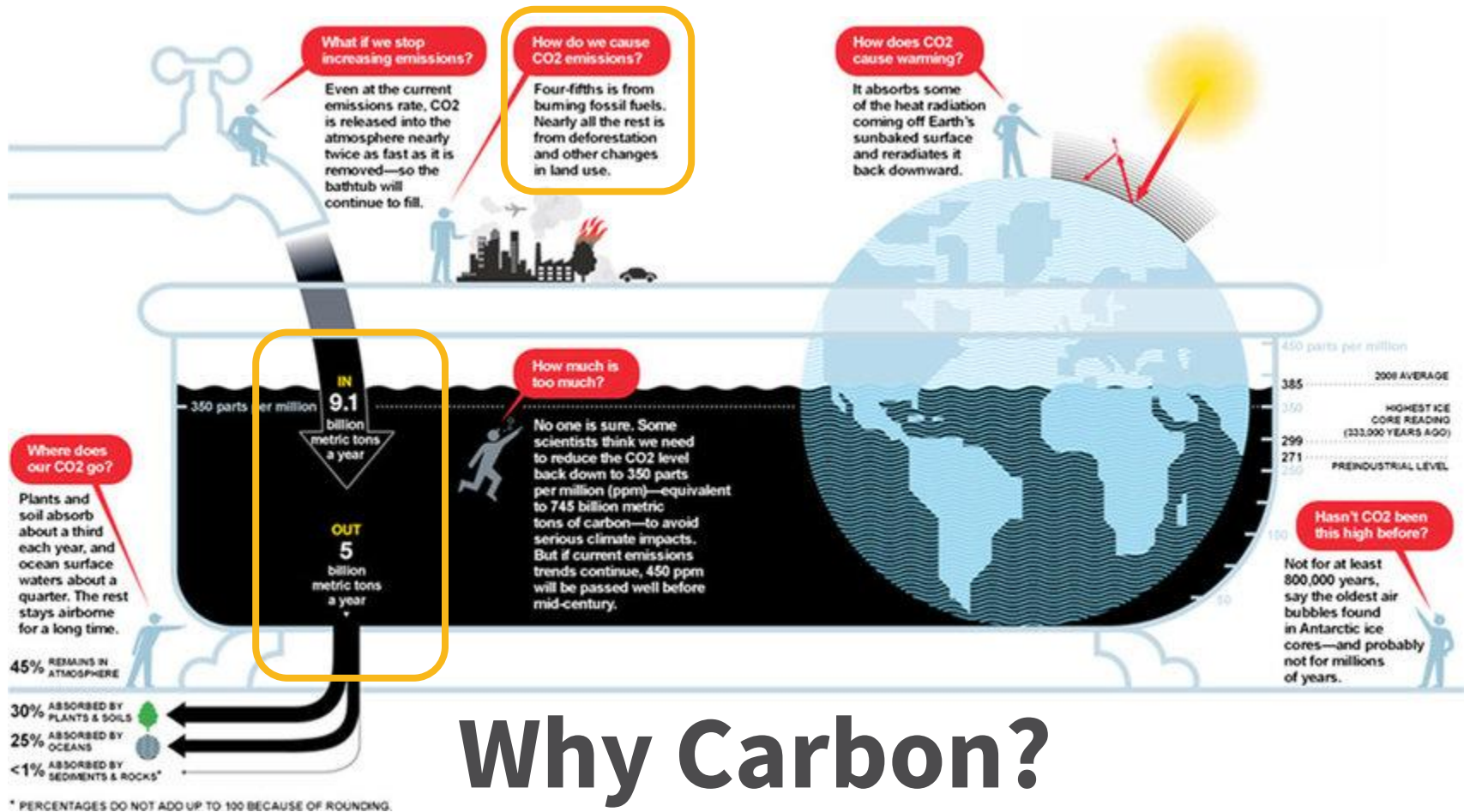




Embodied Carbon 101

Suni Dillard HMFH Architects and CLF Boston | NE
Green Communities + Leading By Example Summit



Portraying stocks and flows: The "Carbon Bathtub" (Source: Graphic: Nigel Holmes. Sources: John Sterman, MIT; David Archer, Univ. of Chicago; Global Carbon Project. National Geographic, Dec. 2009; available at ngm.nationalgeographic.com/big-idea/05/carbon-bath)

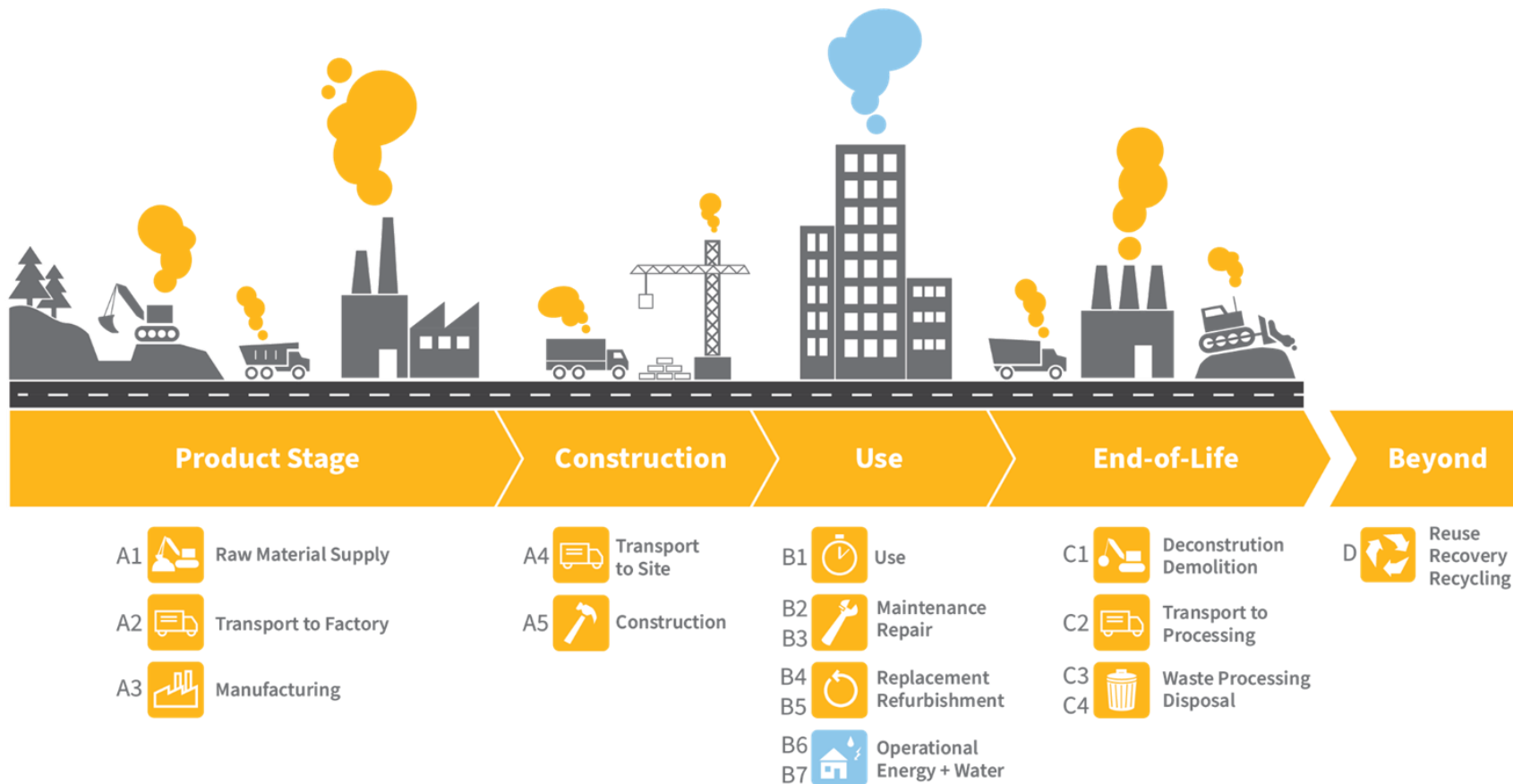
What is embodied carbon?

What is embodied carbon?

Embodied carbon:

the greenhouse gas (GHG) emissions generated from the manufacture, transport, installation, maintenance, and disposal/recovery of construction materials

What is embodied carbon in the built environment?



How do you measure embodied carbon?

