Why Embodied Carbon Matters, and What You Should Do About It

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REBUILD 2021

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Meet Your Speaker



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Learning Objectives: 1.0 AIA CE Hour

Learning Objective 1: Participants will be able to define embodied carbon and its basic metrics.

Learning Objective 2: Participants will be able to explain the different stages of lifecycle assessment (LCA) and why they matter to embodied carbon data.

Learning Objective 3: Participants will be able to describe ways of gauging and optimizing projects for lower embodied carbon as part of a building design workflow.

Learning Objective 4: Participants will be able to identify ways in which embodied carbon metrics are becoming integral to green building rating systems.

AIA Continuing Education

Learning Objectives: 1.0 GBCI LU (BD+C Specific)

Learning Objective 1: Define embodied carbon and understand its basic characteristics and metrics.

Learning Objective 2: Explain a workflow to optimize a project for minimal embodied carbon in accordance with the LEED v4 BD+C Building Life-Cycle Impact Reduction credit.

Learning Objective 3: Describe how LEED v4 BD+C can assist in gauging and optimizing building products and materials through disclosure documents such as environmental product declarations (EPDs).

Learning Objective 4: Identify ways in which embodied carbon metrics are becoming integral to LEED v4 BD+C as part an Integrative Process.

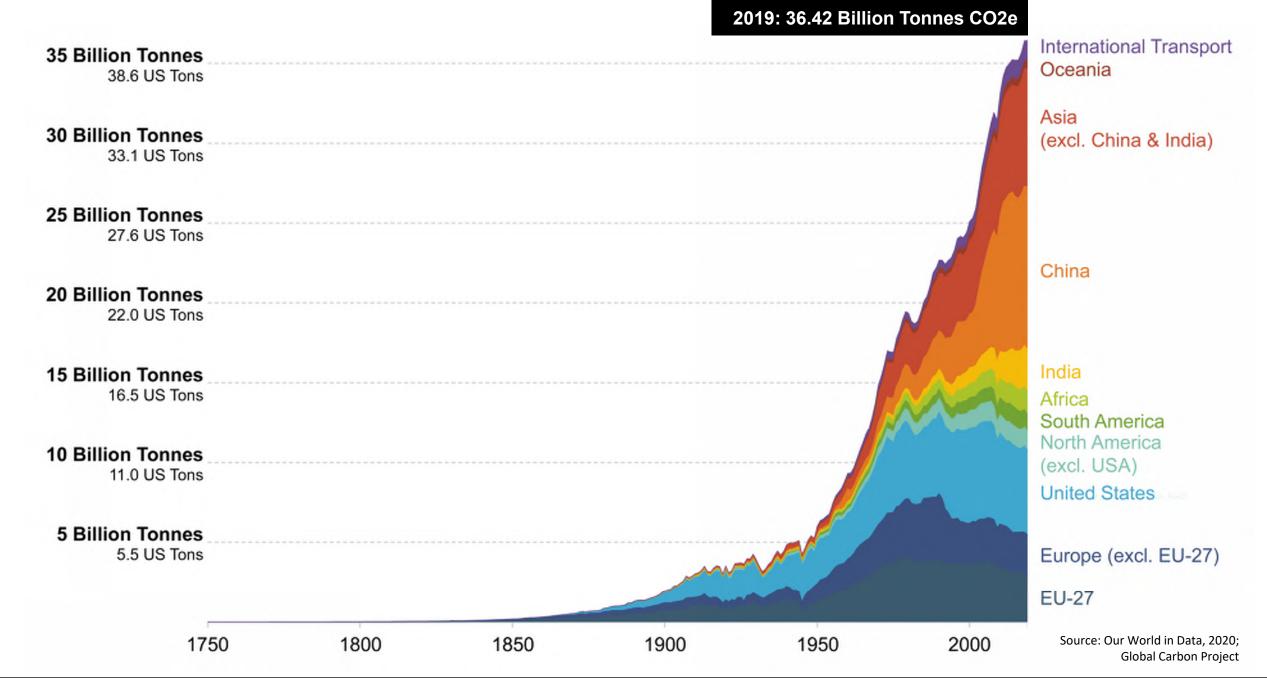


Part 1: Global context on carbon emissions **Part 2:** Defining embodied carbon for buildings Part 3: Modeling and measuring embodied carbon **Part 4:** Role of building product disclosures **Part 5:** Gauging total carbon intensity

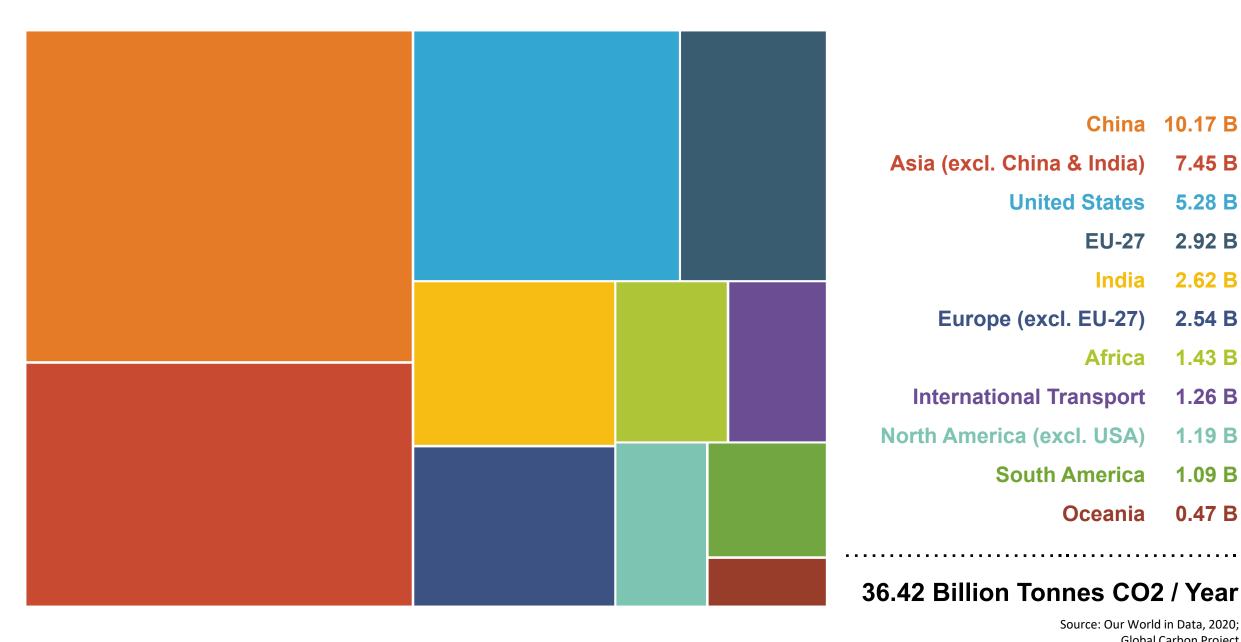
Global context on carbon emissions

The world is on a carbon binge.





WHY EMBODIED CARBON MATTERS, AND WHAT YOU SHOULD DO ABOUT IT | DANIEL OVERBEY | REBUILD 2021



Source: Our World in Data, 2020; **Global Carbon Project**

China 10.17 B

EU-27

India

Africa

Oceania

7.45 B

5.28 B

2.92 B

2.62 B

2.54 B

1.43 B

1.26 B

1.19 B

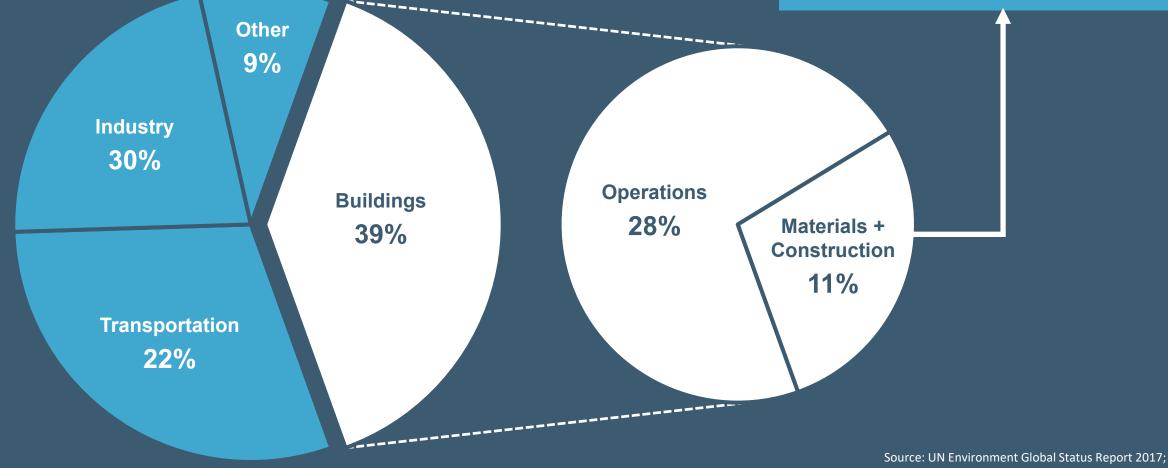
1.09 B

0.47 B

Global CO2 Emissions by Sector

4.0 Billion Tonnes

of annual global carbon emissions come from embodied carbon



EIA International Energy Outlook 2017



Projected average annual new construction globally: 65.98 Billion SF / year = 4.0 Billion Tonnes of CO2



Let us take a closer look at U.S. figures.

