Embodied Carbon in Construction

AIANY CRAN Carbon Leadership 2021

Jordan Dentz and Austin Izzo

The Levy Partnership, Inc

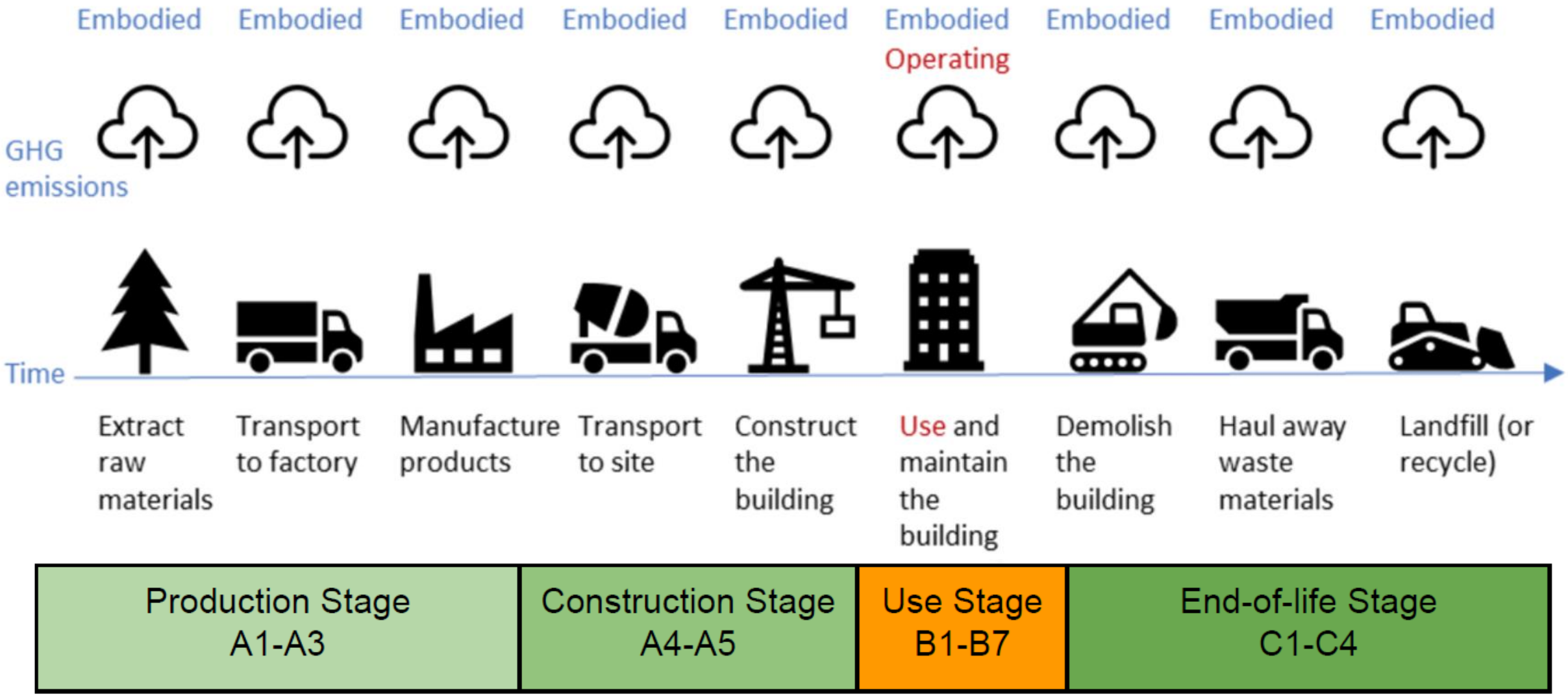
February 24, 2021

The Levy Partnership

Table of Contents

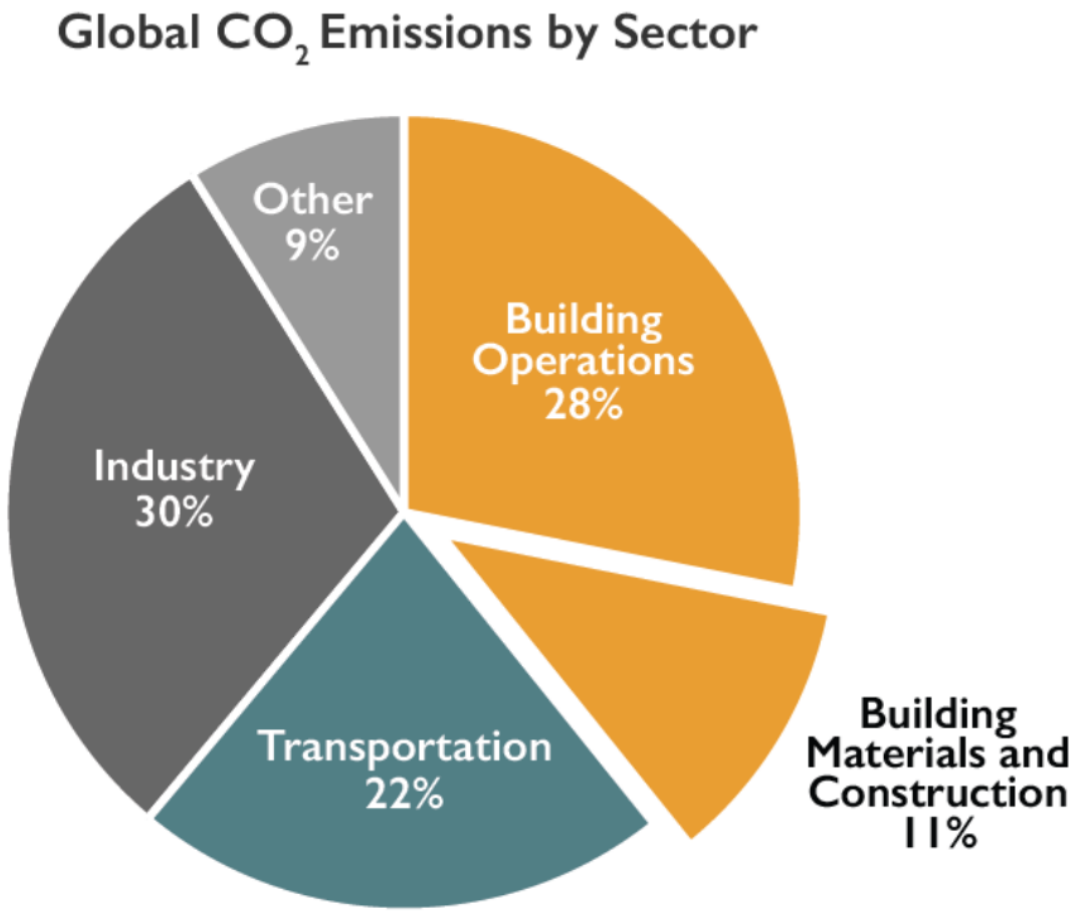
What & Why?

What is Embodied Carbon (EC)?

