Embodied Carbon: A Hidden Climate Solution

Alaska Center for Appropriate Technology

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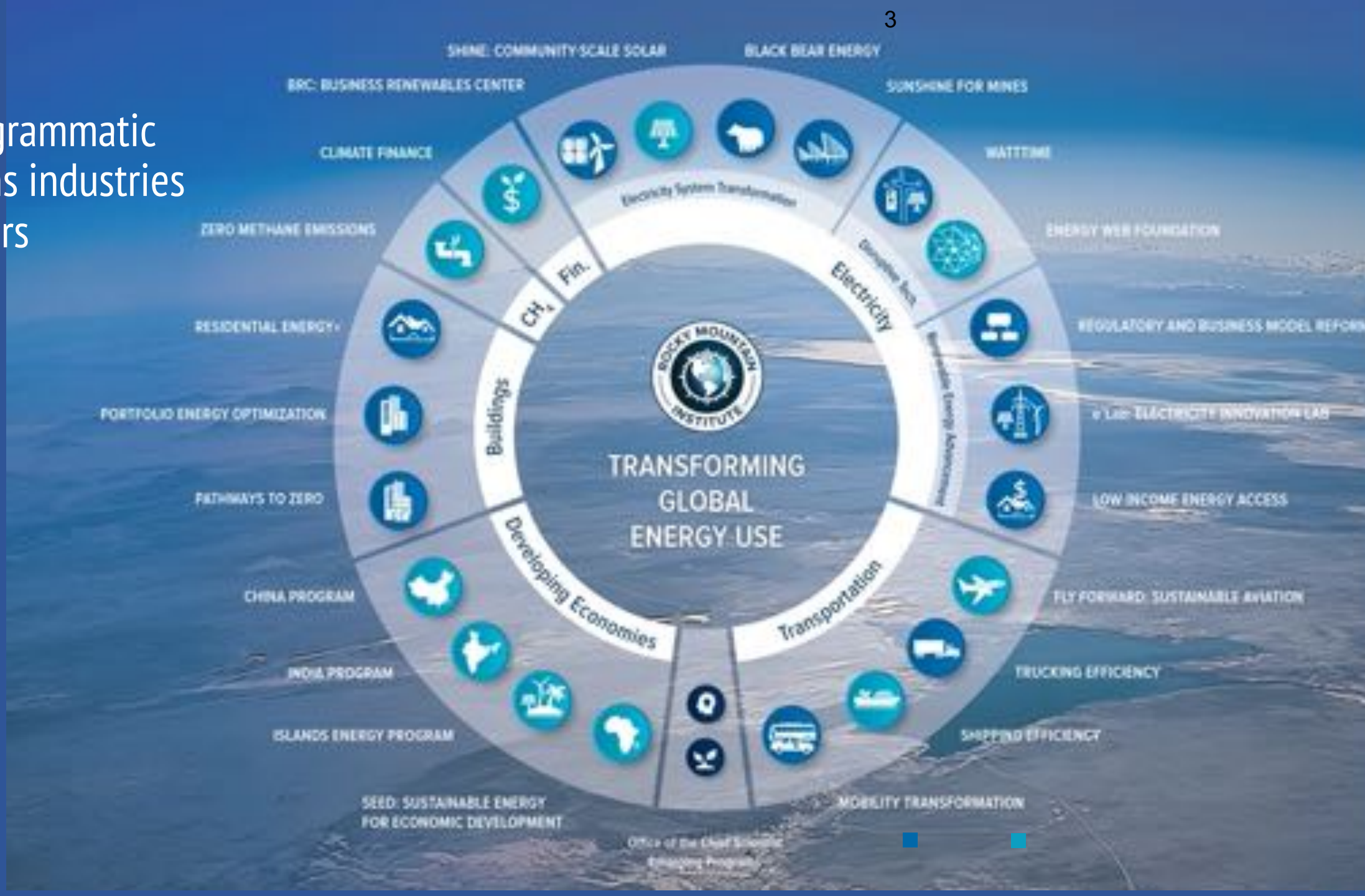
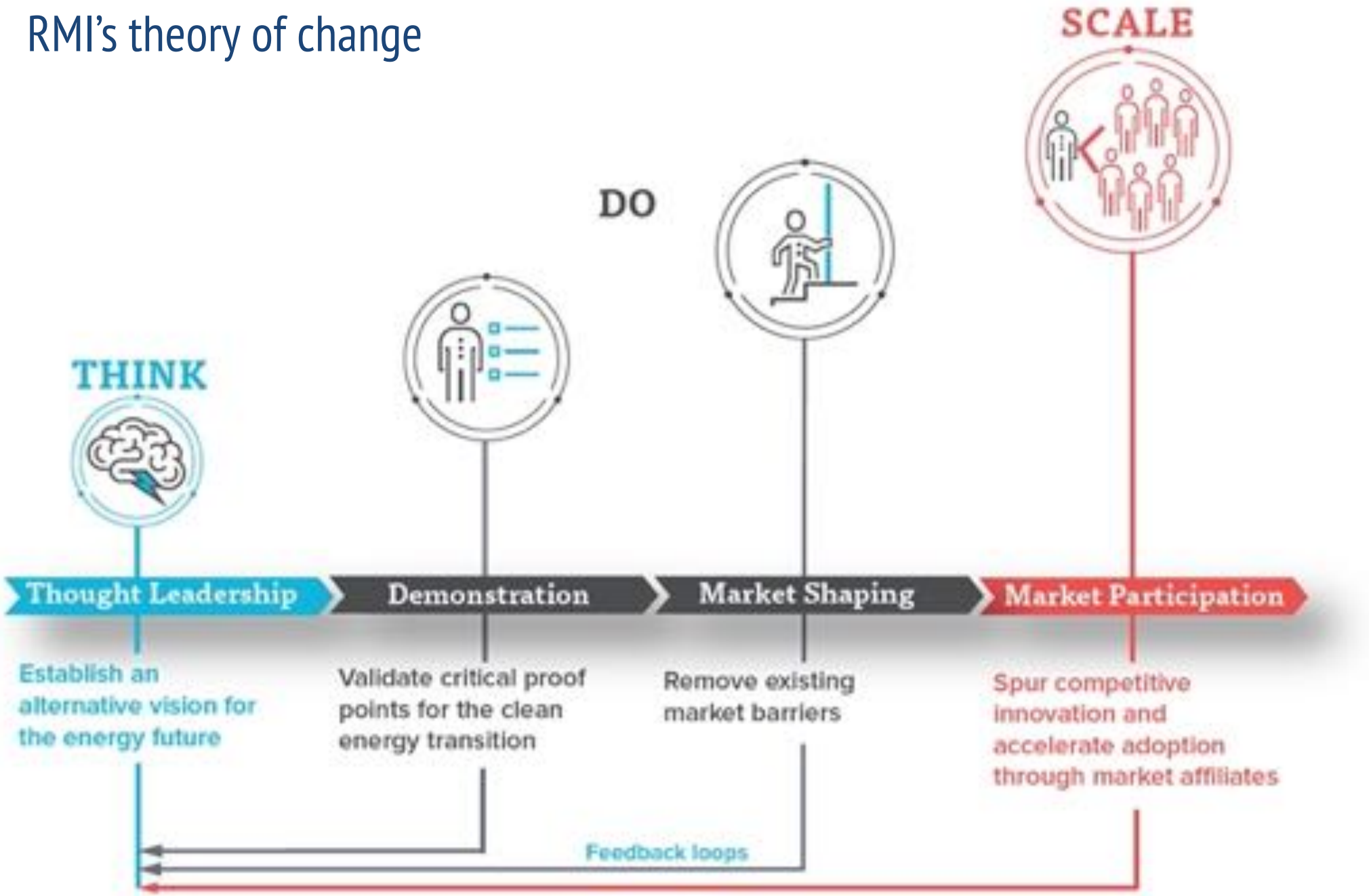
Principal
Carbon-Free Buildings

As an independent non-profit "think-and-do" tank, RMI engages businesses, communities, institutions, and entrepreneurs to transform the global energy system to secure a clean, prosperous, zero-carbon future for all

RMI's programmatic work spans industries and borders



RMI's theory of change



RMI Carbon Free Buildings group is driving progress through four key initiatives

CFB Initiatives	Description
Building Electrification	Driving the technical, policy, and regulatory solutions to accelerate the transition to **all-electric buildings.**
ABCC/REALIZE	Deploying high-quality, prefabricated **mass-scale net zero retrofit packages** that are easy to install and financed through utility cost savings.
Pathways to Zero	Catalyzing early movers on a path to district scale **zero carbon buildings, zero embodied carbon,** and **grid interactivity** by working with companies, campuses, districts, cities, states and the Federal Government.
Portfolio Energy Optimization	Accelerating commercial and residential building retrofits by streamlining energy project analysis and **investment prioritization across portfolios**.