Global Carbon Projection: U.S. = 5.28 Billion Tonnes CO2 (2019)

Operational carbon: **1.48 B** Tonnes CO2 Embodied
carbon:
0.58 B
Tonnes CO2

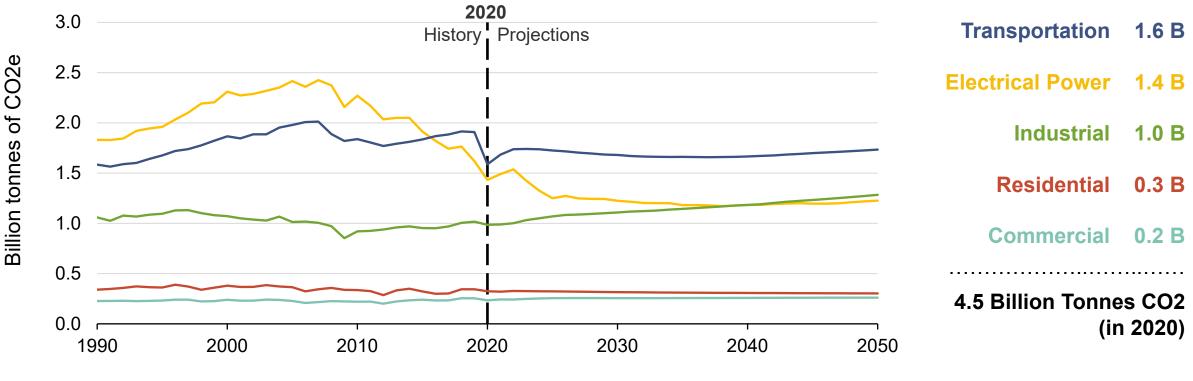
U.S. Energy-Related CO2 Emissions

Energy-related carbon dioxide emissions

EIA AEO2021 reference case

Global Carbon Project: US = 5.28 Billion Tonnes (2019)

Energy Information Administration: US = 5.09 Billion Tonnes (2019)

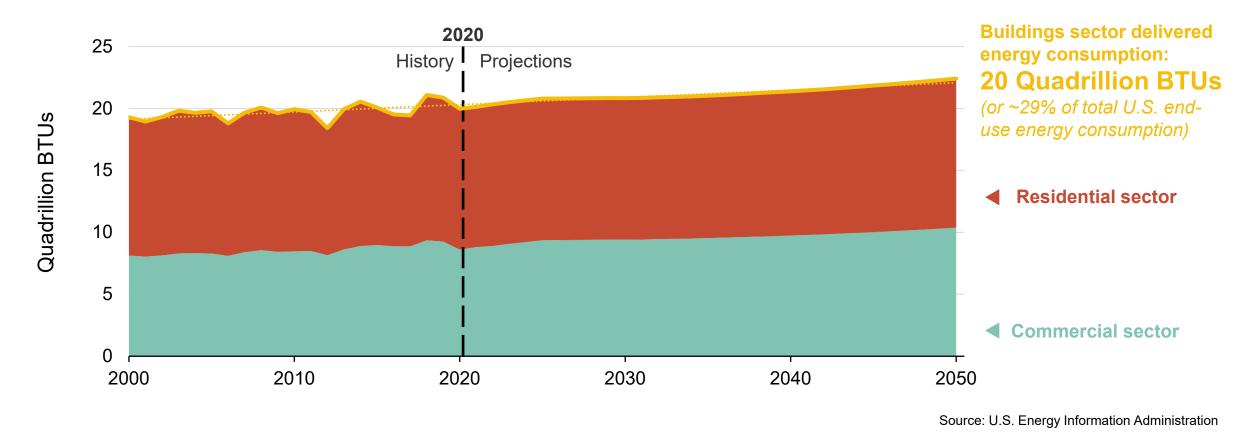


Source: U.S. Energy Information Administration

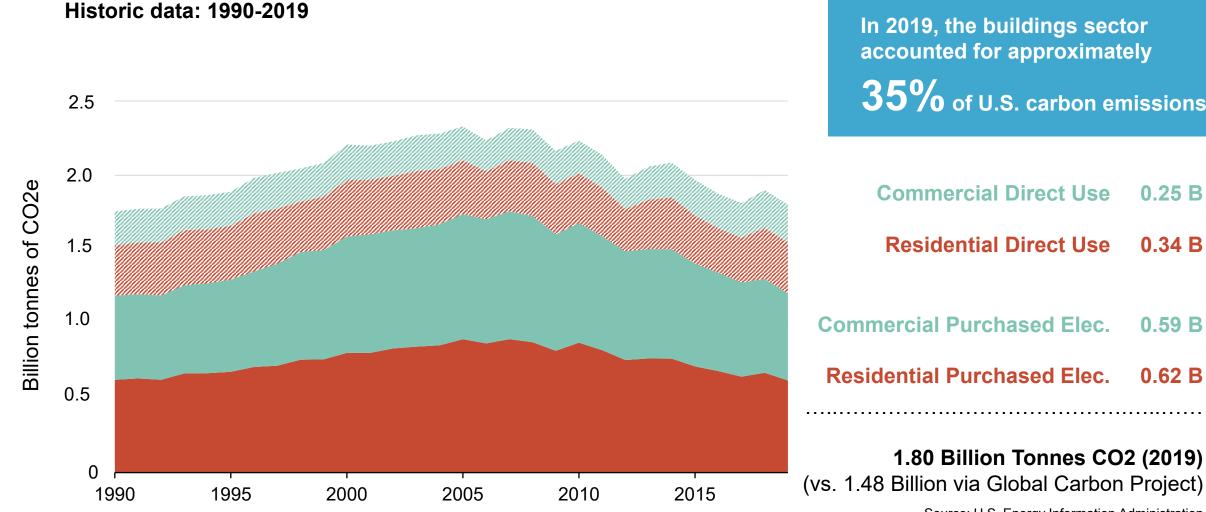
U.S. Buildings Sector Delivered Energy Consumption

Buildings delivered energy consumptions

EIA AEO2021 reference case



U.S. Buildings Sector Energy-Related CO2 Emission



In 2019, the buildings sector accounted for approximately

35% of U.S. carbon emissions.

Commercial Direct Use	0.25 B
Residential Direct Use	0.34 B
Commercial Purchased Elec.	0.59 B
Residential Purchased Elec.	0.62 B
1.80 Billion Tonnes CO	2 (2019)

Source: U.S. Energy Information Administration

Defining embodied carbon for buildings



Scope

Stages

Define the Scope

The scope can make a huge difference in the total embodied carbon figures.

When it comes to defining embodied carbon on a building project, design teams should clarify the scope of the assessment. Which of the following does the scope include?

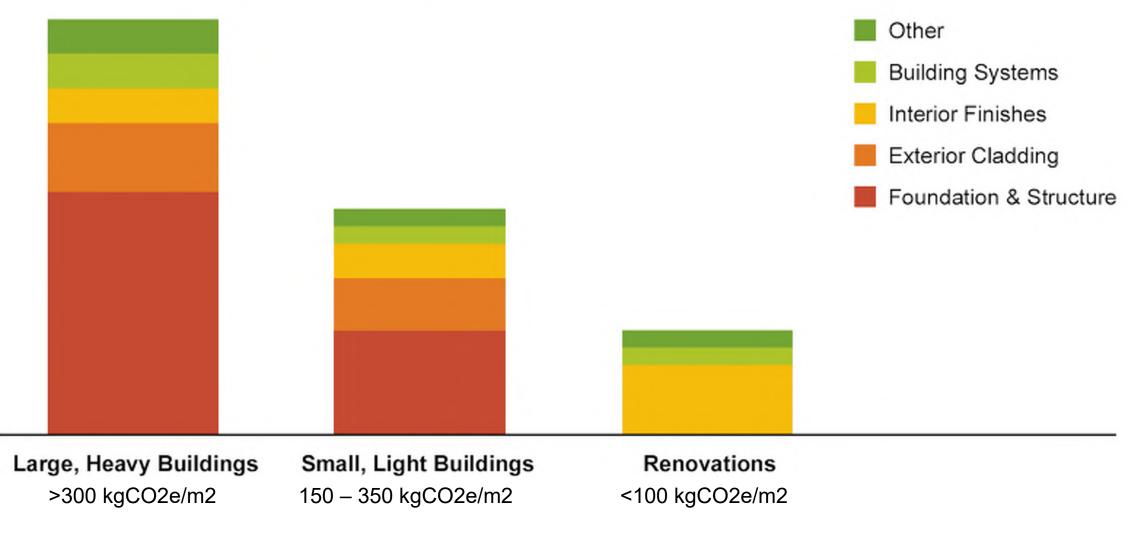
- Substructure
- Superstructure
- Enclosure
- Interiors
- Others (e.g. mechanical systems)

A new multi-story commercial building is going to be responsible for much more embodied carbon than a renovation project of the same magnitude.