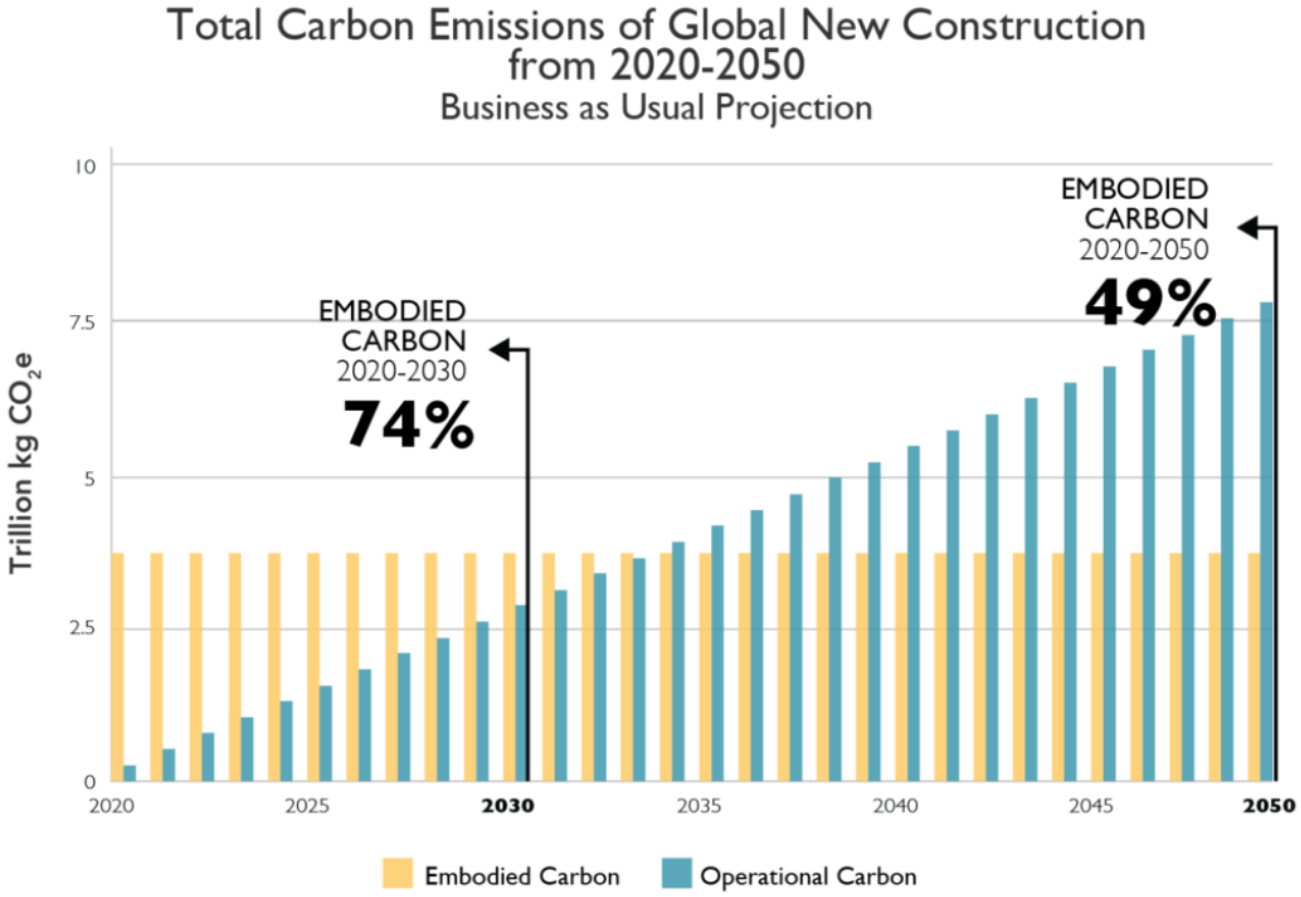


https://www.c40knowledgehub.org/s/article/Embodied-Carbon-of-Buildings-and-Infrastructure-International-Policy-Review?language=en_US, BN-EN-159782011

By 2050 embodied carbon will make up **HALF** of Global Carbon Emissions in New Construction



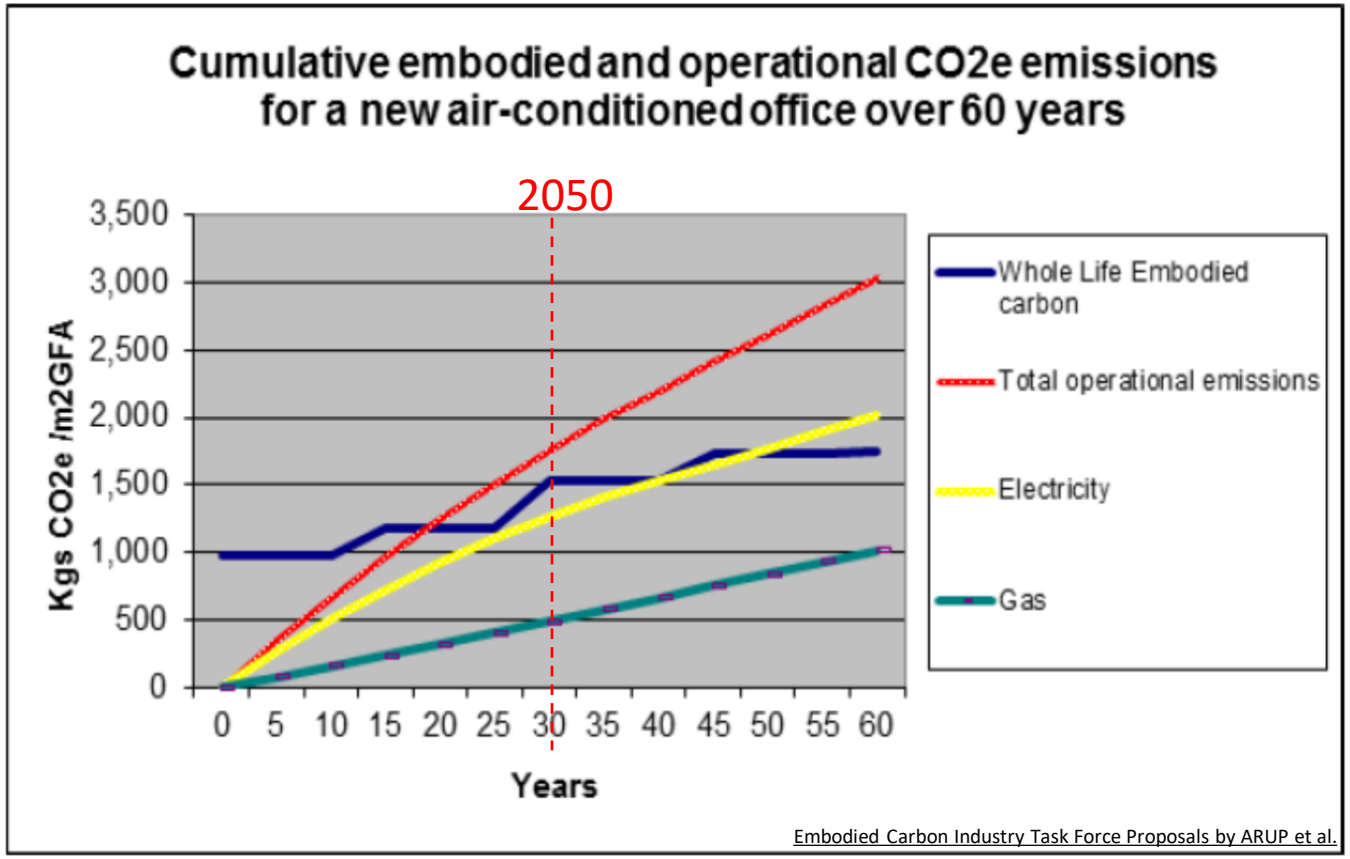
https://architecture2030.org/new-buildings-embodied/



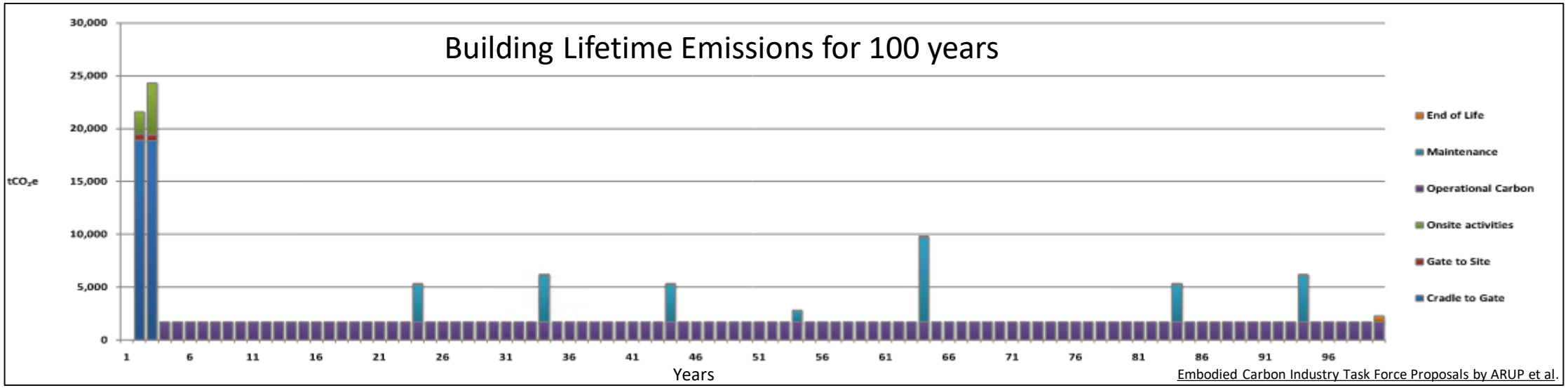
https://architecture2030.org/new-buildings-embodied/

The time is now!

- Example Office Building: In 2050, EC is 45% of emissions
- Lower operational emissions increases the importance of EC



Embodied Carbon Industry Task Force Proposals by ARUP et al.



