

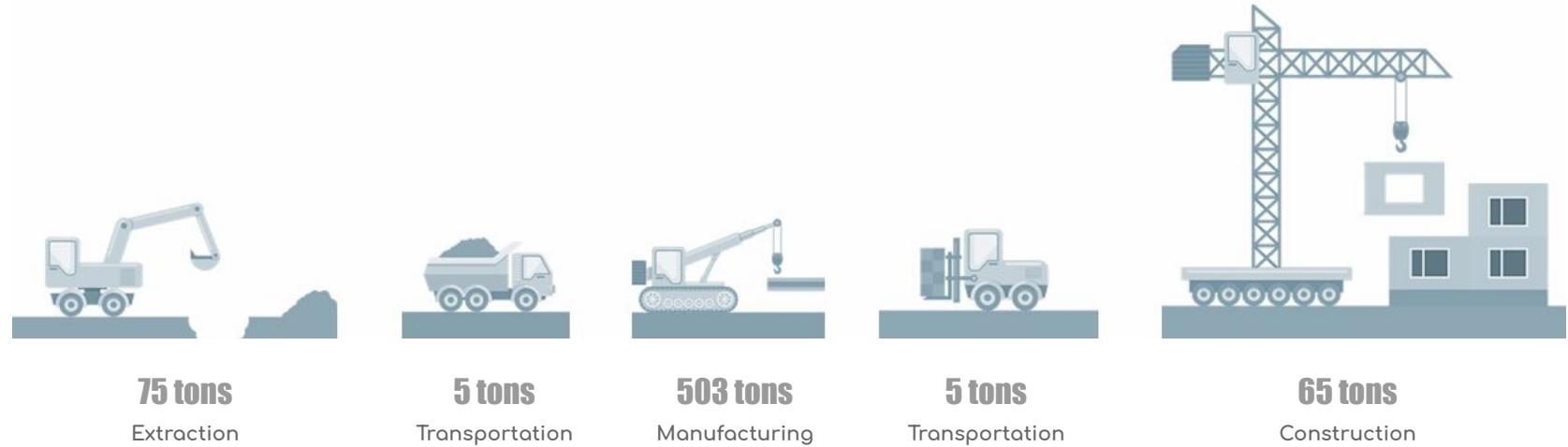
DATA ANALYSIS &  
DATA PHYSICALIZATION

# Embodied Carbon

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/ JESSICA CHEN  
/ YOUNGJU KIM

# WHAT IS EMBODIED CARBON?

Embodied Carbon is the sum of carbon released in all the production processes for a material or a product.



# WHY EMBODIED CARBON?

## why Embodied Carbon?

Carbon footprint from materials accounts for 11 % of all human caused emissions on the planet.

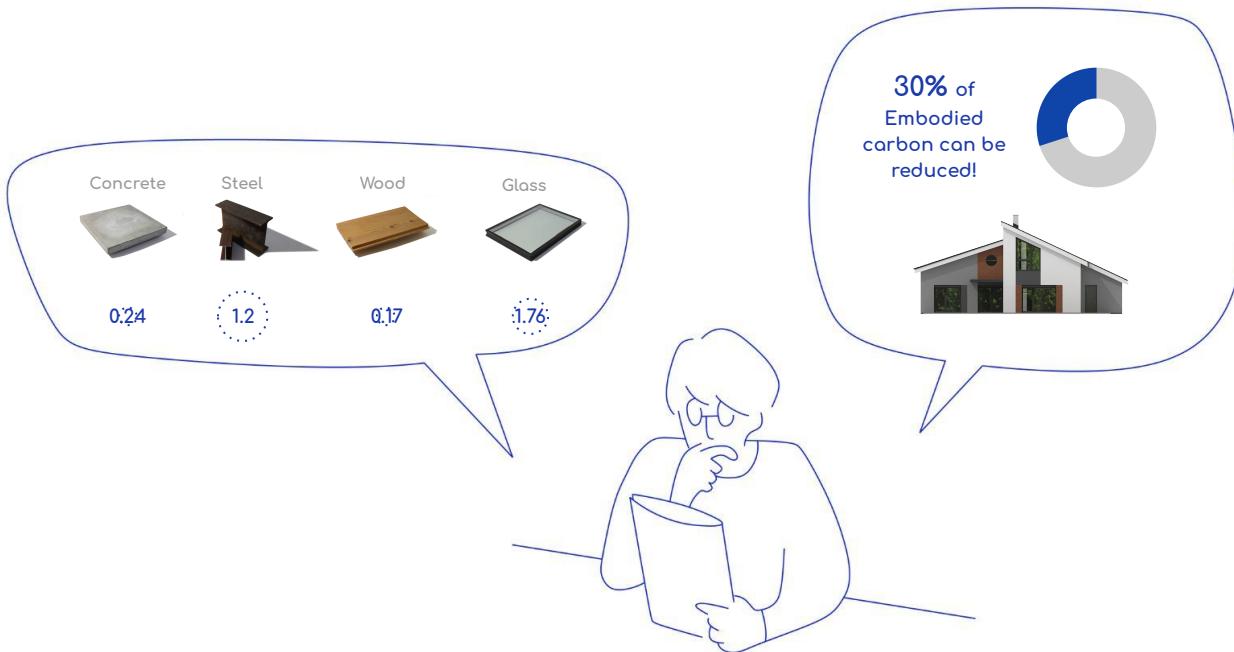


Global CO2 Emissions by Sector



## Goal

1. How much embodied carbon is associated with each material?
2. How much embodied carbon footprint an entire building will have if we are going to be able to reduce it?



MATERIAL DATABASE : open EPD

## dataset

### EC3 openEPD

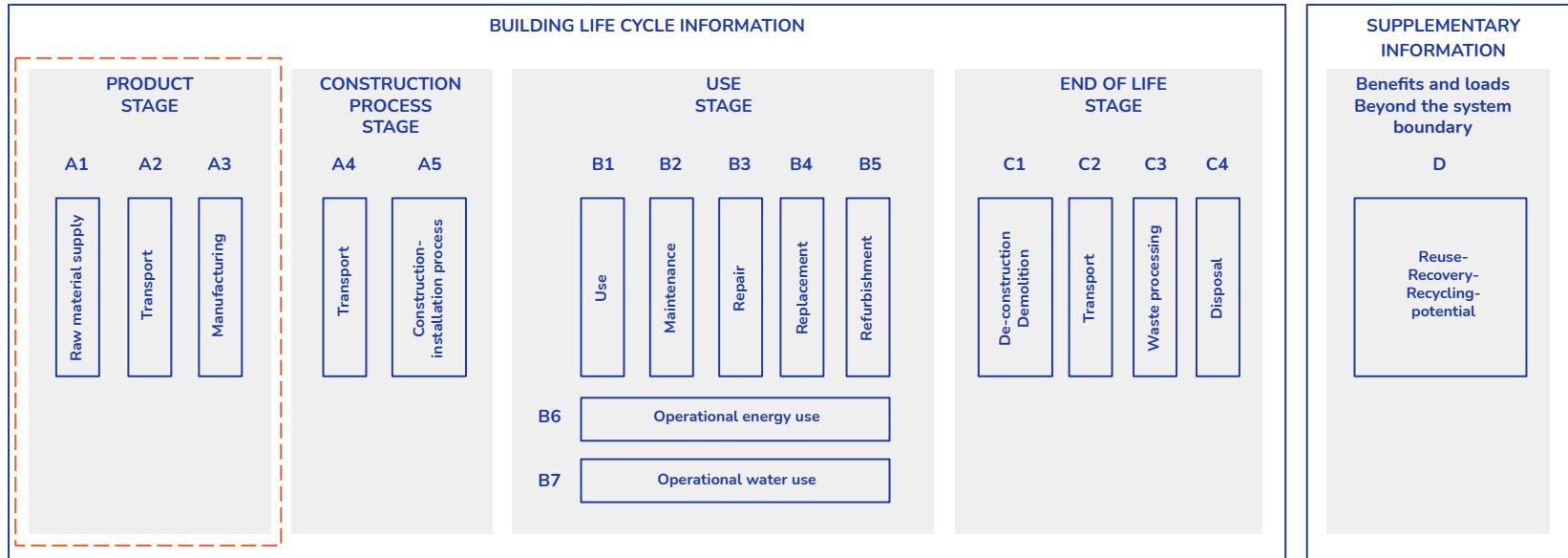
EPDs									<a href="#">Create EPD</a>	<a href="#">Add An EPD To...</a>
	Category	Manufacturer	Plant	Name	Description	Program Operator	Verifier Org	Declared Unit	Last Updated in EC3	Tools
W	Cladding	Falcon Panel Produ...	Salamander Techni...	Resysta® Profiles a...	Resysta profiles off...	BRE Global	BRE Global	96.5 m2	Wed Jul 29 2020	
W	Cladding	Falcon Panel Produ...	Resysta Internation...	Resysta® Profiles a...	Resysta profiles off...	BRE Global	BRE Global	96.5 m2	Wed Jul 29 2020	
W	Finishes	Falcon Panel Produ...	Salamander Techni...	Resysta® Profiles a...	Resysta profiles off...	BRE Global	BRE Global	52.2 m2	Wed Jul 29 2020	
W	Finishes	Falcon Panel Produ...	Resysta Internation...	Resysta® Profiles a...	Resysta profiles off...	BRE Global	BRE Global	52.2 m2	Wed Jul 29 2020	
W	Carpet	Interface, Inc.	Troup County	Modular carpet on ...	This Environmental ...	UL Environment	Industrial Ecology C...	1 m2	Wed Jul 29 2020	
E	Gypsum Finishing C...	CertainTeed Gypsu...	Calgary, AB	#Suspicious Easi-Fil ...	The Light Weight an...	UL Environment	Industrial Ecology C...	100 m2	Wed Jul 29 2020	
E	Glazing (IGU)	Saint-Gobain Isover...	CLIMAVER A2 PLUS	The product Climav...	International EPD S...	Marcel Gómez Cons...	Industrial Ecology C...	1 m2	Wed Jul 29 2020	
W	Acoustical Ceilings	Ecophon AB	Saint-Gobain Ecoph...	Ecophon Gedina	This Environmental ...	International EPD S...	DNV GL	1 m2	Wed Jul 29 2020	
E	Gypsum Board	Saint-Gobain Const...	Gyproc ГКЛ 12.5 м...	Standard Gypsum b...	Renewables	Industrial Ecology C...	1 m	Wed Jul 29 2020		
W	Board	Saint-Gobain Argent...	ISOVER	Acustiver P	Panel de lana de vid...	International EPD S...	Marcel Gómez Cons...	1 m2	Wed Jul 29 2020	
E	Steel	Tenaris S.A.	COILED TUBING Te...	Oil Country Tubular...	Tenaris supplies tub...	International EPD S...	Industrial Ecology C...	1 tonne	Wed Jul 29 2020	
W	Slurry	National Ready Mix	Artesia	S70169	660-C-4000 AIR	ASTM International	Industrial Ecology C...	1 m3	Wed Jul 29 2020	
E	Board	Karl Bachl Kunststo...	the BASF SE site	Insulation board m...	/ Product definition ...	Institut Bauen und ...	IBU Independent Ex...		Wed Jul 29 2020	
W	Slurry	RiverBend Materials	Corvallis	397523	52 W/C 1/2" Exterior	NRMCA	Sustainable Solutio...	1 m3	Wed Jul 29 2020	
W	Slurry	RiverBend Materials	Corvallis	397522	52 W/C 1/2" INTERI...	NRMCA	Sustainable Solutio...	1 m3	Wed Jul 29 2020	
W	Slurry	National Ready Mix	Vernon	S70177	660-EW-3250P AIR	ASTM International	Industrial Ecology C...	1 m3	Wed Jul 29 2020	
W	Slurry	National Ready Mix	Vernon	S70175	1/2/3500 @44 Hrs/6...	ASTM International	Industrial Ecology C...	1 m3	Wed Jul 29 2020	



