Shrinking Carbon Emissions Through Innovative Cement and Concrete Technologies

CARBON CURE™

Simply better concrete.

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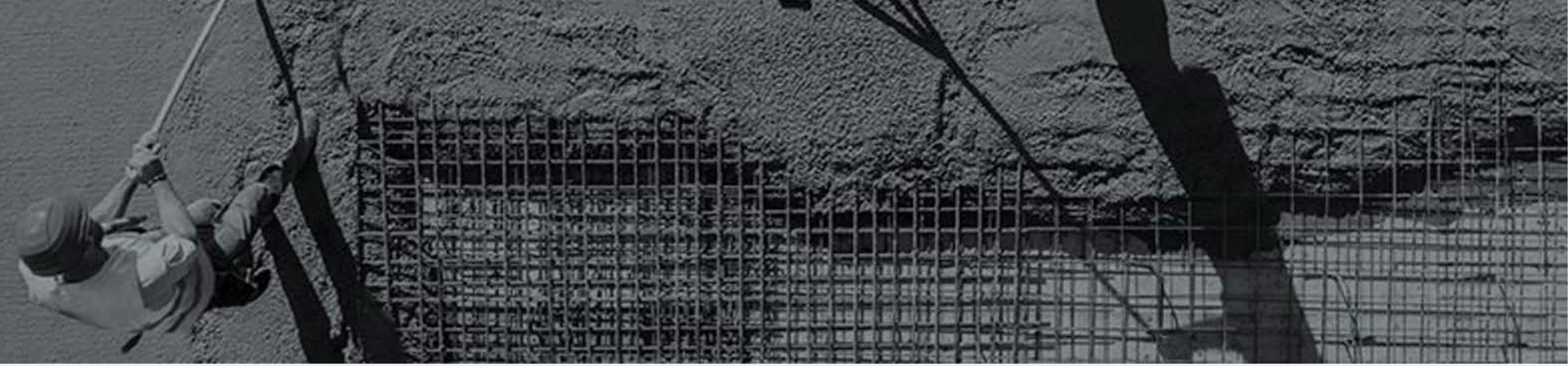
- Q&A and survey at the end



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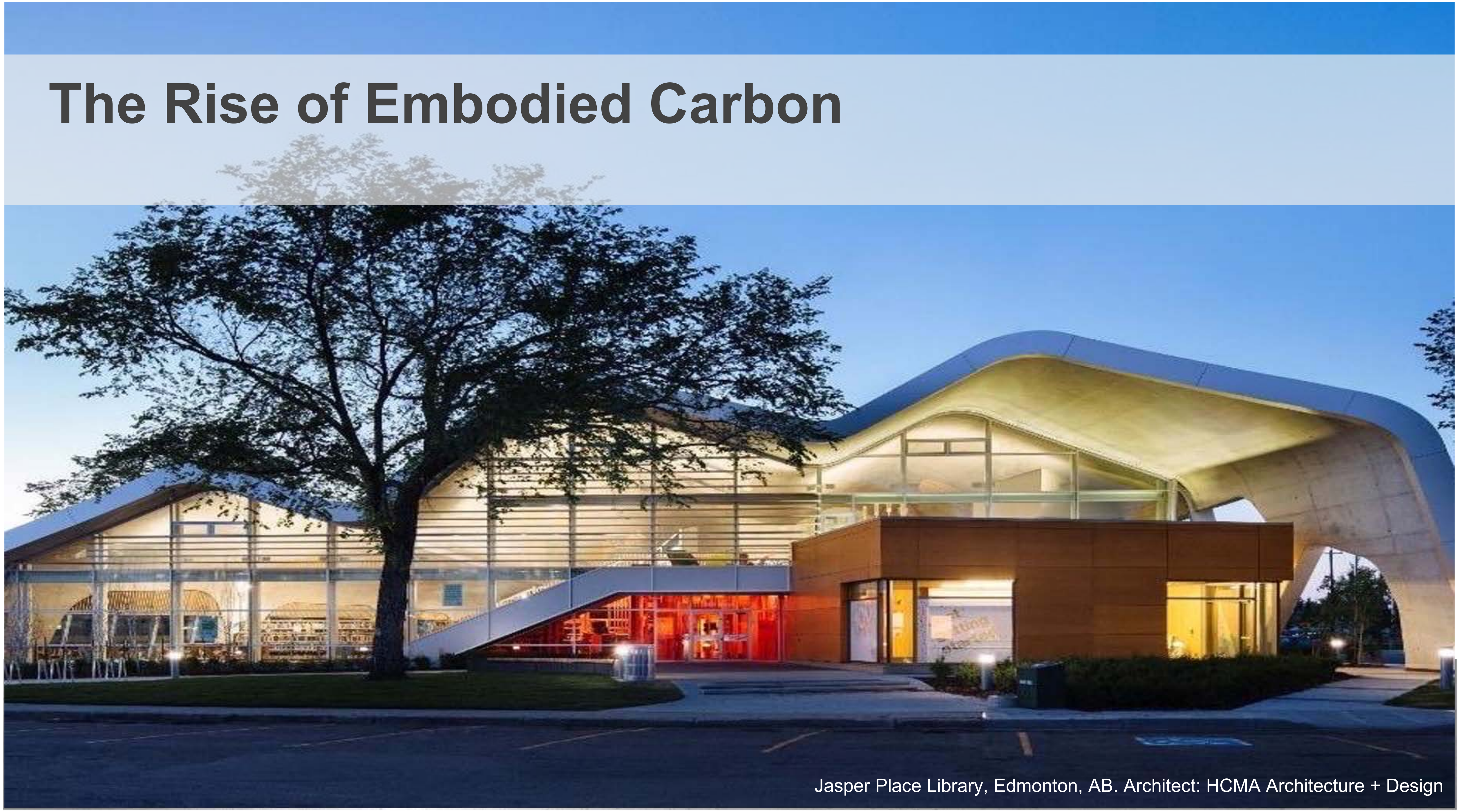
Speakers

Adam Auer
Vice President, Environment and Sustainability, Cement Association of Canada

Matt Dalkie
P. Eng., LEED AP BD + C, Technical Services Engineer, Lafarge Canada Inc.