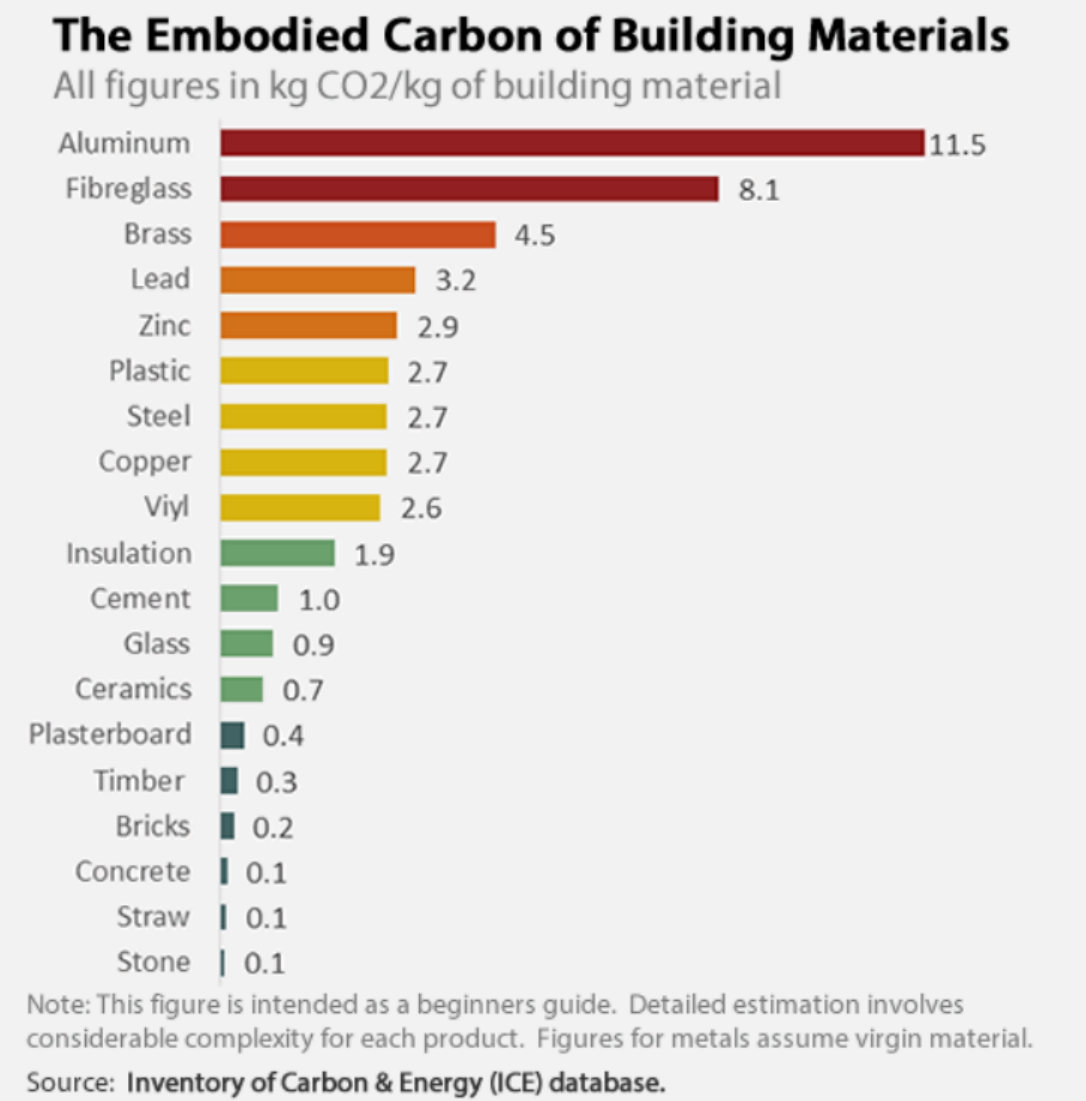
Embodied Carbon Industry Task Force Proposals by ARUP et al.

Where is EC in Construction?

EC “Hot Spots”

- Foundation
- Framing & Structural Components
- Enclosures
- Insulation

EC of Building Materials by Weight



Material category	Property	A1 Material Extraction	A2 Transport	A3 Manufacturing
Structural steel[7]	Approx. % of impact:	>90%	<5%	<10%
	Source of impacts:	Steelmaking (includes material mining, etc.)	Transportation to fabricator	Fabrication (cutting, welding, shaping steel)
Concrete[8]	Approx. % of impact:	>90%	<5%	<10%
	Source of impacts:	Production of cement, aggregate, water and admixtures (including material mining, etc.)	Transportation to concrete plant	Mix design (recipe) and concrete mixing
Cement[9]	Approx. % of impact:	<10%	<5%	>90%
	Source of impacts:	Raw material mining	Transportation to cement kiln	Manufacturing cement
Clay masonry[10]	Approx. % of impact:	<5%	small	>95%
	Source of impacts:	Mining of clay	Transportation and storage	Firing and factory operations
Glue laminated beam[11]	Approx. % of impact*	<10%	<5%	>90%
	Source of impacts:	Wood milling (includes forestry harvest and lumber shaping)	Transportation to a fabrication facility	Fabrication (drying, cutting, gluing, pressing)

*not including emissions from bio-fuel combustion or within the broader forest context.

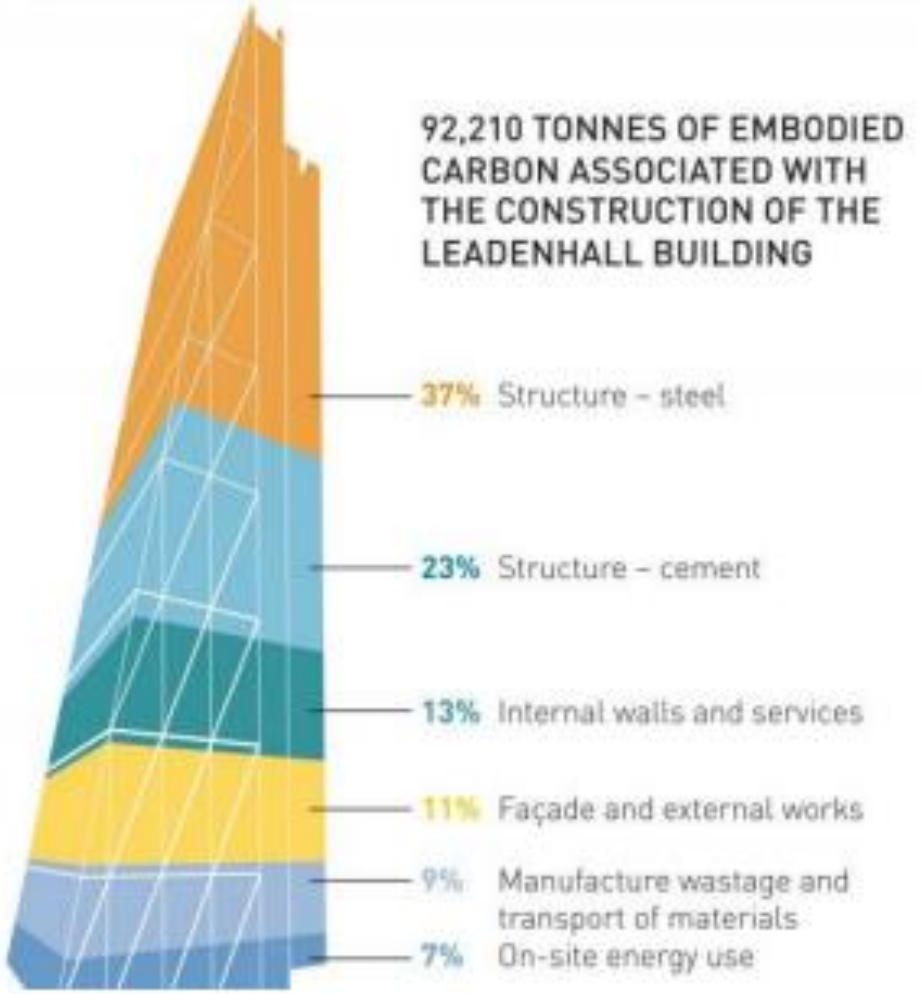
Buy Clean Washington Study by Kate Simonen et al.

Where is EC in Construction?

