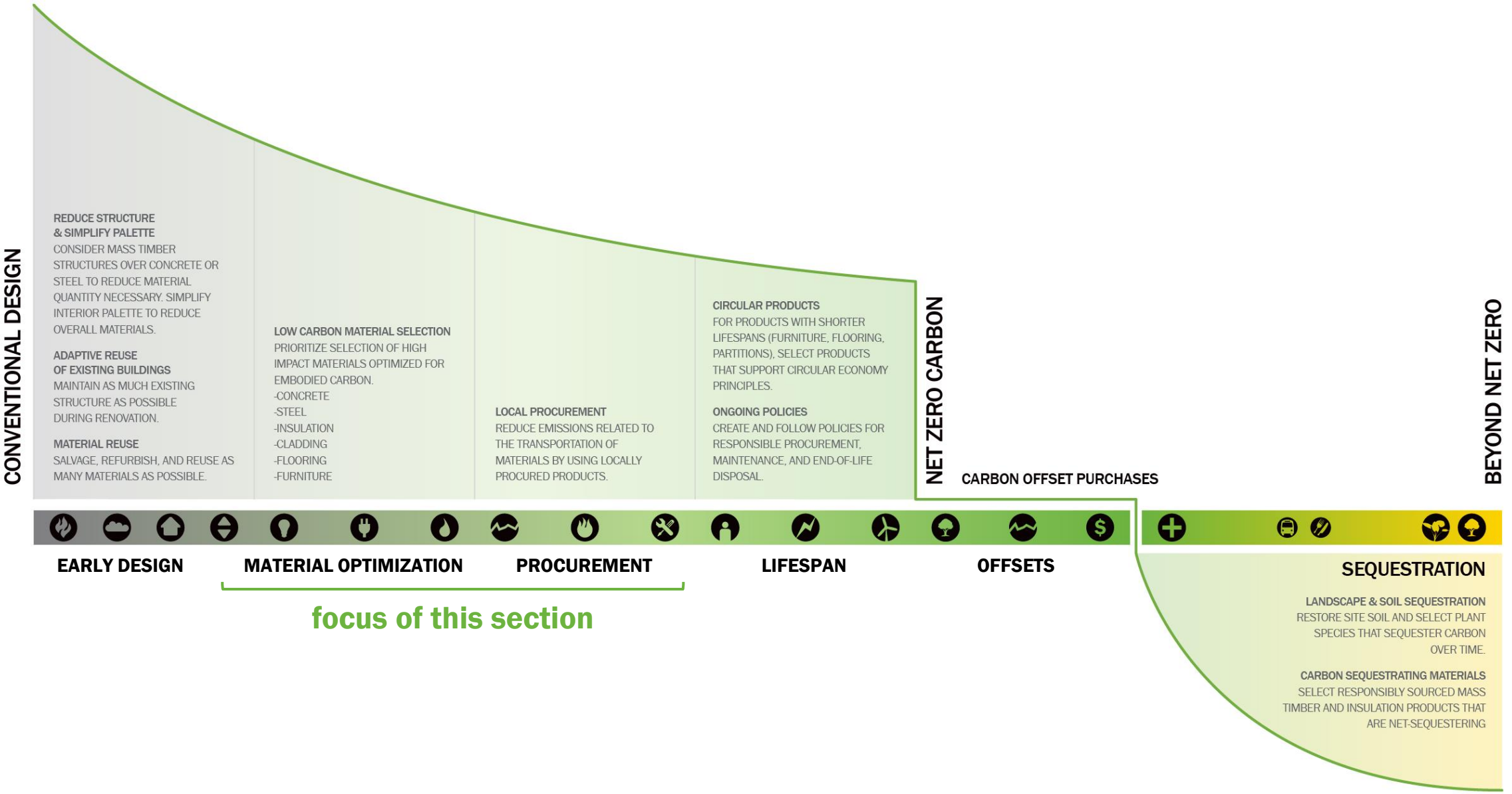
Embodied Carbon Optimization & Implementation

September 2023

Getting to Zero Carbon



LCA Process: Baseline Characterization

Baseline GWP Characterization by Scope and Material

Gather Material Quantities
(from BIM model or manual takeoffs)

Assign Industry Average EPDs
(Environmental Product Declarations)

Run Through a WBLCA Software
To understand baseline characterization

One Click LCA

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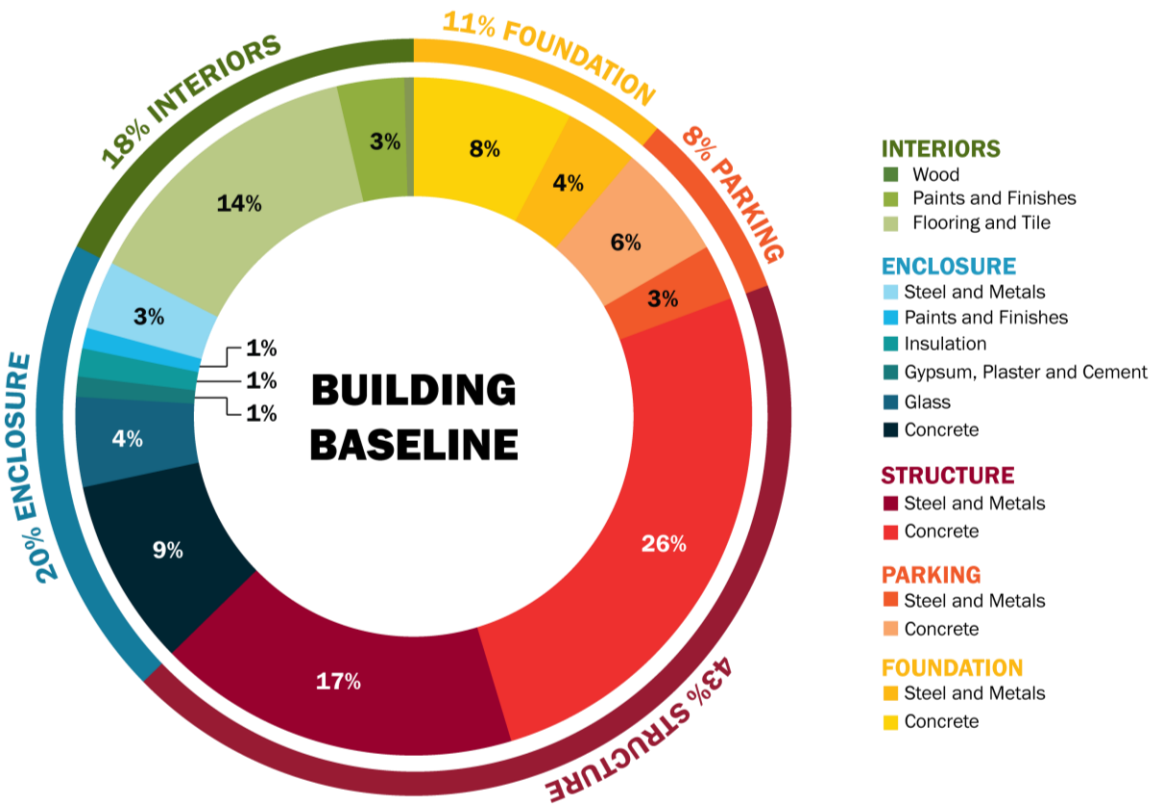
Athena Impact Estimator for Buildings



Identify your biggest carbon drivers early in the project

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Common Impact Reduction Measures

Savings Potential and Cost Premium Estimates

Test Potential Impact Reduction Measures (IRMs)