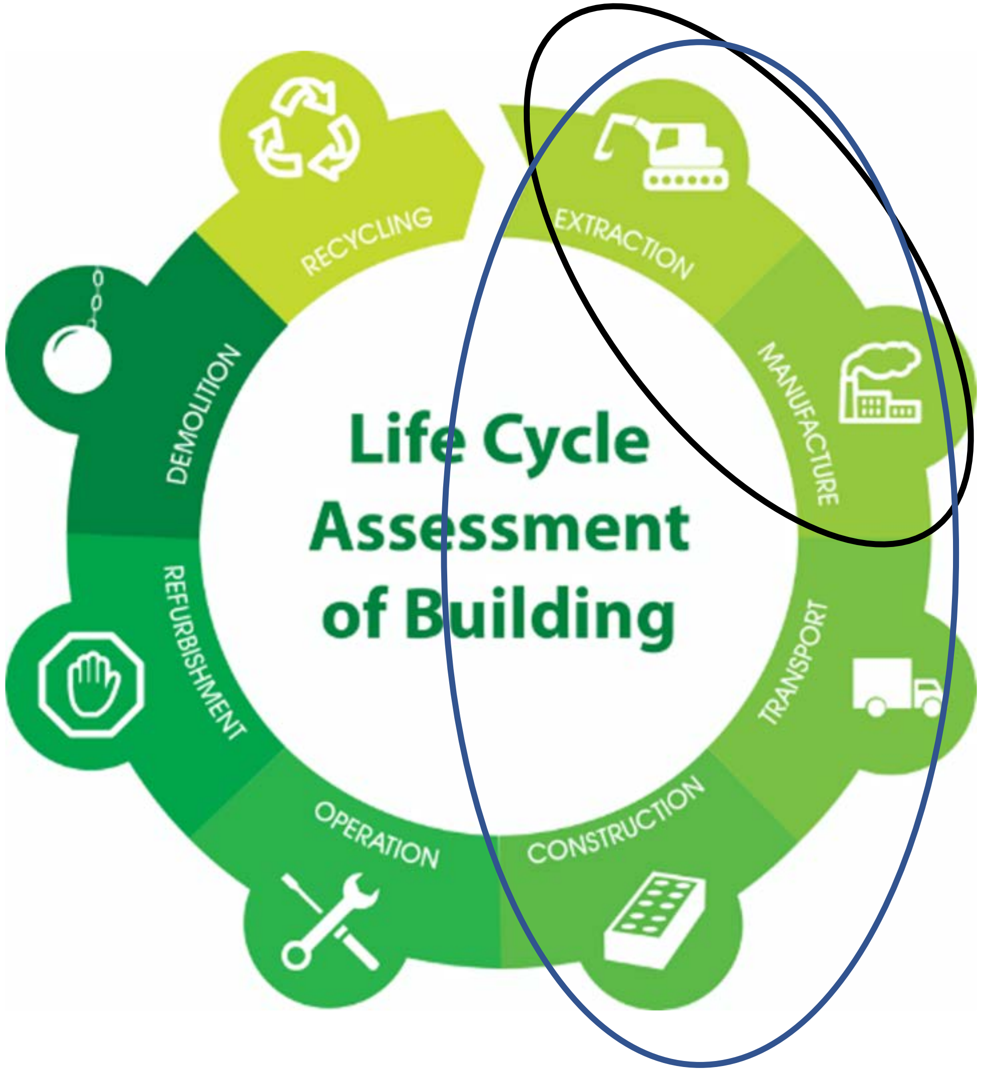
Kevin Davis
Regional Sales Director, CarbonCure Technologies

The Rise of Embodied Carbon



Jasper Place Library, Edmonton, AB. Architect: HCMA Architecture + Design

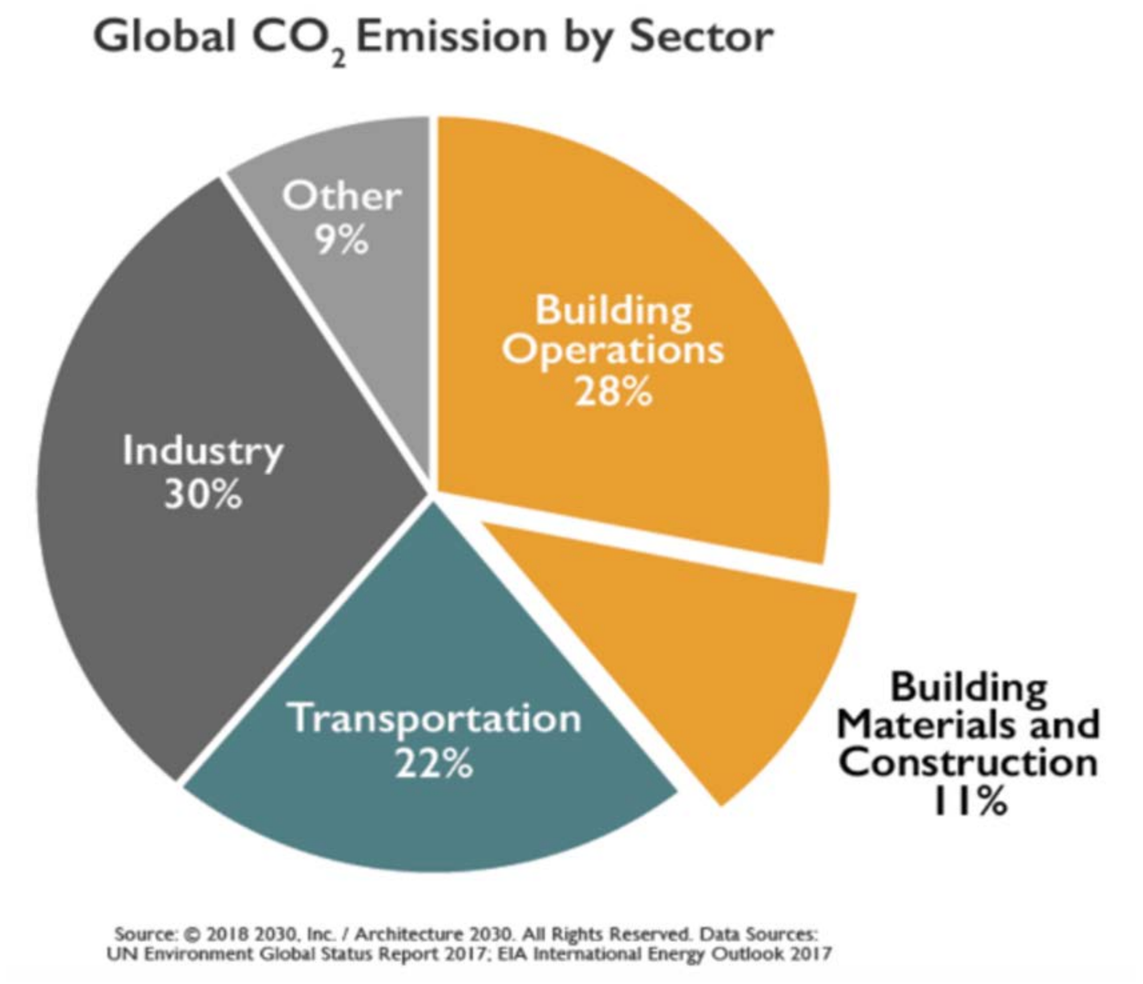
What is embodied carbon?



- Embodied Carbon of **Materials**
  - Extraction and manufacturing
- Embodied Carbon of **Buildings**
  - Materials + transportation, construction
  - *end of life carbon impacts