- EC can be found in every material used in construction

https://en.wikipedia.org/wiki/122_Leadenhall_Street

Embodied Carbon in the Leadenhall Building UK



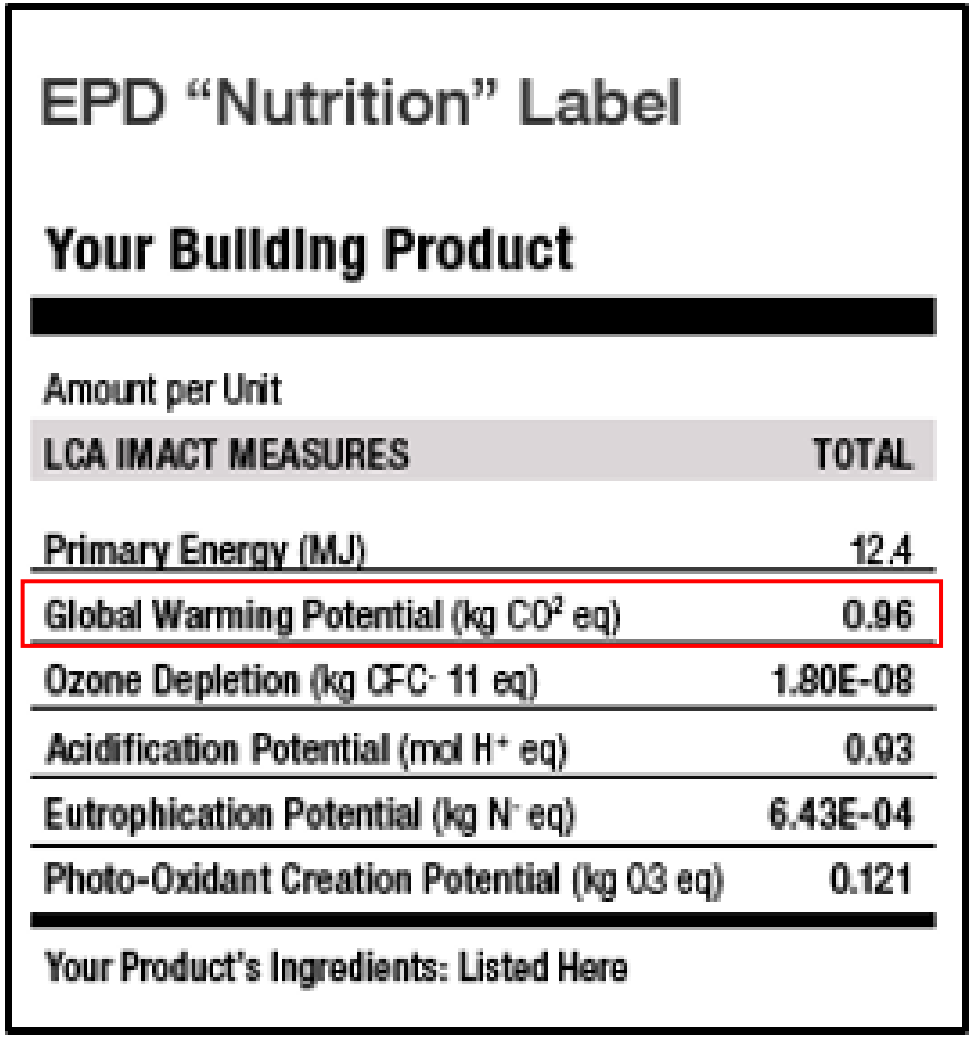
Tackling Embodied Carbon in Buildings by The Crown Estate & UKGBC

Quantifying EC: Environmental Product Declarations

- Life cycle emissions per unit of material
- Importance: ubiquity and transparency

Beware:

- EPD ≠ Green
- Different calculation methods complicate comparisons
- Different materials use different units



EPD "Nutrition" Label

Your Building Product

Amount per Unit

LCA IMACT MEASURES	TOTAL
Primary Energy (MJ)	12.4
Global Warming Potential (kg CO^2 eq)	0.96
Ozone Depletion (kg CFC- 11 eq)	1.80E-08
Acidification Potential (mol H^+ eq)	0.93
Eutrophication Potential (kg N^- eq)	6.43E-04
Photo-Oxidant Creation Potential (kg O3 eq)	0.121

Your Product's Ingredients: Listed Here

EPD "nutrition label" for concrete mixes

https://westcoastclimateforum.com/cfpt/concrete/strategy1

Environmental Product Declaration

Life Cycle Impact Results (per m^3)

Declared Unit: 1 m^3 of 3,000 psi concrete

OPERATIONAL IMPACTS (per m^3)	Residential Concrete
Plant Operating Energy Consumption (MJ)	15.8
On-Site Plant Fuel Consumption (MJ)	172.9
Concrete Batch Water (m^3)	1.94E-01
Vehicle and Equipment Wash Water (m^3)	6.2E-01
On-Site Waste Disposed (kg)	0.68
ENVIRONMENTAL IMPACTS	
Total Primary Energy (MJ)	3,136
Climate Change (kg CO_2 eq)	364
Ozone Depletion (kg CFC11 eq)	1.34E-08
Acidification Air (kg SO_2 eq)	2.41
Eutrophication Air (kg N eq)	5.55
Photochemical Ozone Creation (kg O3 eq)	1.14

https://www.master-builders-solutions.com/en-us/sustainability/quantifying-sustainability

Reduction Strategies

3 Guiding Principles

Use Smart

- Reuse, smaller footprint, program efficiency

Build Smart

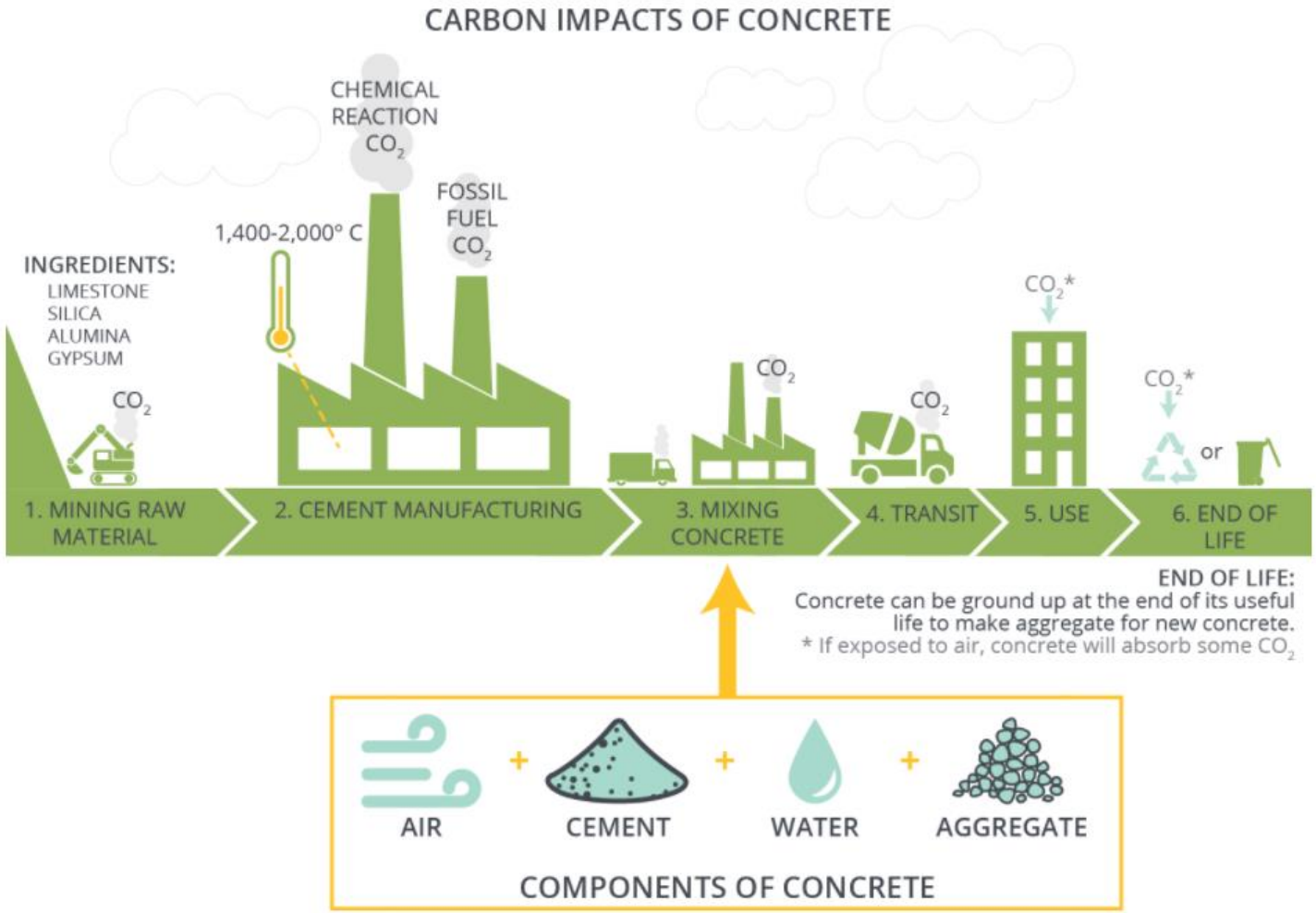
- Alternative materials, efficient structure, life cycle thinking