MASS TIMBER STRUCTURAL ELEMENTS

15-50% REDUCTION
before sequestration
-1 - 10% cost premium

CONCRETE OPTIMIZATION

5-30% REDUCTION
0 - > 1% cost premium

STEEL PROCUREMENT

2-15% REDUCTION
0 - > 1% cost premium

REBAR PROCUREMENT

1-7% REDUCTION
0 - > 1% cost premium

INTERIOR FINISHES

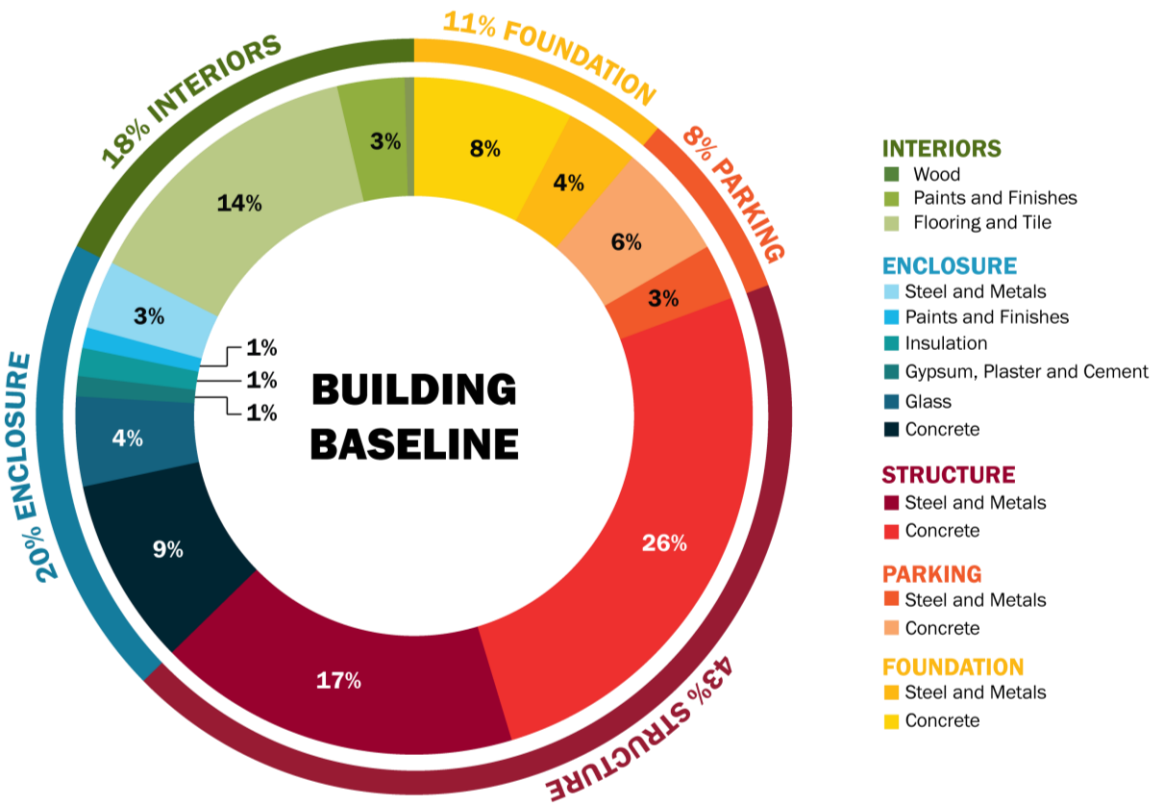
5-15% REDUCTION
0 - > 1% cost premium

INSULATION SELECTION

2-16% REDUCTION
no cost premium

FACADE MATERIALS

3-10% REDUCTION
up to 10% cost premium



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Mass Timber

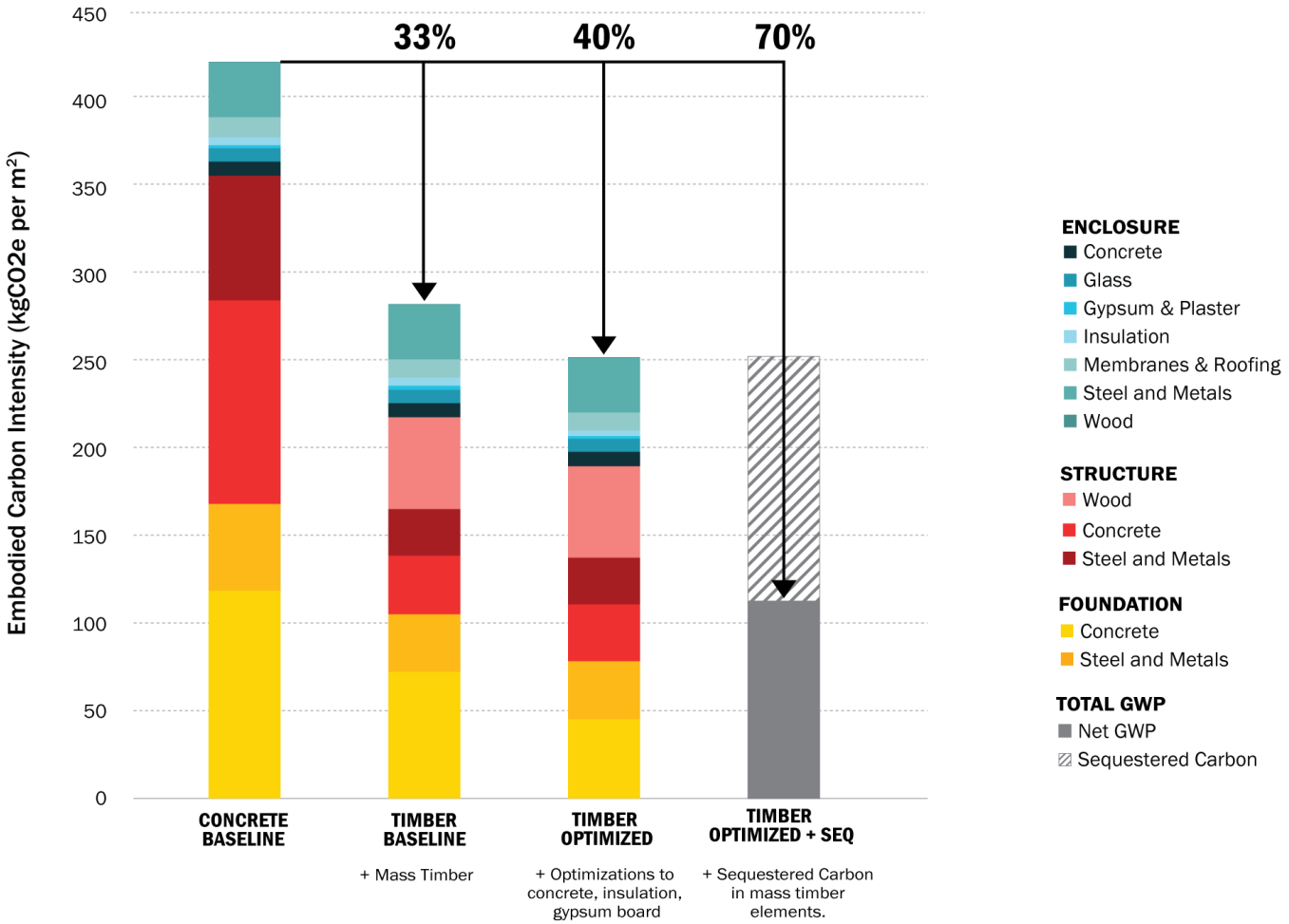
Common Impact Reduction Measures

MASS TIMBER STRUCTURAL ELEMENTS

Mass timber is a much less carbon intensive structural material and contains sequestered carbon in the wood fiber, making it a carbon negative material.