openEPD is an open data format for passing digital third-party verified Environmental Product Declarations (EPDs) among Program Operators, EPD Databases, Life Cycle Analysis tools, design tools, reporting, and procurement.

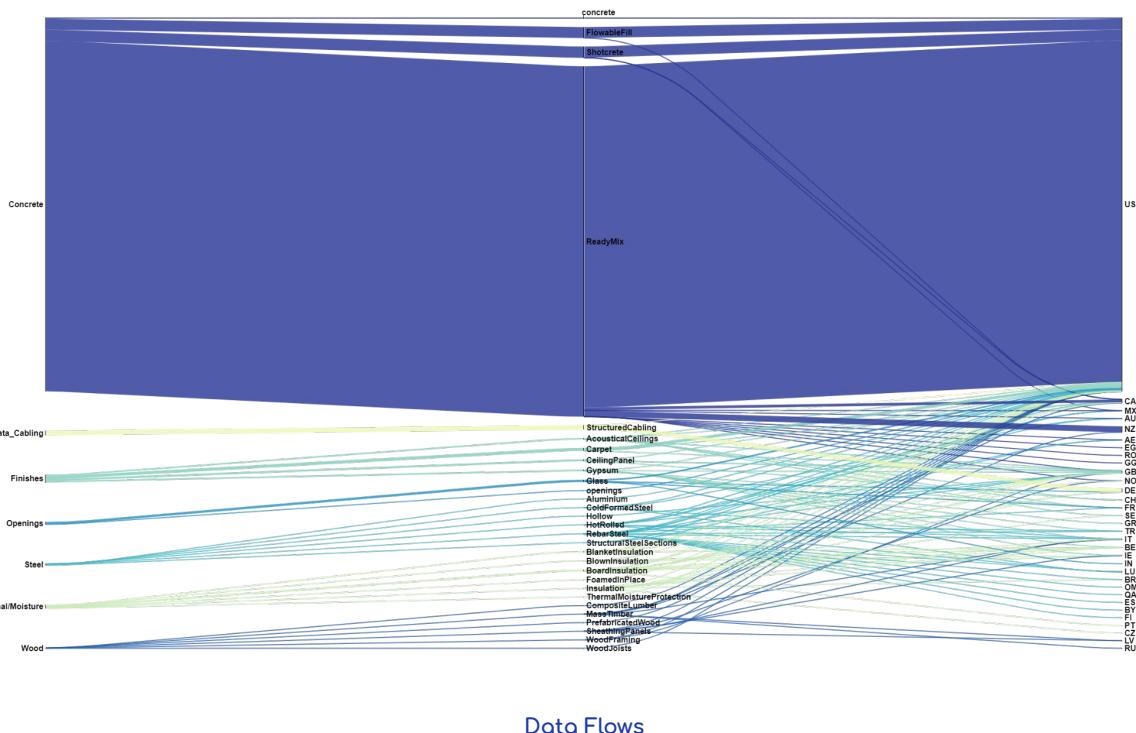
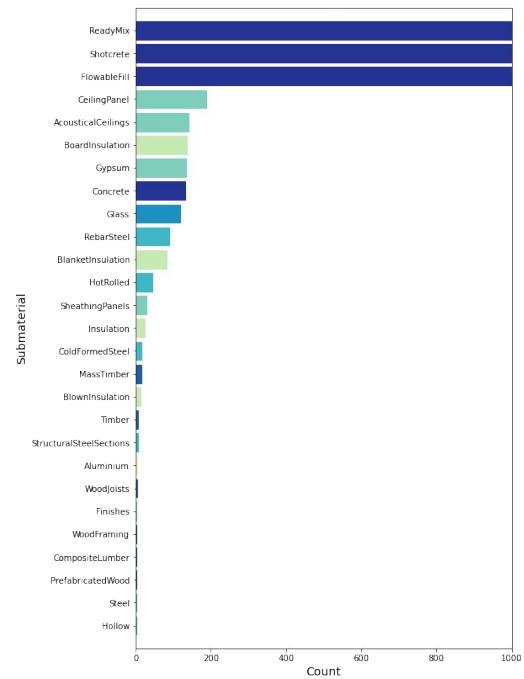
dataset

## EC3 openEPD



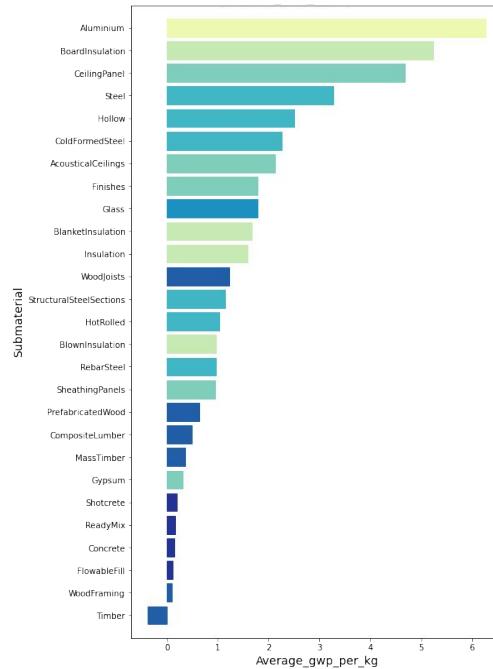
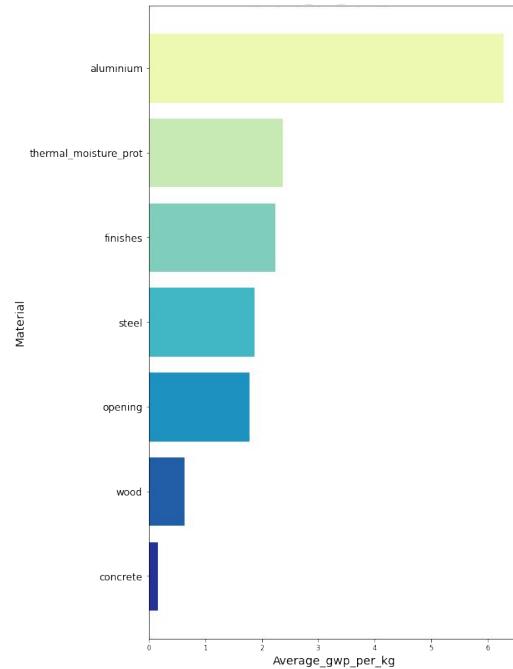
# dataset

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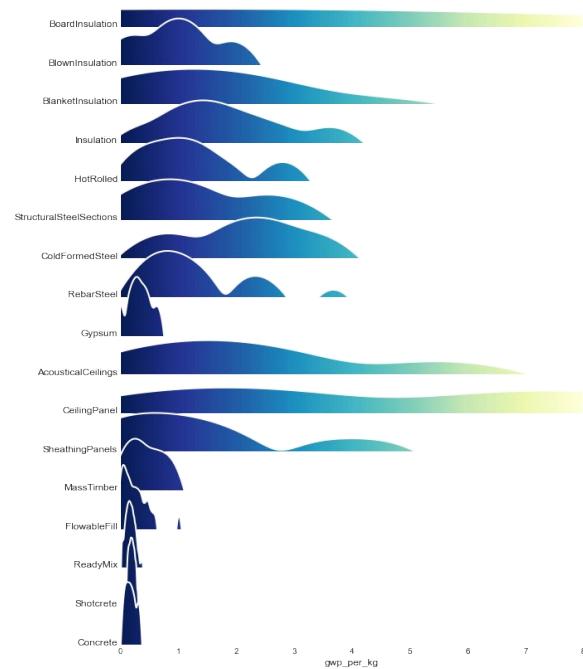