The LEED Gold IU Eskenazi Museum renovation reused over 95% of the existing walls, floor, and roof components. Image source: Indiana University

Carbon Emissions by Building Type and Materials



Adapted from: Larry Strain, "Time Value of Carbon" (2017)

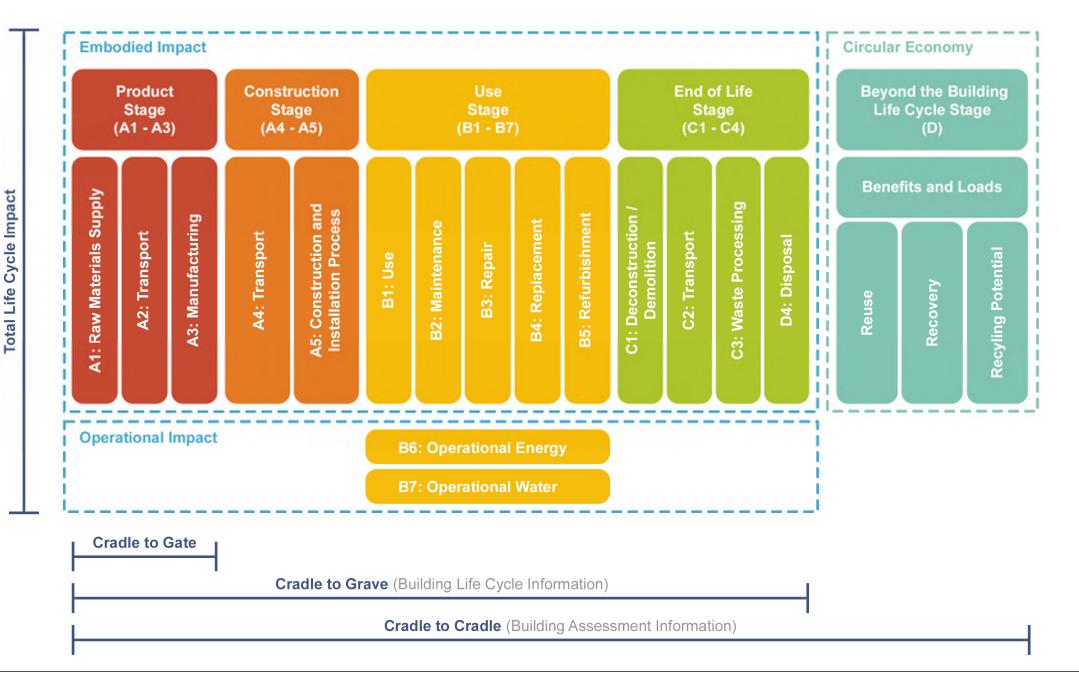
Define the Stages

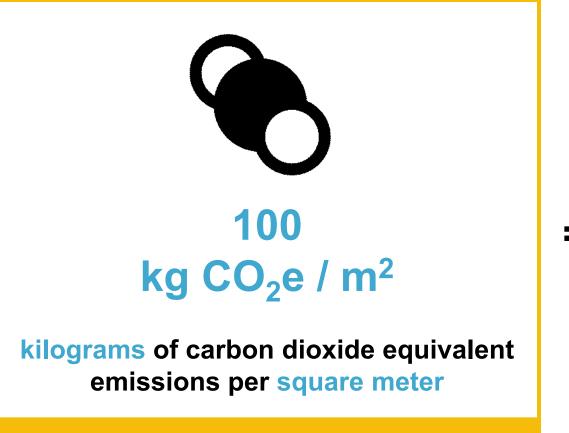
Not all lifecycle assessments cover the same stages.

Standard EN 15978:2011: Sustainability of construction works - Assessment of environmental performance of buildings -Calculation method was developed by the European Committee for Standardization (CEN).

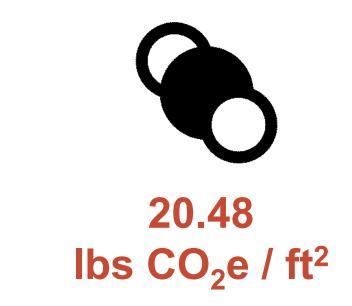
This document defines a calculation method, based on LCA and other quantified environmental information, to assess the environmental performance of a building.



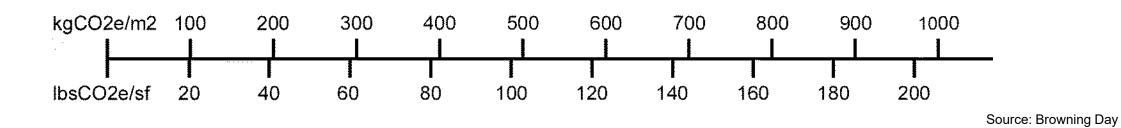




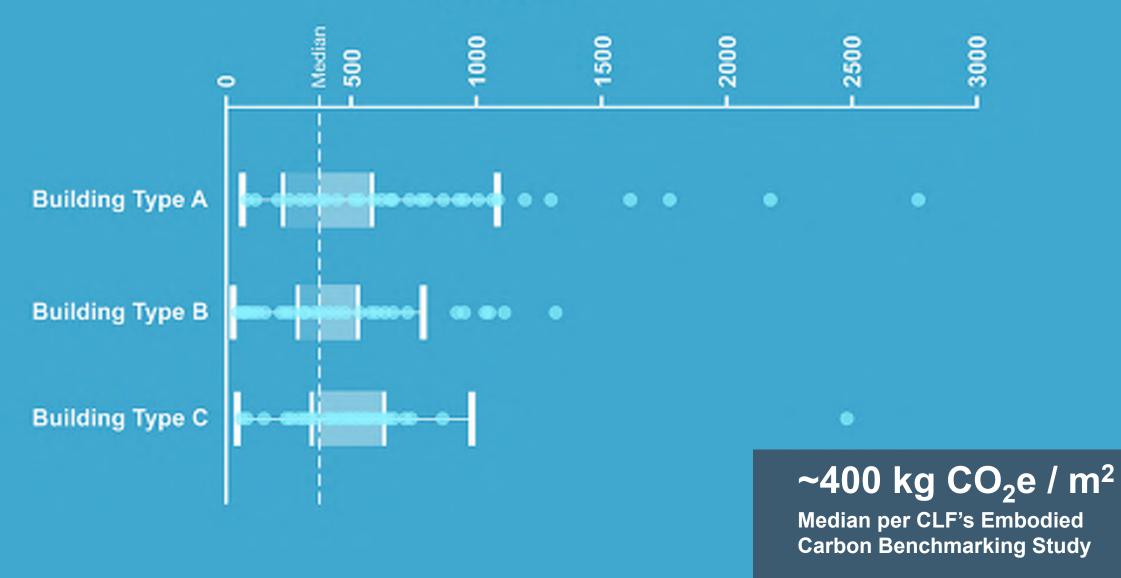
Becoming the industry's standard unit.



pounds of carbon dioxide equivalent emissions per square foot



Embodied Carbon Life Cycle (kg CO2e / m2)



Case Study: IUPUI Innovation Hall

Case Study



IUPUI Innovation Hall Indianapolis, Indiana

Gross area: 101,900 sf.

Multidisciplinary research classroom facility on the Indianapolis campus. Tracking LEED v4 Gold.

24% energy improvement over baseline.

Energy conservation measures include:

- Filtered fume hood analysis / optimization
- HVAC Energy Use reduction
- Water Use savings
- Lighting power density reduction
- Daylighting

Embodied

499

kgCO2e/m2

Operational

275

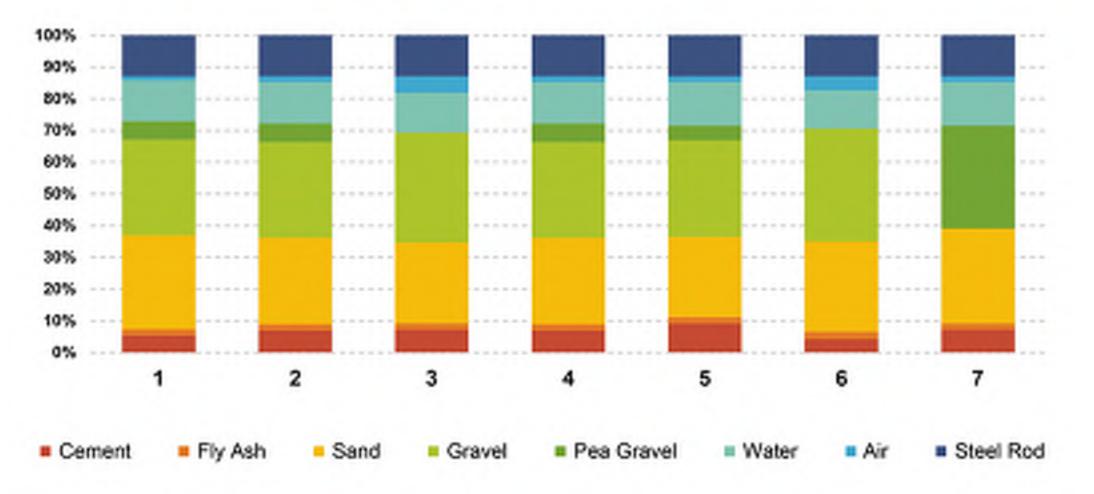
<u>kgCO2e/m2</u> year

Source: IUPUI

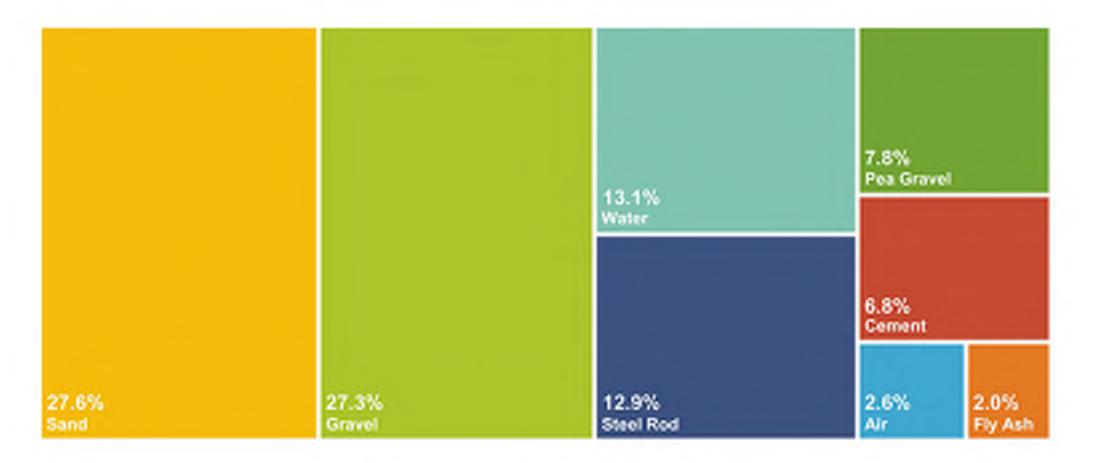
Structural Cast-In-Place Concrete: Steel Reinforced Non-Air-Entrained Lean Mix Summaries