The Recipe for Carbon-Free Buildings

Low Embodied Carbon

11% of global energy-related emissions are spent creating and transporting building materials

Zero Operational Carbon

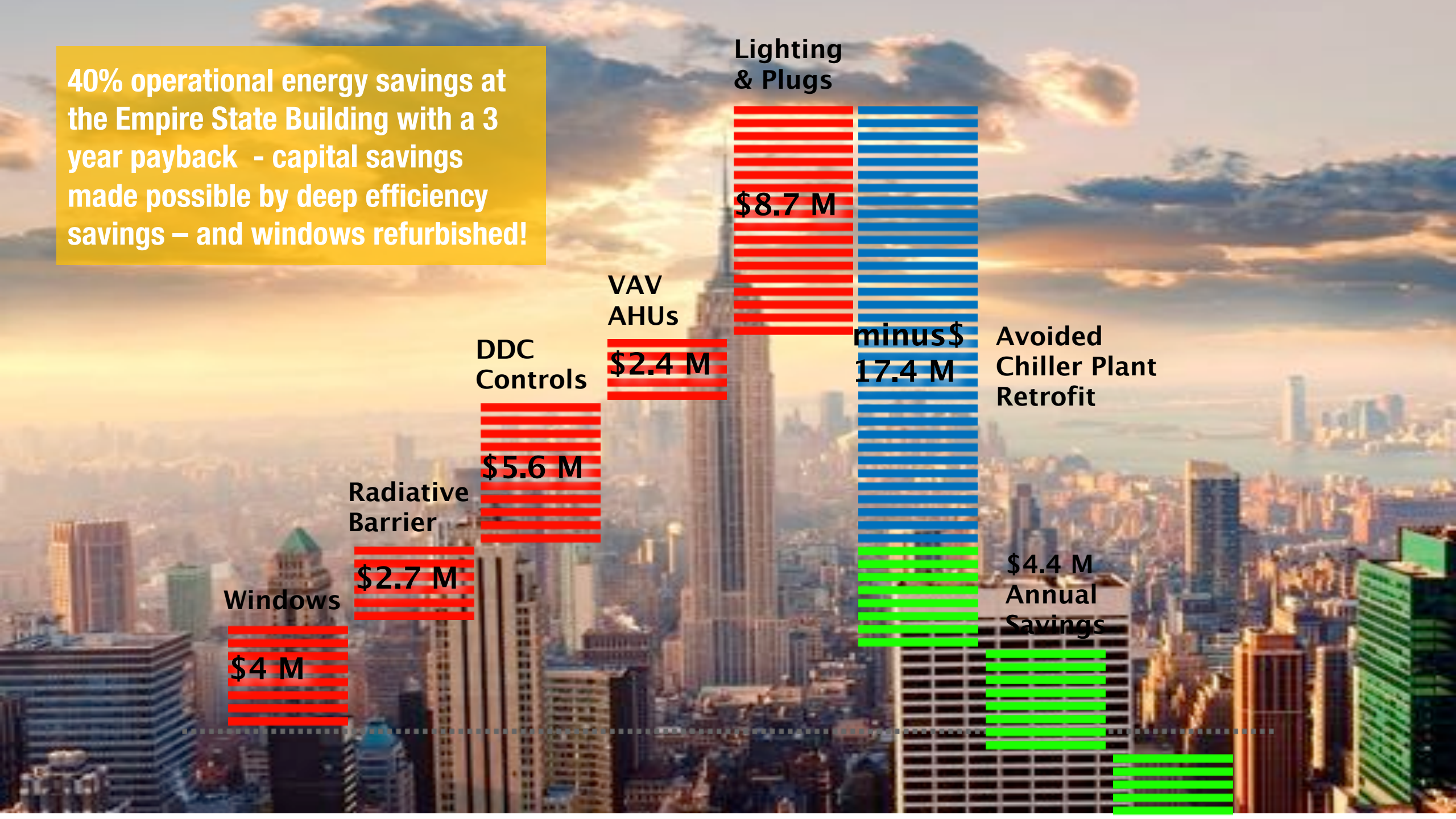
28% of global energy-related emissions are spent powering our buildings

28% Of global energy-related emissions are spent powering our buildings

Low Embodied Carbon + Efficiency + Electrification + Demand Flexibility + Renewable Energy + Low GWP Refrigerants = **carbon free, healthy, resilient buildings**

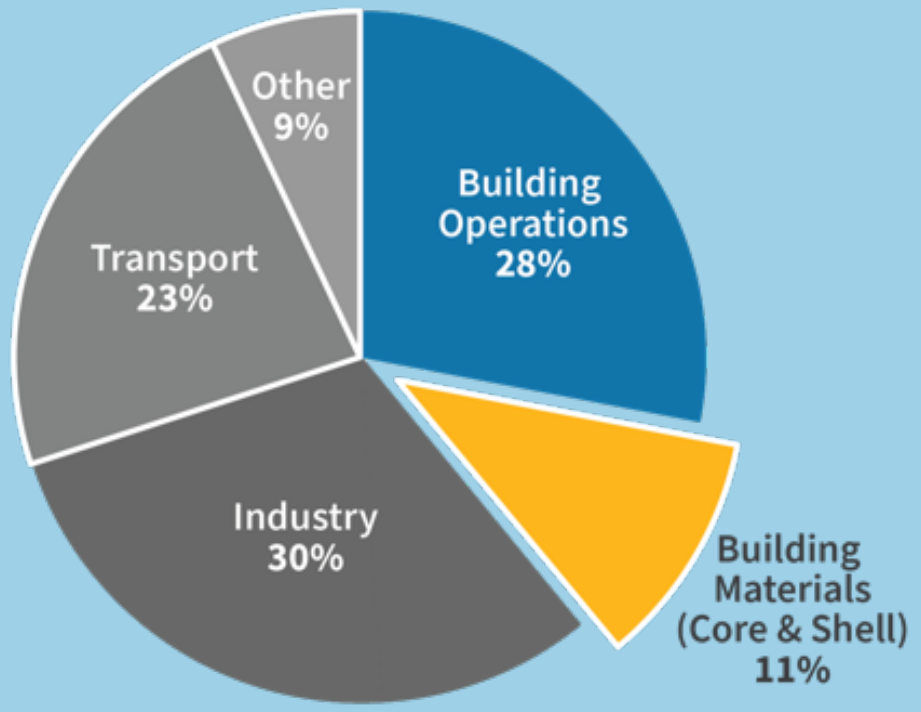
Contextual and Infrastructure Factors

- Industrial emissions (Raw materials extraction, processing, manufacturing and transportation)
- Carbon-Free Mobility (Managed EV charging and Public Transportation)
- Carbon-Free Electric Grid


40% operational energy savings at the Empire State Building with a 3 year payback - capital savings made possible by deep efficiency savings – and windows refurbished!
Lighting & Plugs
$8.7 M
VAV AHUs
$2.4 M
DDC Controls
$5.6 M
Radiative Barrier
$2.7 M
Windows
$4 M
minus$ 17.4 M
Avoided Chiller Plant Retrofit
$4.4 M Annual Savings

Embodied Carbon is **Significant**

Global energy-related CO2 emissions by sector:



Adapted from the UNEP 2019 Global Status Report

Building materials and construction currently constitutes the 4th largest source of energy-related emissions, at **11% of the global** annual total.

Embodied carbon is everywhere

Embodied carbon refers to the greenhouse gas (GHG) emissions associated with the manufacturing, transportation, installation, maintenance, and disposal of building materials.

Upfront embodied carbon focuses on the GHG emissions released before a building is constructed. These can also be thought of as **supply chain emissions.**

Image Source: *Carbon Leadership Forum, 2020*

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Low-Embodied Carbon Program

Embodied Carbon is an opportunity

Energy efficiency and grid decarbonization efforts will decrease operational carbon over time.

By 2050, it is projected that embodied carbon will take up almost half the total carbon emissions from new construction.