Buy Smart

- Transparency, policy, codes/specs

Design Strategies: Concrete/Cement

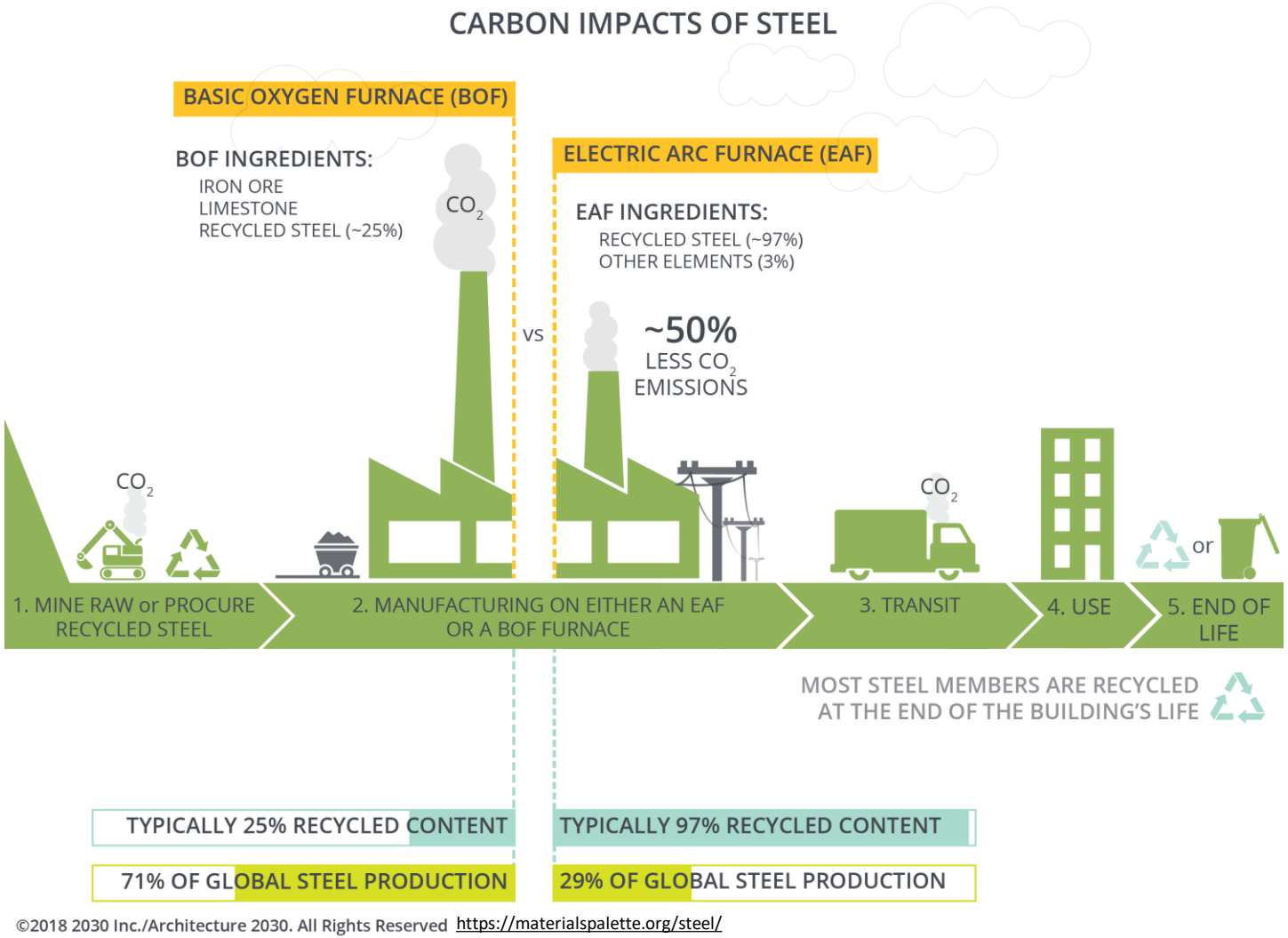
- Avoid over-engineering (e.g. lighten slabs)
- Use timber
- Use smart concrete materials
  - Mixing methods
  - 56 or later day strength
  - Carbon sequestering/CO2 injected concrete technology
  - Portland Limestone Cement (PLC) instead of Portland Cement (PC)
  - Specify hard, clean & strong aggregates
- Consider innovative products: glass pozzolan, rice husk ash concrete, hempcrete
- Use regionally specific data
- Include environmental impact in specifications



 https://materialspalette.org/concrete/

Design Strategies: Steel

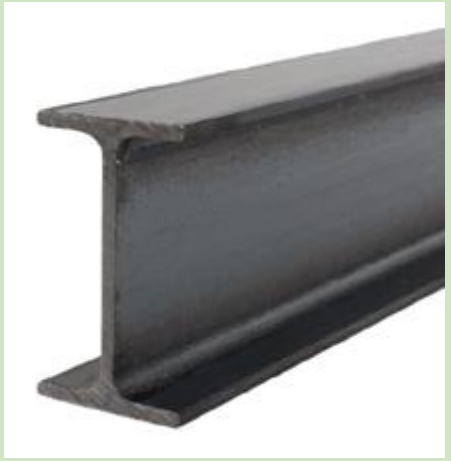
- Use shapes compatible with electric arc furnaces (rather than basic oxygen furnaces)
- Braced frames instead of moment resisting frames
- Joists and trusses reduce amount of steel compared to rolled shapes
- Avoid over-engineering
- Replace steel with timber
- Innovative products to look forward to: Hydrogen steel production
- Specify 90-100% recycled content where possible
- Choose North American



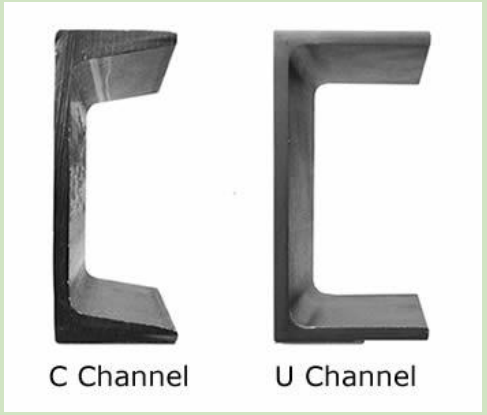
 https://materialspalette.org/steel/

Steel shapes

Hot Rolled Shapes made with electric arc furnaces: wide flange, angles, channels, rebar



http://www.chambersteel.com/Wide%20Flange%20Beams.htm



https://www.steel-sections.com/steelsections/steel-channel-basics.html

https://www.engineeringtoolbox.com/american-wide-flange-steel-beams-d_1319.html

Hollow Structural Shapes Steel Decking made with basic oxygen furnaces

https://www.canam-construction.com/en/construction-products/steel-deck/

http://www.hgmetal.com/products/hollow-section/

Design Strategies: Insulation

- Design compact enclosures
- Minimize thermal weak spots
- Reduce plastic foams
- Specify different insulations for different uses
- Choose low EC materials
  - Bio-based & blown in
  - Wood fiberboard
  - Cellulose
  - Hemp
  - Cement bonded wood wool
- Review EPDs to ensure sustainable harvesting of natural products

Insulation Material	R-value R/inch	Density lb/ft³	Emb. E MJ/kg	Emb. Carbon $kgCO_2/kg$	Emb. Carbon $kgCO_2/ft^2 \cdot R$	Blowing Agent (GWP)	Bl. Agent kg/kg foam	Blowing Agent GWP/ bd-ft	Lifetime GWP/ $ft^2 \cdot R$
Cellulose (dense-pack)	3.7	3.0	2.1	0.106	0.0033	None	0	N/A	0.0033
Fiberglass batt	3.3	1.0	28	1.44	0.0165	None	0	N/A	0.0165
Rigid mineral wool	4.0	4.0	17	1.2	0.0455	None	0	N/A	0.0455
Polyisocyanurate	6.0	1.5	72	3.0	0.0284	Pentane (GWP=7)	0.05	0.02	0.0317
Spray polyurethane foam (SPF) – closed-cell (HFC-blown)	6.0	2.0	72	3.0	0.0379	HFC-245fa (GWP=1,030)	0.11	8.68	1.48
SPF – closed-cell (water-blown)	5.0	2.0	72	3.0	0.0455	Water (CO_2) (GWP=1)	0	0	0.0455
SPF – open-cell (water-blown)	3.7	0.5	72	3.0	0.0154	Water (CO_2) (GWP=1)	0	0	0.0154
Expanded polystyrene (EPS)	3.9	1.0	89	2.5	0.0307	Pentane (GWP=7)	0.06	0.02	0.036
Extruded polystyrene (XPS)	5.0	2.0	89	2.5	0.0379	HFC-134a[1] (GWP=1,430)	0.08	8.67	1.77

