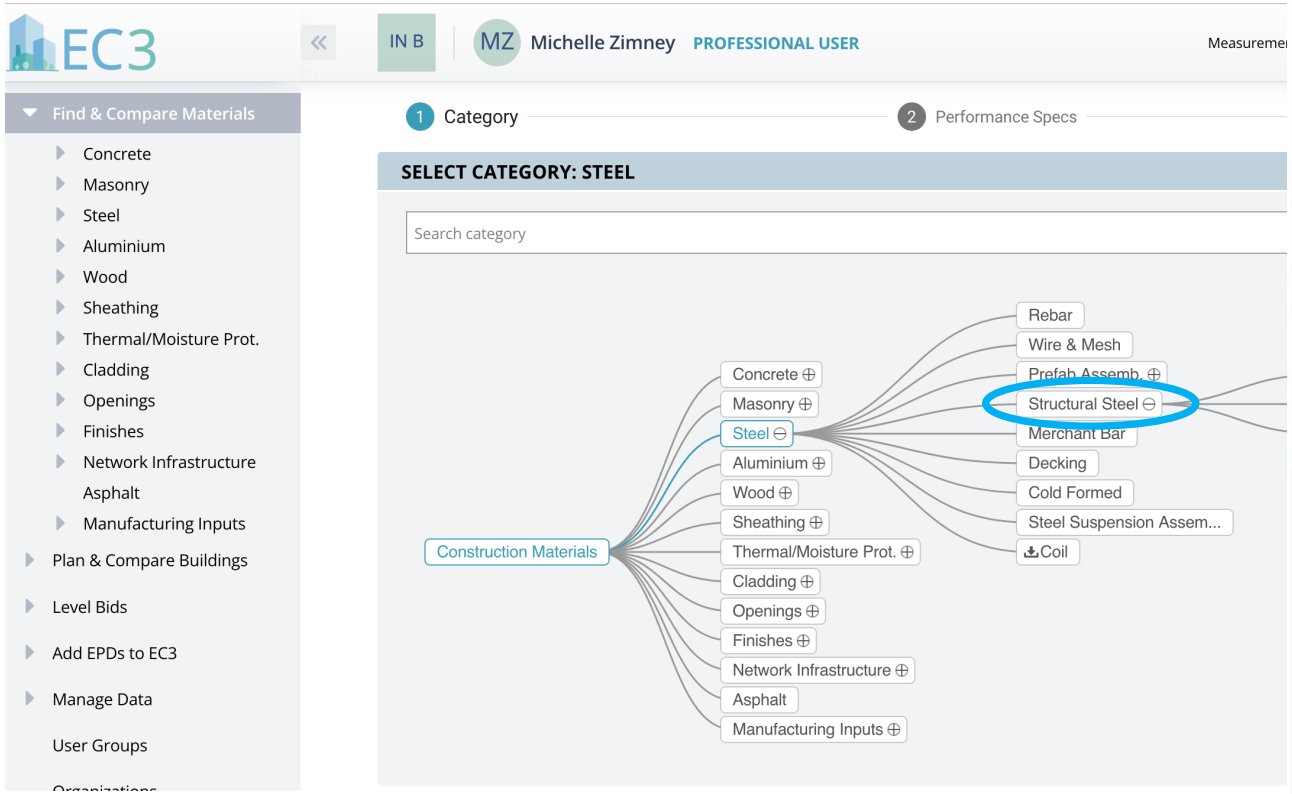
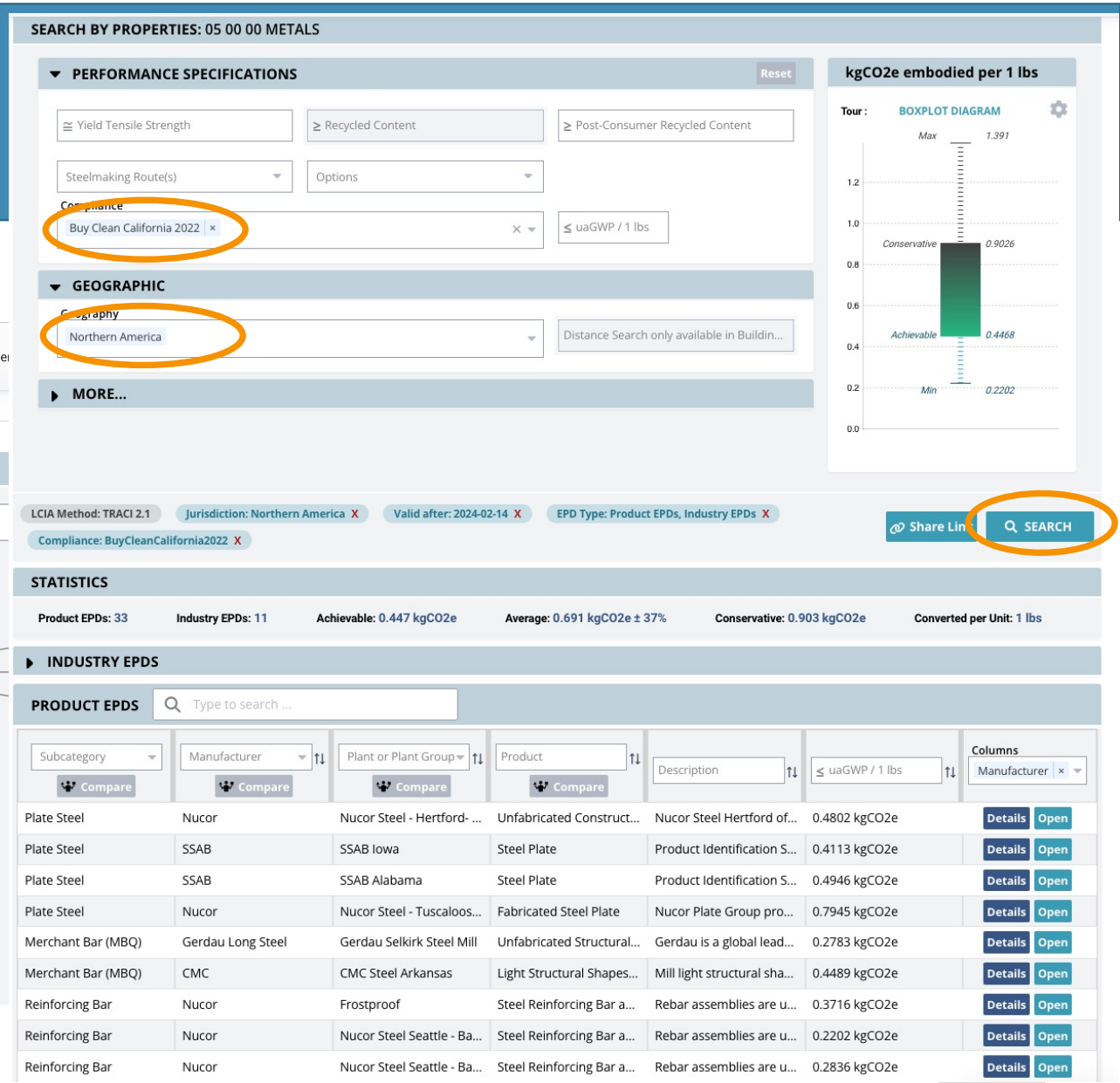
EC3 Tool: Searchable EPD database





