

# CARBON COUNTING

Balancing Operating and Embodied Carbon in Facade Design



## SPEAKERS



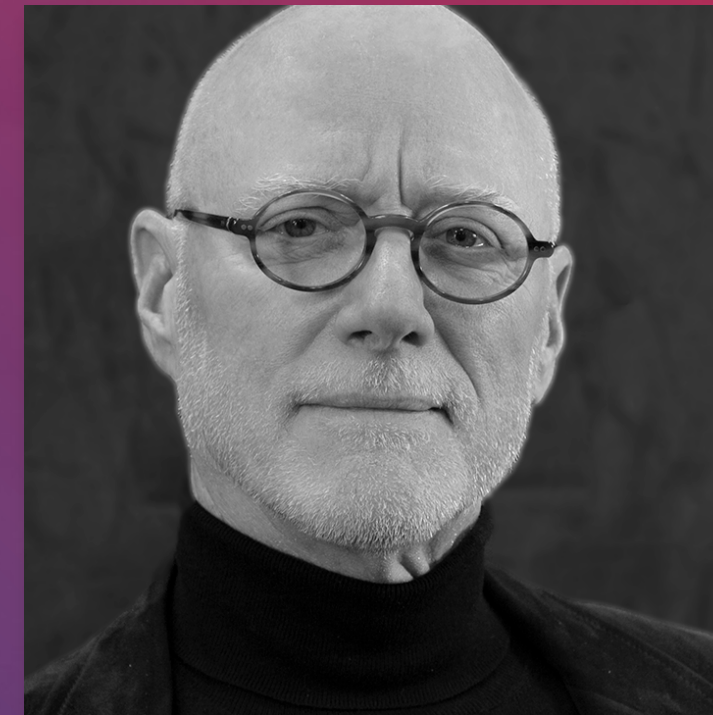
**Stacy Smedley, LEED  
BD+C**

*Director of Sustainability  
Skanska USA Building*



**Kjell Anderson, AIA,  
LEED Fellow**

*Director of Sustainable Design  
LMN Architects*



**Mic Patterson, PhD,  
LEED AP+**

*Ambassador of Innovation &  
Collaboration  
The Facade Tectonics Institute*



**Kate Simonen, AIA, SE,  
LEED AP**

*Founding Director  
Carbon Leadership Forum;  
Associate Professor  
University of Washington*

# Carbon Smart Building

**Kate Simonen AIA SE**

**Director Carbon Leadership Forum**

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[www.carbonleadershipforum.org](http://www.carbonleadershipforum.org)



# CARBON LEADERSHIP FORUM

Inspire, Inform and Enable Low Carbon Construction

## DIAMOND



Carbon Innovations



## PLATINUM



## GOLD



SIMPSON GUMPERTZ & HEGER



Engineering of Structures and Building Enclosures



thinkstep



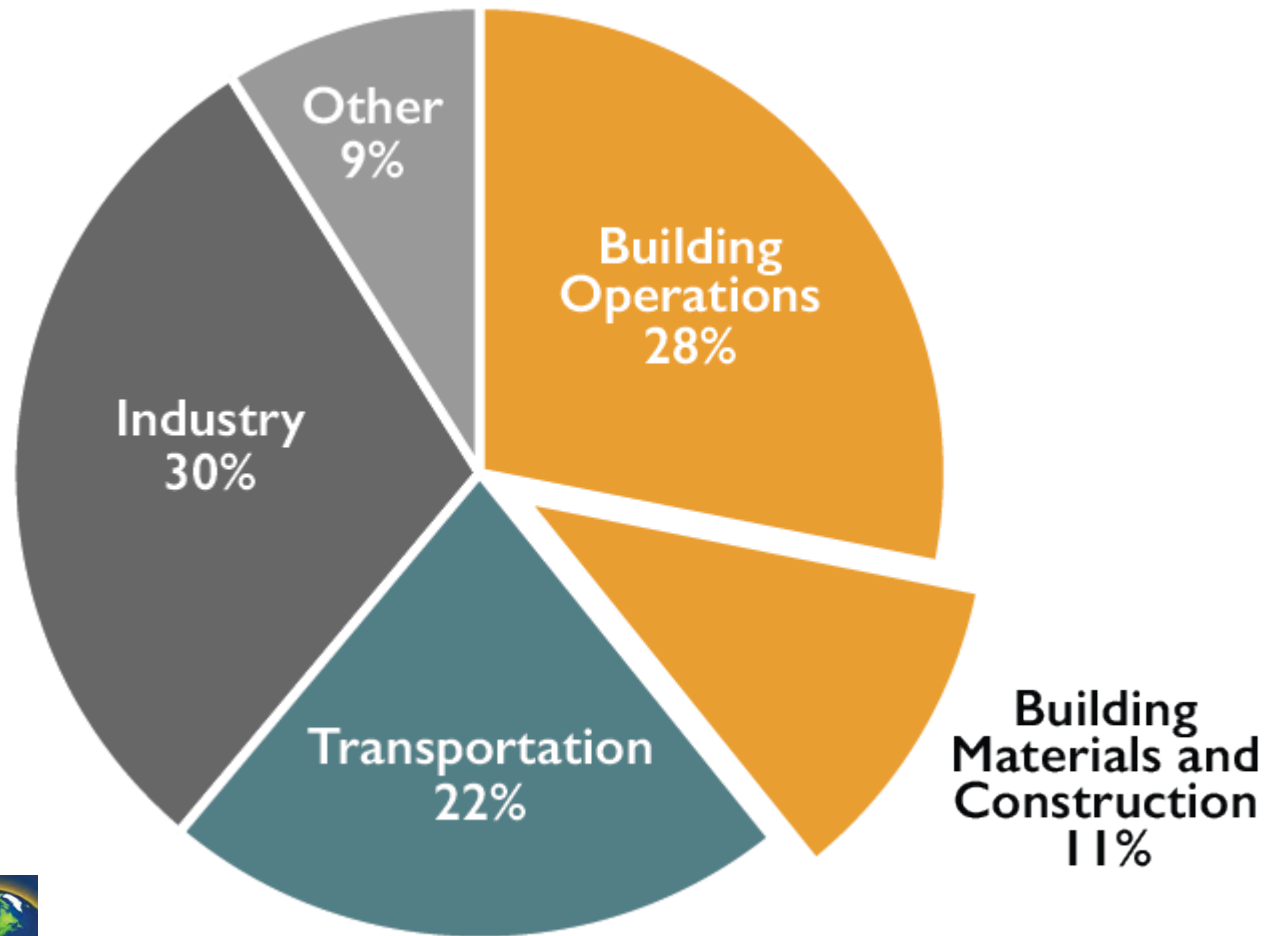
KIERAN TIMBERLAKE

## SILVER

## SUPPORTERS

# Buildings and the **Climate Crisis**

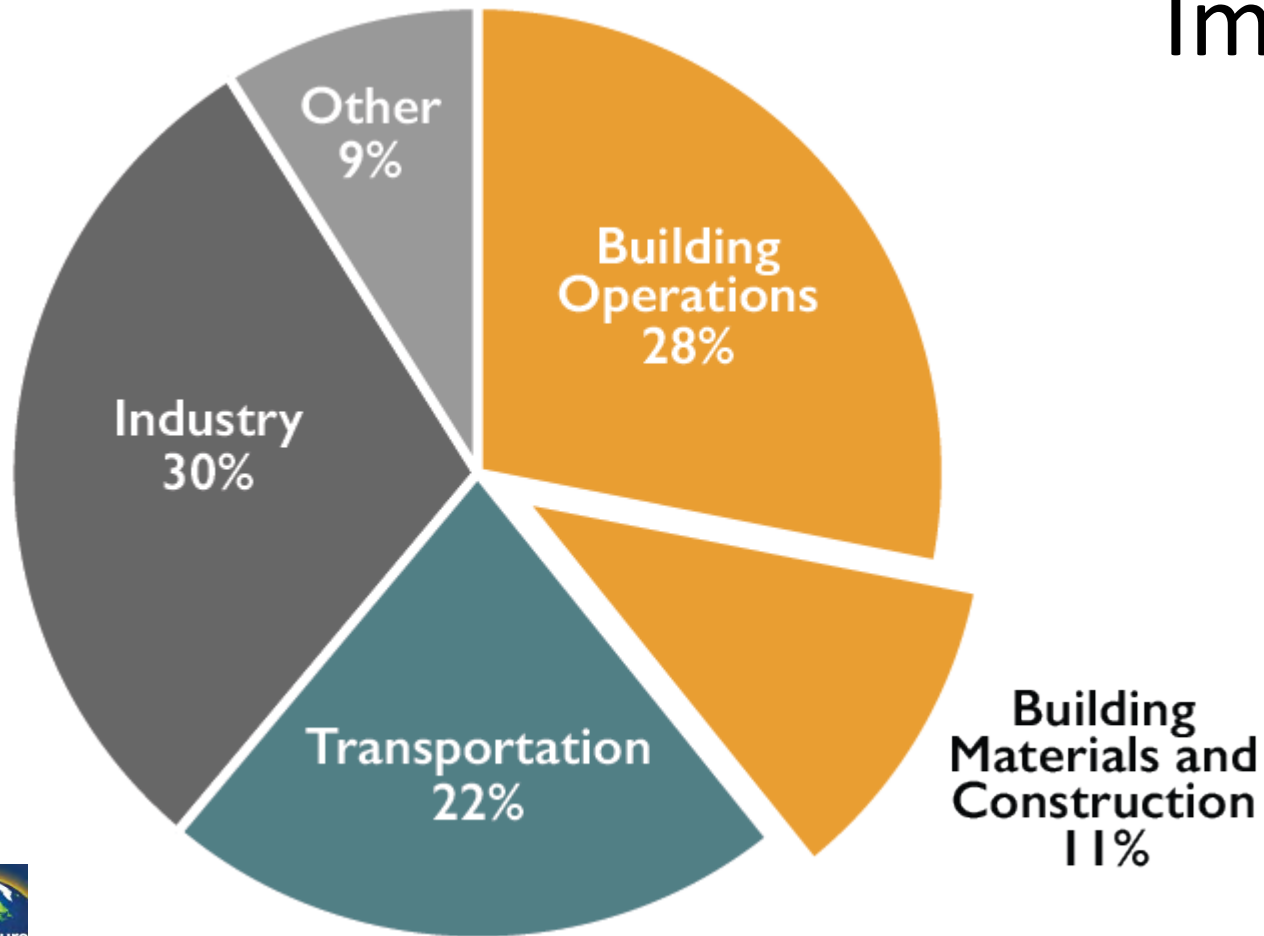
Global CO<sub>2</sub> Emission by Sector



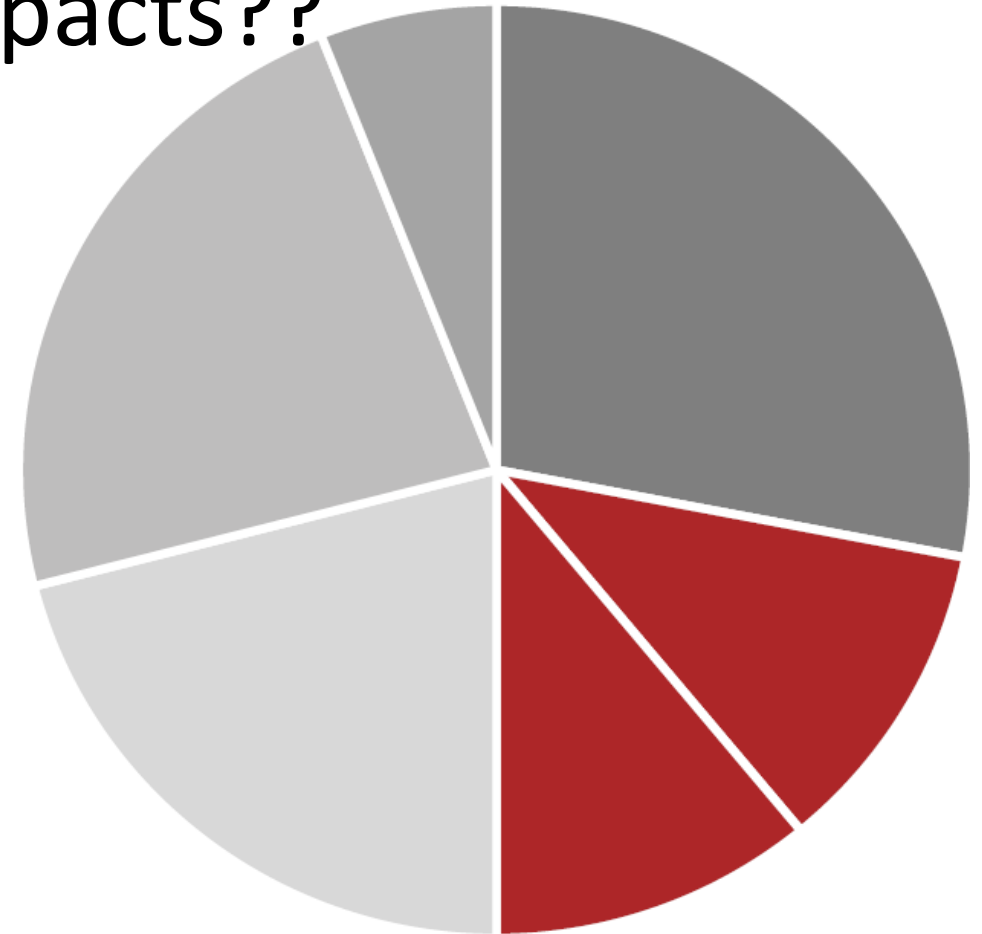
Source: © 2018 2030, Inc. / Architecture 2030. All Rights Reserved. Data Sources: UN Environment Global Status Report 2017; EIA International Energy Outlook 2017

# Buildings and the **Climate Crisis**

Global CO<sub>2</sub> Emission by Sector



Total Building Material Impacts??



## How the building sector meets global climate targets

- 1 New Buildings to Zero Net Operating Carbon by 2030
- 2 Existing Buildings to Zero Net Operating Carbon by 2050
- 3 Integrate Buildings into an Optimized Energy Grid
- 4 Eliminating Embodied Carbon in Buildings
- 5 Measure & Improve Health & Equity <http://carbonsmartbuilding.org/declaration>

**CARBON SMART BUILDING**  
**DECLARATION**

# Operating vs Embodied Carbon

## Understanding Carbon

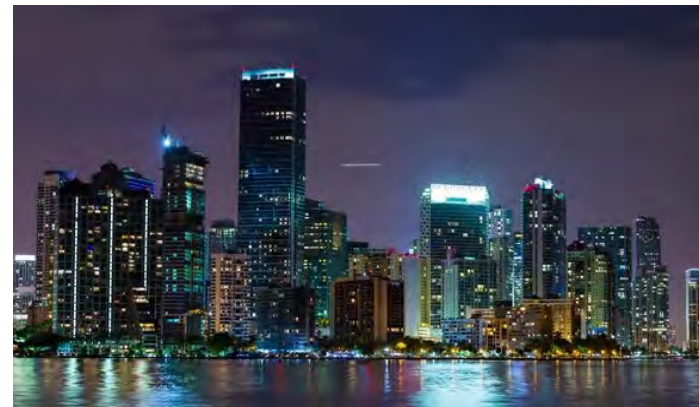


### Embodied Carbon

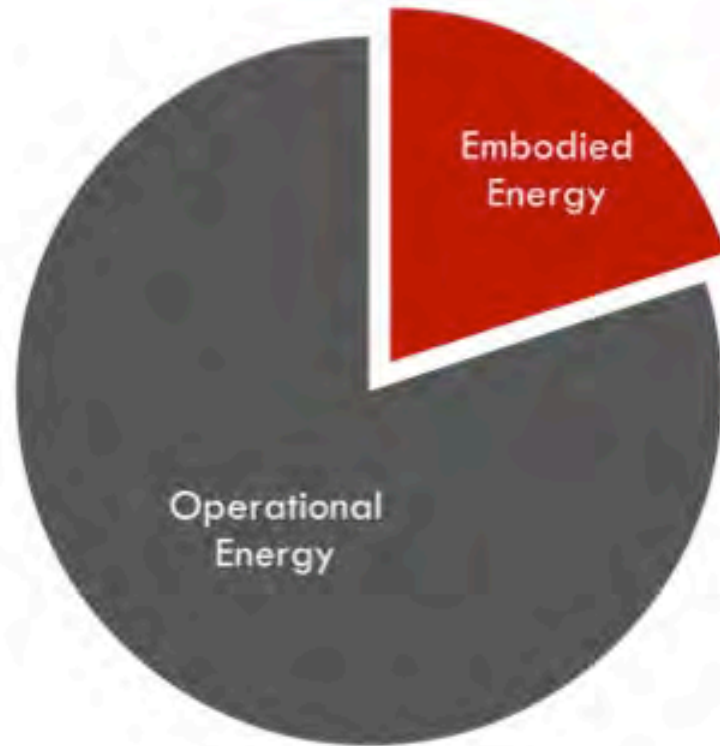
Manufacture, transport and installation of construction materials

### Operational Carbon

Building Energy Consumption



# Operating vs Embodied Carbon



Typical Building



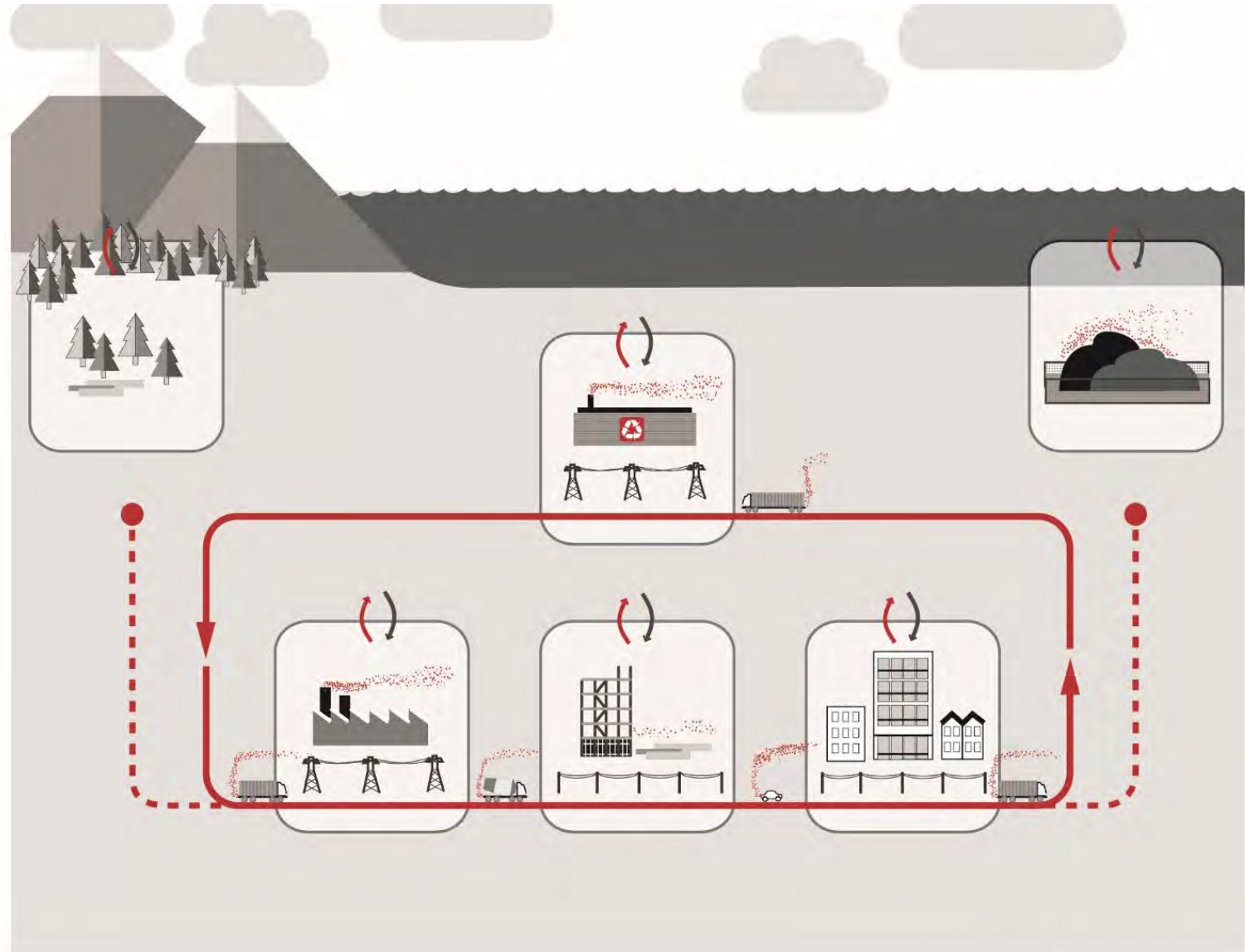
High Performance

# Life Cycle Assessment: Embodied Carbon

Emissions due to:

- Material extraction
- Transportation
- Manufacturing

Life Cycle Assessment (LCA) is method used to calculate embodied carbon.