Strategies to maximize the carbon savings of mass timber construction:

- Ensure wood is harvested from sustainably managed forests
- Design the building to accommodate deconstruction and reuse of mass timber elements to extend the value of their sequestration
- Prioritize local suppliers that use cleaner fuel and more efficient equipment / vehicles



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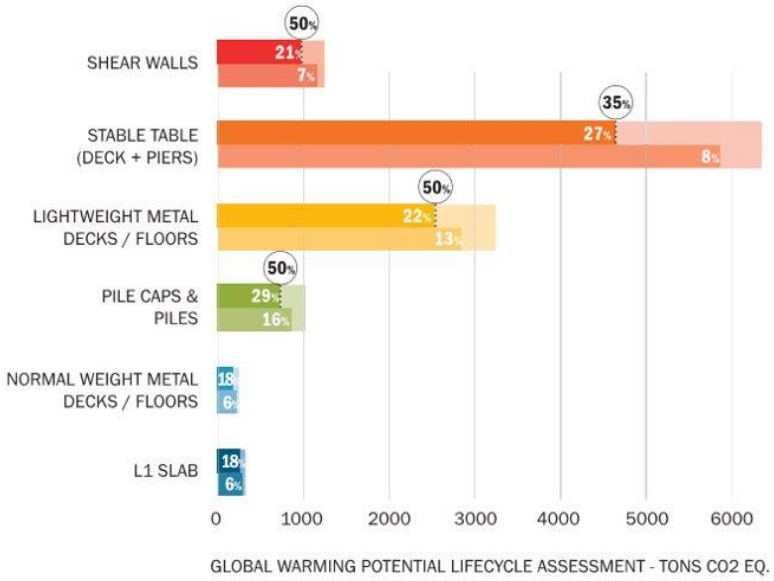
Concrete Optimizations

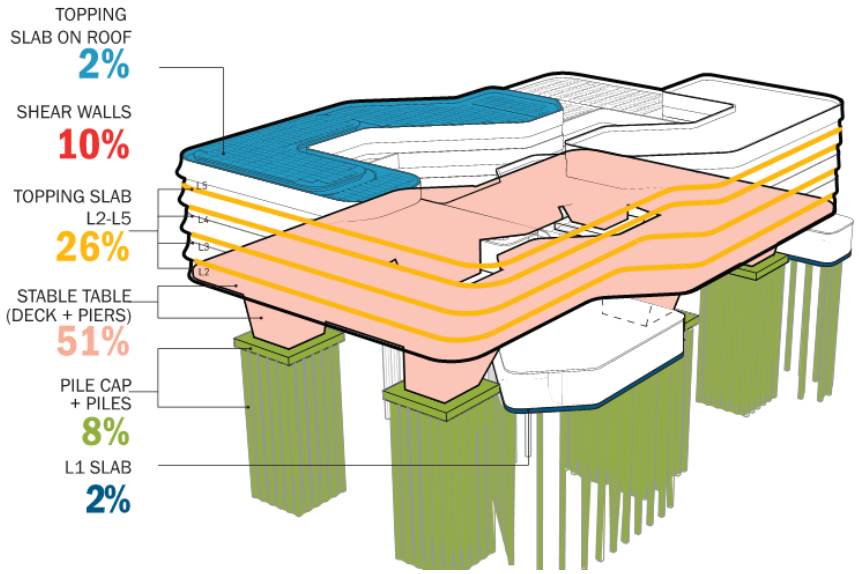
Common Impact Reduction Measures

CONCRETE OPTIMIZATION

Concrete optimization is routinely one of the biggest reduction opportunities for projects.

- Cement replacement with slag or fly ash
  - 15% is standard in the Bay Area
  - 35%-70% should be achievable in foundations
  - 25% or more in other applications
- Using high quality aggregate
- CarbonCure
- Using post tensioning is recommended where possible. It requires higher grade concrete, but reduces the volume required and saves embodied carbon.
- **Work with the structural engineer, contractor, and concrete supplier early to set global warming potential (GWP) targets for concrete.**





Steel Procurement

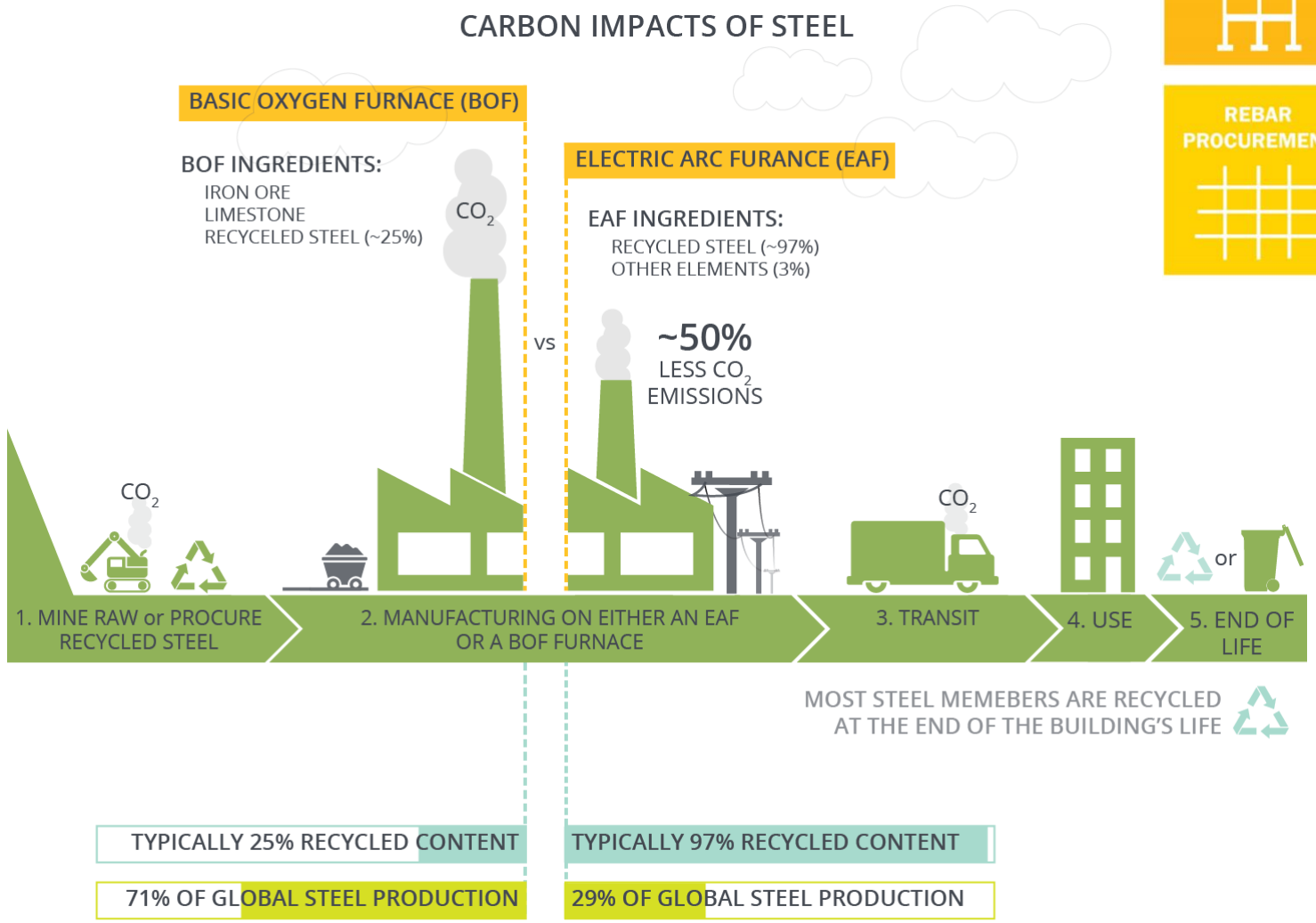
Common Impact Reduction Measures

Prioritize steel that is manufactured in an electric arc furnace – these use cleaner fuels and tend to have higher recycled content.

