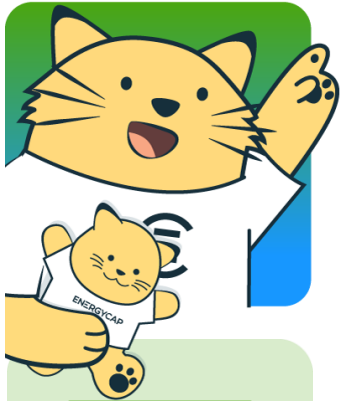




BUILDING DECARBONIZATION Key Issues and Solutions for Occupancy Wellness and Sustainability



Al LaPera

Kimley-Horn Associates

A night landscape featuring a large, bright full moon in the upper left corner, casting a glow over a sky filled with soft, white clouds. Below the clouds, a dark silhouette of a mountain range stretches across the horizon. The foreground is a calm body of water, reflecting the moonlight and the colors of the sky. The overall color palette is dominated by deep blues, purples, and whites.

***“We do these things not
because they are easy but
because they are hard”***



- John F. Kennedy



1

Define what “decarbonizing” a building project means, including explaining key terms such as “embodied carbon” and “net zero carbon”.

2

Use key approaches in building design, material selection and specification to reduce the embodied carbon in the building envelope and structure.

3

Employ beneficial electrification to reduce buildings’ operational carbon dioxide emissions.

4

Design to meet building performance standards as more local jurisdictions adopt these practices to meet community greenhouse gas emission reduction goals.

Decarbonization - *Definitions*

Are super!

Decarbonization - *Definitions*



1. “Carbon” emissions = greenhouse gas emissions
2. Greenhouse effect = global warming potential (GWP)
3. All other greenhouse gases’ GWPs are normalized to CO₂
4. CO₂e = carbon dioxide equivalents, measured in metric tons [1000 kg or 2200 lb] (mTCO₂e)
5. 20-year versus 100-year GWPs. Our current challenge is immediate, which means that we focus on the 20-yr GWPs



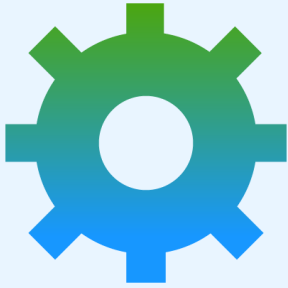
Decarbonization - *Definitions*



1. **Decarbonization** is both the journey and the destination: Reducing, then eliminating the **embodied** and **operational** carbon of a building through
 - Increased both building design/construction *and* operational efficiency
 - On-site renewable energy generation
 - Off-site greenhouse gas (GHG) emission offsets
2. **Embodied** carbon is the CO₂e associated with the building construction, including extraction, manufacture, and transportation of the building materials, as well as its ultimate demolition
3. **Operational** carbon is the CO₂e associated with operating and maintaining the building throughout its lifetime. Most of this CO₂e is associated with the energy used in building operations
4. **Net-zero carbon buildings** use renewable energy production and other GHG offsets to reduce their CO₂e to zero

Pop quiz #1!

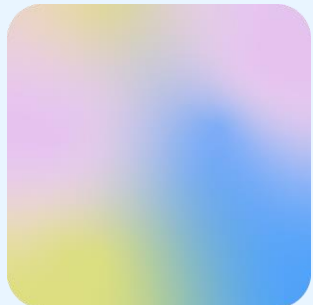
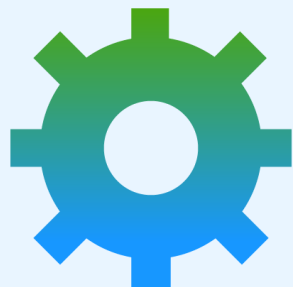
**List the order of GHG emitters
By sector, from least to greatest.**



- a) Transportation, farming, building operations
- b) Building materials, transportation, building operations
- c) Building operations, building materials, farming
- d) Building materials, building operations, transportation
- e) Farming, building operations, building materials

Pop quiz #1!!

List the order of GHG emitters
By sector, from least to greatest.



- a) Transportation, farming, building operations
- b) **Building materials (22.7%), transportation (23%), building operations (28%)**
- c) Building operations, building materials, farming
- d) Building materials, building operations, transportation
- e) Farming, building operations, building materials

Embodied vs Operational Carbon



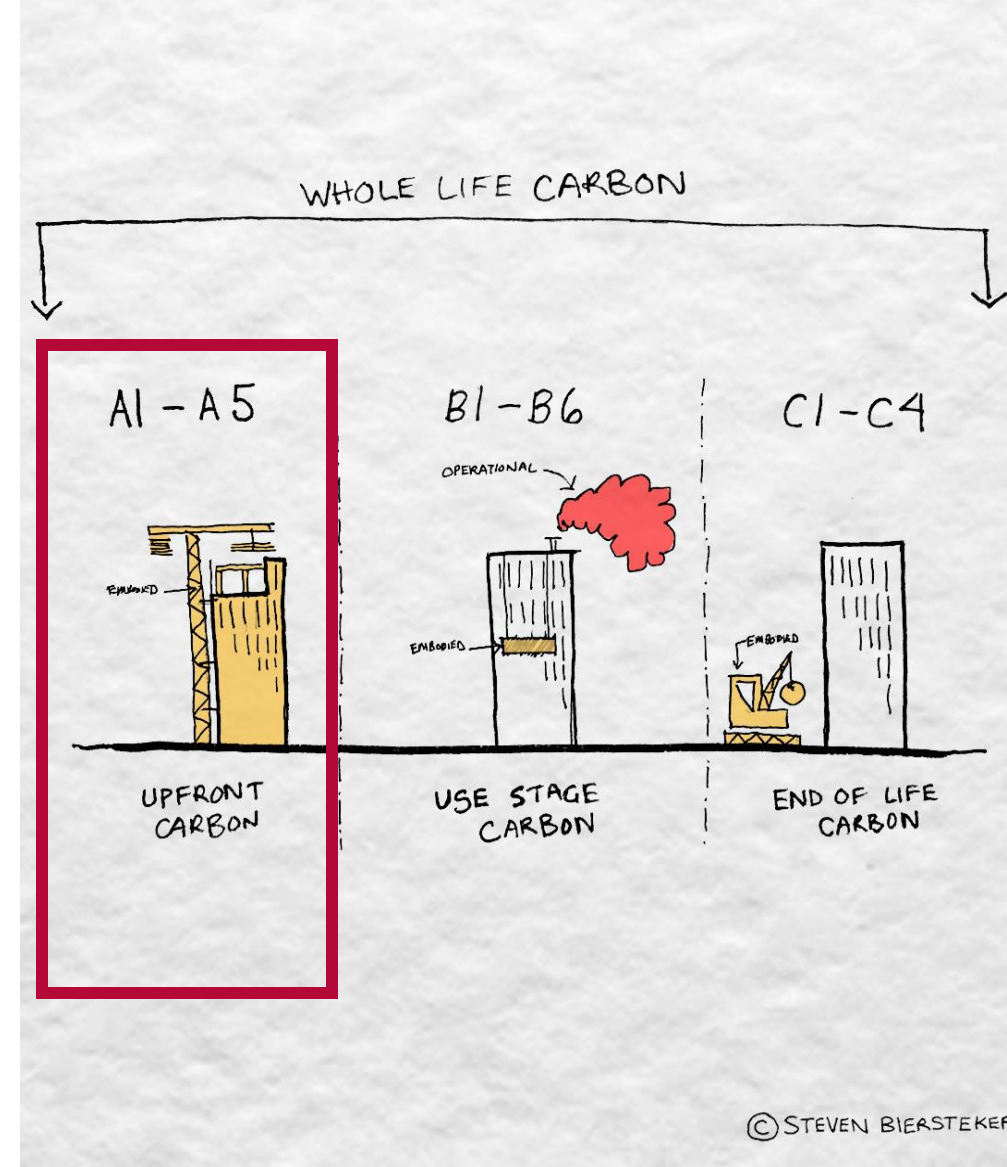
Image Credit: Stacy Smedley/Skanska

Understanding The Building Carbon Cycle

WHOLE CARBON CYCLE

Upfront Carbon (Embodied)

- ✓ Modules A1-A3: Product Stage (Cradle to Gate)
- ✓ Module A4: Transport Emissions (Factory Gate to Site)
- ✓ Module A5: Construction Installation Emissions



Understanding The Building Carbon Cycle

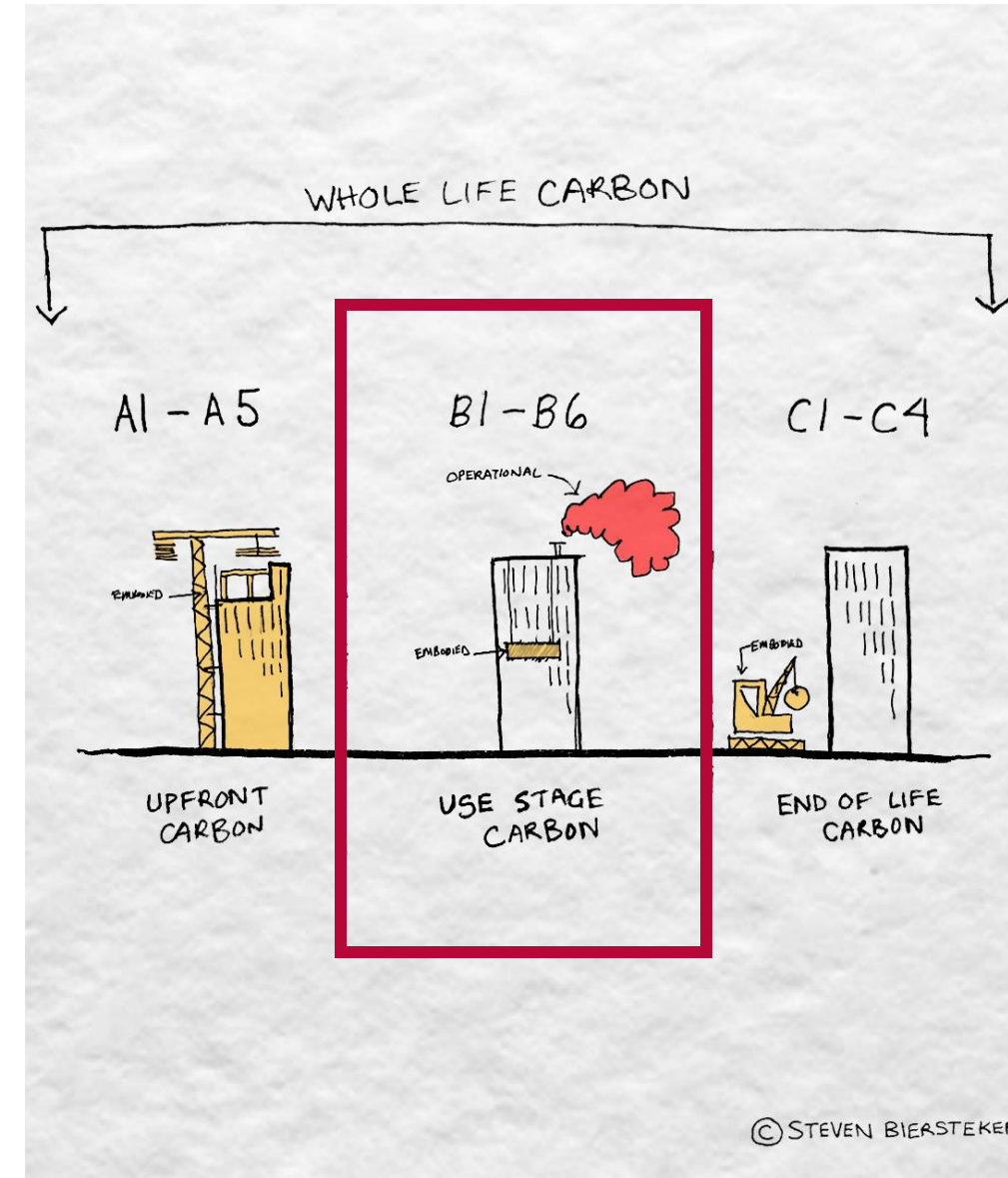
WHOLE CARBON CYCLE

Use Stage Carbon (Operational)