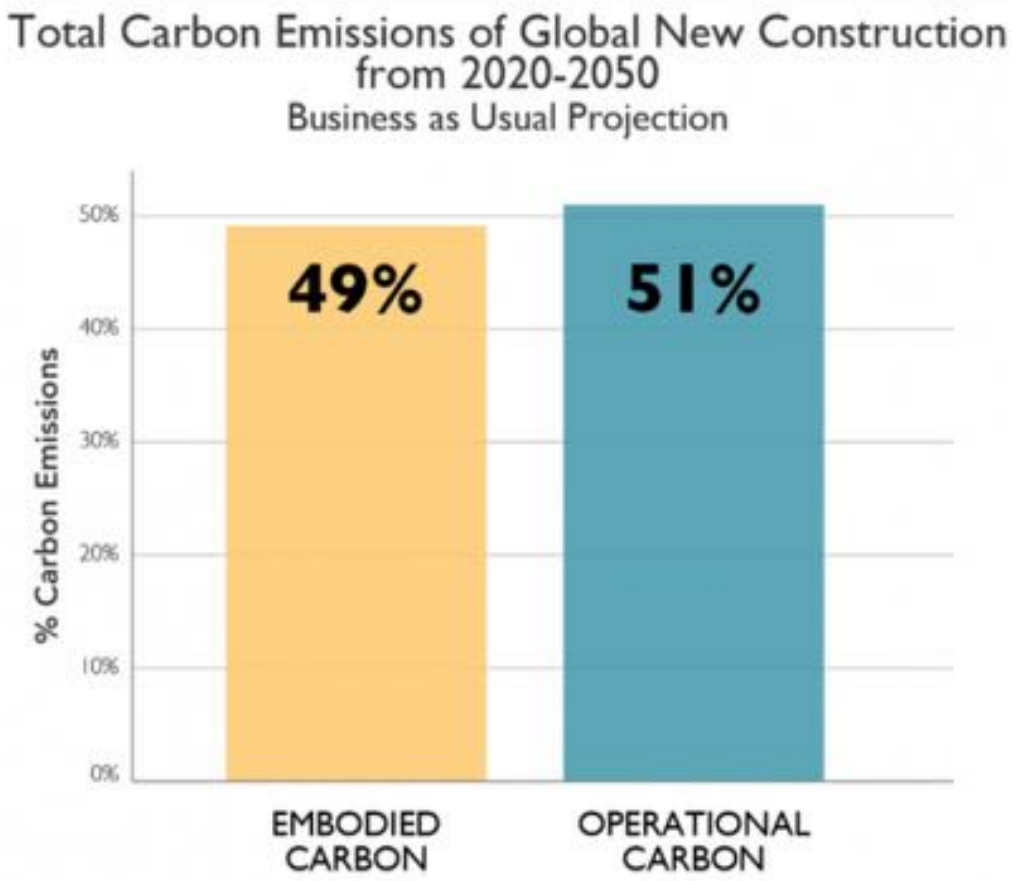

Image Source: *Architecture2030, 2020*

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Embodied carbon is urgent

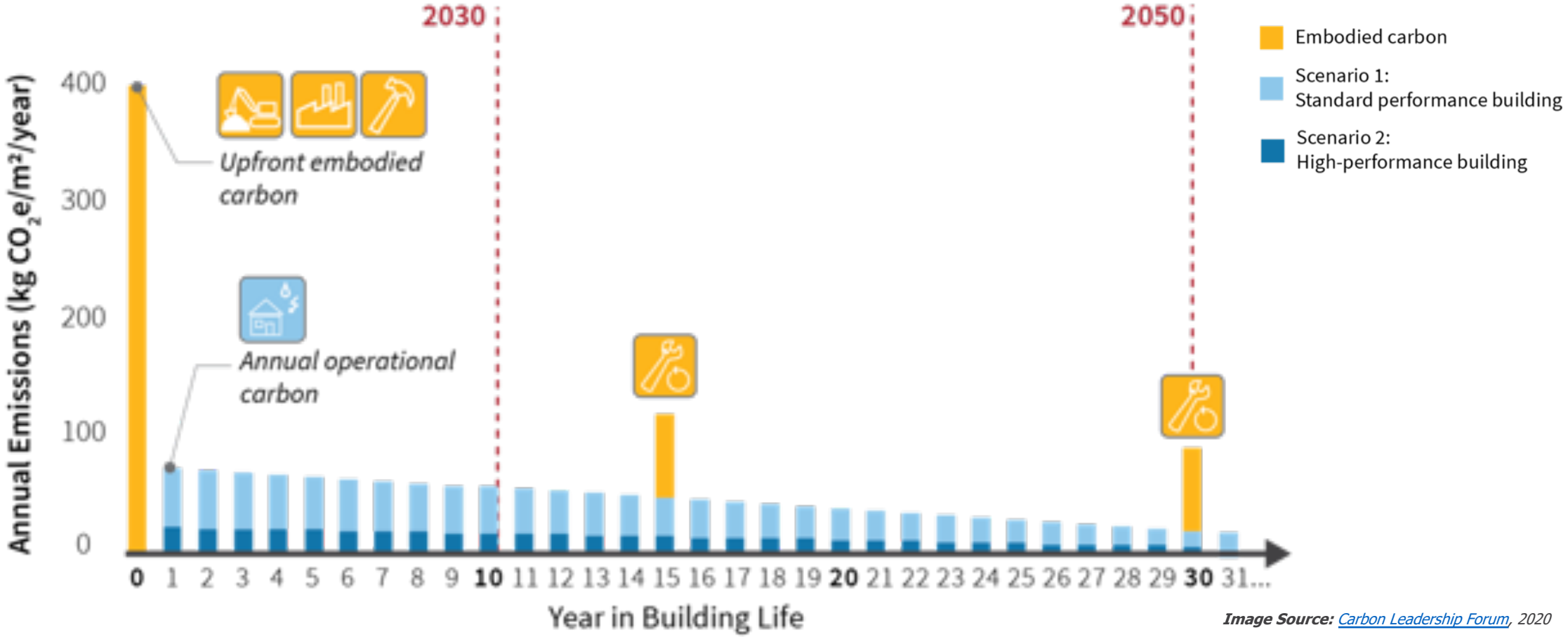

Image Source: *Carbon Leadership Forum, 2020*

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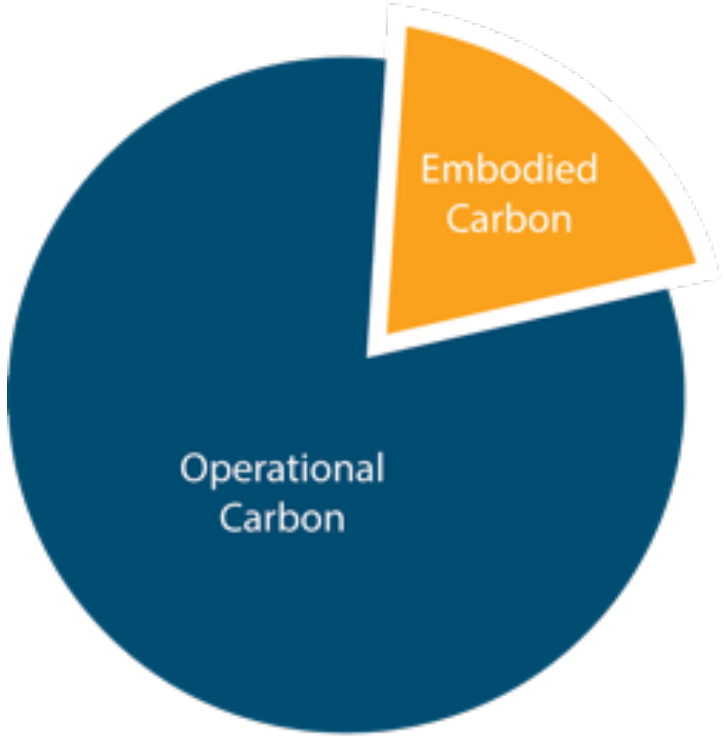
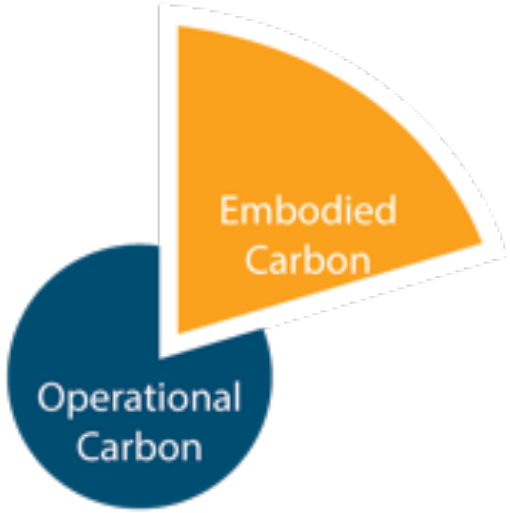
Embodied Carbon is proportionally increasing

Energy efficiency and grid decarbonization efforts will decrease operational carbon over time.

There are no analogous efforts for embodied carbon.