## dataset

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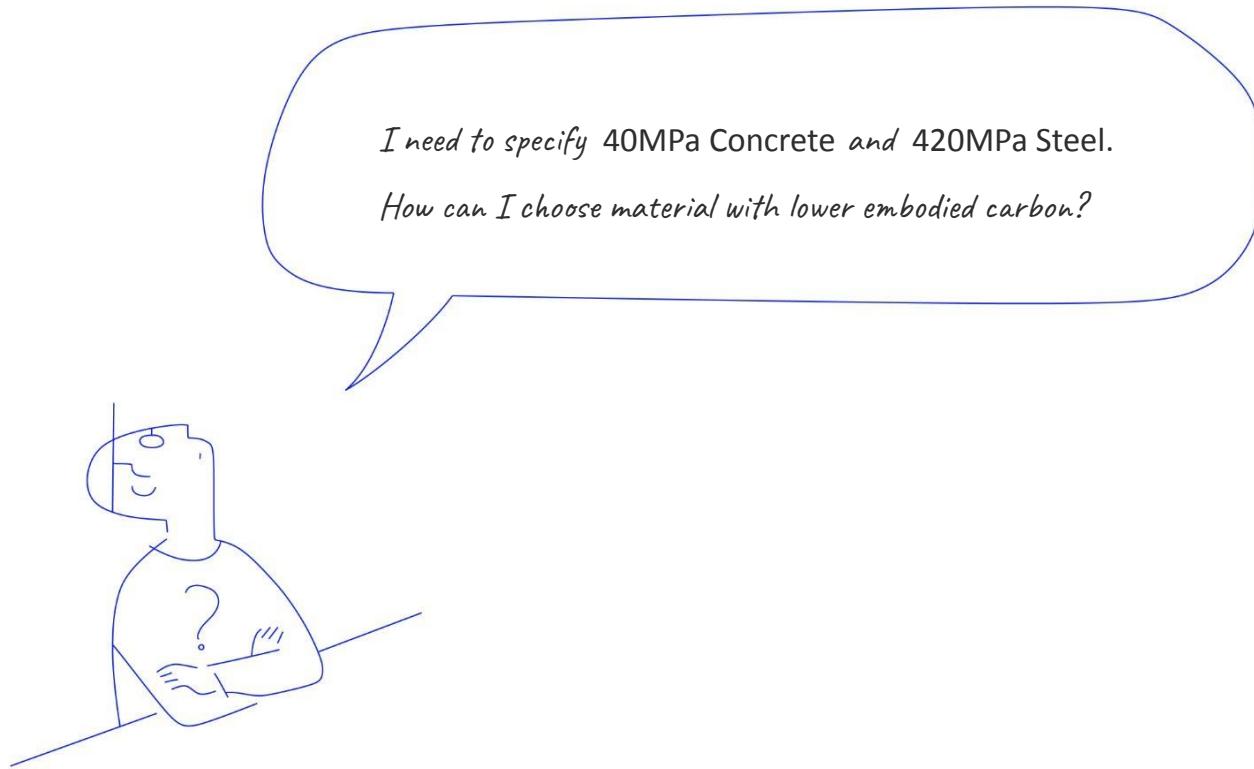
Average Embodied Carbon per kg by Materials



Data distribution of Embodied Carbon per kg

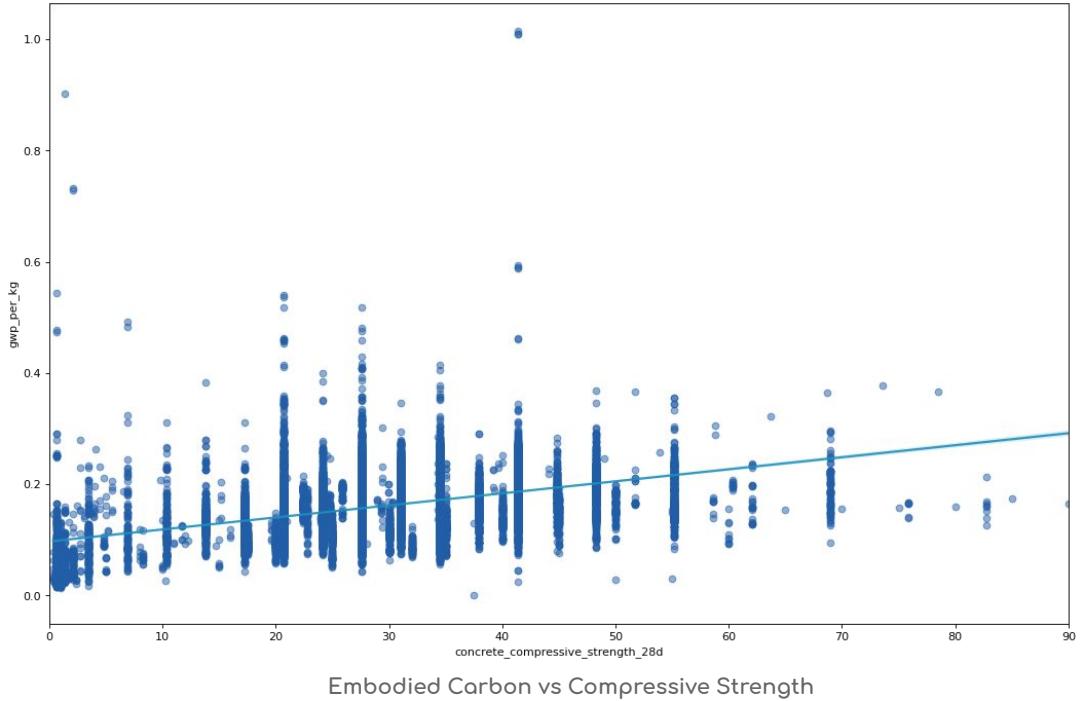
What's the impact of material choice in buildings?

## Material Selection: Scenario 1



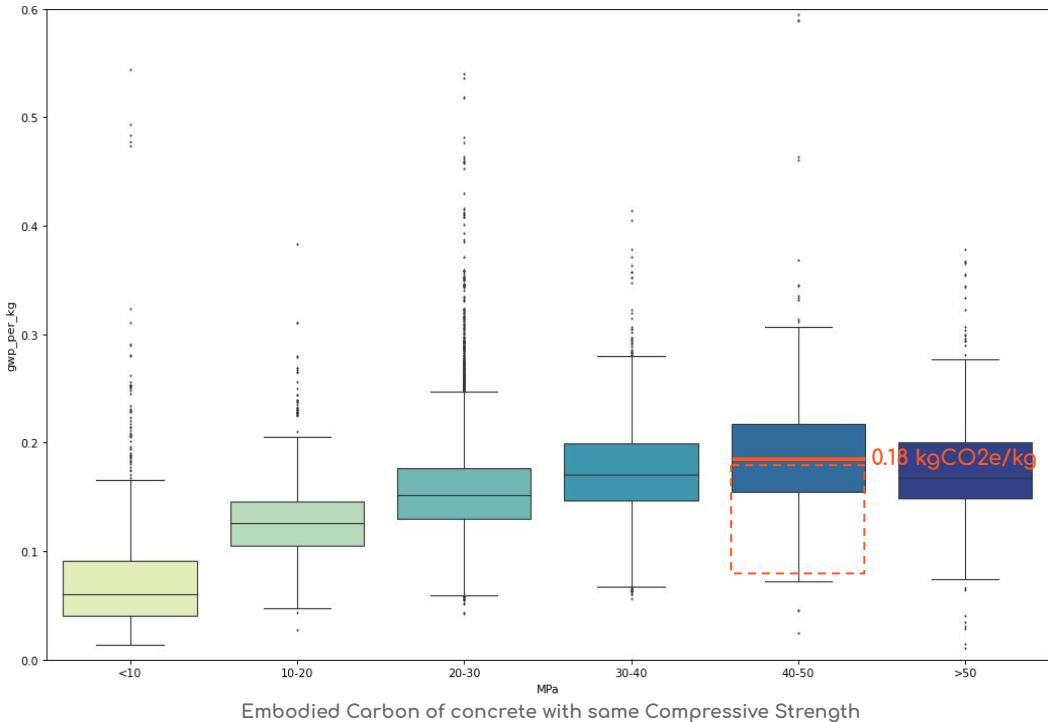
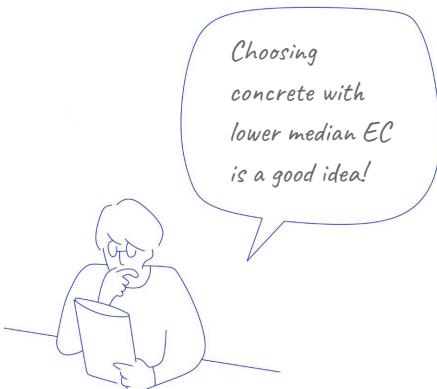
Concrete  
Embodied Carbon  
vs. Compressive Strength