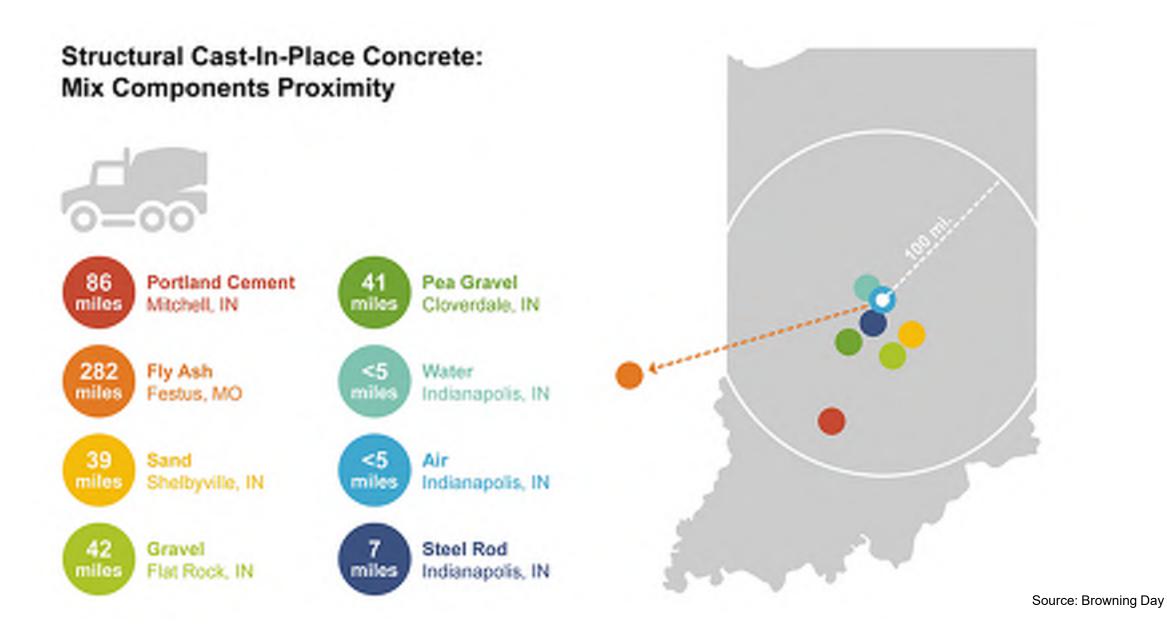
Mix Number 28-Day Strength	1 3000 psi	2 4000 psi	3 4000 psi	4 4000 psi	5 6000 psi	6 2000 psi	7 4000 psi
Cement	1.68	2.19	2.24	2.19	2.87	1.32	2.24
Fly Ash	0.60	0.60	0,60	0.60	0.60	0.72	0.60
Sand	9.18	8.43	7,89	8.43	7.83	8.81	9.29
Gravel	9.34	9.34	10.75	9.34	9.41	11.03	0.00
Pea Gravel	1.81	1.84	0.00	1.84	1.47	0.00	10.03
Water	3.99	4.07	3.89	4.07	4.28	3.77	4.30
Aii	0.41	0.54	1.62	0.54	0.54	1.35	0.54
Steel Rod	4.00	4.00	4.00	4.00	4.00	4.00	4.00
Tota)	31.00	31.00	31.00	31.00	31.00	31.00	31.00

Structural Cast-In-Place Concrete: Components By Proportion Per Mix



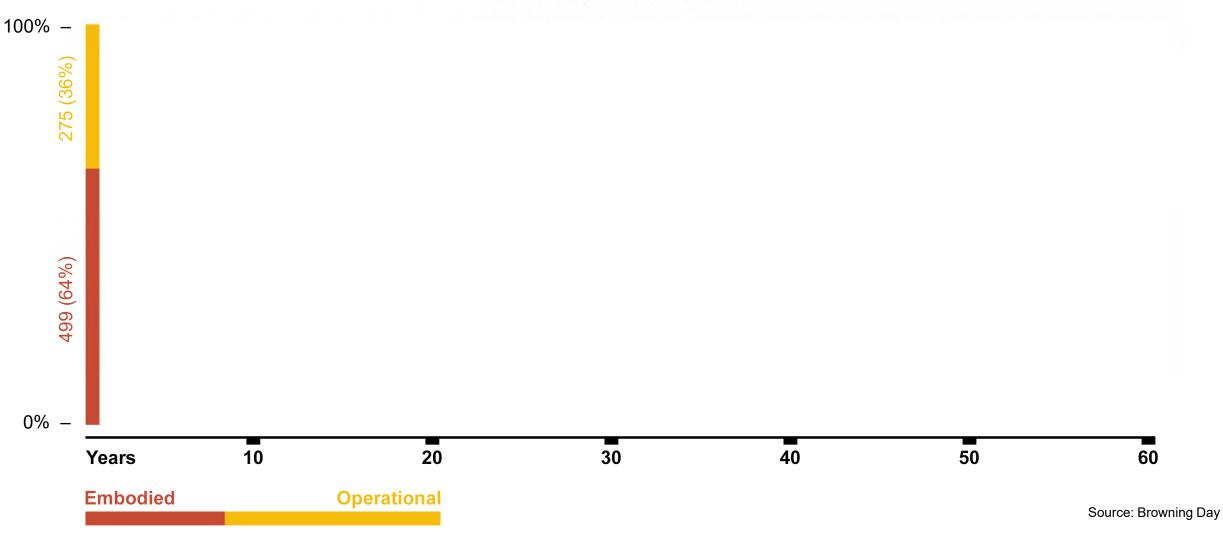
Structural Cast-In-Place Concrete: Mix Components Treemap, Average Proportions





Embodied vs Cumulative Operational Carbon Impact by Year

Embodied carbon figures only account for the building's structure and envelope. Figure assumes the same average energy consumption every year. Maintenance not included.



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IUPUI Innovation Hall

Our embodied carbon data painted an incomplete picture.

- 1. Embodied carbon only accounts for structure and exterior cladding.
- 2. Interior fit out and mechanical systems likely to be renovated over time.
- 3. Operational carbon does not account for the greening of the utility grid.



Source: IUPUI

Modeling and measuring embodied carbon



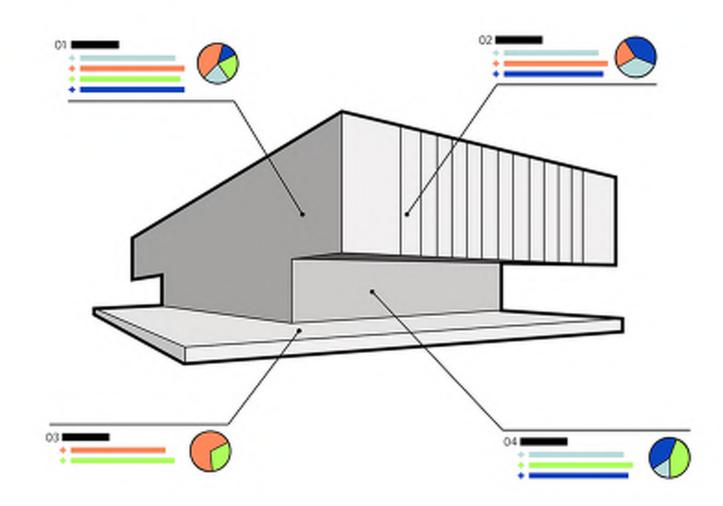
Modeling and Measuring Embodied Carbon

We can now leverage building information modeling (BIM) and other modeling tools to conduct environmental impact assessments on whole buildings.

These tools tap into industry-wide datasets.

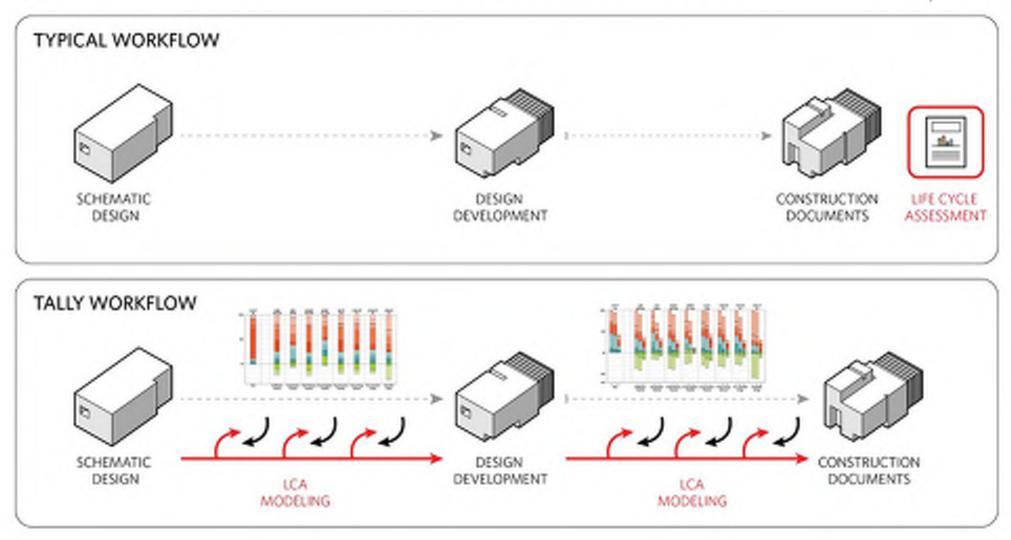
The AIA Design Data Exchange (DDx) now allows 2030 Commitment signatories to record and track embodied carbon figures from the following tools:

- Athena
- Tally
- EC3
- OneClick LCA
- eTool



Source: Kieran Timberlake





Source: Kieran Timberlake

LEED and Embodied Carbon

LEED v4 BD+C: Building life-cycle impact reduction

Option 4. whole-building life-cycle assessment (3 points)

For new construction (buildings or portions of buildings), conduct a life-cycle assessment of the project's structure and enclosure that demonstrates a minimum of 10% reduction, compared with a baseline building, in at least three of the six impact categories listed below, one of which must be global warming potential.