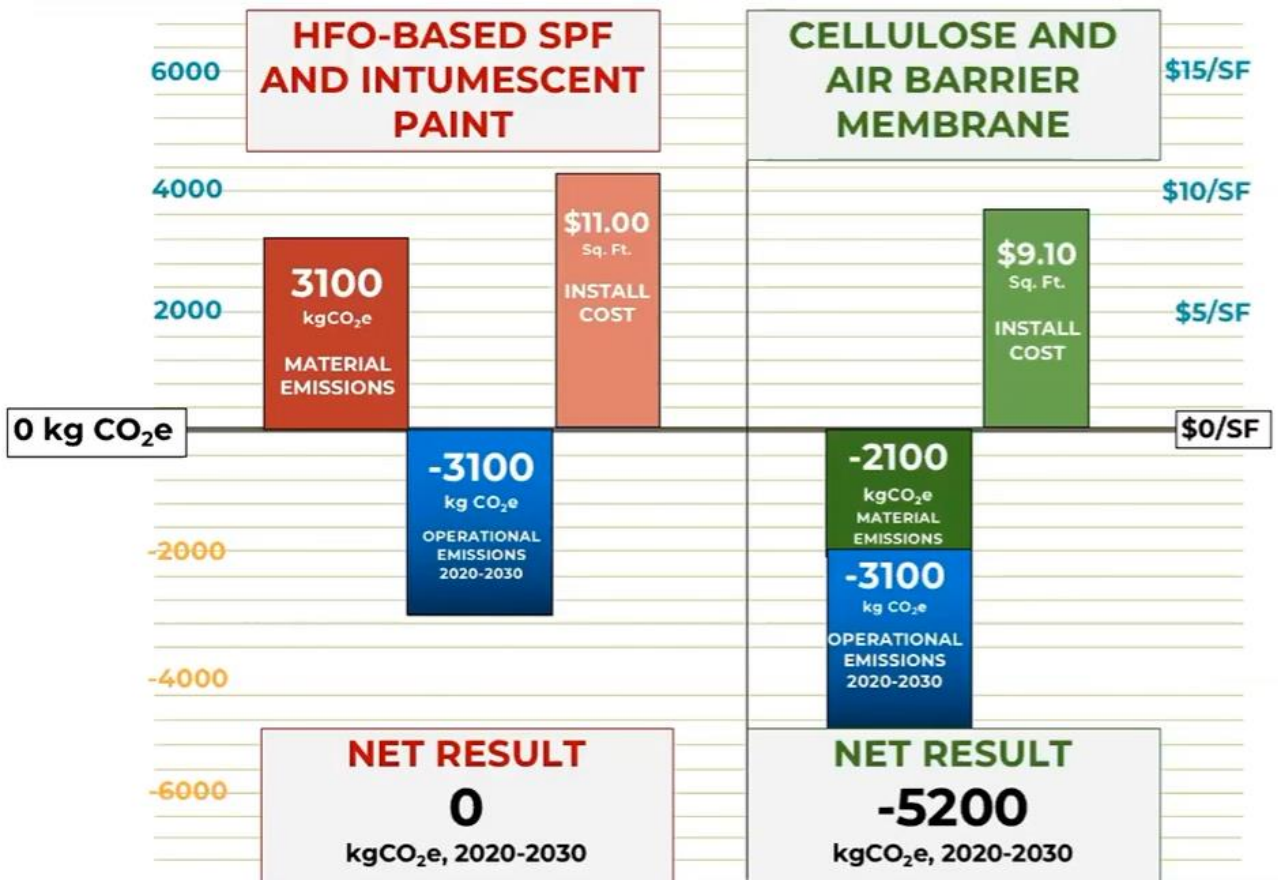
https://www.buildinggreen.com/news-article/avoiding-global-warming-impact-insulation

More insulation does not always equal lower carbon footprint

Buildings as a Carbon Sink

- Insulation made from natural materials can sequester CO_2
- Buildings have potential to be a carbon sink
- Requires intentional use of low carbon materials throughout a building
- Operational performance need not be compromised
- **Beware:** All natural materials are not equal due to harvesting, processing and transportation. Transparency is key: Forest Stewardship Council, Declare labels

Case Study: Closed Cavity Roof Insulation Retrofit by New Frameworks



NESEA: Embodied Carbon in Materials: Real Steps to Drawing Down Carbon in our Buildings

Design for Deconstruction/Reuse

- Building re-use has potential to reduce EC
- Document materials and methods
- Design for deconstruction
  - Reduce chemical connections
  - Accessible connections
  - Mechanical fasteners
  - Simplicity
  - Separate systems

https://www.re-thinkingthefuture.com/fresh-perspectives/a973-designing-for-deconstruction/

Tools and Resources

“In order for action to scale, we need easy access to data and tools” Kate Simonen, CLF

Estimating Embodied Carbon

- Design LCA Tools
  - Athena Impact Estimator
  - SE-2050
  - eTool (LCA)*
  - One Click LCA*
  - Tally (Revit application)*
- Carbon Accounting Tools
  - EC3 Tool – uses EPDs to guide procurement
  - Specialty tools: Beacon (Revit plug-in), Woodworks, climate earth, etc.
- Material Databases
  - Carbon smart materials palette
  - The Quartz Project
  - Ecological Building Network (EB Net)
  - Building for Environmental and Economic Sustainability (BEES)
  - Bath Inventory of Carbon and Energy (ICE)

https://kierantimberlake.com/page/tally

Athena Impact Estimator for Highways

https://calculatelca.com/

One Click LCA

Product of Bionova Ltd

https://www.oneclicklca.com/

SE2050 COMMITTING TO ZERO

https://se2050.org/

eTool®

https://etoolglobal.com/

EC3

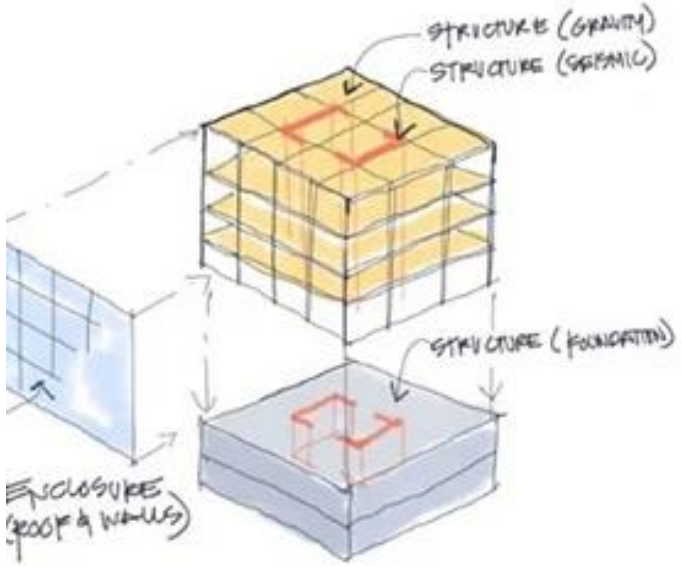
https://www.buildingtransparency.org/en/

CARBON SMART MATERIALS PALETTE™

https://materialspalette.org/

* = payment required

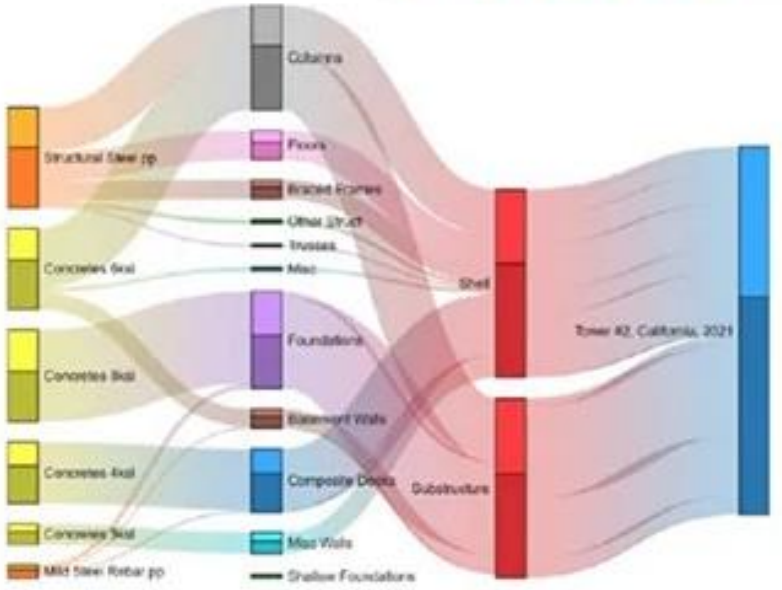
Embodied Carbon in Construction Calculator (EC3)



Life Cycle Impact Results (per m³)