**Positive correlation**  
between  
embodied carbon and  
compressive strength  
of concrete

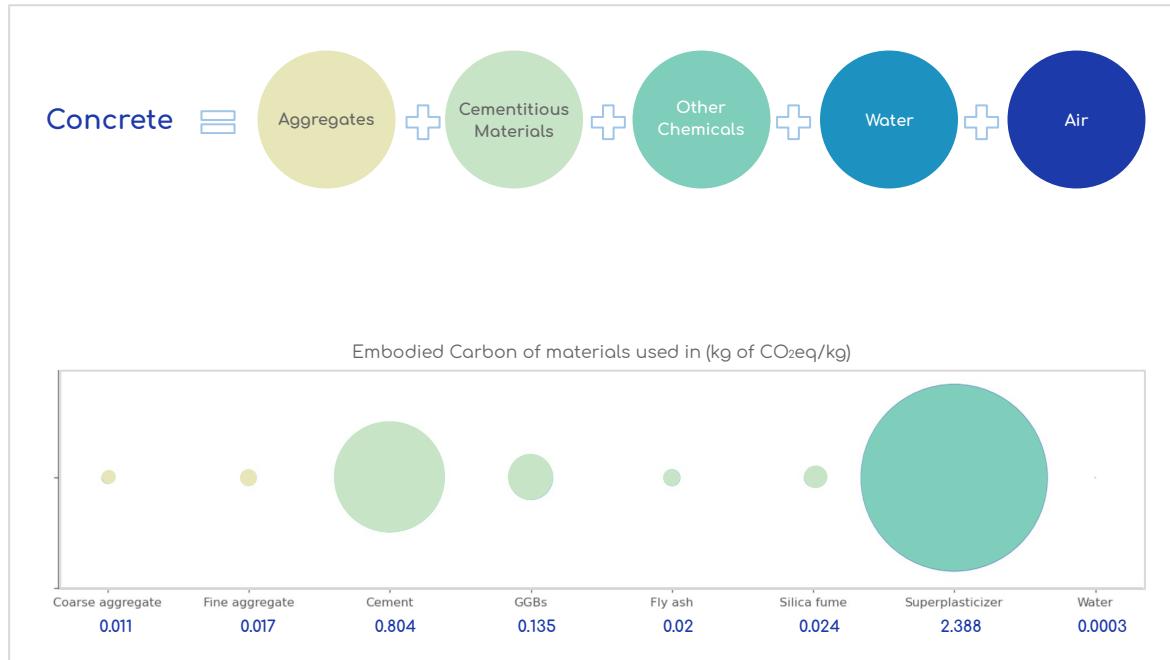
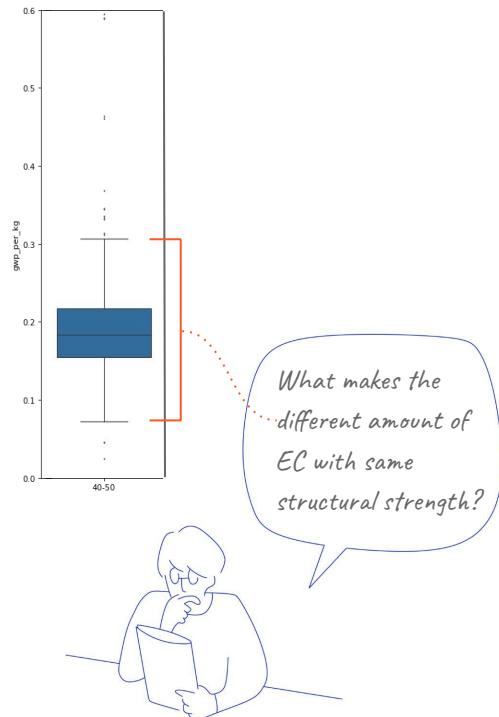


## Concrete Embodied Carbon vs. Compressive Strength

The median EC of  
1 kg of concrete with  
compressive strength of  
40- 50 MPa is  
**0.18 kgCO<sub>2</sub>e.**