No impact category assessed as part of the life-cycle assessment may increase by more than 5% compared with the baseline building.

Under **LEED v4.1 BD+C** project teams can get 1 point just for running the LCA model (to encourage more modeling).



Source: USGBC

Case Study: IPL Eagle Branch Library

Case Study



IPL Eagle Branch Library Indianapolis, Indiana Gross area: 18,663 sf. Branch of the Indianapolis Public Library. LEED v4 Gold certified.

50% energy improvement over baseline.

Energy-efficiency with on-site renewable energy combined for a predicted energy cost savings of over 80%.

Envelope and structure were optimized to reduce the building's embodied carbon by over 15%.

Through efficient fixtures and fittings, th Eagle Branch reduced indoor water consumption by nearly 35%.

Nearly 63% of construction waste was diverted from landfill.

Embodied

412

kgCO2e/m2

Operational

33

kgCO2e/m2

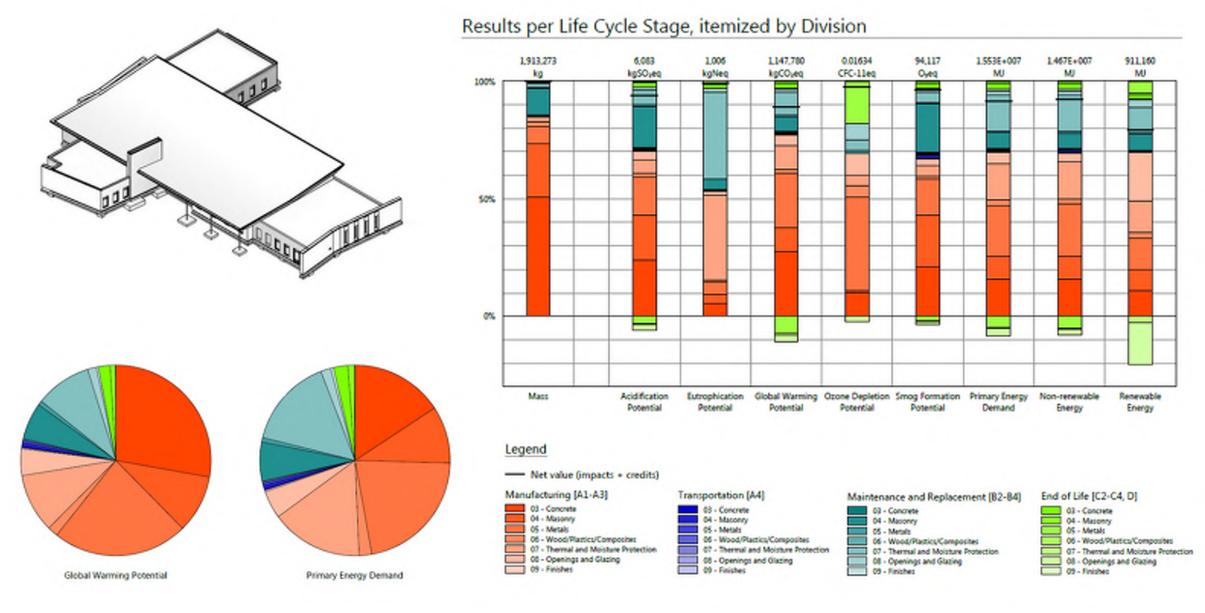
year

Source: Browning Day



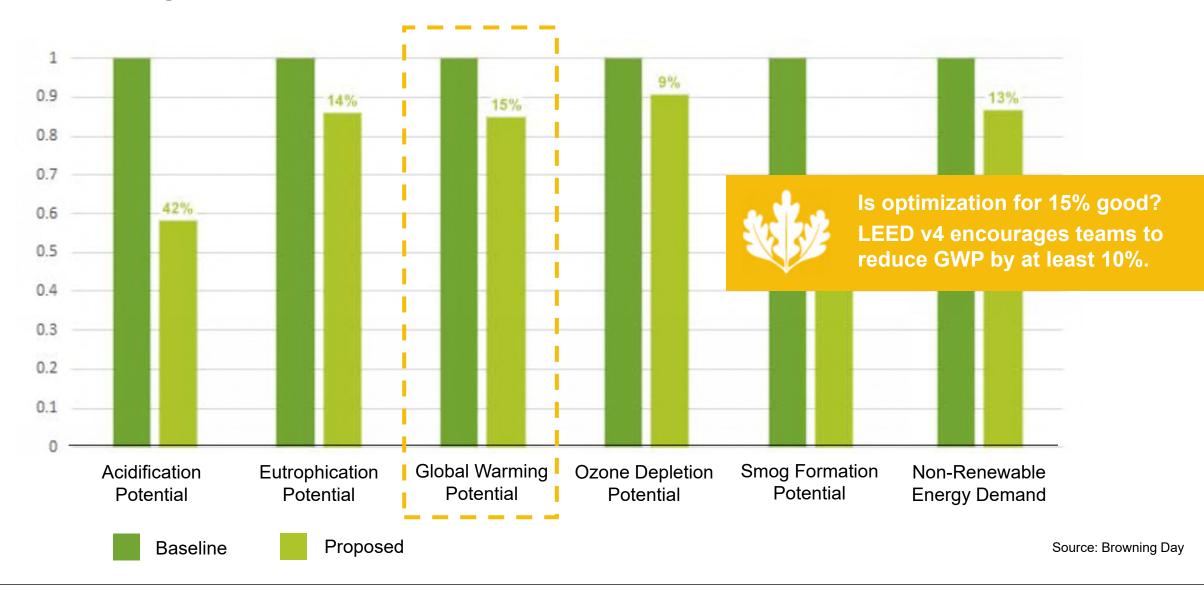






Source: Browning Day

Life-Cycle Assessment: Baseline vs Proposed



IPL Eagle Branch Library

Baseline embodied carbon: 486 kgCO2e/m2

Proposed embodied carbon: 412 kgCO2e/m2 (15% reduction)

Embodied carbon optimization measures:

- Added fly ash content to concrete.
- Reduced cantilever / structural steel.
- Reduced curtainwall system areas (good for operational carbon too).
- Changed XPS and fiberglass batt to mineral wool.
- Supplanted some limestone for brick.



Source: Browning Day

Case Study: Infosys Training Center

Case Study



Infosys Training Center

Indianapolis, Indiana

Gross area: 160,585 sf.

Corporate headquarters and training center.

Tracking LEED v4 Platinum. 24% energy improvement over baseline.

400kW on-site photovoltaic system to offset \$75,000 / year in energy costs.

Energy conservation measures include:

- Optimized envelope solutions.
- High-efficiency mechanicals.
- Daylight / lighting optimization.

Project reveals the embodied carbon intensity of "heavy" structures.

