Reducing the Carbon Footprint of Concrete

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Copyright Materials

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Learning Objectives

By the end of this presentation, participants will be able to:

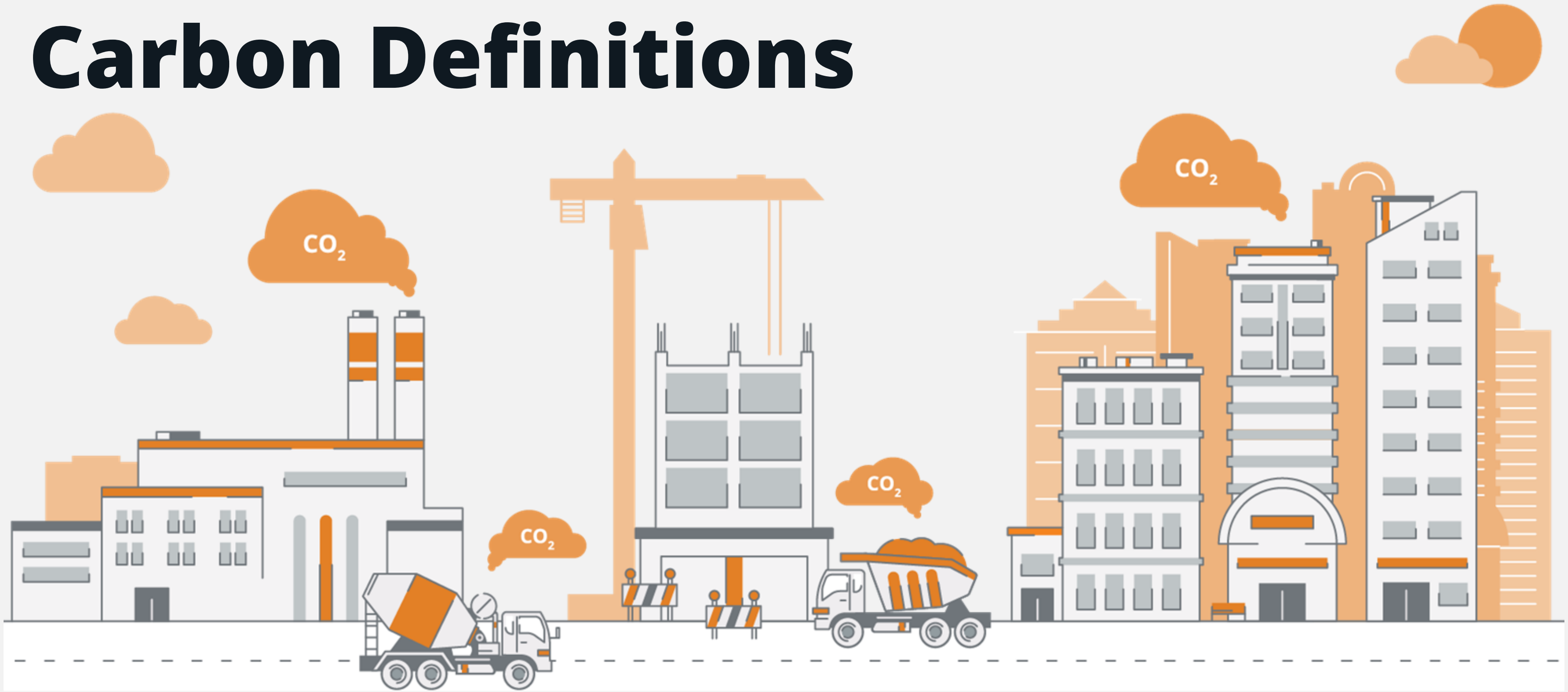
1. Understand the impact of embodied carbon from the built environment and describe the means through which cement manufacturing contributes to embodied carbon.

2. Utilize assessment and reporting resources such as Environmental Product Declarations (EPDs) to evaluate the environmental impact of building materials.

3. Explore the innovative method of CO_2 mineralization as a means to reduce embodied carbon in concrete production, and describe the method's impact on the fresh and hardened properties of concrete

4. Embrace best practices in concrete design to reduce the carbon impact of concrete, and empower concrete producers to adopt lower carbon solutions while ensuring concrete performance requirements are maintained.

Carbon Definitions

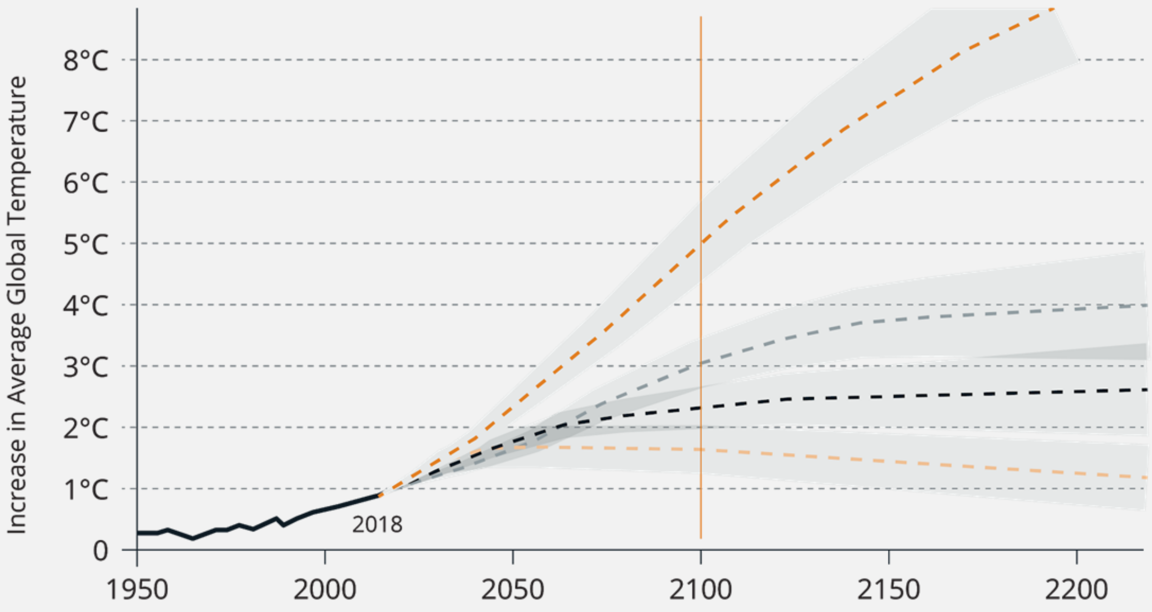


Embodied Carbon
The emissions from manufacturing, transportation, and installation of building materials.

Operational Carbon
The emissions from a building's energy consumption.

Global CO_2 Challenge

Global Temperature Projections for various RCP Scenarios



RCP8.5
Business-as-usual
2.2 trillion tons carbon

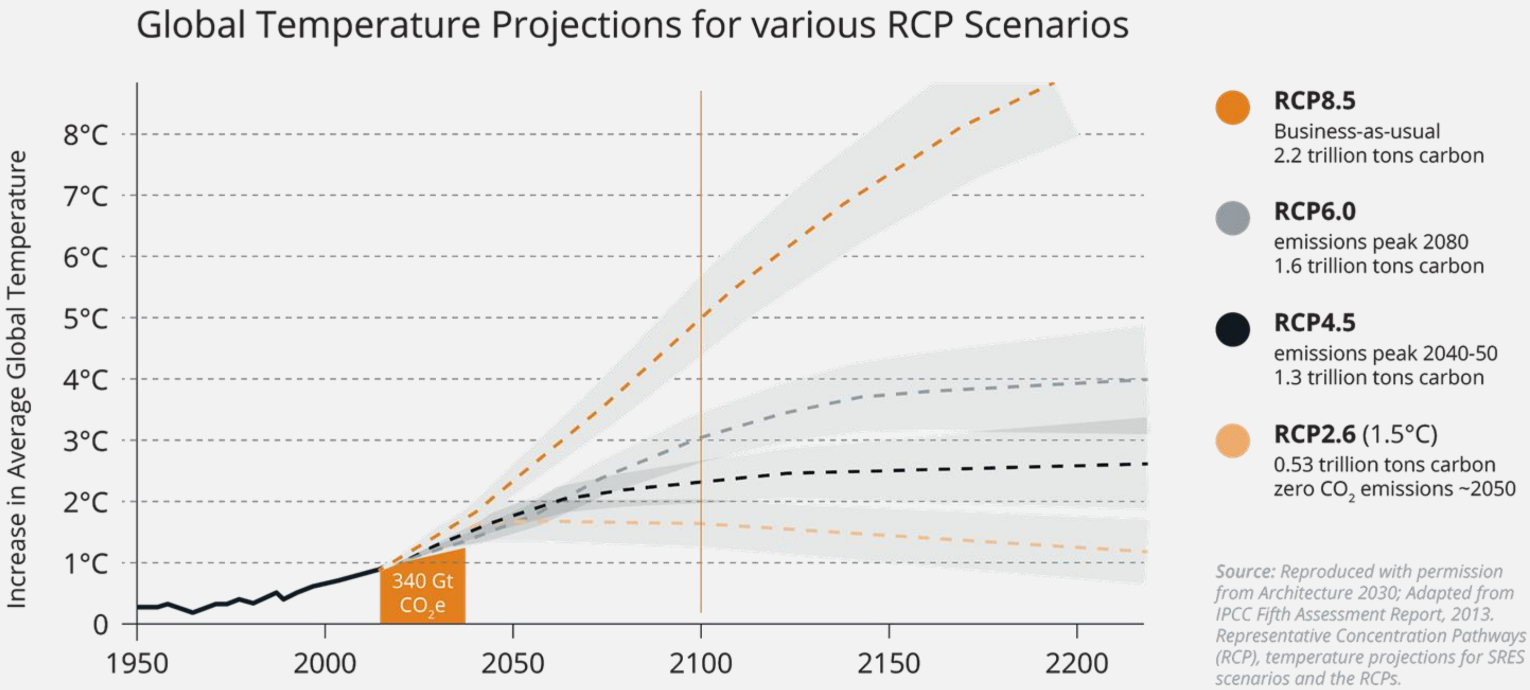
RCP6.0
emissions peak 2080
1.6 trillion tons carbon