METHOD



**Life Cycle
Assessment
(LCA)**

**IMPACT
CATEGORY**



**Global
Warming
Potential
(GWP)**

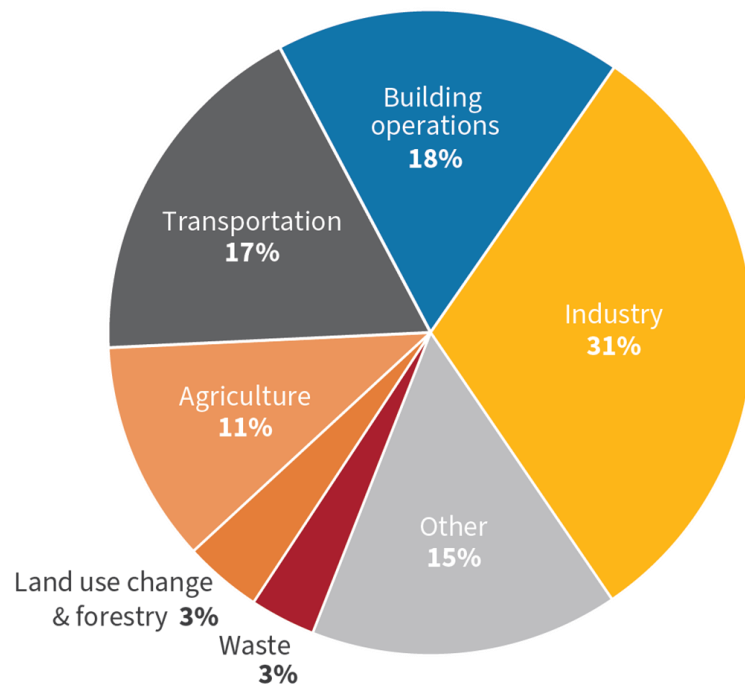
**UNIT OF
MEASUREMENT**



kg CO₂e

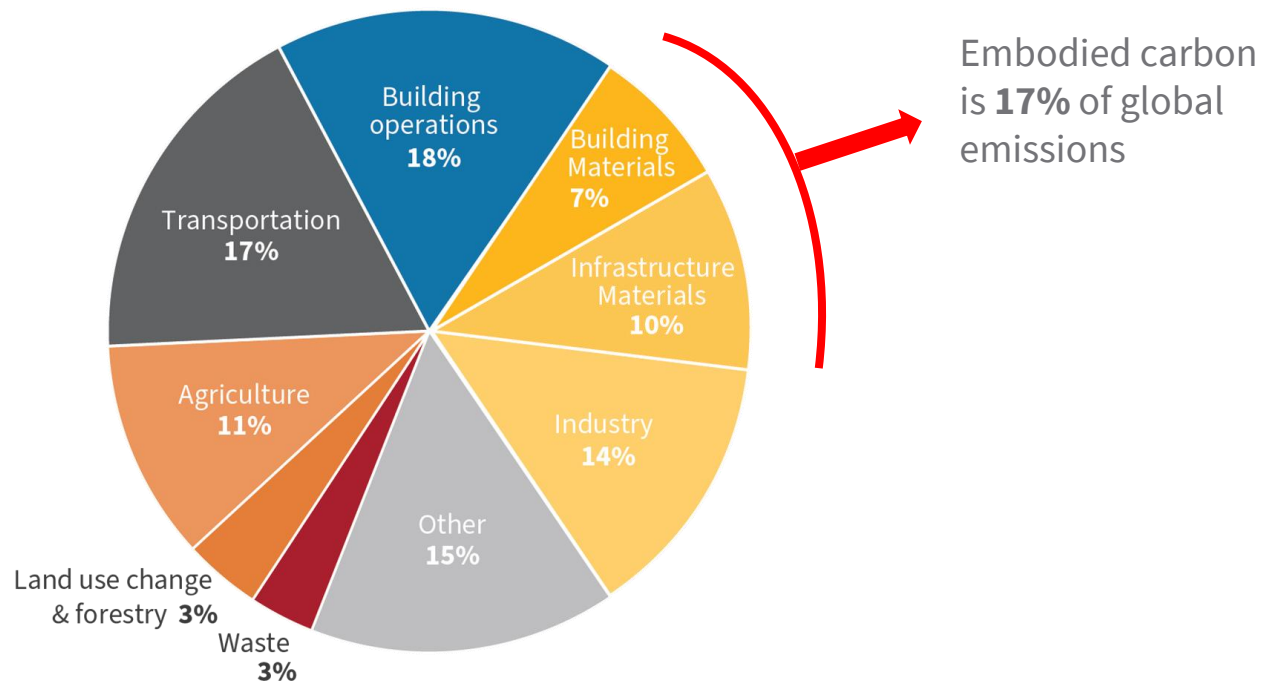
What are the climate impacts of the built environment?

Global greenhouse gas emissions by sector (2019)



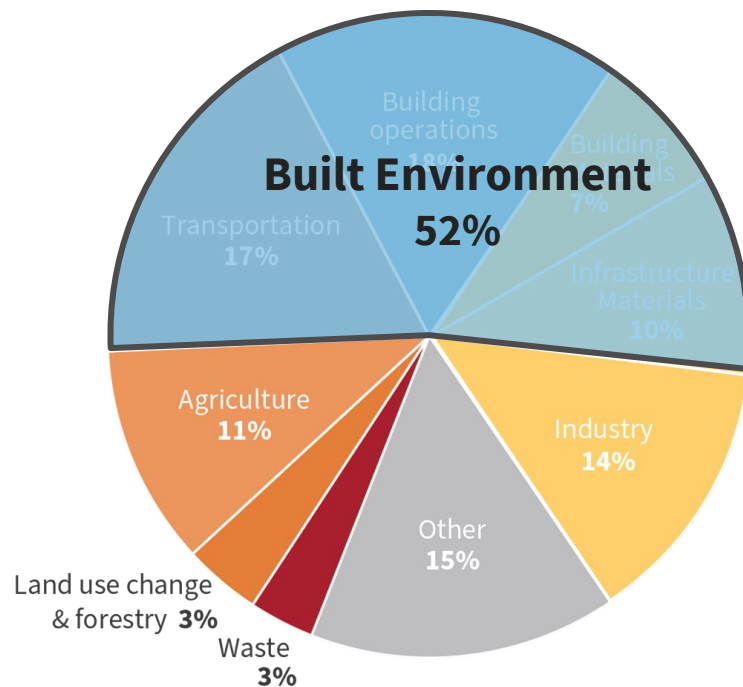
Data Source: [World Greenhouse Gas Emissions: 2019](#), World Resources Institute (WRI), 2022.

Global greenhouse gas emissions by sector (2019)



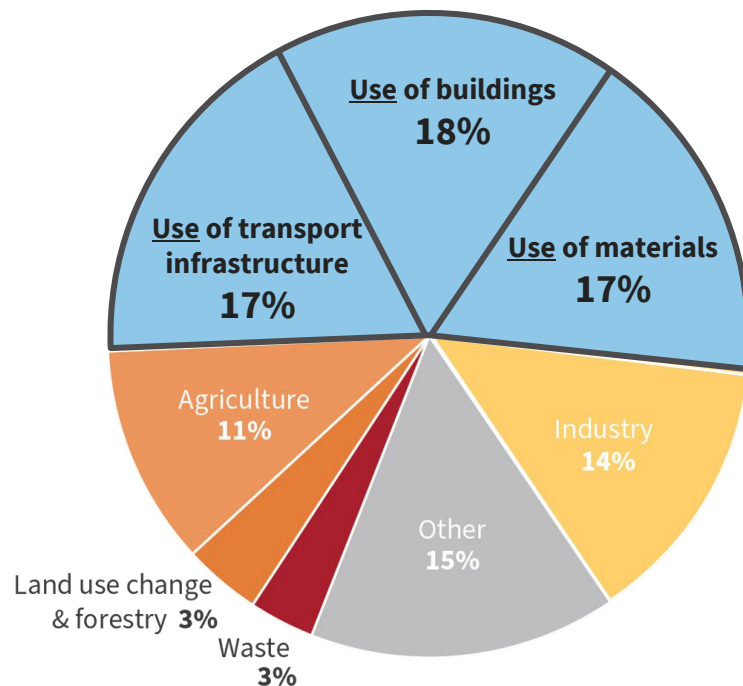
Data Source: [World Greenhouse Gas Emissions: 2019](#), World Resources Institute (WRI), 2022.