Building as Usual



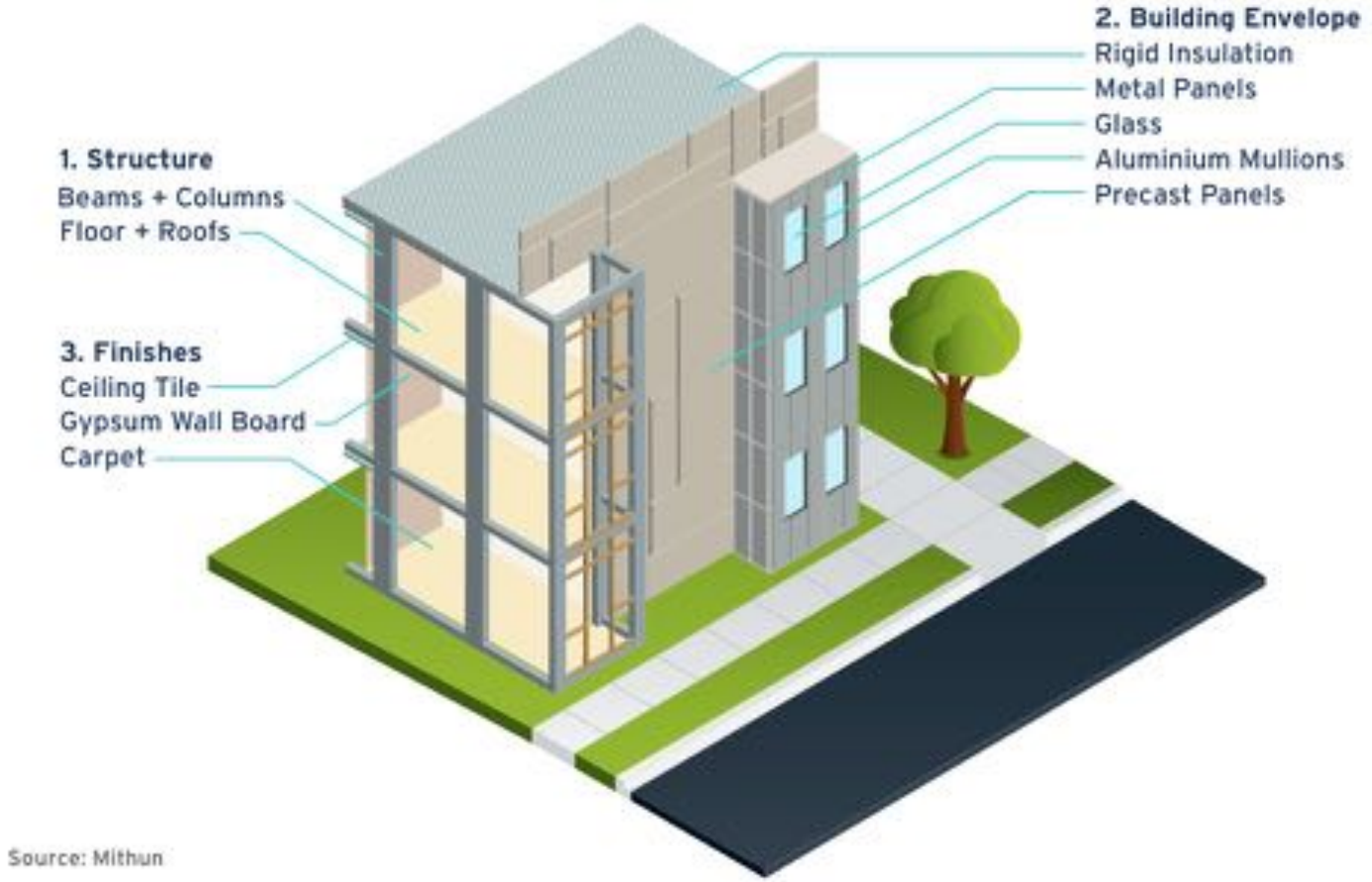
High Performance Buildings

Image Source: *Carbon Leadership Forum, 2020*

Strategies for reducing embodied carbon

Typical Embodied Carbon Hotspots

Most of a building's embodied carbon is attributable to structural materials, building envelope materials, and certain finishes.



Source: Mithun

Opportunities for reductions

Whole-Building Design Concepts	Material Substitution	Specification

Strategies
• Make design decisions that reduce embodied carbon
  • Example: Use less materials overall
  • Example: Use existing buildings
	Strategies
	• Use alternate, low-carbon materials to do the same job
	  • Example: Use timber instead of steel
	  • Example: Use carbon sequestering materials
		Strategies
		• Specify the carbon limit for a material
		  • Example: Specify low-embodied carbon concrete

Top building material categories for reducing embodied carbon

Case Study - Material Approach

Helen Sommers Building, Olympia, Washington

27% embodied carbon reduction

The Helen Sommers Building constructed for the State of Washington used a procurement approach to lower the carbon footprint of the concrete used on the project by 27% compared to the Pacific Northwest average, saving over 1,300 metric tons of greenhouse gas emissions.

Estimated reductions: 1,300 metric tons of CO2e

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Case Study – Building Re-Use

Building 610 Police Station, Denver CO

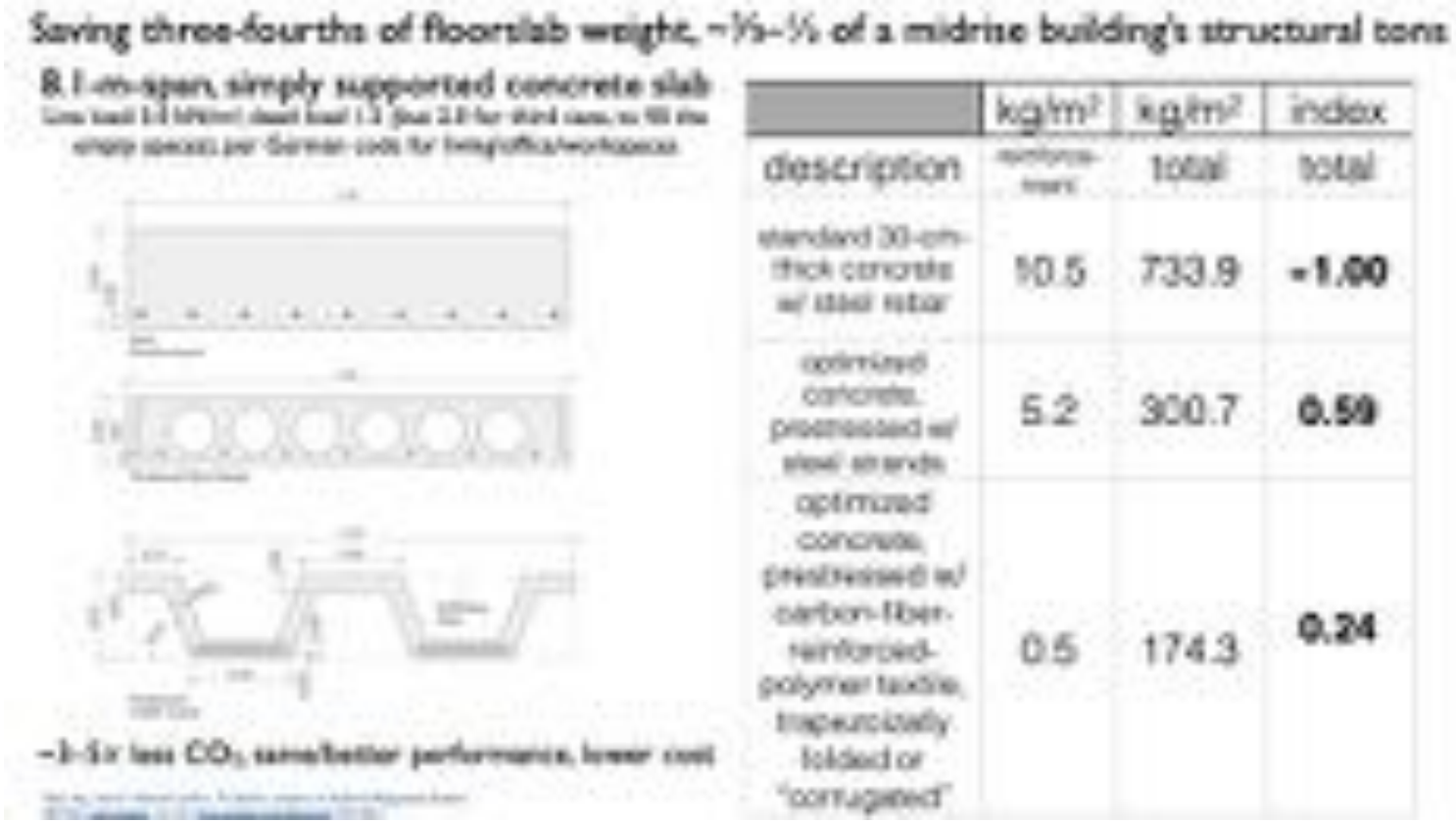
Existing warehouse re-use

Instead of demolishing a simple warehouse to make way for a new building, the design team took advantage of the opportunity to re-use the building's shell, saving money while reducing emissions.