RCP4.5
emissions peak 2040-50
1.3 trillion tons carbon

RCP2.6 (1.5°C)
0.53 trillion tons carbon
zero CO_2 emissions ~2050

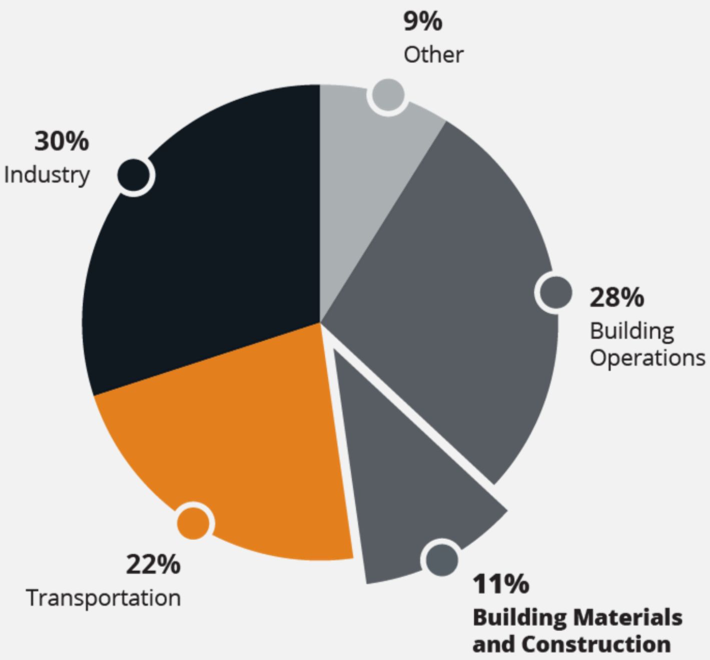
Source: Reproduced with permission from Architecture 2030; Adapted from IPCC Fifth Assessment Report, 2013. Representative Concentration Pathways (RCP), temperature projections for SRES scenarios and the RCPs.

Global CO_2 Challenge



Source: Reproduced with permission from Architecture 2030; Adapted from IPCC Fifth Assessment Report, 2013. Representative Concentration Pathways (RCP), temperature projections for SRES scenarios and the RCPs.

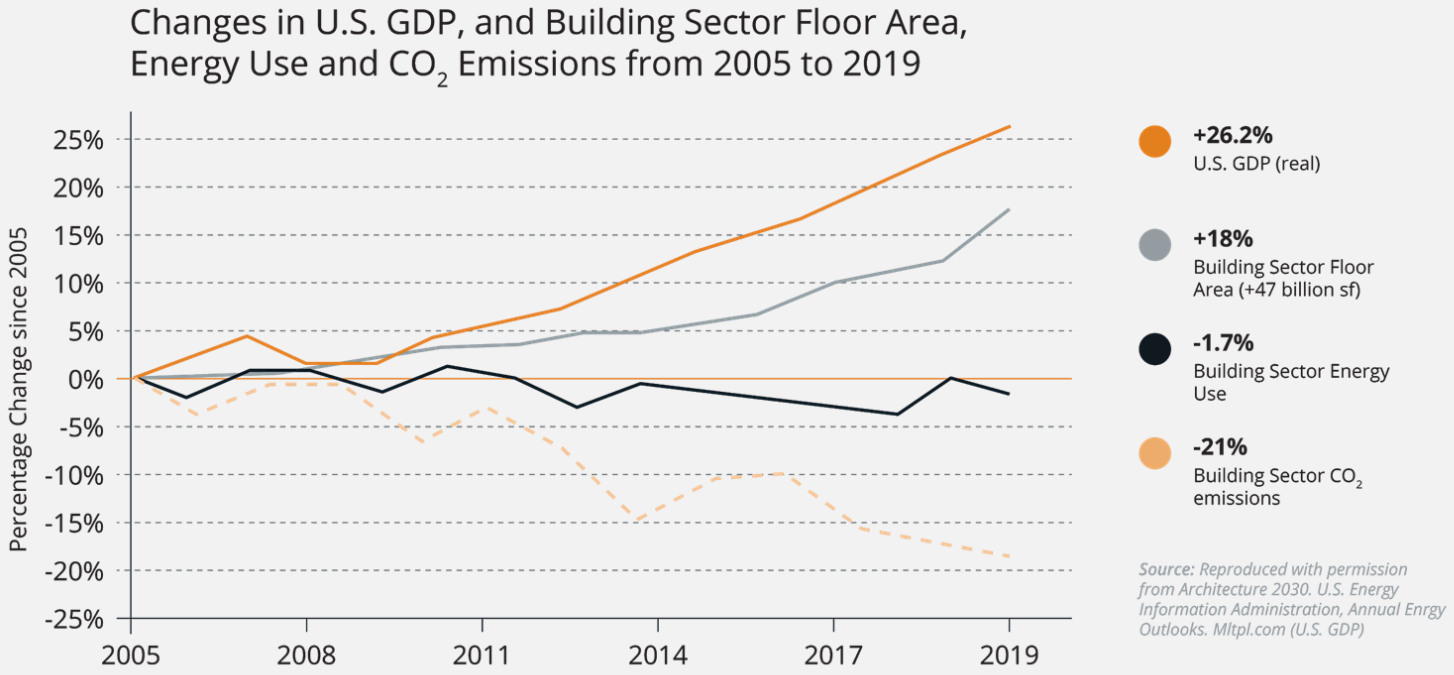
Global CO_2 Emissions by Sector



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

Decoupling of Operational Emissions

Efforts by designers to create more efficient and sustainable buildings are having an impact



But what about the emissions associated with building materials?

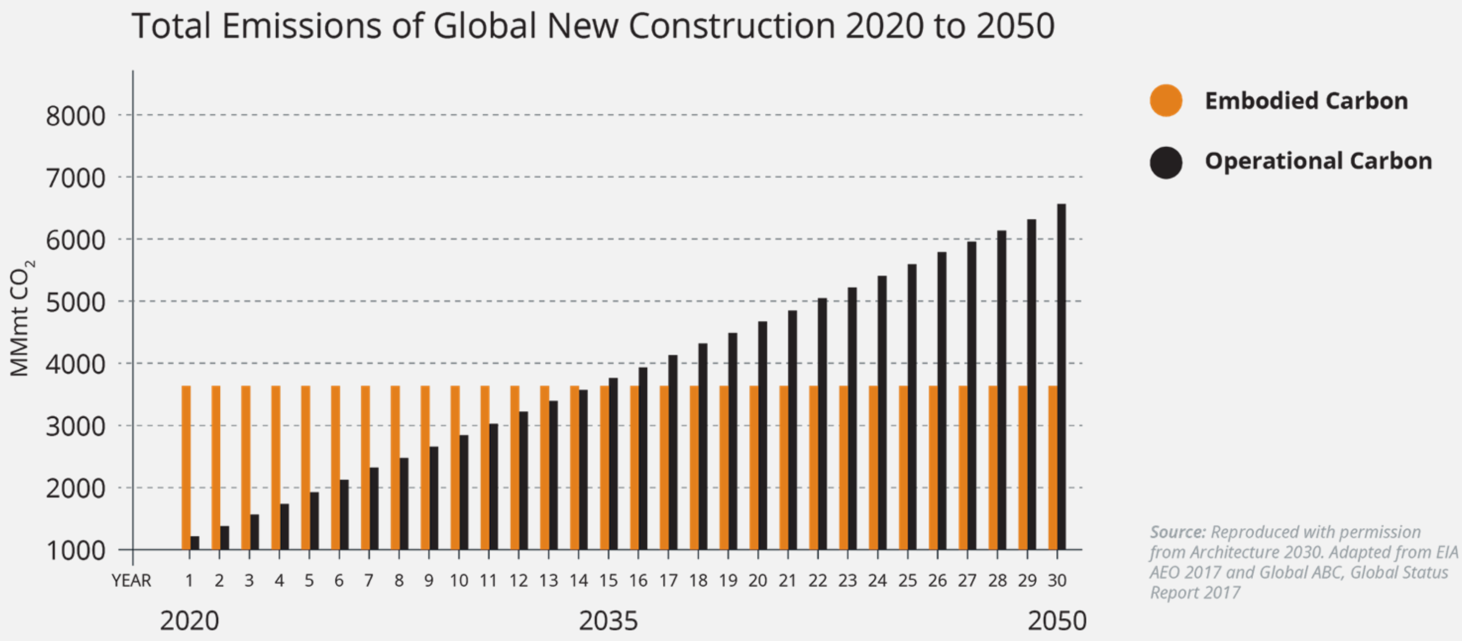
Did you know?