Global greenhouse gas emissions by sector (2019)



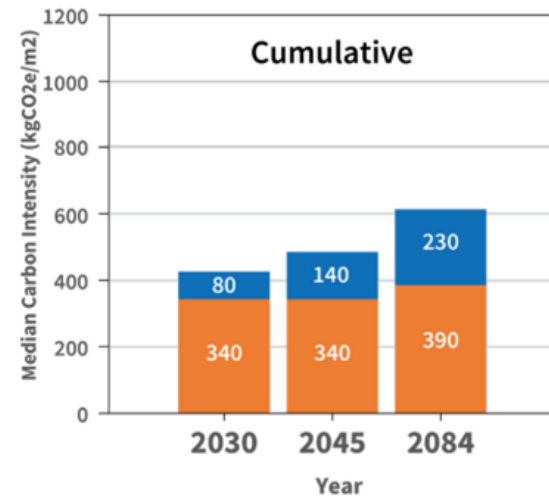
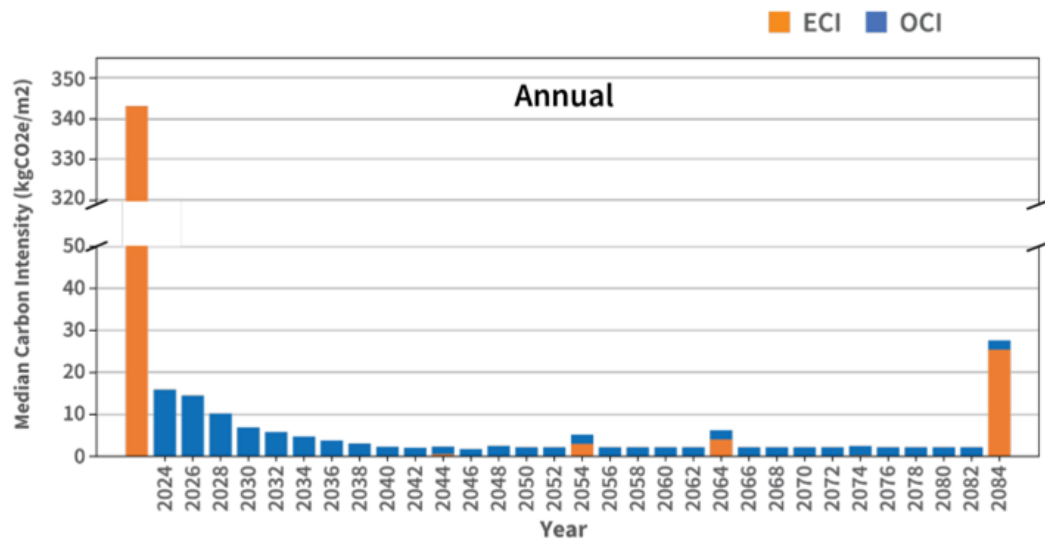
Data Source: [World Greenhouse Gas Emissions: 2019](#), World Resources Institute (WRI), 2022.

Global greenhouse gas emissions by sector (2019)



Data Source: [World Greenhouse Gas Emissions: 2019](#), World Resources Institute (WRI), 2022.

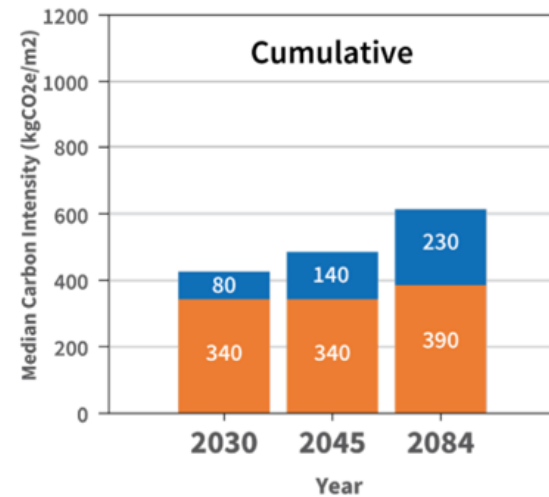
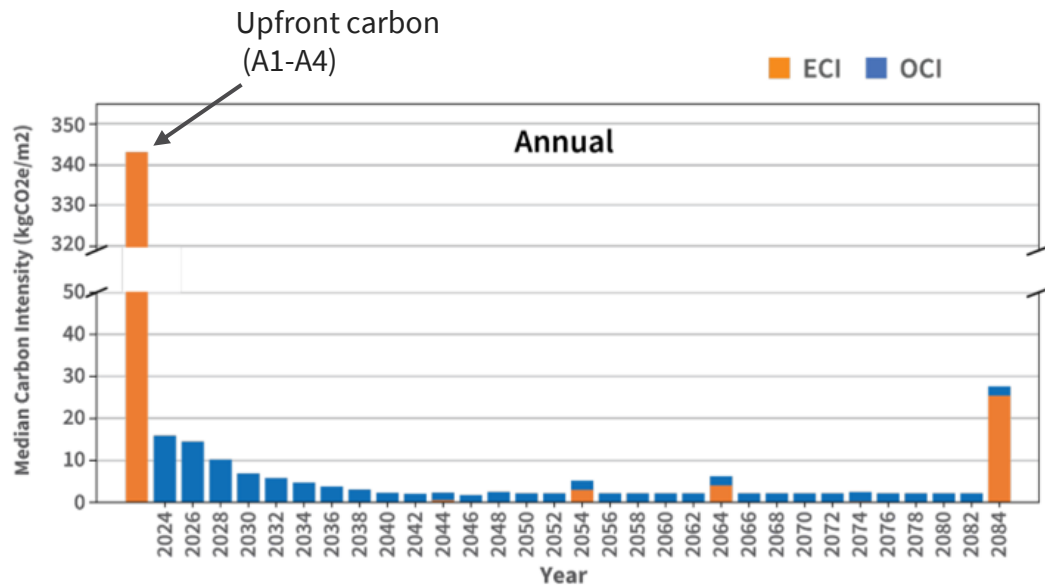
Embodied carbon at the building scale



Example from analysis of 30 buildings in the State of California.

Benke et al. (2024). *The California Carbon Report: Six Key Takeaways for Policymakers*. Carbon Leadership Forum, University of Washington. Seattle, WA. <http://hdl.handle.net/1773/51415>