- ✓ Module B1: In Use Emissions
- ✓ Module B2: Maintenance Emissions
- ✓ Modules B3-B4: Repair & Replacement Emissions
- ✓ Module B5: Refurbishment Emissions

- ✓ Module B6: Operational Energy Emissions

- ✓ Module B7: Operational Water Use
- ✓ Module C8: User Carbon

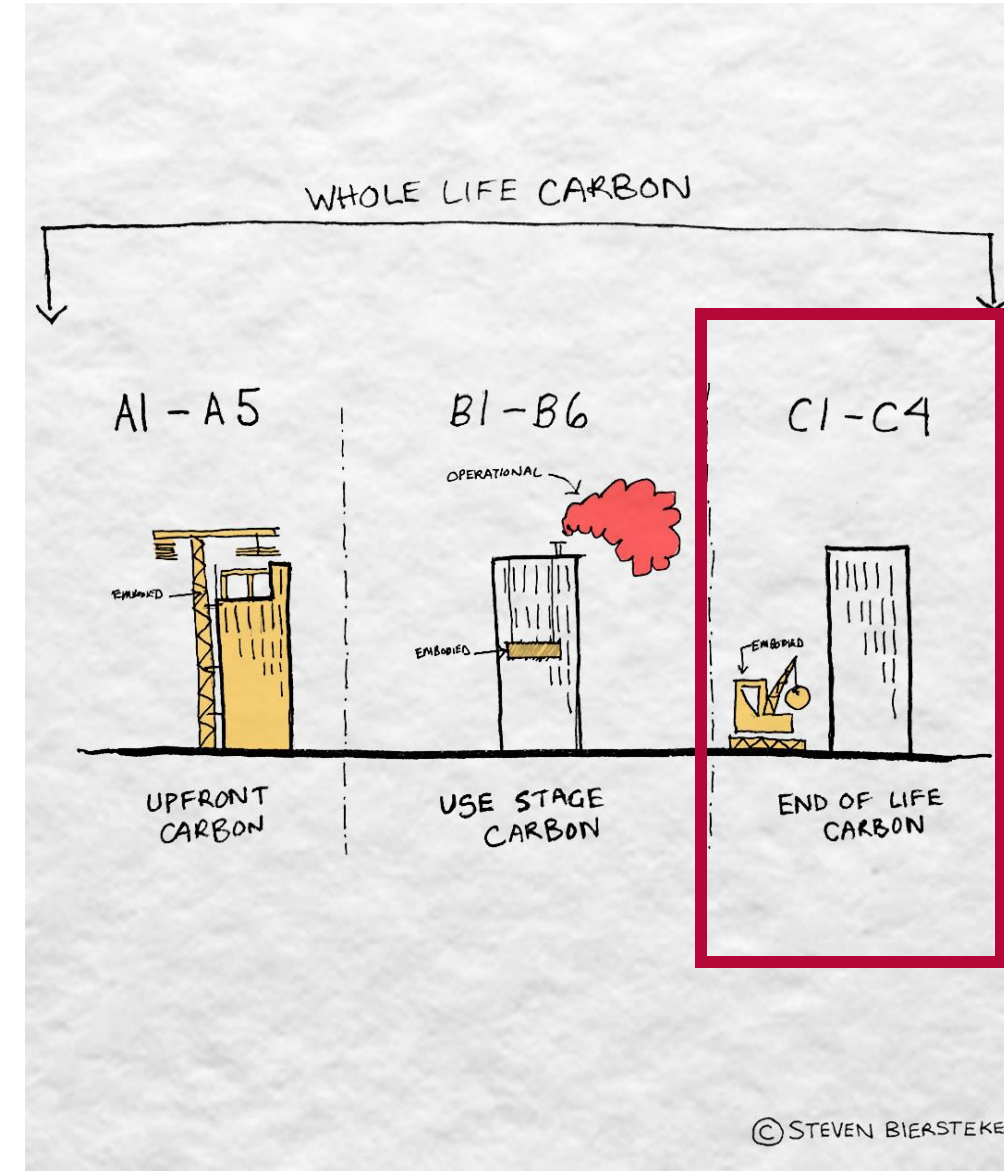


Understanding The Building Carbon Cycle

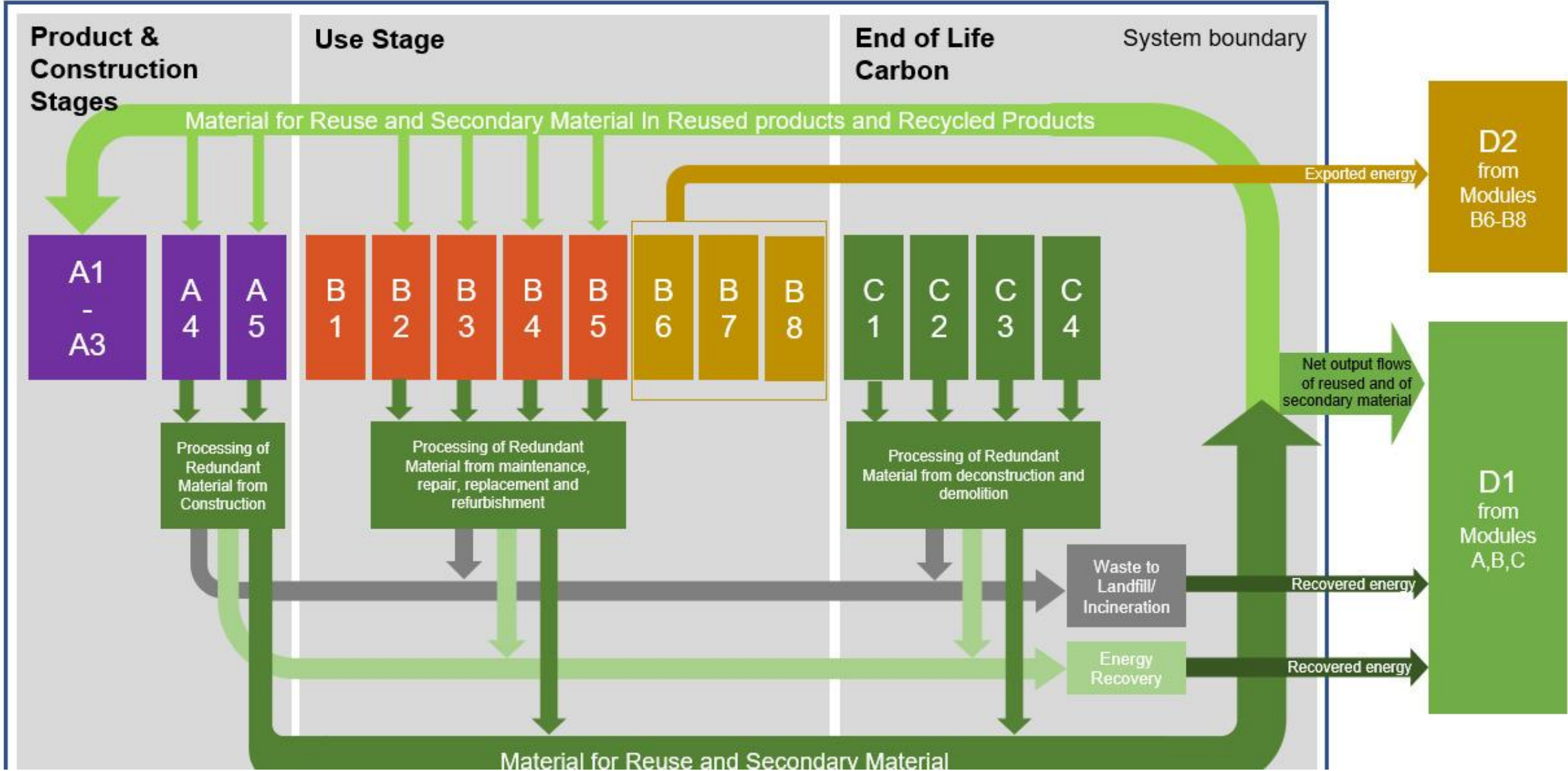
WHOLE CARBON CYCLE

End of Life Carbon (Embodied)

- ✓ Module C1: Deconstruction Emissions
- ✓ Module C2: Transport Emissions
- ✓ Module C3: Waste Processing Emissions
- ✓ Module C4: Disposal Emissions