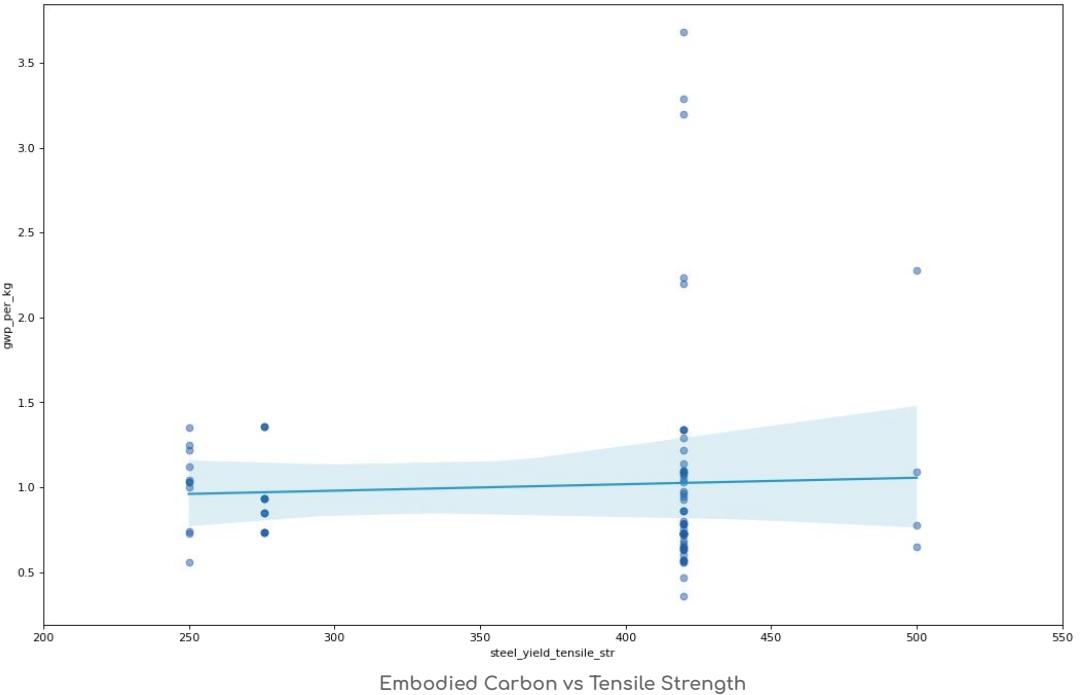
## Concrete Composition of Concrete



Steel

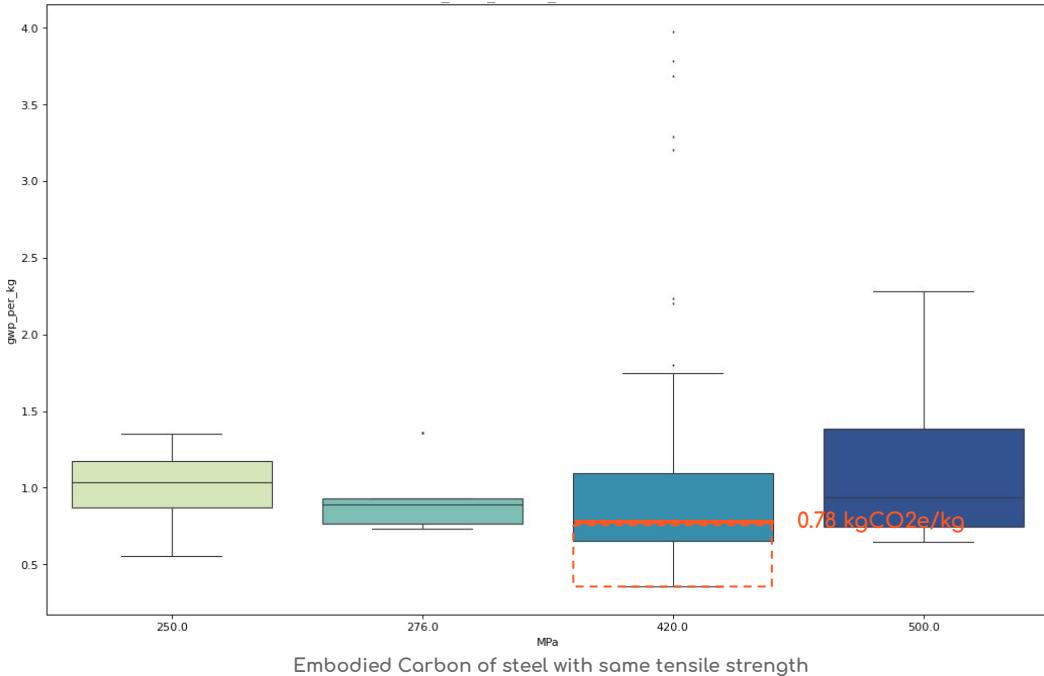
## Embodied Carbon vs. Tensile Strength

No correlation  
between  
embodied carbon and  
tensile strength of steel



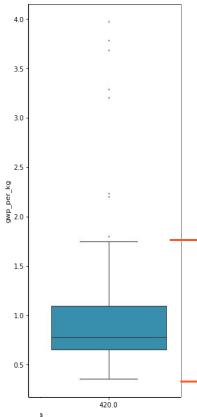
Steel

## Embodied Carbon vs. Tensile Strength

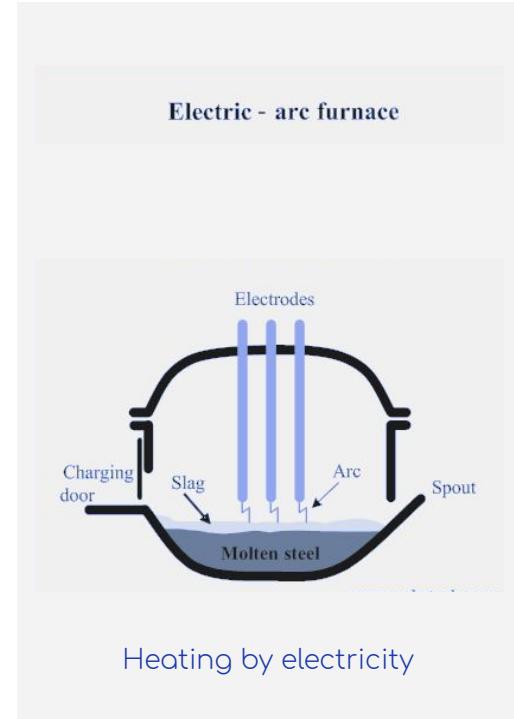
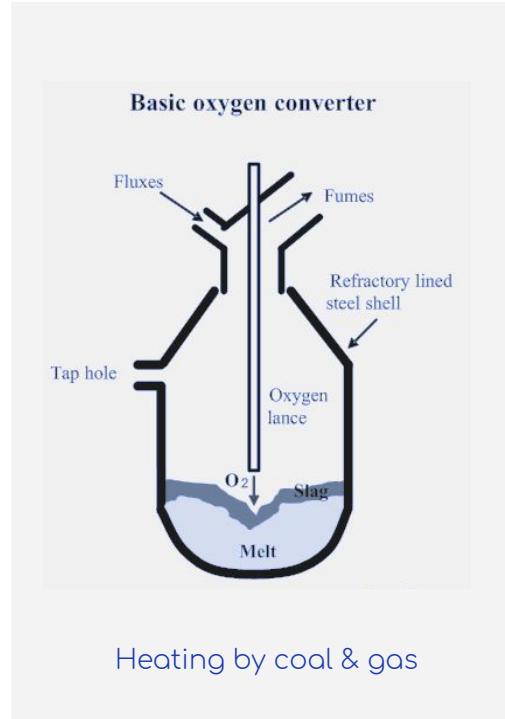


Steel

## Some Embodied Carbon Factors for Steel



**Process Matters**  
By using electric arc furnaces (EAFs)  
instead of basic oxygen furnace can  
reduce EC in steel

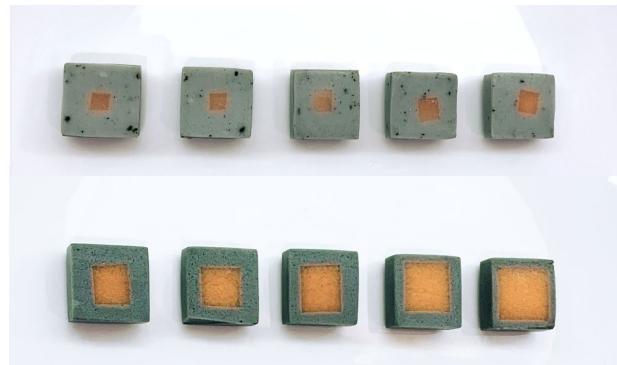


Data Physicalization

## Concrete Wagashi & Section cut



Concrete



Steel



Putting Cubes in a Container



Data Physicalization  
Material Palette for Opaque



## Data Physicalization Material Palette for Transparent

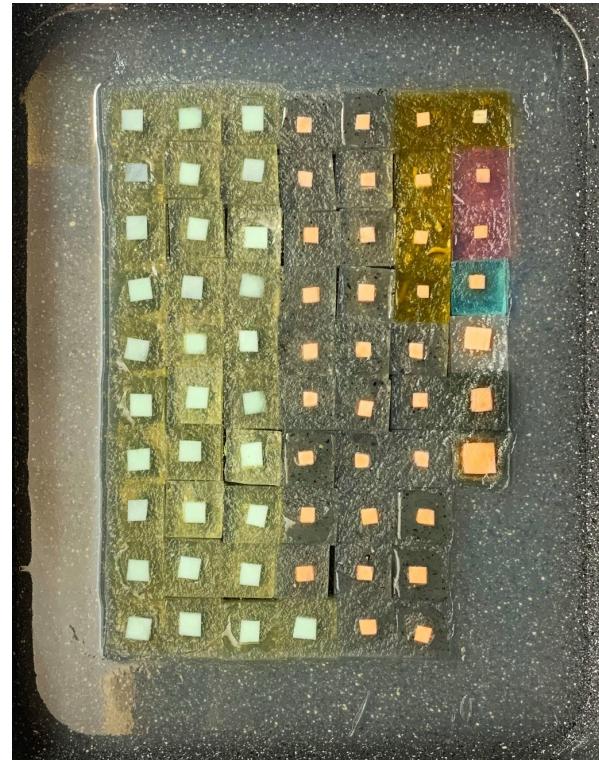


Data Physicalization

Material Palette comparison



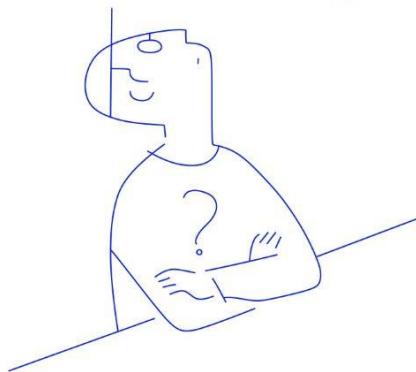
The result of 1st round



The result of 2nd round

## Material Selection: Scenario 2

Which one would be more effective, keeping same structural material with a different gwp or changing the structural material?