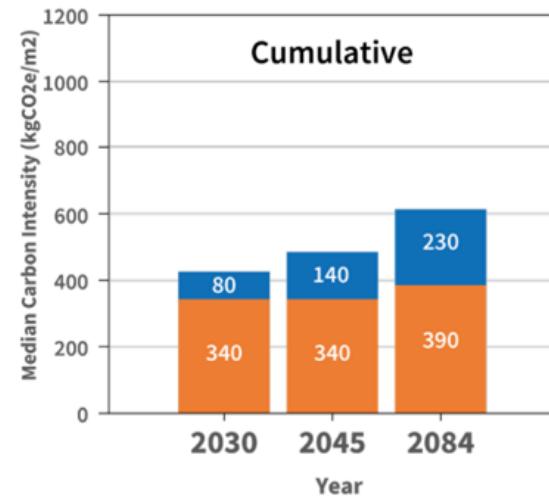
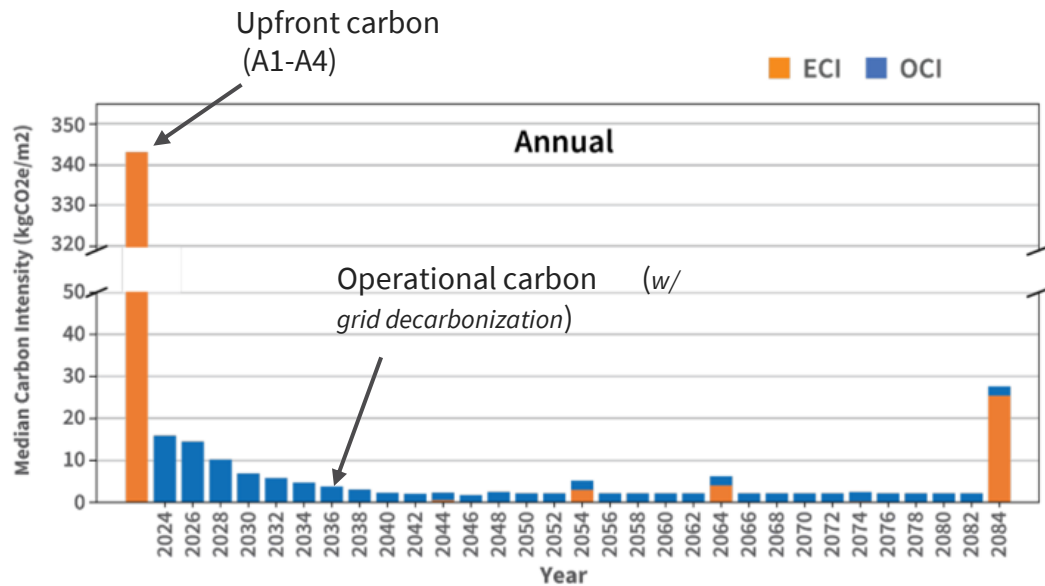
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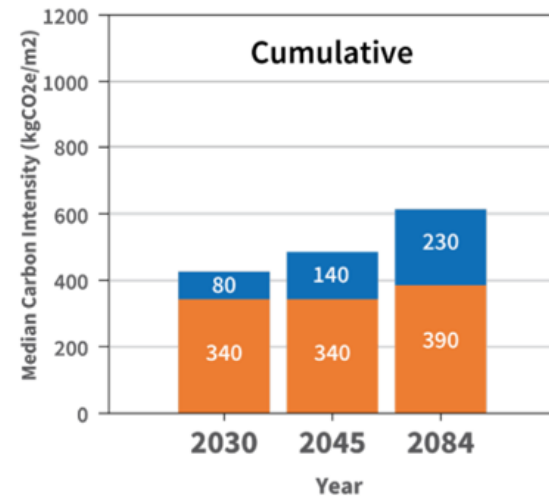
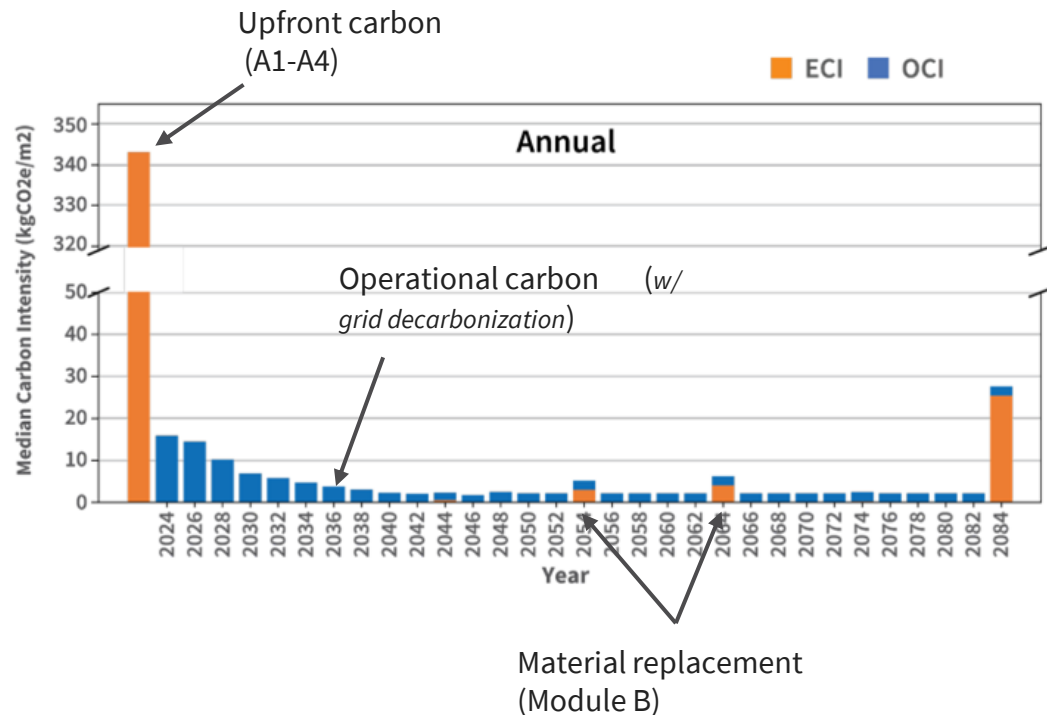
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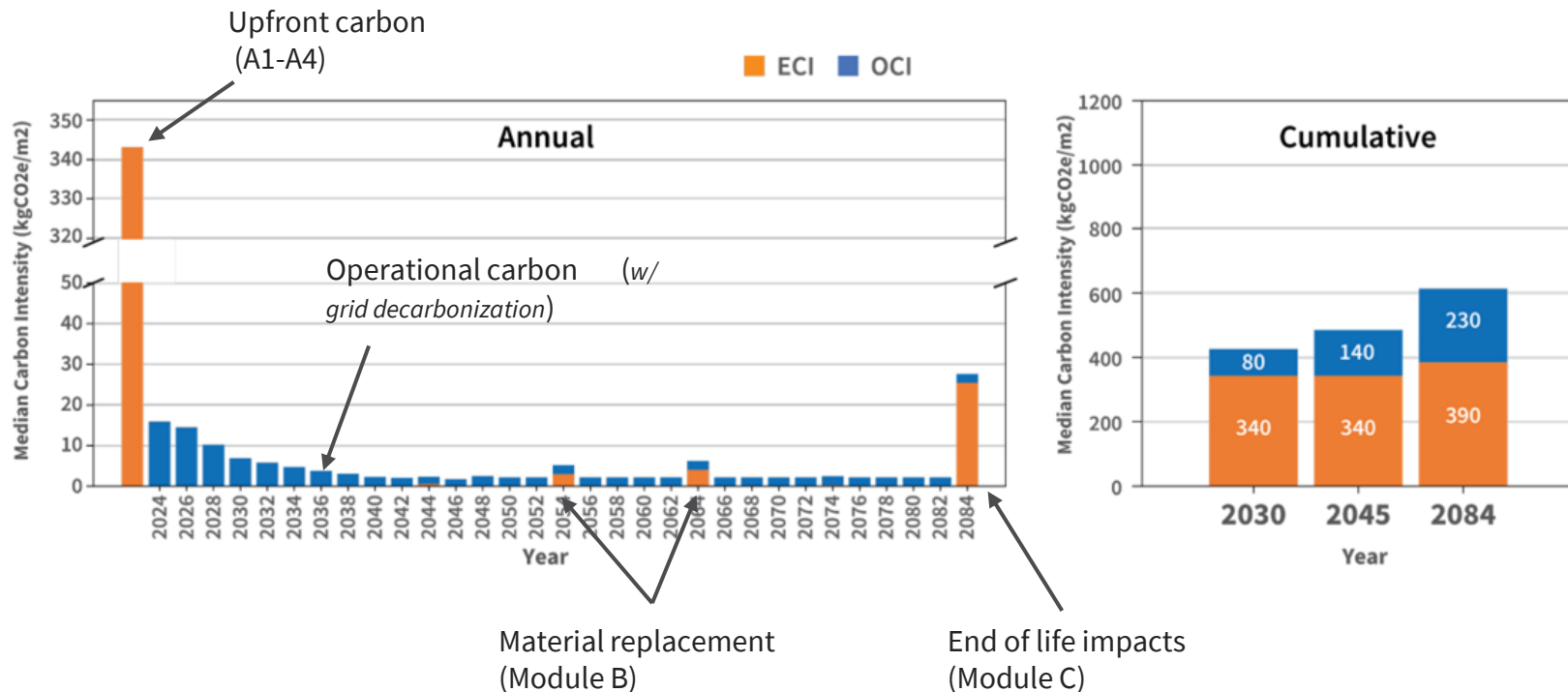
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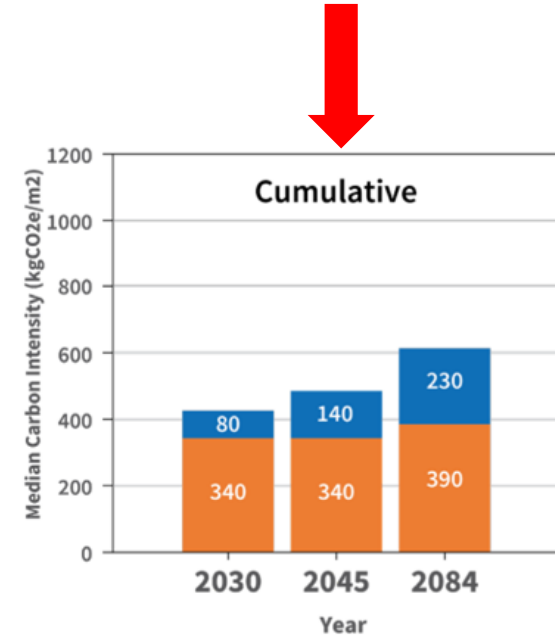
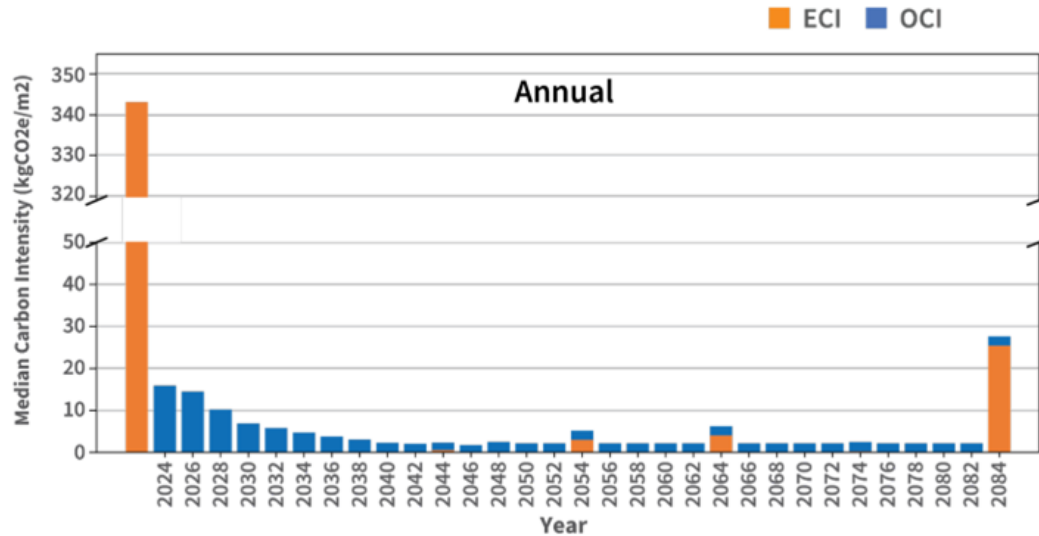
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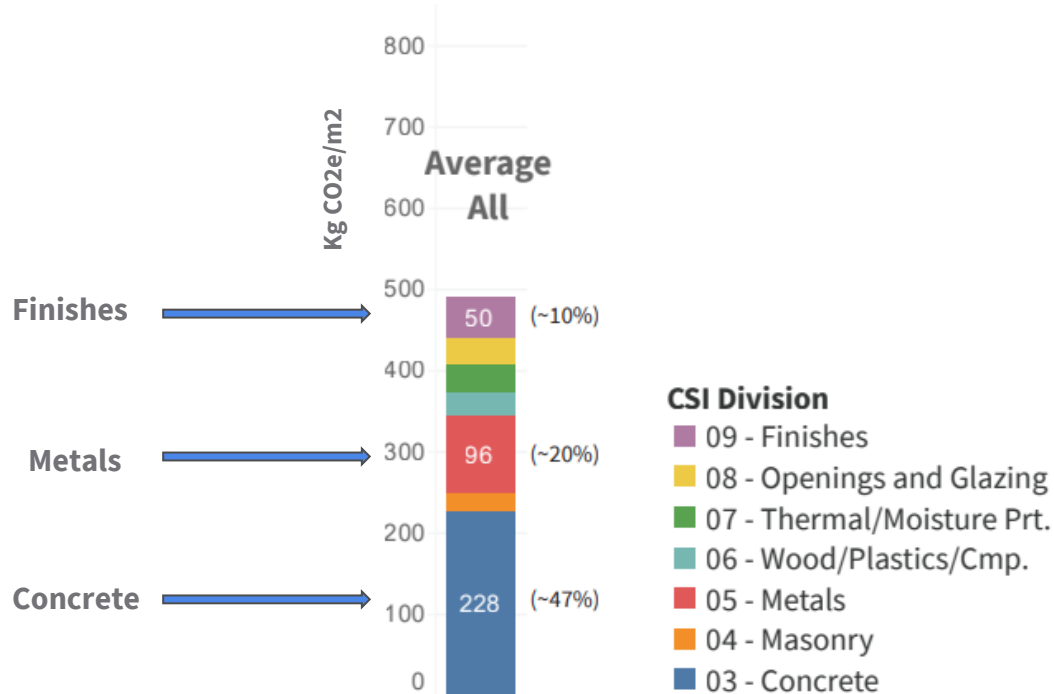
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Which materials have the highest impacts? (30 California buildings)