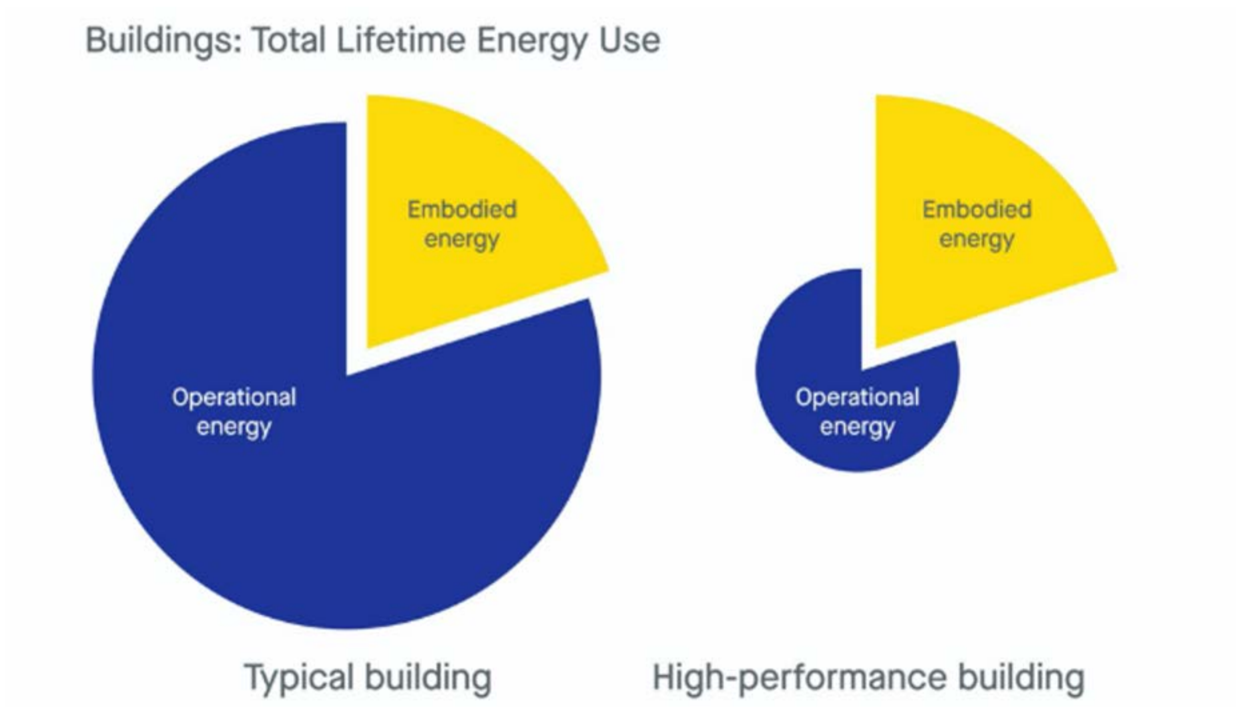
*i.e. **"upfront"** carbon*

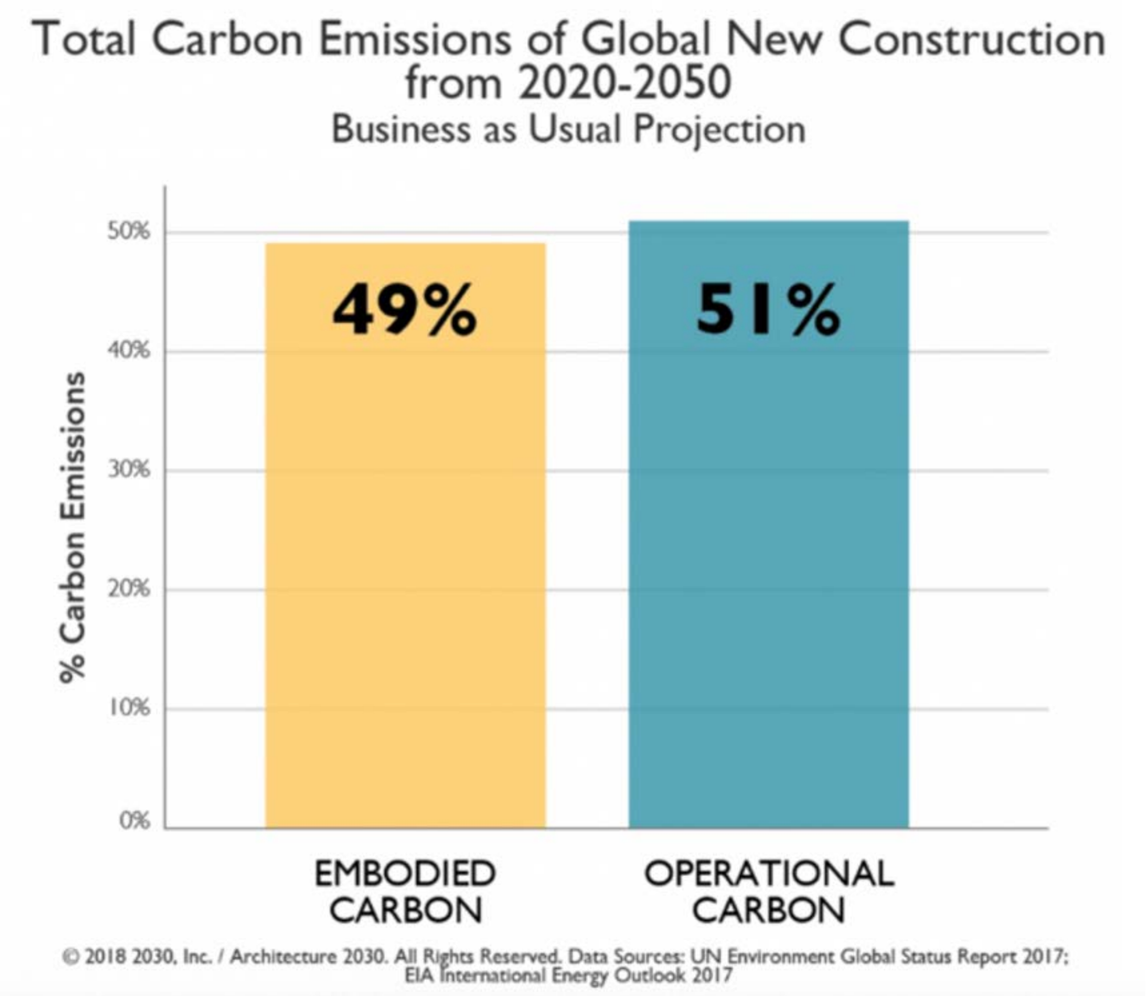
Embodied carbon is a significant source of emissions



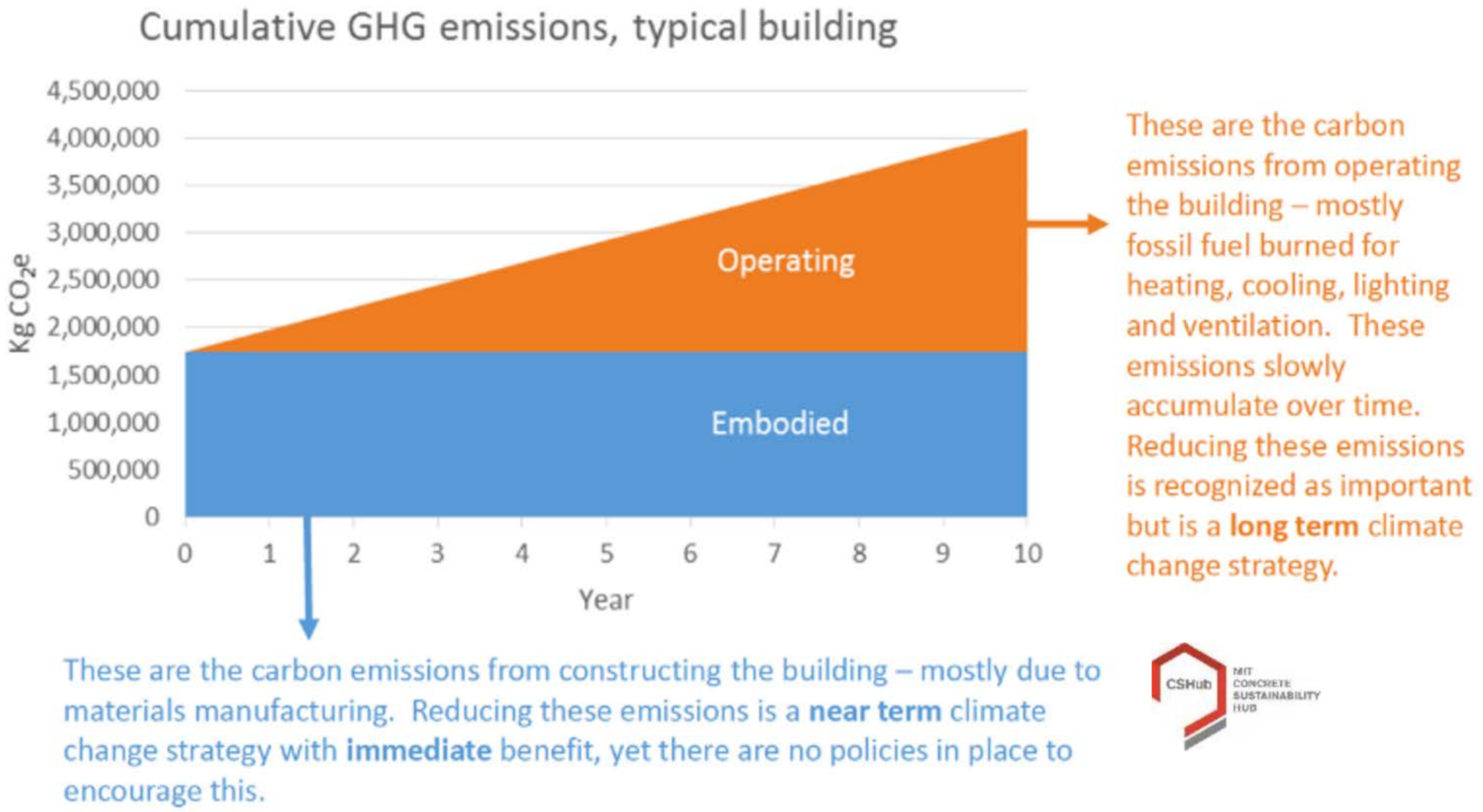
- Buildings account for almost 40% of global GHG emissions
- About 25% of building emissions are associated with "upfront" carbon emissions from materials and construction activities