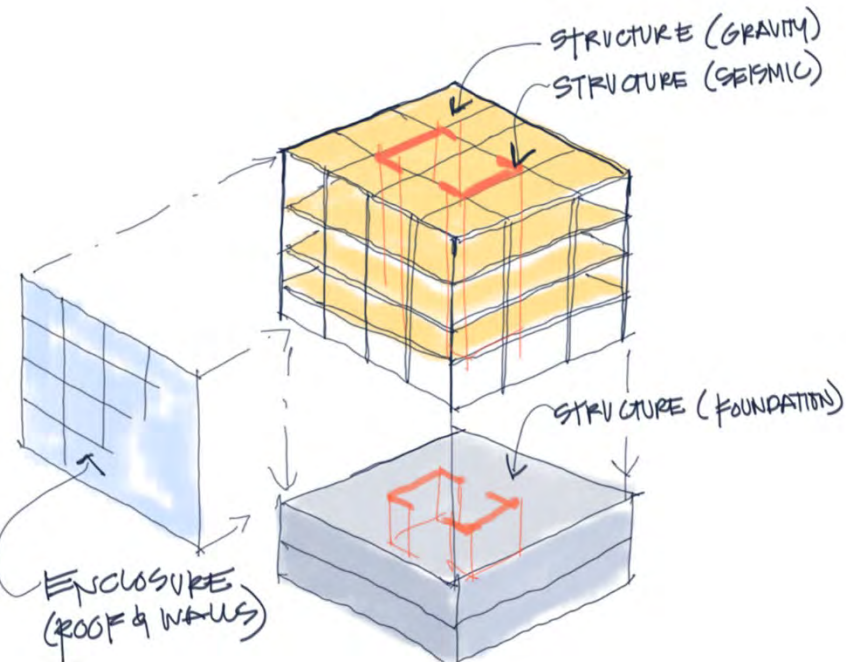
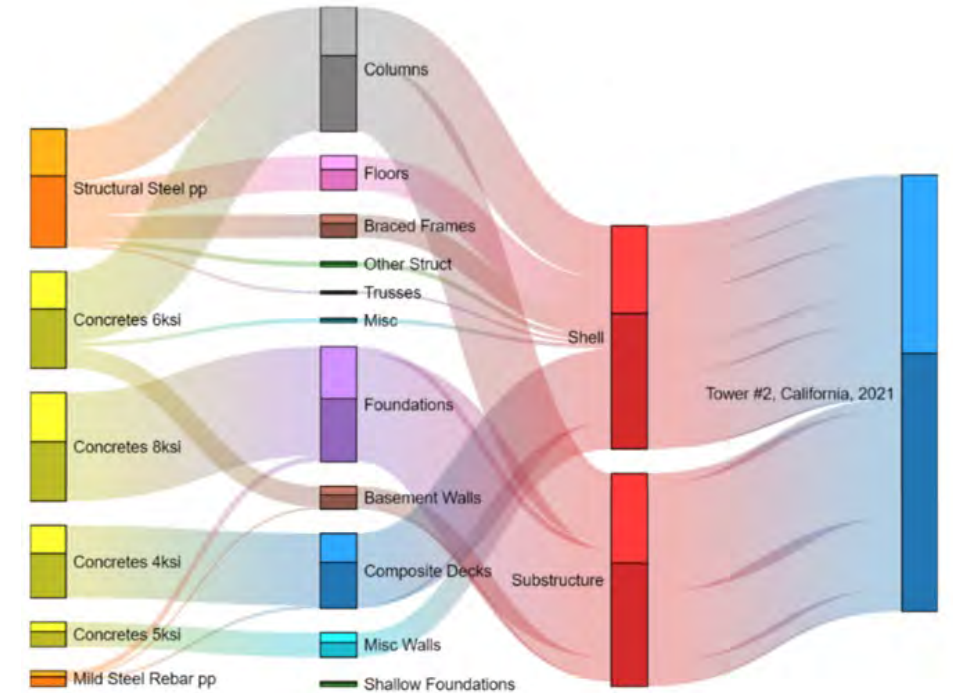
# Estimating Embodied Carbon



## Life Cycle Impact Results (per m<sup>3</sup>)

Declared Unit: 1 m<sup>3</sup> of 10,000 psi concrete at 28 days

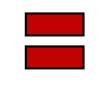
OPERATIONAL IMPACTS	PerformX™ PECC10K
Plant Operating Energy (MJ)	38.6
On-Site Plant Fuel Consumption (MJ)	11.1
Concrete Batch Water (m <sup>3</sup> )	1.68E-01
Concrete Wash Water (m <sup>3</sup> )	1.91E-02
On-Site Waste Disposal (kg)	0.0
ENVIRONMENTAL IMPACTS	
Total Primary Energy (MJ)	3,017
Climate Change (kg CO <sub>2</sub> eq)	445
Ozone Depletion (kg CFC 11 eq)	1.31E-08
Acidification Air (kg SO <sub>2</sub> eq)	2.96
Eutrophication (kg N eq)	0.09
Photochemical Ozone Creation (kg O <sub>3</sub> eq)	0.61



**MATERIAL QUANTITY ESTIMATE**



**EMBODIED CARBON PER MATERIAL LCA/EPDs**



**BUILDING EMBODIED CARBON (EC) ESTIMATE**

# Embodied Carbon Strategies

**#1**

**OPTIMIZING  
PROJECT  
TYPE**

## Decisions

- Location
- Program
- (N) vs (E)

## Tools

- Rules of Thumb
- Quick LCAs  
(Athena/OneClick)

**#2**

**OPTIMIZING  
BUILDING  
SYSTEMS**

## Decisions

- System Type
- Building Configuration
- Thermal performance

## Tools

- Rules of Thumb
- Detailed LCAs  
(Athena/OneClick/Tally)

**#3**

**OPTIMIZING  
SPECIFICATION &  
PROCUREMENT**

## Decisions

- Performance Specs.
- Suppliers
- EC Targets

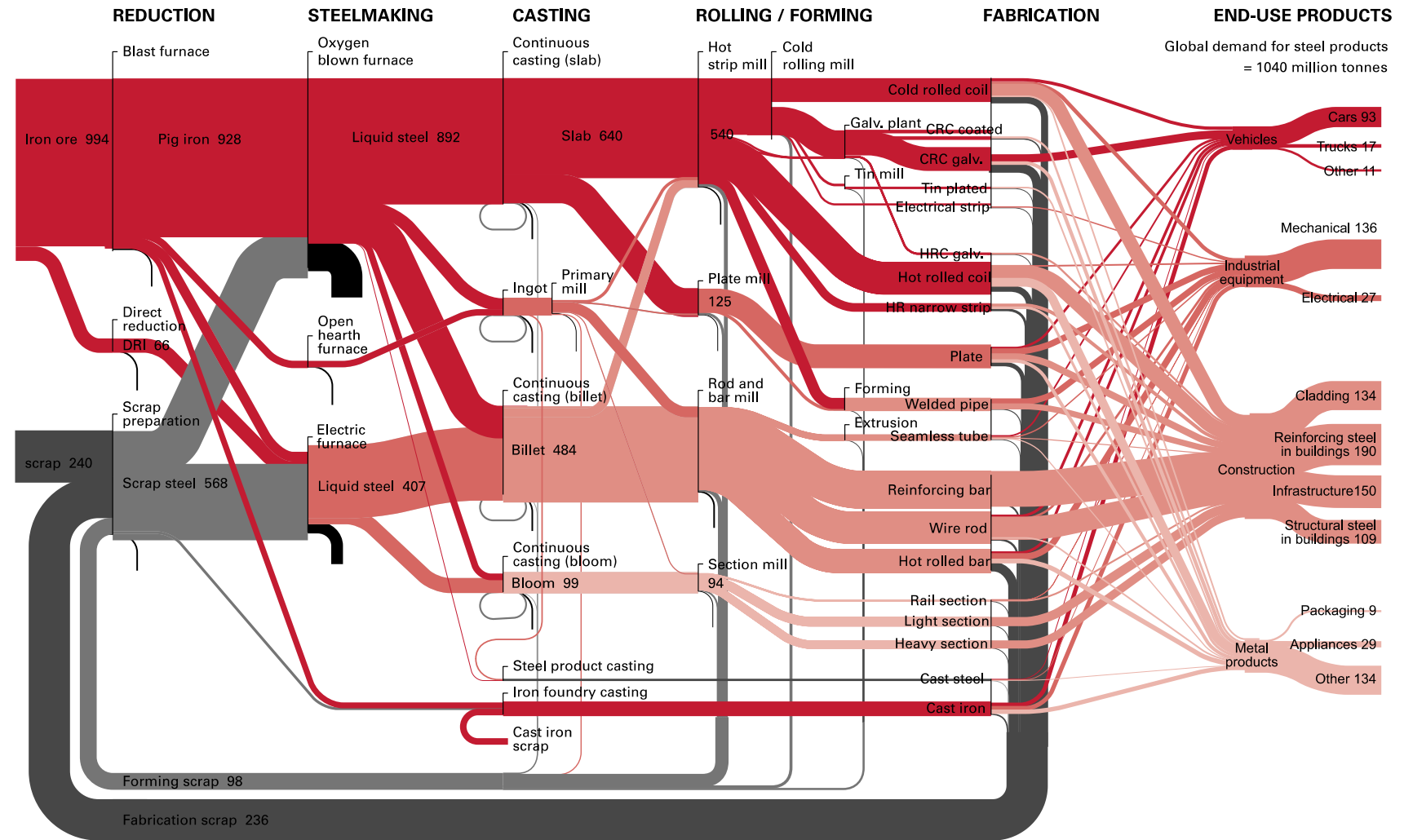
## Tools

- Rules of Thumb
- Detailed LCAs  
(EPDs/EC3)

# Embodied Carbon Supply Chain

## Every Material Unique

- Supply Chain
- LCA methods
- Variability
- Opportunities



Adapted from Cullen et. al 2012

# EPDs Enable Embodied Carbon Transparency

## Environmental Product Declarations

Nutrition Facts	
Serving Size 2/3 cup (55g) Servings Per Container About 8	
Amount Per Serving	
<b>Calories</b> 230	Calories from Fat 40
	<b>% Daily Value*</b>
<b>Total Fat</b> 8g	<b>12%</b>
Saturated Fat 1g	5%
Trans Fat 0g	
<b>Cholesterol</b> 0mg	<b>0%</b>
<b>Sodium</b> 160mg	<b>7%</b>
<b>Total Carbohydrate</b> 37g	<b>12%</b>
Dietary Fiber 4g	16%
Sugars 1g	
<b>Protein</b> 3g	



### Life Cycle Impact Results (per m<sup>3</sup>)

Declared Unit: 1 m<sup>3</sup> of 10,000 psi concrete at 28 days

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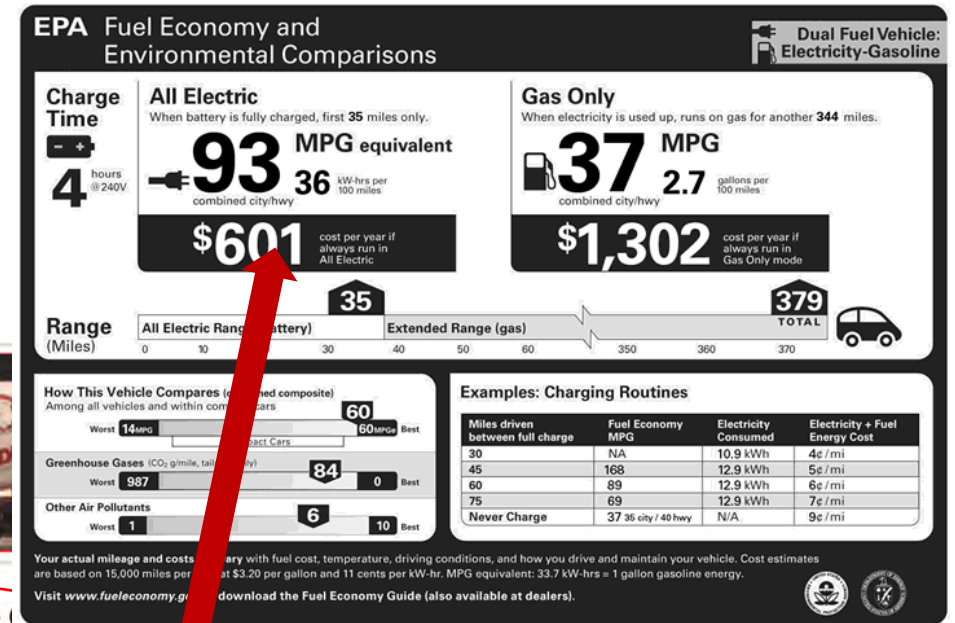
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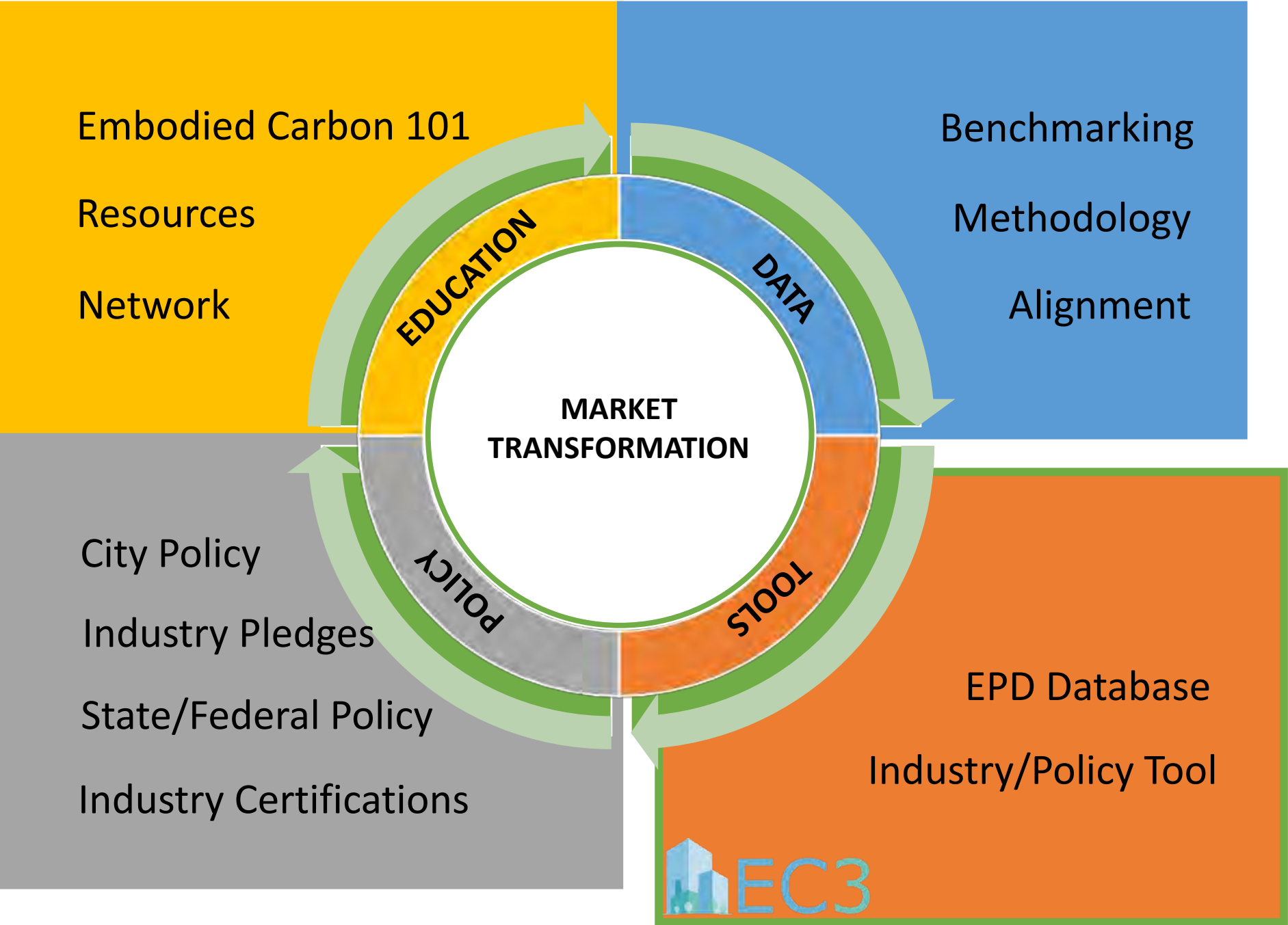
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### EPD Results are like MPG

- Estimates based on standard assumptions (PCR)
- Known variability
- Directionally accurate

CLF Projects:  
Aligning  
towards  
market  
transformation

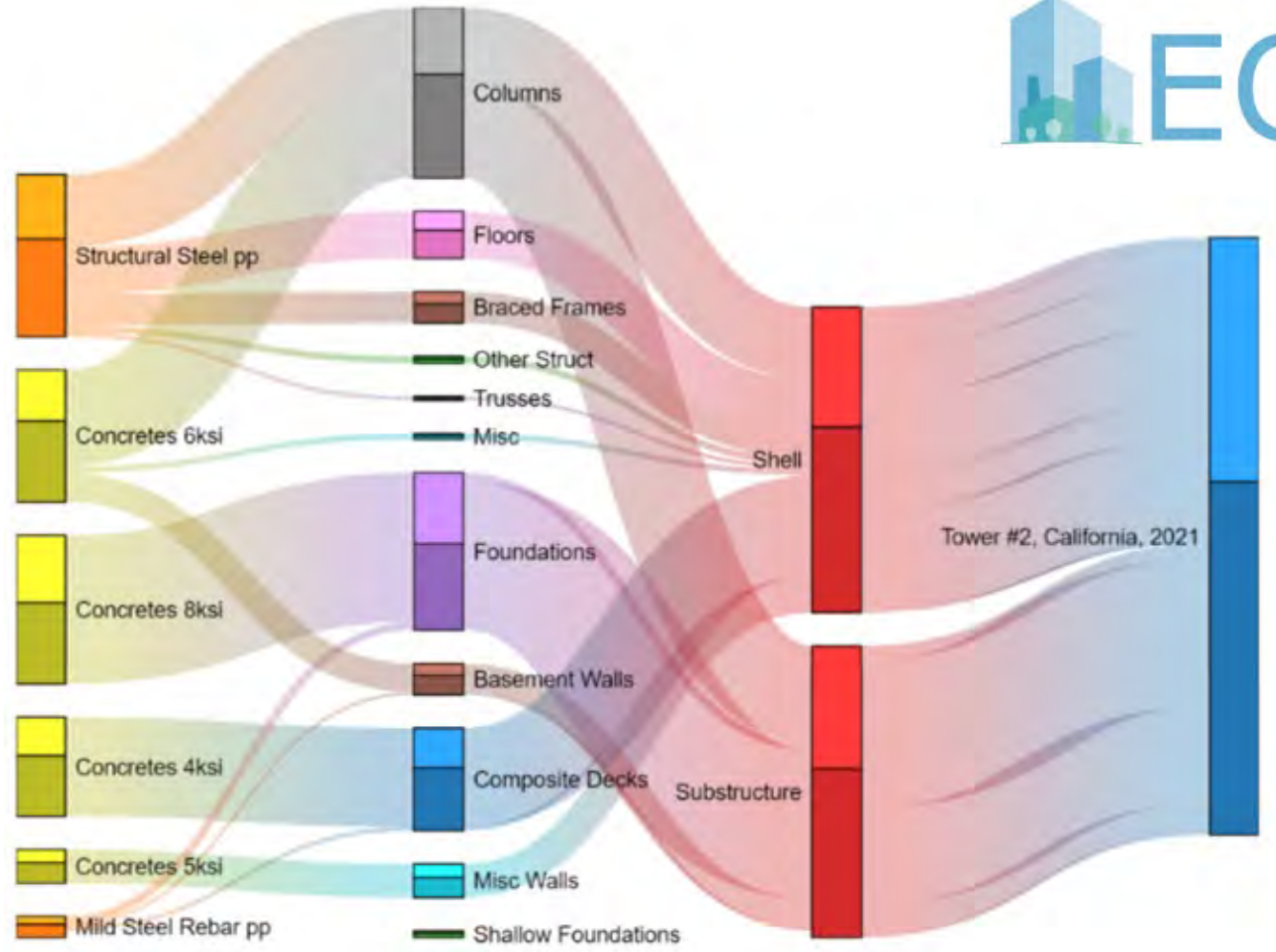


# EC3: Embodied Carbon Calculator for Construction

## PROJECT SPONSORS



ALEXANDRIA



PROJECT LEADERSHIP

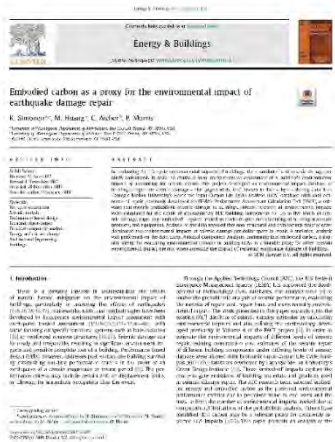


UNIVERSITY of WASHINGTON



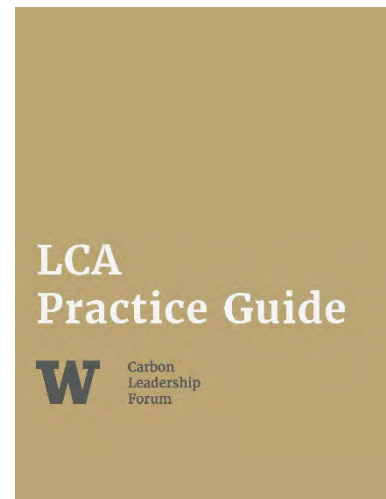


# EMBODIED CARBON NETWORK



Edited by  
The Center for Low Carbon Buildings  
Oregon Department of Environmental Quality

Published by  
The Center for Low Carbon Buildings  
Department of Architecture  
University of Washington  
10000 4th Avenue NE, Box 355000  
Seattle, WA 98195-5000  
February 2017



[www.carbonleadershipforum.org/resources/](http://www.carbonleadershipforum.org/resources/)  
[www.embodiedcarbonnetwork.org](http://www.embodiedcarbonnetwork.org)



# CARBON LEADERSHIP FORUM

Inspire, Inform and Enable Low Carbon Construction

## RECOMMENDED ACTIONS (Practitioners)

- Act **NOW** on Embodied Carbon
- Demand embodied carbon transparency via EPDs.
- Start making purchasing based on Embodied Carbon
- Support embodied carbon research, data and tools
- Learn more: become an embodied carbon leader!

## IN ORDER TO:

- Incentivize low carbon material/products
- Help drive market innovation and investment
- Drive better quality data and tools

[www.carbonleadershipforum.org/resources/](http://www.carbonleadershipforum.org/resources/)

[www.embodiedcarbonnetwork.org](http://www.embodiedcarbonnetwork.org)



# CARBON LEADERSHIP FORUM

Inspire, Inform and Enable Low Carbon Construction

## DIAMOND

**MITHUN**

**STOPWASTE**  
at home • at work • at school

Carbon Innovations

THE RUSSELL FAMILY FOUNDATION

## PLATINUM



The American  
Institute  
of Architects

**ARUP**  
**Interface**

**SKANSKA**

**Thornton Tomasetti**

**CENTRAL**  
Stronger, Cleaner, Greener Concrete.  
A U.S. CONCRETE COMPANY

**Orca**  
Optimal Ready-Mixed Concrete Aggregates  
Distributed by **Eagle Rock**  
AGGREGATES, INC.

## GOLD

**climate earth**

MAGNUSSON  
KLEMENCIC  
ASSOCIATES  
Structural + Civil Engineers



SIMPSON GUMPERTZ & HEGER

Engineering of Structures  
and Building Enclosures



thinkstep

**URBAN**  
FABRICK  
CONNECTING POLICY AND  
PRACTICE WITH DESIGN



**walter  
p moore**

KIERAN TIMBERLAKE

## SILVER

## SUPPORTERS

The Skanska logo is located in the top left corner of the image. It consists of the word "SKANSKA" in a bold, blue, sans-serif font, preceded by a small icon of three curved lines representing a stylized 'S' or a building's structure. The background of the entire image is a construction site with several yellow tower cranes and a building under construction, all set against a clear blue sky filled with many small birds in flight. A semi-transparent white horizontal band runs across the middle of the image, containing the main text.

**SKANSKA**

**Reducing the Carbon Footprint of Every Building.**



**WHY do carbon emissions  
matter... to SKANSKA???**

Over the next 35 years,

**two trillion ft<sup>2</sup>**

of new and rebuilt buildings  
will be constructed in cities worldwide.

An entire New York City  
**every 35 days**

for 35 years!