*Example from analysis of 30 buildings in the State of California.
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Takeaways for Policymakers. Carbon Leadership Forum, University
of Washington. Seattle, WA. <http://hdl.handle.net/1773/51415>*

Which materials have the highest impacts? (EU building stock in 2050)

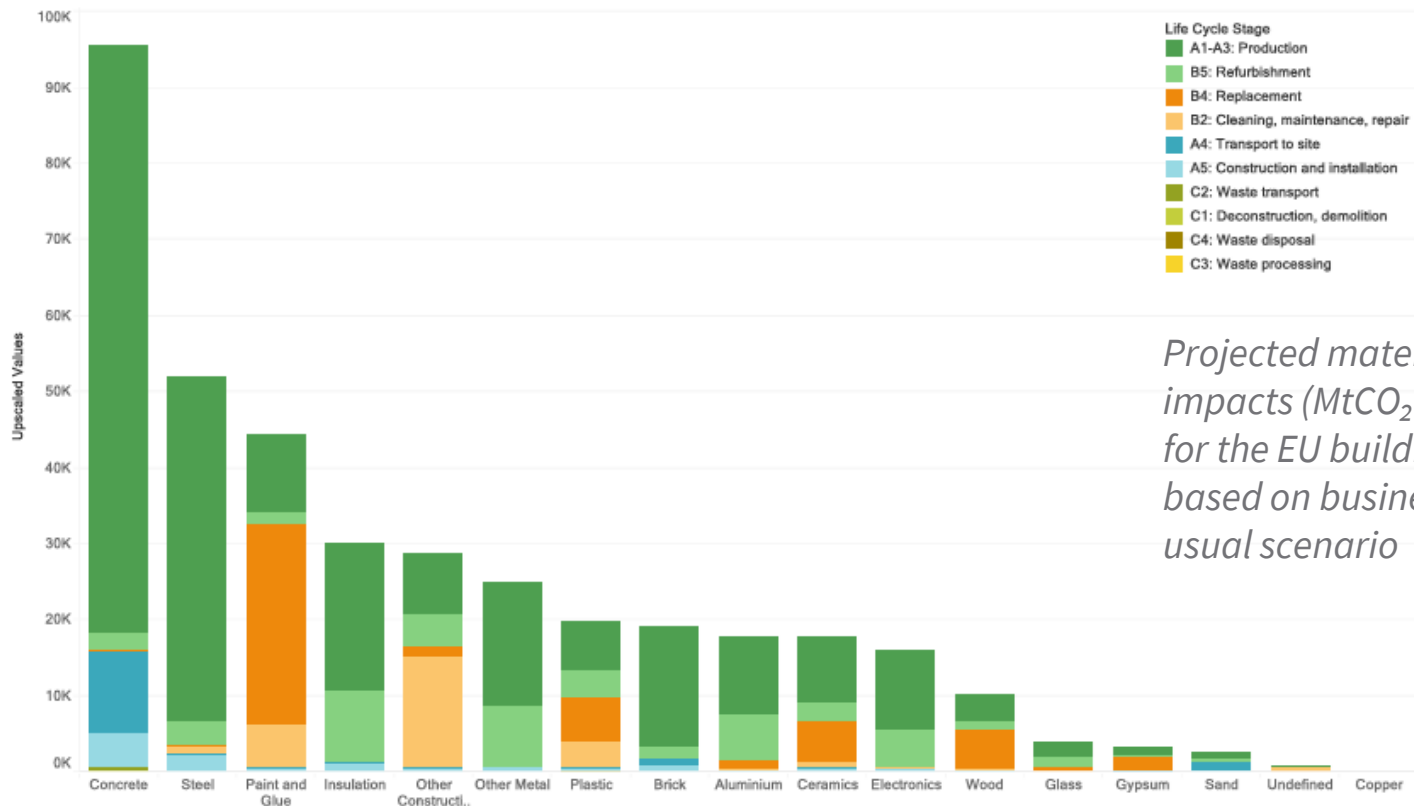


Image from (2023) [Supporting the Development of a Roadmap for the Reduction of Whole Life Carbon of Buildings](#)

Which materials have the highest impacts? (503 residential homes in Toronto)