Embodied carbon is becoming more important as buildings become more efficient





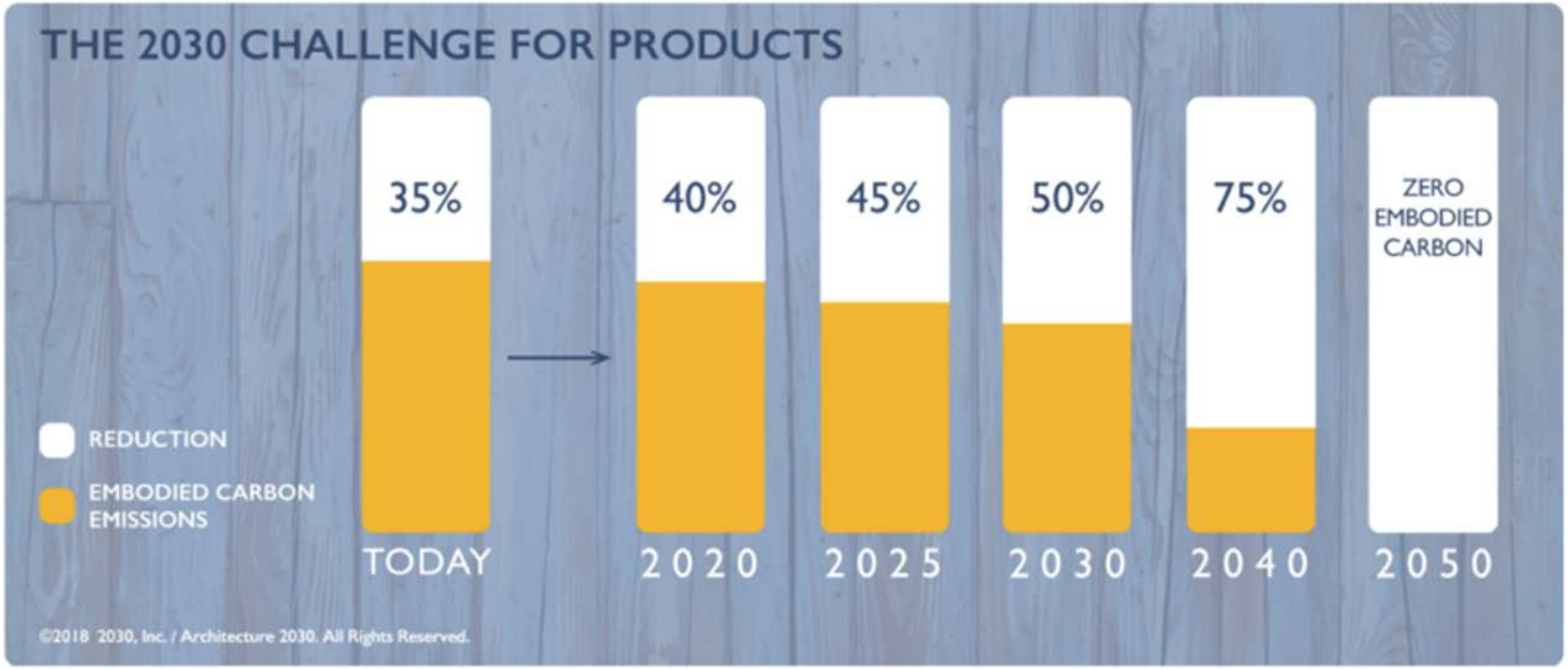
Timing of emissions (“radiative forcing”) give reductions in embodied carbon added climate mitigation value



CSHub MIT CONCRETE SUSTAINABILITY HUB

The Global 2050 Challenge

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



Mission alignment with:

CLF Carbon Leadership Forum

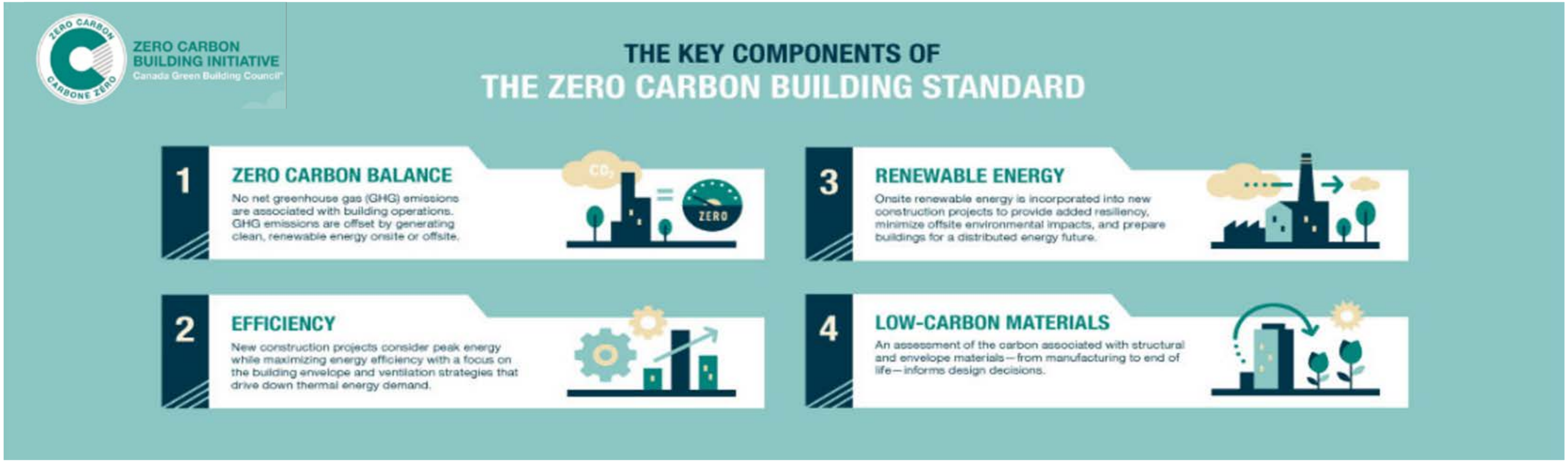
architecture 2030

SEI ASCE

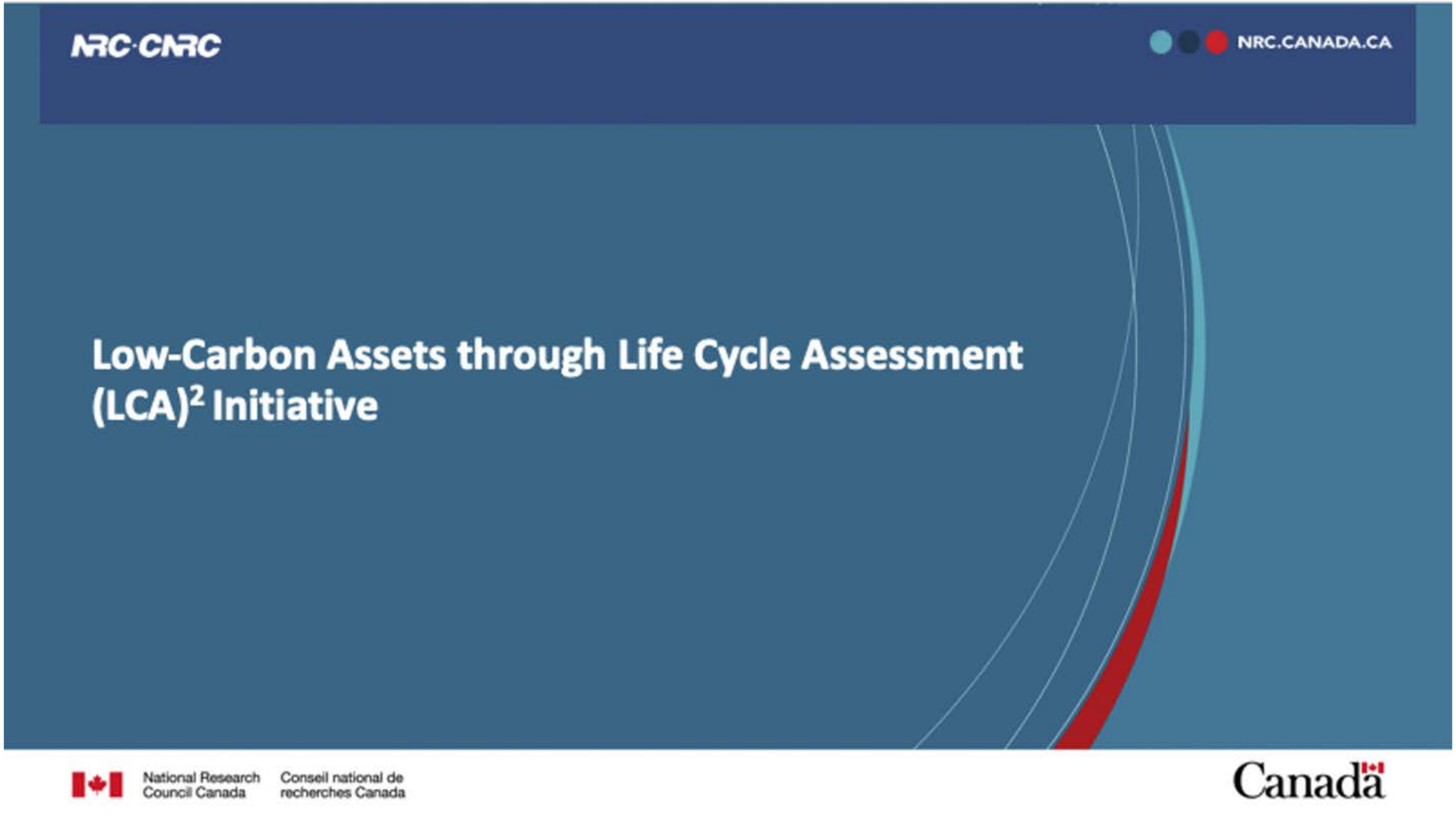
WORLD GREEN BUILDING COUNCIL

CaGBC Zero Carbon Building Initiative
A comprehensive approach to zero carbon buildings