- Maximize recycled content – High recycled steel or reused steel. Target 50% recycled content.
- Look for manufacturers that use carbon-free energy at their plants (i.e., Pacific Northwest rebar is often manufactured using hydropower).
- Look for steel manufacturers that publish plant-specific environmental product declarations (EPDs)

STEEL PROCUREMENT

REBAR PROCUREMENT



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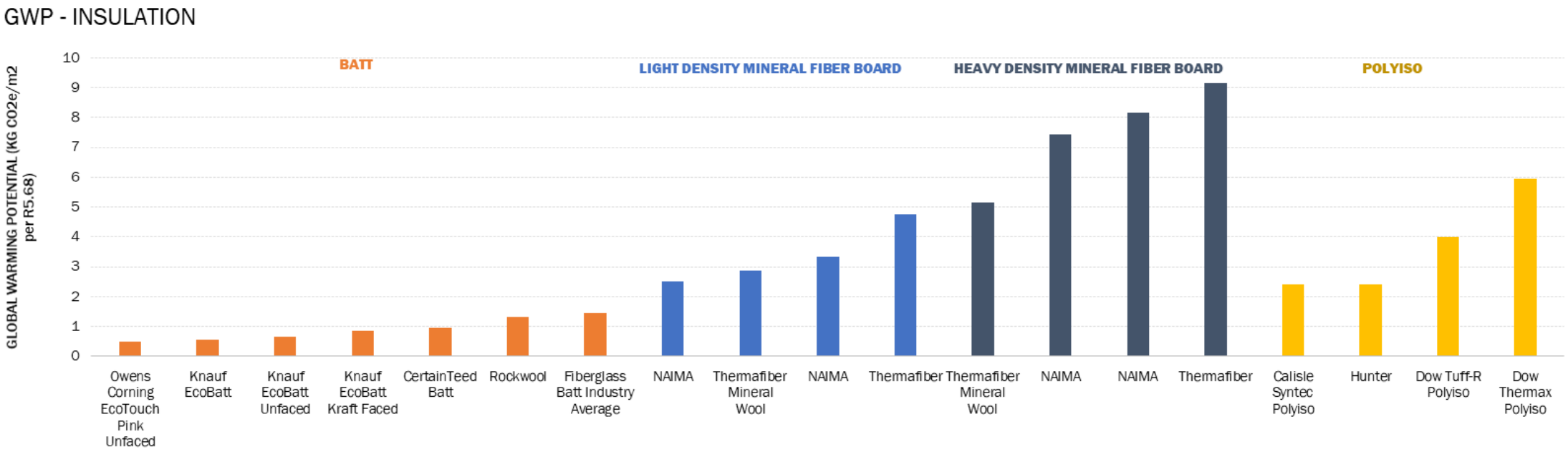
Insulation

Common Impact Reduction Measures

INSULATION SELECTION

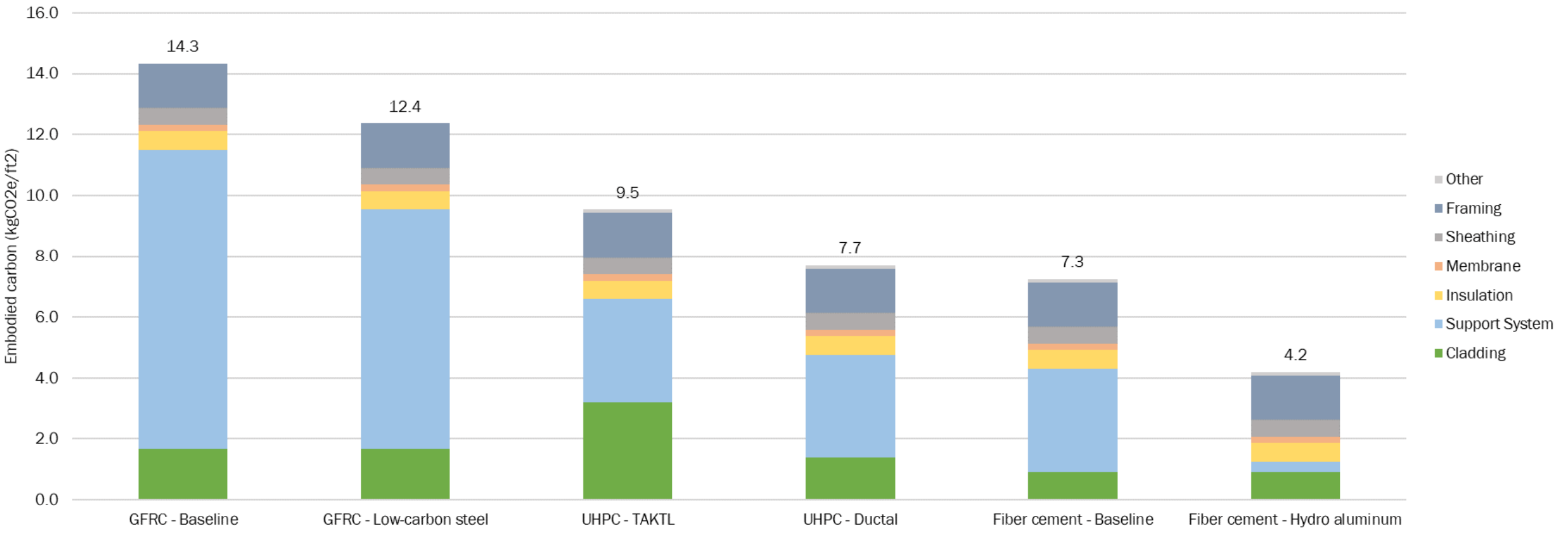


There's a wide range of carbon impacts for insulation depending on the type selected. Note: when comparing insulation, you must factor in changing thickness to maintain the same R-value.

Façade Options

Common Impact Reduction Measures

FACADE MATERIALS



When optimizing façade systems – consider the whole assembly. There may be insulation and structural support implications.

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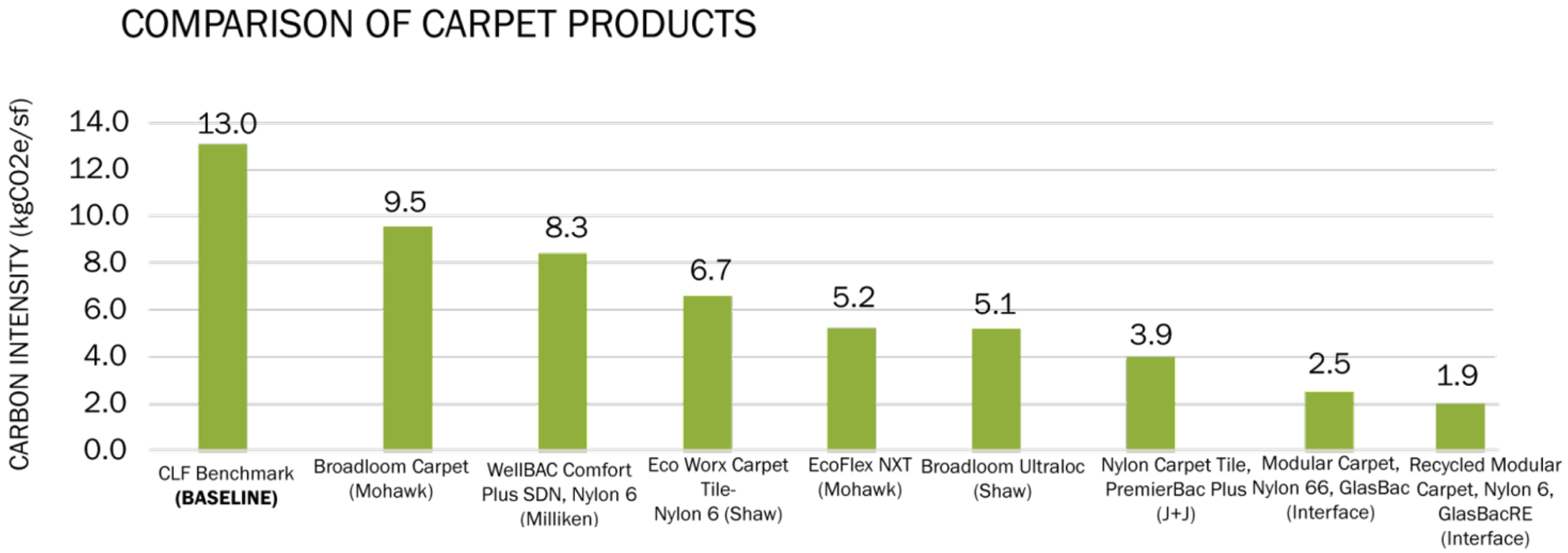
Carpet