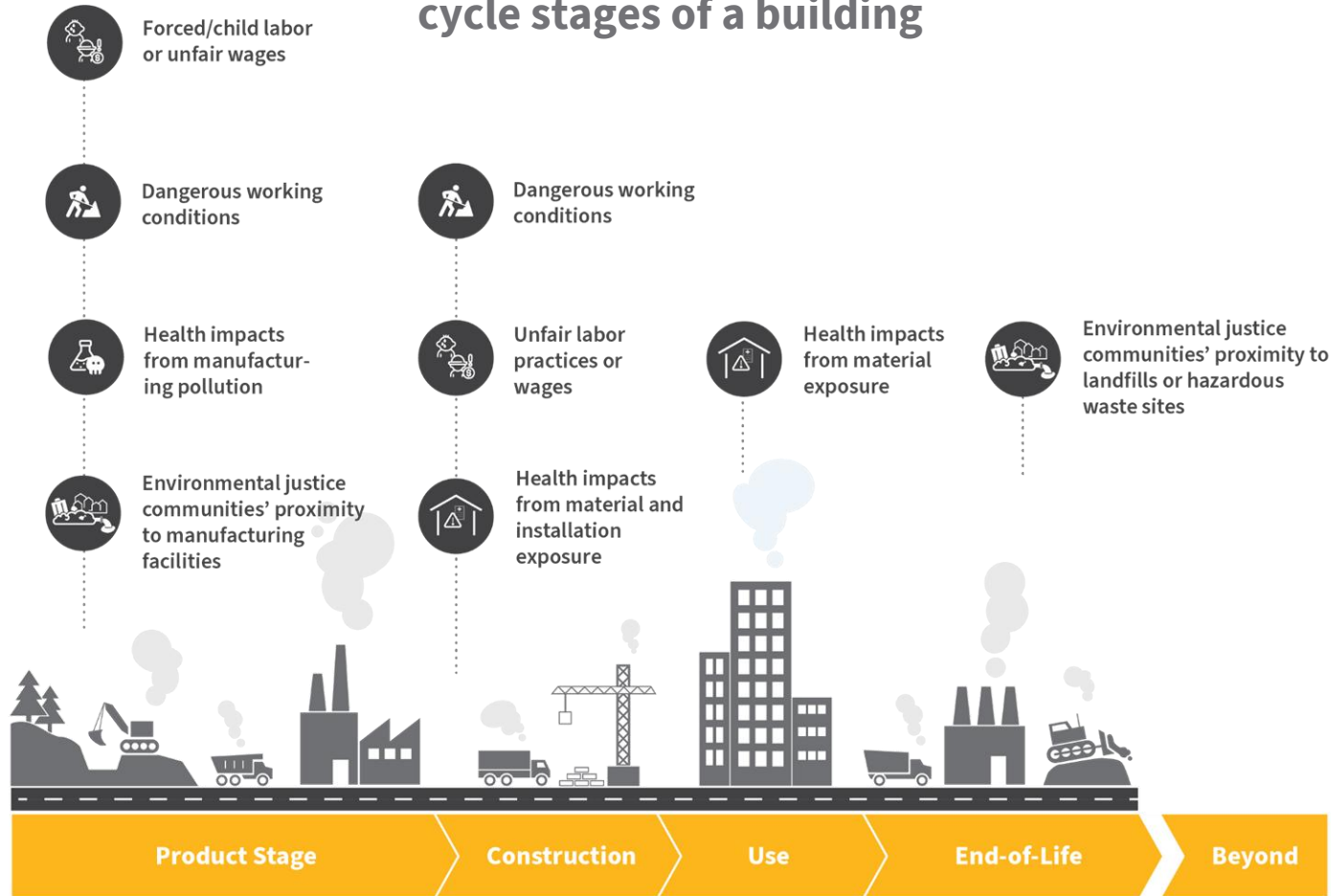
Modeled material impacts for 503 residential homes in the Toronto, Canada area

Image: Magwood, C., Bowden, E., Trottier, M. Emissions of Materials Benchmark Assessment for Residential Construction Report (2022). Passive Buildings Canada and Builders for Climate Action.

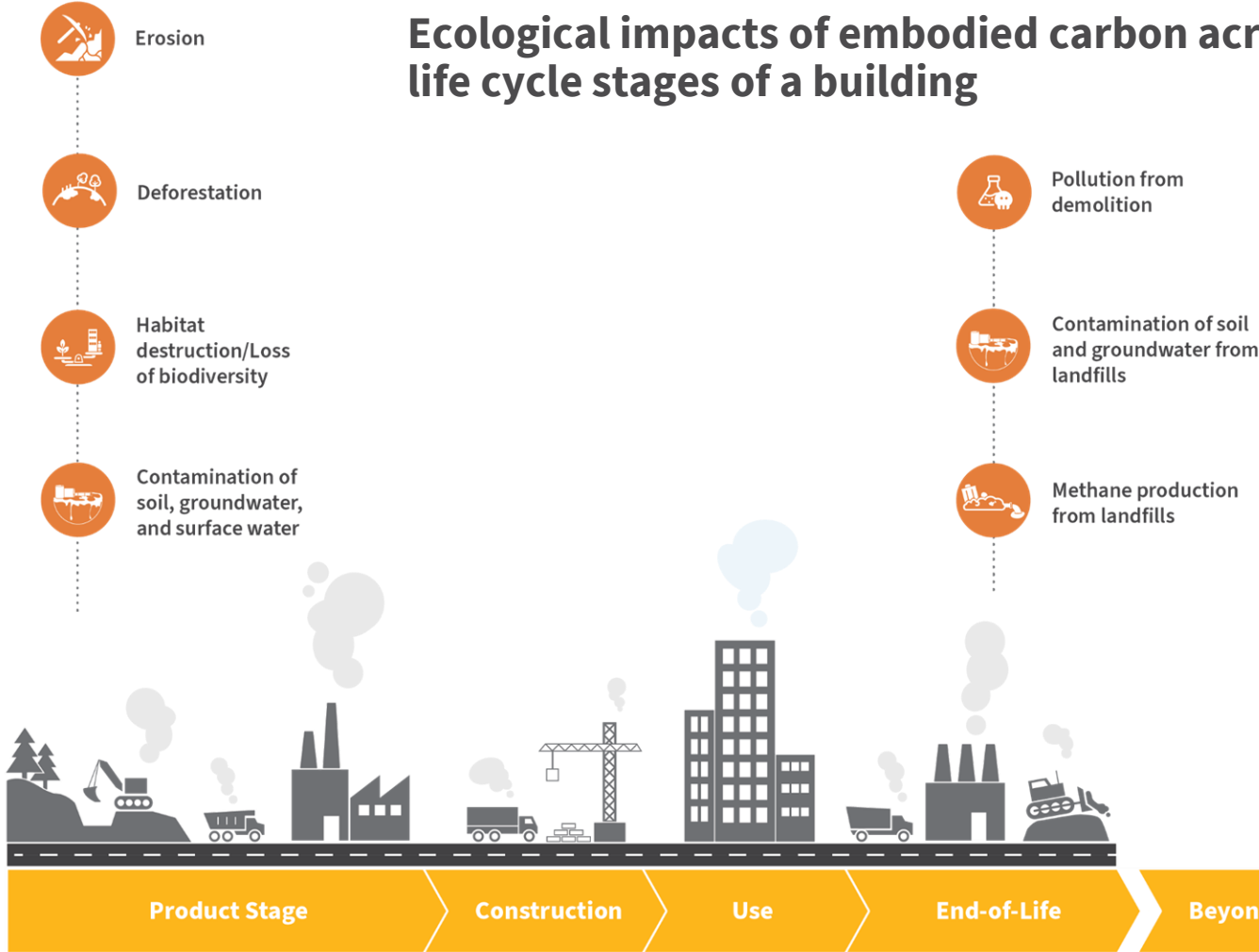
https://www.buildersforclimateaction.org/uploads/1/5/9/3/15931000/bfca_pbc-embarc_report-web.pdf