Understanding The Building Carbon Cycle



Net-Zero Carbon

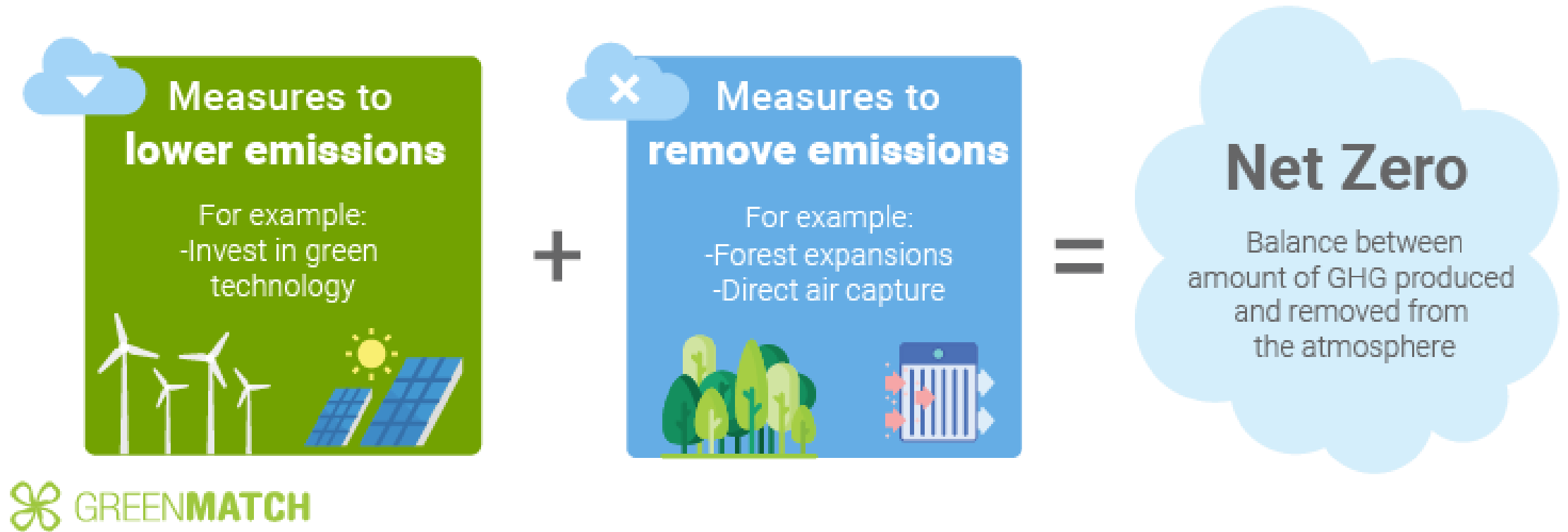


Image Credit: Green Match

1 mTCO₂e*

Emitted by:



110 gallons of gasoline consumed



1100 lb of coal burned



40 home BBQ propane cylinders used



188 therms of natural gas burned

Avoided by:



40 trash bags of waste recycled instead of landfilled



40 incandescent lamps switched to LEDs

Sequestered by:



16 tree seedlings growing for 10 years

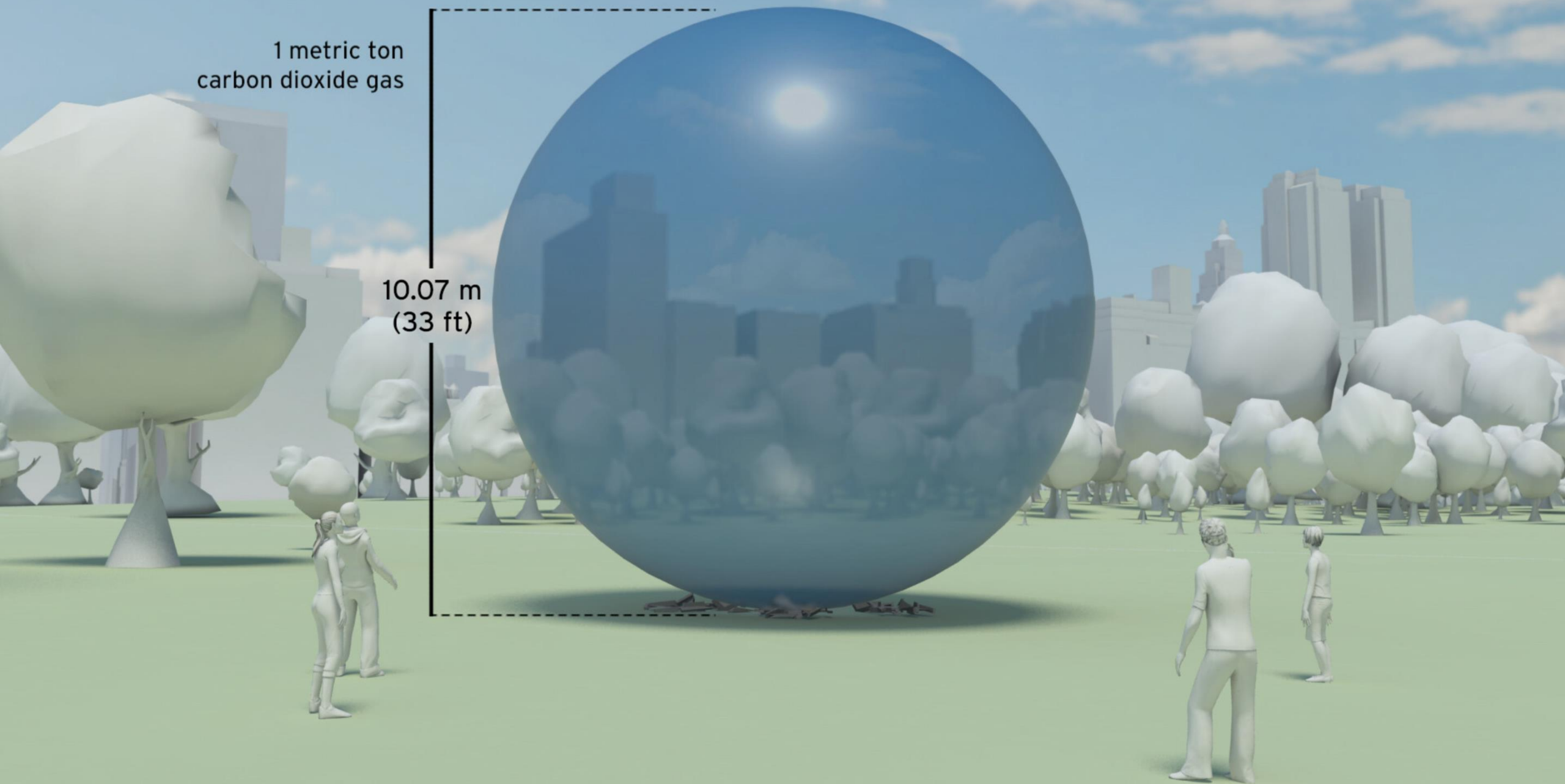


1.2 acres of forest in one year

[*https://www.epa.gov/energy/greenhouse-gas-equivalencies-calculator](https://www.epa.gov/energy/greenhouse-gas-equivalencies-calculator)

1 metric ton
carbon dioxide gas

10.07 m
(33 ft)



Global Warming Impact

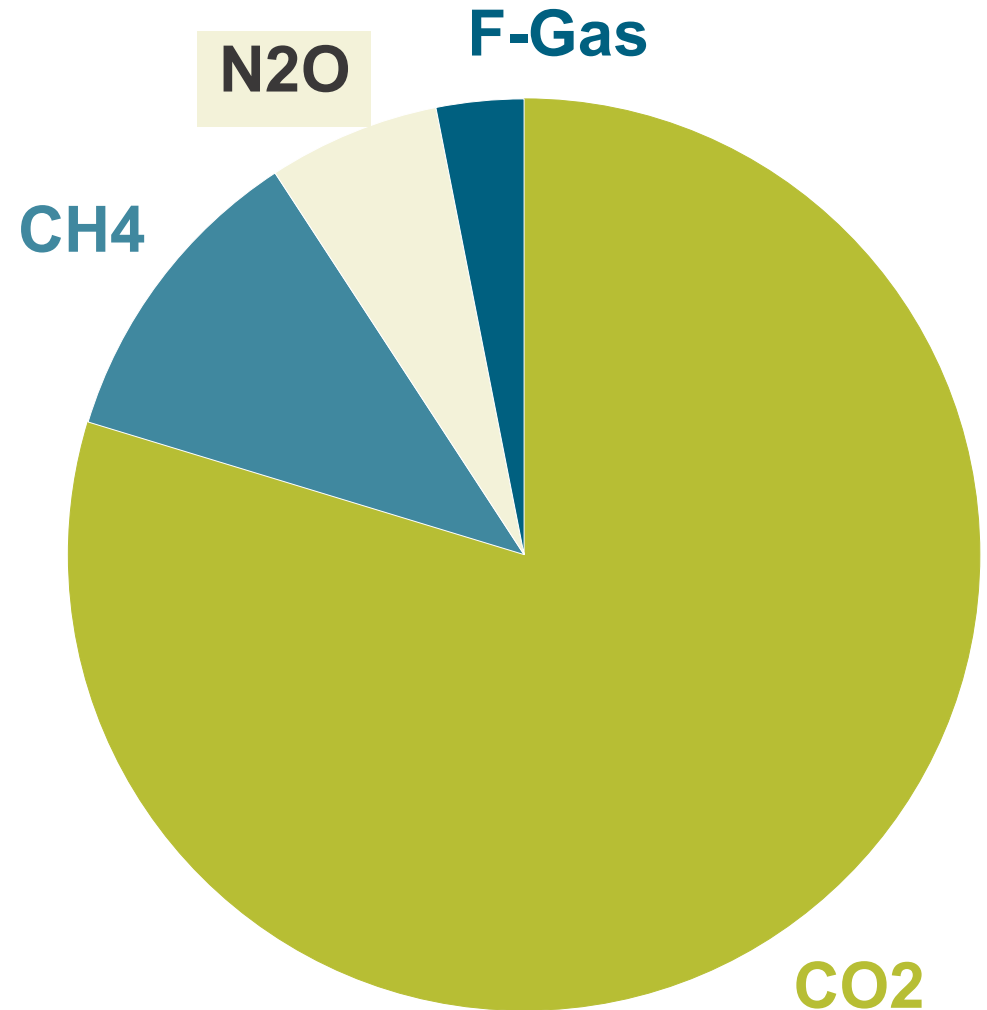
US GHG emissions (**6.3 billion mTCO₂e in 2022** – 20 yr Impact)*

- 79.7% Carbon Dioxide (**CO₂**)
- 11.1% Methane (**CH₄**)
- 6.1% Nitrous Oxide (**N₂O**)
- 3.1% Fluorinated Gases (**F-Gas**)

***Per EPA 430-R24-004**

Some equivalents (20-yr Impact)