Embodied

969

kgCO2e/m2

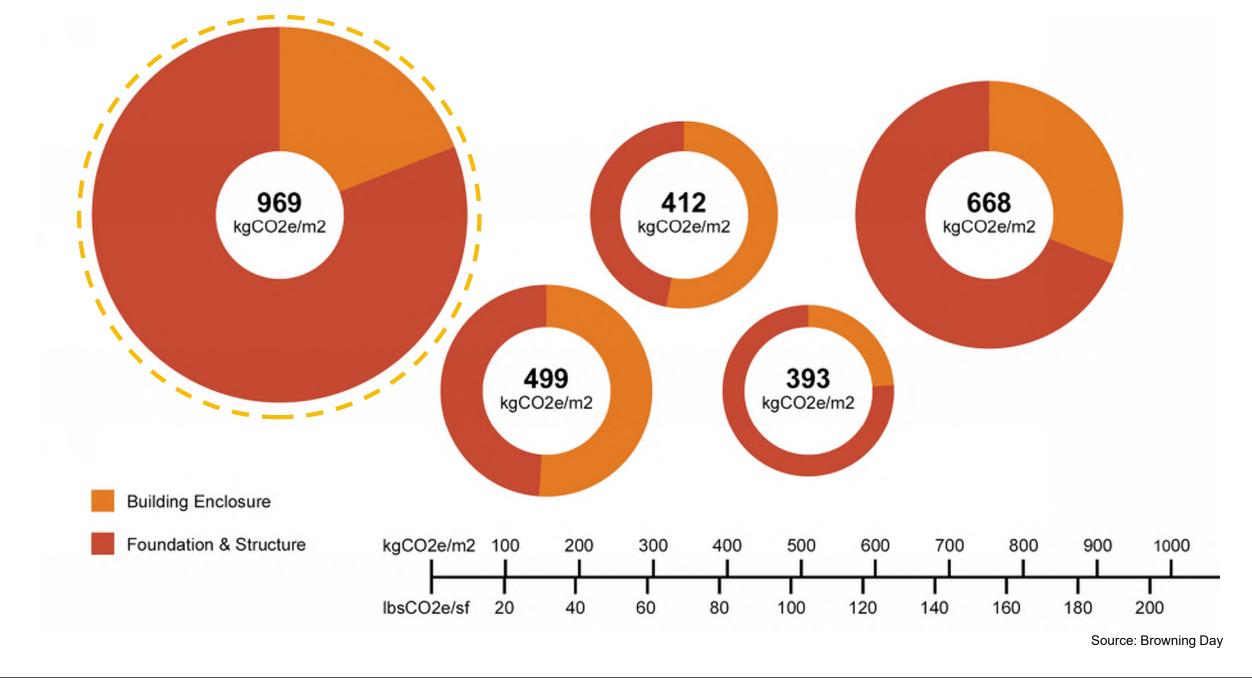
Operational

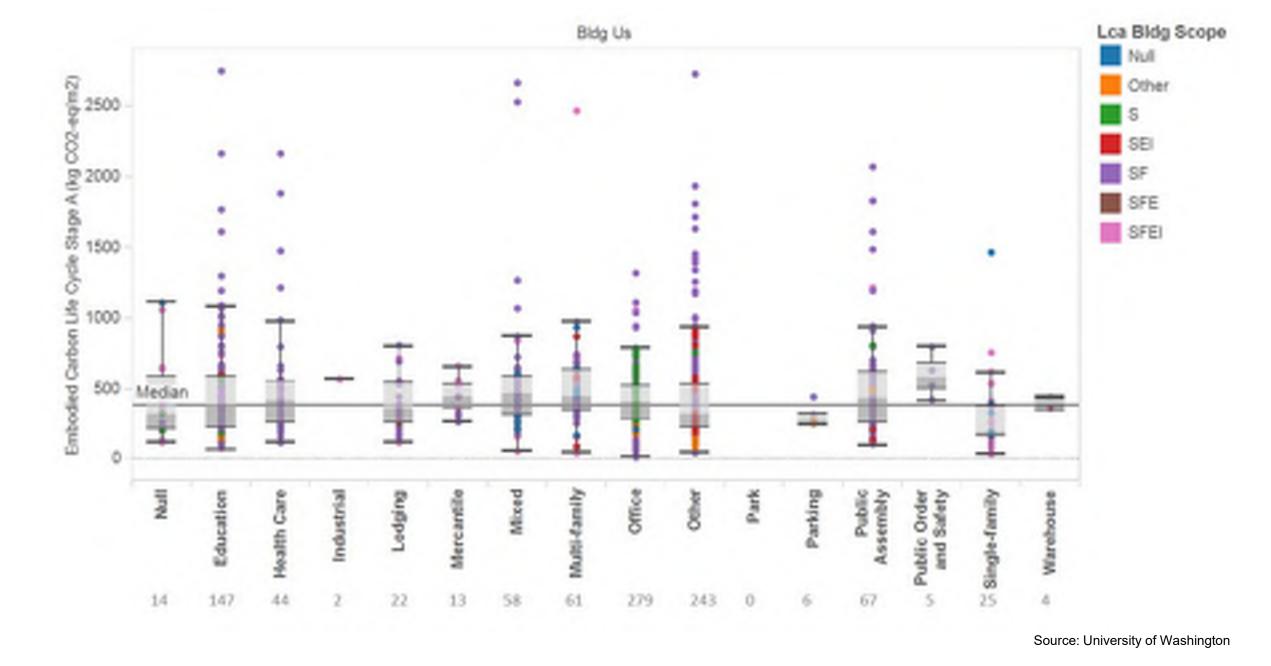
3

kgCO2e/m2

vear

Source: Browning Day





Role of building product disclosures



Environmental Product Declarations

Product transparency documents.

Lots of them:

- Environmental Product Declarations (EPDs).
- Declare label.
- Health Product Declarations.
- Etc.

But extremely difficult to compare products for optimization with regard to environmental / human health impacts.

EPDs are a premiere source for embodied carbon information for specific building products.

Think of EPDs like nutrition labels on food.

Product Impacts

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

Amount Per Declared Unit	
Global Warming Potential	445 kgCO ₂ eq
Emitted	460 kgCO ₂ eq
Sequestered	-15 kgCO ₂ eq
Ozone Depletion	0.000 kgCFC11eq
Acidification	2.96 kgSO ₂ eq
Eutrophication	0.09 kgNeq
Smog Formation	0.61 kgO₃eq
Primary Energy Demand	3017 MJ
Non-renewable	3000 MJ
Renewable	17 MJ

Source: University of Washington

Interface

Information on un-declared modules

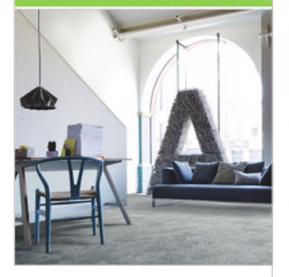
ENVIRONMENTAL PRODUCT as per ISO 14025 and EN 15804

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Owner of the Declaration	Interface Europe Manufact
	Institut Bauen und Umweit
	Institut Bauen und Umwelt
	EPD-INT-20150224-CBC1
	21.01.2016
Valid to	20.01.2021

Modular carpet tiles pile material polyamide 6.6 with 25-50% 500-600 g/m², solution dyed, Graphlex® backing system

Interface[®]

www.bau-umwelt.com / https://epd-online.com



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Modules B3 - B7 are not relevant during the service life of the carpet and are therefore not declared. Modules C1, C3/1 and C3/2 cause no additional impact (see "LCA: Calculation rules") and are therefore not

Environmental Product Declaration Interface® - Modular carpet tiles, 500-600 gitt/ PA 6.6, 25-50% recycled content

LEED v4 BD+C: Building product disclosure and optimization environmental product declarations

Product-Specific EPD (no PCR)

1/4 product

Industry-Wide (Generic) EPD

• 1/2 product

Product-Specific Type III EPD

1 product



Source: Interface

DESC	RIPT	ION O	F THE	SYST	ЕМ ВО	UND	ARY (X = IN	CLL	JDED	IN	LCA	; MNE) = MO	DULE I	NOT D	ECLAF	RED)
PROE	DUCTS	TAGE	CONST ON PRO STA	DCESS		USE STAGE END OF LIFE STAGE							BENEFITS AND LOADS BEYOND THE SYSTEM BOUNDARIES					
Raw material supply	Transport	Manufacturing	Transport from the gate to the site	Assembly	Use	Maintenance	Repair	Replacement	Refurbishment	Operational energy		Operational water	De-construction	Transport	Waste processing	Disposal	Reuse- Recovery-	Recycling- potential
A1	A2	A3	A4	A5	B1	B2	B 3	B4	B	5 E	6	B7	' C'	I C2	C3	C4		D
X	Х	х	X	X	X	х	MND	MND	MN	ID MI	ND	MN	D MN	DX	X	X		x
RESI	ILTS (OF TH	IE LCA	- ENV	IRONI	IENT	AL IM	PACT	: 1 r	n² flo	orc	ovei	ring					
Param eter	Ur	nit	A1-A3	A4	A5	B1	B2	: c	2	C3/3	С	4/1	C4/2	C4/3	D	D/1	D/2	D/3
GWP	[kg CC) ₂ -Eq.]	8.22	0.19	0.76	0.00	0.3	5 0.	01	0.03	3	.92	6.31	0.00	-0.21	-0.14	-2.72	-0.57
ODP	[kg CFC	:11-Eq.]	4.11E-8	7.83E-13	1.51E-9	0.00E+	0 9.58	5-9 4.27	E-14	2.18E-11	8.42	2E-12	7.18E-9	0.00E+0	-6.89E- 11	-1.02E- 10	-9.12E- 10	-1.77E-8
AP	[kg SC		2.14E-2	8.53E-4	8.61E-4					1.47E-4			2.40E-3		-5.41E-4		-7.14E-3	
EP	[kg (PO		3.81E-3	2.16E-4					-	8.01E-6	-				-3.72E-5			
POCP ADPE	[kg ethe [kg St		2.85E-3	-3.15E-4 7.47E-9						8.60E-6 5.14E-9	_		1.70E-4 -7.01E-7	0.00E+0	-4.53E-5 -2.06E-8	-4.00E-5 -2.39E-8		-3.68E-4 -2.44E-7
ADPE	[Kg St [M		177.00	2.62	5.58	0.00			14	0.33		9 E-0	2.33	0.00	-2.00E-0	-2.39E-0	-38.30	-2.44E-7
Captio	GWP	e Globa	al warmin	g potentia	al; ODP = = Format	Depleti	on poter ential of	ntial of th roposph	e stra eric o	tospher zone ph	ic oz	one la hemic	yer; AP al oxida	= Acidifica hts; ADPE resources	tion poter = Abiotic	tial of lan	d and wa	ter; EP =

Aggregating EPDs into a Project Model

The EC3 Tool could be a game-changer.

The Embodied Carbon in Construction Calculator (EC3) tool.

From the Carbon Leadership Forum (University of Washington).

Free and easy-to-use; allows benchmarking, assessment and reductions in embodied carbon.

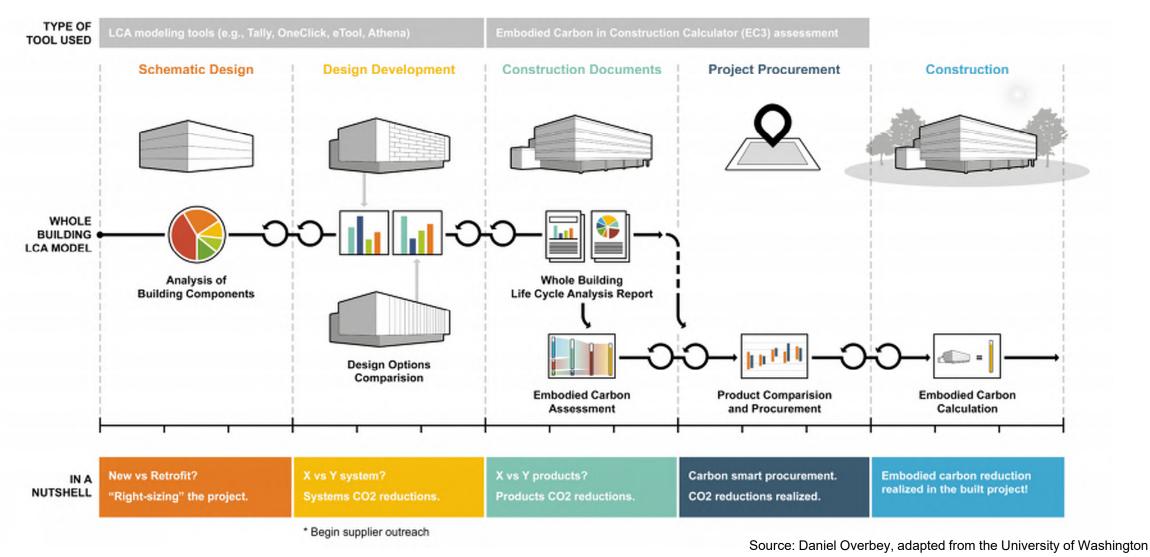
Allows for supply chain specific analysis of embodied carbon data, utilizing the first searchable and sortable database of all United States and Canadian Environmental Product Declarations (EPDs).