Common Impact Reduction Measures

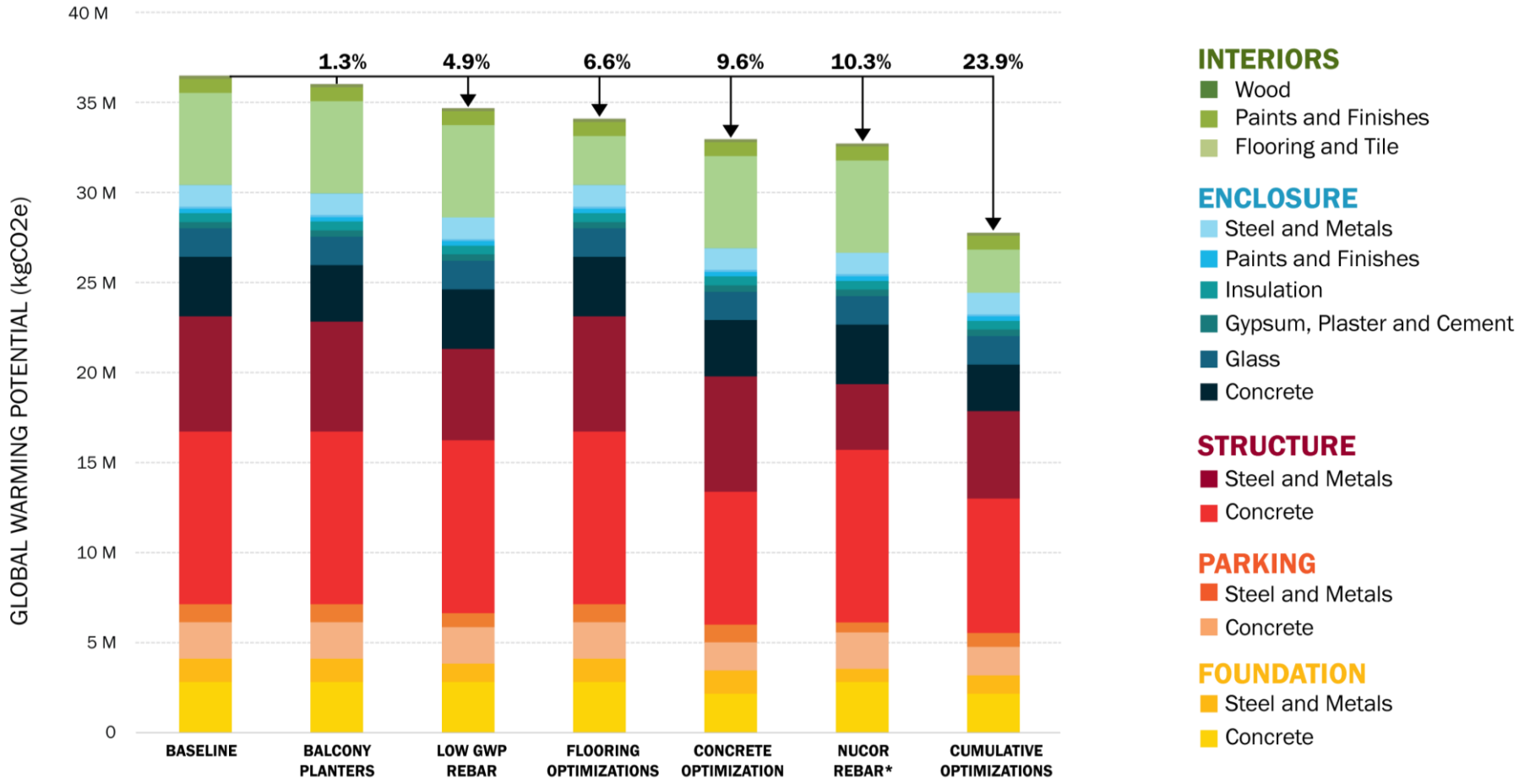
INTERIOR FINISHES



Due to frequent replacement, carpet can be responsible for 20%+ of a project's carbon footprint over a 60-year analysis period.

IRM Selection

Baseline GWP Characterization by Scope and Material



Test Impact Reduction Measures (IRMs) throughout the design phase and incorporate them into specifications and bidding documents before procurement begins.

Procurement Optimization & Follow Through

Carbon Leadership Forum (CLF) Baselines

North American Material Baselines

2023 Carbon Leadership Forum

North American Material Baselines

BASELINE REPORT v2 | AUGUST 2023

CLF Carbon Leadership Forum

Table 3: North American Material Baselines (ready-mixed concrete in Table 1+2) (cont.)

Category	Product Type	Description	CLF Baseline GWP [kg CO_2e per declared unit]	Declared Unit	Method	Additional Life Cycle Stages See Appendix	Data Sources and Notes
STEEL							
Rebar Appendix D2	Rebar - unfabricated	Unfabricated steel reinforcement bar, including plain carbon steel and low-alloy steel bars of multiple grades and sizes	753	1 metric ton	Industry	☐	CRSI. (2022). Environmental product declaration - Steel reinforcement bar. Converted to unfabricated product GWP. See appendix for details.
Rebar Appendix D2	Rebar - fabricated	Fabricated steel reinforcement bar, including plain carbon steel and low-alloy steel bars of multiple grades and sizes	854	1 metric ton	Industry	☐	CRSI. (2022). Environmental product declaration - Steel reinforcement bar.
Steel wire and mesh Appendix D3	Steel wire and mesh	Steel wire and mesh for concrete reinforcement	None	1 metric ton	–	☐	No adequately representative data source.
Structural steel Appendix D4	Hot-rolled sections - unfabricated	Unfabricated hot-rolled steel shapes for structural applications, including: wide flange and other beams, channels, angles, and tees	1,000	1 metric ton	Industry	☐	AISC. (2021). Environmental product declaration - Fabricated hot-rolled sections. Converted to unfabricated product GWP. See appendix for details.
Structural steel Appendix D4	Hot-rolled sections - fabricated	Fabricated hot-rolled steel shapes for structural applications, including: wide flange and other beams, channels, angles, and tees	1,220	1 metric ton	Industry	☐	AISC. (2021). Environmental product declaration - Fabricated hot-rolled sections.
Structural steel Appendix D4	Plate steel - unfabricated	Unfabricated flat steel products (generally thicker than 6 mm or ¼") for structural applications	1,480	1 metric ton	Industry	☐	AISC. (2021). Environmental product declaration - Fabricated steel plate. Converted to unfabricated product GWP. See appendix for details.
Structural steel Appendix D4	Plate steel - fabricated	Fabricated flat steel products (generally thicker than 6 mm or ¼") for structural applications	1,730	1 metric ton	Industry	☐	AISC. (2021). Environmental product declaration - Fabricated steel plate.
Structural steel Appendix D4	Hollow structural sections (HSS) - unfabricated	Unfabricated hollow steel sections (square, rectangle, circle) for structural applications	1,710	1 metric ton	Industry	☐	STI. (2021). Environmental product declaration - Hollow structural sections.
Structural steel Appendix D4	Hollow structural sections (HSS) - fabricated	Fabricated hollow steel sections (square, rectangle, circle) for structural applications	1,990	1 metric ton	Industry	☐	AISC. (2021). Environmental product declaration - Fabricated hollow structural sections.
Cold-formed steel framing Appendix D4	Cold-formed steel framing	Galvanized cold-formed steel shapes for light framing, such as studs and track	2,440	1 metric ton	Industry	☐	SFIA. (2021). Cold-formed steel framing.
Open-web steel joists Appendix D4	Open-web steel joists	Prefabricated steel joists and girders with open middle web and top and bottom chords	1,430	1 metric ton	Industry	☐	SJI. (2022). Environmental product declaration - Open web steel joists and joist girders.
Steel decking Appendix D4	Steel decking	Includes range of surface treatments (galvanized or uncoated steel to which paint may be applied) and thickness/ gauge.	2,320	1 metric ton	Industry	☐	SDI. (2022). Environmental product declaration - Steel roof and floor deck.
ALUMINUM							
Aluminum extrusions Appendix E1	Aluminum extrusions - mill finish	Standard (non-thermally-improved) extrusions with mill finish (no additional surface treatment)	10,250	1 metric ton	Industry	☒	AEC. (2022). Environmental product declaration - Aluminum extrusions - mill finished, painted, and anodized.
Aluminum extrusions Appendix E1	Aluminum extrusions - painted	Standard (non-thermally-improved) extrusions with paint finish	11,670	1 metric ton	Industry	☒	AEC. (2022). Environmental product declaration - Aluminum extrusions - mill finished, painted, and anodized.
Aluminum extrusions Appendix E1	Aluminum extrusions - anodized	Standard (non-thermally-improved) extrusions with anodized finish	10,760	1 metric ton	Industry	☒	AEC. (2022). Environmental product declaration - Aluminum extrusions - mill finished, painted, and anodized.