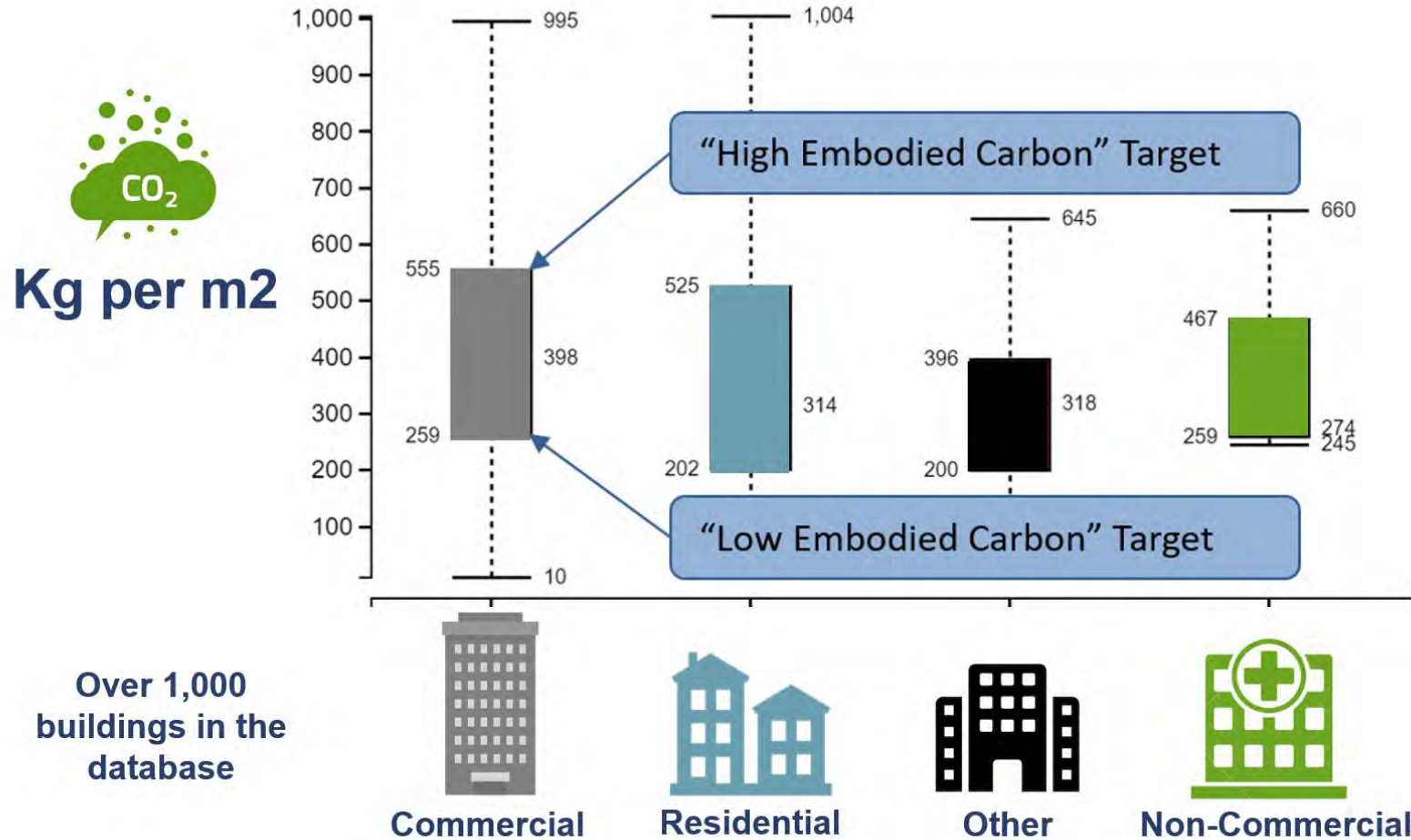




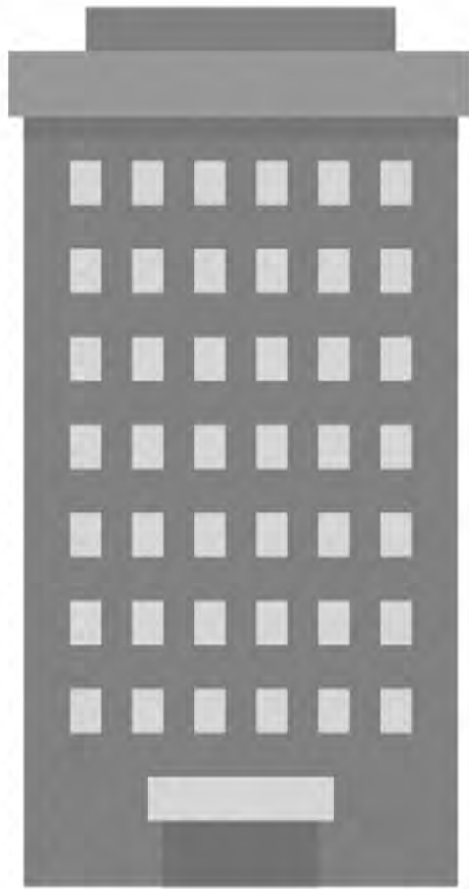




# Embodied Carbon Benchmarking Study



<http://www.carbonleadershipforum.org/data-visualization/>



**Seattle Midrise Office**



**16% operational**  
**84% embodied**  
(over 50 life cycle)

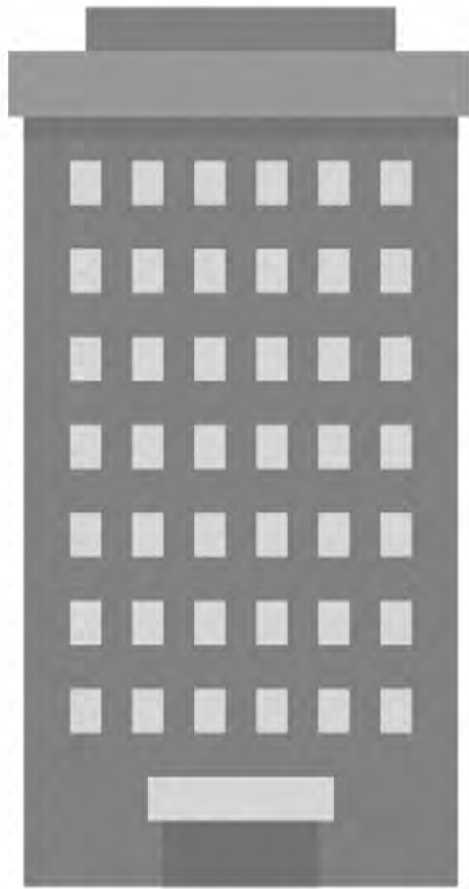
**55,000 tons of CO<sub>2</sub>**



Or... a  flying for 70 days

Or... 10,762  driving for 1 year

Or... 172,897  of crude oil



**Seattle Midrise Office**



**16% operational**  
**84% embodied**  
(over 50 life cycle)

**55,000 tons of CO<sub>2</sub>**



... a



flying for 70 days

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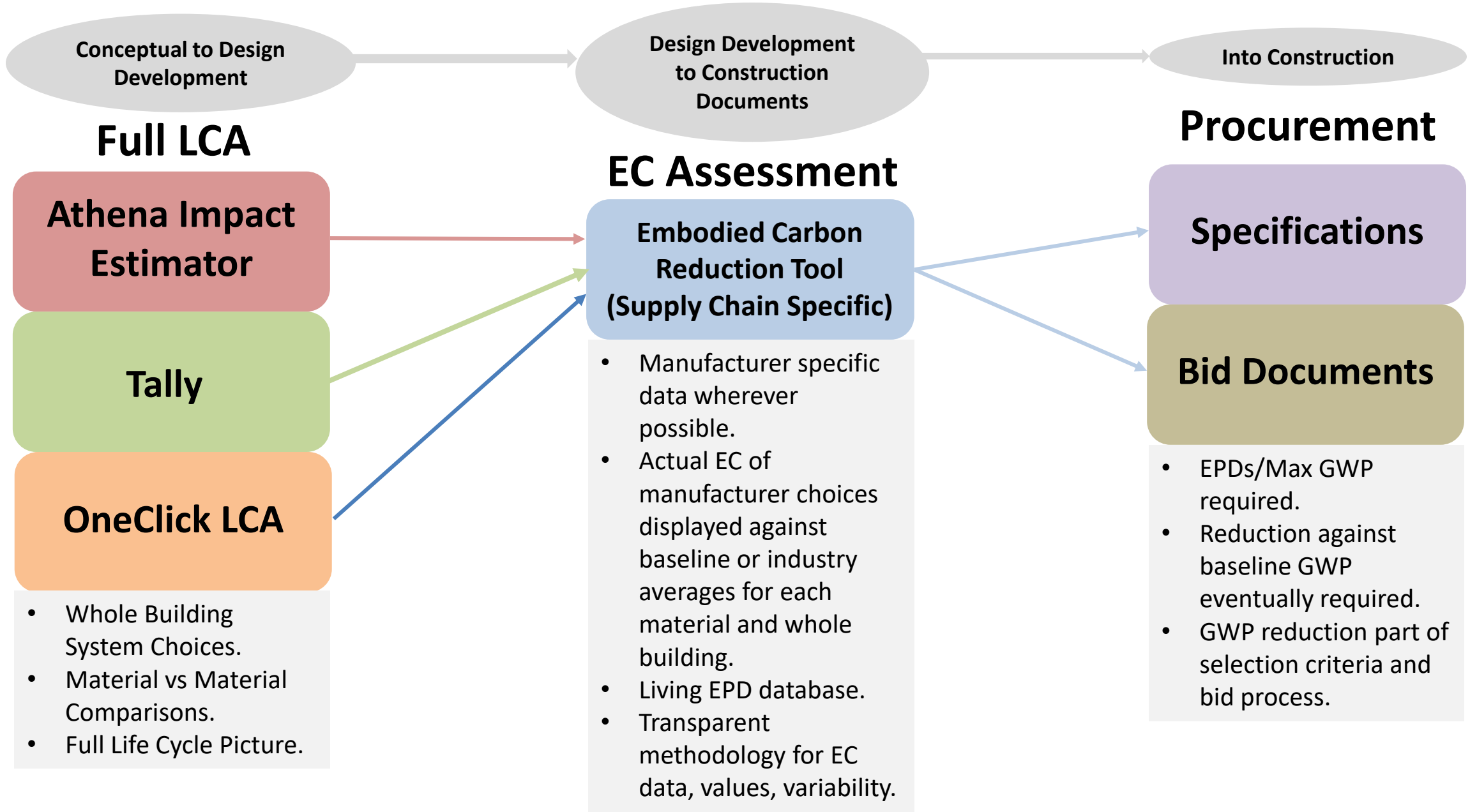
driving for 1 year



... 172,897



of crude oil



Embodied Carbon  
Reduction Tool  
(Supply Chain Specific)



- Wish List
- Available to Everyone
- Easy to Use
- Free to Use
- Open & Transparent Data Source
- Open API (willing/able to share data with other tools)
- Focused on Supply Chain Accountability



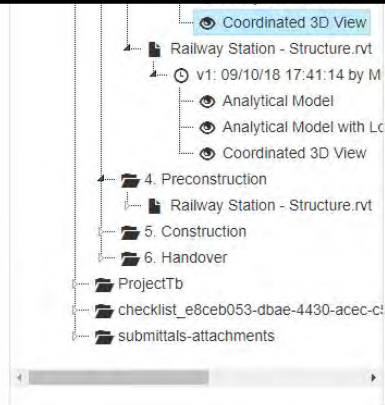
Embodied Carbon  
Calculator for Construction

# Material Quantities

ASTM Uniformat II Classification for Building Elements (E1557-97)

Level 1 Major Group Elements	Level 2 Group Elements	Level 3 Individual Elements
A SUBSTRUCTURE	A10 Foundations	A1010 Standard Foundations A1020 Special Foundations A1030 Slab on Grade
	A20 Basement Construction	A2010 Basement Excavation A2020 Basement Walls
	B SHELL	B10 Superstructure
B20 Exterior Enclosure		B2010 Exterior Walls
		B2020 Exterior Windows

02. Parking Garage			
A SUBSTRUCTURE			
A10 FOUNDATIONS			
A1010 Standard Foundations			
03.01 Concrete			
03300.001	Spread Footings		1,848.00 cy
03300.001	Continuous Footings		87.00 cy
03300.001	Mat Footings		1,190.00 cy
03300.001	Tower Crane Footing		93.00 cy
03.02 Rebar			
03210.600	Steel Bar Reinforcement in Spread Footings (70lbs/CY)		59.00 tons
03210.600	Steel Bar Reinforcement in Matt Foundations (110lbs/CY)		60.00 tons
03210.600	Steel Bar Reinforcement in Continuous Footings(50lbs/CY)		2.00 tons
03210.600	Steel Bar Reinforcement in Tower Crane Matt Foundations(110lbs/CY)		32.00 tons



# Environmental Product Declarations



Nutrition Facts	
Serving Size 2/3 cup (55g)	
Servings Per Container About 8	
Amount Per Serving	
<b>Calories</b> 230	Calories from Fat 40
% Daily Value*	
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Building Transparency | SKANSKA | SS Stacy Smedley | EC3 Developer's Blog

### CONCRETE SEARCH BY PROPERTIES

**DESIGN INTENT**

Compressive Strength: 5000 psi | @ Curing Time: 28d | Compressive Strength Other: | @ Curing Time: | Slump (min): | Options: | W/C Ratio: | SCM: | GWP: |

**GEOGRAPHIC**

Filter by Country/Region: USA | Filter by State/Province: California |

**ADVANCED**

Filter by Product Name: | Filter by Product Description: | Filter by Industry standards: | Valid EPDs after: 2019-05-31 |

**SAVE OR RESTORE**

Jurisdiction : US|CA X and Strength @28d = 5000 psi X and Valid EPDs after : 2019-05-31 X **SEARCH**

### SEARCH RESULTS AND STATISTICS

Samples: 1830 | Achievable: 235 kgCO2e | Average: 286 kgCO2e ± 59.7 kgCO2e | Conservative: 333 kgCO2e | Declared Unit: 1 yd3

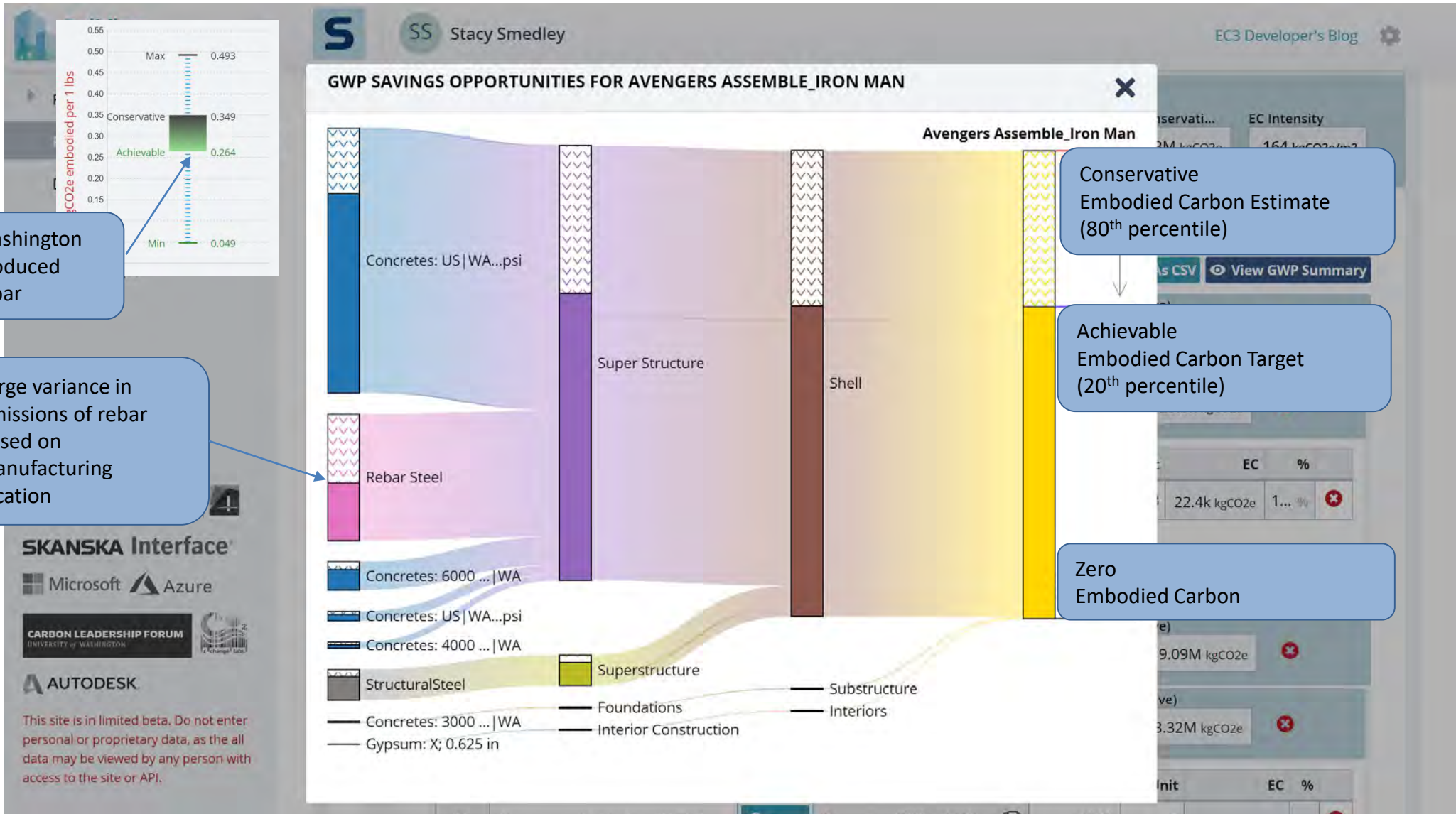
Category	Value (kgCO2e embodied per 1 yd3)
Max	599
Conservative	333
Achievable	235
Min	82

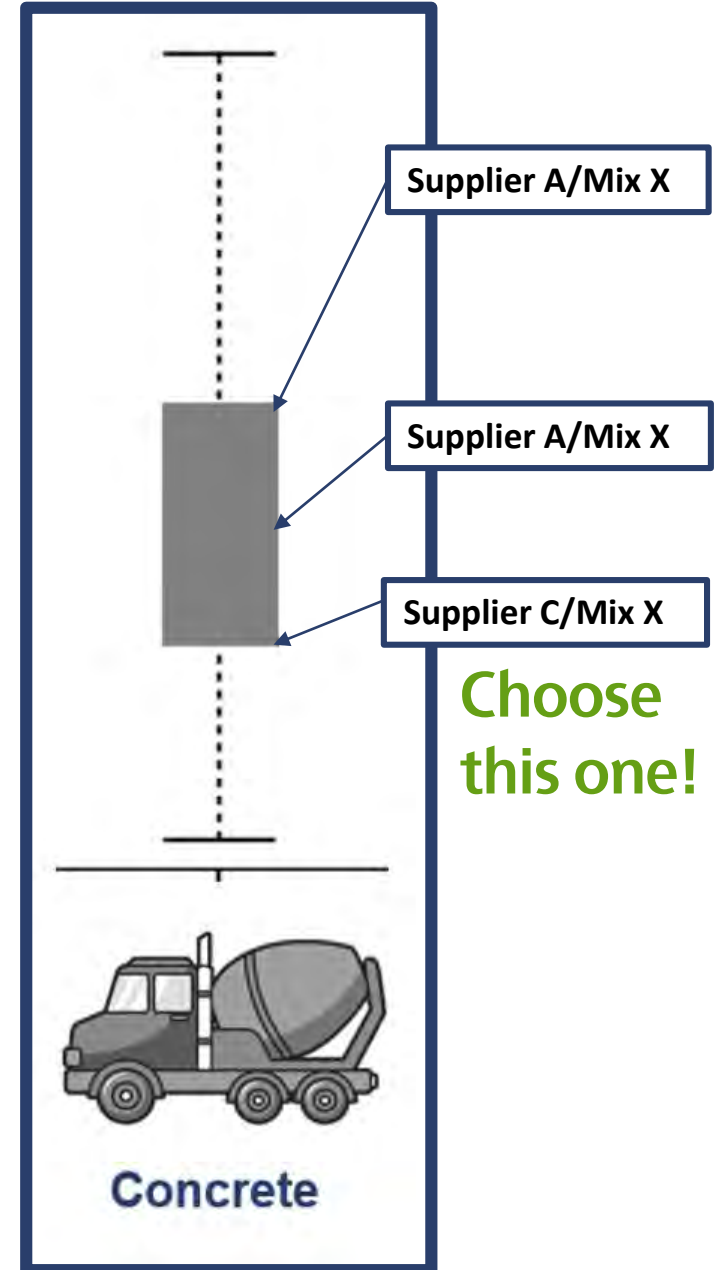
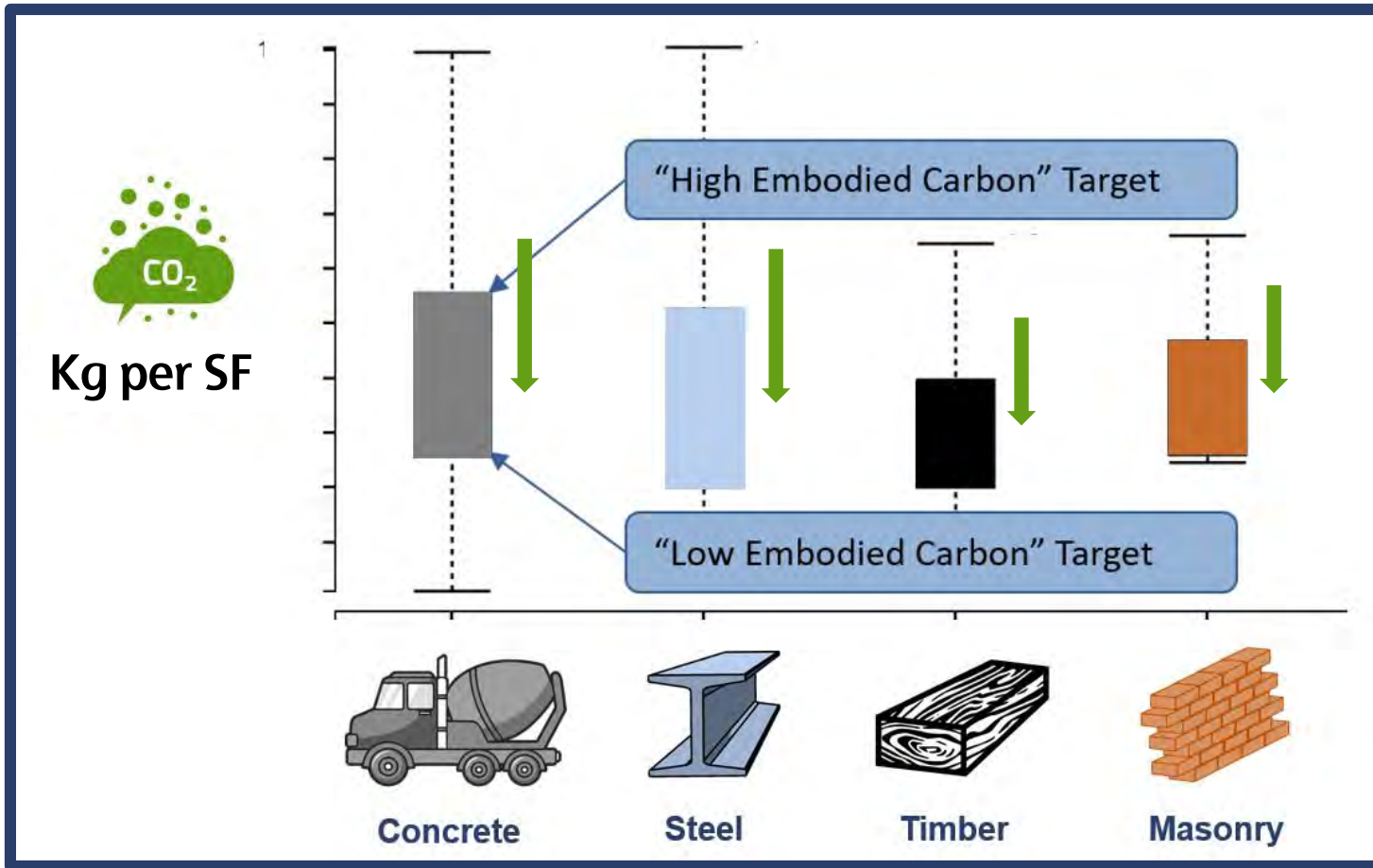
Quickly understand CO2e range of a specific material

Search by what you currently know re: material performance and criteria

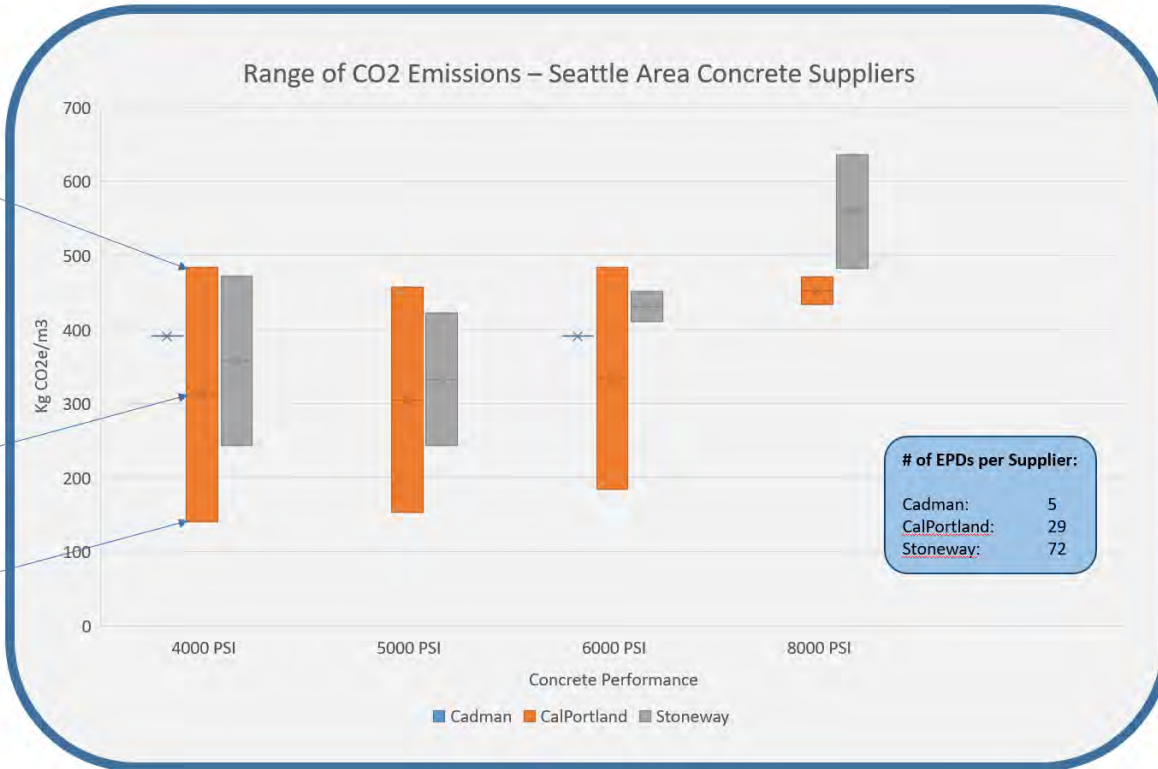
Number of manufacturer EPDs currently in database that meet material parameters







30% reduction in CO2 emissions  
JUST BY having data and ASKING.