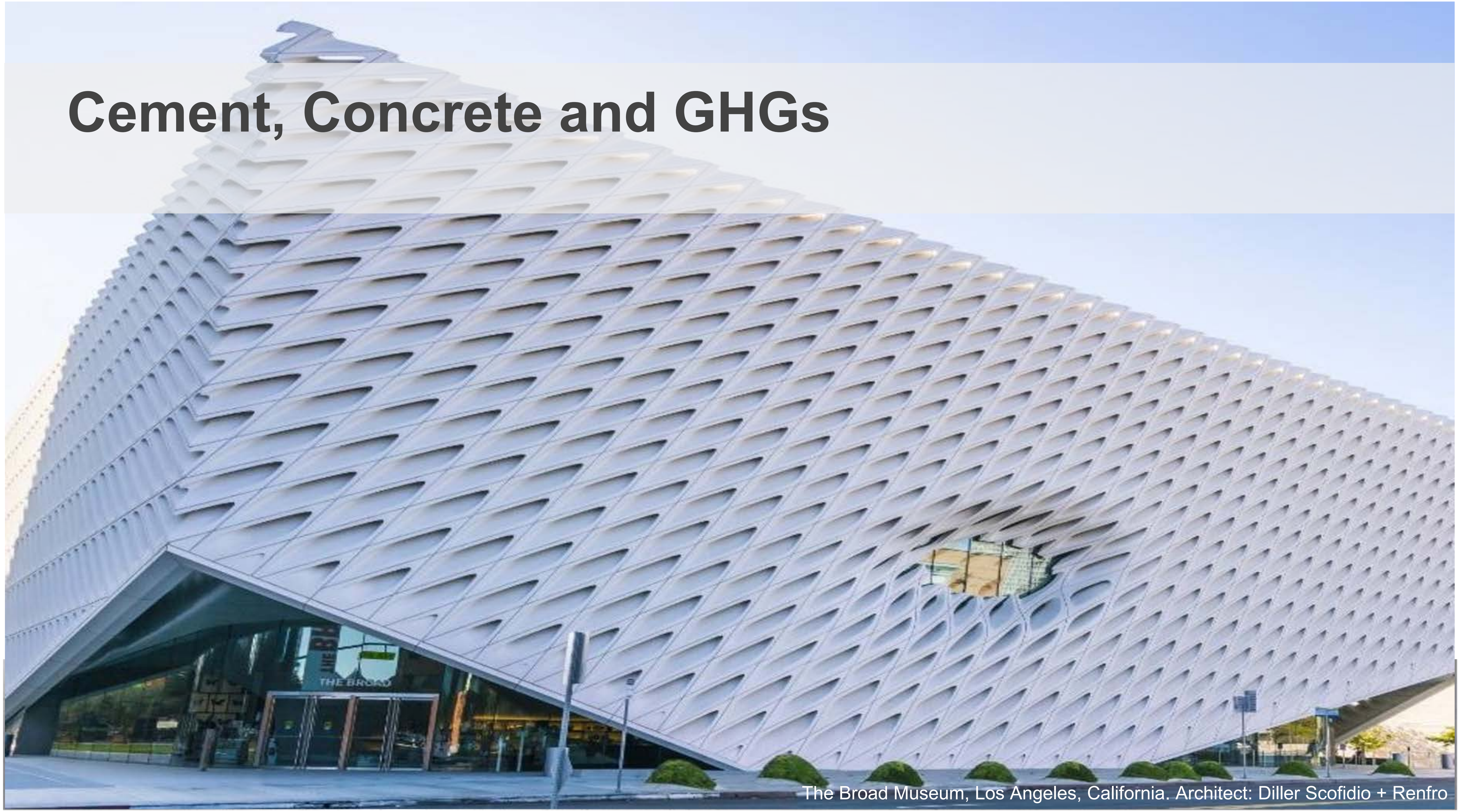
Source: Skansa



Government of Canada: LCA2



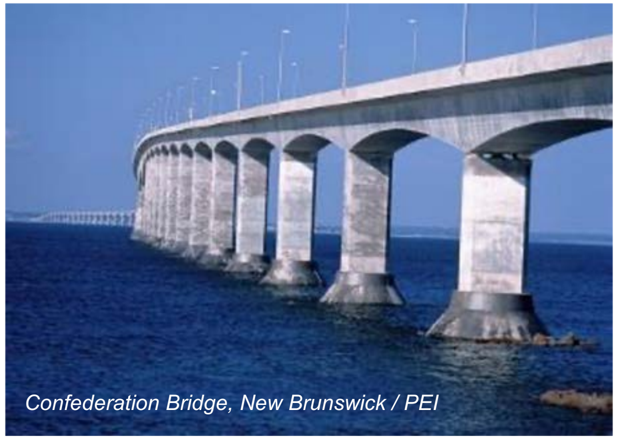
Cement, Concrete and GHGs



The Broad Museum, Los Angeles, California. Architect: Diller Scofidio + Renfro

Concrete is the world's most important building material …

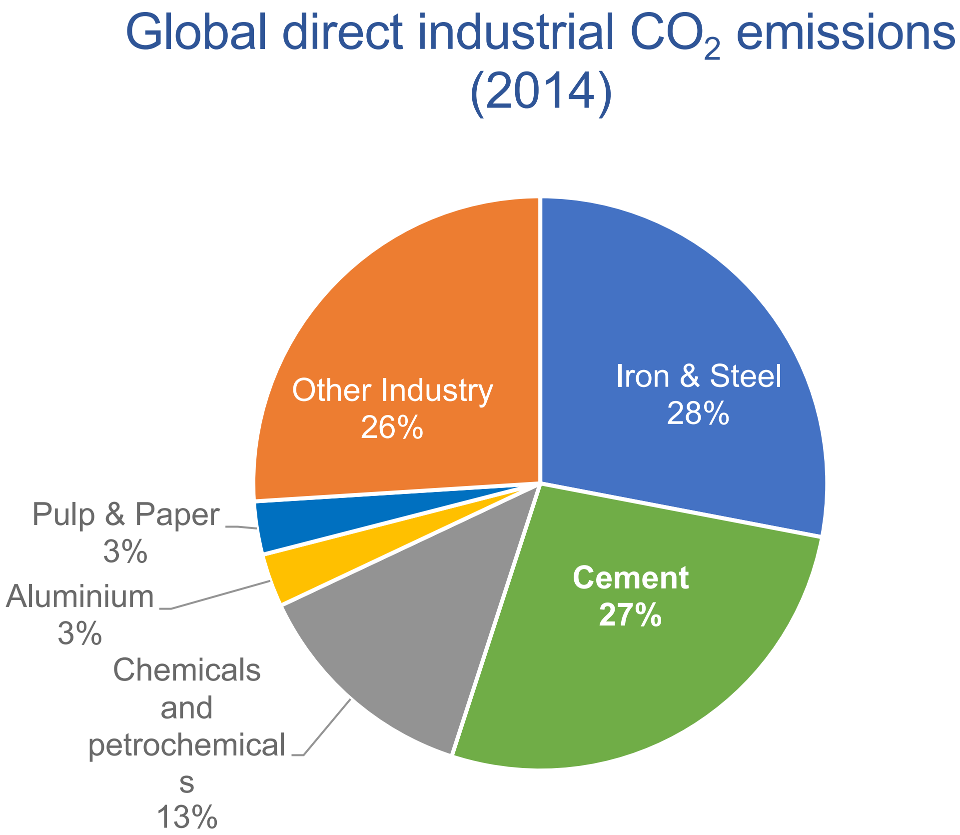
- Virtually all construction - above and below ground - requires concrete
- Twice as much concrete is used than all other materials combined
  - 4 billion tonnes of cement and over **20 billion tonnes of concrete** are produced globally each year*
  - Second most consumed commodity in the world, **second only to water**
- Cement is a global commodity, but concrete is inherently local