Estimated reductions: 153 metric tons of CO2e are bundled up in the reuse of building 610

Example: Use Less Materials Overall

- Design for structural efficiency and material savings to reduce embodied carbon and lower up-front costs
- Lighter structures lead to "compounding efficiency"
- Tip: Conduct a whole-building Life cycle assessment (WBLCA) and track embodied carbon in terms of kilograms of CO2e per square foot



Example: Use timber instead of steel

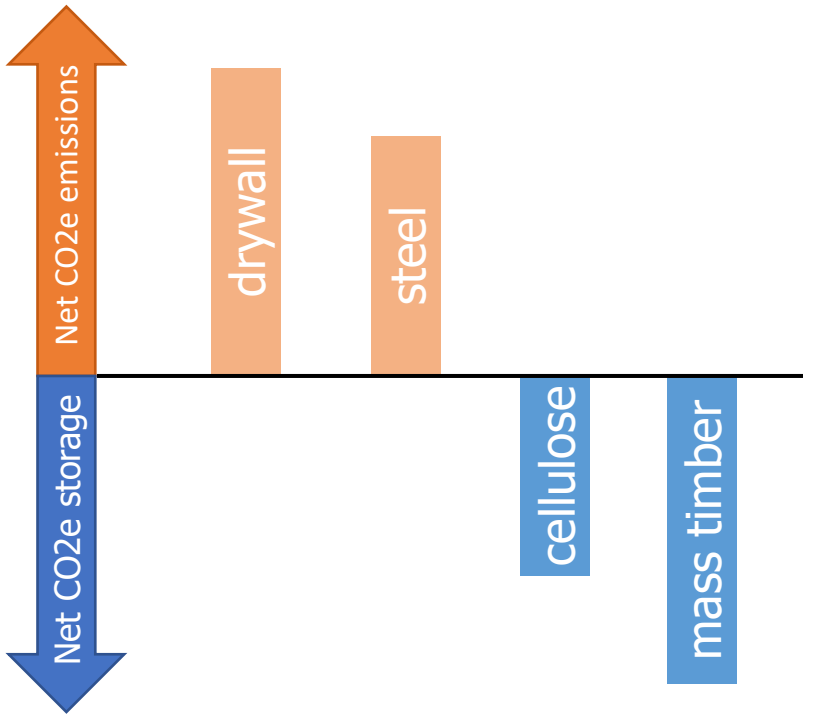
- Timber is typically seen as a lower-carbon alternative to steel and concrete when used as a structural material

- Tip: Differences in harvesting practices produce great disparities in the amount of carbon sequestered. Look for sustainably grown products, such as those certified by the Forest Stewardship Council (FSC)

Brock Commons, University of British Columbia
Image Source: KK Law

Example: Use carbon sequestering materials to achieve net-zero embodied carbon buildings

- It is possible to achieve net-zero embodied carbon, or even negative embodied carbon buildings
- Carbon Sequestering Materials: plant-based materials that store more atmospheric carbon than was emitted in harvesting & manufacturing
- Tip: Use carbon negative materials to offset carbon intensive materials and achieve net zero embodied carbon

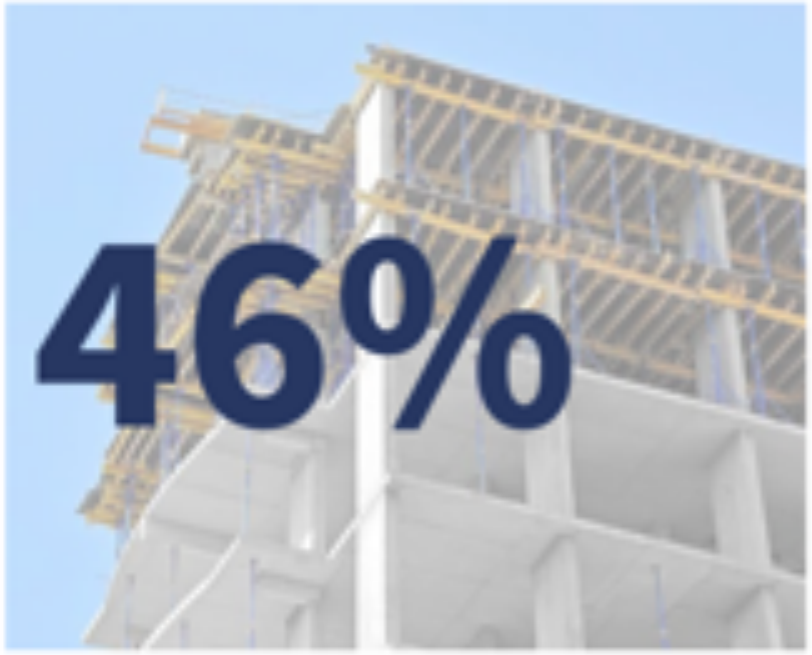


Illustrative graph

The cost of reducing embodied carbon

Case Studies in Embodied Carbon Reductions

Achieved Reductions:



Steel reinforced concrete slab

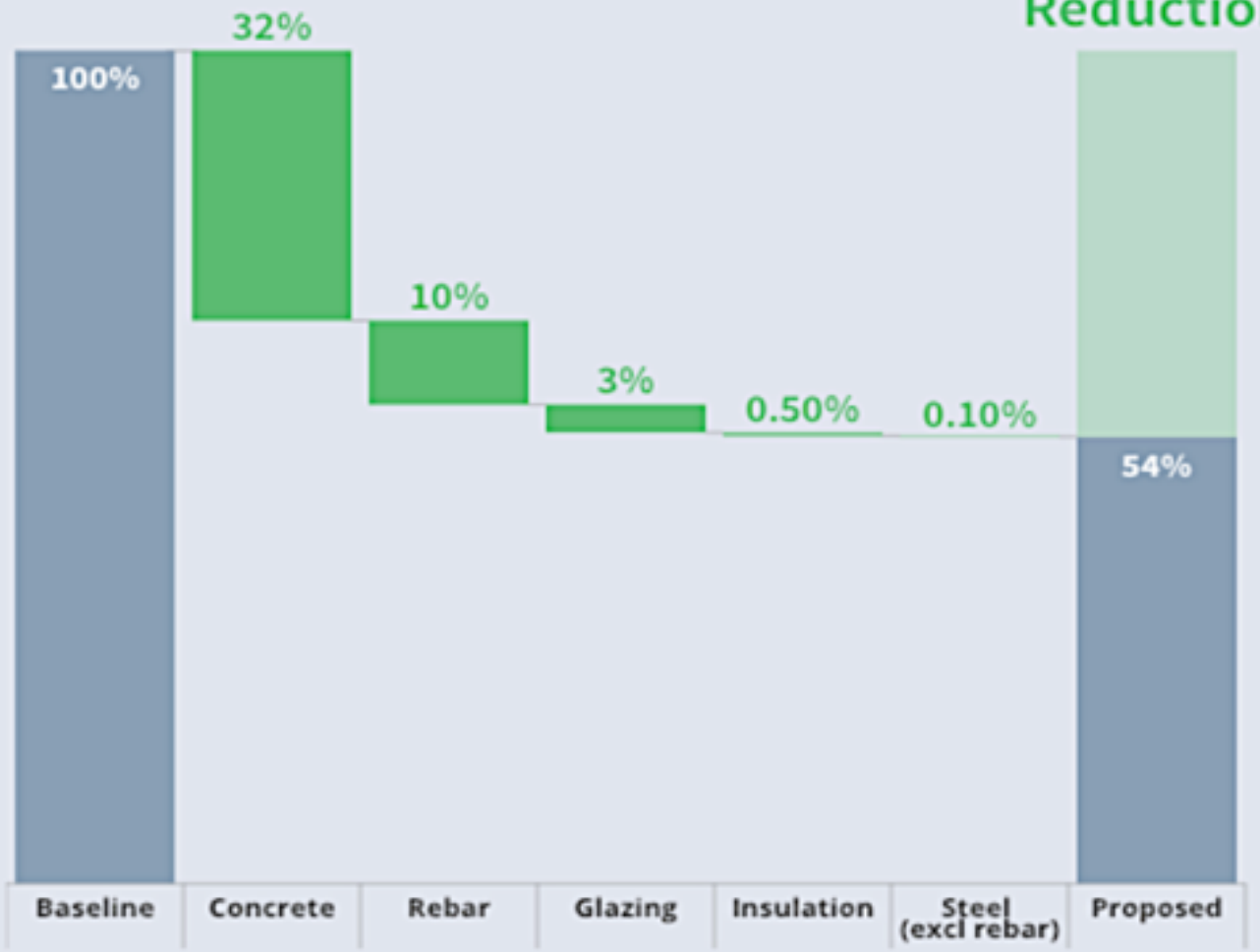
Wood-framing with concrete slab

Tilt-Up concrete

Case Study 1: Mid-Rise Concrete & Steel Construction

- Five-story
- 200,000 ft²
- Mixed-use office building
- Steel-reinforced concrete slab
- Above-grade construction