**Embodied carbon is connected
to labor, pollution, climate
justice, and public health**

Human impacts of embodied carbon across life cycle stages of a building



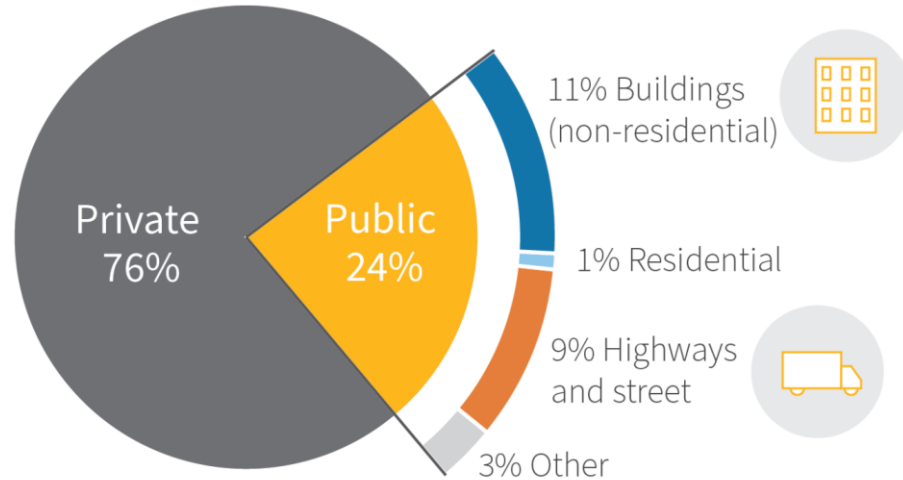
Ecological impacts of embodied carbon across life cycle stages of a building



How is embodied carbon measured at the scale of a:

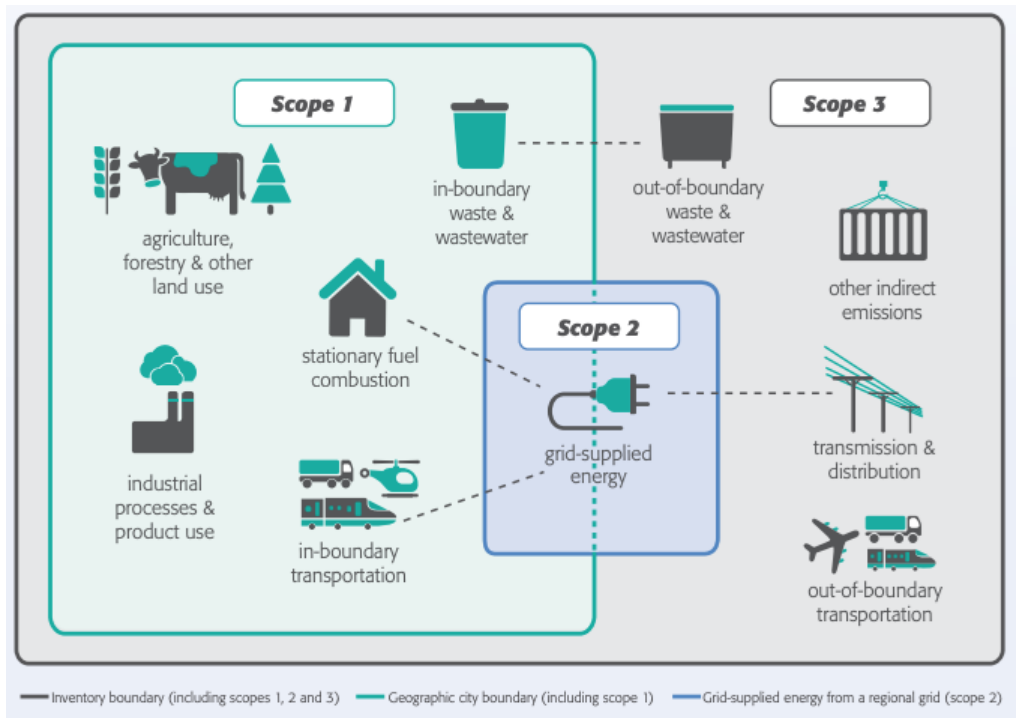
Government, Business, Individual

Embodied carbon of construction in the United States (2010-2023)



Data sources: [US Census Bureau](#) ("Annual Value of Construction Spending Put in Place" for 2012 - 2023); US EPA Office of Research and Development ([USEEIO v1.1](#) data).

Corporate/Organizational GHG Reporting: Scopes 1, 2, and 3

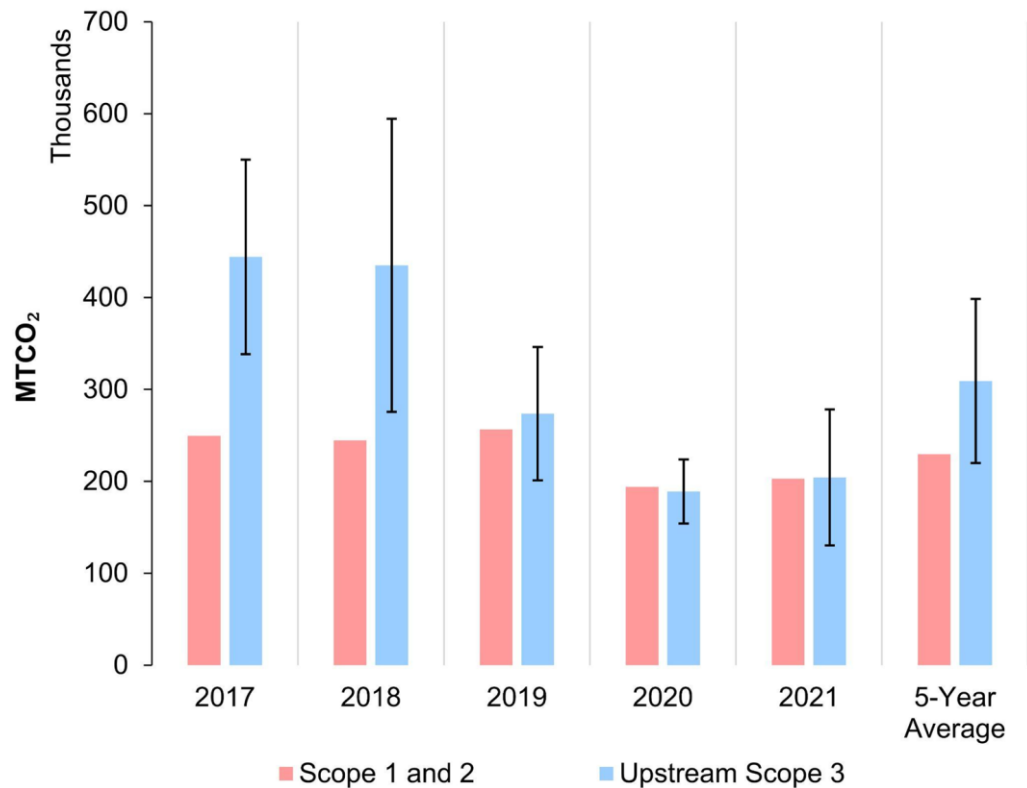
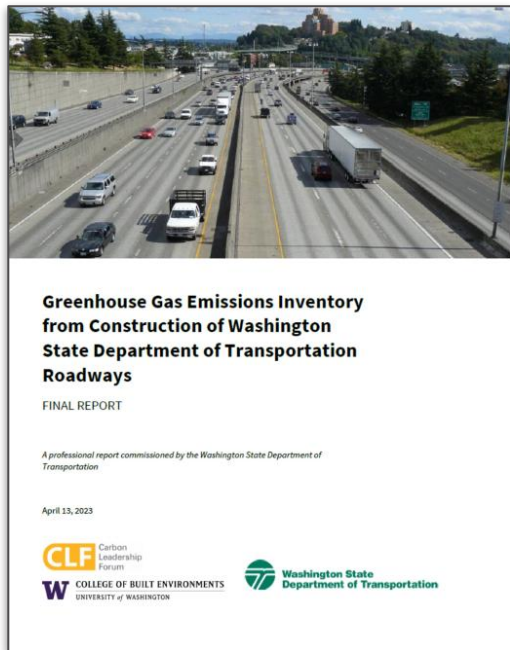


The Greenhouse Gas Protocol Corporate Accounting and Reporting Standard splits GHG emissions into three scopes:

- **Scope 1 emissions** are from a company's operations that are under a facility's direct control, e.g., on-site fuel combustion;
- **Scope 2 emissions** are from usage of electricity, steam, heat and/or cooling purchased from third parties; and
- **Scope 3 emissions** are upstream and downstream value chain emissions, including upstream supply chain emissions from purchased products, transport emissions, and business travel and downstream emissions from transport of products, usage of sold products and product disposal.