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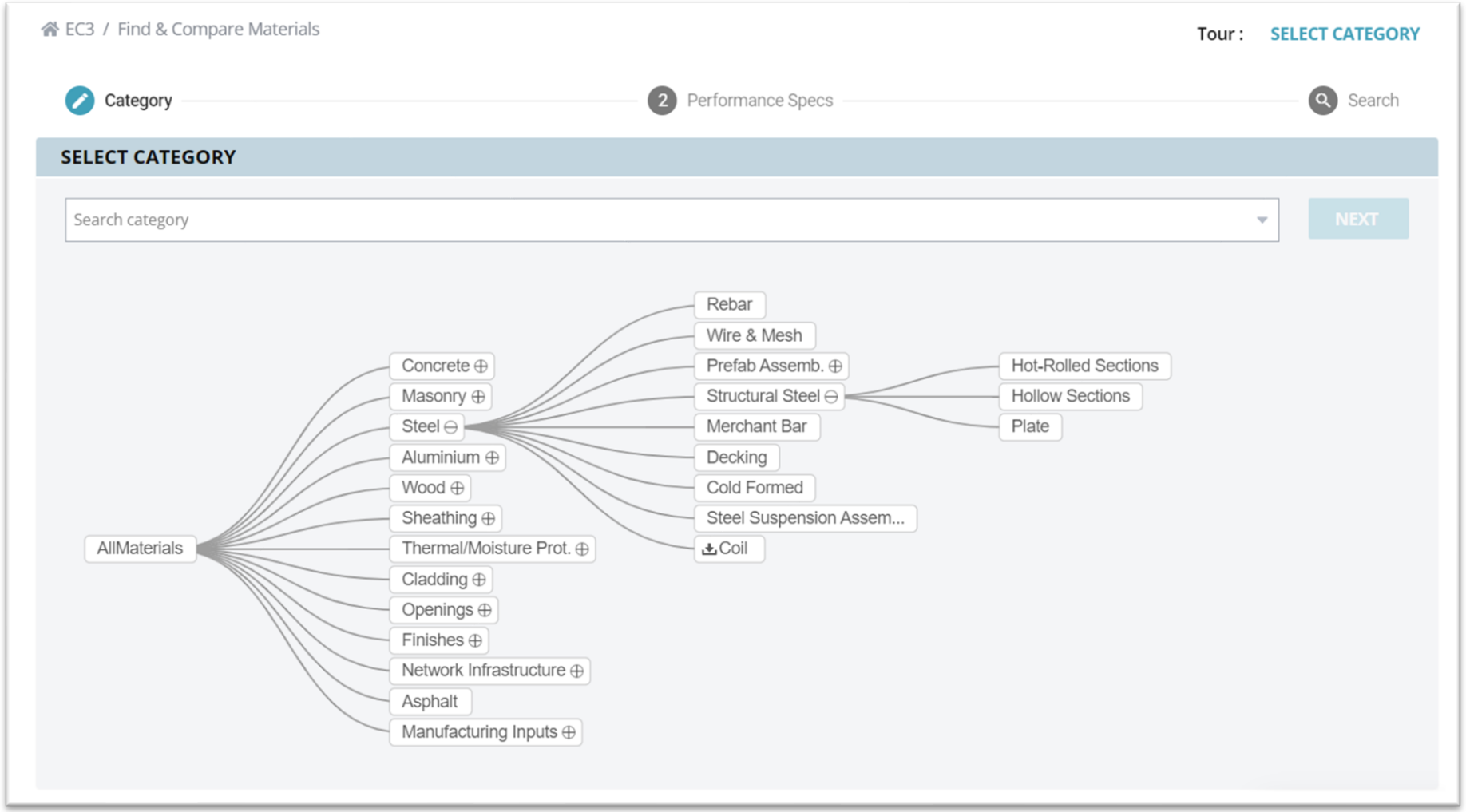
Embodied Carbon in Construction Calculator (EC3)

buildingtransparency.org/ec3



EC3 is a great resource for finding procurement optimizations

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Embodied Carbon in Construction Calculator (EC3)

Look at EPD Availability for a Given Product

STATISTICS

Product EPDs: 43 | Industry EPDs: 1 | Achievable: 0.776 kgCO2e | Average: 0.969 kgCO2e ± 48.4% | Conservative: 1.03 kgCO2e | Converted per Unit: 1 kg