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Sample EPD: Declared Unit, Validity and Scope

INFO PAGE

MENTAL PRODUCT DECLARATION

NUCOR®

Fabricated Hot-Rolled Structural Steel Sections
Designated Steel Construction Product

According to ISO 14025, EN 15804 and ISO 21930:2017

EPD PROGRAM AND PROGRAM OPERATOR NAME, ADDRESS, LOGO, AND WEBSITE	UL Environment 333 Pfingsten Road Northbrook, IL 60611	https://www.ul.com/ https://spot.ul.com
GENERAL PROGRAM INSTRUCTIONS AND VERSION NUMBER	General Program Instructions v.2.5 March 2020	
MANUFACTURER NAME AND ADDRESS	Nucor Corporation, 1915 Rexford Road, Charlotte, North Carolina 28211	
DECLARATION NUMBER	4789793365.102.1	
DECLARED PRODUCT & FUNCTIONAL UNIT OR DECLARED UNIT	Fabricated Hot-Rolled Structural Steel Sections, 1 metric ton	
REFERENCE PCR AND VERSION NUMBER	Part A: Calculation Rules for the LCA and Requirements Project Report, (IBU/UL Environment, V3.2, 12.12.2018) and Part B: Designated Steel Construction Product EPD Requirements (UL Environment, V2.0, 08.26.2020).	
DESCRIPTION OF PRODUCT APPLICATION/USE	Hot rolled structural steel sections used in construction	
PRODUCT RSL DESCRIPTION (IF APPL.)	N/A	
MARKETS OF APPLICABILITY	North America	
DATE OF ISSUE	January 1, 2021	
PERIOD OF VALIDITY	5 Year	
EPD TYPE	Product-Specific	
EPD SCOPE	Cradle to gate	
YEAR(S) OF REPORTED PRIMARY DATA	2019	
LCA SOFTWARE & VERSION NUMBER	GaBi v10	
LCI DATABASE(S) & VERSION NUMBER	GaBi 2020.2	
LCIA METHODOLOGY & VERSION NUMBER	IPCC AR5 + TRACI 2.1	