Confederation Bridge, New Brunswick / PEI

** https://www.statista.com/statistics/219343/cement-production-worldwide/*

… but it is used in high volume and leading to significant GHGs

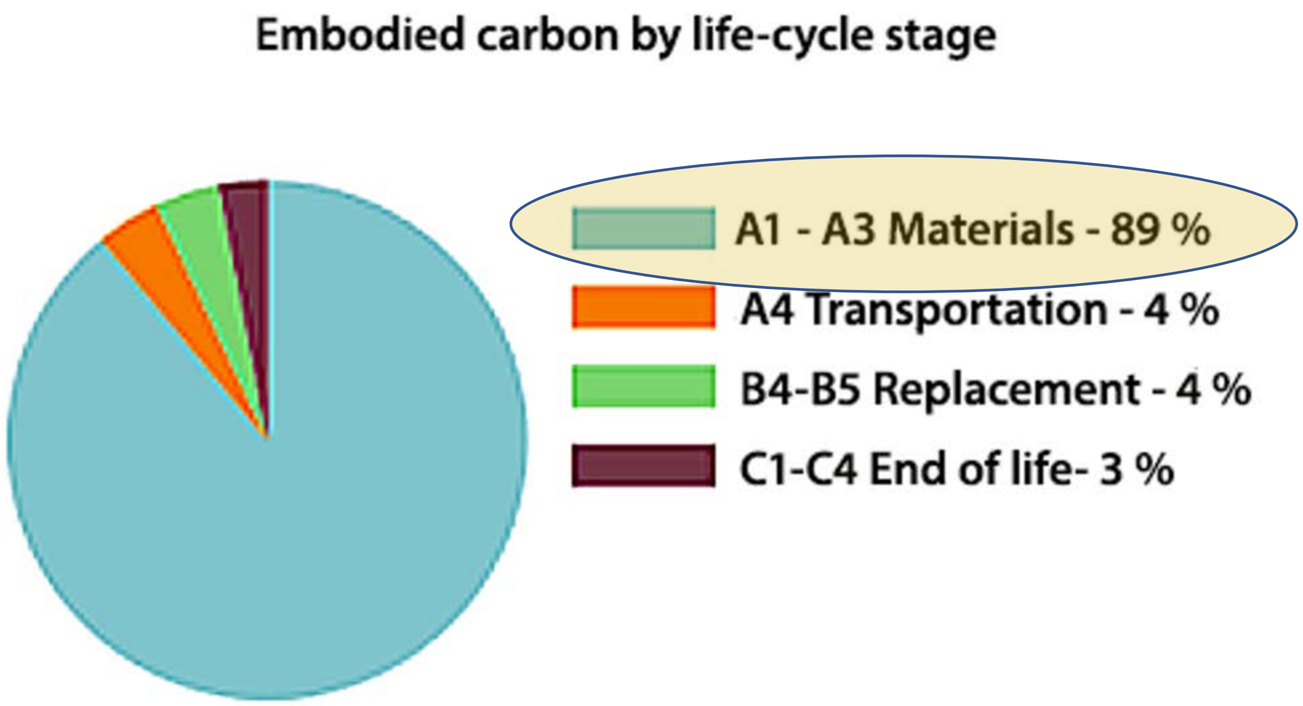


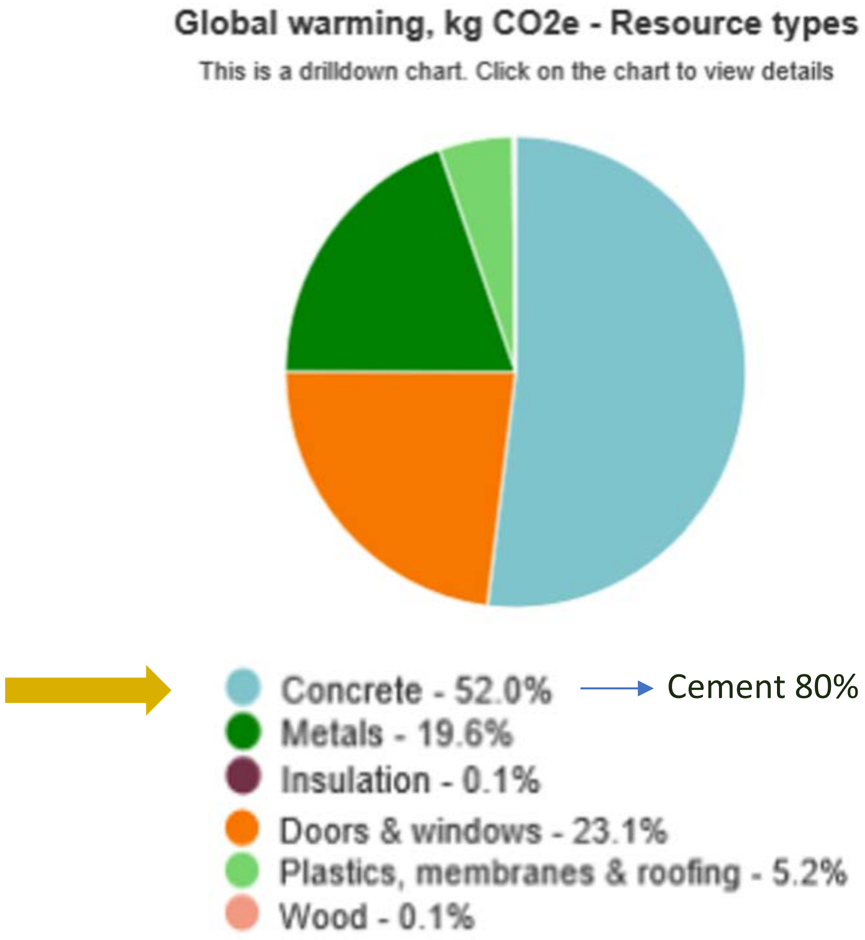
Information on this slide is sourced from International Energy Agency, Energy Technology Perspectives 2017

- Up to **8% of global emissions** come from the cement produced to make concrete*
- **1.5%** (10.8MT) of Canada's GHG emissions in 2017**
- Deep cement and concrete decarbonization technologies and strategies are essential to decarbonizing the built environment.

**Andrew, R.M., Global CO_2 emissions from cement production, Earth System Science Data, 2017*
***Environment and Climate Change Canada*

Example: Office Building





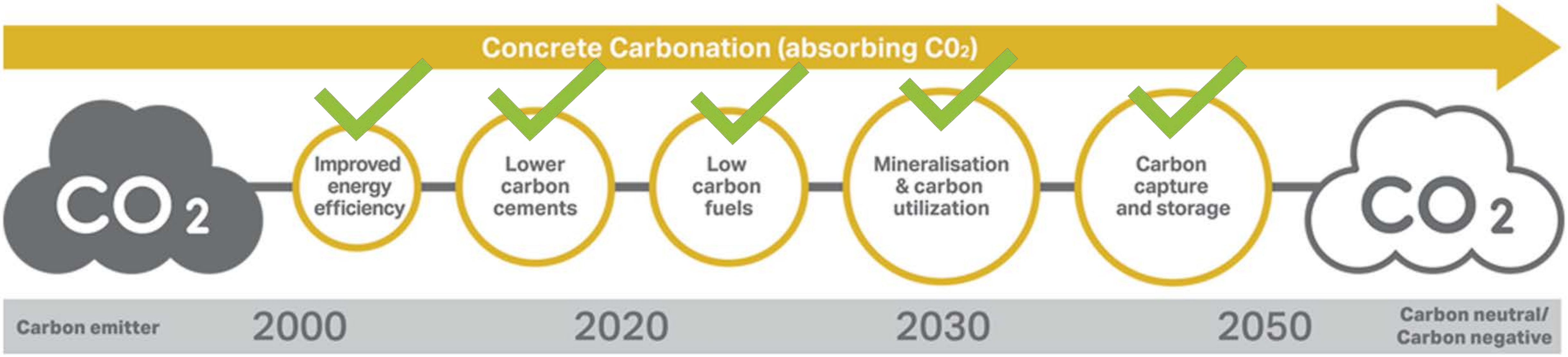
Concrete products and solutions for every application

- Concrete and concrete products are ubiquitous within Canada's building stock, providing efficient solutions for all building archetypes.
- Cast-in-place concrete, concrete block and precast concrete systems offer a variety of solutions for both structural and non-structural applications.

Decarbonizing Concrete

The Confederation Bridge, PEI-N.B. Architect: Jean M. Muller

Decarbonizing our buildings: a shared opportunity



Cement makes up 10% -15% of a concrete mix but accounts for 80% or more of concrete's GHG emissions.

Energy use for cement manufacturing reduced by 20% and GHG intensity by 15% over the last 20 years

Portland-limestone cement (PLC) and blended cements can reduce GHGs by 30% → nearly 3MT of carbon emissions per year Canada-wide

Using low carbon fuels in cement manufacturing could reduce GHGs by 2-3MT per year → another 20%-30%

New technologies that cure concrete with CO_2 now being deployed could reduce its carbon intensity by up to 70% when they become mainstream

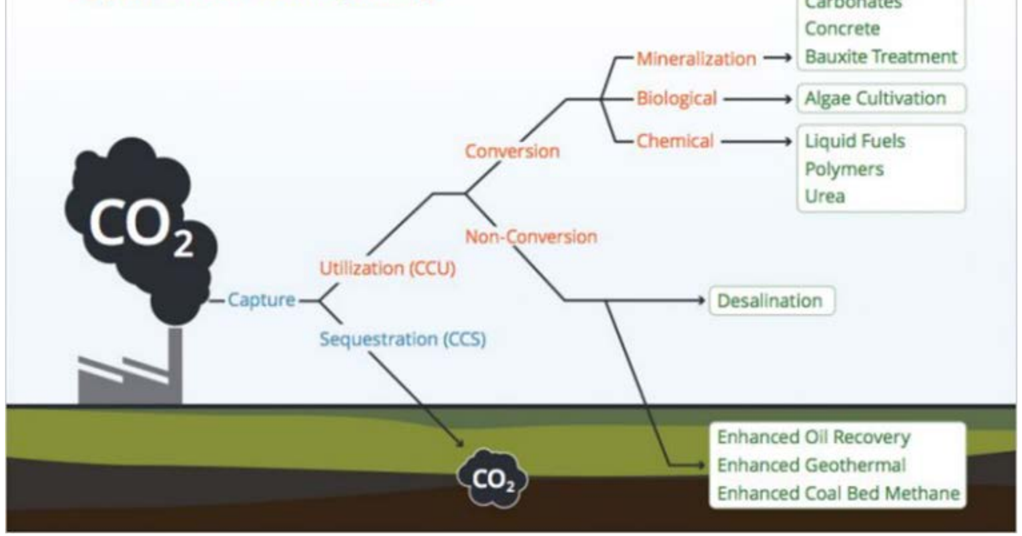
Implementation of carbon capture systems that could potentially capture virtually 100% of cement manufacturing emissions is already underway in Canada