Typical 28 day cure time  
Minimal SCM's

Typical 28 day cure time  
Some SCM's.

56 day cure time  
More SCM's

## SECTION 03 30 00 – CAST-IN-PLACE CONCRETE

### SUBMITTALS (added language)

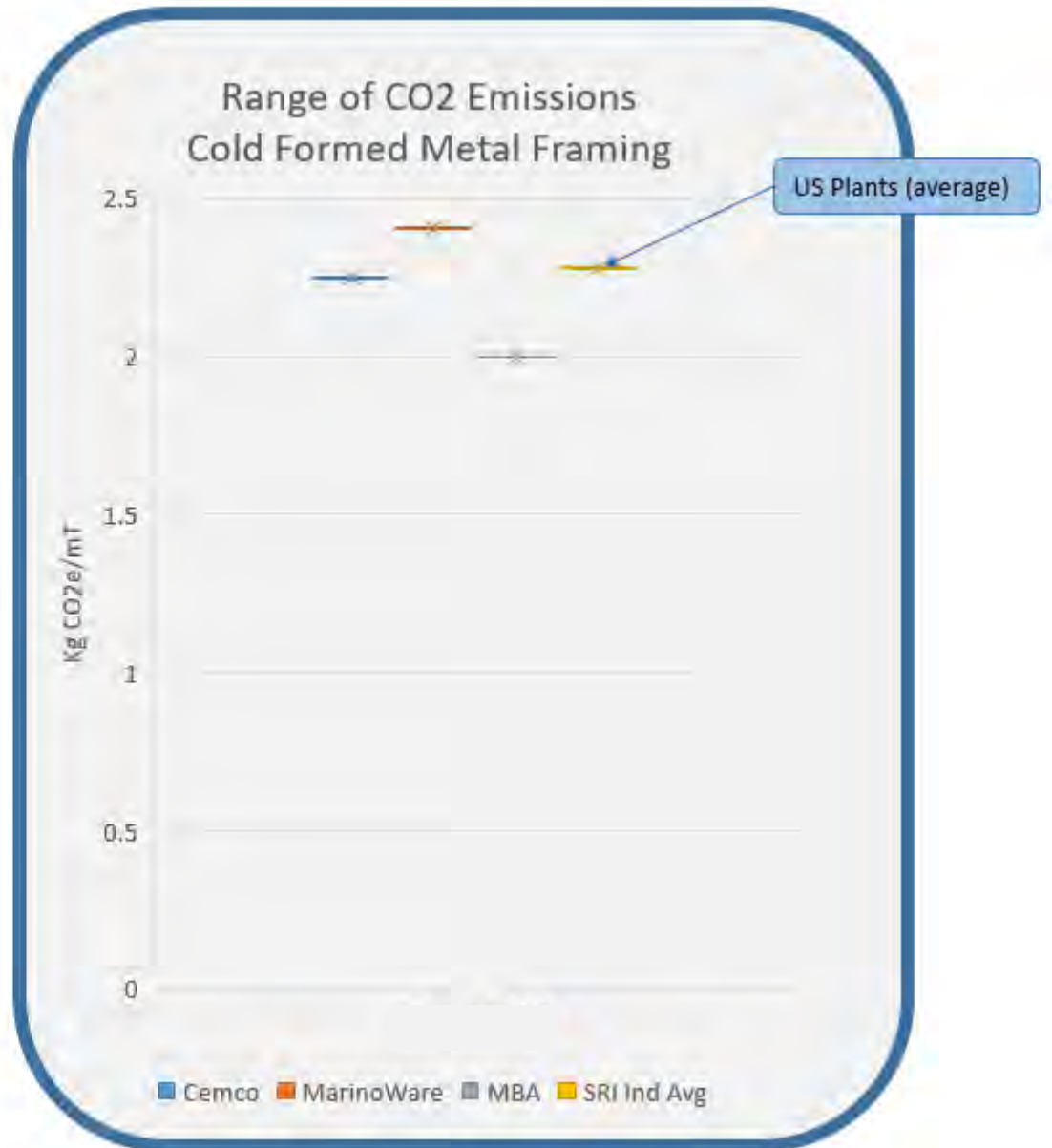
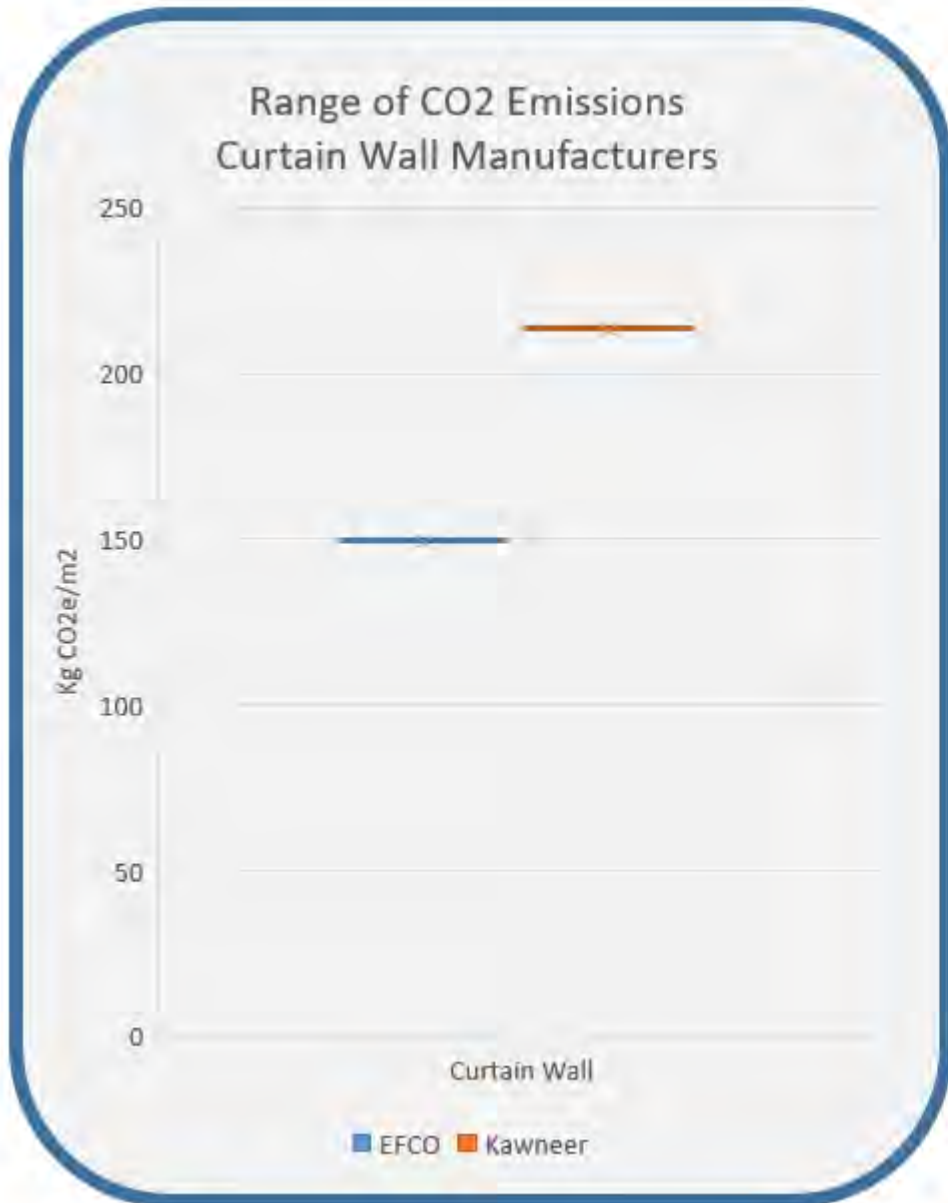
- A. Environmental Product Declaration (EPD): Submit in accordance with the Specification Section for LEED Submittals, Section 013510.01.B.1– Environmental Product Declarations.
- Submit a product-specific EPD for 90% by volume for all concrete mixes used in the project in the "Concrete Mix Specification Table" within the Concrete section of the structural general notes.
  - Impact Categories:
    - Global Warming Potential (GWP): All GWP information submitted shall be in the form of kgCO<sub>2</sub>e/kg.
  - Plant-specific GWP information will be one of the decision criteria when awarding this scope. However, information for each impact category noted above will be reviewed. The impact category information will be evaluated against both industry average impact category datasets, as defined by National Ready Mix Concrete Association (NRMCA) regional mix EPD datasets, as well as the impact category information reported within mill-specific EPDs from competing bidders. If mill-specific impact category information is not provided, industry average EPDs will be used.

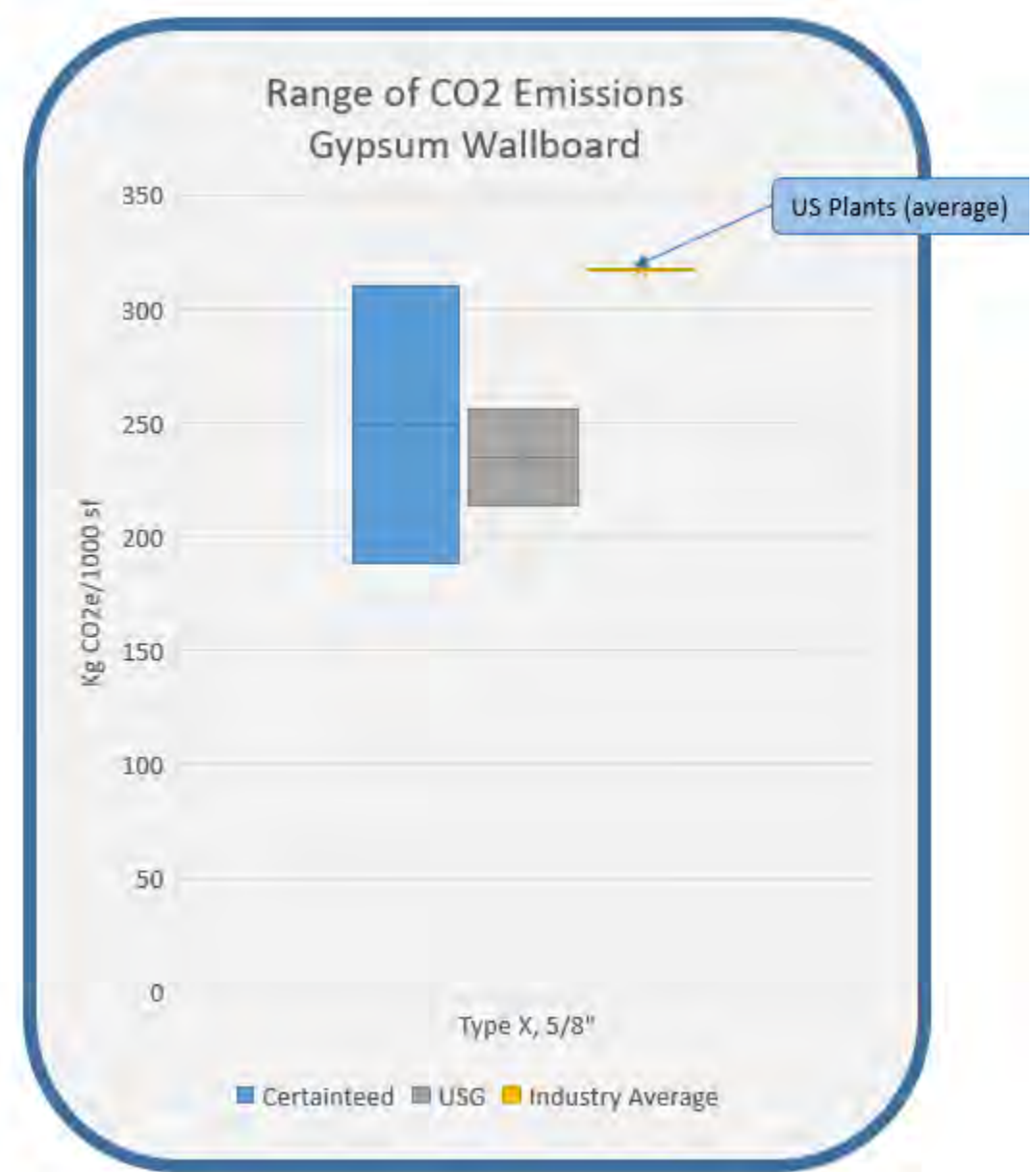
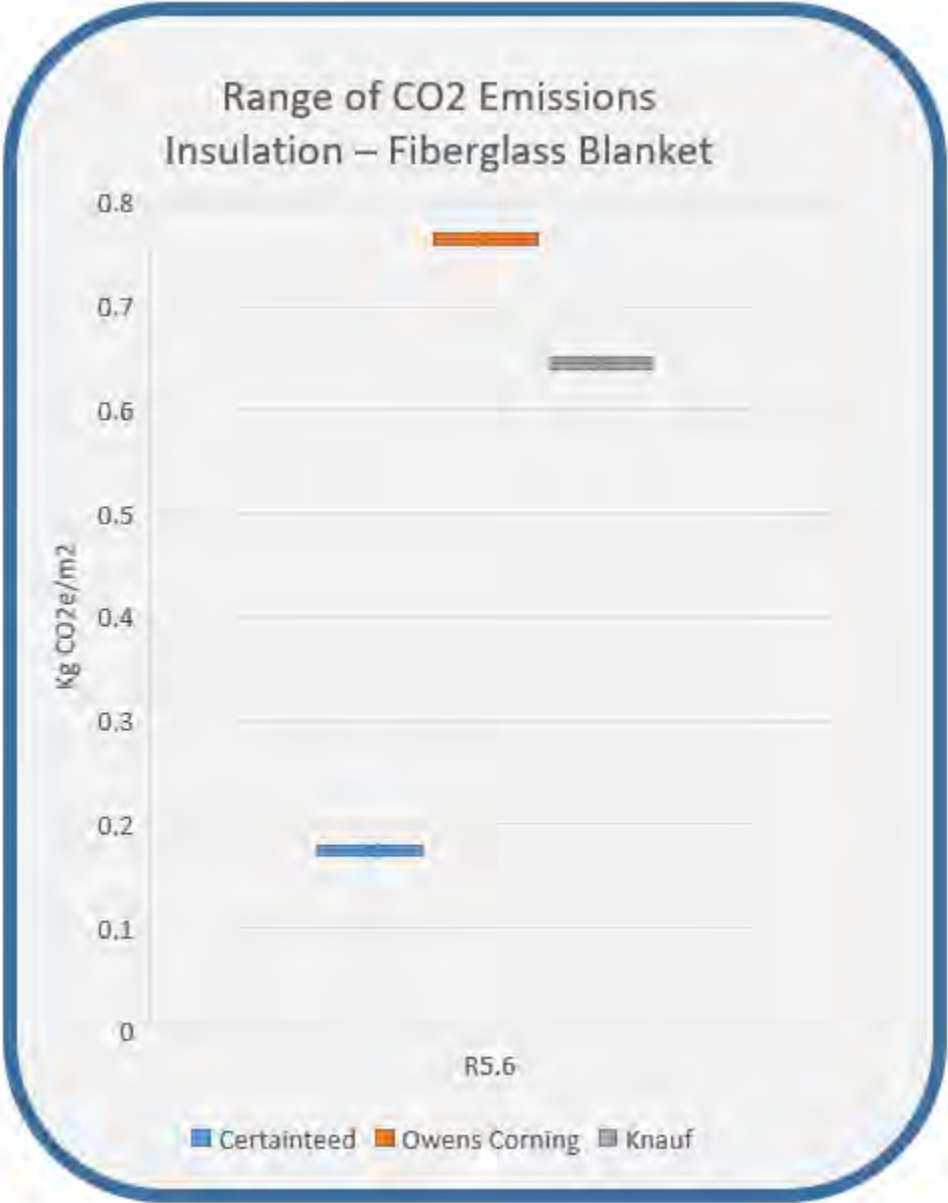
The Project has a commitment to reducing the embodied carbon footprint of the materials used in construction by a minimum of 15%, aiming to reach a 30% reduction target. Because of this mandate from the Owner and the GC team's support of actionable carbon reduction of materials, the following items are requested as a part of the Concrete scope of work:

- Environmental Product Declarations (EPDs) for All Concrete Mixes Utilized on the Project:**
  - Subcontractor/Supplier shall provide on-demand EPDs for Project ready-mix concrete mixes, at milestones as the design progresses, to support Project emissions reductions tracking.
  - Project GC's and Design Teams will provide mix performance requirements, locations and proposed schedule of pour to assist in assuring EPDs generated reflect mixes to be procured during construction.
  - EPDs of concrete mixes generated will be required with construction submittals to confirm carbon emissions, aka Global Warming Potentials (GWPs) of mixes installed.
- Actual Reductions of Carbon Emissions in Concrete Mixes Utilized on the Project:**
  - The Project is piloting the use of the Embodied Carbon in Construction Calculator (EC3) which includes a database of available EPDs from national materials associations (such as the NRMCA) as well as local suppliers and manufacturers of certain materials, including ready mix concrete.
  - The Project will utilize these available EPDs in the EC3 database to establish GWP baselines per concrete mix and enable assessment of Project specific EPD GWP numbers in order to understand reductions for the Project.
- As part of each Subcontractor/Supplier RFP Response, please provide a representative EPD for the following proposed concrete mixes, as provided by Project Structural Engineers. Potential GWP of each mix, provide in EPD, will be part of the assessment of each supplier's RFP response, alongside other key metrics.**

Member	Nominal f'c*	Exposure Class **	Shrinkage Limit (%)	Max Aggregate Size	Modulus	Supplier A	Supplier B	NRMCA Industry Average (PNW)	Supplier A (compared to average)	Supplier B (compared to average)
Spread Footings/Mats	5.0 ksi					Mix 1 300 kgCO2/m3	Mix 1 530 kgCO2/m3	455.53 kgCO2/m3	-34.14%	16.35% (above the average)
Basement Walls (Shotcrete)	5.0 ksi					Mix 2 420 kgCO2/m3	Mix 2 500 kgCO2/m3	455.53 kgCO2/m3	-7.80%	9.76% (above the average)
Basement Walls (Cast-in-Place)	5.0 ksi					Mix 1 300 kgCO2/m3	Mix 3 370 kgCO2/m3	455.53 kgCO2/m3	-34.14%	-18.78%
Slab on Grade	5.0 ksi					Mix 1 300 kgCO2/m3	Mix 4 300 kgCO2/m3	455.53 kgCO2/m3	-34.14%	-34.14%
Interior Mild Slab, Beams and Columns	5.0 ksi					Mix 3 290 kgCO2/m3	Mix 1 530 kgCO2/m3	455.53 kgCO2/m3	-36.34%	16.35% (above the average)
Interior Post-tensioned Slabs	6.0 ksi/3.0 ksi at stressing					Mix 4 370 kgCO2/m3	Mix 5 440 kgCO2/m3	480.03 kgCO2/m3	-22.92%	-8.34%
Post-tensioned Slabs exposed to weather	6.0 ksi/3.0 ksi at stressing					Mix 4 370 kgCO2/m3	Mix 6 400 kgCO2/m3	480.03 kgCO2/m3	-22.92%	-16.67%
Interior Shear Walls	5.0 ksi					Mix 3 290 kgCO2/m3	Mix 7 440 kgCO2/m3	455.53 kgCO2/m3	-36.34%	-3.41%
	6.0 ksi					Mix 5 310 kg/m3	Mix 8 340 kg/m3	480.03 kgCO2/m3	-35.42%	-29.17%
	8.0 ksi					Mix 6 340 kgCO2/m3	Mix 9 325 kgCO2/m3	588.03 kgCO2/m3	-42.18%	-44.73%
Misc. Curbs/Sidewalks/Mech. Pads	4.5 ksi				Mix 1 300 kgCO2/m3	Mix 10 375 kgCO2/m3	455.53 kgCO2/m3	-34.14%	-17.68%	
Interior Slab on Deck	5.0 ksi				Mix 3 290 kgCO2/m3	Mix 11 340 kgCO2/m3	455.53 kgCO2/m3	-36.34%	-25.36%	
								Avg Reduction	<b>-31.40%</b> below industry avg	<b>-12.99%</b> below industry avg

**Choose this one!**









Home All Materials ▾ / Concretes ▾

### CONCRETE SEARCH BY PROPERTIES

#### DESIGN INTENT

Compressive Strength

≅ 5000 psi

@ Curing Time

28d ▾

≅ Compressive Strength Other

@ Curing Time

Slump (min)

Options ▾

≤ W/C Ratio

≥ SCM

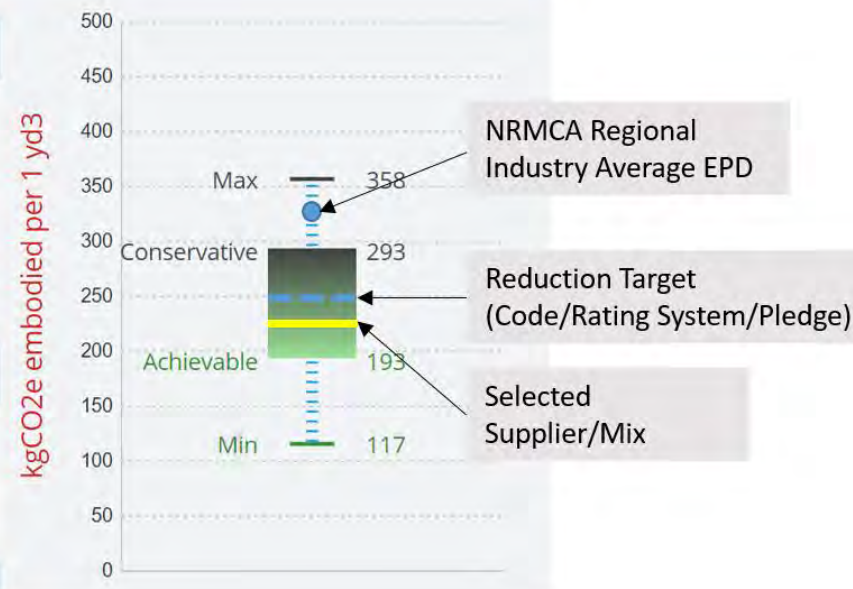
≤ GWP

#### GEOGRAPHIC

Filter by State/Province

Washington × ▾

#### ADVANCED

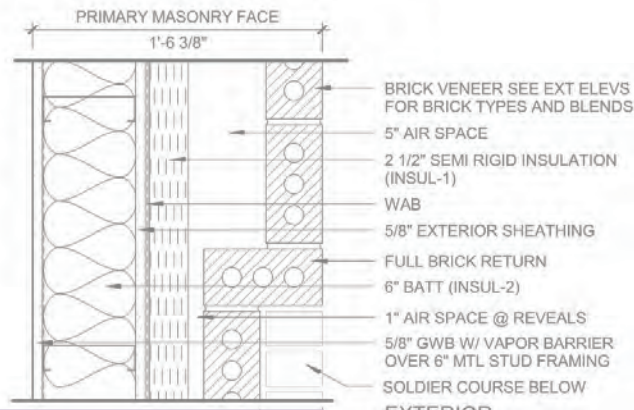


# Cities, States and the AEC Industry will lead the way.



# BRICK OVER MINERAL WOOL

## WALL DETAILS:



## BRICK OVER MTL STUDS

UVALUE = 0.065

- 5/8" GWB TYPE X
- CONT VAPOR BARRIER SHEET
- 6" MTL STUDS @ 16" O.C.
- FIBERGLASS BATT INSULATION (R19)
- 5/8" EXTERIOR GYPSUM SHEATHING
- WAB-1 (FLUID APPLIED ELASTOMERIC)
- 2-1/2" SEMI RIGID MIN WOOL (R10.8)
- 5" AIR SPACE
- MASONRY BRICK VENEER



## RANKINGS:

Global Warming Potential  
**6<sup>th</sup>**

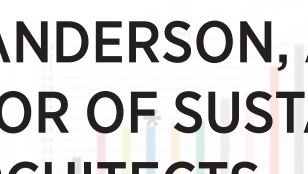
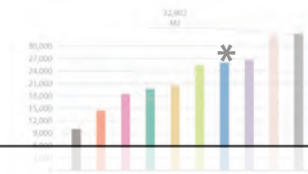
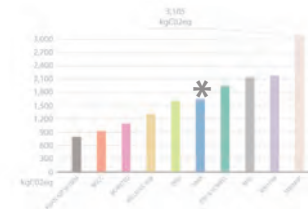
Non-renewable Energy Depletion  
**7<sup>th</sup>**