This PCR review was conducted by:	UL Environment PCR Review Panel epd@ulenvironment.com
This declaration was independently verified in accordance with ISO 14025: 2006. ☐ INTERNAL ☒ EXTERNAL	Grant R. Martin, UL Environment
This life cycle assessment was independently verified in accordance with ISO 14044 and the reference PCR by:	James Mellentine, Thrive ESG

This PCR Review was conducted by:

This declaration was independently verified in accordance with ISO 14025: 2006.
☐ INTERNAL ☒ EXTERNAL

This life cycle assessment was independently verified in accordance with ISO 14044 and the reference PCR by:

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Sample EPD: Where to find kg CO2 eq (aka GWP)

ENVIRONMENTAL PRODUCT DECLARATION

NUCOR®

Fabricated Hot-Rolled Structural Steel Sections
Designated Steel Construction Product

CERTIFIED ENVIRONMENTAL PRODUCT DECLARATION

According to ISO 14025, EN 15804 and ISO 21930:2017

Table 2. LCIA results, per 1 metric ton

PARAMETER	UNIT	A1	A2	A3	TOTAL
GWP 100	kg CO_2 eq.	1.10E+03	1.07E+01	1.10E+02	**1.22E+03**
ODP	kg CFC 11 eq.	4.67E-10	1.00E-09	3.38E-08	**3.53E-08**
AP	kg SO_2 eq.	2.80E+00	4.96E-02	2.98E-01	**3.15E+00**
EP	kg N eq.	1.32E-01	4.20E-03	1.51E-02	**1.51E-01**
SFP	kg O_3 eq.	4.49E+01	1.43E+00	2.92E+00	**4.92E+01**
ADP_{fossil}	MJ surplus	1.27E+03	1.72E+01	8.52E+01	**1.37E+03**

Table 3. LCIA results, per 1 short ton

PARAMETER	UNIT	A1	A2	A3	TOTAL
GWP 100	kg CO_2 eq.	9.96E+02	9.70E+00	9.97E+01	**1.10E+03**
ODP	kg CFC 11 eq.	4.24E-10	9.08E-10	3.07E-08	**3.20E-08**
AP	kg SO_2 eq.	2.54E+00	4.50E-02	2.70E-01	**2.86E+00**

TABLE 5.409.3
PRODUCT GWP LIMITS

BUY CLEAN CALIFORNIA MATERIALS PRODUCT CATEGORY[1]	MAXIMUM ACCEPTABLE GWP VALUE (unfabricated) ($GWP_{allowed}$)	UNIT OF MEASUREMENT
Hot-rolled structural steel sections	1.77	MT CO_2e/MT
Hollow structural sections	3.00	MT CO_2e/MT
Steel plate	2.61	MT CO_2e/MT
Concrete reinforcing steel	1.56	MT CO_2e/MT
Flat glass	2.50	kg CO_2e/MT
Light-density mineral wool board insulation	5.83	kg CO_2e/1 m^2
Heavy-density mineral wool board insulation	14.28	kg CO_2e/1 m^2

1.22E+03 kg CO2e
= 1.22*1000 kg CO2e
= 1220 kg CO2e

BUT
1000 kg = 1 MT

SO
1220 kg CO2e / 1000
= 1.22MT CO2e per MT

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TABLE 5.409.3
PRODUCT GWP LIMITS

BUY CLEAN CALIFORNIA MATERIALS PRODUCT CATEGORY[1]	MAXIMUM ACCEPTABLE GWP VALUE (unfabricated) ($GWP_{allowed}$)	UNIT OF MEASUREMENT
Hot-rolled structural steel sections	1.77	MT CO_2e/MT
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Concrete reinforcing steel	1.56	MT CO_2e/MT
Flat glass	2.50	kg CO_2e/MT
Light-density mineral wool board insulation	5.83	kg CO_2e/1 m^2
Heavy-density mineral wool board insulation	14.28	kg CO_2e/1 m^2

Documenting Prescriptive Path (non-concrete)

There is no form, but documentation to demonstrate compliance might include a table similar to below with each required material listed and accompanied by EPD-sourced EC numbers. Also submit EPDs and signed WS-5 declaration statement.