Declared Unit: 1 m³ of 10,000 psi concrete at 28 days

OPERATIONAL IMPACTS	PerformUC™ PECC10K
Plant Operating Energy (MJ)	38.6
On-Site Plant Fuel Consumption (MJ)	11.1
Concrete Batch Water (m³)	1.68E-01
Concrete Wash Water (m³)	1.91E-02
On-Site Waste Disposal (kg)	0.0
ENVIRONMENTAL IMPACTS	
Total Primary Energy (MJ)	3,017
Climate Change (kg CO_2 eq)	445
Ozone Depletion (kg CFC 11 eq)	1.31E-08
Acidification Air (kg SO_2 eq)	2.96
Eutrophication (kg N eq)	0.09
Photochemical Ozone Creation (kg O_3 eq)	0.61

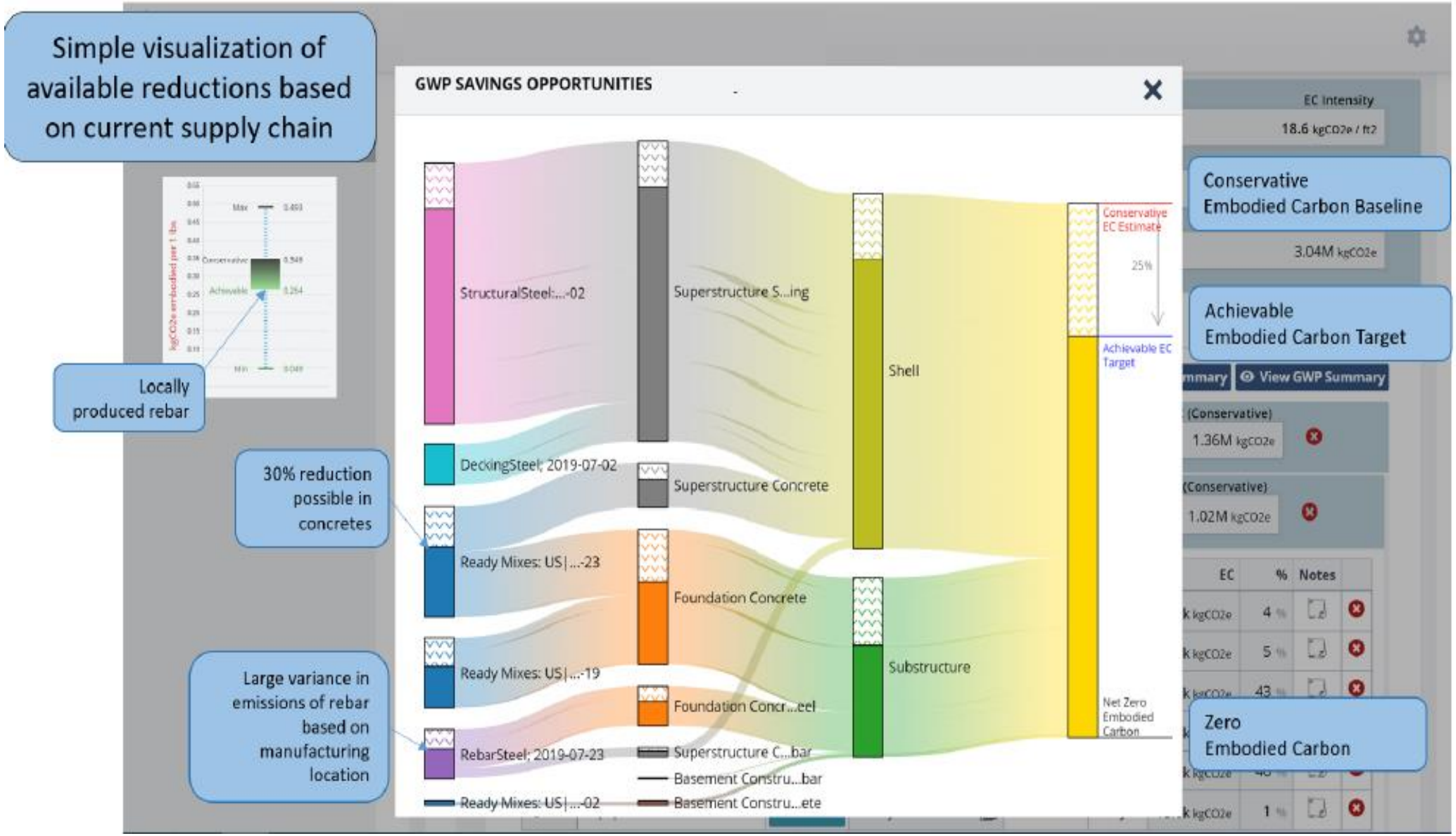


MATERIAL QUANTITY ESTIMATE ✖ **EMBODIED CARBON** PER MATERIAL **EPDs** = BUILDING **EMBODIED CARBON (EC)** ESTIMATE

2019

https://www.bimplus.co.uk/technology/free-embodied-carbon-calculator-help-move-greener-/

1. Design & Plan Buildings



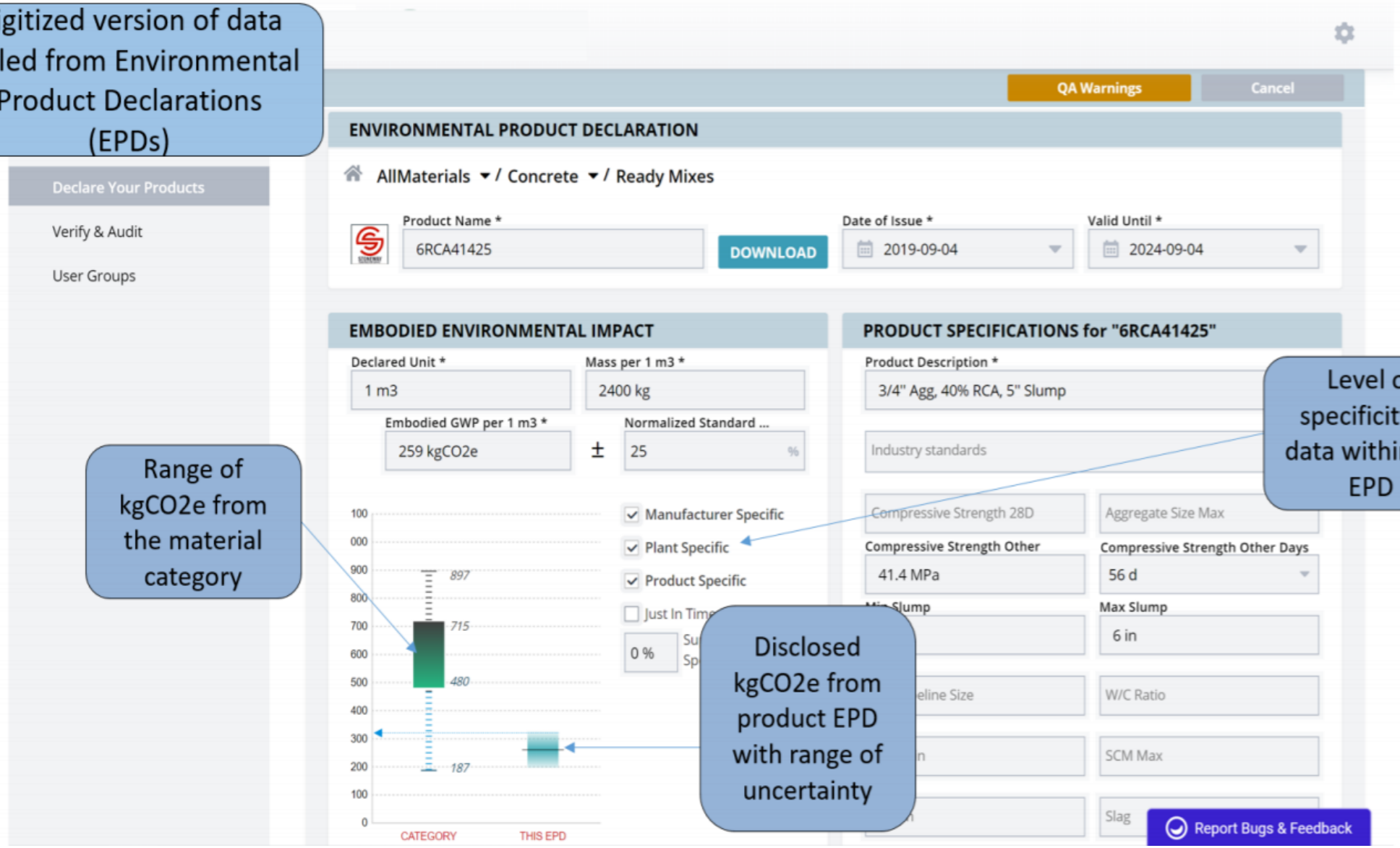
https://www.buildingtransparency.org/en/ec3-resources/ec3-downloads/