# EMBODIED CARBON IN YOUR WALLS

KJELL ANDERSON, AIA, LEED FELLOW  
DIRECTOR OF SUSTAINABLE DESIGN  
LMN ARCHITECTS

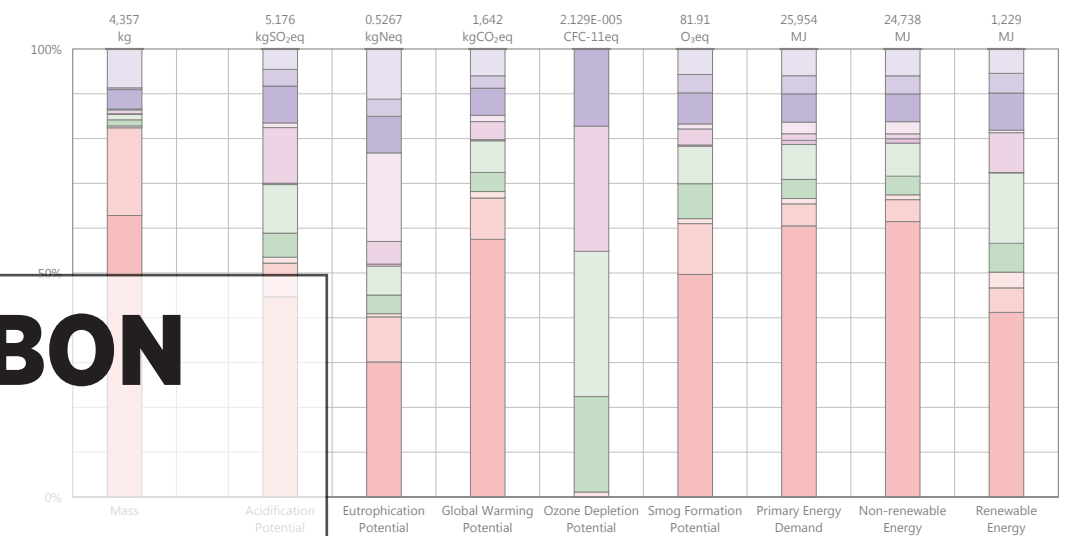
Smog Formation Potential  
**6<sup>th</sup>**

Ozone Depletion Potential  
**6<sup>th</sup>**



## MATERIAL IMPACTS:

Results per Division, itemized by Material



## KEY TAKEAWAYS

### What could be better:

- Brick module. The only difference between this wall and EWU is the exact size of brick. Brick mass is slightly higher for SAAS.
- Thin brick "EIFS style" assembly has even lower impacts than traditional framed brick (depending on detailing)

### Future investigations:

- Office standard for thin brick

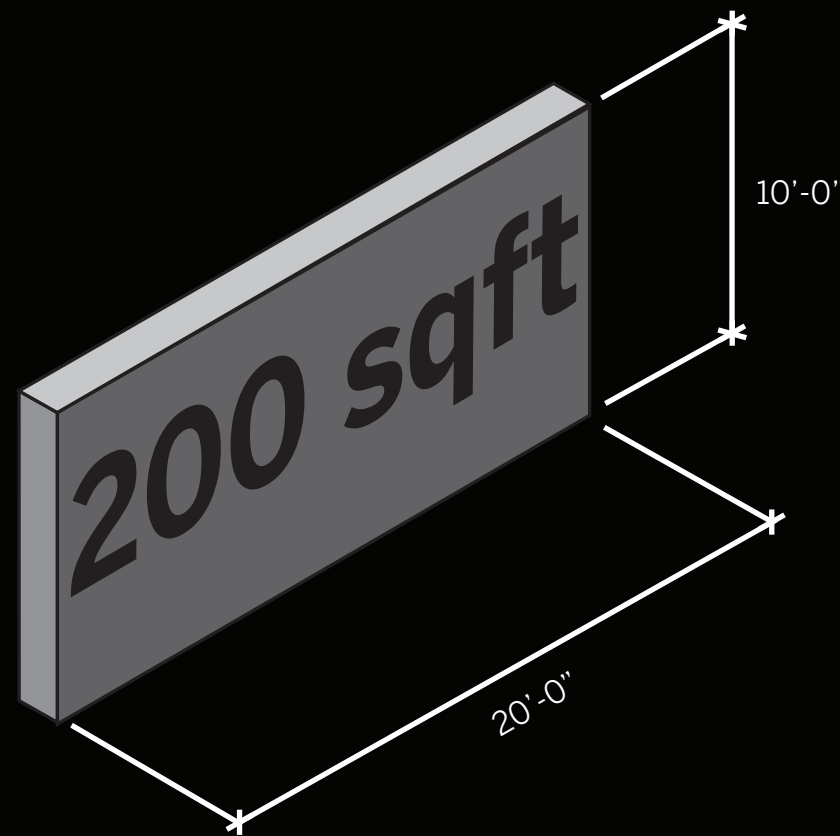
# THE RULES

## 10 PROJECTS



## 10 WALL TYPES

- Primary Opaque Wall Element
- 200 sqft modeled, includes typical details



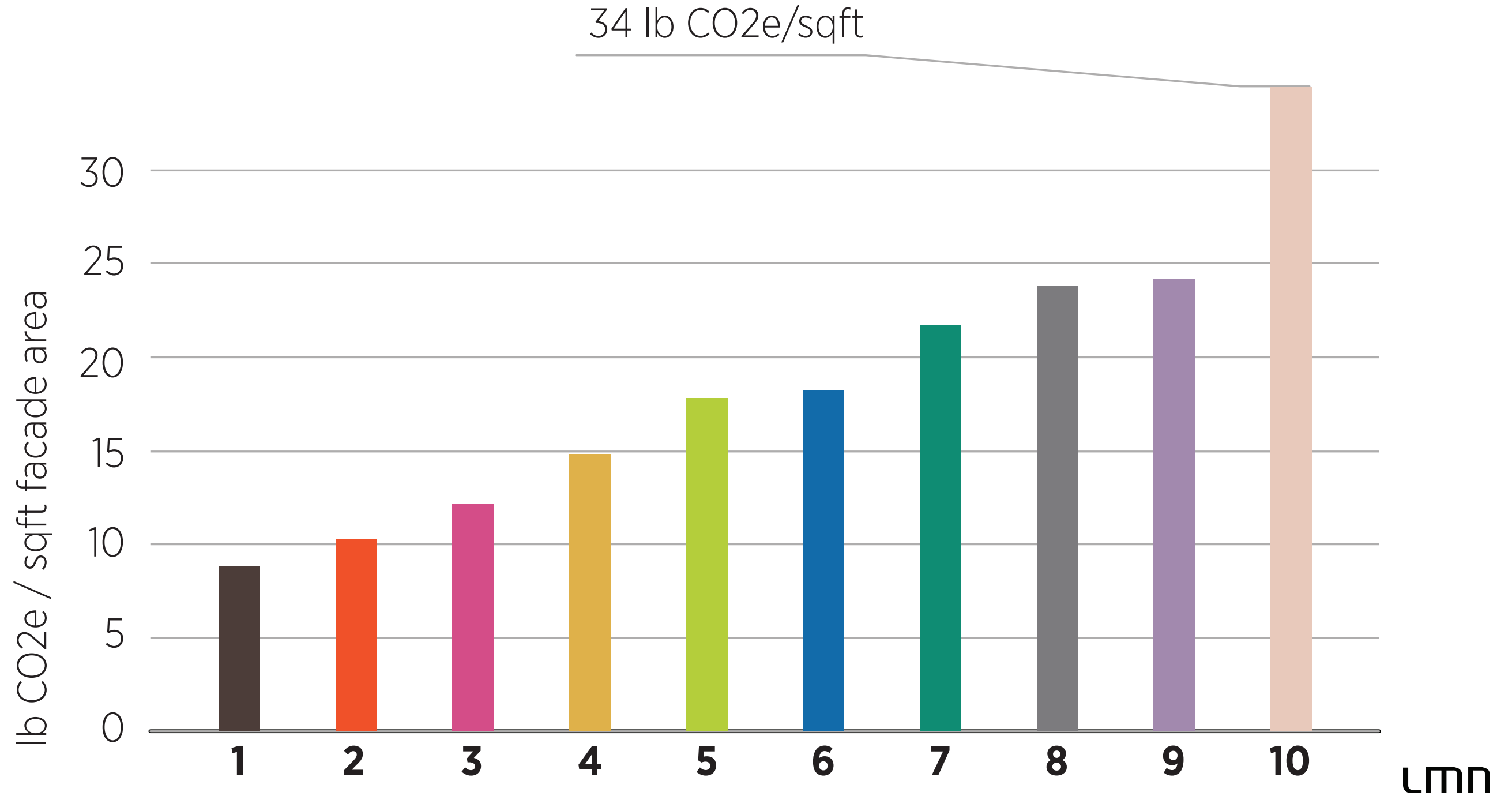
## LCA IMPACTS OF EACH

- GLOBAL WARMING POTENTIAL
- DEPLETION OF NON-RENEWABLES
- ACIDIFICATION POTENTIAL
- EUTRIFICATION POTENTIAL
- SMOG FORMATION POTENTIAL
- OZONE DEPLETION POTENTIAL

ORIGINAL STUDY BY BRAD BENKE

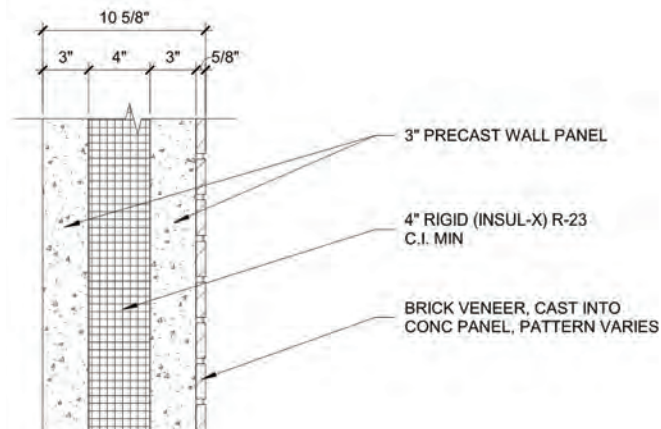
# THE RESULTS

Ordered by global warming potential



# THIN BRICK OVER CONCRETE SANDWICH PANEL

## WALL DETAILS:



## PRECAST WITH THIN BRICK

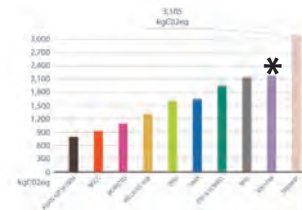
UVALUE = TBD

- 3" PRECAST
- 4" XPS
- 3" PRECAST
- 5/8" MASONRY BRICK INLAY

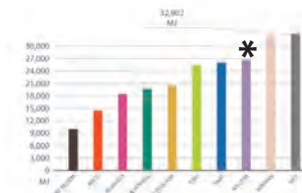


## RANKINGS:

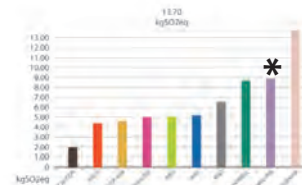
Global Warming Potential  
**9<sup>th</sup>**



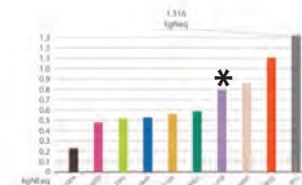
Non-renewable Energy Depletion  
**8<sup>th</sup>**



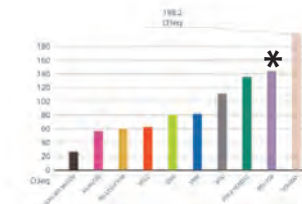
Acidification Potential  
**9<sup>th</sup>**



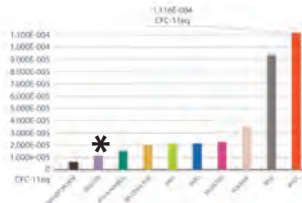
Eutrophication Potential  
**7<sup>th</sup>**



Smog Formation Potential  
**9<sup>th</sup>**

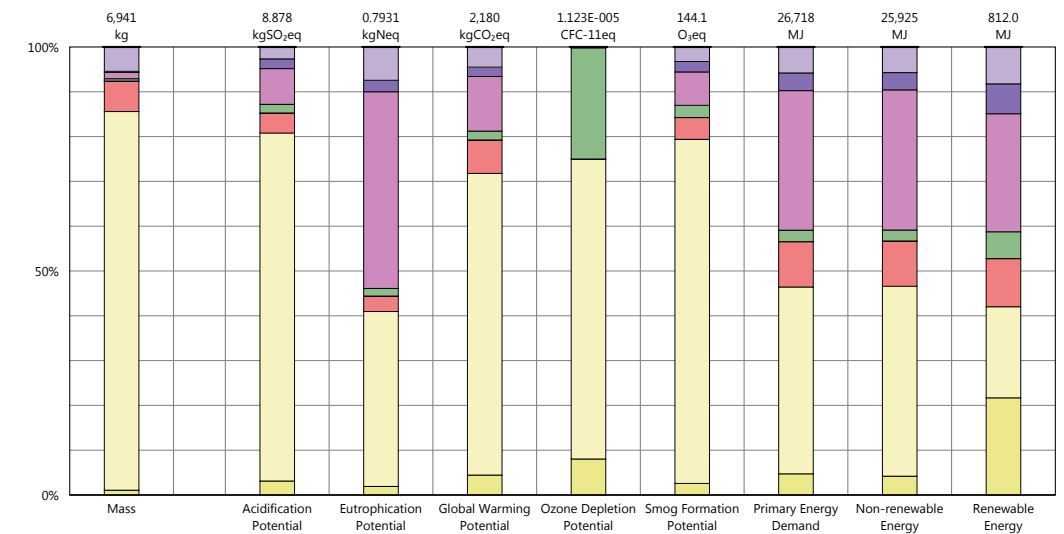


Ozone Depletion Potential  
**2<sup>nd</sup>**



## MATERIAL IMPACTS:

### Results per Division, itemized by Material



### Legend

- 03 - Concrete
  - Steel, reinforcing rod
  - Structural concrete, 5000 psi, 25% fly ash
- 04 - Masonry
  - Brick, generic
  - Mortar type S
- 05 - Metals
  - Cold formed structural steel
- 07 - Thermal and Moisture Protection
  - Polystyrene board (XPS), Pentane foaming agent
- 09 - Finishes
  - Paint, interior acrylic latex
  - Wall board, gypsum, fire-resistant (Type X)

### KEY TAKEAWAYS

#### What makes it bad:

- Overall mass. 2nd highest mass of all walls
- Brick adds impacts without providing function (other than aesthetic)

#### What could be better:

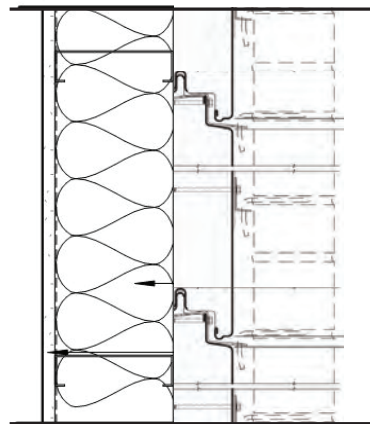
- Traditional framed brick has lower impacts.
- Thin brick "EIFS style" assembly has even lower impacts than traditional framed brick (depending on detailing)
- Additional fly ash or slag in concrete if construction schedule allows.

#### Other Considerations:

- Life expectancy of concrete vs framed walls. All walls were assuming 60 year life.
- U-value is unknown

# BRICK OVER METAL INSULATING PANEL

## WALL DETAILS:



### BRICK & CENTRIA PANEL OVER MTL STUD

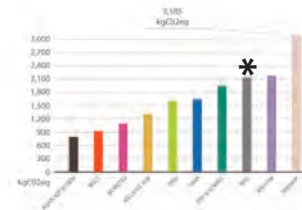
UVALUE = TBD

- 5/8" GWB TYPE X
- 6" METAL STUDS W/ BATT INSUL
- 3" CENTRIA PANEL
- AIR SPACE
- MASONRY BRICK FACE

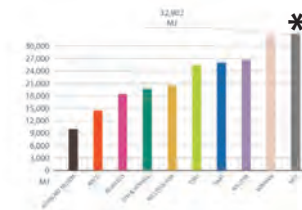


## RANKINGS:

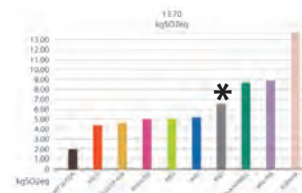
Global Warming Potential  
**8<sup>th</sup>**



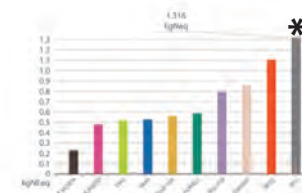
Non-renewable Energy Depletion  
**10<sup>th</sup>**



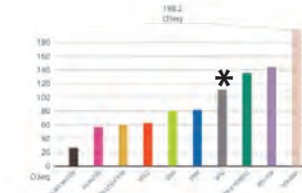
Acidification Potential  
**7<sup>th</sup>**



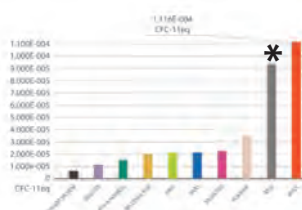
Eutrophication Potential  
**10<sup>th</sup>**



Smog Formation Potential  
**7<sup>th</sup>**

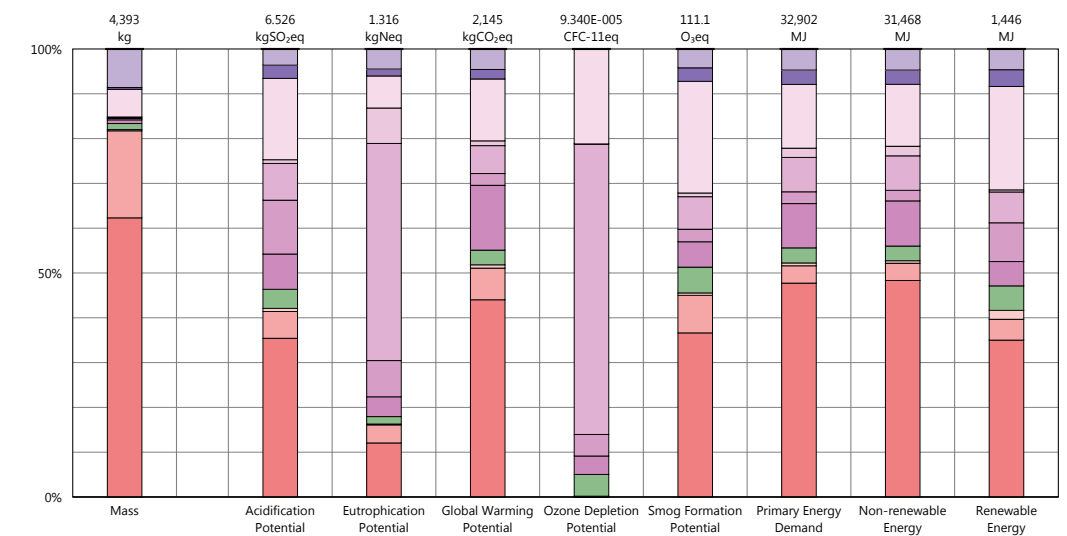


Ozone Depletion Potential  
**9<sup>th</sup>**



## MATERIAL IMPACTS:

### Results per Division, itemized by Material



### Legend

- 04 - Masonry
  - Brick, generic
  - Mortar type S
  - Steel, reinforcing rod
- 05 - Metals
  - Cold formed structural steel
- 07 - Thermal and Moisture Protection
  - Closed cell, spray-applied polyurethane foam, high density
  - Fasteners, stainless steel
  - Fluoropolymer coating, metal stock
  - Polyethylene sheet vapor barrier (HDPE)
  - Steel, sheet
- 09 - Finishes
  - Paint, interior acrylic latex
  - Wall board, gypsum, fire-resistant (Type X)

### KEY TAKEAWAYS

#### What makes it bad:

- Insulated metal panel is redundant when used behind brick.
- Foam insulation in insulated metal panel has high impacts

#### What could be better:

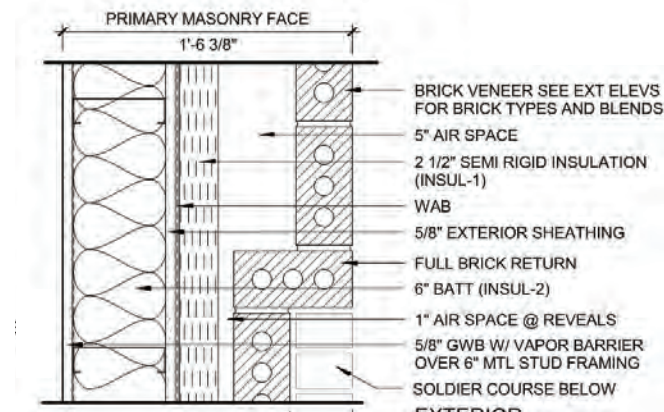
- Ditch the insulated metal panel when used behind brick and use an assembly similar to SAAS and MSU..

#### Other Considerations:

- Construction time benefits for insulated metal panel?
- U-value was unknown.