Material	Manufacturer	Max GWP Allowed	Product Actual GWP (per EPD)
Hot-rolled structural steel	Nucor	1.77 MT CO2e/MT	1.22MT CO2e/MT
Hollow structural steel	N/A	3.00 MT CO2e/MT	
Steel plate	N/A	2.61 MT CO2e/MT	
Concrete reinforcing steel		1.56 MT CO2e/MT	
Flat glass		2.5 kg CO2e/MT	
Light-density mineral wool board insulation		5.83 kg CO2e/1 m2	
Heavy-density mineral wool board insulation	N/A	14.28 kg CO2e/1 m2	

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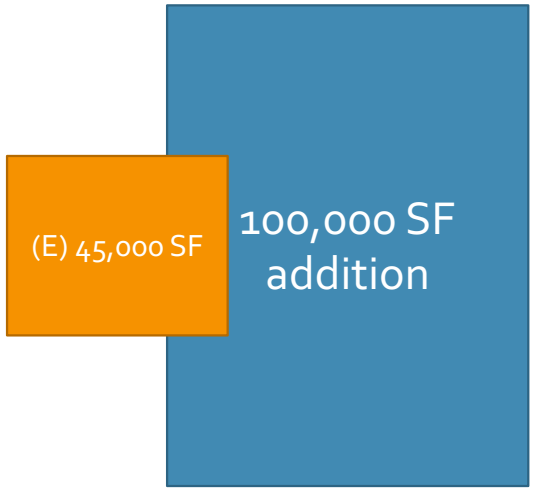
Documenting Prescriptive Path (concrete)



For Concrete, a weighted calculation must be performed per exception equation 5.409.3.1

GWPn < GWPallowed

Where GWPn = Σ (GWPn)(vn) and GWPallowed = Σ (GWPallowed)(vn)

- n = each concrete mix installed in the project
- GWPn = the GWP for concrete mix n per concrete mix EPD
- GWPallowed = the GWP potential allowed for concrete mix n per Table 5.409.3
- vn = the volume of concrete mix n installed in the project, in m3

Concrete, Ready-Mixed[2, 3]		
CONCRETE PRODUCT CATEGORY	MAXIMUM GWP ALLOWED VALUE ($GWP_{allowed}$)	UNIT OF MEASUREMENT
up to 2499 psi	450	kg CO_2e/m^3
2500–3499 psi	489	kg CO_2e/m^3
3500–4499 psi	566	kg CO_2e/m^3
4500–5499 psi	661	kg CO_2e/m^3
5500–6499 psi	701	kg CO_2e/m^3
6500 psi and greater	799	kg CO_2e/m^3
Concrete, Lightweight Ready-Mixed[2]		
CONCRETE PRODUCT CATEGORY	MAXIMUM GWP ALLOWED VALUE ($GWP_{allowed}$)	UNIT OF MEASUREMENT
up to 2499 psi	875	kg CO_2e/m^3
2500–3499 psi	956	kg CO_2e/m^3
3500–4499 psi	1039	kg CO_2e/m^3

- GWPn = the GWP for concrete mix n per concrete mix EPD

GWP data will be found on EPDs

GWPallowed = the GWP potential allowed for concrete mix n per Table 5.409.3

Documenting Prescriptive Path (concrete)

Concrete, Ready-Mixed[2,3]		
CONCRETE PRODUCT CATEGORY	MAXIMUM GWP ALLOWED VALUE ($GWP_{allowed}$)	UNIT OF MEASUREMENT
up to 2499 psi	450	kg CO_2e/m^3
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up to 2499 psi	875	kg CO_2e/m^3
2500–3499 psi	956	kg CO_2e/m^3
3500–4499 psi	1039	kg CO_2e/m^3

100,000 SF addition

GWPn < GWPallowed

Where GWPn = Σ (GWPn)(vn) and GWPallowed = Σ (GWPallowed)(vn)