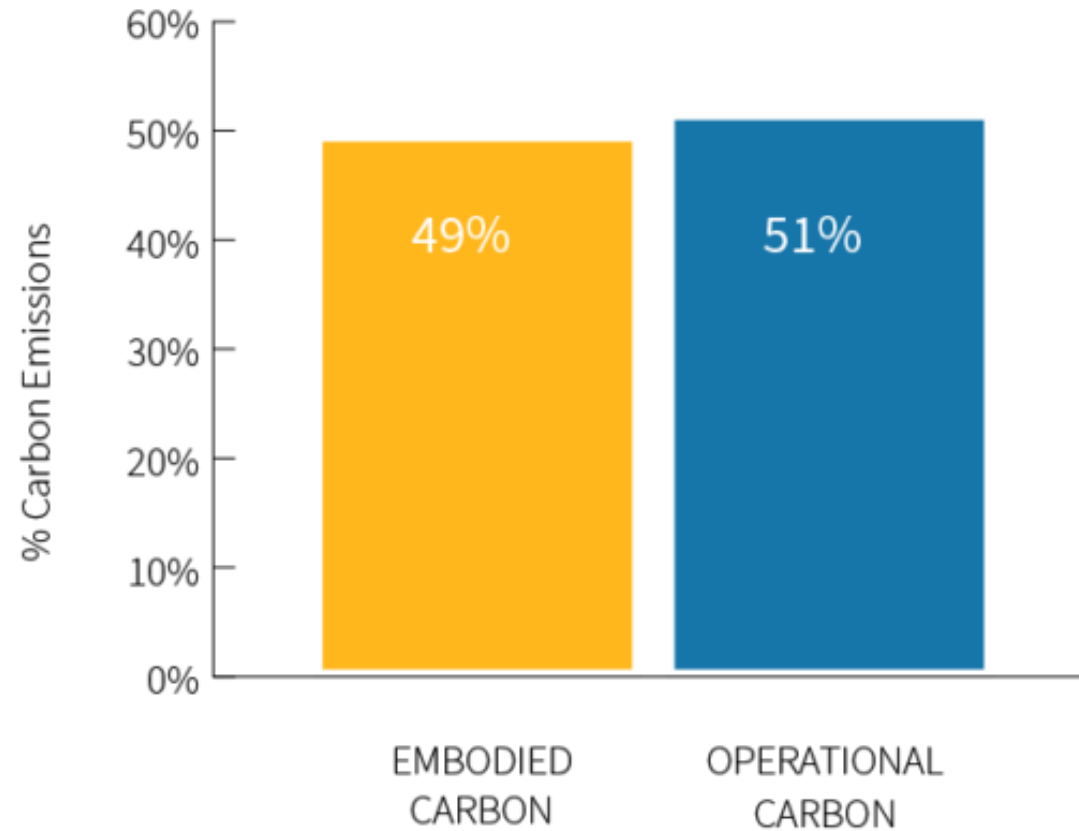
- 1 lb **CH₄** = 80 lb CO₂e
- 1 lb **N₂O** = 265 lb CO₂e
- 1 lb R-410A (an **F-Gas**) = 2000 lb CO₂e



Reducing Embodied Carbon

Are super!

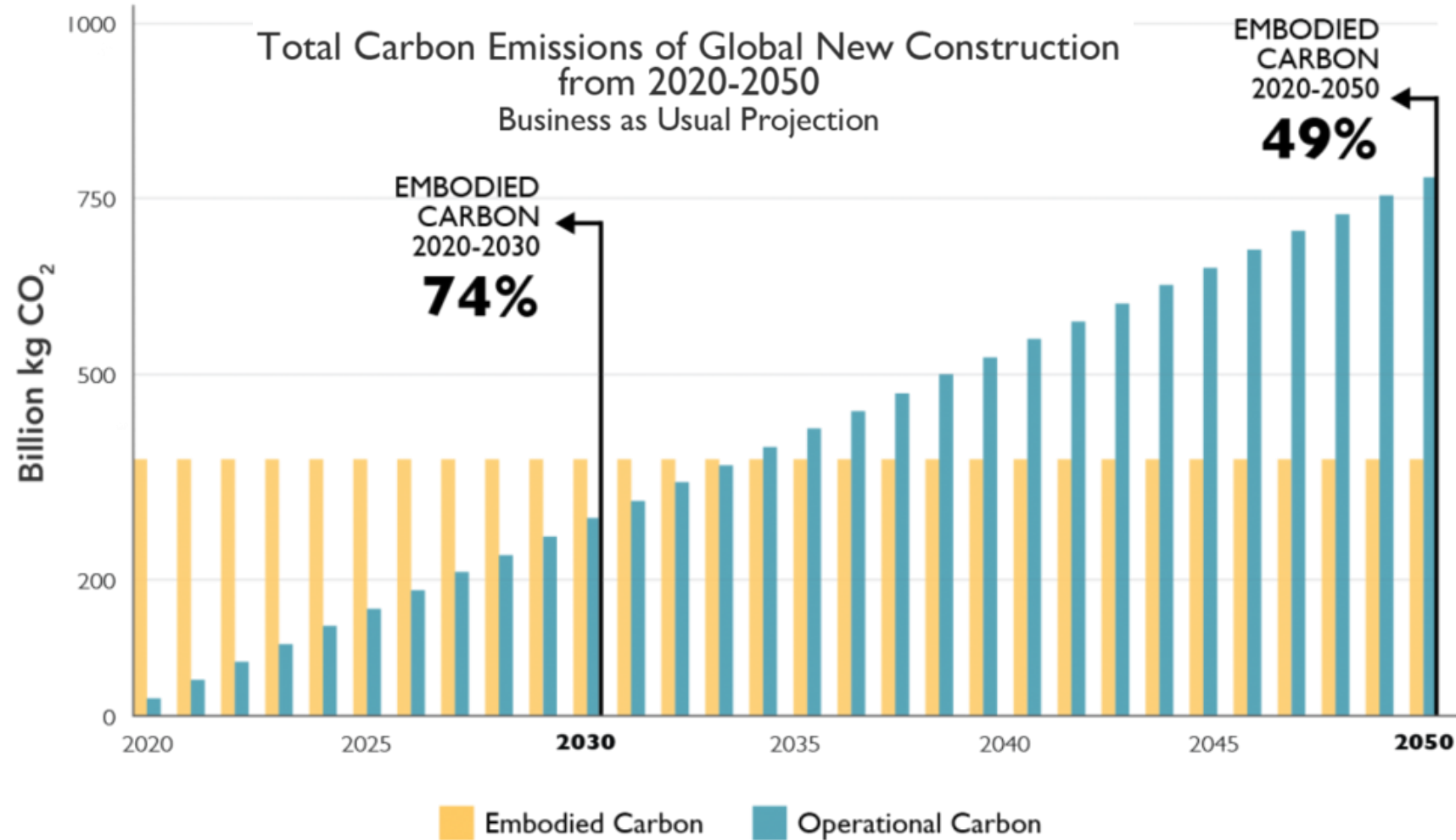
Total Carbon Emissions – New Construction



Total Carbon Emissions of Global New Construction from 2020-2050
Business as Usual Projection

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

Time Value of Embodied Carbon



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Data Sources: UN Environment Global Status Report 2017; EIA International Energy Outlook 2017

Reducing Embodied Carbon

Where is the embodied carbon?

Typical US commercial construction
Average 500 – 600 kg CO₂e/sq m
(110 – 130 lb CO₂e/sq ft)