The world’s building stock is expected to double by the year 2060. This means we’re building an entire New York City every month for the next 40 years.

Did you know?

Of that new construction, embodied carbon is expected to account for nearly 50% of the buildings' total carbon emissions.

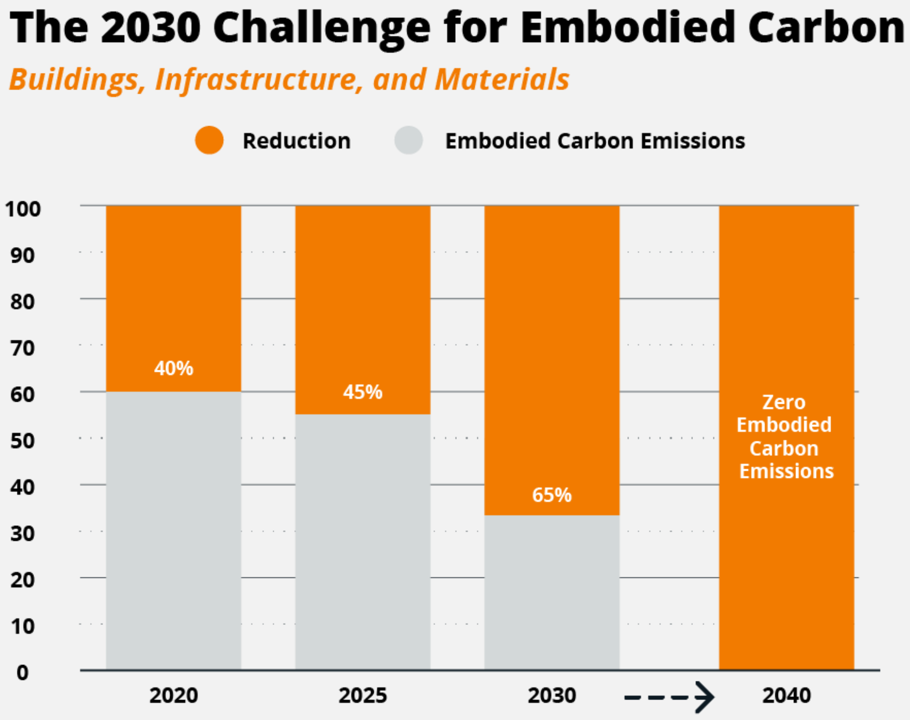
Time Value of CO_2 – New Buildings



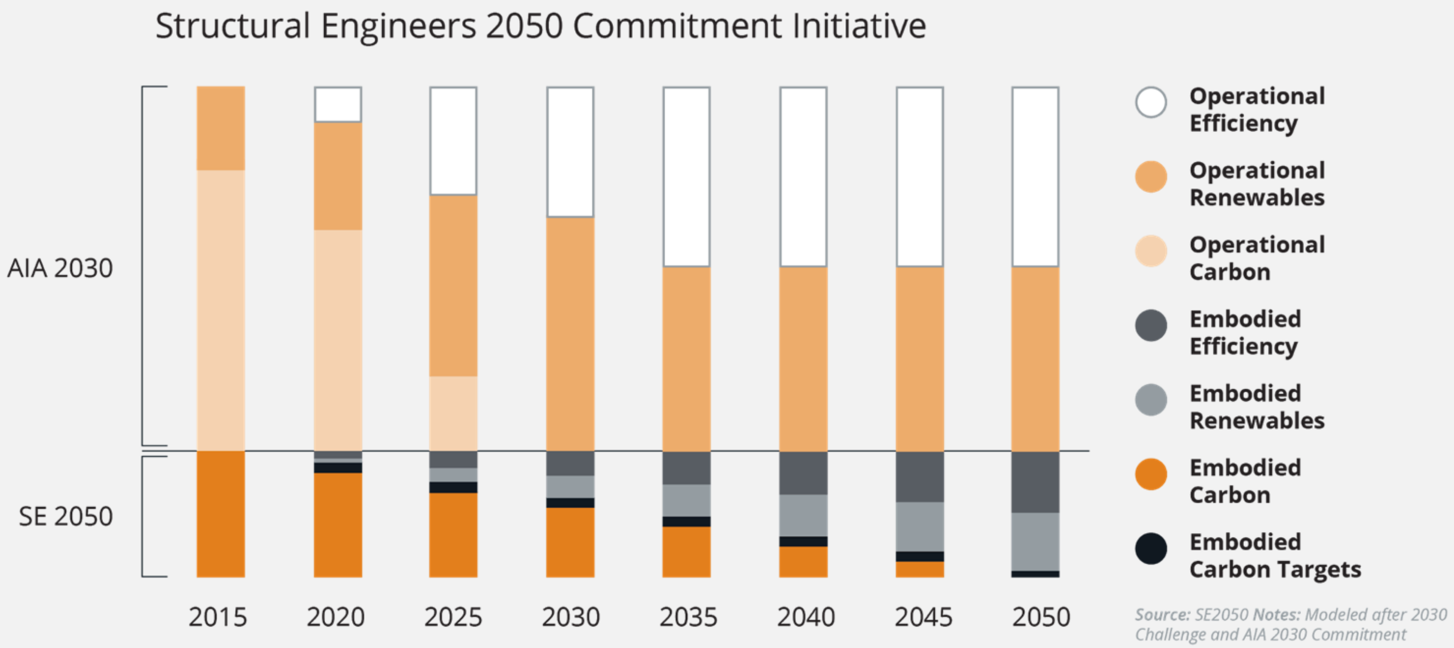
Source: Reproduced with permission from Architecture 2030. Adapted from EIA AEO 2017 and Global ABC, Global Status Report 2017

Architecture 2030

"If we do not achieve a **65% reduction** in total global emissions **by 2030,** we will have lost the opportunity to meet the 1.5-2 ℃ warming threshold and **climate change will become irreversible.** The immediate focus for embodied carbon reductions must therefore be on the **next decade**."



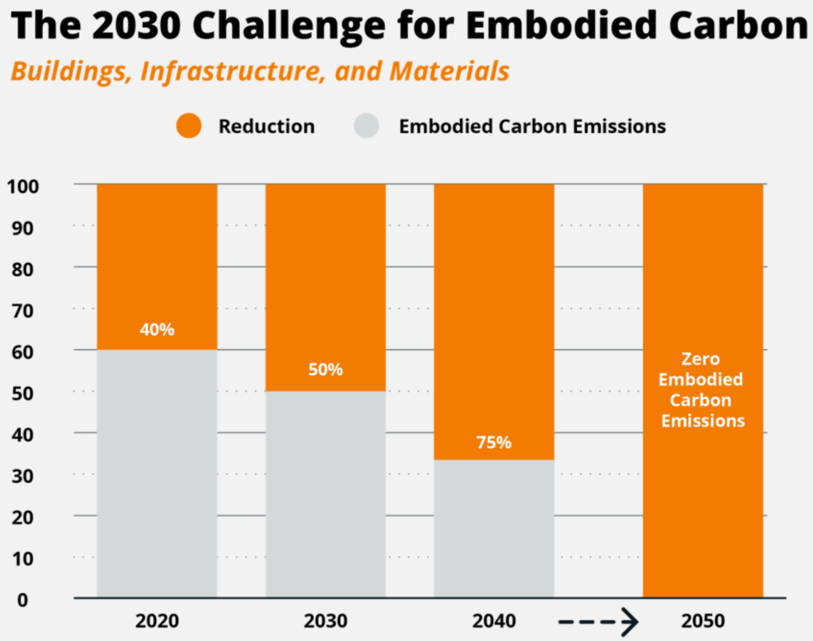
Structural Engineers 2050



Source: SE2050

The Embodied Carbon Challenge

A multi-disciplinary challenge to achieve net-zero embodied carbon by 2050



Mission alignment with:

Carbon Leadership Forum

WORLD GREEN BUILDING COUNCIL

C40 CITIES

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New Emphasis on Embodied Carbon

Green buildings certification systems now address embodied carbon

LEED BD+C:
New Construction | v4.1 - LEED v4.1

Building Life-Cycle Impact Reduction

Possible 5 points

2 points
Demonstrated impact reduction of at least **5%** in Global Warming Potential and 2 other impact categories.