## Building

### GWP of Varied Structure of 2000 sqft Housing

#### STEEL STRUCTURE



#### RC STRUCTURE



#### WOOD STRUCTURE



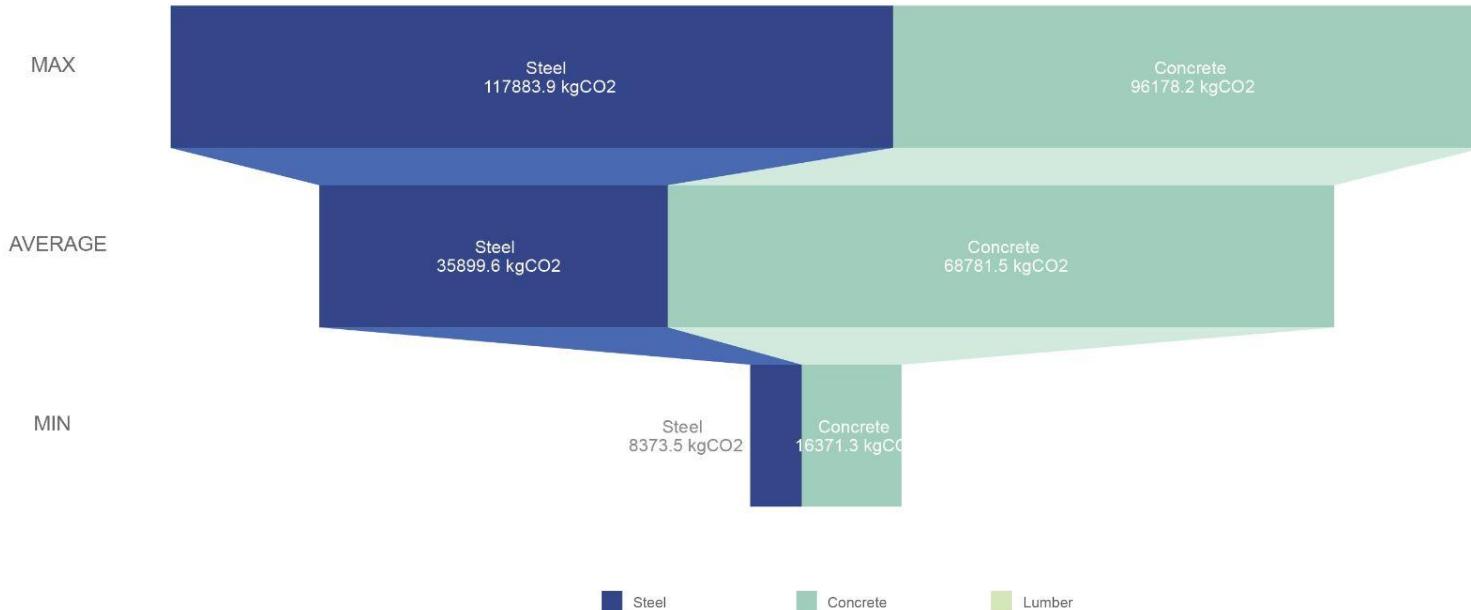
Steel

Concrete

Lumber

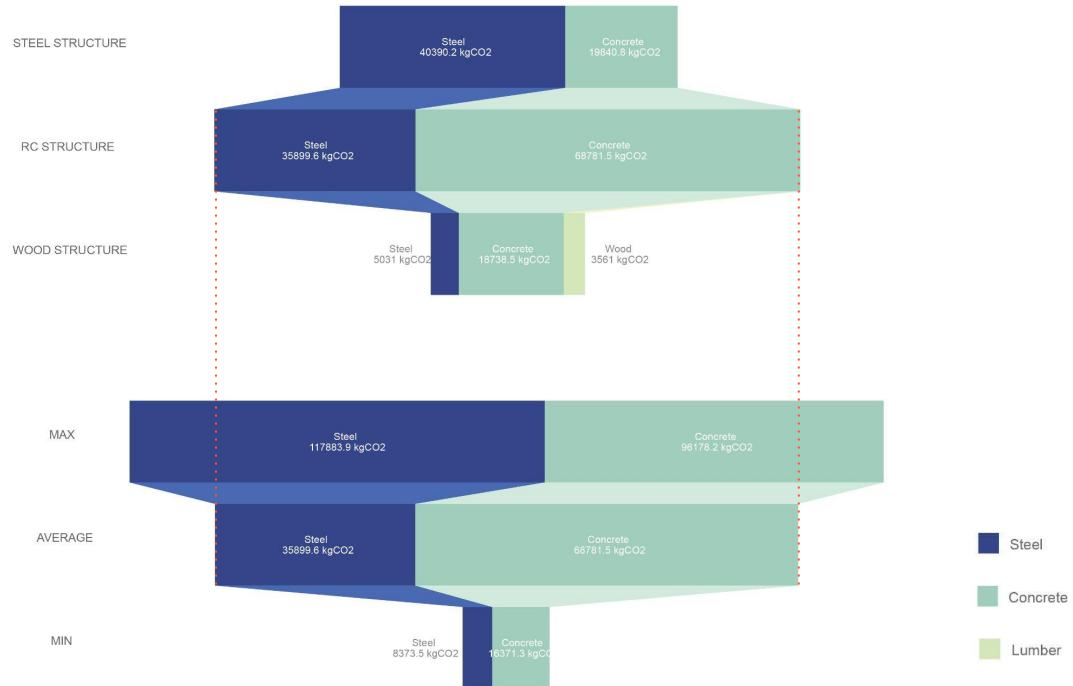
Building

## Max and Min GWP of RC Structure of 2000 sqft Housing



## Building

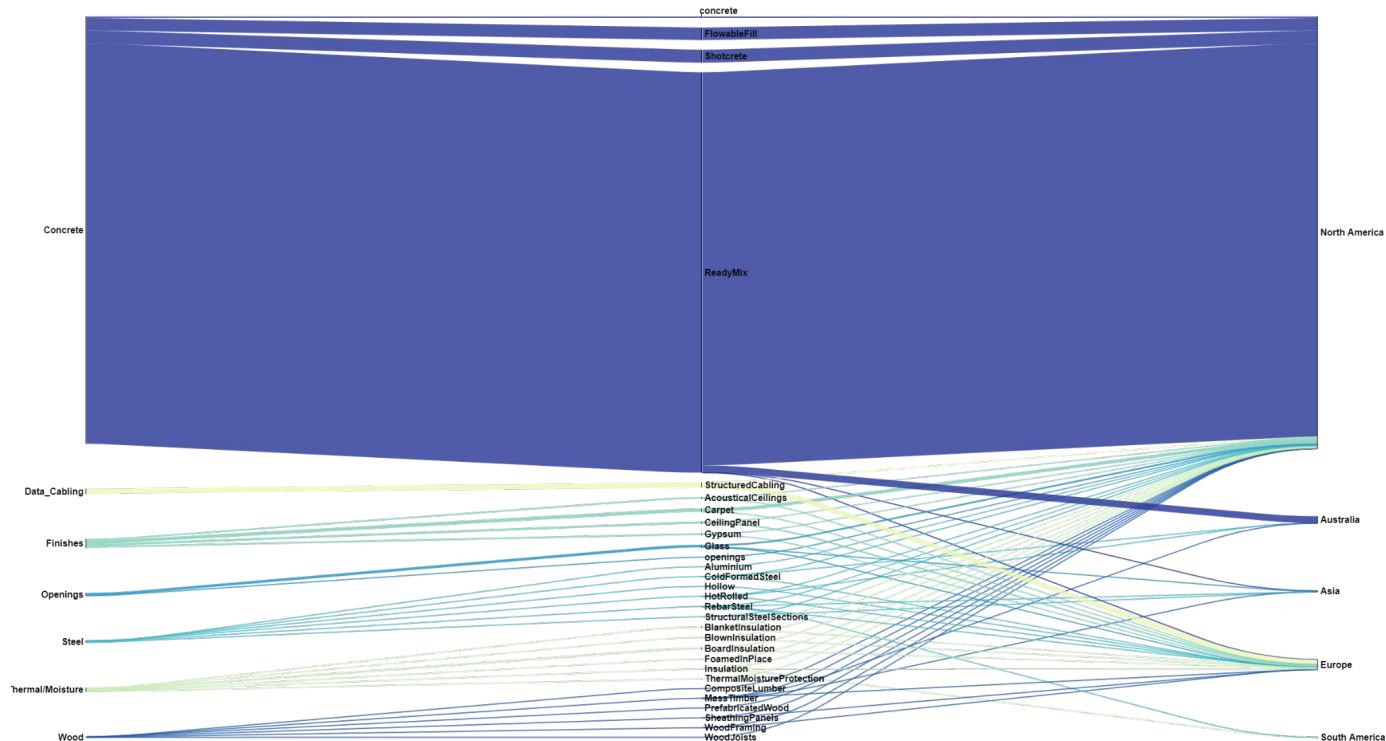
### Max and Min GWP of RC Structure VS Different Structures



Future suggestions for Embodied Carbon dataset

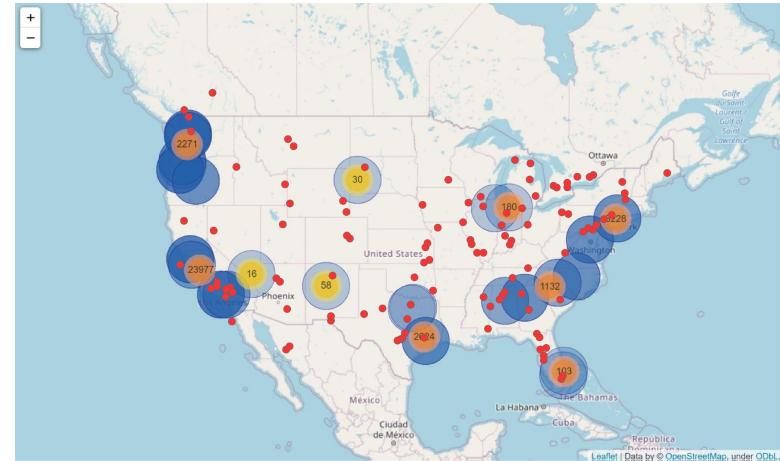
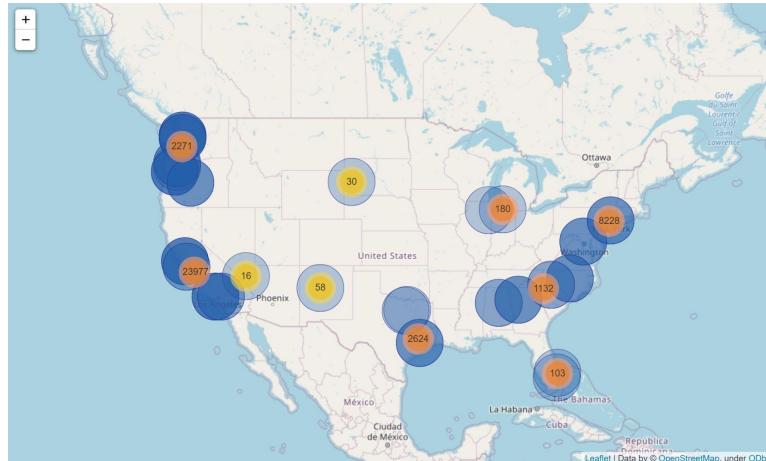
## Criticism

### Skewed Dataset



## Criticism

### Comparison actual location of concrete manufacture companies and our data



Source : <https://www.usgs.gov/media/images/location-cement-plants-and-counties-producing-construction-sand-and>