buildingtransparency.org

& Compare Materials	PRODUCT EPI	DS							
Concrete ReadyMix	Samples: 163	Achievable kgCO2e	: 227 Au	erage: 357 kgCO2e :	44.1% C	onservative: 466 kgCO	2e	Decla	ered Unit: 1 yd3
Shotcrete Slurry Paving ***	Subcategory ReadyMix V	✓ Manufact ♦ ♥ Compare	✓ Plant	v Product ●	✓ Descript	Compres	≰ EC3/1	yd3 o	Details
Precast Concrete 🐃	ReadyMix	Stoneway Conc	Black River	5C45437	Cadman Equal.	5000 psi	275 kgCO	2e	Details Vie
Cast Decks and Underlayment	ReadyMix	Stoneway Conc	Black River	458374C	FO, #8 CA, Cont.	5000 psi	285 kgCO	2e	Details Vie
Grouting Ner lasonry Ner wel luminium lood hermal/Moisture Proc. ladding Ner penings	Plant Name Product Nar Description: 80% confide	n Name: Stoneway C Black River ne: 458374C FQ, #8 CA, Control F nce GWP is below: 2 ed in EPD: 232 kgCO	low 85 kgCO2e				1,200 1,000 800 000	- 18	60
shes	Declared Ur	vit: 1 yd3					400		CJ fare
oring a Cabling ***	Concrete Co	impressive Strength	28D: 5000 psi				200	220	
ohait 🚧	Aggregate S	ize Max: 0.374 in							
gregates 🐃	Min Pipeline	Size: 1.5 in						HIS SEARCH	BELECTED MATERIAL

Source: University of Washington

Whole-Building Embodied Carbon Modeling Workflow



Gauging total carbon intensity



Shift the conversation to total carbon intensity.

Annual U.S. CO2e emissions: ~ 5 B Tonnes

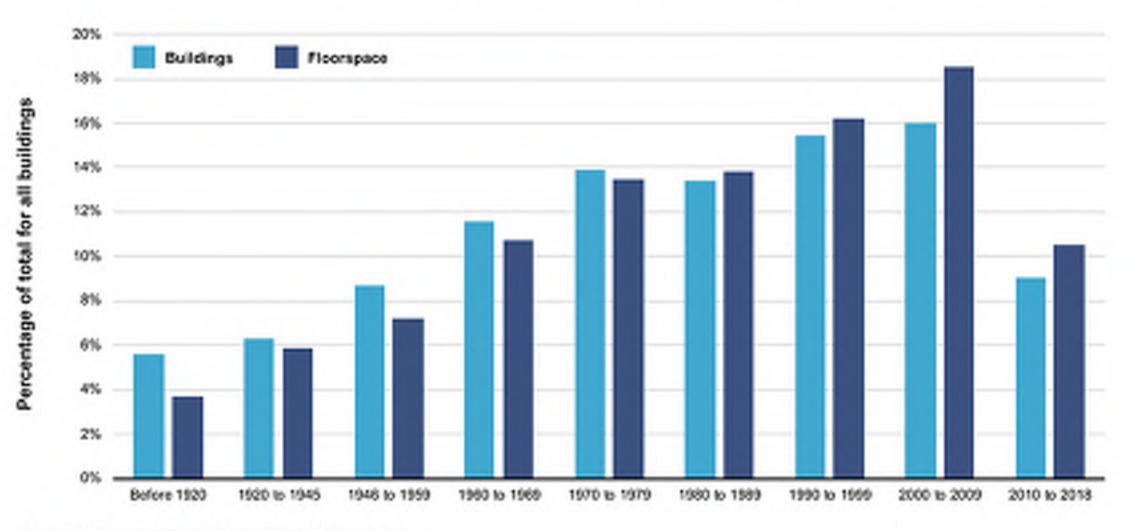
28% operational carbon: 1.4 B Tonnes 11% embodied carbon: 0.6 B Tonnes

Emerging data on embodied carbon suggests: < 150 kgCO2e/m2 = good > 1,000 kgCO2e/m2 = bad

We now tools and workflows.

Huge opportunity to improve existing buildings.

Share of Number of U.S. Buildings and Floorspace by Year Constructed

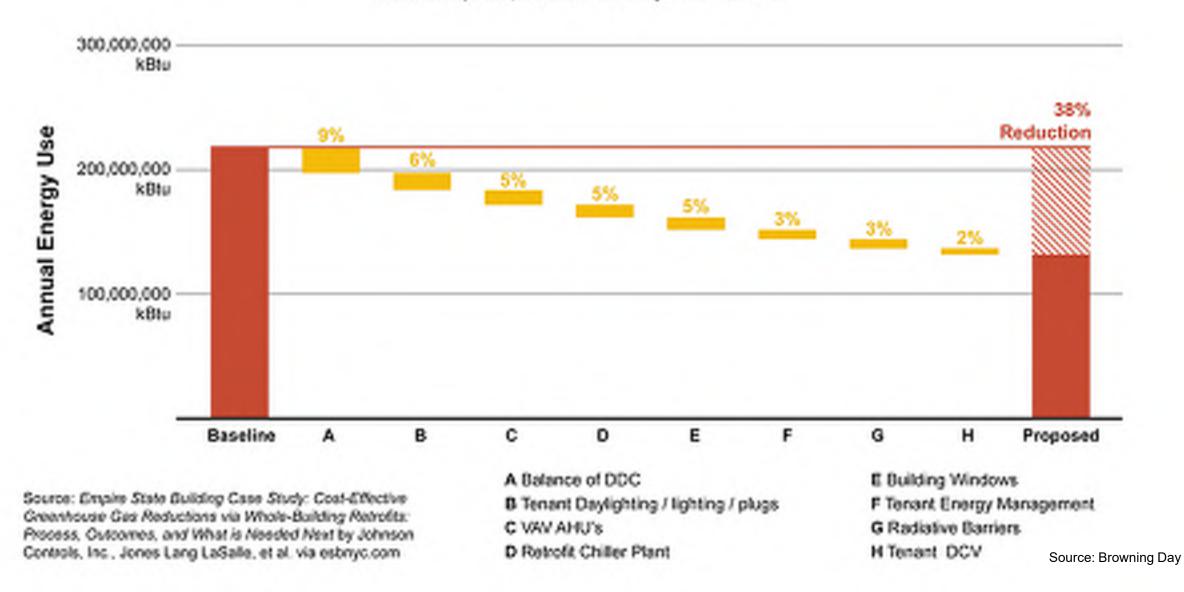


Source: 2018 Commercial Buildings Energy Consumption Survey, U.S. Energy Information Administration.

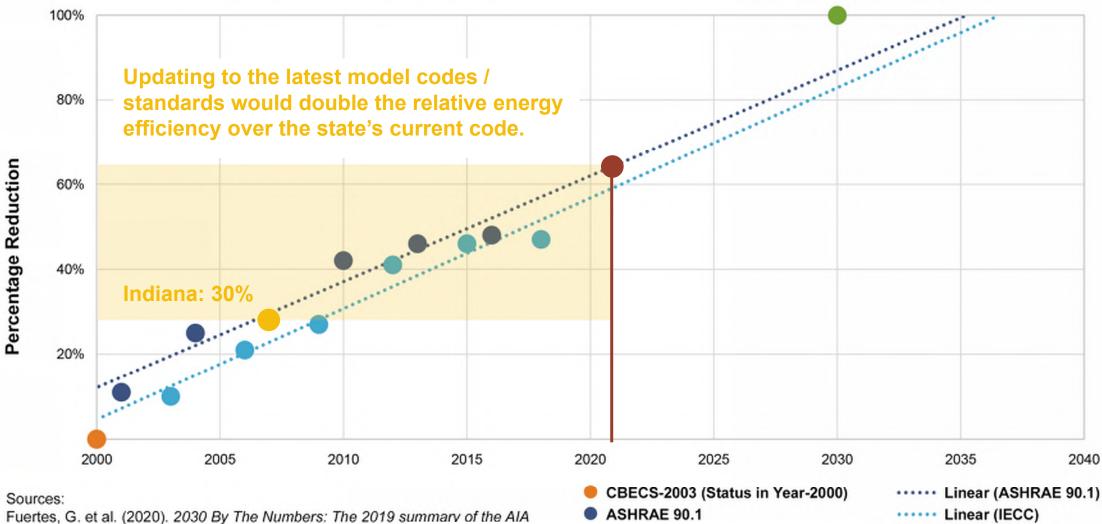
Source: Browning Day

Annual Energy Savings by Measure

Case Study: Empire State Building, New York, NY



Predicted EUI Reduction in Building Energy Codes (2000-2019)