- n = each concrete mix installed in the project
- GWPn = the GWP for concrete mix n per concrete mix EPD
- GWPallowed = the GWP potential allowed for concrete mix n per Table 5.409.3
- vn = the volume of concrete mix n installed in the project, in m3

GWP data will be found on EPDs

From Table 5.409.3

Concrete Calculation

n (mix)	volume (vn)	psi	GWPn	GWPn * vn		GWPallowed	GWPallowed * vn
	m3		*kgCO2e*			*kgCO2e*	
foundation	108	4000	320.1	34570.8		566	61128
slab	1080	3000	225.9	243972		489	528120
columns	12	4500	291.5	3498		661	7932
			Σ GWPn*vn	282040.8	<	Σ GWPallowed*vn	597180

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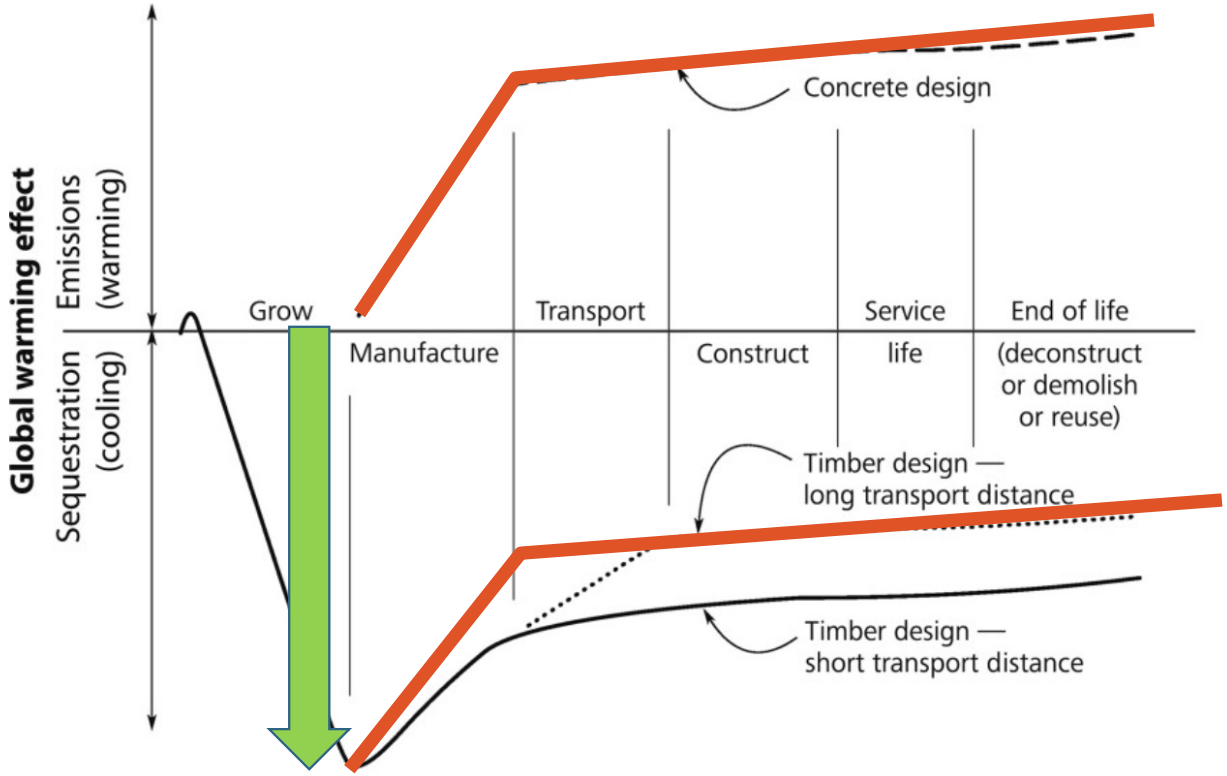
A Note About Carbon Sequestering Materials

Trees but also….