# Future suggestions for Embodied Carbon dataset



EPD verifications  
Incentive Policy

Better  
EPD Dataset

More  
Material Options

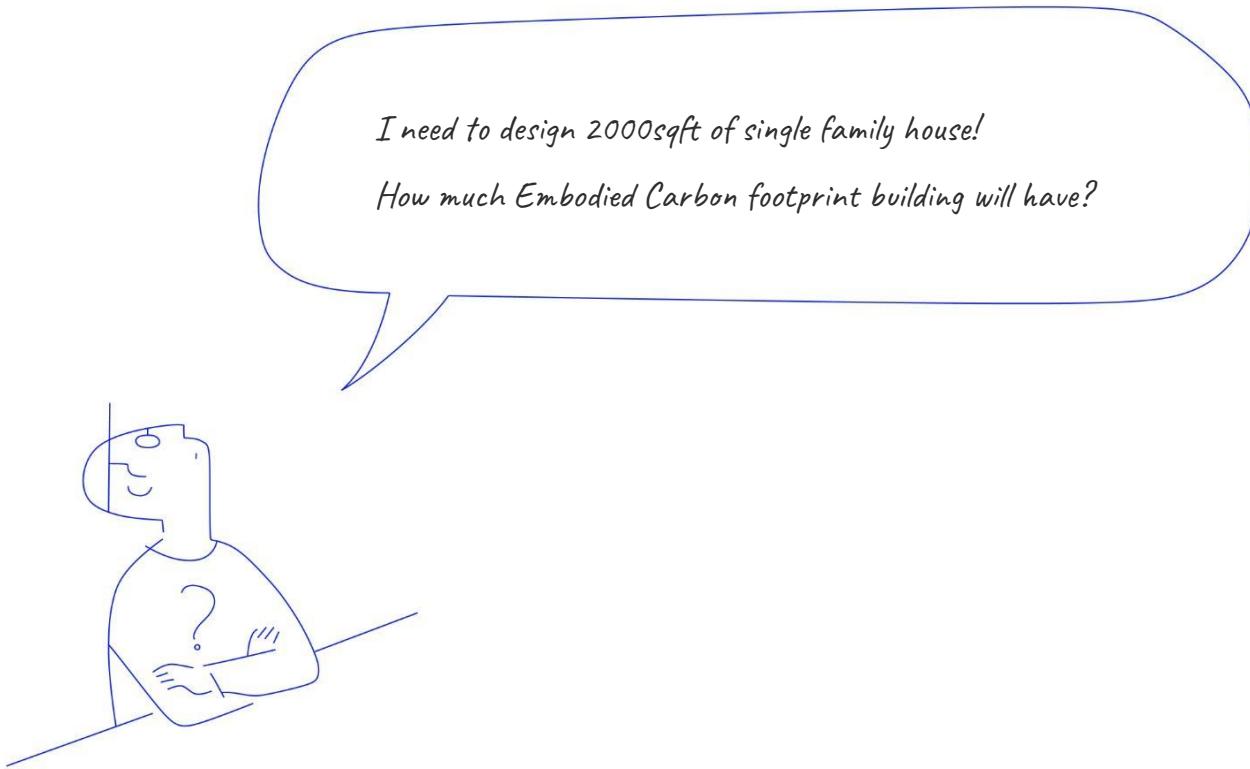
Greener  
Environment

Q&A

## Future Suggestion

1. Compare different databases
2. Encourage more material manufacturers to perform EPD verifications (incentives from the gov.)
3. Encourage embodied carbon related policies
4. Have a more evenly distributed data
5. Look at other aspect of trade offs of material such as cost, physical properties.

## Material Selection: Scenario 3

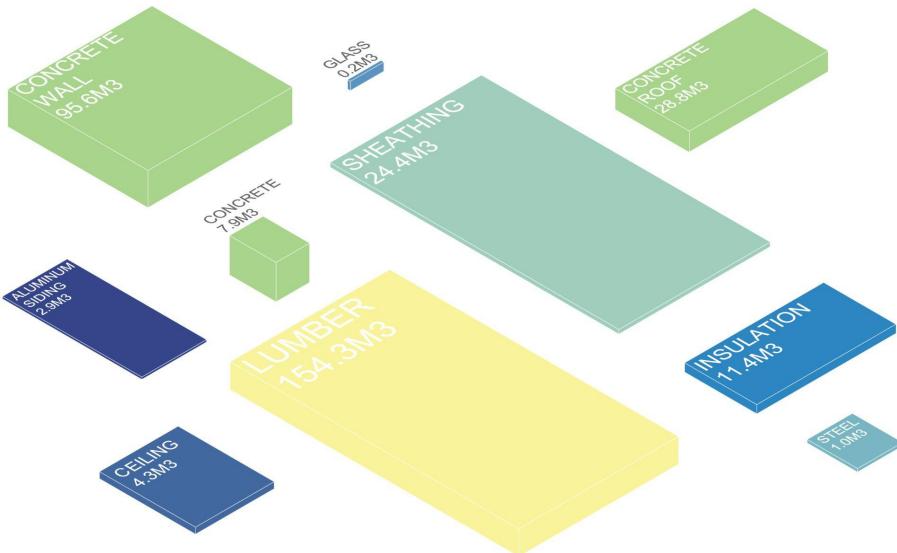


How much Embodied Carbon is associated with each material?

$$\text{Embodied Carbon (gwp)} = \text{Material Volume (m}^3\text{)} \times \text{Material Density (kg/m}^3\text{)} \times \text{Material Embodied Carbon (gwp/kg)}$$

## Building

Material used for 2000 sqft Single Family House



	Materials	Volume
Concrete	Concrete Wall	95.5 m <sup>3</sup>
	Concrete Roof Panel	28.8 m <sup>3</sup>
	Concrete	1.9 m <sup>3</sup>
Lumber		154.2 m <sup>3</sup>
Sheathing		24.4 m <sup>3</sup>
Aluminum Siding		2.9 m <sup>3</sup>
Insulation		11.4 m <sup>3</sup>
Ceiling		4.3 m <sup>3</sup>
Glass		0.2 m <sup>3</sup>
Steel		1.0 m <sup>3</sup>

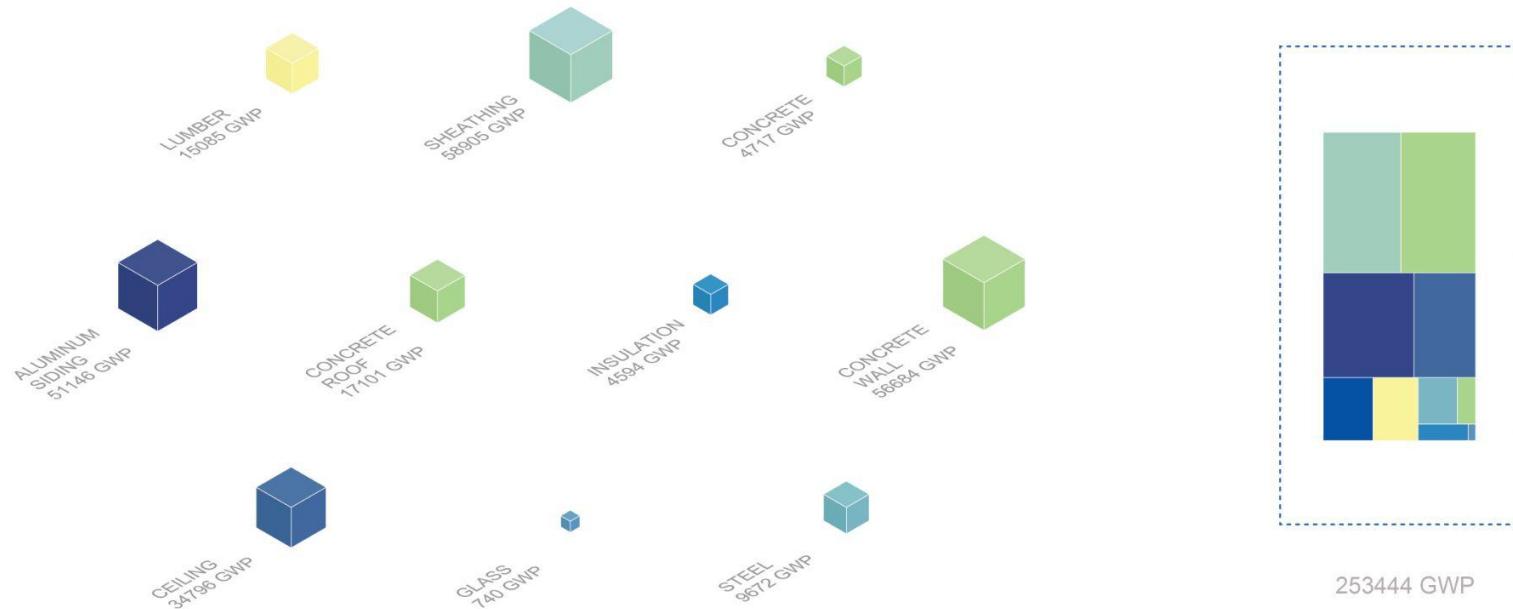
## Building

### Material's GWP per 1m<sup>3</sup> (Min-Average-Max)



## Building

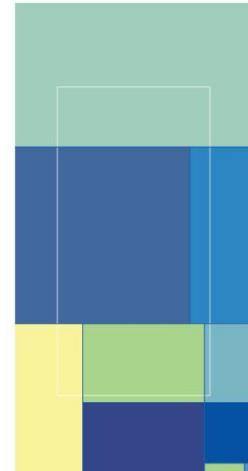
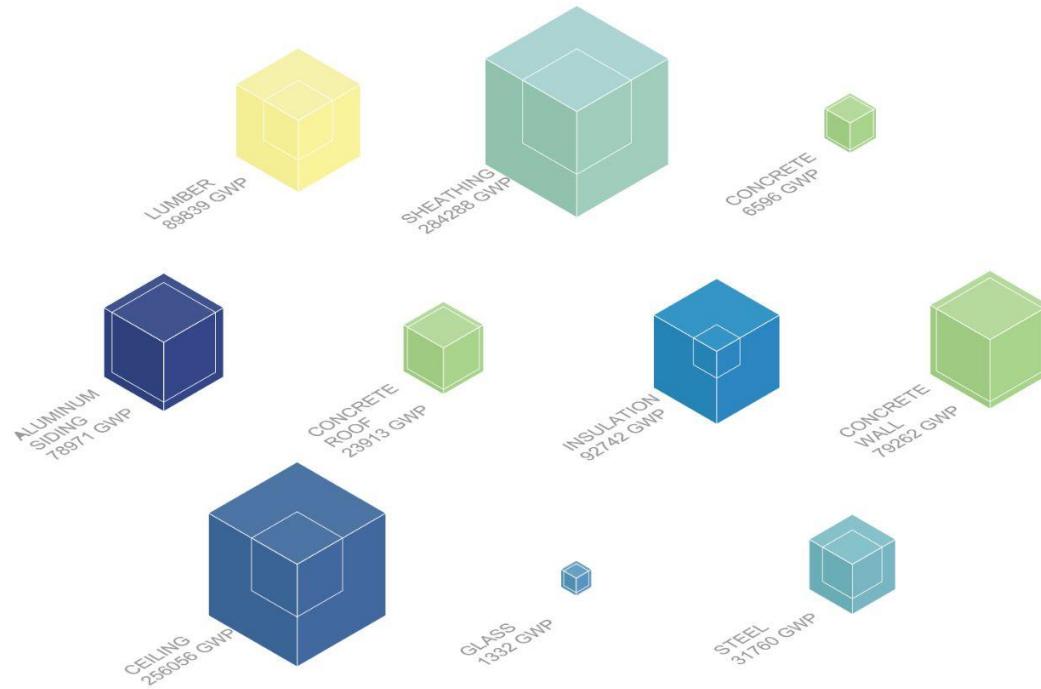
### Average GWP for 2000 sqft Single Family House