2. Find and Compare Products

https://www.buildingtransparency.org/en/ec3-resources/ec3-downloads/

3. Declare Products

Digitized version of data pulled from Environmental Product Declarations (EPDs)



Range of kgCO2e from the material category

Level of specificity of data within the EPD

Disclosed kgCO2e from product EPD with range of uncertainty

https://www.buildingtransparency.org/en/ec3-resources/ec3-downloads/

Embodied Carbon in Construction (EC3) in Focus

- Utilizes robust dataset of construction material EPDs
- Applies conservative estimate for data gaps
- Displays uncertainty
- Allows users to combine materials for a whole building assessment
- Find and compare material choices for design and procurement stages
- Free, open source
- Connectivity to A360 & Tally

https://www.buildingtransparency.org/en/

EC in Policy & Credentials

- LEED v4 offers points for WBLCA's and reduction of EC
- States and townships are beginning to incorporate EC into building codes
- Buy Clean California (BCCA)
- UN Sustainable Development Goals 9, 11, 12

https://www.cdrecycler.com/article/leed-usgbc-top-10-states-2019/

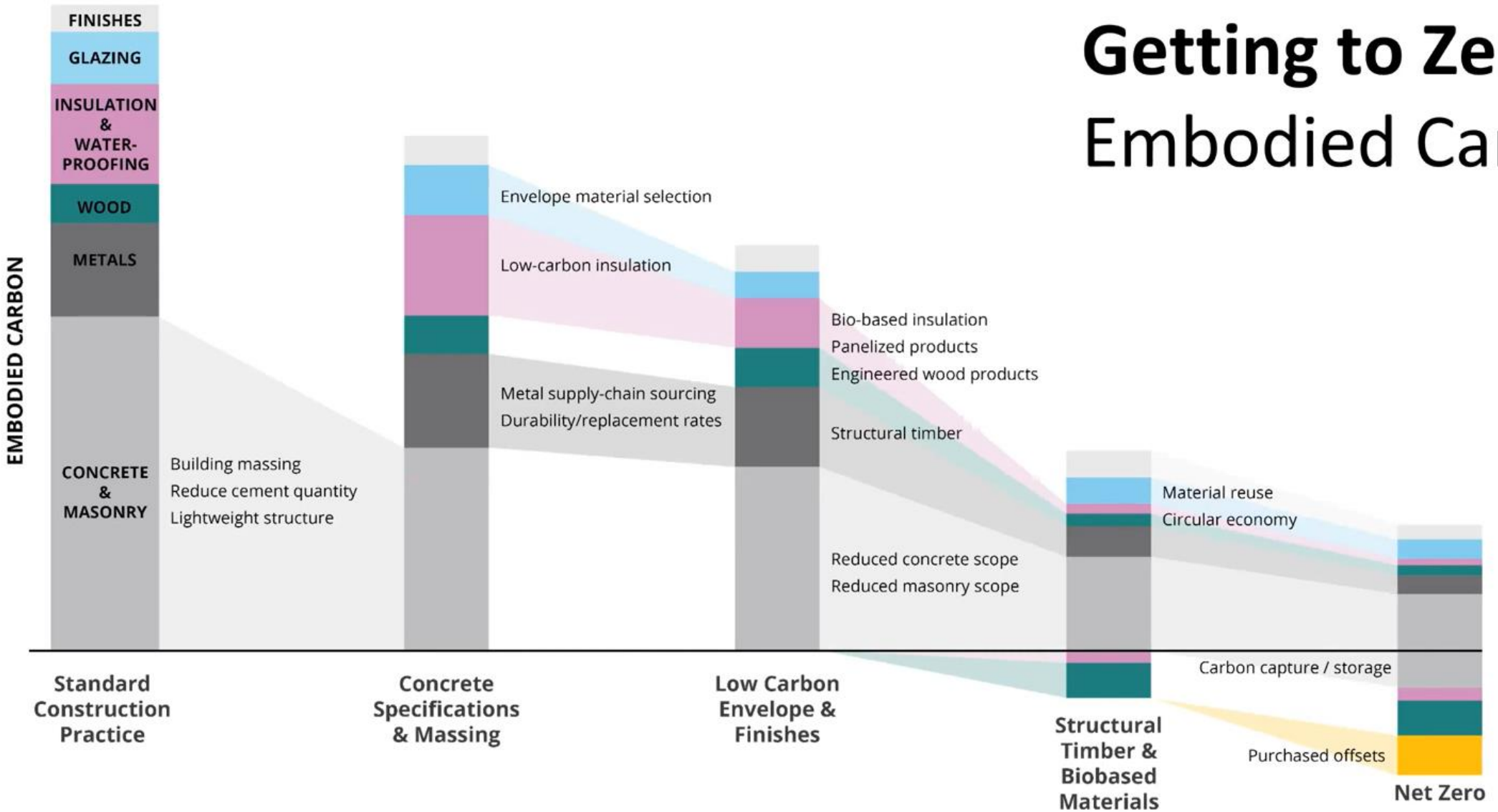
https://buyclean.org/buy-clean-california/

https://sdgs.un.org/goals

Wrap Up

- Set Internal Targets
- Use Smart
- Build Smart
- Buy Smart
- Advocate for Change & Transparency
- Share Resources & Knowledge

Getting to Zero
Embodied Carbon



https://carbonleadershipforum.org/news-and-events/webinars/

Challenges in quantifying EC

- Data Gaps and barriers: availability, consistency, transparency
- Variation in the harvest and processing of natural materials
- Complexity of existing buildings
- Geographic and climatic conditions can limit material options
- Cost
- Understanding the impact of furnishings and MEP

What to Look for moving forward

- Policy drivers
- New technologies: bio-based insulation, steel manufactured with hydrogen, carbon sequestering concretes
- Increased awareness of EC calculators and tools

Resources

- **CLF:** Broad range of resources and guidance for reducing EC in the building industry. Creators of EC2 tool.
- **Urban Land Institute EC Guide:** Aimed at helping real estate developers understand and reduce embodied carbon
- **Buy Clean Washington Study:** A review and evaluation of policies and regulations to limit embodied carbon of structural materials used in state building projects
- **Living Future Embodied Carbon Guidance:** Guidance on calculating and reducing embodied carbon
- **ASTM2921-16a:** Guide to comparing WBLCAs
- **International Green Construction Code (IGCC):** recommended practices for reducing EC in built construction
- **EC3 Tool Video Tutorials:** Video guides on using EC3 tool

Thank You

Jordan Dentz

jdentz@levypartnership.com

Vice President

The Levy Partnership

Austin Izzo

aizzo@levypartnership.com

Building Sustainability Intern

The Levy Partnership

Sources

1. https://www.buildinggreen.com/feature-shorts/what-s-epd-environmental-product-declaration-faqs
2. EPDs are the future of Building Industry, Whether You Like it or Not
3. https://carbonleadershipforum.org/guidance-on-embodied-carbon-disclosure/
4. https://www.buildinggreen.com/feature-shorts/what-s-epd-environmental-product-declaration-faqs
5. The Urgency of Embodied Carbon and What You Can Do about It _ BuildingGreen
6. Whole Building Life Cycle Assessment Through LEED V4_GBCI
7. Buy Clean California Act
8. https://www.marincounty.org/depts/cd/divisions/sustainability/low-carbon-concrete-project
9. https://sdgs.un.org/goals
10. https://architecture2030.org/new-buildings-embodied/
11. Tackling embodied carbon in buildings
12. Greenprint-Embodied-Carbon-Report_FINAL
13. 106 - Out of Site, In the Air
14. Embodied-Carbon-Industry-Task-Force-Proposals_June-2014_Final
15. CLF EC101 Webinar
16. Avoiding the Global Warming Impact of Insulation
17. The Embodied Carbon Conundrum_ Solving for All Emission Sources from the Built Environment - New Buildings Institute
18. https://carbonleadershipforum.org/what-we-do/initiatives/ec3/
19. Heatspring: Embodied Carbon in Materials Powerpoint
20. https://materialspalette.org/concrete/
21. https://materialspalette.org/steel/
22. https://materialspalette.org/insulation/
23. Design_for_disassembly-guide
24. Reducing The Embodied Carbon of Construction Materials_CanadianArchitect
25. https://materialspalette.org/carpet/
26. https://www.metropolismag.com/interiors/interior-designers-climate-carbon/pic/101548/
27. Summary Report of Embodied Carbon Impacts of MEP Systems and TI_CLF
28. https://www.architectmagazine.com/technology/concrete-steel-or-wood-searching-for-zero-net-carbon-structural-materials_o
29. https://buildingtransparency-live-87c7ea3ad4714-809eeaa.divio-media.com/filer_public/b1/f6/b1f649b6-e73d-4a2b-9f97-e151f3b6de7d/ec3-key_features.pdf
30. Magwood – Opppurtunities for carbon capttuer in buildings…