3 points
Demonstrated impact reduction of at least **10%** in Global Warming Potential and 2 other impact categories.

4 points
Demonstrated impact reduction of **20%** in Global Warming Potential, at least **10%** in 2 other impact categories, and building reuse and/ or use of salvaged materials

Materials & Resources

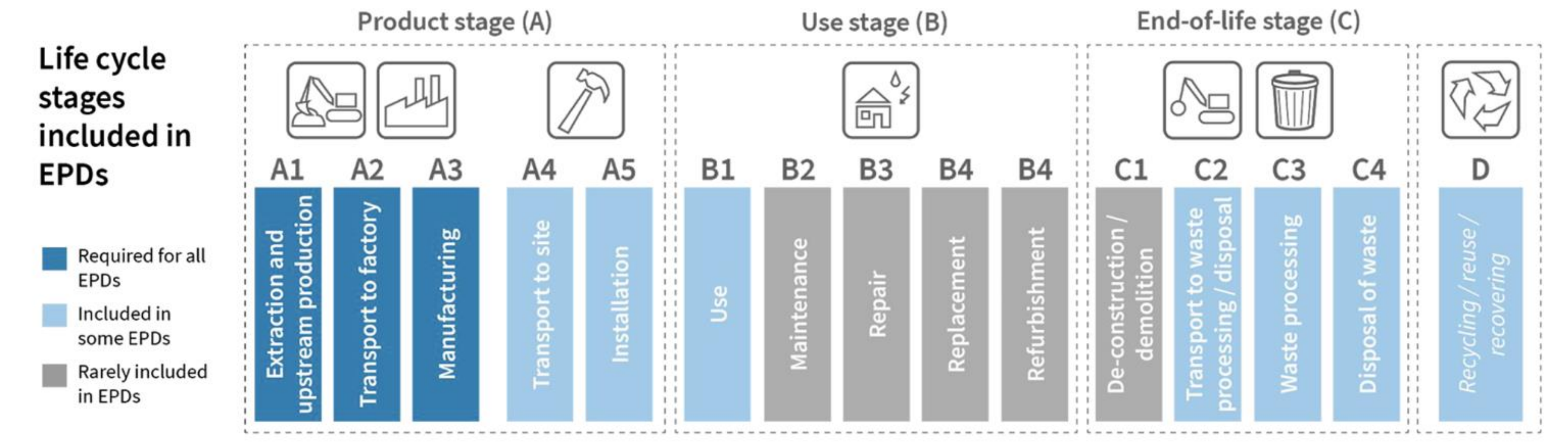
Focuses on minimizing embodied environmental impacts to support a life-cycle approach that improves performance.

Option 4:
Whole Building Life Cycle Assessment (1-4 points)

Conduct a life cycle assessment and show a 10% impact reduction in embodied CO_2 emissions + 2 other impact categories shown on an Environmental Product Declaration

Life Cycle Assessment (LCA)

Independently verified in accordance with ISO 14040 and ISO 14044



Source: Carbon Leadership Forum

Environmental Product Declarations

Independently-verified documents based on international standards that report the environmental impacts of a product.

Environmental Facts Functional unit = 1 yd^3 of concrete	**Impact**
Primary Energy Demand (BTU)	9.3×10^5
Global Warming Potential (lb CO_2 eq)	360
Acidification Potential (lb H+ eq)	40
Eutrophication Potential (lb N eq)	0.4
Ozone Depletion Potential (lb CFC-11 eq)	1.98×10^{-5}
Smog Potential (lb O_3 eq)	21

Environmental Product Declaration (EPD)

Think of EPD's as **a nutrition label for your concrete**. This tool gives transparency into the overall carbon impact.

Things to consider:

1. Industry and governments are driving change
2. Be proactive in your adoption
3. EPDs report of 6 core mandatory impact indicators
4. Implement solutions that reduce Global Warming Potential (GWP) to gain a competitive advantage

EPD Providers: Athena, Climate Earth, NRMCA

Average Cost: $5k-$15k

New Tools for Increased Transparency

Embodied Carbon in Construction Calculator (EC3) Tool

Material Quantity
Estimate

✖

Embodied Carbon
Per Material
EPDs

=

Embodied Carbon(EC)
Building Estimate

Source: Skanska USA; Carbon Leadership Forum

Concrete is the most abundant man-made material in the world.

As a result, cement production creates **~7%** of the world's CO_2 emissions and is one of the **largest contributors** to embodied carbon in the built environment.

Source: Architecture 2030

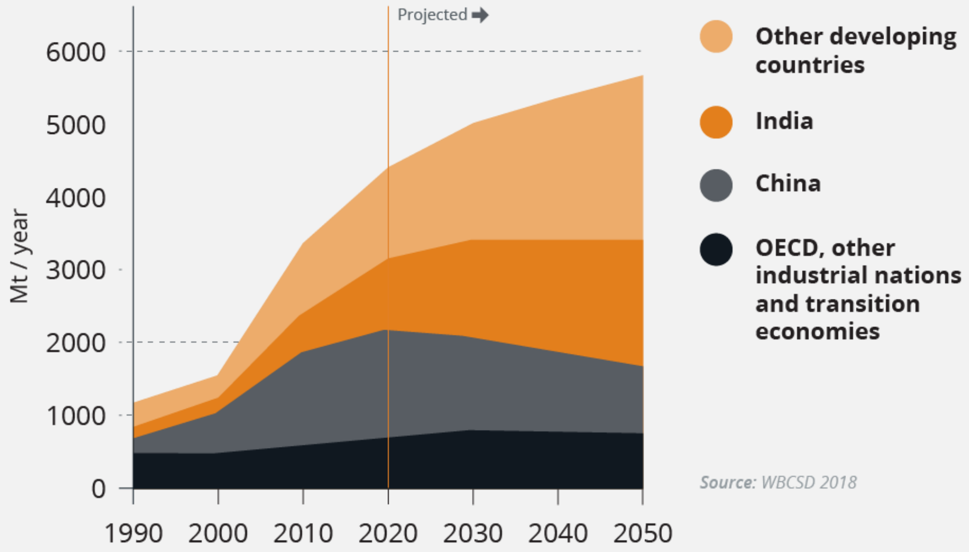
Cement makes up only 12% of the weight of concrete, but is responsible for 95% of the CO_2 footprint.

Cement Demand Projection

Cement demand expected to grow 12 to 23% by 2050.

-IEA, Cement Sustainability Initiative

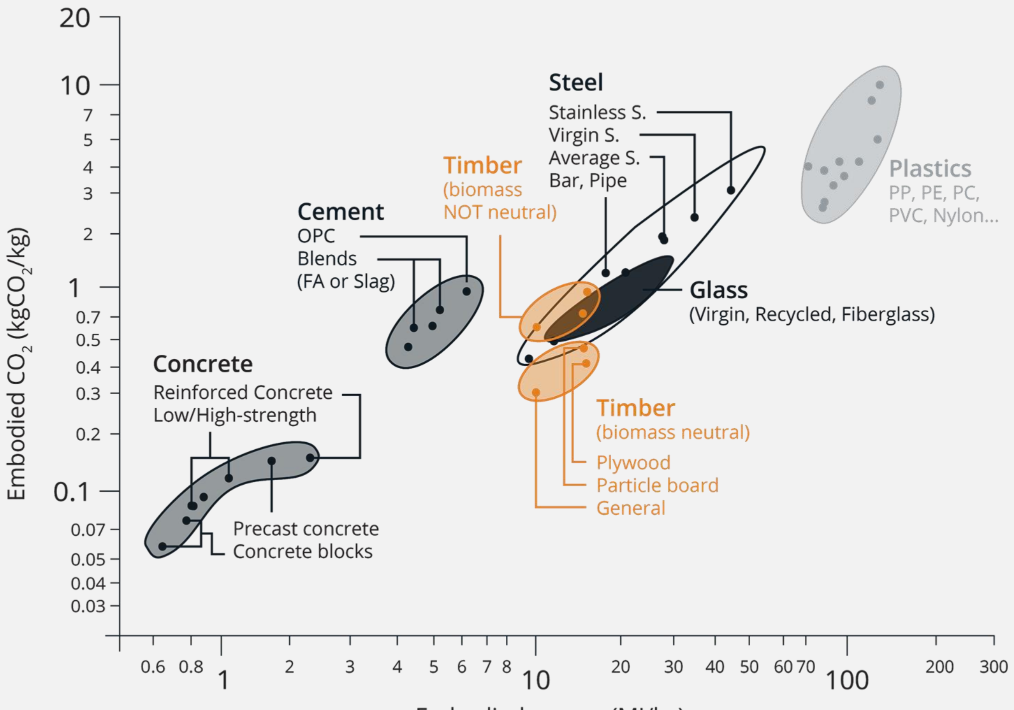
World Portland Cement Production 1990-2050



Estimated Lifecycle Impacts of Materials

Concrete is a low impact material.