Washington State Dept of Transportation GHG inventory



Source: <https://carbonleadershipforum.org/ghg-emissions-inventory-washington-roadways/>

Community-based GHG emissions inventories

PRODUCTION- BASED INVENTORY

Quantifies emissions
**produced within a
regional boundary**

*(power plants,
factories, cars, cattle,
forestry, etc.)*

Methodology fairly standardized -
guidelines include [IPCC](#) (national), [US EPA](#)
(state), and [CDP-ICLEI](#) (city)

CONSUMPTION- BASED INVENTORY

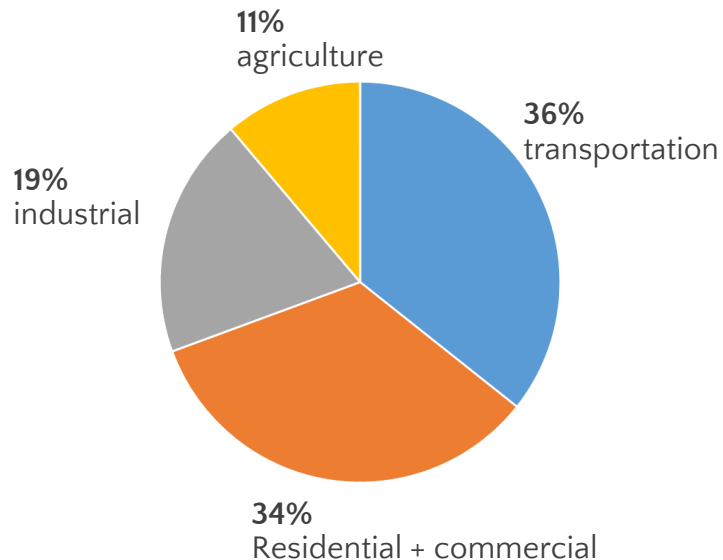
Quantify emissions
**consumed within a
regional boundary**

*(electricity, food,
construction goods, etc.)*

Methodology **not** yet standardized;
[state approach](#) published by US
EPA

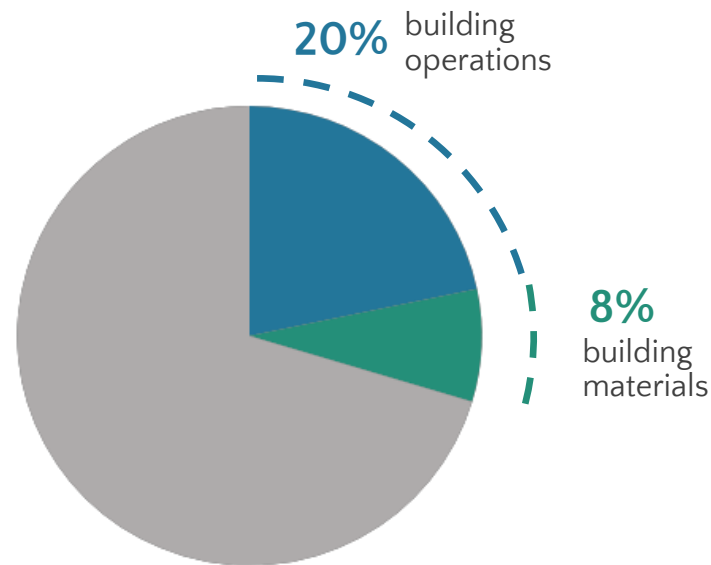
Oregon's greenhouse gas inventories (2015)

Production based inventory



Total = 63 MMT CO₂e

Consumption based inventory



Total = 88.7 MMT CO₂e

Moving beyond carbon inventories

Policy levers for reducing embodied carbon



Planned Actions

Climate action plans, pledges, executive orders, and commitments.



Government Procurement

Green purchasing programs and policies like “Buy Clean.”



Zoning and Permitting

Land-use regulations and permitting incentive programs.



Building Codes and By-laws

Regulations designating embodied carbon requirements.



Deconstruction and Reuse

Extending the life of a material or building to avoid embodied carbon emissions associated with new materials.



Green Building Rating Systems

Requirements in permitting, zoning or in executive orders



Industrial Regulations & Incentives

Facility limits, Cap and trade programs, trade regulations

Planned actions



MA Executive Order 594, Leading by Example: Decarbonizing and Minimizing Environmental Impacts of State Government

- Issued April 2021 by Governor Baker
- In support of the statewide goal of achieving net zero greenhouse gas emissions by 2050; to be achieved through -
 - **Advancing high performance buildings for new construction;**
 - Expanding energy efficiency and decarbonizing fuels in existing buildings;
 - Acquiring fuel efficient and zero emission vehicles and
 - Continuing the deployment of new renewable energy.

Section 3: Massachusetts LEED Plus 2.0 Standard for New Construction

- Part VIII: Additional Directives
 - ***“Evaluate and implement strategies to reduce embodied carbon contained in building materials, where possible and cost-effective.”***

AEC Industry levers

Embodied Carbon Reduction Strategies

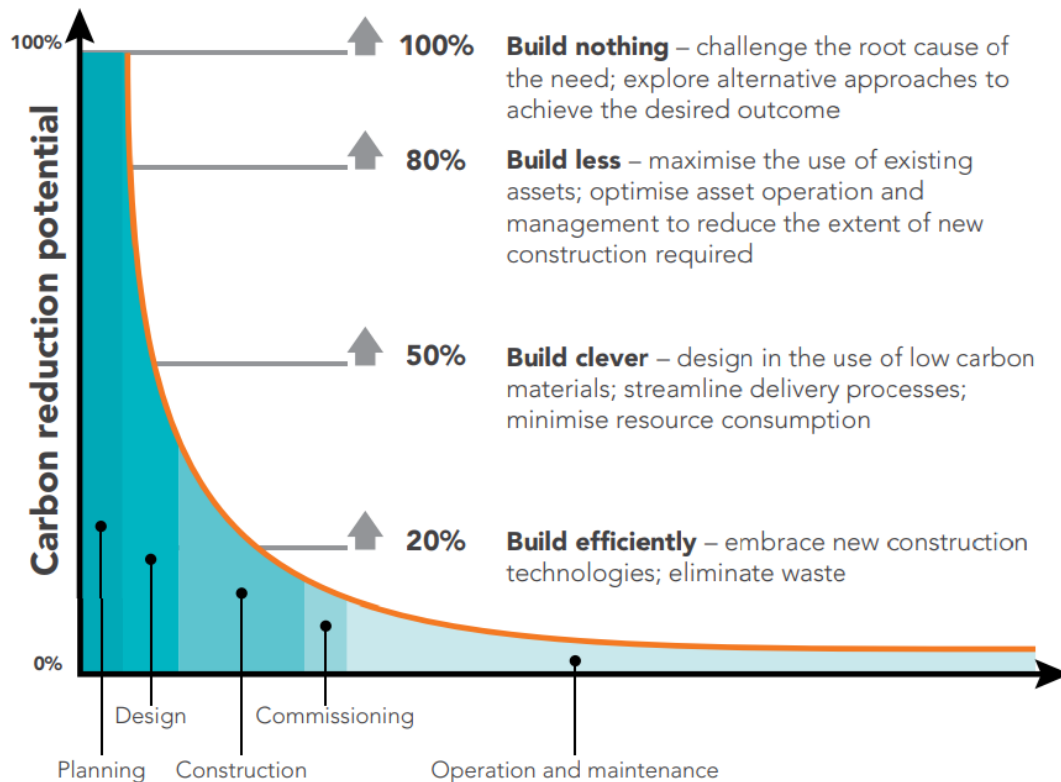


Image from UKGBC (2019)
[Net Zero Carbon Buildings:
A Framework Definition](#)

Embodied carbon reduction strategies

Design



- Reuse, renovation and retrofitting
- Reduce new floor area
- Reduce below-grade construction
- Design lightweight, efficient structures
- Use WBLCA to optimize envelope design

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Material and System Selection

- Understanding high-impact materials
- Carbon storing materials
- MEP refrigerants
- Insulation
- Select finishes carefully
- Design for disassembly
- Select salvaged or refurbished materials

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Specification and Procurement

- Integrate EPDs & GWP limits into project specifications
- Optimize concrete specifications and mix design
- Source sustainable wood
- Use to EPDs to identify lower-carbon facilities and products
- Evaluate cost and carbon in the bid process

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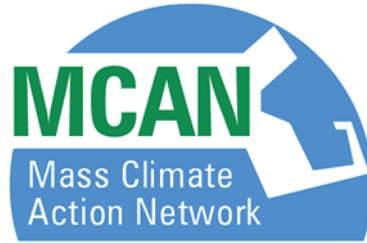
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Process

- Identify embodied carbon as a priority
- Set a project reduction target
- Use WBLCA to evaluate design decisions
- Use EPDs during procurement
- Make firm-wide commitments



Local resources.