# BRICK OVER MINERAL WOOL

## WALL DETAILS:



## BRICK OVER MTL STUDS

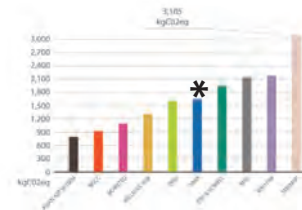
UVALUE = 0.065

- 5/8" GWB TYPE X
- CONT VAPOR BARRIER SHEET
- 6" MTL STUDS @ 16" O.C.
- FIBERGLASS BATT INSULATION (R19)
- 5/8" EXTERIOR GYPSUM SHEATHING
- WAB-1 (FLUID APPLIED ELASTOMERIC)
- 2-1/2" SEMI RIGID MIN WOOL (R10.8)
- 5" AIR SPACE
- MASONRY BRICK VENEER

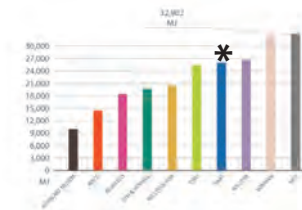


## RANKINGS:

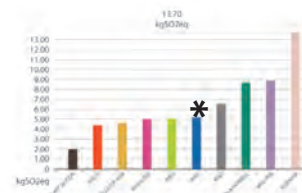
Global Warming Potential  
**6<sup>th</sup>**



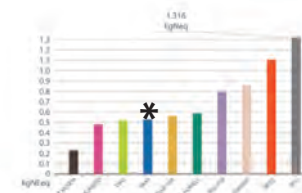
Non-renewable Energy Depletion  
**7<sup>th</sup>**



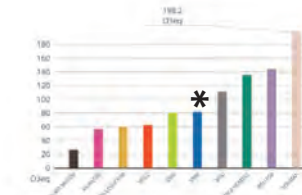
Acidification Potential  
**6<sup>th</sup>**



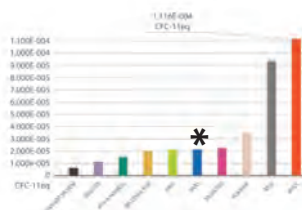
Eutrophication Potential  
**4<sup>th</sup>**



Smog Formation Potential  
**6<sup>th</sup>**

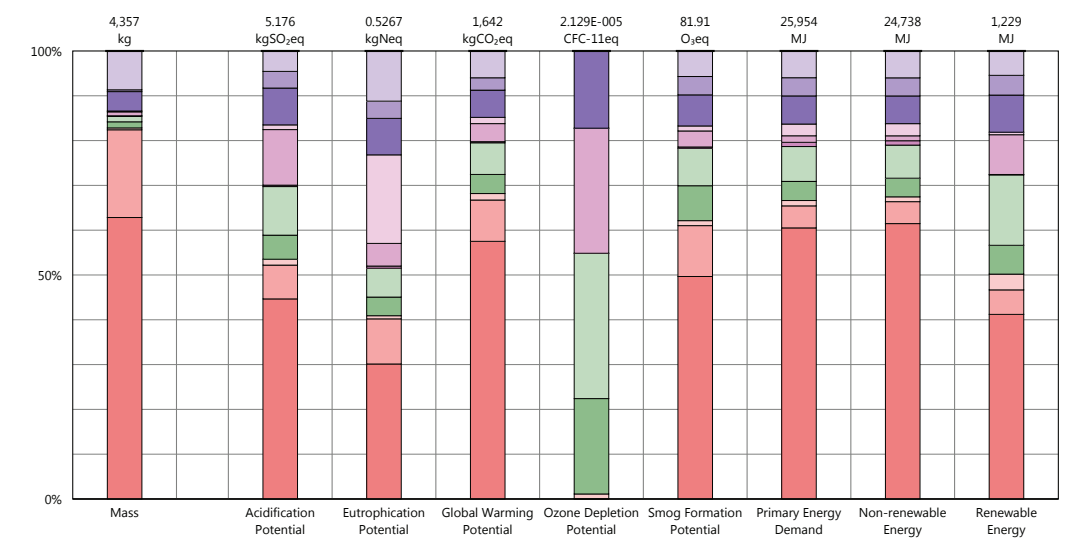


Ozone Depletion Potential  
**6<sup>th</sup>**



## MATERIAL IMPACTS:

Results per Division, itemized by Material



### Legend

- 04 - Masonry
  - Brick, generic
  - Mortar type S
  - Steel, reinforcing rod
- 05 - Metals
  - Cold formed structural steel
  - Fiberglass blanket insulation, unfaced
- 07 - Thermal and Moisture Protection
  - Fluid applied elastomeric air barrier
  - Mineral wool, TI 135 (U = 0.035 W/mK) ECOSE, EPD - Knauf Insulation
  - Polyethelene sheet vapor barrier (HDPE)
- 09 - Finishes
  - Fiberglass mat gypsum sheathing board
  - Paint, interior acrylic latex
  - Wall board, gypsum, fire-resistant (Type X)

### KEY TAKEAWAYS

#### What could be better:

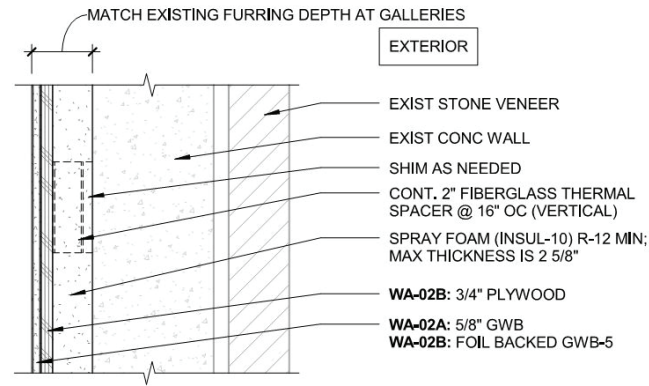
- Brick module. The only difference between this wall and EWU is the exact size of brick. Brick mass is slightly higher for SAAS.
- Thin brick "EIFS style" assembly has even lower impacts than traditional framed brick (depending on detailing)

#### Future investigations:

- Office standard for thin brick

# EXISTING FACADE WITH ADDED INSULATION

## WALL DETAILS:



## EXISTING STONE W/ NEW INSULATION

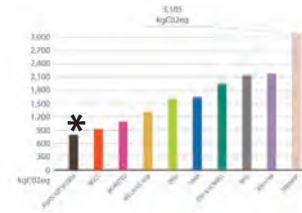
UVALUE = TBD

- 5/8" GWB TYPE X
- 3/4" PLYWOOD
- 2-1/2" CLOSED CELL SPRAYFOAM INSUL
- \*OMITTED\* EXISTING CONC
- \*OMITTED\* EXISTING STONE

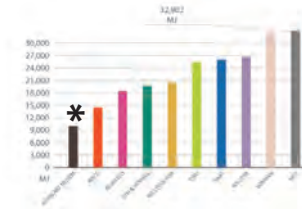


## RANKINGS:

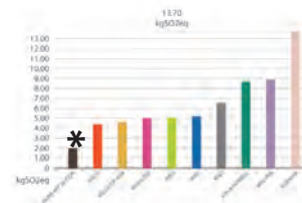
Global Warming Potential  
**1<sup>st</sup>**



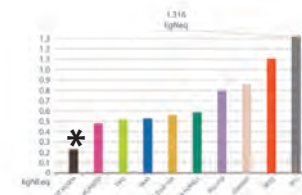
Non-renewable Energy Depletion  
**1<sup>st</sup>**



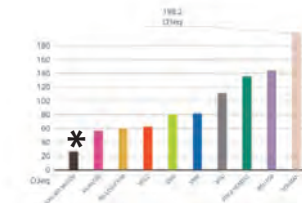
Acidification Potential  
**1<sup>st</sup>**



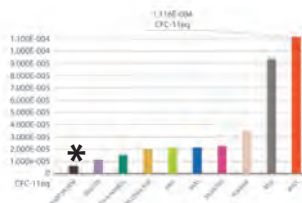
Eutrophication Potential  
**1<sup>st</sup>**



Smog Formation Potential  
**1<sup>st</sup>**

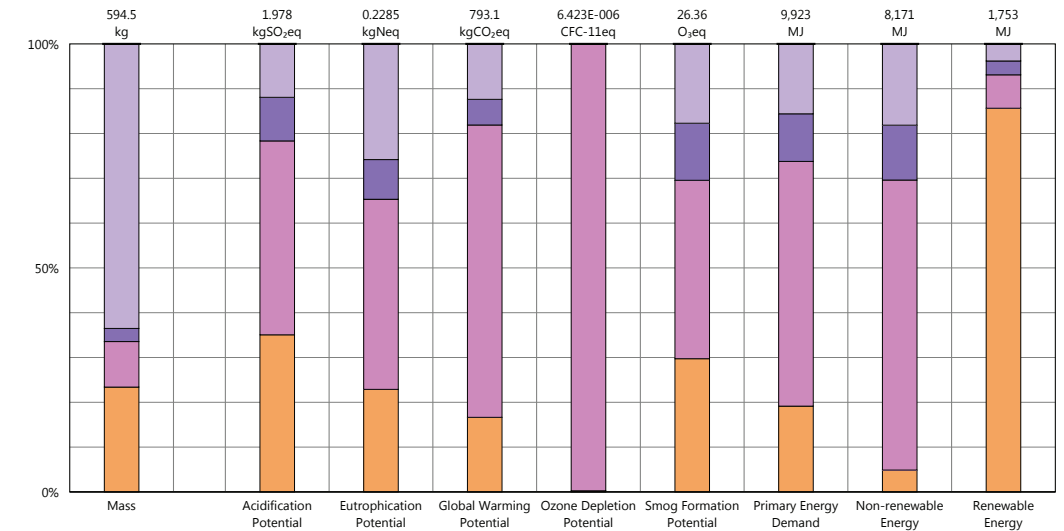


Ozone Depletion Potential  
**1<sup>st</sup>**



## MATERIAL IMPACTS:

Results per Division, itemized by Material



### Legend

- 06 - Wood/Plastics/Composites
  - Interior grade plywood, US PNW
- 07 - Thermal and Moisture Protection
  - Closed cell, spray-applied polyurethane foam, high density
- 09 - Finishes
  - Paint, interior acrylic latex
  - Wall board, gypsum, fire-resistant (Type X)

### KEY TAKEAWAYS

#### What makes it good:

- Salvaging existing structure will almost always be the most efficient wall solution.

#### What could be better:

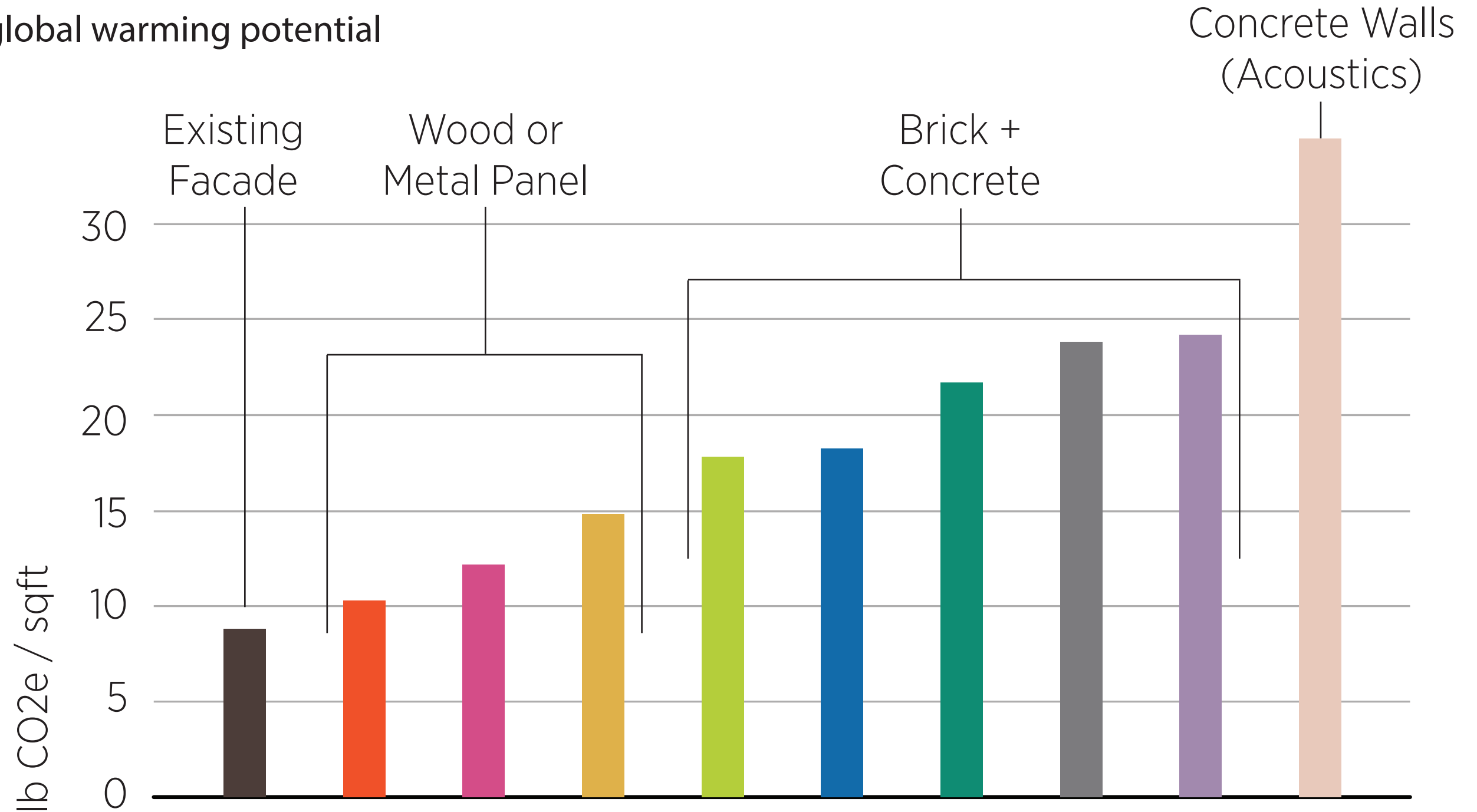
- Insulation. Spray foam has very large impacts due to the blowing agent. Mineral wool would significantly lower the embodied impacts.

#### Future investigations:

- X

# THE RESULTS

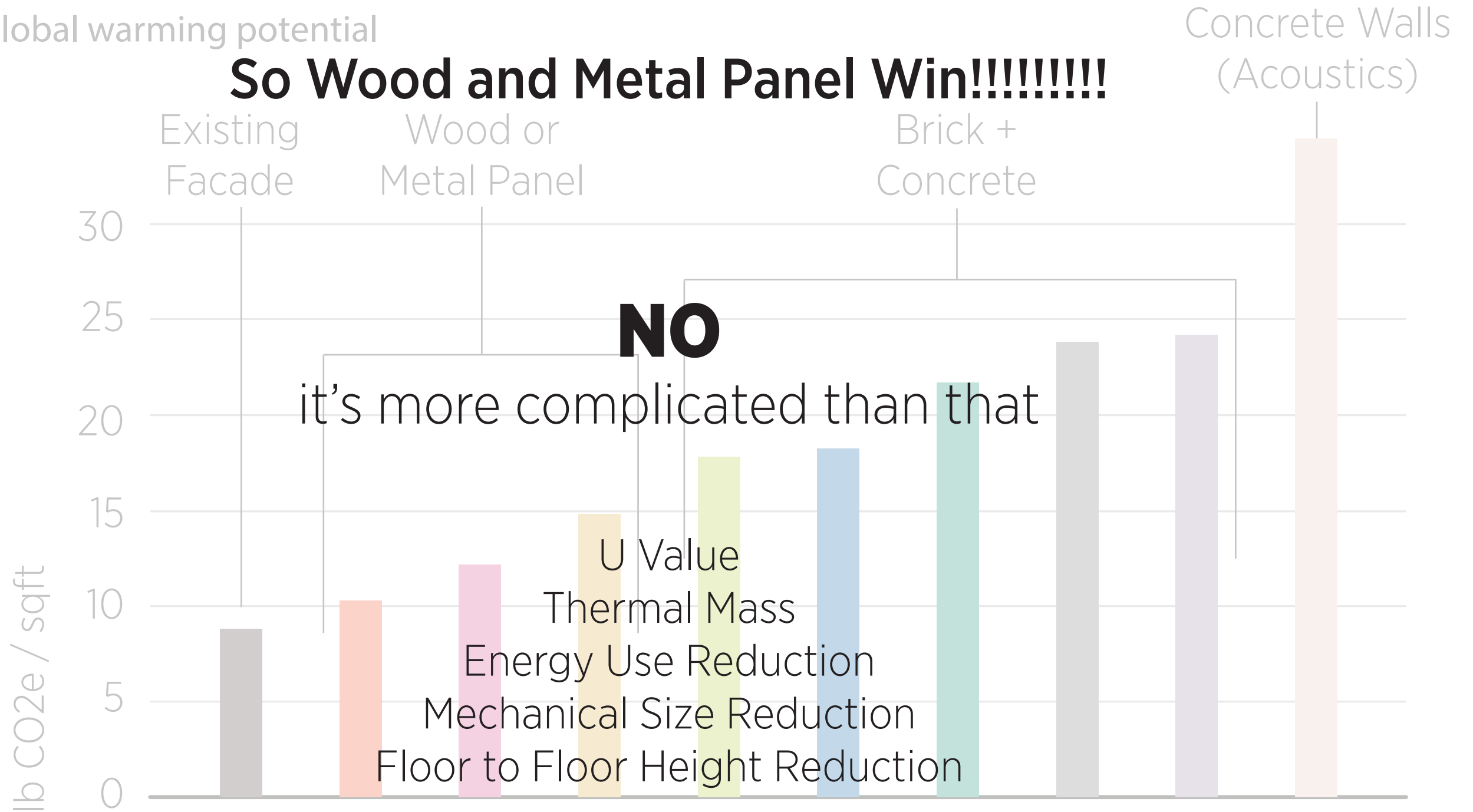
Ordered by global warming potential



# THE RESULTS

Ordered by global warming potential

**So Wood and Metal Panel Win!!!!!!!!!!**



# THE BIGGER PICTURE

## Embodied Carbon

### **Envelope +**

Structure

Interiors

### **MEP Systems -**

Landscape

## Operational Carbon

### **Energy Use -**

Refrigerants

Watergy

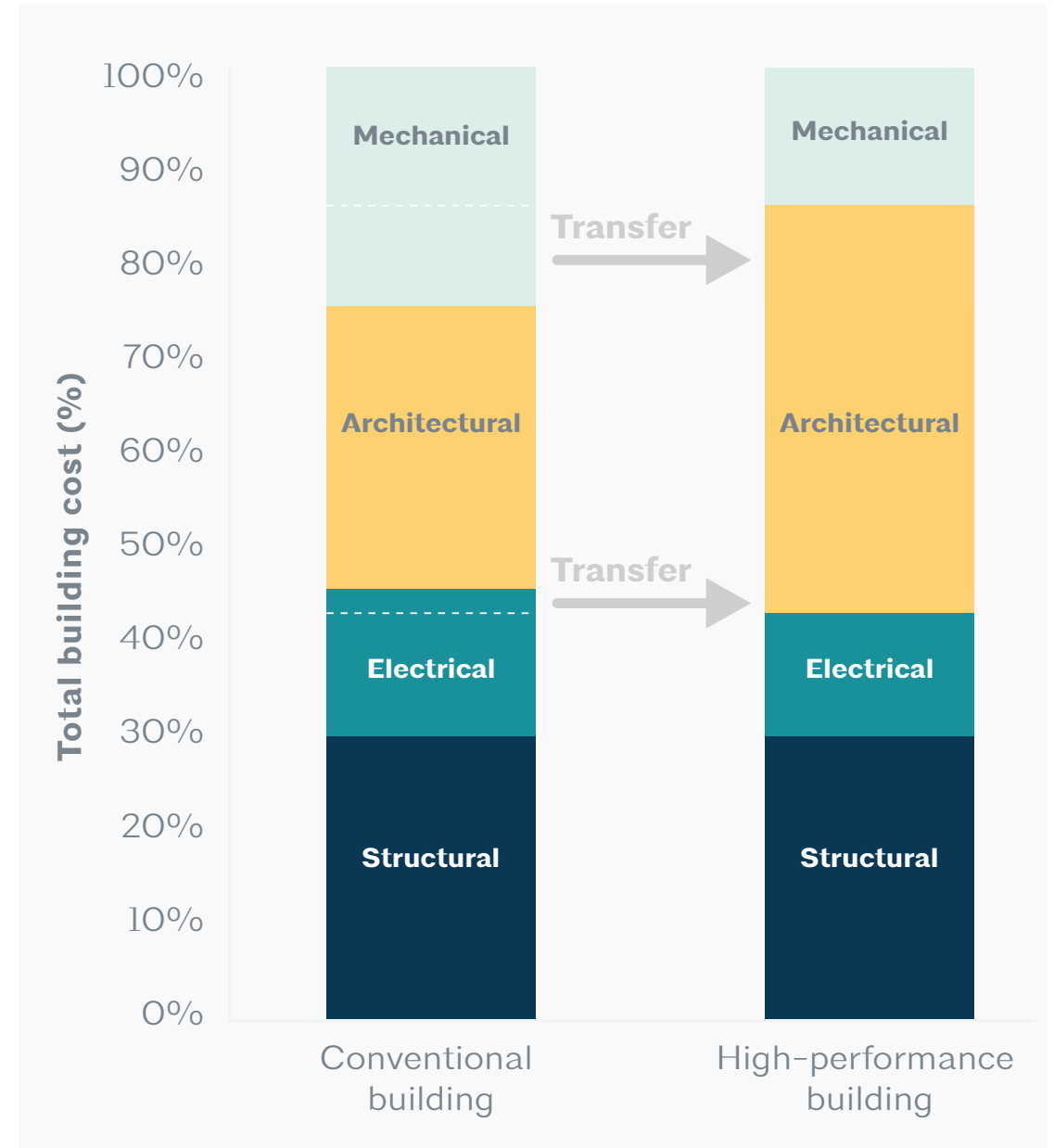
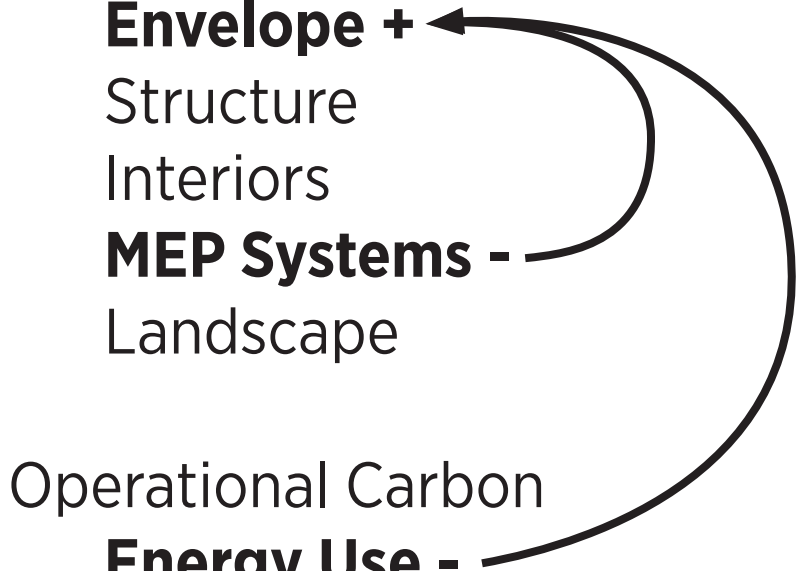
Maintenance