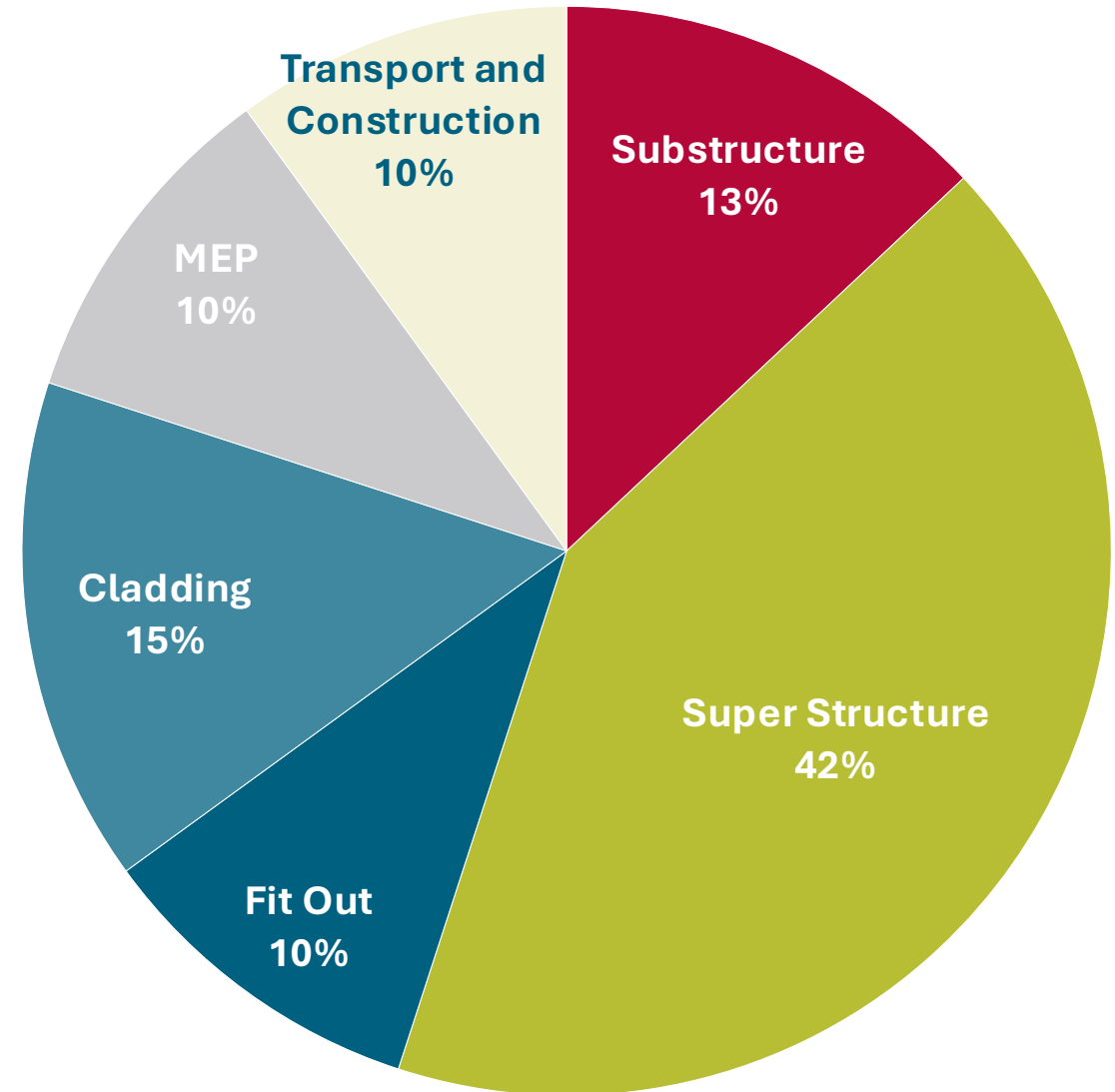


Image Credit: Greengage Environmental

Reducing Embodied Carbon

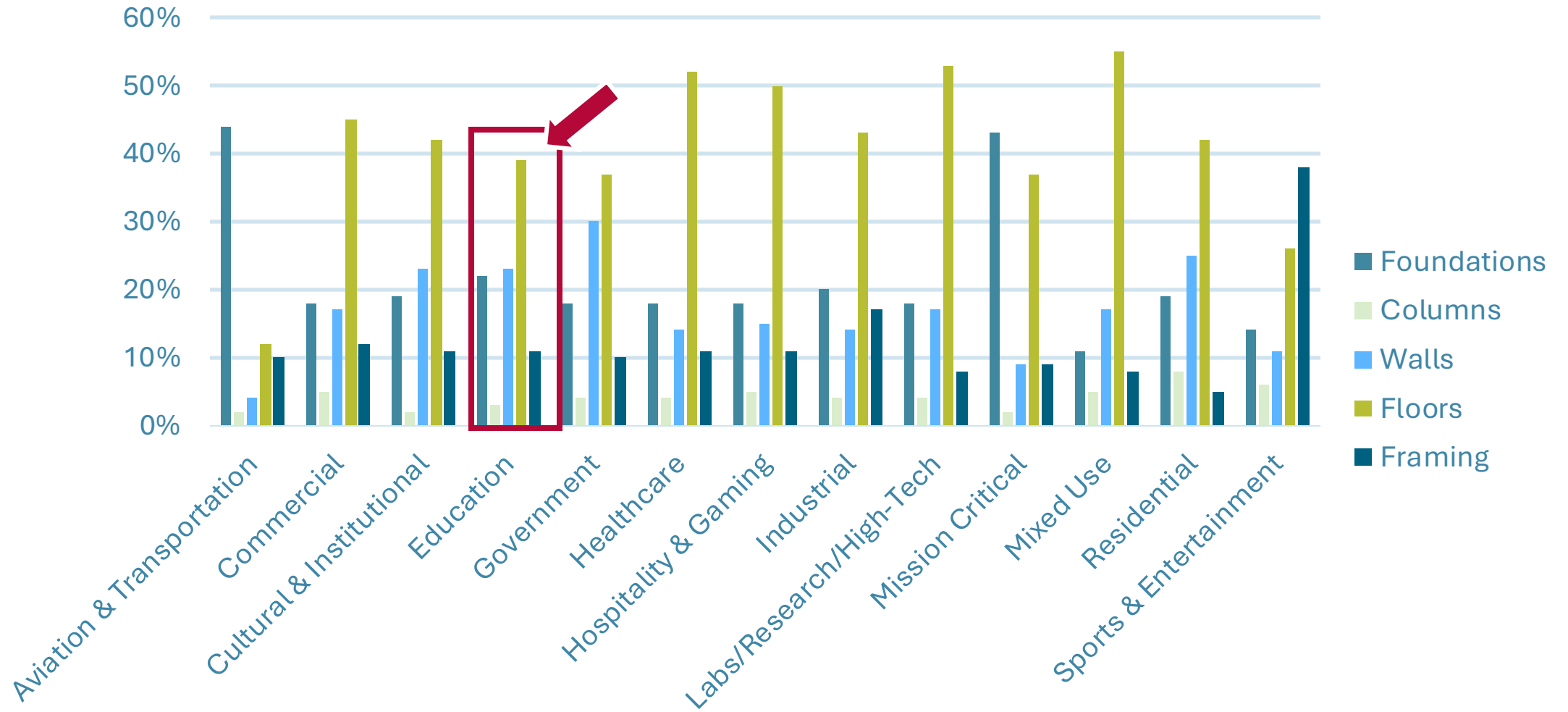


Image Credit: Thornton Tomasetti

Reducing Embodied Carbon

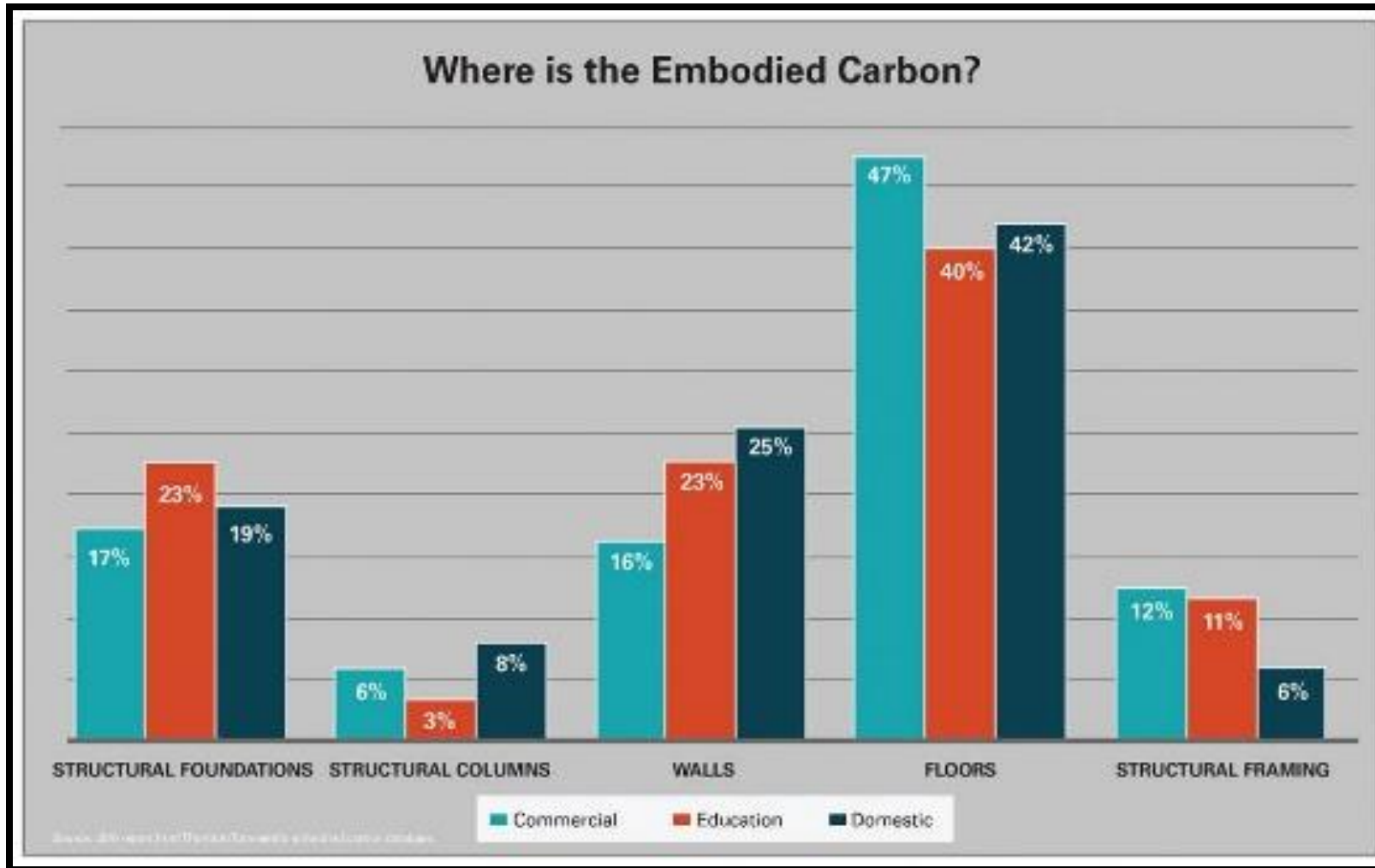
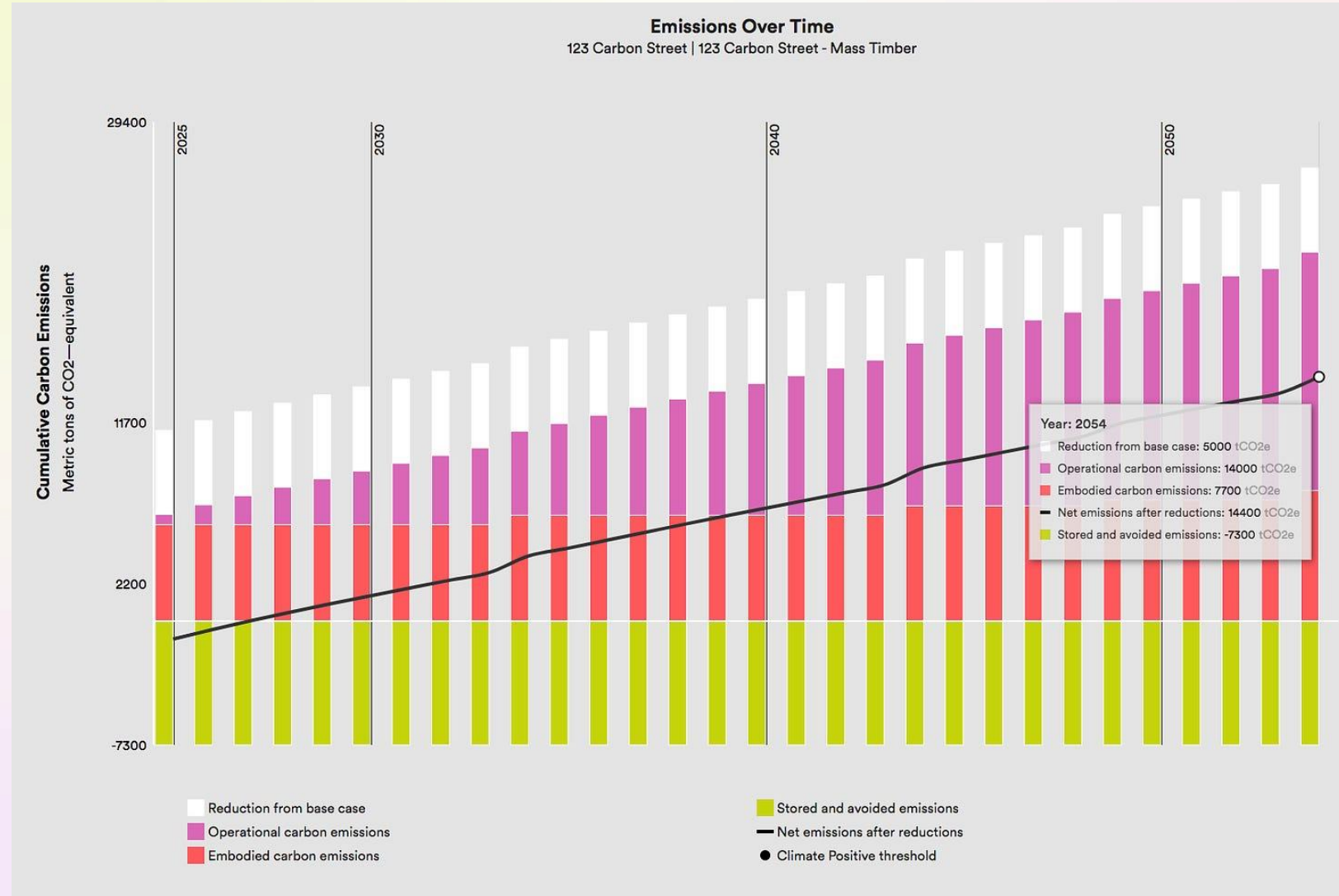