Embodied Carbon Reduction by Material Category



CO_2e reduced (metric tons)

2,228

Up-front embodied carbon reduction from baseline

46%

Cost premium of low-embodied-carbon measures

< 0.5%

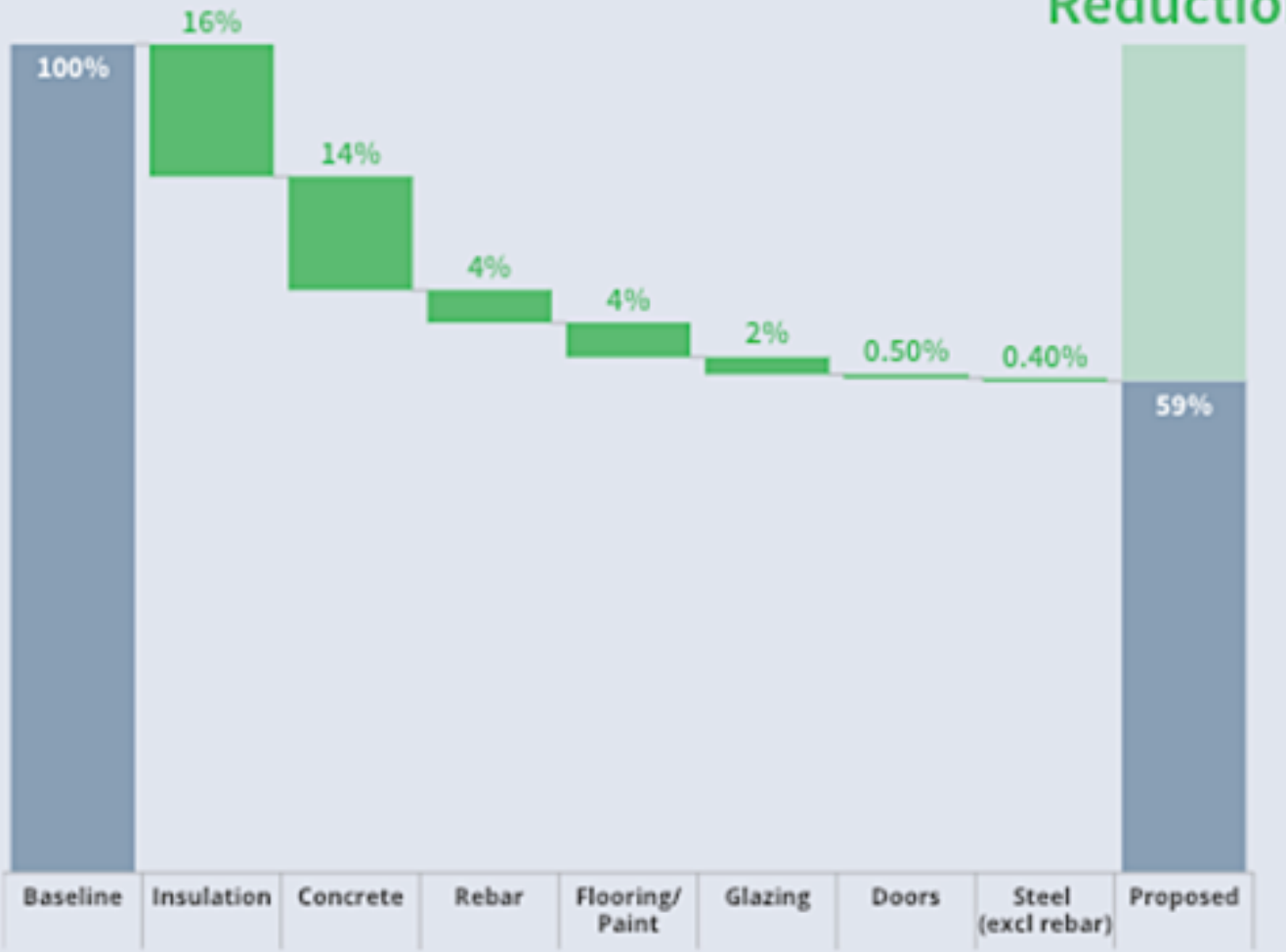
Of Total Budget

Case Study 2: Mid-Rise Stick-Built Construction

- Six-story
- 125,000 ft^2
- Mixed-use multifamily building
- Lumber framing above a steel-reinforced concrete slab
- Above-grade construction

Embodied Carbon Reduction by Material Category

41% Total Reduction



CO_2e reduced
(metric tons)

1,482

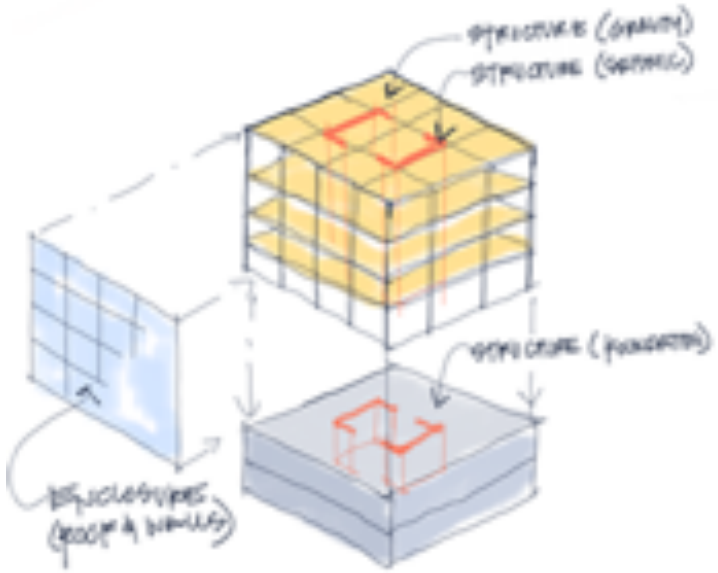
Up-front embodied carbon reduction from baseline