Landscape

## Other

Transportation

Food + Goods



Credit: AIA Building Performance Guide

# THE BIGGER PICTURE

Embodied Carbon

**Envelope +**

Structure

Interiors

**MEP Systems -**

Landscape

Operational Carbon

**Energy Use -**

Refrigerants

Watergy

Maintenance

Landscape

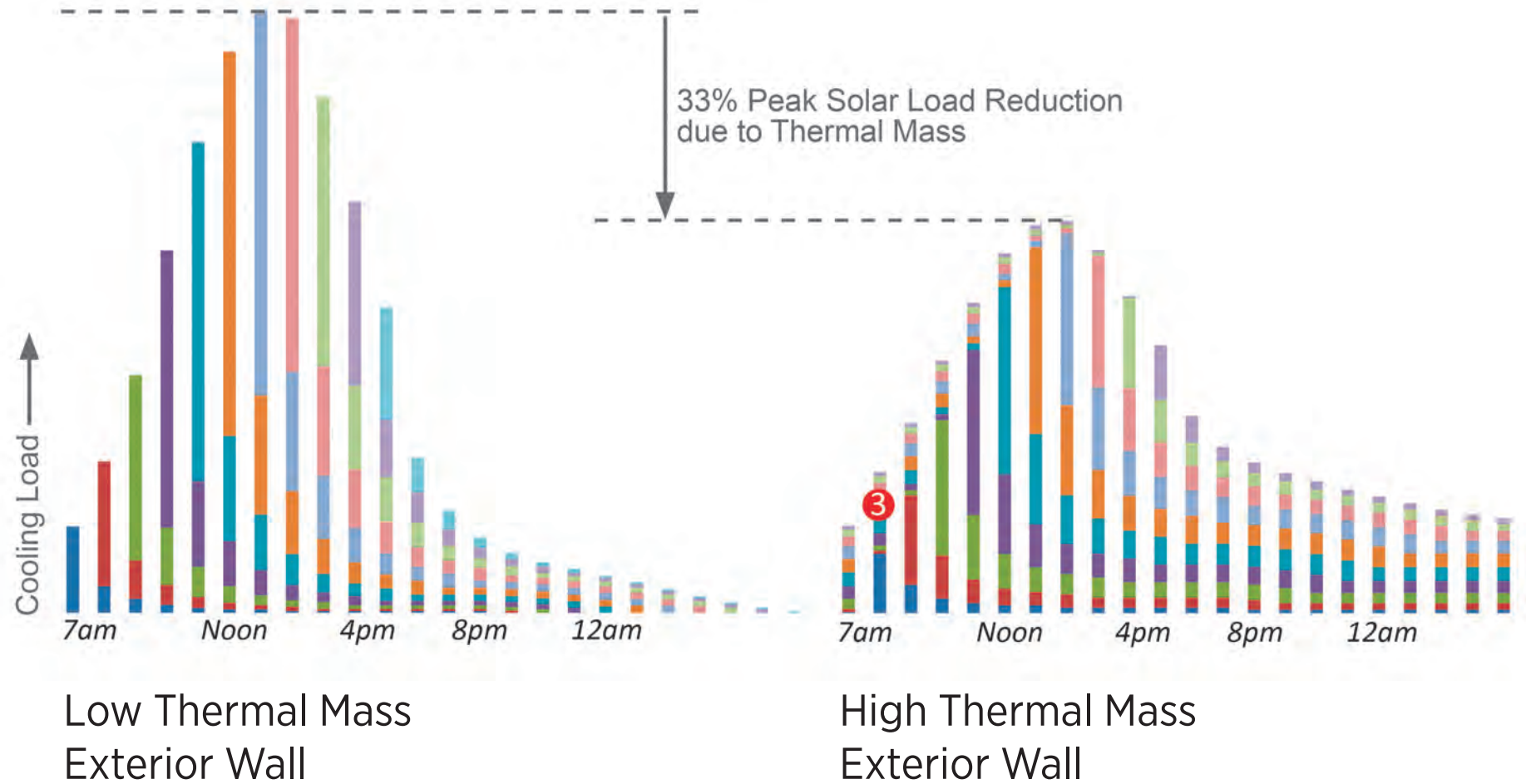
Other

Transportation

Food + Goods



## When Does Solar Get Through the Opaque Wall?



# THE BIGGER PICTURE

## Embodied Carbon

**Envelope +**

Structure

Interiors

**MEP Systems -**

Landscape

## Operational Carbon

**Energy Use -**

Refrigerants

Watergy

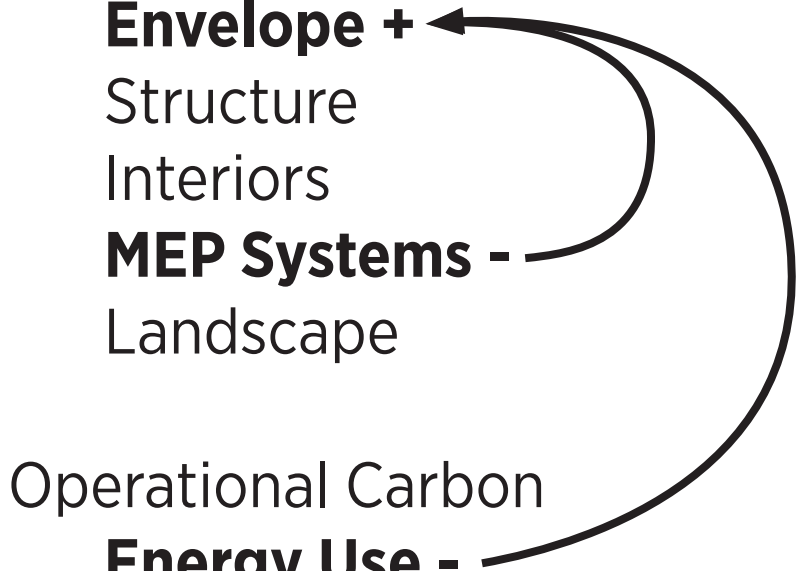
Maintenance

Landscape

## Other

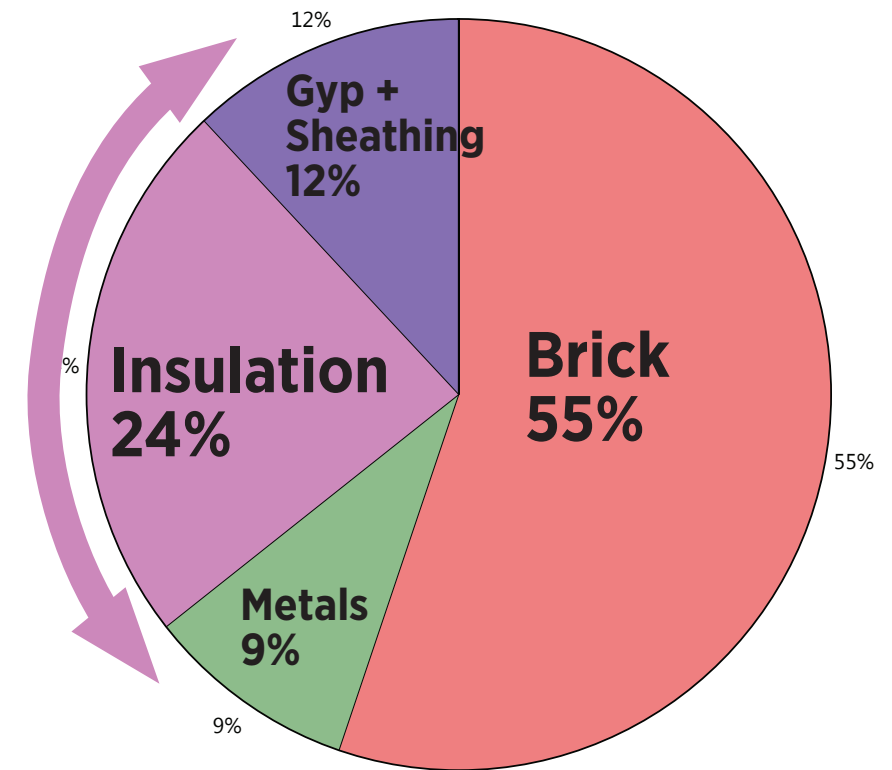
Transportation

Food + Goods



More Insulation is (generally) better...

Global Warming Potential Breakdown of  
*Brick Over Mineral Wool*



# THE BIGGER PICTURE

Embodied Carbon

**Envelope +**

Structure

Interiors

**MEP Systems -**

Landscape

Operational Carbon

**Energy Use -**

Refrigerants

Watergy

Maintenance

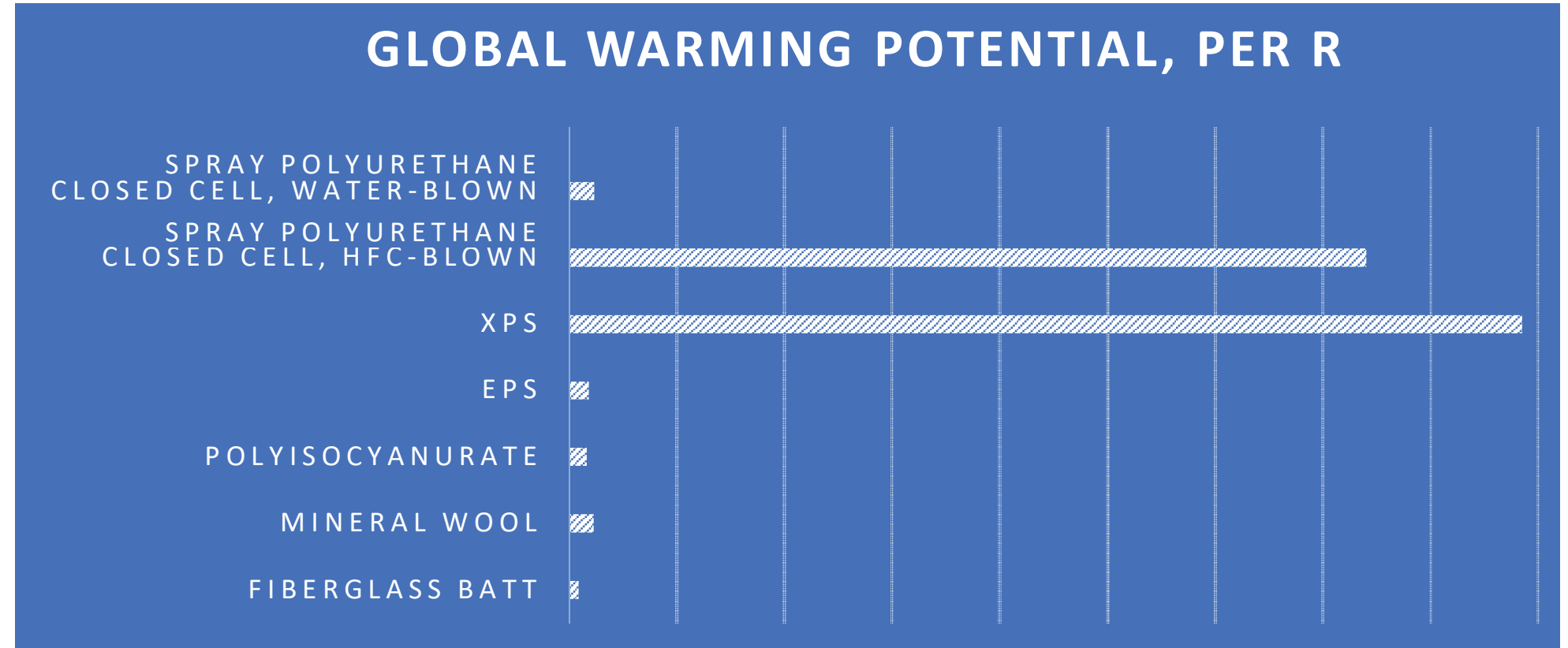
Landscape

Other

Transportation

Food + Goods

More Insulation is (generally) better...  
IF it's a low-GWP insulation



...better if it's not made from fossil fuels

..and even better if it sequesters carbon!

# THE BIGGER PICTURE

Embodied Carbon

**Envelope +**

Structure

Interiors

**MEP Systems -**

Landscape

Operational Carbon

**Energy Use -**

Refrigerants

Watergy

Maintenance

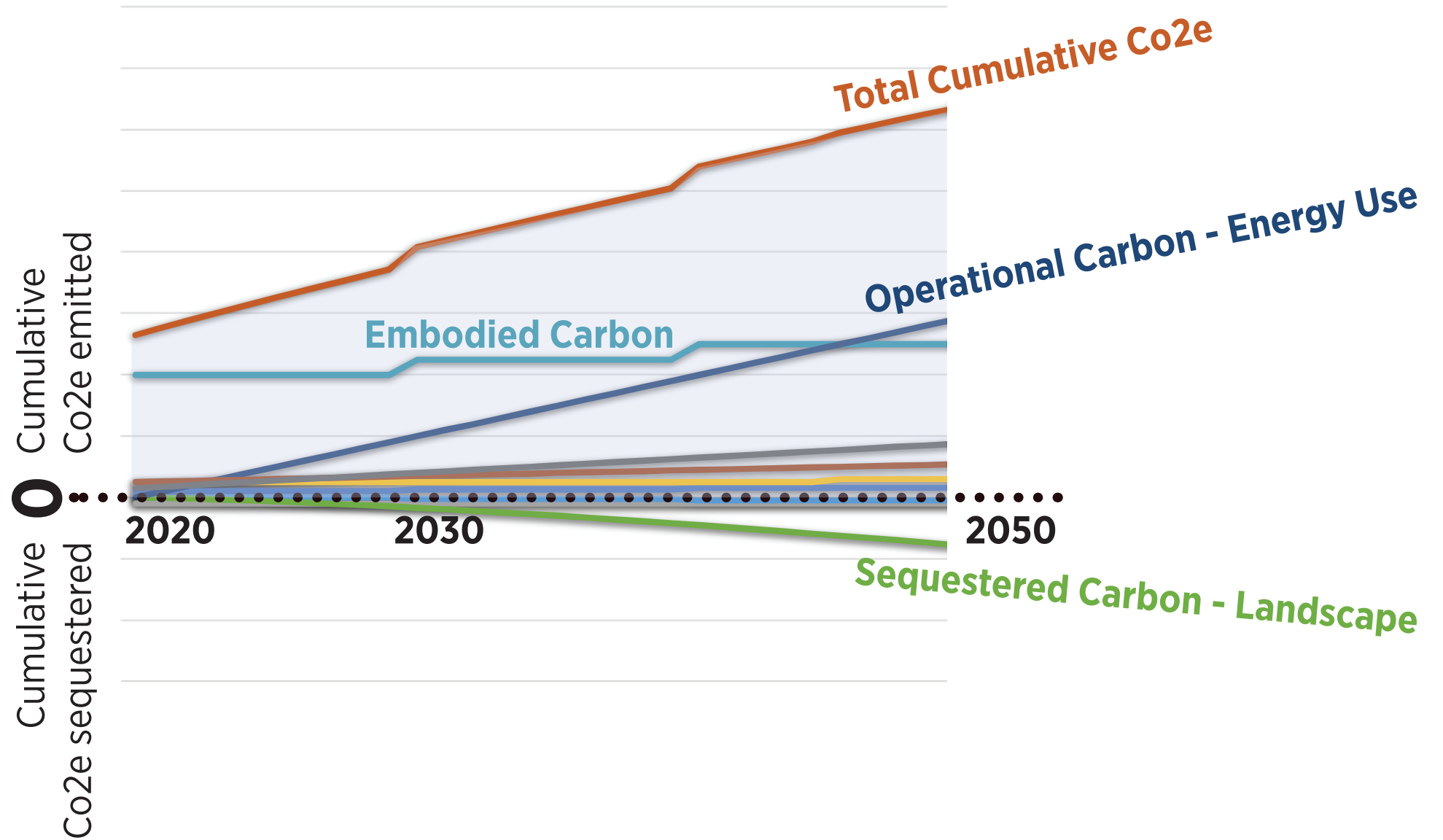
Landscape

Other (not included)

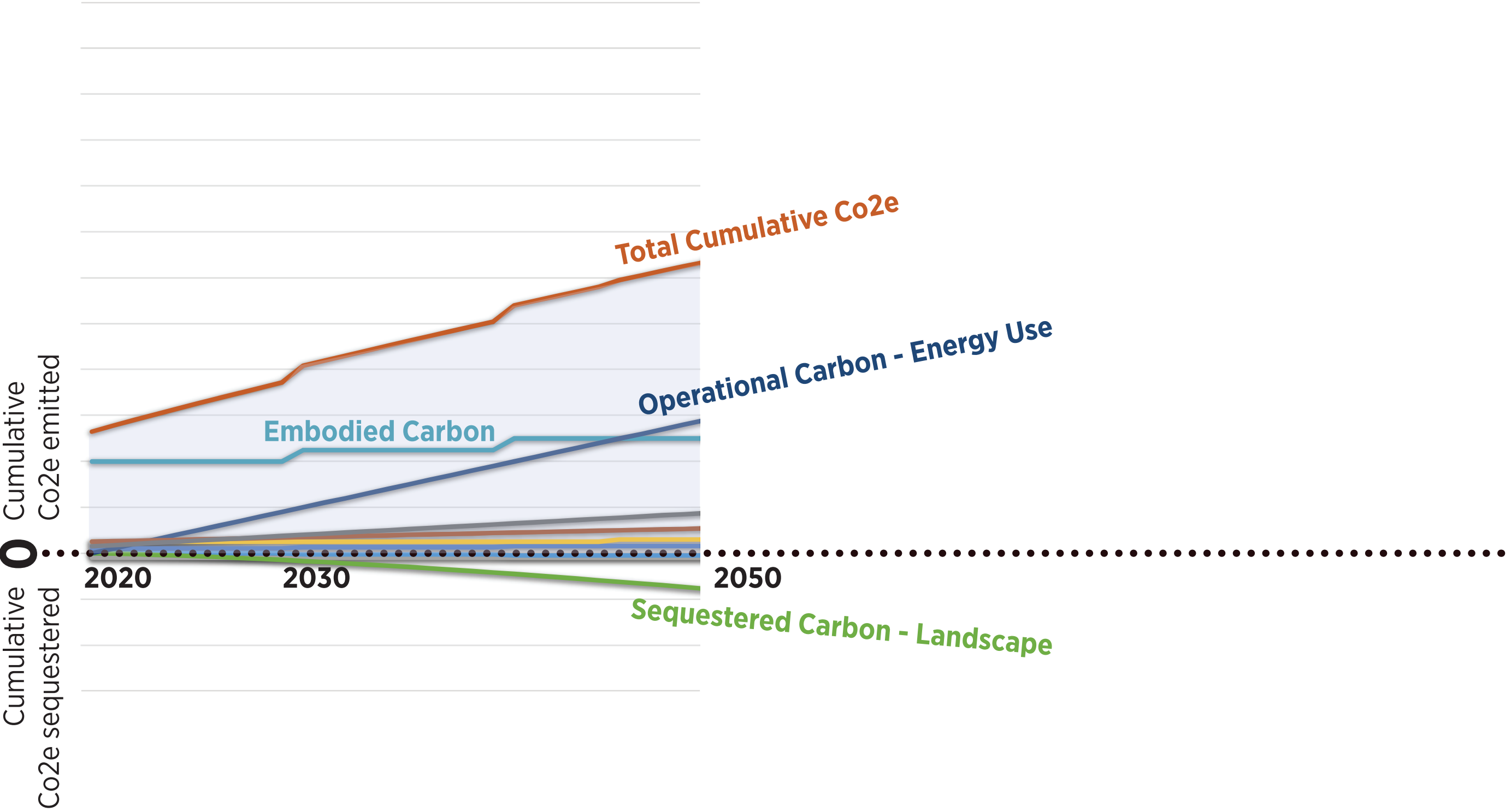
Transportation

Food + Goods

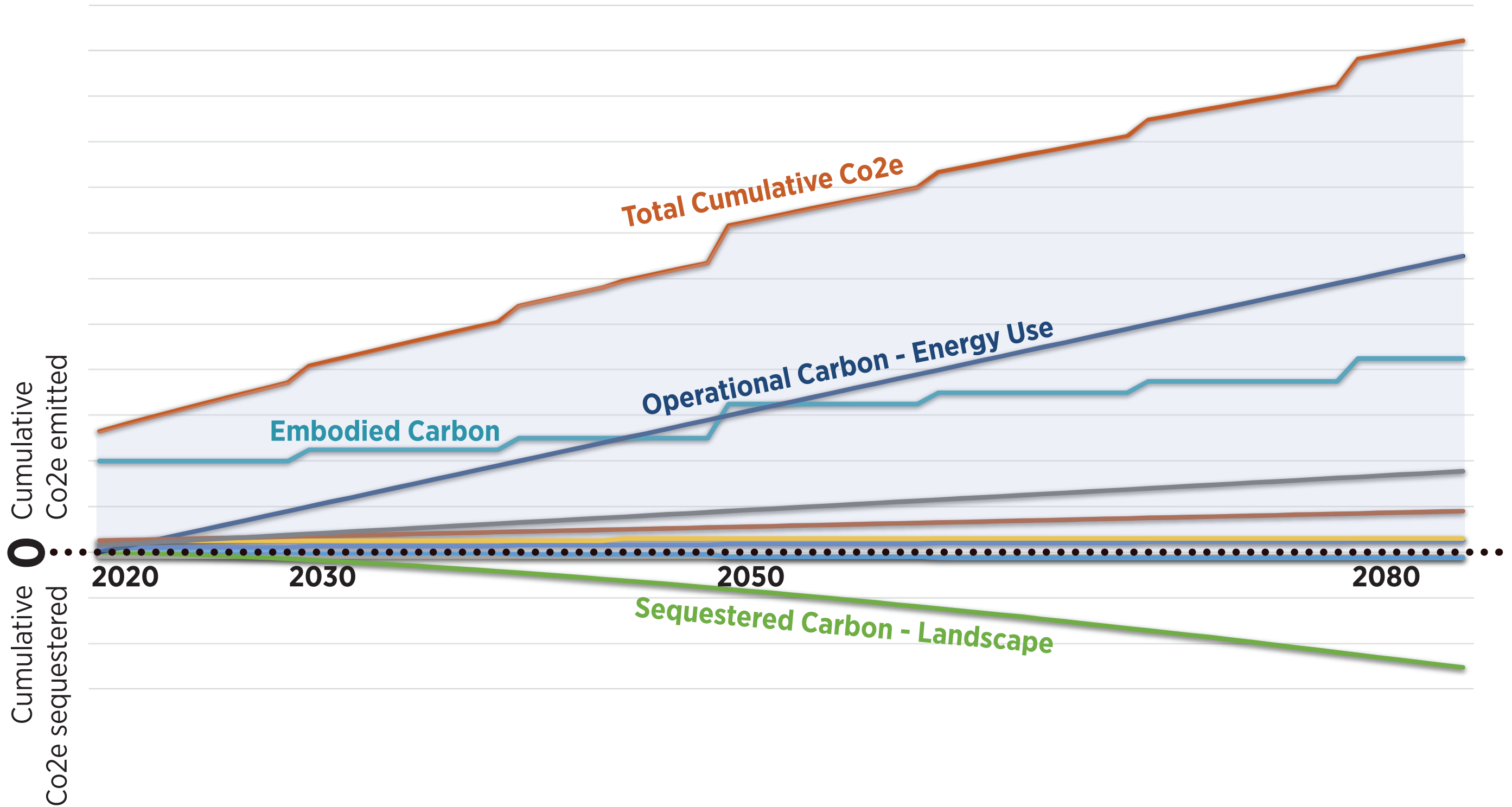
## Cumulative Co2e - Office Building Projection



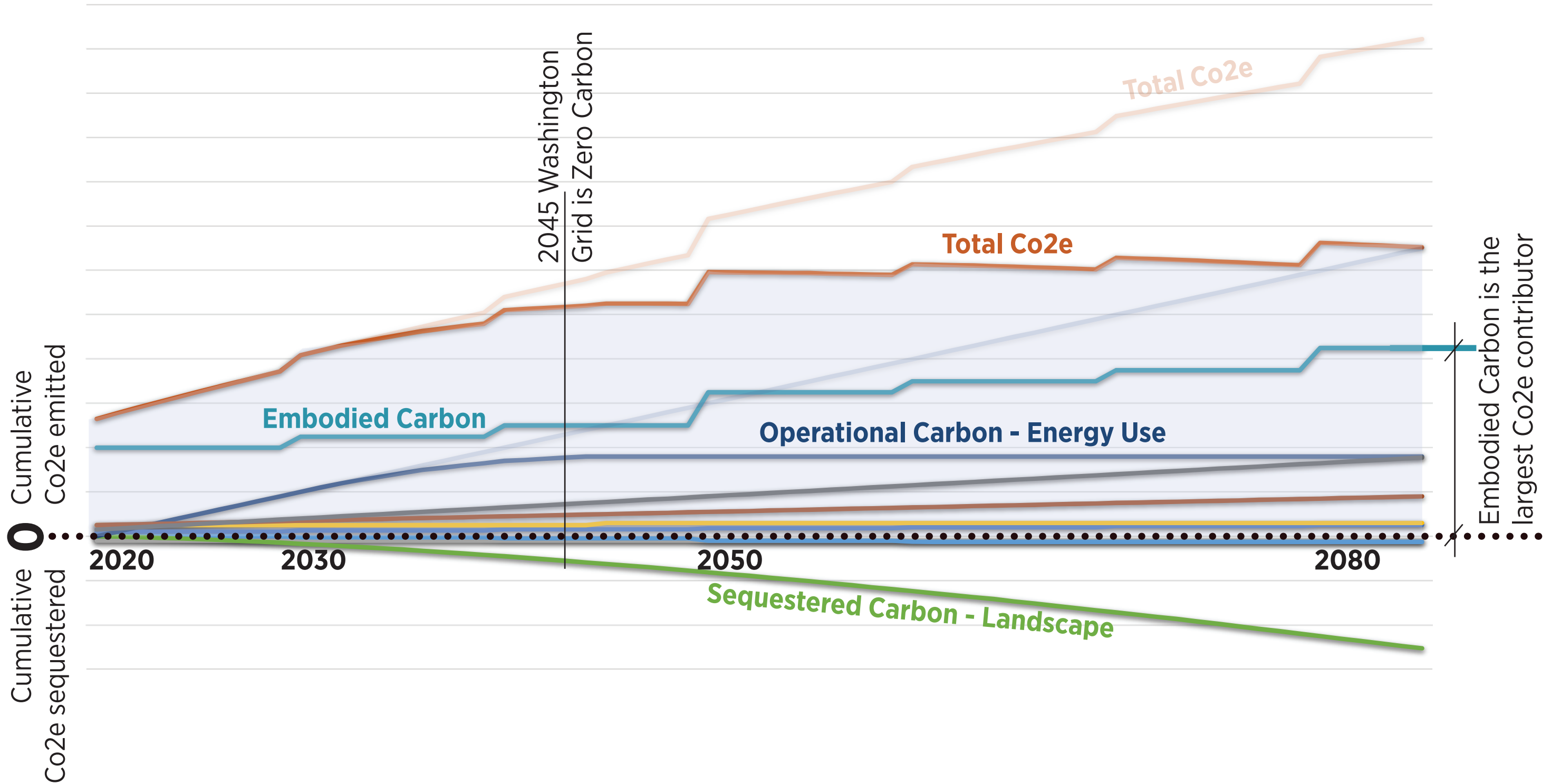
# Cumulative Co2e - Office Building Projection



# Cumulative Co2e - Office Building Projection

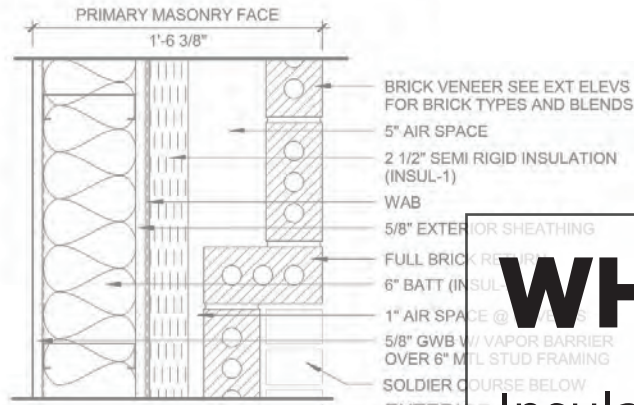


# Cumulative Co2e - Office Building Projection



# BRICK OVER MINERAL WOOL

## WALL DETAILS:



### BRICK OVER MTL STUDS

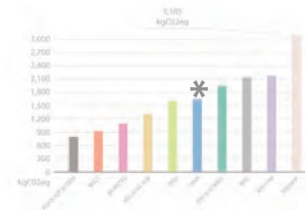
UVALUE = 0.065

- 5/8" GWB TYPE X
- CONT VAPOR BARRIER SHEET
- 6" MTL STUDS @ 16" O.C.
- FIBERGLASS BATT INSULATION (R19)
- 5/8" EXTERIOR GYPSUM SHEATHING
- WAB-1 (FLUID APPLIED ELASTOMERIC)
- 2-1/2" SEMI RIGID MIN WOOL (R10.8)
- 5" AIR SPACE
- MASONRY BRICK VENEER



## RANKINGS:

Global Warming Potential  
**6<sup>th</sup>**



# WHAT CAN WE DO?

Insulation:

Don't pick high GWP Insulation

Find the Point of Diminishing Returns

Use Energy Modeling to trade MEP cost for Envelope upgrades

Walls:

Ask for EPDs, choose better products within a class

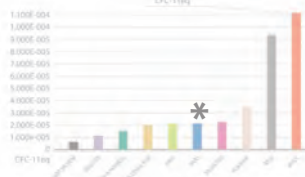
Sometimes higher envelope Co2e is preferable

Get your hands dirty - calculate embodied carbon!