Image Credit: Thornton Tomasetti

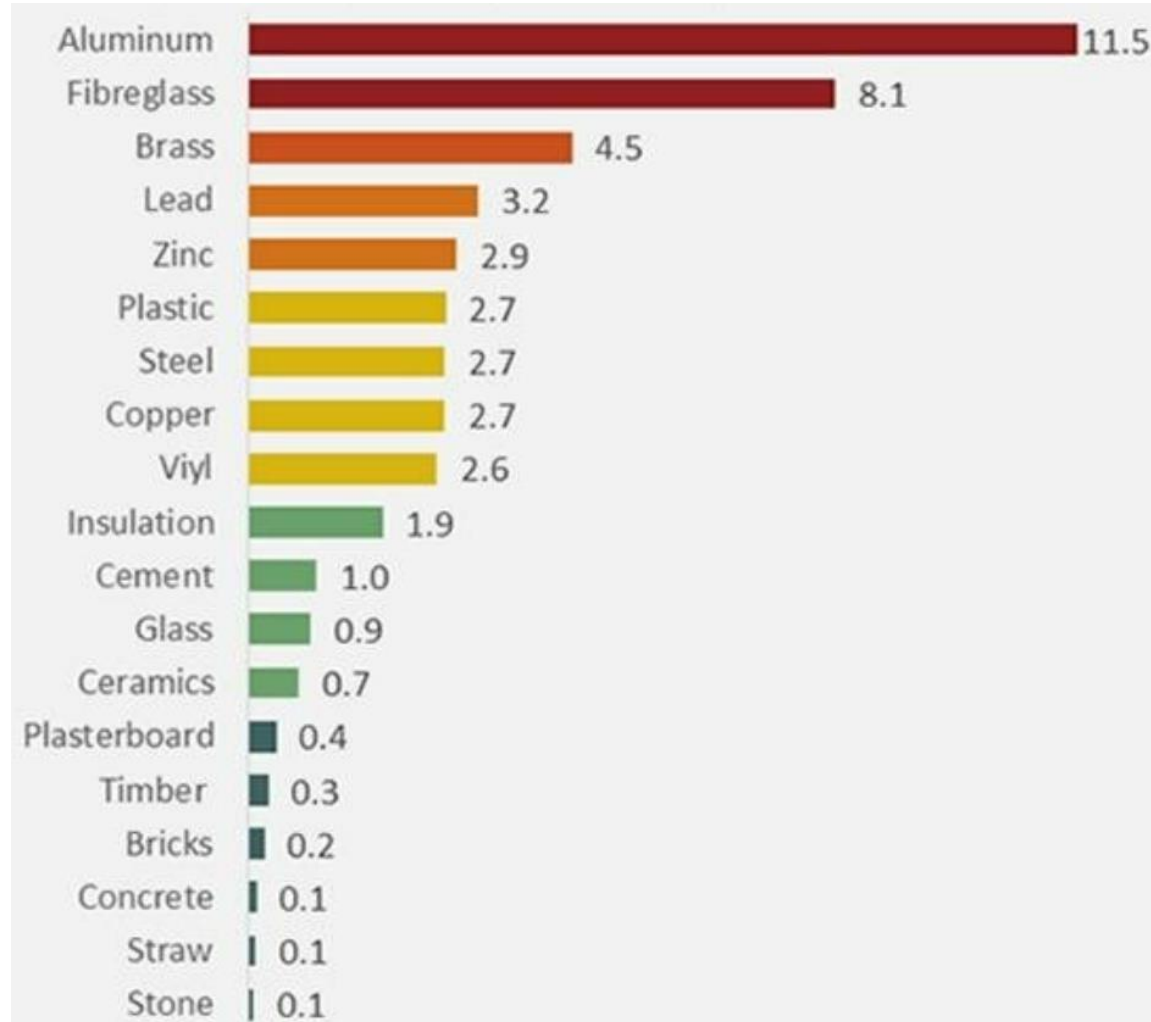
Image Credit: EPIC



Image Credit: EPIC



Reducing Embodied Carbon



All figures in kg CO2e/kg of building material

Source: Inventory of Carbon & Energy (ICE) database

Download:

<http://www.circularecology.com/ice-database.html>

Reducing Embodied Carbon

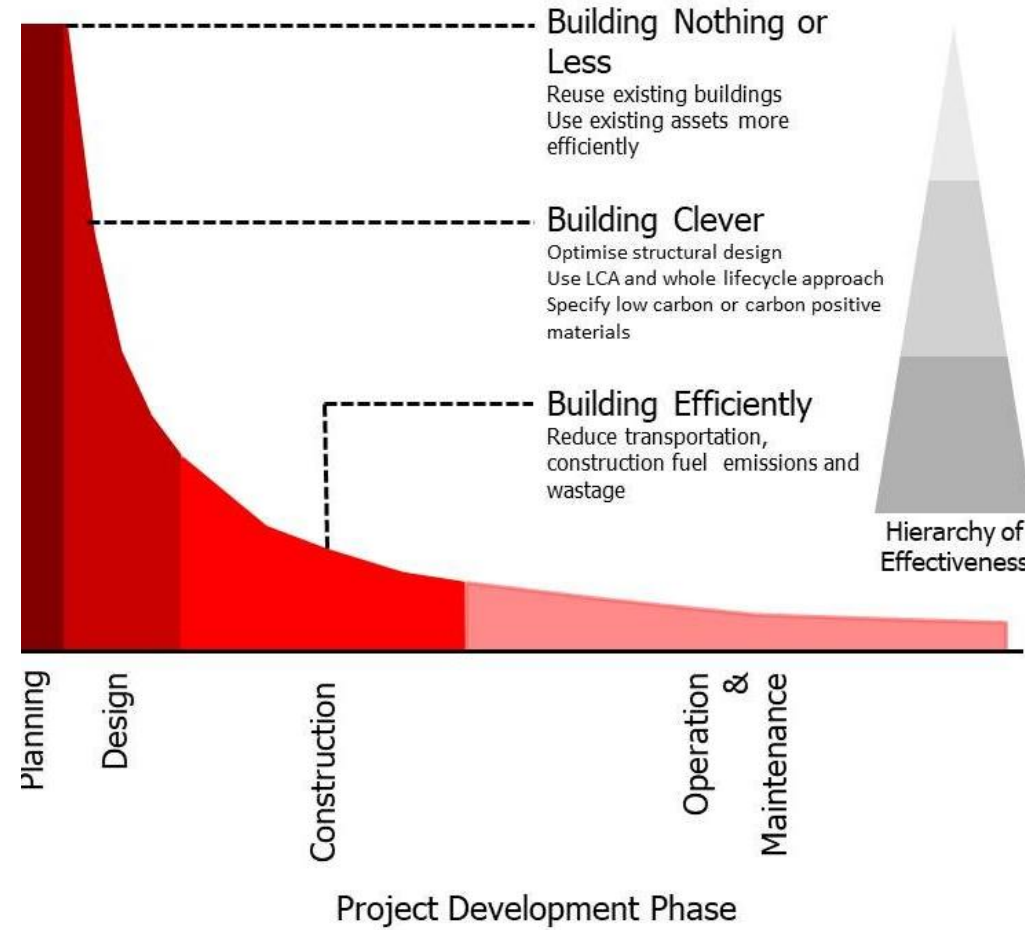


Image Credit: Marked Performance Ltd

Source: <https://www.marked-performance.com/articles/embodied-carbon>

Reducing Embodied Carbon

Build Nothing or Less

- Adaptive reuse of existing buildings
- Use existing assets more efficiently

Build Effectively

- Optimize structural design
- Use LCA and whole lifecycle approach
- Specify low carbon or carbon positive materials

Build Efficiently

- Reduce transportation
- Reduce construction fuel emissions and waste

In 2040, **2/3 of the global building stock** will be buildings that exist today. Without upgrades, they will still be emitting GHGs.



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Data Source: IEA Energy Technology Perspectives 2020, February 2021 Revised Edition

Scope Emissions

Are super!

What are Scope Emissions?

They are Greenhouse Gas (GHG) emissions that are broken down into three categories:

Scope 1

Scope 2

Scope 3

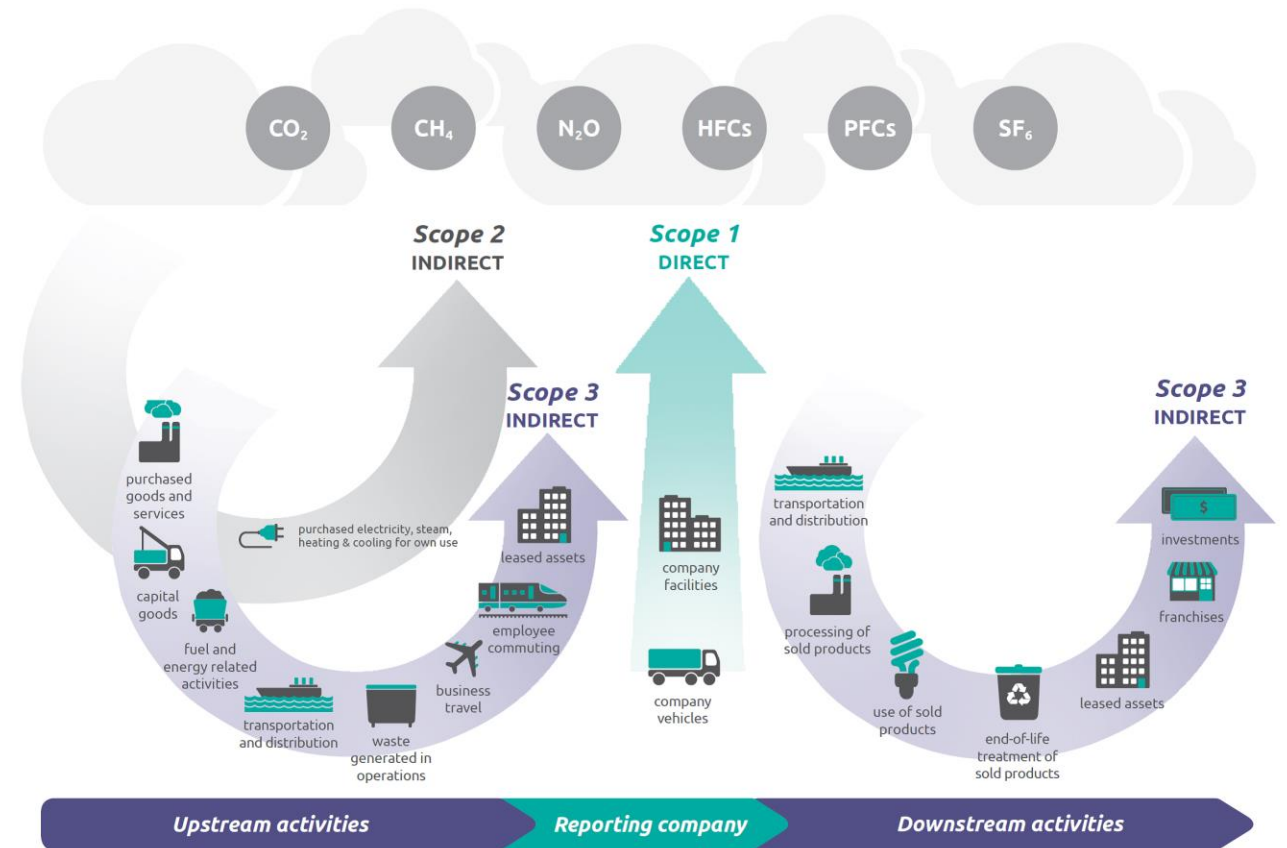
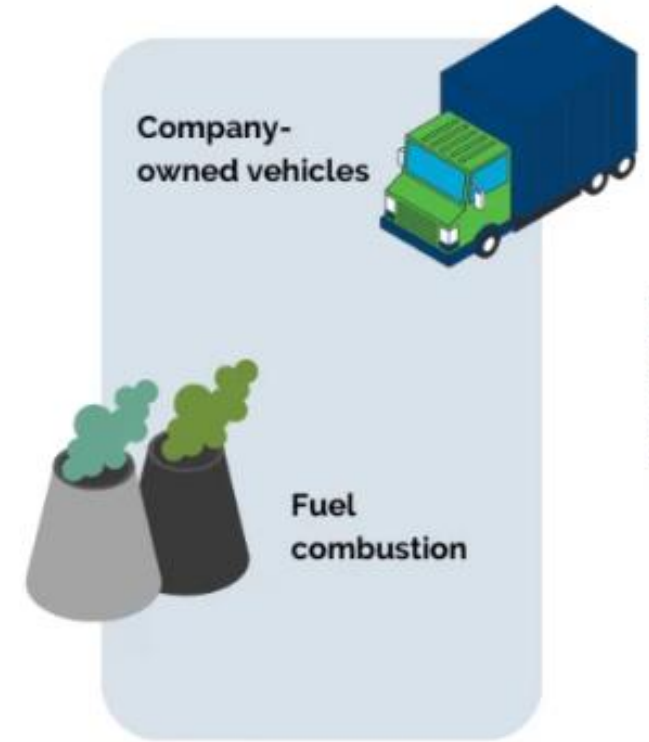