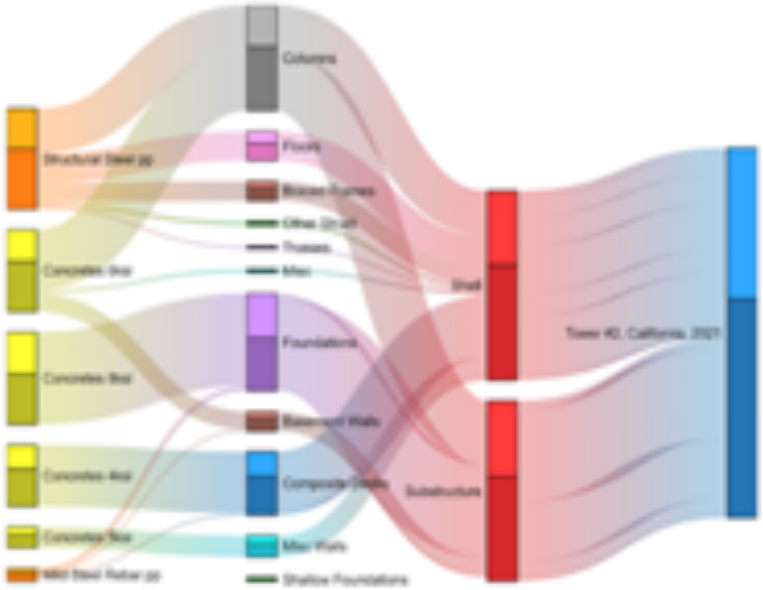
41%

Cost premium of low-embodied-carbon measures

< 0.5%
Of Total Budget

Process for Case Study Analysis





MATERIAL QUANTITY ESTIMATE

EMBODIED CARBON PER MATERIAL EPDs

BUILDING EMBODIED CARBON (EC) ESTIMATE

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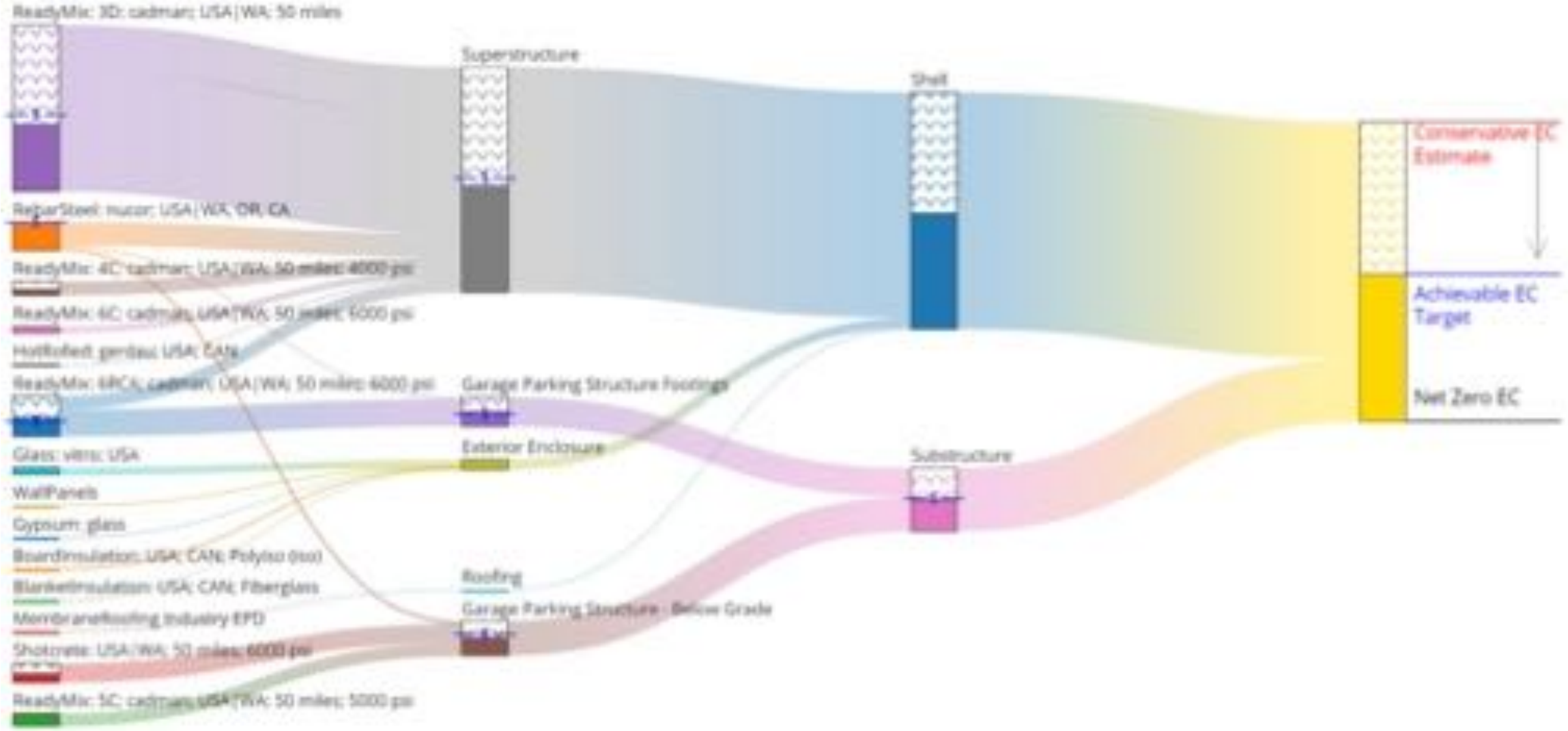
Process for Case Study Analysis

Up-front embodied carbon reduction from baseline: **46%**



Concrete Solutions Guide

1. **Know Your Numbers:** Performance-Oriented Specifications

2. **Mix It Up:** Supplementary Cementitious Materials (SCMs)

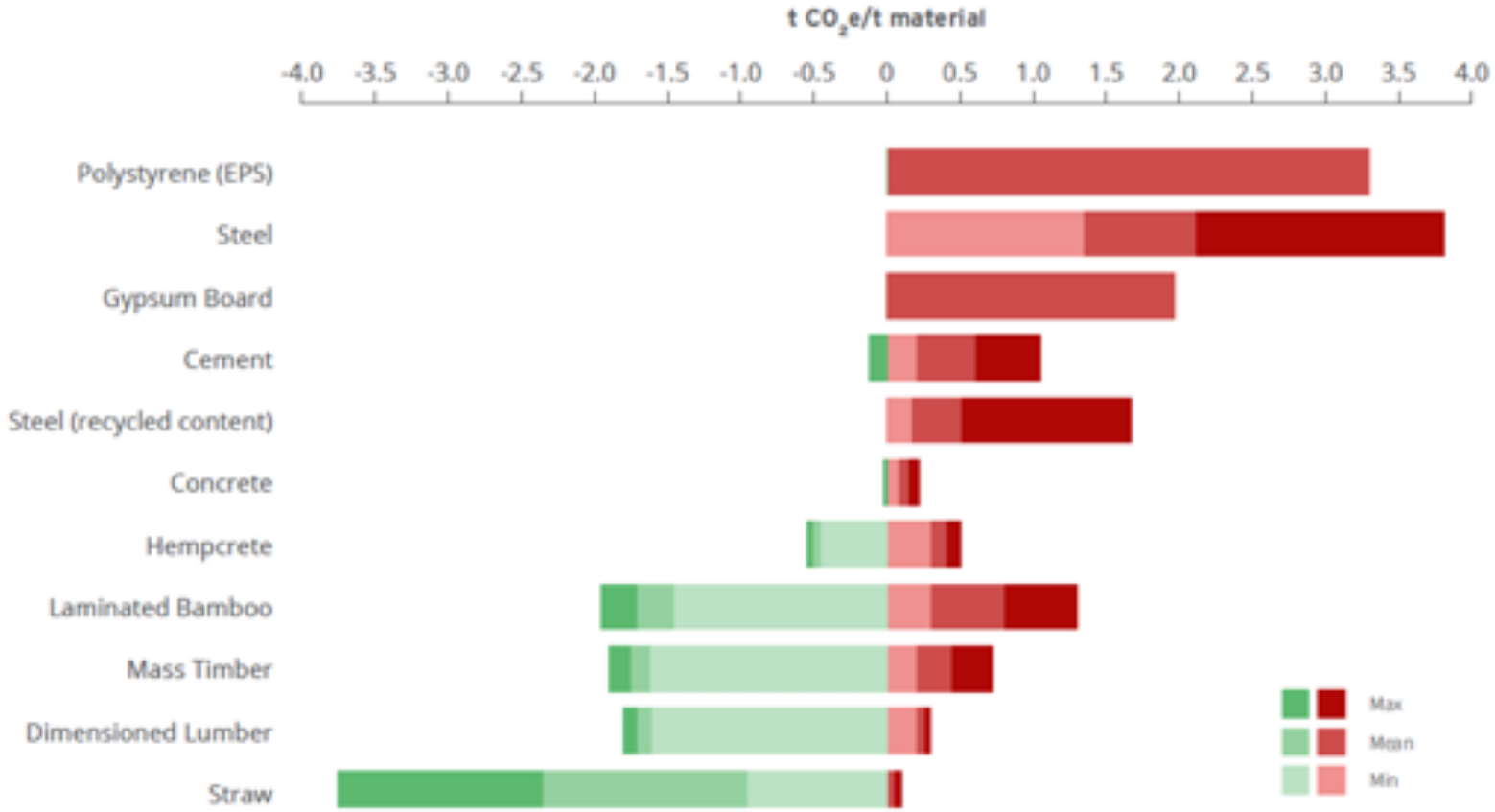
3. **Plug and Play:** Sensors Can Save Time, Money, and Materials

4. **Embrace Circularity:** Concrete Recycling

5. **Carbon as a Service:** Sequestering CO2 in Concrete

6. **Use Green Heat:** Decarbonize Kiln Technology

Carbon storage in a selection of building materials



Source: Table S6, Galina Churkina et al., "Buildings as a Global Carbon Sink," Nature *Sustainability*, 2020

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Example: Lower-carbon insulation

- Insulation products vary widely in embodied carbon
- Can start with avoiding insulations with HFC blowing agents while availability/comfort with carbon-storing insulations grows