- Hemp
- Straw
- Ag residues
- Seaweed
- Cork
- Bamboo
- Mushrooms
- Even Algae



Courtesy New Society Publishers

Storing Carbon into the Future - Materials

Categories of carbon-storing materials

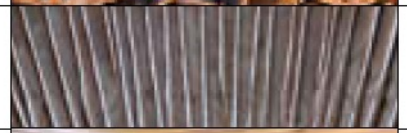
SOURCES			PRODUCTS
Biogenic Carbon Storage			
Agricultural and forestry residues and by-products	Straw (rice, wheat), hulls (rice), shells (nuts), stalks		Board products, insulation, cladding, aggregate
Waste stream fibers	Paper, cardboard, textiles		Board products, insulation
Purpose-grown crops	Cork, bamboo, hemp		Boards, flooring, insulation, structure, cladding
Lab-grown materials	Mycelium composites		Insulation, structure
Timber	Lumber, mass timber, sheet goods		Structure, board products, flooring, cladding
Mineralized Carbon Storage			
Biomineralization	Algae and microbe-grown cement		Concrete, concrete masonry unit (CMU), brick
Captured carbon	Synthetic limestone aggregate and accelerated carbonation		Concrete, CMU, brick
Biochar	Biogenic carbon transformed into stable, pyrogenic carbon through combustion in the absence of oxygen		Aggregate, tiles, bricks

Exhibit 2 | RMI Graphic. Source: RMI Analysis.

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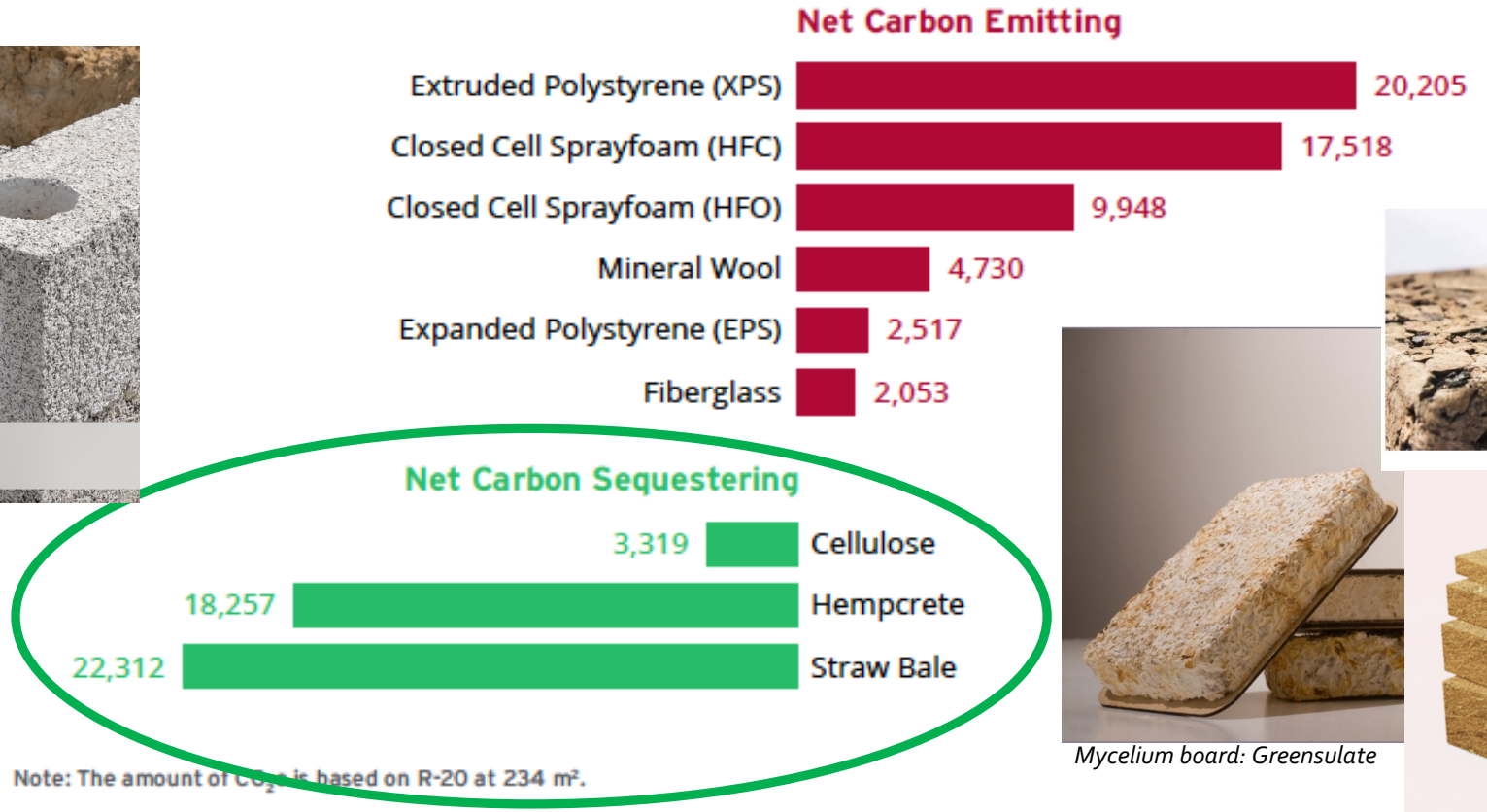
Insulation: Carbon Sequestration Opportunities