Eutrophication Potential  
**4<sup>th</sup>**

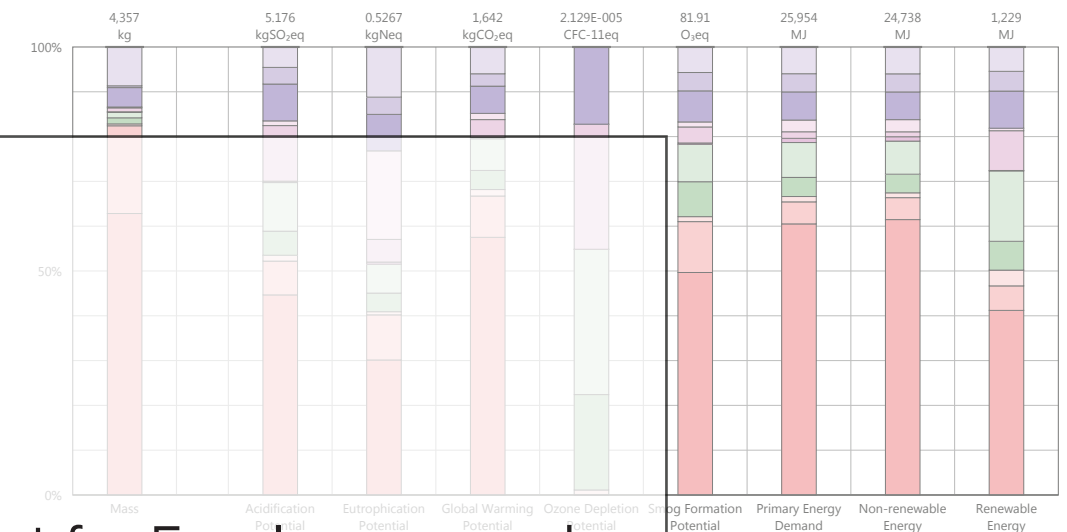


Ozone Depletion Potential  
**6<sup>th</sup>**



## MATERIAL IMPACTS:

Results per Division, itemized by Material



Legend

- 04 - Masonry
  - Brick, generic
  - Mortar type S
  - Metal reinforcing rod
- 05 - Steel
  - Cold formed structural steel
  - Reinforcing rod
  - Reinforcing rod, uncoated
- 06 - Insulation
  - Fluid applied elastomeric air barrier
  - Mineral wool, TI 135 (U = 0.135 W/mK) ECOS<sup>®</sup> EPD - Knauf Insulation
- 07 - Finishes
  - Fiberglass mat gypsum sheathing board
  - Paint, interior acrylic latex
  - Wall board, gypsum, fire-resistant (Type X)

### KEY TAKEAWAYS

What could be better:

- Brick module. The only difference between this wall and EWU is the exact size of brick. Brick mass is slightly higher for SAAS.
- Thin brick "EIFS style" assembly has even lower impacts than traditional framed brick (depending on detailing)

Future investigations:

- Office standard for thin brick

Kjell Anderson  
LMN Architects

# Facade Tectonics

## MATERIAL MATTERS ●

Materiality and embodied carbon considerations in contemporary curtainwall systems



Mic Patterson PhD LEED AP BDC  
Facade Tectonics Institute

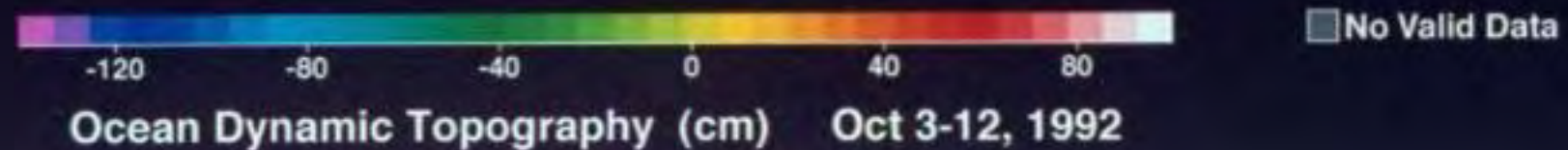
FTI Forum: Seattle!  
Seattle, 16 July 2019



# CONTEXT

- climate change
- sea level rise

an existential threat to humanity



# DIGITAL PROCESSES



have enabled what  
architectural critic  
Peter Blake called  
*wet-dream architecture* ...

# DIGITAL PROCESSES



- easily generated complex form
- not so easily fabricated and erected
- complexity has a knock-on effect

# TREND ASSESSMENT

result: step-change in

**COMPLEXITY and  
MATERIALITY**

...of facade program implementation

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# CARBON +

---

Performance considerations typically focus on operational carbon consumption and new construction.

embodied carbon + operational carbon = whole building lifecycle carbon

$$EC + OC = WLC$$

$$EC + OC = WLC$$



- material driven
- front loaded



- distributed over OC
- gradually offsets EC

factor in time value of carbon (TVC)

$$EC + OC = WLC$$

this changes everything

# WHOLE LIFE CARBON (WLC)

## conventional wisdom

...embodied carbon is <10% of WBLC

## was this ever true?

...embodied carbon increases as % of WBLC as operational energy efficiency improves

## research indicates

...% embodied carbon of WBLC could be 50-60% or higher (Kiel Moe using Howard Odem's energy metric)

Material selection and extended service life are the most effective means of reducing embodied carbon footprint.

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# SERVICE LIFE

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Optimizing service life as a strategy to minimize lifecycle embodied carbon.

**How long should a building last?**

**Table 4.3: Summary of service life and design service life data and opinion from literature review.**

<b>reference</b>	<b>building service life (years)</b>
Iselin and Lemer (1993, 13)	15-30
Crowther (1999, 3)	40
Athena Institute (2006, iv)	40-60 (conservative)
informal polling	40-60 ("should last" speculation)
Kestner and Webster (2010, 1)	50
ASHRAE 189.1 (2014)	50 (minimum)
Khasreen (2009, 679-80)	50-75
PNNL (D&R International 2011)	70-75 median lifespan of commercial buildings
CSA S478-95 (2007, 7)	50-99 most buildings 100+ monumental and heritage buildings
Bohne (et al. 2015, 306)	100
Kesik and Saleff (2009)	250 foundation and structure (armature)
Christopher Alexander (from Brand 1994, 127)	300 for foundation and structure
(Mouzon 2016)	1000
Wood (2015)	indefinitely (as long as wanted; tall buildings)
	<b>curtainwall system service life (years)</b>
Brand (1994, 13)	20 (not curtainwall specific)
Richards (2015, 159)	20-30 year replacement cycle
Kim (2011, 3436-45)	20 glass; 40 frame
Mayer (2006)	25-35 (to major renovation: replace IGUs, gaskets, frame caps)
(IBI 2000)	32-38 (average)
Dean (n.d.)	30-40 (anodized aluminum curtainwall)
informal polling	30-40 ("should last" speculation)
Meadows (2014, 51)	40 (how long it should last with proper maintenance)
Zaborski (2017)	40 estimated
deJonge (1996, 8)	40 approx. expected
Cheung and Farnetani (2016, 39)	40-50 service life approx. limit
Kesik and Saleff (2009)	50 design service life (5 cycles to match structure)
University of Washington (2015)	50 design service life

# Javits Convention Center

Categories of threat to service life  
(from Silva et al. 2016, 16).

- physical deterioration
- economic obsolescence
- functional obsolescence
- technological obsolescence
- changes in social context
- obsolescence due to the building envelope
- legal obsolescence
- aesthetic obsolescence
- environmental obsolescence



Curtainwall system designs fail to anticipate the need for future maintenance, repair and retrofit to prevent obsolescence.

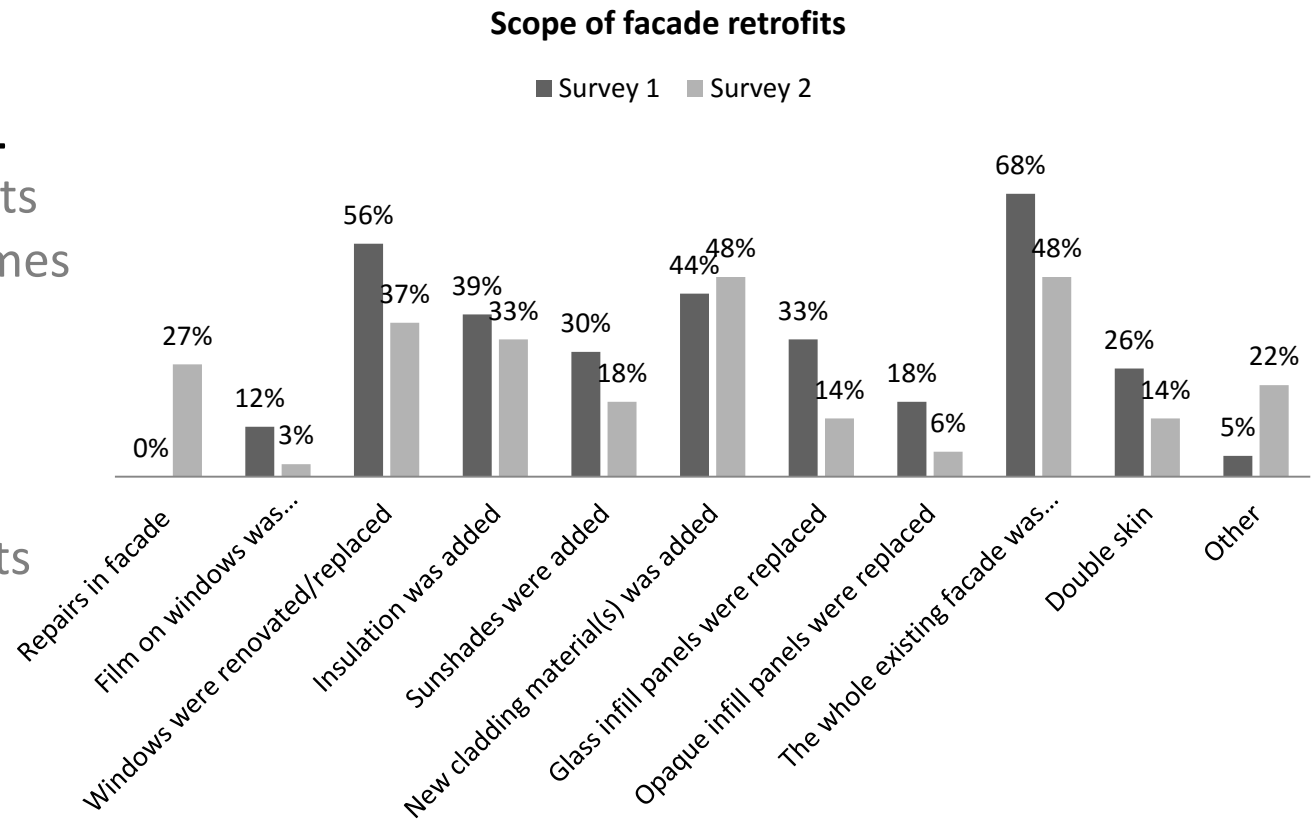
# Identification

- **Online Survey 1**

300+ respondents  
200 building names  
32 countries  
Re-clad

- **Online Survey 2**

200+ respondents  
110 buildings  
16 countries  
Re-clad +  
Over-clad



Outline

Methodology

Identification

Website

Typology

Demographics

Next?

# ITS NOT ALL ABOUT ENERGY!

consider the (dis)abilities...

**durability** (+differential)

...of systems, components and materials

**adaptability**

...to new technology, future loads, and  
changing conditions of use

**repairability**

...to treat damage and degradation

# **ITS NOT ALL ABOUT ENERGY!**

consider the (dis)abilities...

## **maintainability**

...ease of maintenance to maximize service life

## **upgradability**

...as an antidote to functional/technical  
obsolescence

## **recyclability**

...reuse and minimization of solid waste

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# EMBODIED CARBON

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As new technology increases operational efficiency, embodied carbon becomes a larger share of consumption.

# EMBODIED CARBON

preliminary material analysis of baseline CW system

CW Unit Makeup	Embodied Energy (kBtu/lb)	Weight per SF of CW (lbs/ft <sup>2</sup> )*	Embodied Energy Use Intensity (kBtu/ft <sup>2</sup> )
Insulating Glass Units	10.73	6.75	72.43
Aluminum Framing	66.21	2.24	148.45
Lift Lug and Anchor	66.21	0.16	10.38
Fasteners	24.38	0.12	2.83
Shadowbox - Alum Panel	66.21	0.44	29.31
Insulation	9.18	0.67	6.12
Backpan-Galv Steel	12.25	0.37	4.50
Gaskets & Seals	26.51	0.23	6.10
Unit total		10.97	280.11

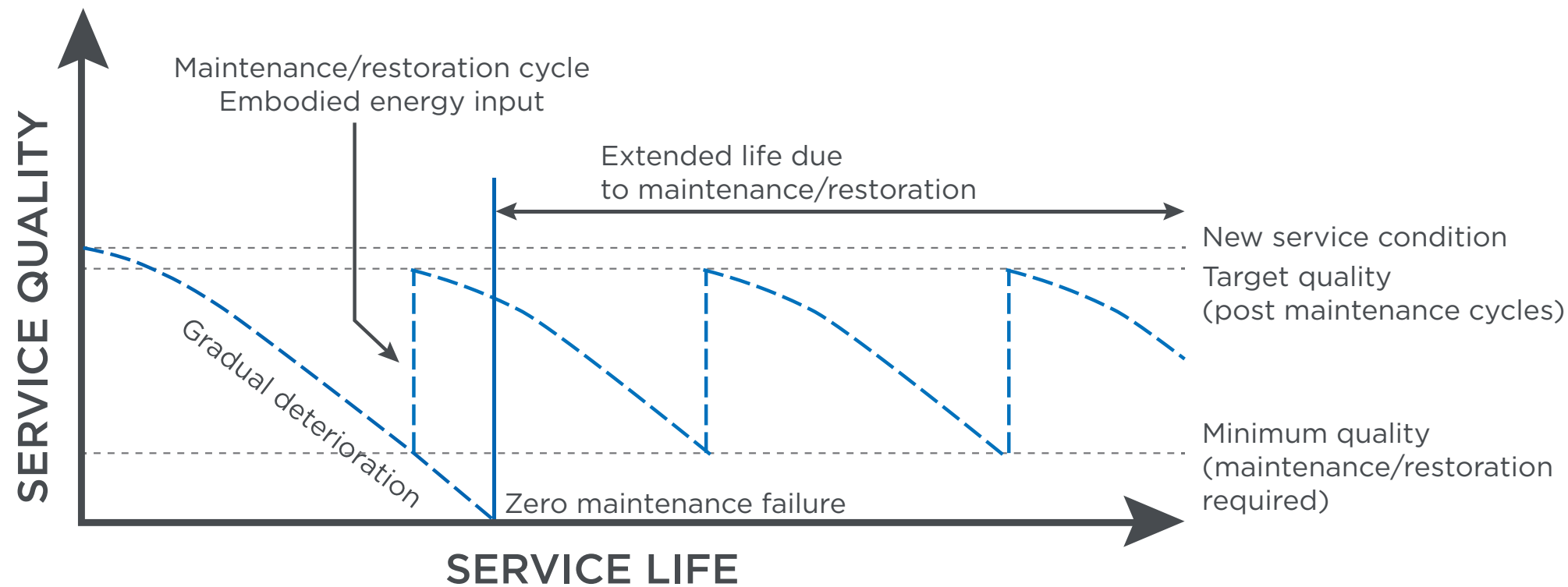
glass @ 26% + aluminum @ 67% = 93%

\*finishes not included

Why materials and service life matter.

- environmental impacts
- carbon footprint
- cost

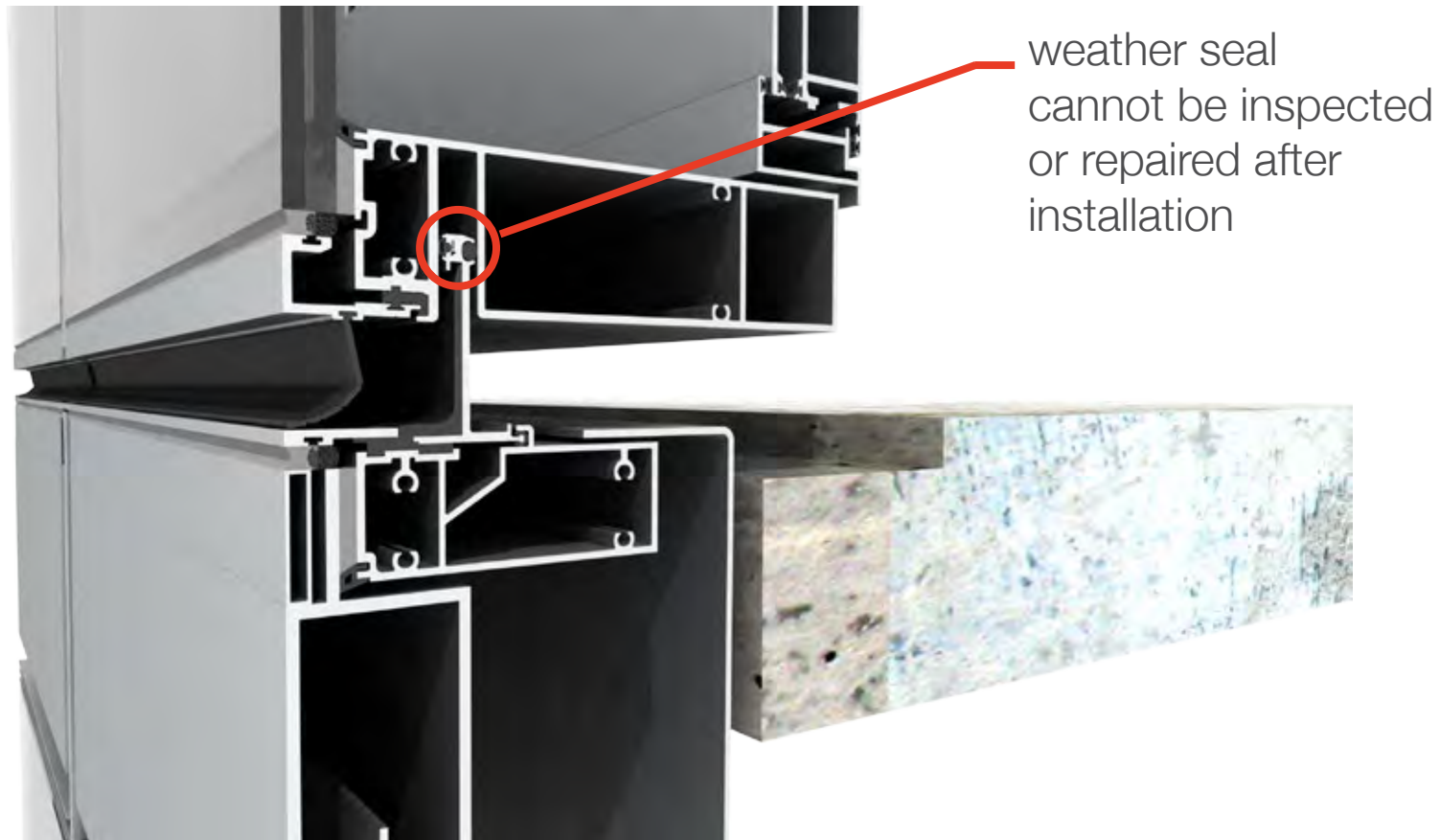
# MAINTENANCE CYCLES



Planned maintenance and partial renovation cycles as a strategy for extending building system service life and minimizing embodied energy and carbon impacts.

# MAINTENANCE THINKING

maintenance has gone the way of craftsmanship



curtainwalls are designed as zero-maintenance systems



- Maintenance planning:
- antithesis of throwaway culture
  - facilitated by discrete assemblies
  - provides redundancy
  - may extend service life
  - puts people to work
  - supports renewable strategies

Enables the ability to endure.

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# ADAPTIVE CAPACITY

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*As predictability wanes in a turbulent world,  
so the need for buffers and adaptive capacity  
increases. - Pricewaterhouse*

# STRATEGIES

pathway  
to ZERO  
CARBON

1. **Base material selection on lifecycle carbon.**
2. **Design for the ages.**
3. **Maximize adaptive capacity.**
4. **Design for the (dis)-abilities; durability, maintainability, repairability, adaptability, upgradability, recyclability.**
5. **Design to realize the full lifecycle durability potential of all materials utilized.**
6. **Minimize use of high embodied carbon materials.**
7. **Embrace the constraints!**

# CONCLUSIONS

- "zero-maintenance" curtainwall systems fail to anticipate the need for future retrofit, leaving replacement as predominant option
- curtainwall systems are not adaptable to emerging high-performance materials and products; as true of new systems as old

**We are busy building tomorrow's problems today with contemporary curtainwall practices.**

*You never change things by fighting the existing reality. To change something, build a new model that makes the existing model obsolete. - R Buckminster Fuller*

**The current need lies beyond  
incremental change...  
embrace the constraints!**

**Facade  
Technics**

**THANK YOU !**

**Mic Patterson**

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# CARBON COUNTING

Balancing Operating and Embodied Carbon in Facade Design



## SPEAKERS



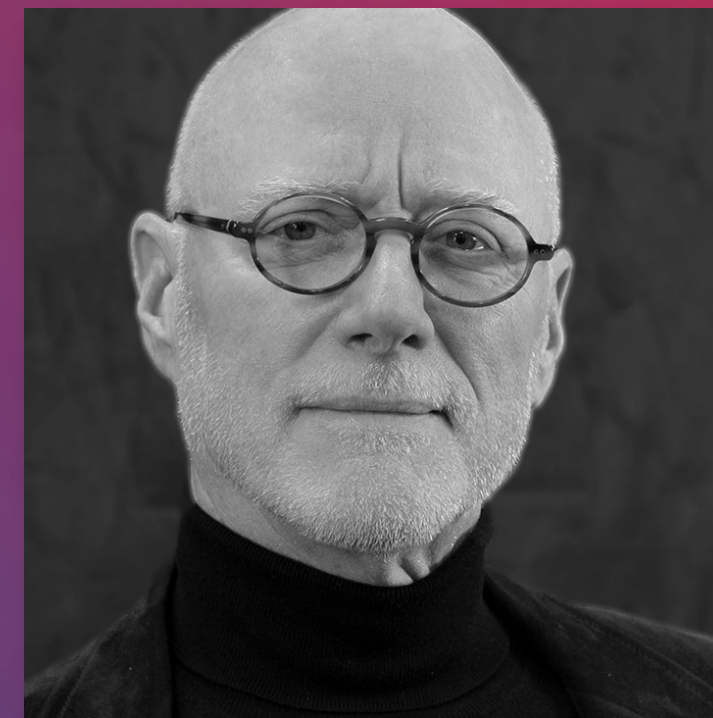
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BD+C**

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Skanska USA Building*



**Kjell Anderson, AIA,  
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