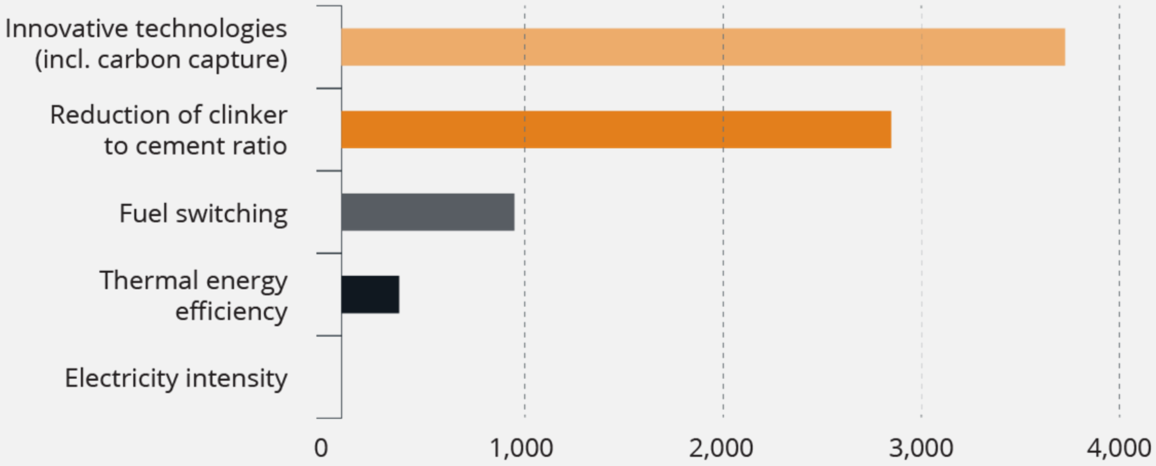
Concrete on its own has **low CO_2 emissions and embodied energy** for every kilogram produced (though cement is higher).



Source: Adapted from Barcelo et al, 2014

IEA Technology Roadmap

Pathway for reducing emissions in the cement and concrete sector



Source: *IEA 2018*
Notes: *Cumulative CO_2 emissions reductions refer to the period from 2020 to 2050 and are based on the low-variability case of the scenarios*

- 48% of emissions reductions must come from carbon capture and utilization strategies
- 37% of reductions must come from reduced clinker to cement ratios

What is CarbonCure?

CO_2 Utilization in Concrete

CarbonCure's technology beneficially repurposes carbon dioxide **to reduce the carbon footprint of concrete without compromising concrete performance**.

CarbonCure Concrete Impact

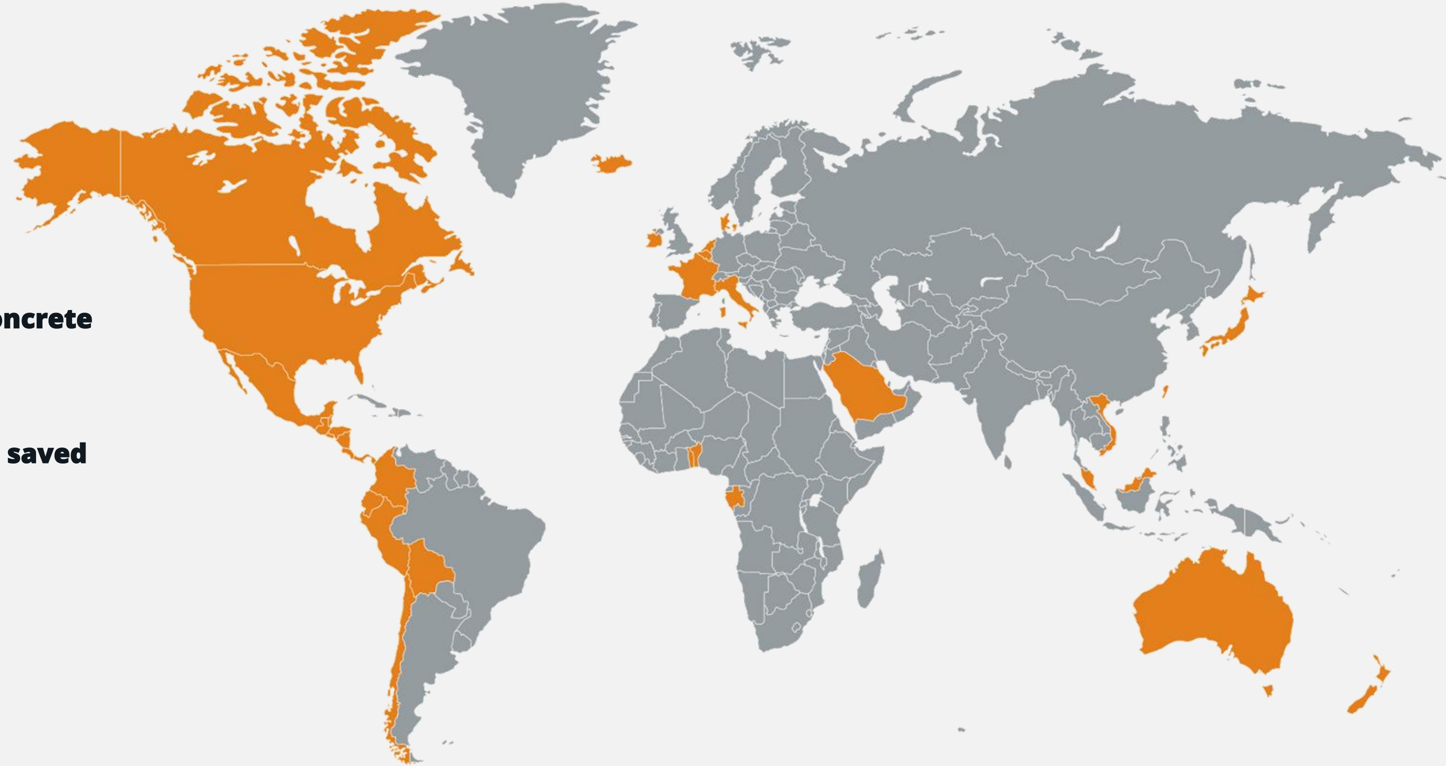
As of October 2021

Available in
450+ concrete plants, 6 continents

Used in
10,800,000+ m^3 / 14,100,000+ yd^3 of concrete

Resulting in
126,000+ tonnes CO_2 saved

Compliant with
ASTM C494 Type S



Award-Winning Innovation

XPRIZE CARBON

nrg | cosia

WINNER

NRG COSIA Carbon XPRIZE 2015-2021

North American Company of the Year

CARBON CURE

2020 GLOBAL CLEANTECH 100

BloombergNEF

New Energy Pioneers

2019

CYCLE CAPITAL MANAGEMENT

GRAND CHALLENGE

Innovative Carbon Uses

MISSION INNOVATION

accelerating the clean energy revolution

Strategic Partners

amazon

THE CLIMATE PLEDGE

Paris... 10 years Early

Breakthrough Energy VENTURES

stripe Climate

CO_2 Supply

CO_2 is captured and distributed to concrete plants by industrial gas suppliers.

Collection

CO_2 is collected from large emitters

Purification

The gas is purified by industrial suppliers

Delivery

The CO_2 is delivered to concrete plants by industrial gas suppliers

Storage

The CO_2 is stored at concrete plants in pressurized tanks

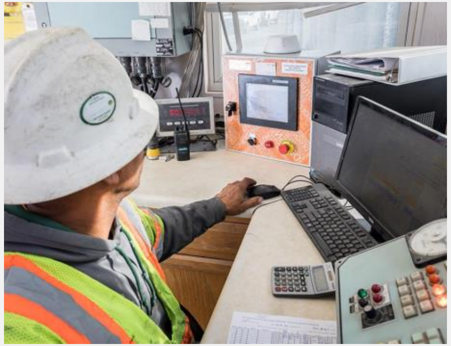
How it Works: Technology

Seamless retrofit technology that operates with no disruption to normal batching procedures

Installation

- CarbonCure equipment installed into existing concrete plans

Integration



- CarbonCure software integrates seamlessly with the batching software

Injection

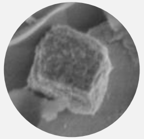
- The equipment injects a precise automated dosage of CO_2 into concrete as it mixes

What Happens When CO_2 is Injected?