Image Credit: EPA

What are Scope Emissions?

Scope 1 (Direct Emissions & Some Indirect)

- Activities controlled or Owned by your organization that release emissions straight into the atmosphere. These are direct emissions.
- Examples of scope 1 emissions could be emissions from on-site fossil fuel combustion, including process emissions and those from industrial processes, refrigeration, heating, air conditioning, electricity generation, and emissions from company-owned vehicles. (**IE: School Busses**)



Scope 1

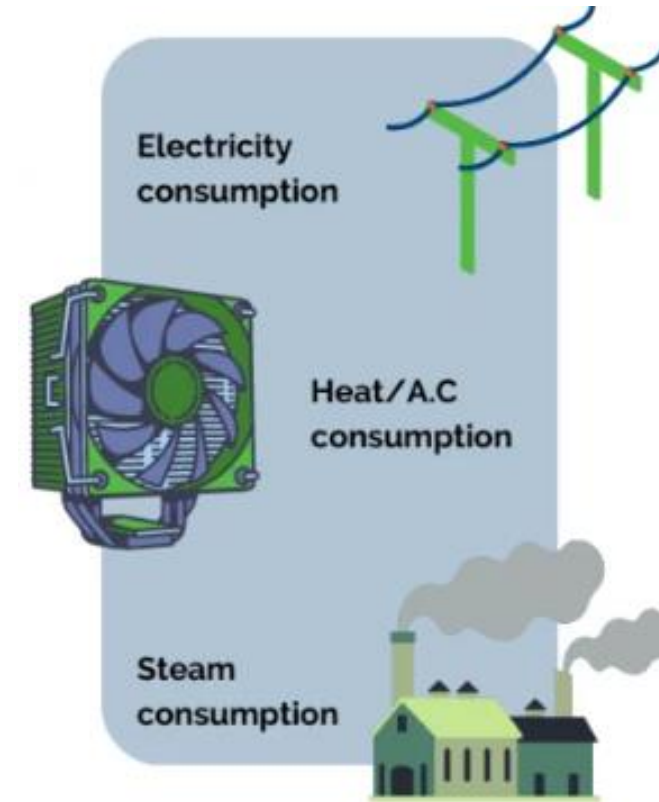
Direct emissions from sources that are owned or controlled by an organization.

Image Credit: Certainty

What are Scope Emissions?

Scope 2 (Energy indirect)

- Emissions being released into the atmosphere associated with your consumption of purchased electricity, heat, steam and cooling. These are indirect emissions that are a consequence of your organization's activities, but which occur at sources you do not own or control.
- Examples of scope 2 emissions:
 - ✓ Electricity or natural gas that's purchased from a local power utility to power a building or facility
 - ✓ Energy consumption and usage for offices and sites that's purchased from a utility
 - ✓ Energy generation from any leased, non-renewable sources
 - ✓ Other purchased emissions from rented or leased equipment not already accounted for in sites and facilities



Scope 2

Indirect emissions from the consumption of purchased electricity, heat, or steam.

Image Credit: Certainty

What are Scope Emissions?

Scope 3 (Other Indirect)

- Emissions that are a consequence of your actions, which occur at sources which you do not own or control and which are not classed as scope 2 emissions.
- Examples of scope 3 emissions:
 - ✓ Emissions from employee commuting and business travel,
 - ✓ Waste disposal
 - ✓ The use of purchased goods and services throughout an organization's supply chain/value chain



Image Credit: Certainty

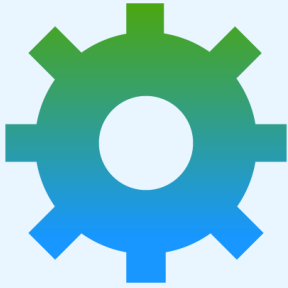
Pop quiz #2!



Ned owns an electric vehicle and brags to his coworkers that he reduced his GHG emissions. Tatiana points out to him that he plugs his car into the electrical grid, and his utility company runs on natural gas, which is a great emitter of GHG. Karl also mentions that lithium is difficult to mine, and its extraction is damaging to the environment. Tatiana's comment is an example of:

- a) Embodied Carbon
- b) Operational Carbon
- c) Scope I emissions
- d) Scope II emissions
- e) Scope III emissions

Pop quiz #2!



Ned owns an electric vehicle and brags to his coworkers that he reduced his GHG emissions (b,c).

Tatiana points out to him that he plugs his car into the electrical grid, and his utility company runs on natural gas, which is a great emitter of GHG (b,d).

Karl also mentions that lithium is difficult to mine, and its extraction is damaging to the environment (a,d,e).

Tatiana's comment is an example of:

- a) Embodied Carbon
- b) Operational Carbon
- c) Scope I emissions
- d) Scope II emissions
- e) Scope III emissions

Beneficial Electrification

Are super!

Beneficial Electrification

Beneficial Electrification

(or strategic electrification) which is a term for replacing direct fossil fuel use (e.g., propane, heating oil, gasoline) with electricity in a way that reduces overall emissions and energy costs.

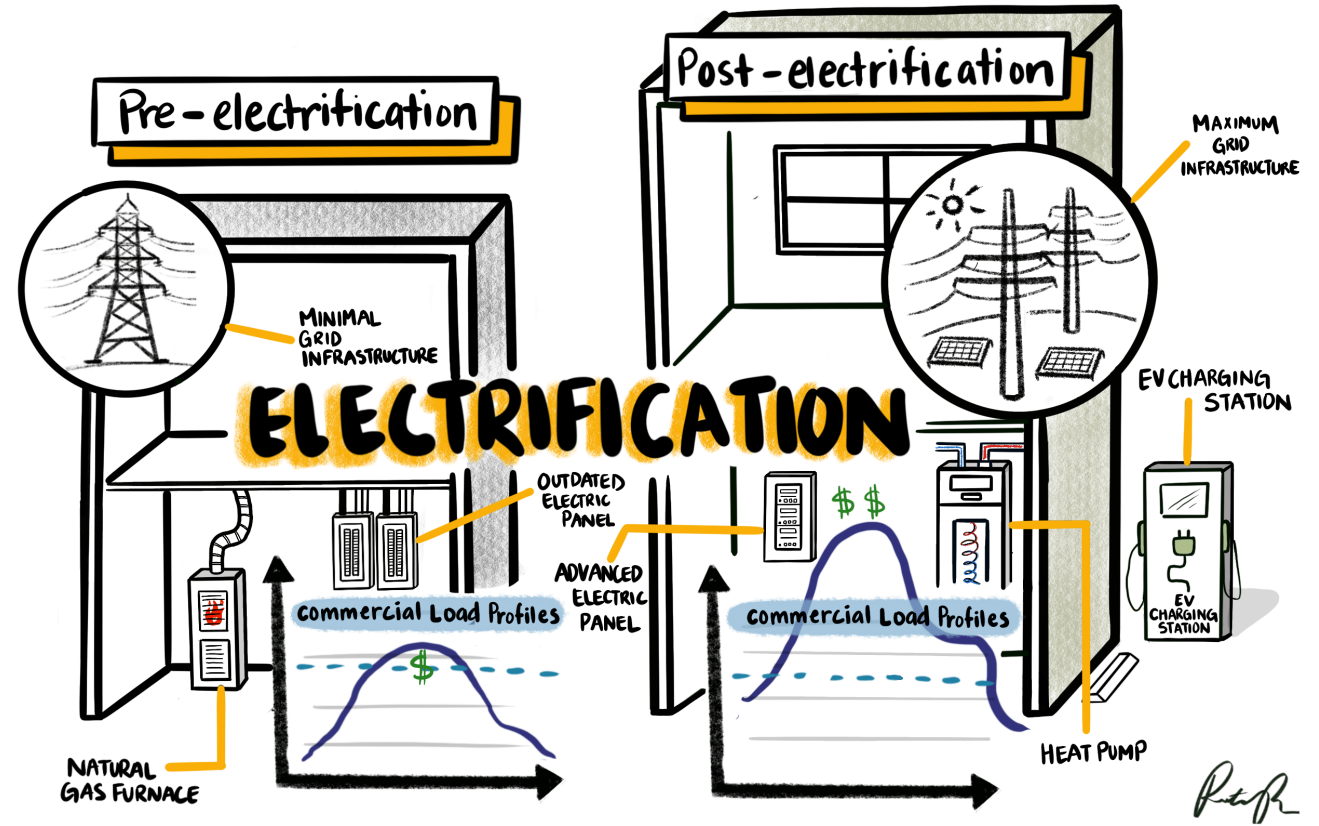
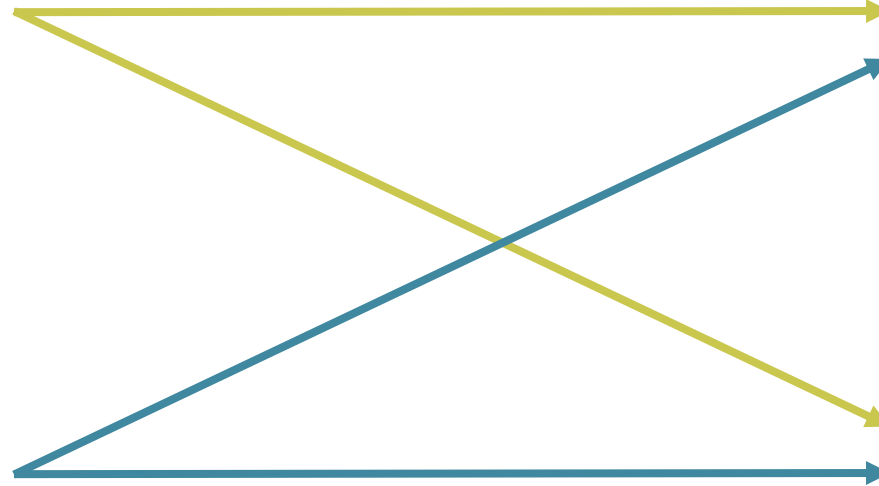


Image Credit: Institute for Market Transformation

Illustration: Rita Perez

Beneficial Electrification

The two sources of operational greenhouse gases from buildings are electricity and burning gas.