2030 Commitment. American Institute of Architects.

Edelson, J. (2016). Zero Energy Performance Index (zEPI). №

Source: Browning Day

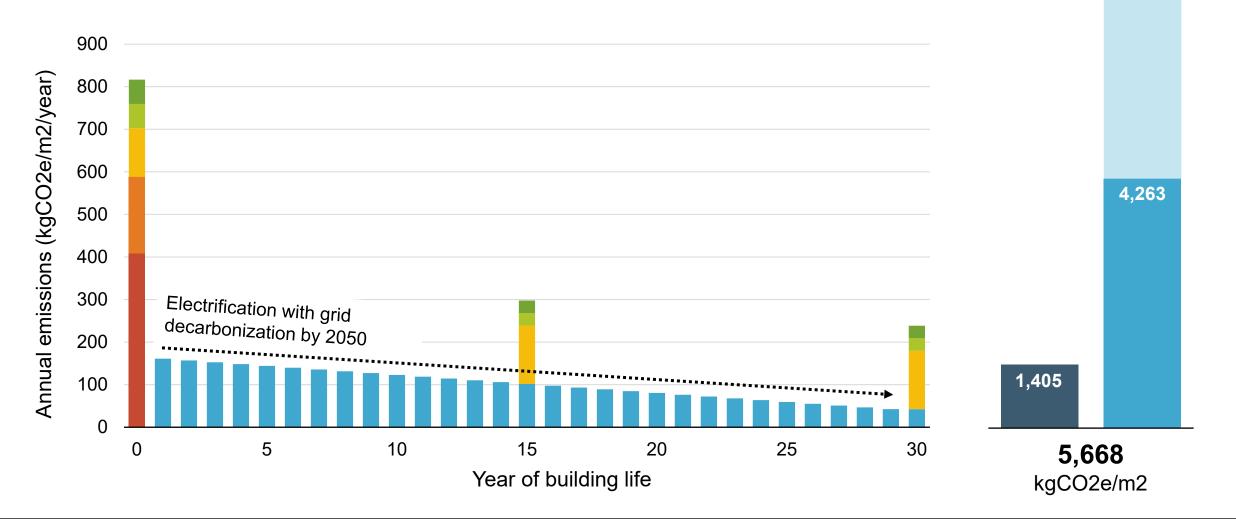
How low can we go?

Embodied Operational For a new building built in 2021 9,660 Embodied carbon = 36% of total carbon intensity (TCI) 900 Annual emissions (kgCO2e/m2/year) 800 Accounted for interiors, MEP systems, etc. 700 based on Strain data: 817 600 Our average embodied carbon: 588 500 Assume renovation every 15-years, based on Strain data. 400 300 Our average operational carbon: 161 200 1,405 100 0 5 15 20 25 30 11,065 0 Year of building life kgCO2e/m2

60-Year Lifetime Total Carbon Intensity

Embodied Operational

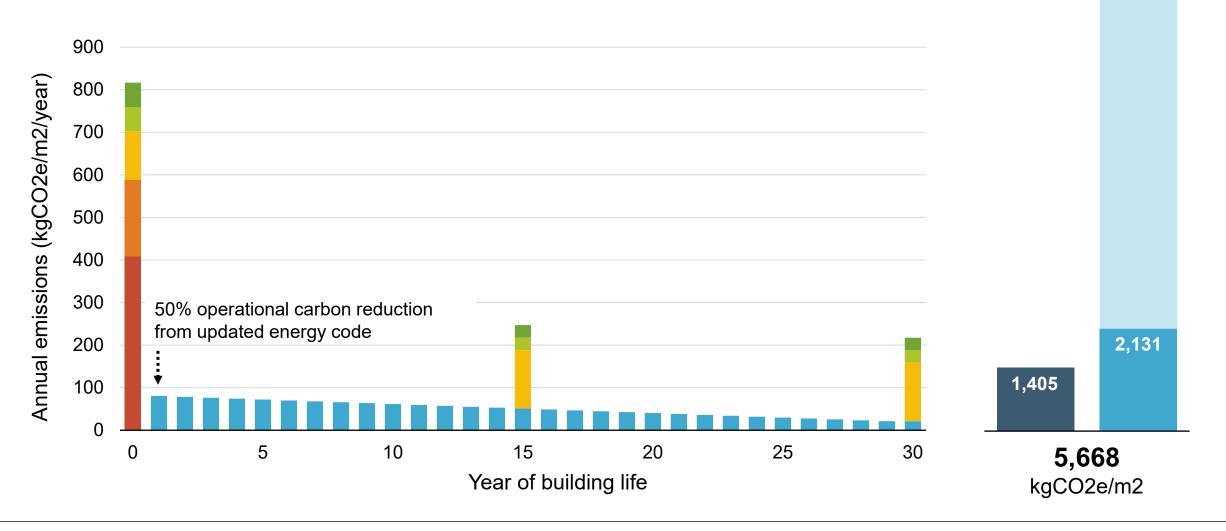




60-Year Lifetime Total Carbon Intensity

Embodied Operational

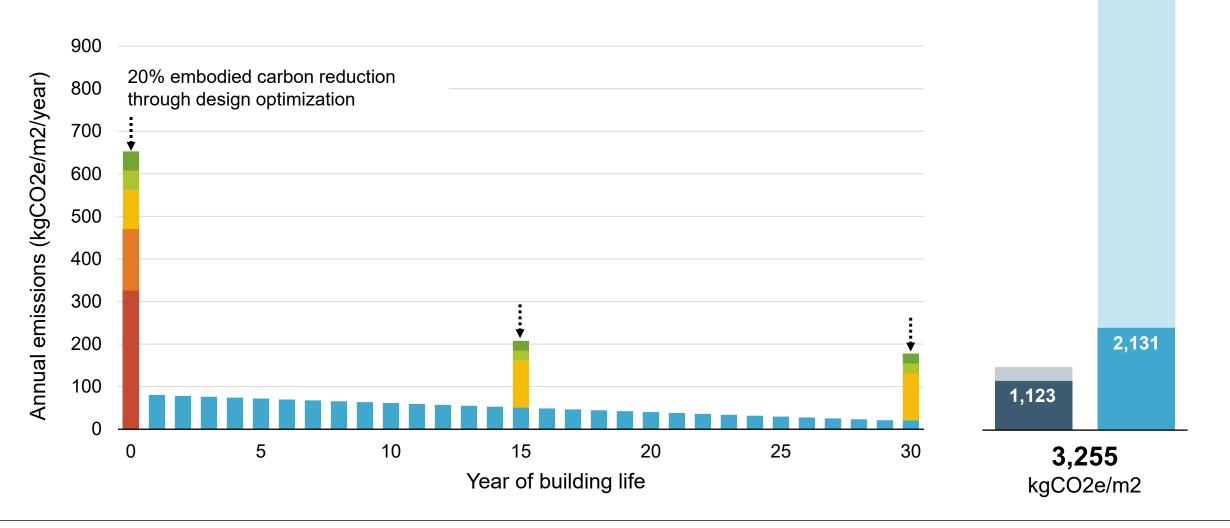
For a new building built in 2021



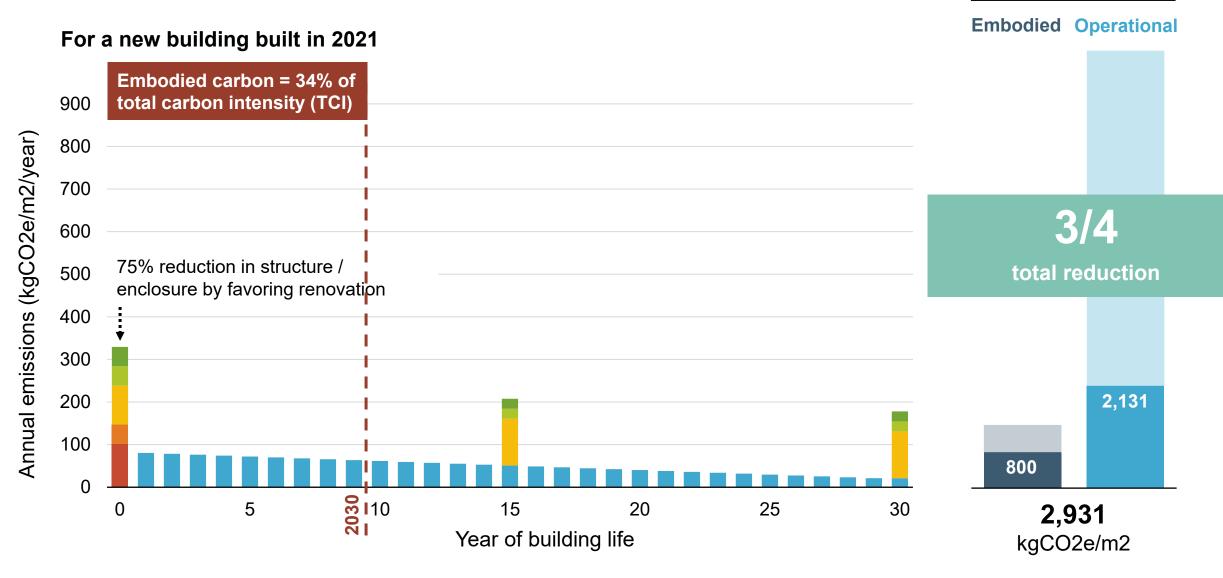
60-Year Lifetime Total Carbon Intensity

Embodied Operational

For a new building built in 2021



60-Year Lifetime Total Carbon Intensity



Four measures can reduce total carbon intensity by 3/4:

- 1. Electrification with grid decarbonization by 2050.
- 2. Updated energy code (and strive toward net zero).
- 3. Design optimization for (\geq 20%) embodied carbon.
- 4. Prioritize renovation.

These measure could reduce total U.S. emissions by 29%, saving over 1.5 Billion Tonnes of CO2e every year.

How to achieve zero carbon?

Operational carbon:

- Advanced refrigerants.
- On-site renewable energy with smart systems and demand flexibility.
- Utilize battery backups and EVs in an aggregator program.

Embodied:

• Carbon sink materials when possible.





Why Embodied Carbon Matters, and What You Should Do About It

Daniel Overbey, AIA, NCARB, LEED Fellow, WELL AP, EcoDistricts AP

REBUILD 2021

October 7, 2021