Exhibit 3 **Embodied carbon of insulation materials (kg CO_2e)**

Hempitecture.com



Note: The amount of CO_2 is based on R-20 at 234 m².

Source: Chris Magwood, *Opportunities for CO_2 Capture and Storage in Building Materials*, 10.13140/RG.2.2.32171.39208, 2019.

Expanded Cork: Corklink

Image courtesy of CorkLink.

Mycelium board: Greensulate

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Storing Carbon into the Future - Landscapes

Tools: i-Tree, climatepositive design Pathfinder

DESIGN TOOLKIT

	Strategies		Description	Actions
1	Increase biomass		Increasing the size and longevity of plants will increase the potential carbon sequestration in biomass. Layering plants increases potential biomass of the whole system.	• Include larger trees and plants, if given appropriate space • Include species that are longer-lived and low-maintenance • Include both fast and slow-growing trees and plants • Include deep-rooted trees and plants • Increase the amount of woody plants • Include deciduous trees in the plant palette • Increase vertical layering of plant types
2	Increase biodiversity		Maximizing biodiversity provides another avenue to achieve functional diversity of plants and has important co-benefits to provide habitat	• Include a diversity of plant species • Increase phylogenetic diversity of the plant community • Choose native plants • Choose genetically local plant sources
3	Increase plant functional diversity		Combining plants with a diversity of functional traits creates a system where more spatial and functional niches are filled, leading to increased productivity and carbon sequestration.	• Include a range of plant sizes: height and spread • Include a range of plant forms and habits • Include a diversity of root depths and architectural type • Include both warm and cool season grasses • Include nitrogen-fixing plants, especially with warm season grasses
4	Design with plant life history strategies		Planting the right type or plant or combining the right type of plants for the site will increase efficiency and resilience of the landscape.	• Match plant life history strategies to the site. • Mix plant life history strategies when appropriate • Include both annual and perennial plants, but a larger proportion of perennial plants • Avoid including plants that will be too competitive or aggressive
5	Layer and cluster plants		Layering and grouping plants can pack in more biomass create nested ecosystems that form rich interconnections and self-organize.	• Grouping small plant communities • Clustering or massing similar types of plants • Vertical layering • Layering through time

Source: American Society of Landscape Architects, Landscape Design for Carbon Sequestration

Source: Bradstone, Ashbourne ECO Concrete Paving

Source: Ross NW Watergardens, Shoi Sugi Ban: Setting Fire to Portland's Fences

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Questions & Discussion

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Closing

- Continuing Education Units Available
  - Contact itzel.torres@ventura.org for AIA and ICC LUs
- Coming to Your Inbox Soon!
  - Slides, Recording, & Survey – Please Take It and Help Us Out!
- Upcoming Courses:
  - January 31 - Energy Code Compliance: Using HERS Measures (Part 1)
  - February 7 - SLOCAOR All Electric HVAC for Realtors
  - February 13 - Elements of a Whole House Assessment: The Home Energy Audit Explained
  - February 14 – Energy Code Implementation: Single Family Construction
  - February 20 – Practical Ways to Address Embodied Carbon
  - February 27 – Residential Load Calculation and Duct Design for Building Departments
- Visit www.3c-ren.org/events for our full catalog of trainings.

Questions about Title 24?

Energy Code Coaches are local experts who can help answer your Title 24 questions. Coaches have decades of experience in green building and energy efficiency improvements. They can provide citations and offer advice for your project to help your plans and forms earn approval the first time.

Online:
3c-ren.org/codes

Call:
805.781.1201

Thank you!

For more info:
3c-ren.org

For questions:
info@3c-ren.org

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TRI-COUNTY REGIONAL ENERGY NETWORK

SAN LUIS OBISPO • SANTA BARBARA • VENTURA