Cement + H_2O → Ca^{2+} (Calcium)

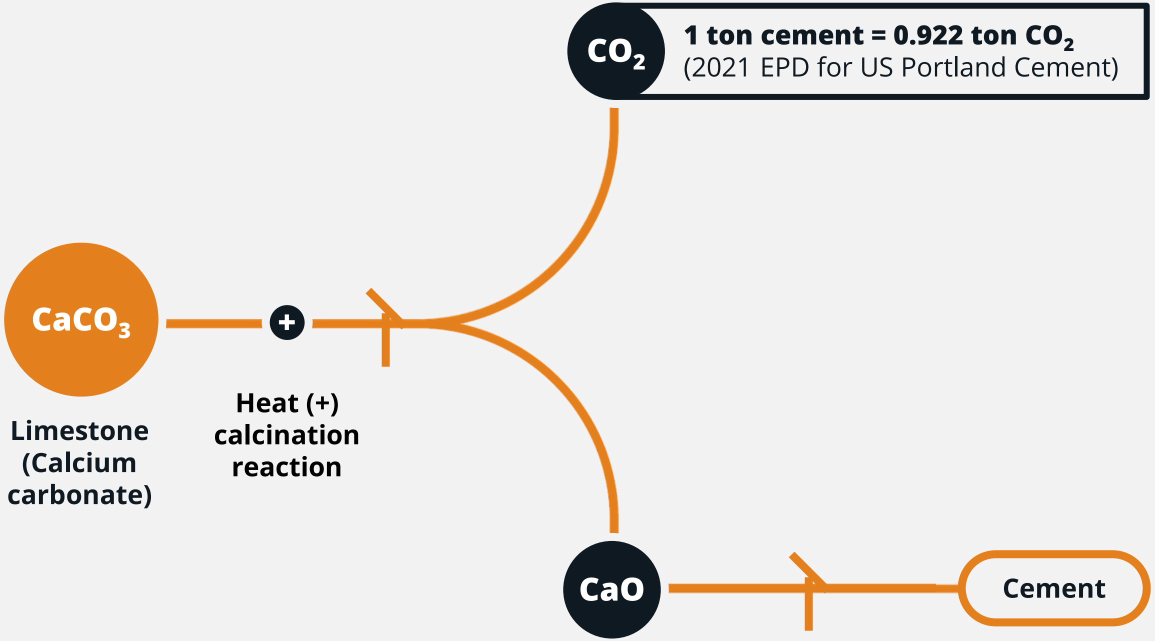
CO_2 + H_2O → CO_3^{2-} (Carbonate)

Ca^{2+} Calcium + CO_3^{2-} Carbonate = $CaCO_3$ Calcium Carbonate

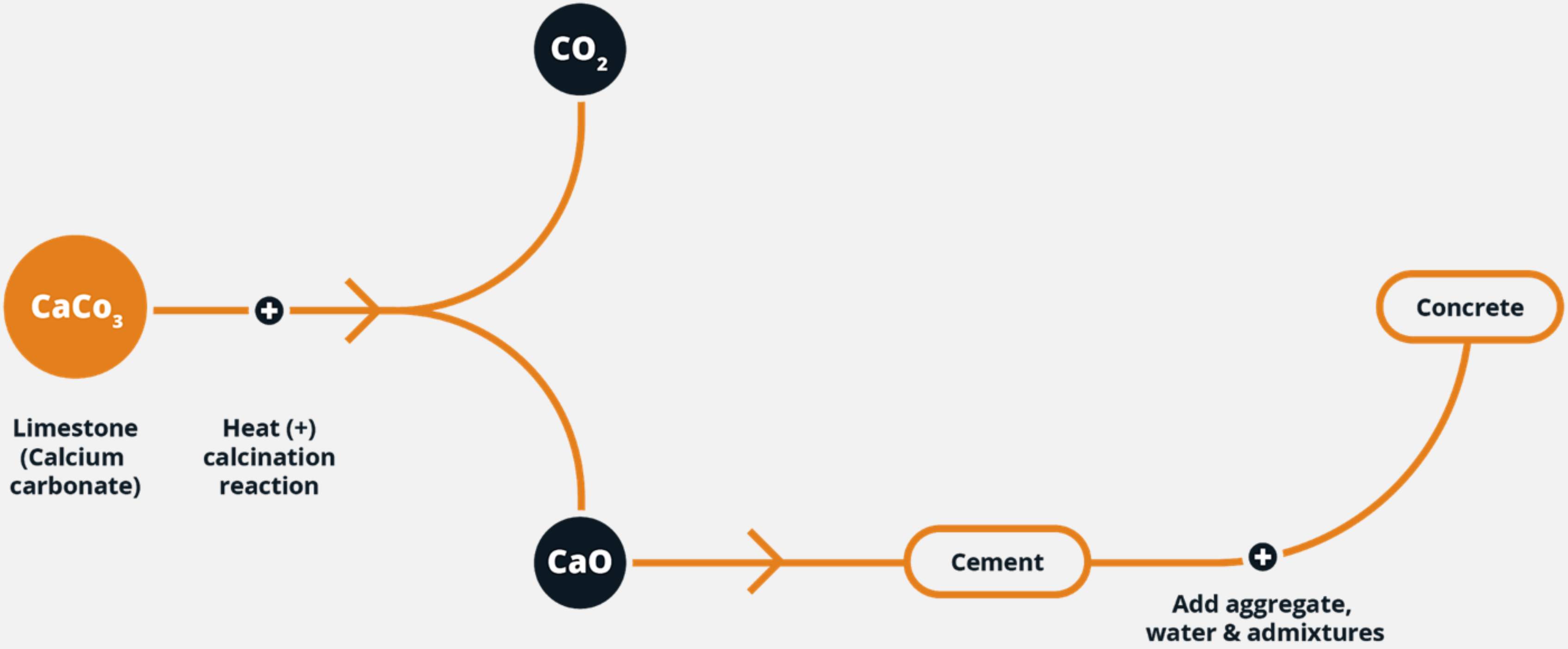


- CO_2 mineralization occurs
- CO_2 converts into **$CaCO_3$ (solid limestone)**

Cement Manufacturing Process



Converting CO_2 to a Mineral



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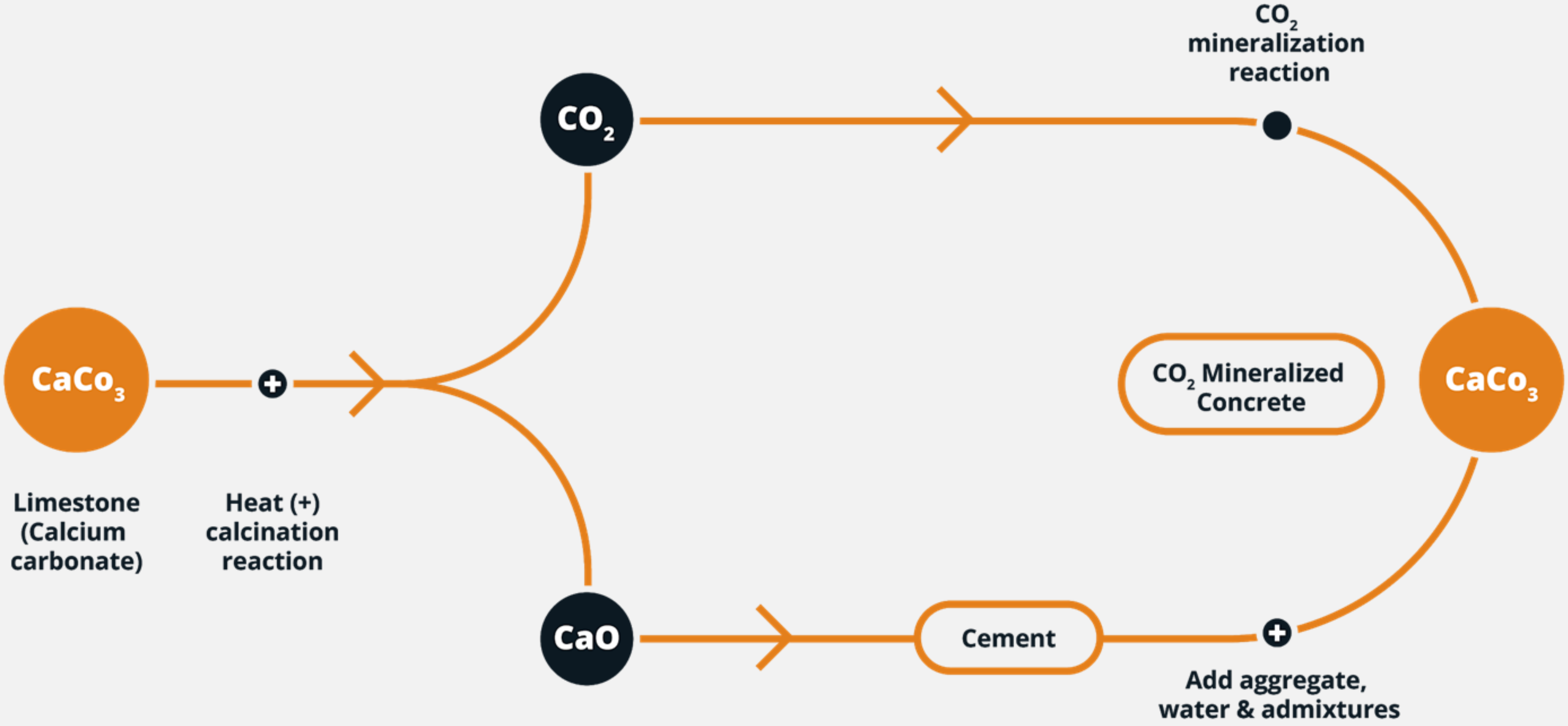