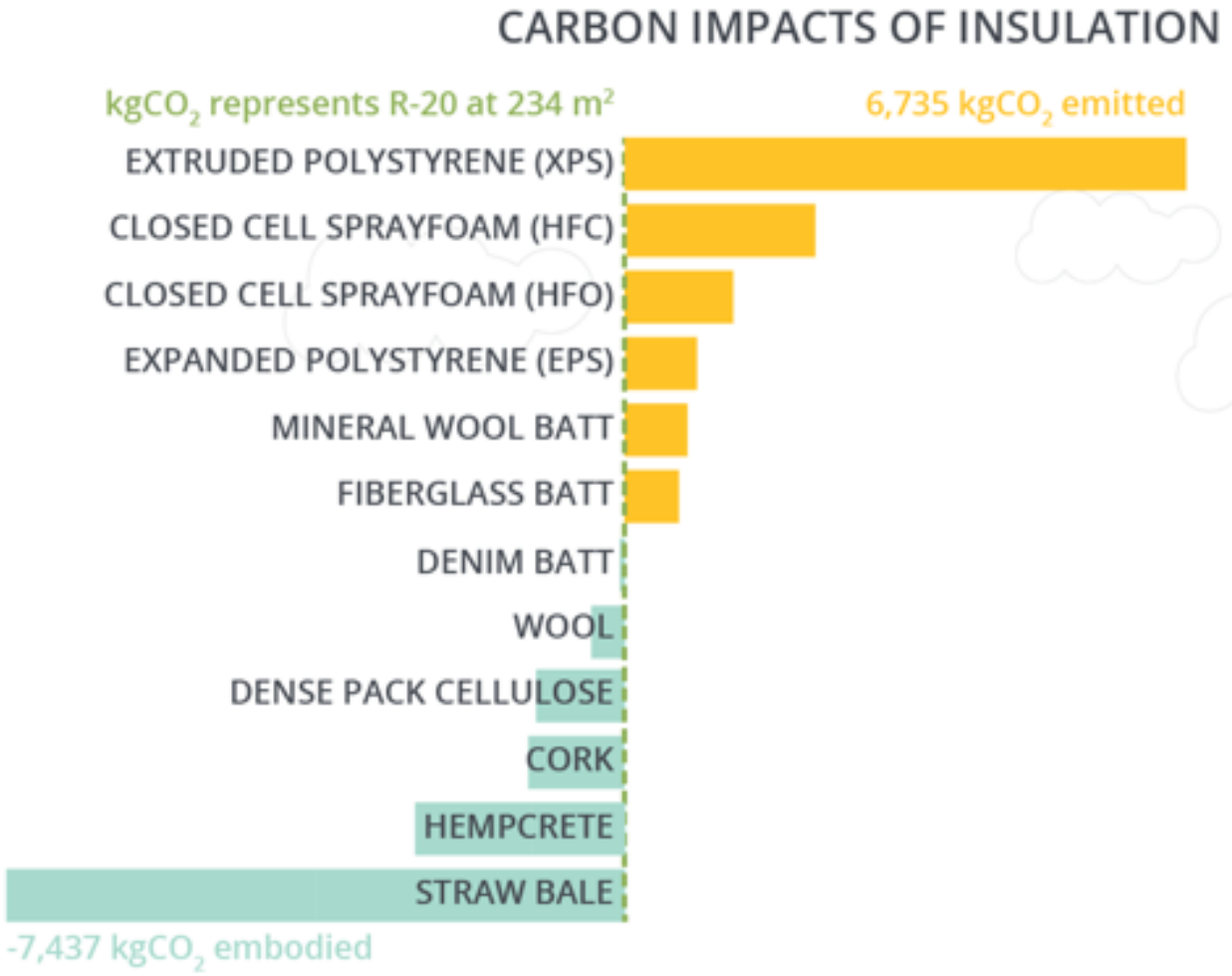

Image Source: [Architecture 2030]

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Alternatives to Traditional Construction Materials & Processes are Emerging

	Examples
Market-ready Materials that are readily available but have not yet achieved high market penetration	• **Plant-based** insulation products • Carbon-negative carpet backing • **Lightweight** wallboard products • Graphene-infused carbon-sequestering paint • Type 1L cement • Next-gen, low-GWP XPS insulation
Near-market ready Materials that are available on a small- or pilot-project scale but are not yet broadly available on the market	• Alternative cement chemistries and processes • **CO2-injected** cement products • Plant-based wall panels • **CO2-sequestered** aggregates for concrete • Magnesium oxide wallboard • Laminated bamboo lumber/structural bamboo
In Development Materials that are readily available but have not yet achieved high market penetration	• Zero-carbon steel • Glass pozzolan SCMs • Cement production powered by **alternative fuels** • Self-healing and living materials

Source: Exhibits 9-11, Reducing Embodied Carbon in Buildings

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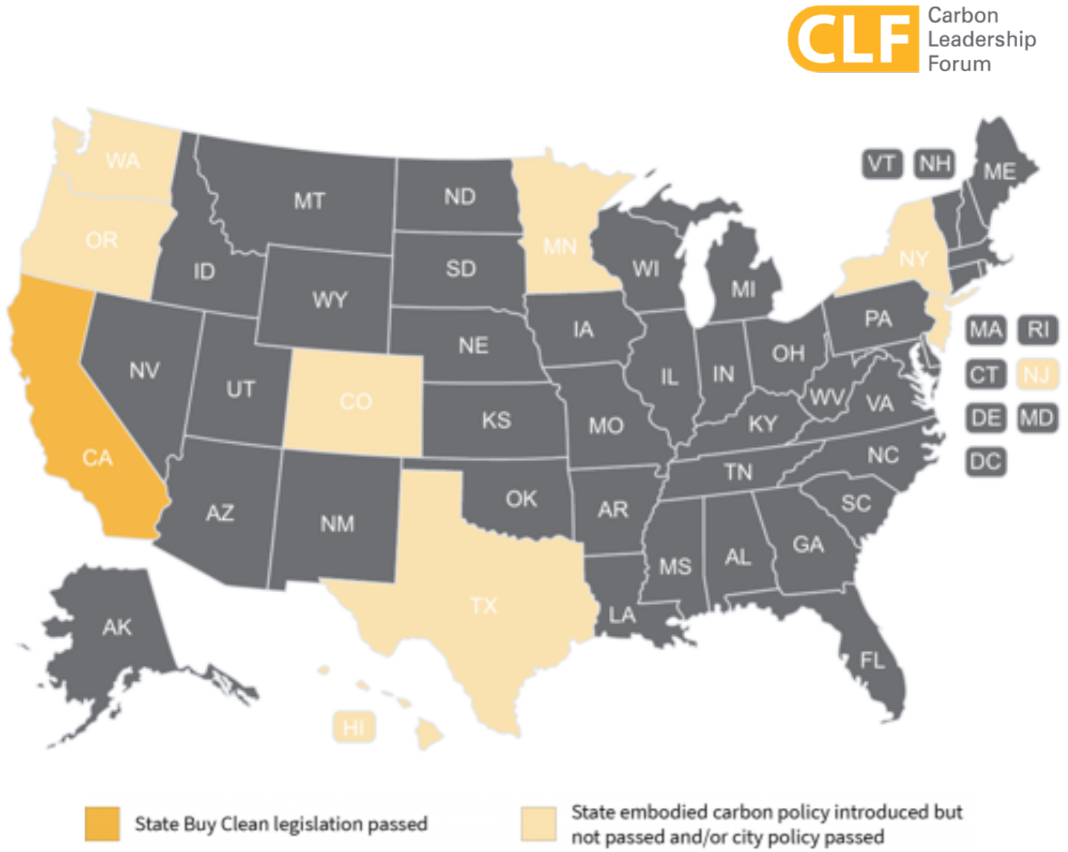
Low-Embodied Carbon Program

Growing embodied carbon-focused policy landscape

- **Federal Procurement** (H.R.1512) + GSA program
- **State Procurement** bills passed in 3 states (CA/CO/NY) and introduced in 5 others (WA, OR, MN, NJ, CT)
- **Local**
  - **Reuse** policies like LA, Portland, San Antonio,
  - **Zoning** like in Vancouver, B.C
  - **Building Codes** like Marin County Low Carbon Concrete Code pass 2019
  - **Climate action plans** such as in Vancouver, King County, Austin, Bay Area
  - **Green building incentive programs** like in Seattle, San Diego, Austin, Somerville
  - **Procurement policy & programs** like in LA, Portland, PANYNJ, Port of Seattle, and Sound Transit



https://carbonleadershipforum.org/clf-policy-toolkit/

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Signed into law by Governor Jared Polis, on July 6th, 2021

This bill sets maximum global warming potential for materials used in public projects, including buildings, roads, highways and bridge projects. GWP is based on EPD type limits, will be reviewed every four years, and will be required on projects solicited after January 1st, 2024

An Act

Buy Clean Colorado Act

HOUSE BILL 21-1303

Concerning measures to limit the global warming potential for certain materials used in public projects

THIS APPLIES TO THE FOLLOWING MATERIALS:

(I) ASPHALT AND ASPHALT MIXTURES;
(II) CEMENT AND CONCRETE MIXTURES;
(III) GLASS;
(IV) POST-TENSION STEEL;
(V) REINFORCING STEEL;
(VI) STRUCTURALSTEEL;AND
(VII) WOOD STRUCTURAL ELEMENTS.

Thank you!

For more information visit
rmi.org/buildings