Design Path to Operational Decarbonization

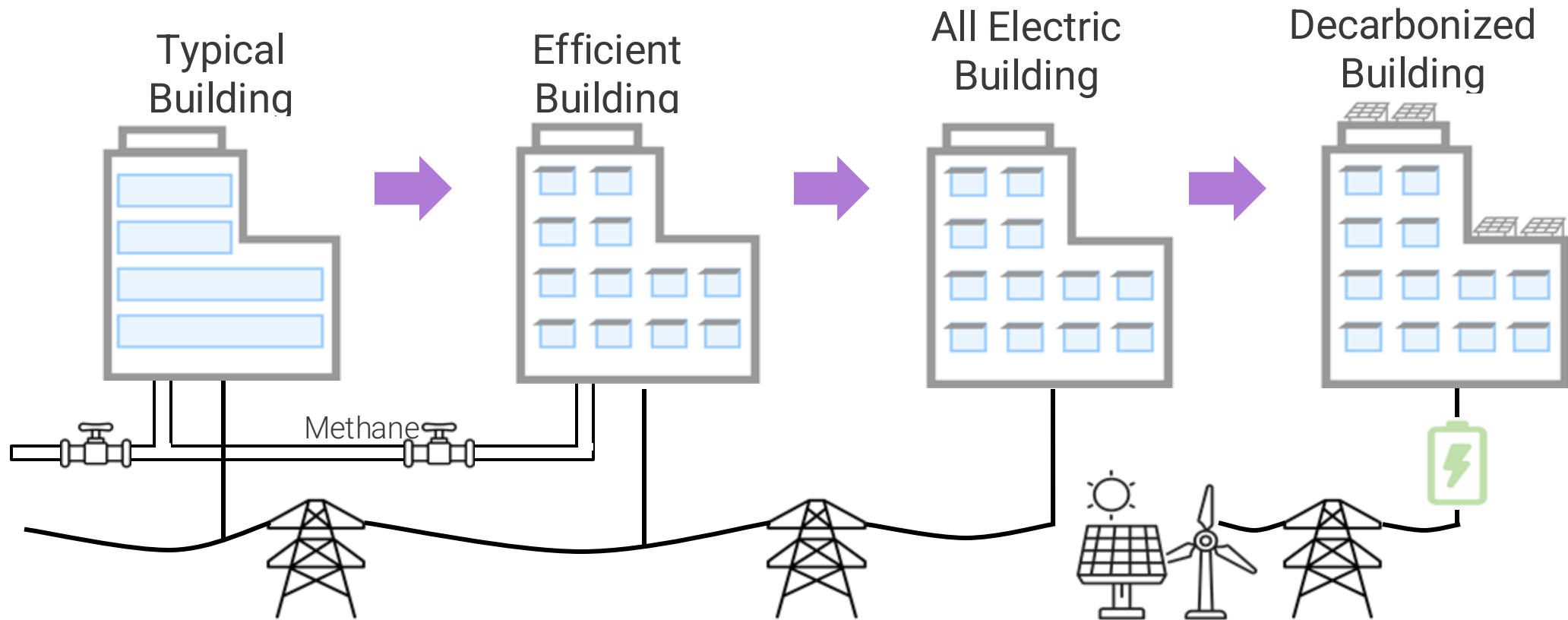


Image Credit: TLC Engineering
Solutions: Wizard Himself

ELECTRIFICATION EXAMPLES

Heating Switchover Electric Resistance to Heat Pumps

At the **Building** – Heating Demand 350 MBH
(100 kW)

- Electric Res(stance → 100 kW
- Heat Pump COP =3*) → 33 kW

At the **Power Plant** (1.5 lb CO₂/hr per kW)

- Electric Resistance → 1500 lb CO₂/hr
- Heat Pump → 500 lb CO₂/hr

**Based on equipment greater than 65,000 BTUH*

ELECTRIFICATION EXAMPLES

Heating Switchover Electric Resistance to Heat Pumps

At the **Building** – Heating Demand 350 MBH (100 kW)

- Electric Resistance → 100 kW
- Heat Pump (COP =8.8*) → 11 kW

At the **Power Plant** (1.5 lb CO₂/hr per kW)

- Electric Resistance → 1500 lb CO₂/hr
- Heat Pump → 166 lb CO₂/hr

**Based on 2023 Energy Code equipment ≤ 65,000 BTUH*

ELECTRIFICATION EXAMPLES

Heating Switchover Natural Gas to Heat Pumps

At the **Building** – Heating
Demand 350 MBH (100 kW)

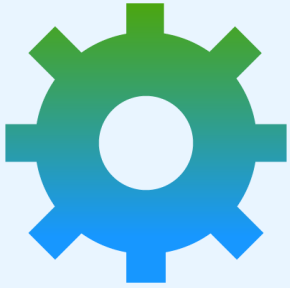
- Natural Gas (80% E_t) → 440 MBH
- Heat Pump (COP =3) → 33 kW

CO2 Emissions (1.13 lb CO2/hr per MBH)

- Natural Gas → 500 lb CO2/hr (combustion* only)
- Heat Pump → 500 lb CO2/hr

**1% leakage results in another 400 lb CO2e/hr, since methane has a GWP about 80 times that of CO2*

Pop quiz #3!



Where is embodied carbon mentioned?

- a) Inflation Reduction Act
- b) Architecture 2030 Challenge
- c) AIA Framework for Design Excellence
- d) Structural Engineering Institute 2050 Committing to Zero
- e) All of the above

Building Performance Standards

Are super!

Building Performance Standards



Since we are concerned with **actual** greenhouse emissions, we should focus on **actual** building performance, not how it is **designed** to perform

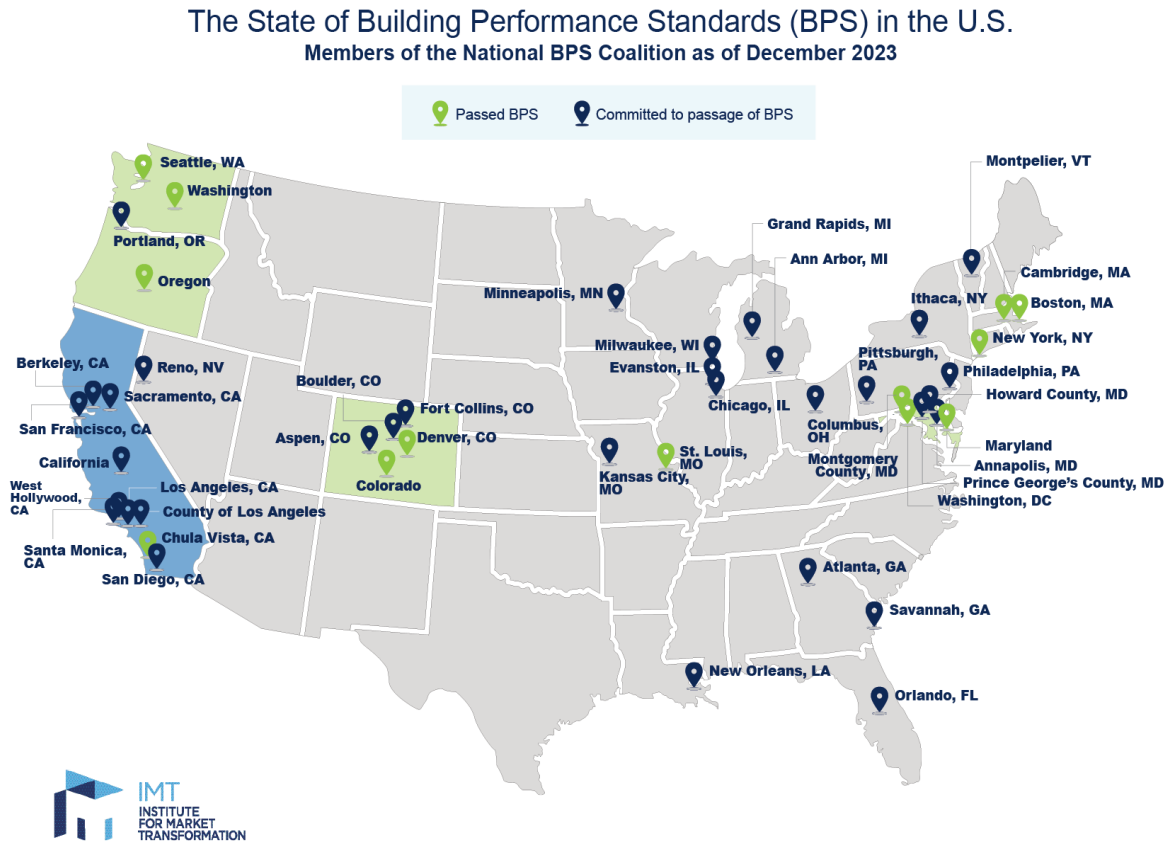


Alternative to energy code review and inspections, which are not often rigorously enforced or applied



As communities and companies establish their own carbon emission reduction goals, performance is being **measured**

Examples of BPS



Map courtesy of Institute for Market Transformation

<https://nationalbpscoalition.org/>

1. Performance disclosure requirements
2. Benchmark existing building emissions by building type
3. Establish goals based on reductions of benchmark emissions
4. Lower allowable emission thresholds over time

Questions & Discussion