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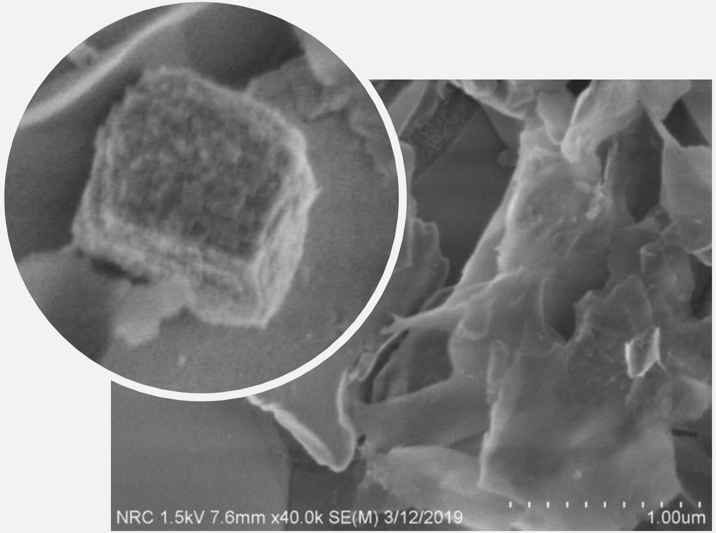
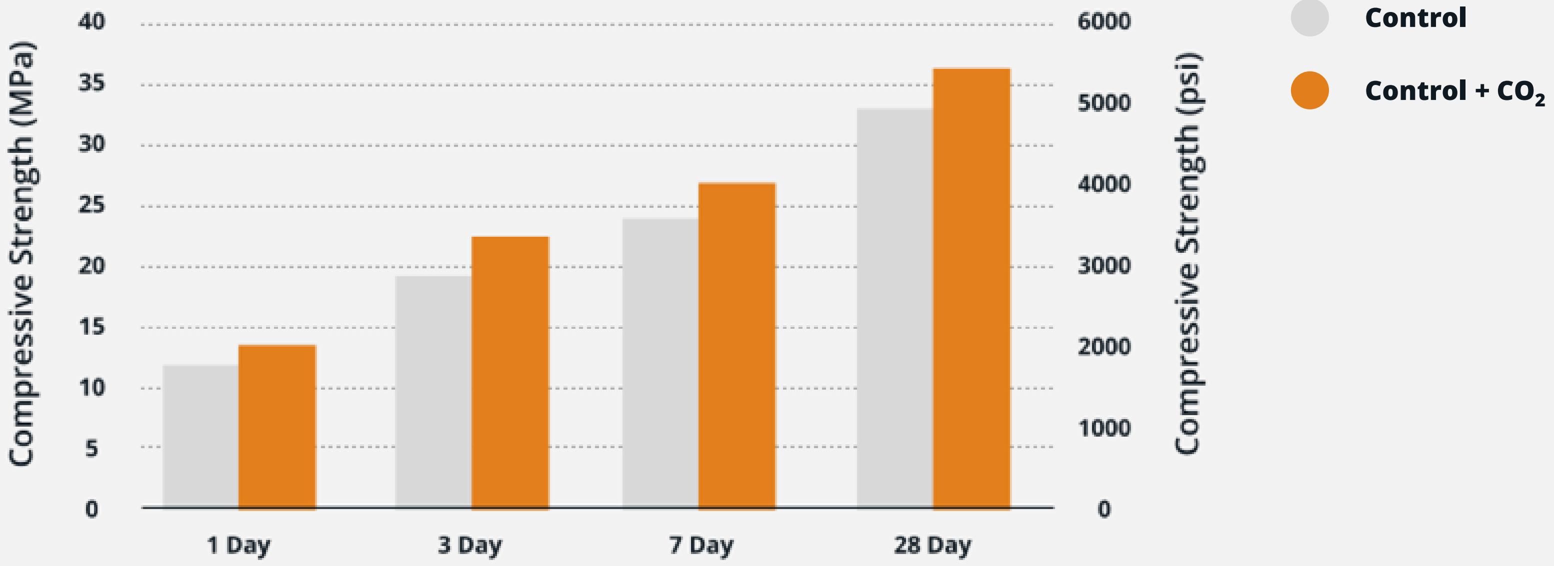


Carbonate product formed
about 400 nm dimension

Nano-calcium carbonate particles act as nucleation sites for hydration. Compressive strength benefits can arise from this interaction.

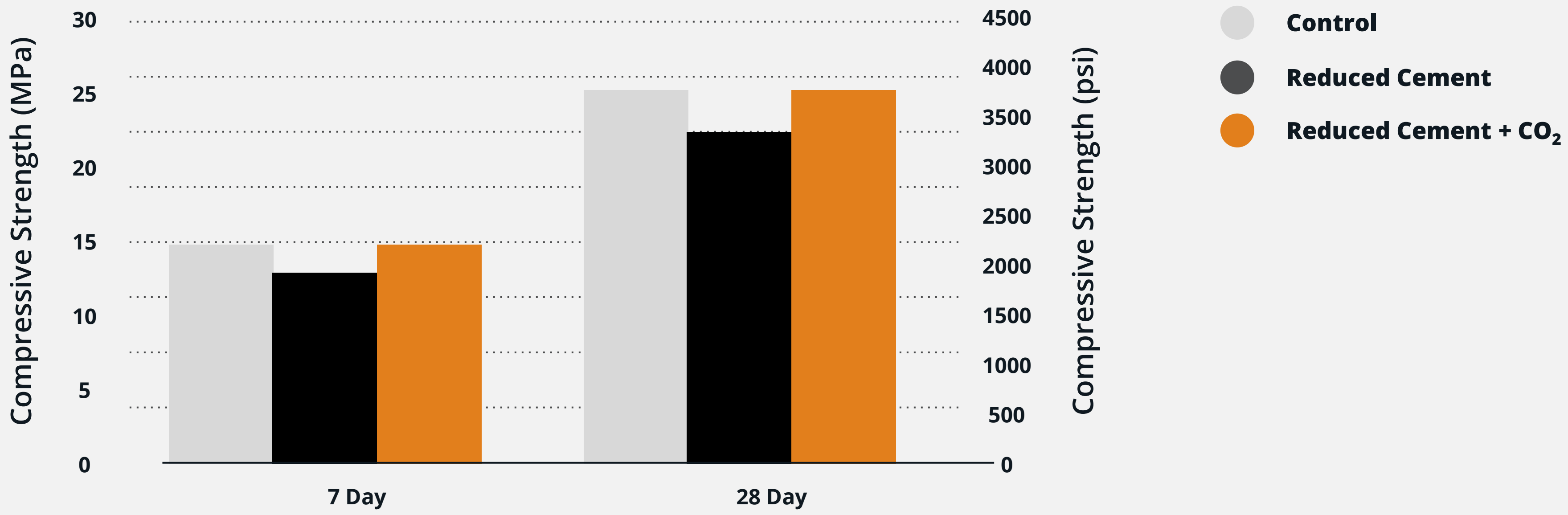
Compressive Strength Gain



Conclusion: *The formation of a calcium carbonate nanomaterial* ***improves the compressive strength*** *of ready mix concrete.*

Source: "Calculating Sustainability Impacts of CarbonCure Ready Mix"

Mix Adjustment Opportunities



Conclusion: *CarbonCure enables concrete producers to* ***reduce cement content*** *without sacrificing strength.*
Source*: "Ready Mix Technology Trial Results".*

CO_2 has a Neutral Impact on...