Aluminum  
Ceiling Material  
Insulation  
Glass  
Steel  
Sheathing  
Concrete  
Lumber

## Building

### Maximum GWP for 2000 sqft Single Family House

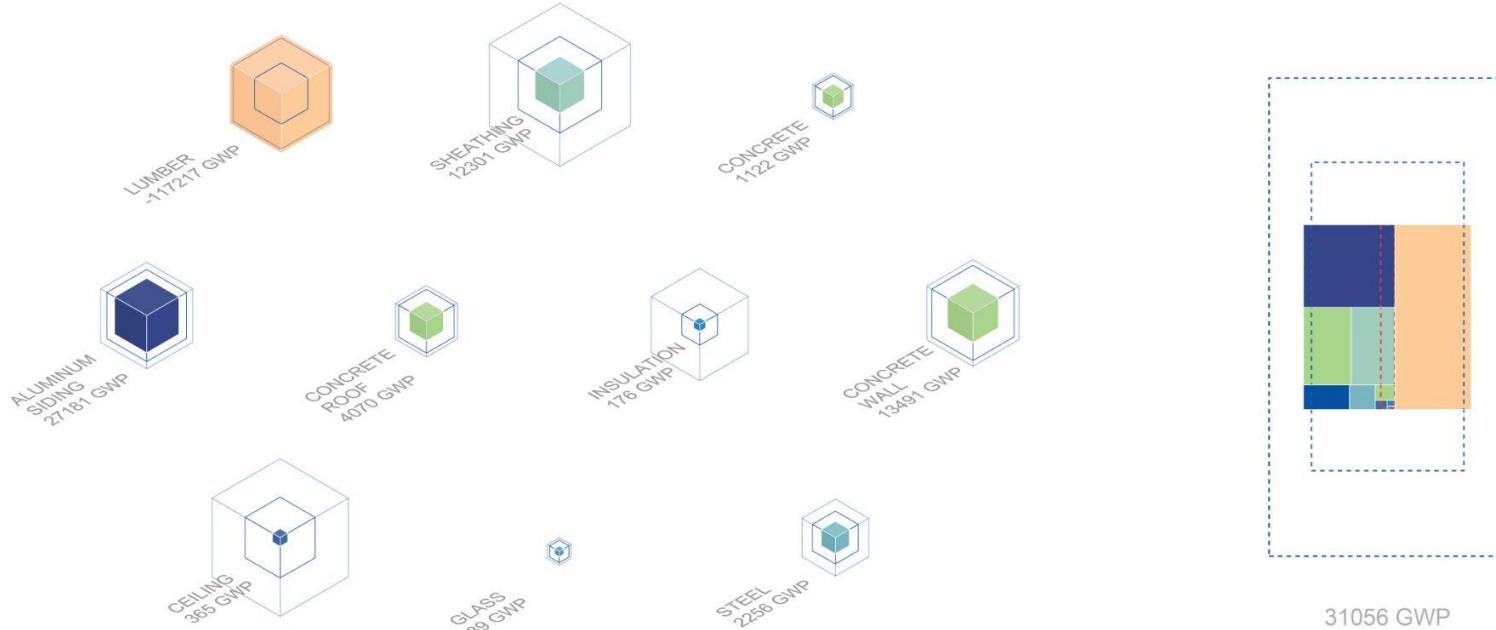


Aluminum  
Ceiling Material  
Insulation  
Glass  
Steel  
Sheathing  
Concrete  
Lumber

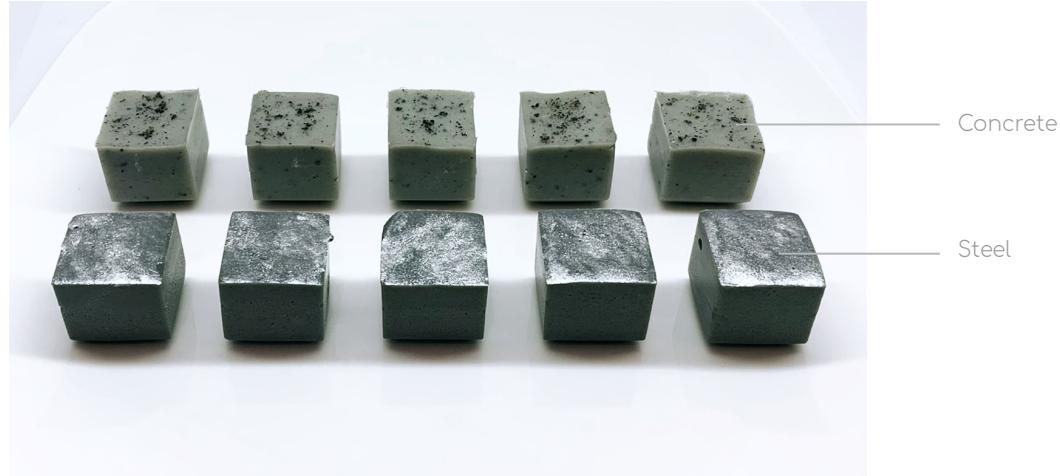
## Building

### Minimum GWP for 2000 sqft Single Family House

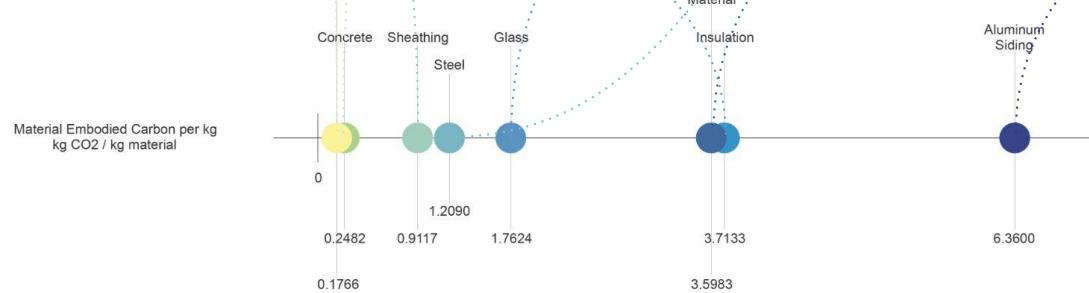
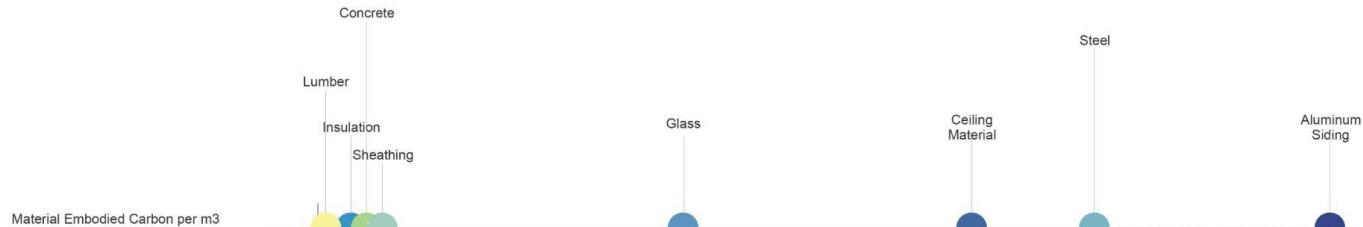
Aluminum  
Ceiling Material  
Insulation  
Glass  
Steel  
Sheathing  
Concrete  
Lumber



## Data Physicalization

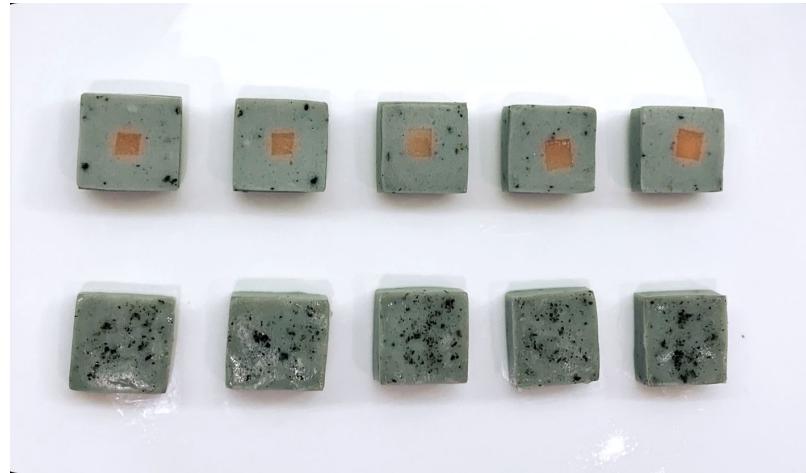


Aluminum  
 Ceiling Material  
 Insulation  
 Glass  
 Steel  
 Sheathing  
 Concrete  
 Lumber



Data Physicalization

Concrete Wagashi & Section cut



Data Physicalization  
Steel Wagashi & Section cut