INDUSTRY EPDS

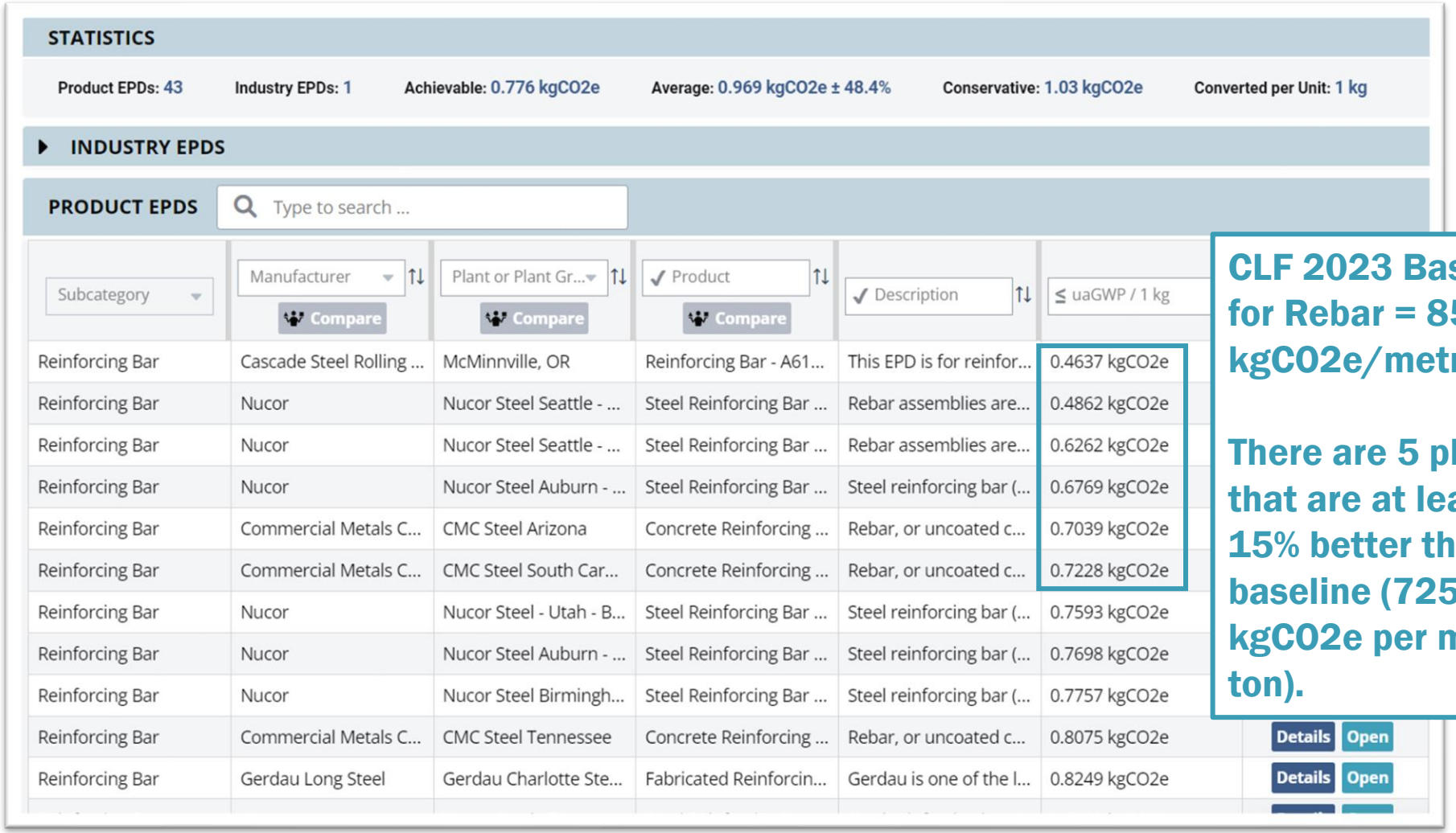
PRODUCT EPDS — Type to search ...

Subcategory	Manufacturer (Compare)	Plant or Plant Gr... (Compare)	Product (Compare)	Description	≤ uaGWP / 1 kg	Columns: Manufacturer	
Reinforcing Bar	Cascade Steel Rolling ...	McMinnville, OR	Reinforcing Bar - A61...	This EPD is for reinfor...	0.4637 kgCO2e	Details	Open
Reinforcing Bar	Nucor	Nucor Steel Seattle - ...	Steel Reinforcing Bar ...	Rebar assemblies are...	0.4862 kgCO2e	Details	Open
Reinforcing Bar	Nucor	Nucor Steel Seattle - ...	Steel Reinforcing Bar ...	Rebar assemblies are...	0.6262 kgCO2e	Details	Open
Reinforcing Bar	Nucor	Nucor Steel Auburn - ...	Steel Reinforcing Bar ...	Steel reinforcing bar (...	0.6769 kgCO2e	Details	Open
Reinforcing Bar	Commercial Metals C...	CMC Steel Arizona	Concrete Reinforcing ...	Rebar, or uncoated c...	0.7039 kgCO2e	Details	Open
Reinforcing Bar	Commercial Metals C...	CMC Steel South Car...	Concrete Reinforcing ...	Rebar, or uncoated c...	0.7228 kgCO2e	Details	Open
Reinforcing Bar	Nucor	Nucor Steel - Utah - B...	Steel Reinforcing Bar ...	Steel reinforcing bar (...	0.7593 kgCO2e	Details	Open
Reinforcing Bar	Nucor	Nucor Steel Auburn - ...	Steel Reinforcing Bar ...	Steel reinforcing bar (...	0.7698 kgCO2e	Details	Open
Reinforcing Bar	Nucor	Nucor Steel Birmingh...	Steel Reinforcing Bar ...	Steel reinforcing bar (...	0.7757 kgCO2e	Details	Open
Reinforcing Bar	Commercial Metals C...	CMC Steel Tennessee	Concrete Reinforcing ...	Rebar, or uncoated c...	0.8075 kgCO2e	Details	Open
Reinforcing Bar	Gerdau Long Steel	Gerdau Charlotte Ste...	Fabricated Reinforcin...	Gerdau is one of the l...	0.8249 kgCO2e	Details	Open

Search by product type and find the lowest manufacturers

Embodied Carbon in Construction Calculator (EC3)

Set a Reasonable Reduction Target Based on Availability



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Reinforcing Bar	Nucor	Nucor Steel Seattle - ...	Steel Reinforcing Bar ...	Rebar assemblies are...	0.4862 kgCO2e	
Reinforcing Bar	Nucor	Nucor Steel Seattle - ...	Steel Reinforcing Bar ...	Rebar assemblies are...	0.6262 kgCO2e	
Reinforcing Bar	Nucor	Nucor Steel Auburn - ...	Steel Reinforcing Bar ...	Steel reinforcing bar (...	0.6769 kgCO2e	
Reinforcing Bar	Commercial Metals C...	CMC Steel Arizona	Concrete Reinforcing ...	Rebar, or uncoated c...	0.7039 kgCO2e	
Reinforcing Bar	Commercial Metals C...	CMC Steel South Car...	Concrete Reinforcing ...	Rebar, or uncoated c...	0.7228 kgCO2e	
Reinforcing Bar	Nucor	Nucor Steel - Utah - B...	Steel Reinforcing Bar ...	Steel reinforcing bar (...	0.7593 kgCO2e	
Reinforcing Bar	Nucor	Nucor Steel Auburn - ...	Steel Reinforcing Bar ...	Steel reinforcing bar (...	0.7698 kgCO2e	
Reinforcing Bar	Nucor	Nucor Steel Birmingh...	Steel Reinforcing Bar ...	Steel reinforcing bar (...	0.7757 kgCO2e	
Reinforcing Bar	Commercial Metals C...	CMC Steel Tennessee	Concrete Reinforcing ...	Rebar, or uncoated c...	0.8075 kgCO2e	Details Open
Reinforcing Bar	Gerdau Long Steel	Gerdau Charlotte Ste...	Fabricated Reinforcin...	Gerdau is one of the l...	0.8249 kgCO2e	Details Open

CLF 2023 Baseline for Rebar = 854 kgCO2e/metric ton

There are 5 plants that are at least 15% better than baseline (725 kgCO2e per metric ton).

Performance Based Specifications: Rebar Example

Incorporate Language into Specifications

Product Requirements

1. EPD: Products must have a compliant Product Specific Type III Environmental Product Declaration (EPD)
2. GWP: Rebar must have a, A1-A3 global warming potential (GWP) less than 725 kgCO2e/metric ton of rebar.

Submittal Requirements

1. A compliant Product Specific Type III Environmental Product Declaration (EPD) demonstrating a GWP intensity that meets the requirements above.