Fresh Properties

- Setting time
- Workability/slump
- Concrete pumping
- Air content
- Temperature
- Finishing

Hardened Properties

- Freeze-thaw
- pH
- Density
- Durability
- Color
- Texture

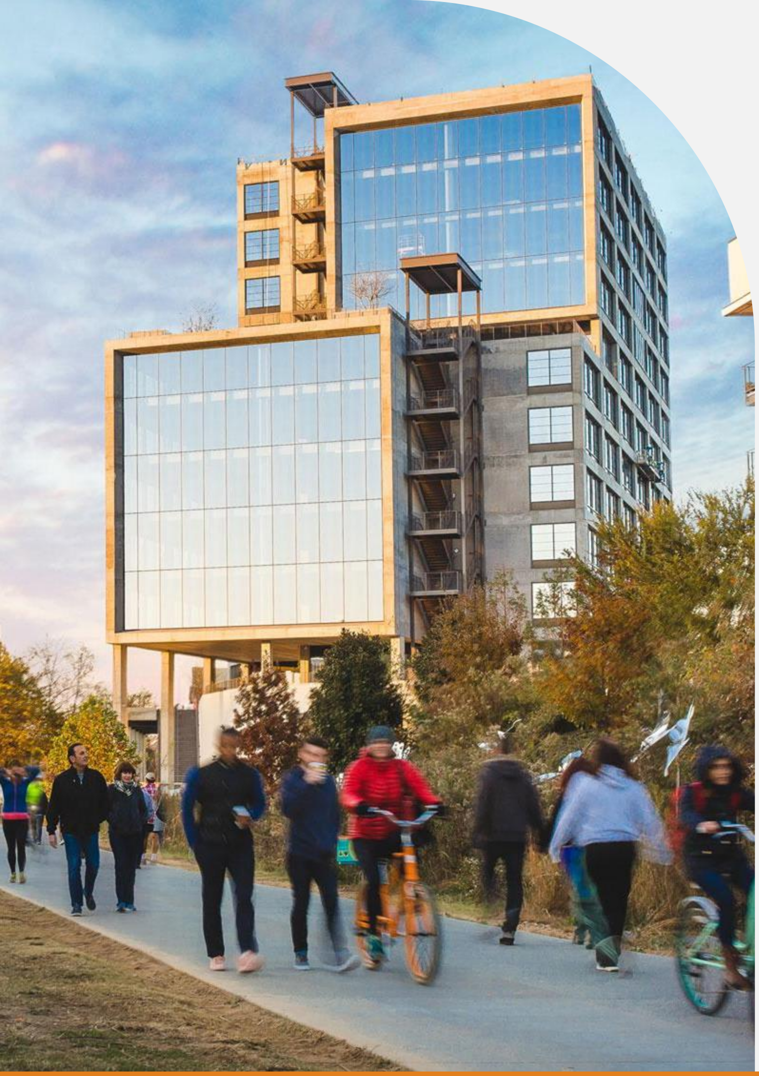
Note: Peer reviewed papers are available to support the above information at carboncure.com.

CarbonCure for Ready Mix

How Much CO_2 Can Be Saved?

15-30 lbs CO_2 saved per yd^3

- CO_2 saved = CO_2 mineralized + CO_2 avoided by reducing cement
- Avg. 5% reduction in GWP (stackable carbon benefit with SCMs)



Reference Project:

725 Ponce

360,000 sq ft commercial office in Atlanta, GA

"Uzun+Case, with input from Thomas Concrete, specified the CarbonCure Technology to reduce the carbon footprint of 725 Ponce. We're proud to have saved 1.5 million pounds of CO_2 while maintaining our high-quality standards for concrete."

Rob Weilacher
Engineer of Record, Uzun+Case

Supplier:
Thomas Concrete

Concrete Usage:
48,000 yd^3 of concrete made with CarbonCure

CO_2 Savings:
1.5 million lbs

CO_2 Savings Equivalent:
888 acres of forest absorbing CO_2 for a year

Reference Project:

Kapolei Interchange - Honolulu, HI

Concrete paving, Department of Transportation highway

"I am pleased to see HDOT moving ahead with CarbonCure, local concrete companies, and Hawaii Gas to reduce the levels of carbon dioxide emitted during the construction process."

David Ige
Governor of The State of Hawai'i

Supplier:
Island Ready Mix

Owner:
Hawaii Department of Transportation

Project Size:
19,000 square feet

CO_2 Savings Equivalent:
30,000 lbs

Reference Project:

LinkedIn – Mountain View, CA

Campus headquarters building

"LinkedIn is proud to support environmental consciousness in the built environment. The design of our new headquarters campus incorporates sustainable concrete solutions, including CarbonCure Technologies through our local concrete experts, Central Concrete."

Jennifer Mitchell
Senior Project Manager, GWS Design + Build Team at LinkedIn

Concrete Supplier:
Central Concrete Supply Co., a business unit of U.S. Concrete

Architect:
STUDIOS Architecture

Building Description:
245,000 ft^2 office building and parking garage

Reference Project:

Amazon HQ2 - Arlington, VA

"We are excited to invest in CarbonCure, a company producing stronger, more sustainable concrete, which will help Amazon and other companies meet The Climate Pledge, a commitment to be net-zero carbon by 2040. We are looking forward to lowering the carbon footprint of many of our buildings by using CarbonCure concrete, including in Amazon's HQ2 building in Virginia."

Kara Hurst
Vice President of Sustainability at Amazon

Concrete Supplier:
Miller & Long

Estimated CO_2 savings:
1,144 tonnes (1,261 tons)

Structural Engineer:
Thornton Tomassetti

Estimated Completion:
2022

Reference Projects

Austin, TX – UT Seay Expansion
Concrete Producer: Lauren Concrete
CO_2 Saved: 21.5 tonnes

Mountain View, CA – LinkedIn Campus
Concrete Producer: Central Concrete
CO_2 Saved: 240,000 lbs

Indianapolis, IN – Infosys Innovation Hub
Concrete Producer: Irving Materials
CO_2 Saved: 109 tonnes

Calgary, AB – East Deicing Apron
Owner: YYC Calgary International Airport
CO_2 Saved: 160 tonnes

Chicago, IL - McDonald's Flagship
Concrete Producer: Ozinga
CO_2 Saved: 13.6 tonnes

Kapolei, HI – Kapolei Interchange.
Concrete Producer: Island Ready-Mix
CO_2 Saved: 1,500 lbs

Atlanta, GA – Georgia Aquarium
Concrete Producer: Thomas Concrete
CO_2 Saved: 150 tonnes

Arlington, VA – Amazon HQ2
Concrete Producers: Miller & Long, Vulcan Materials
CO_2 Savings Estimate: 1,043 tonnes

What's next for us? Reclaimed WashWater Technology

- ***Stabilize*** returned cementitious solids in RW slurry tank using CO_2
- ***Recycle*** stabilized solids back into concrete production (replacing virgin cementitious)
- ***Reduce*** offsite waste streams, helping producers achieve ***net zero discharge*** operation

How can you help reduce concrete's carbon impact?

- **Communicate** your commitment to embodied carbon reduction throughout the supply chain *early* and *often*
- Design strengths for what you **need**
- Use **supplementary cementitious materials** and/or **low-carbon cement**
- **Remove** unnecessary prescriptive concrete specs
- Consider **performance**-based concrete specs
- Specify and/or approve **CO_2 mineralized concrete**

Barriers to Innovation: Specs

Prescriptive specs may result in unnecessary limitations to sustainability improvements

Prescriptive Spec		Performance Spec
Minimum cement/cementitious requirement	Consider →	Specify strength (eliminate minimum cement requirement)
Maximum supplementary cementitious content		Specify strength (eliminate maximum SCM requirement)
Maximum water/cement ratio		Use only when appropriate for exposure class and performance requirement

Specify Concrete Sustainably

- **Strategies for Low-Carbon Concrete:**
  - Performance-Based Specifications, not Prescriptive-Based Specifications
  - Require cement replacement %
  - Strength at 28, 56, and 84 Days
  - Set maximum (not minimum) cement content

- **Specify SCMs & Admixtures:**
  - Fly Ash
  - Slag
  - Superplasticizers
  - CO_2 Mineralization

Easiest option?
Ask your concrete producers what they can do!

Questions?

CARBON CURE™

Build for the Future.
Build with CarbonCure.

A building or infrastructure project may save as much CO_2 as 100s if not 1000s of acres of trees absorb over a year.

Who knew that building with concrete could be like planting trees?

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CARBON CURE™

Simply better concrete.