ENVIRONMENTAL PRODUCT DECLARATION

STEEL REINFORCING BAR AND MERCHANT BAR PRODUCTS

NUCOR STEEL SEATTLE, INC.
2424 SW ANDOVER ST. SEATTLE, WA 98106

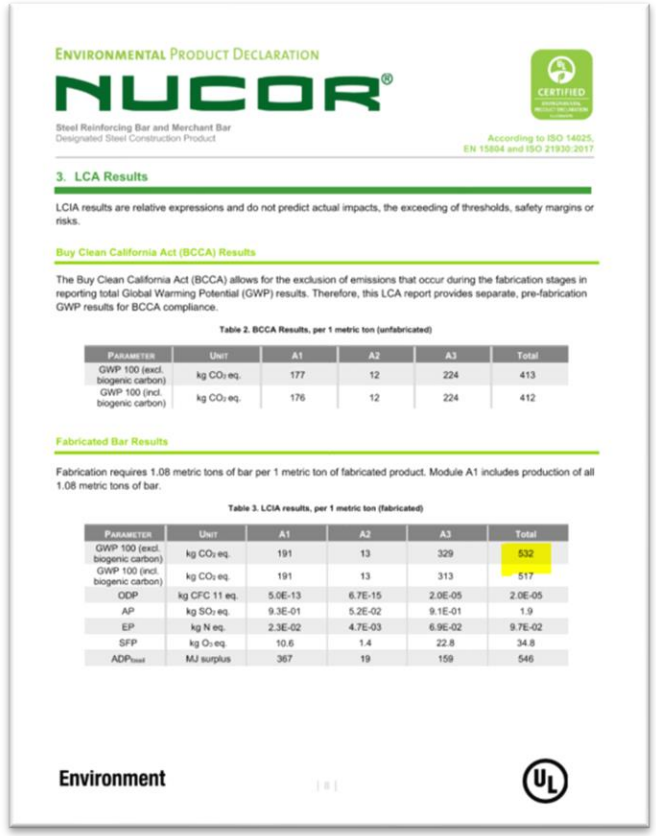
NUCOR

Nucor Steel Seattle, Inc. is the state of Washington's largest recycler, with the capacity to process over a million tons of scrap steel each year. Using an electric arc furnace, a steel recycling technology we helped to pioneer, we produce high-quality steel with 99.4% recycled content.

We recognize our role in protecting the environment and have demonstrated a long-standing commitment to do so. We have invested tens of millions of dollars in our Seattle facility to make it among the most efficient and environmentally responsible steel plants in the world.

In addition to being ISO14001 certified, we operate on an electric grid that is nearly carbon free

CERTIFIED ENVIRONMENTAL PRODUCT DECLARATION



ENVIRONMENTAL PRODUCT DECLARATION

NUCOR®

Steel Reinforcing Bar and Merchant Bar
Designated Steel Construction Product

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

3. LCA Results

LCIA results are relative expressions and do not predict actual impacts, the exceeding of thresholds, safety margins or risks.

Buy Clean California Act (BCCA) Results

The Buy Clean California Act (BCCA) allows for the exclusion of emissions that occur during the fabrication stages in reporting total Global Warming Potential (GWP) results. Therefore, this LCA report provides separate, pre-fabrication GWP results for BCCA compliance.

Table 2. BCCA Results, per 1 metric ton (unfabricated)

Parameter	Unit	A1	A2	A3	Total
GWP 100 (excl. biogenic carbon)	kg CO_2 eq.	177	12	224	413
GWP 100 (incl. biogenic carbon)	kg CO_2 eq.	176	12	224	412

Fabricated Bar Results

Fabrication requires 1.08 metric tons of bar per 1 metric ton of fabricated product. Module A1 includes production of all 1.08 metric tons of bar.

Table 3. LCIA results, per 1 metric ton (fabricated)

Parameter	Unit	A1	A2	A3	Total
GWP 100 (excl. biogenic carbon)	kg CO_2 eq.	191	13	329	532
GWP 100 (incl. biogenic carbon)	kg CO_2 eq.	191	13	313	517
ODP	kg CFC 11 eq.	5.0E-13	6.7E-15	2.0E-05	2.0E-05
AP	kg SO_2 eq.	9.3E-01	5.2E-02	9.1E-01	1.9
EP	kg N eq.	2.3E-02	4.7E-03	6.9E-02	9.7E-02
SFP	kg O_3 eq.	10.6	1.4	22.8	34.8
ADP_{fossil}	MJ surplus	367	19	159	546

Environment

Performance Based Specifications: Concrete Example

Concrete

Product Requirements

1. EPD: Each mix design must have a compliant Product Specific Type III Environmental Product Declaration (EPD)
2. GWP: Concrete must achieve an A1-A3 global warming potential (GWP) intensity that is 20% below the NRMCA Regional Benchmark.

Submittal Requirements

1. A compliant Product Specific Type III Environmental Product Declaration (EPD) demonstrating a GWP intensity that meets the requirements above.

Athena Sustainable Materials Institute www.athenasmi.org

A Cradle-to-Gate Life Cycle Assessment of Ready-Mixed Concrete Manufactured by NRMCA Members – Version 3.2

This project report and its results are used to support the development of an industry wide or sector average Environmental Product Declaration for the production of 72 concrete mix designs

Comissioner: National Ready Mixed Concrete Association (NRMCA)

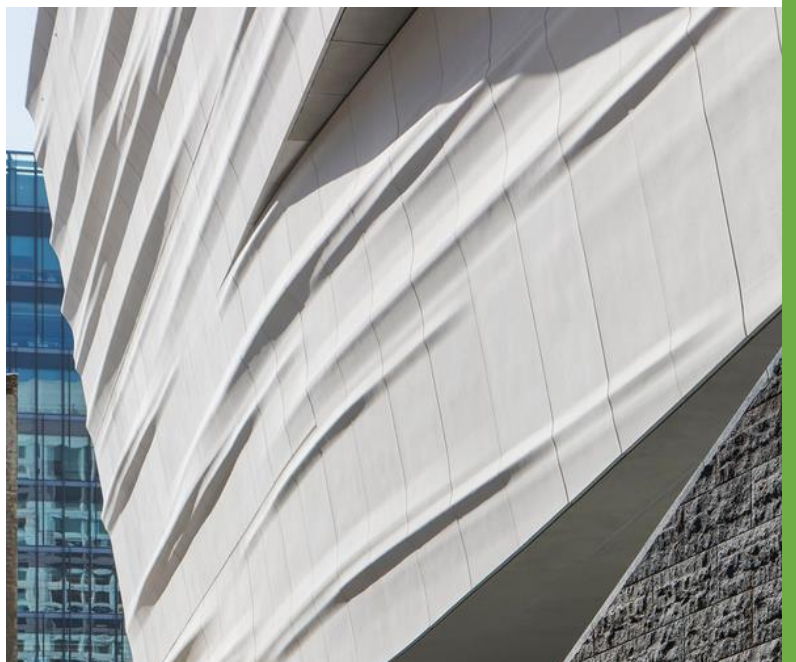
EPD Program Operator: NSF International

Table E6-Pacific Southwest LCA Results (per cubic yard)

Strength	psi @28 days	2,500	3,000	4,000	5,000	6,000	8,000
Core Mandatory Impact Indicator							
GWP	kg CO2e	196.51	213.46	247.32	288.90	306.44	348.96
ODP	kg CFC11e	4.91E-06	5.28E-06	6.01E-06	6.90E-06	7.30E-06	8.22E-06
AP	kg SO2e	0.74	0.78	0.85	0.94	0.99	1.08
EP	kg Ne	0.24	0.26	0.29	0.34	0.36	0.41
SFP	kg O3e	17.35	18.12	19.59	21.37	22.41	24.24
ADPf	MJ, NCV	458.40	470.65	492.46	522.89	545.74	572.52
ADPe	kg Sbe	1.08E-04	1.11E-04	1.16E-04	1.22E-04	1.28E-04	1.34E-04

Ask for embodied carbon info during the bidding process (i.e. "what is the lowest GWP mix you have that meets all performance requirements"?)

Work with structural engineer, contractor, and concrete supplier early on to understand high GWP impacts on cure time.



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