Combining carbon-neutral cement with other low-carbon technologies, such as biomass fuels or carbonated aggregates could transform concrete into a carbon-negative building material

Cement: Active strategies to reduce manufacturing emissions

- **Low Carbon Fuels**
  - e.g. C&D waste (i.e. wood), non-recyclable plastics, non-recyclable tires, rail ties, biosolids, etc.
  - Future: Renewable Natural Gas? Hydrogen?
- **Low Carbon Blended Cements**
  - Portland Limestone Cements
  - SCMs (blended into cement or concrete)
- **Carbon Capture and Storage**
  - Carbon capture at the cement plant
  - Carbon utilization in concrete

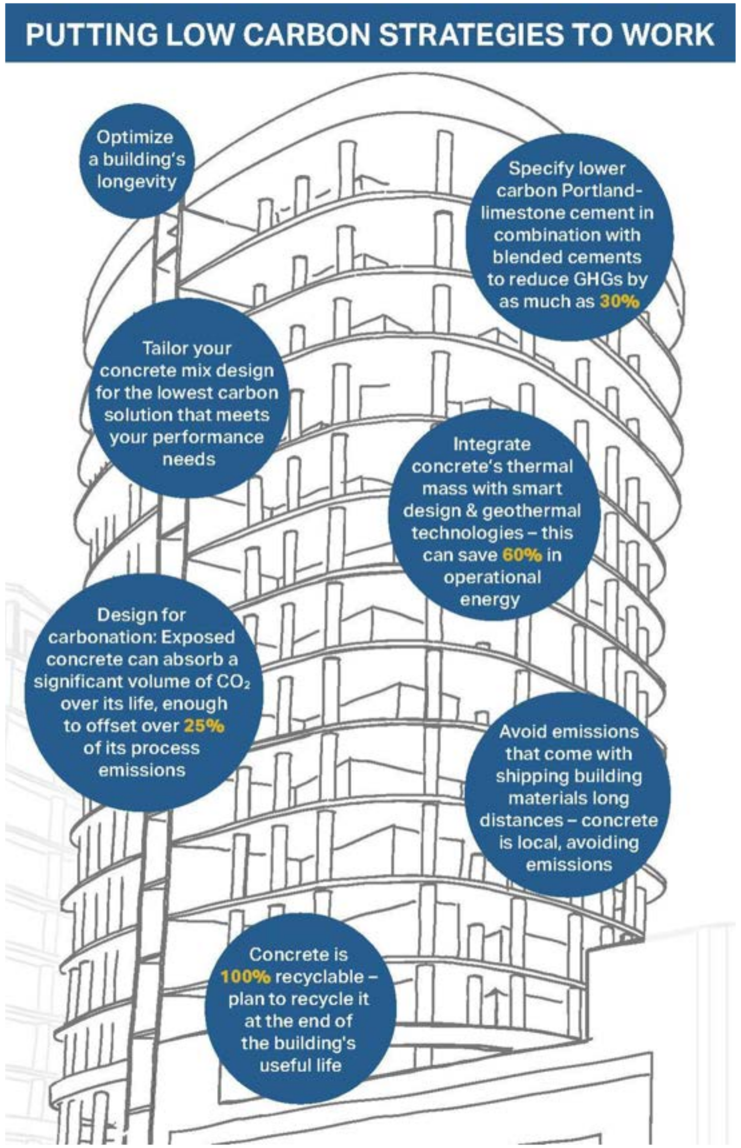
Figure 1. Paving the way — A selection of today's carbon capture and utilization pathways



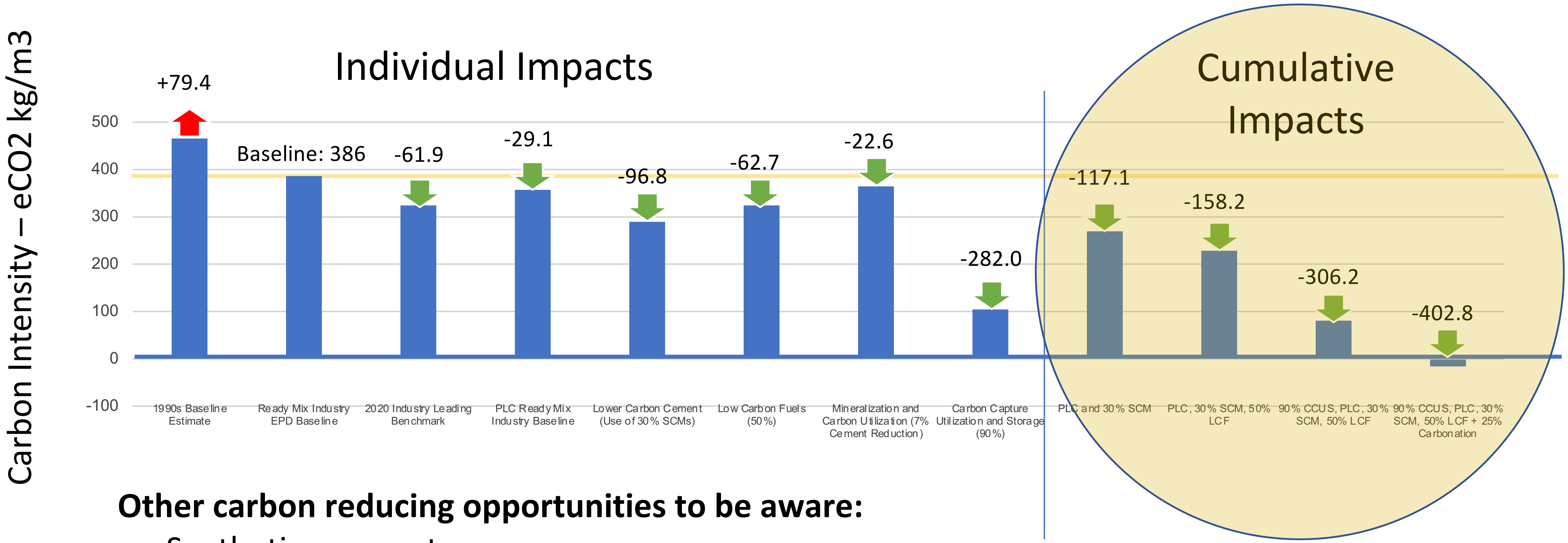
Design and specification GHG touchpoints

- Concrete's role in building performance
  - Thermal mass
  - Air infiltration
  - Resilience/longevity

- Low carbon concrete strategies
  - Portland limestone cement
  - Mix optimization
  - Material efficiency
  - Design for carbonation
  - Recyclability



Data!



Other carbon reducing opportunities to be aware:

- Synthetic aggregates
- Concrete carbonation

SHRINKING CARBON EMISSIONS

Innovative Cement and Concrete Technologies

November 17, 2020

LOWER CARBON CEMENT FUEL SWITCHING

- Description
  - Replace coal with other lower carbon or waste fuels
- Limitations
  - Only addresses fuel emissions
  - Some fuels assumed to be carbon neutral – biogenic materials
  - Potential limited by fuel type and availability, and process type
- Potential
  - 5 to 40% reduction depending on fuel types and process and carbon neutrality assumptions
- Status and Viability
  - Currently available and in use globally

LOWER CARBON CEMENT
PORTLAND LIMESTONE CEMENT

- Description
  - Limestone added during the cement grinding process
  - Between 5 and 15% limestone added
- Limitations
  - Some specification limits for some applications
- Potential
  - 5 to 10% reduction depending on level of limestone
- Status and Viability
  - Currently widely available and in use, although restrictions to use in some provinces

LOWER CARBON CONCRETE SCM – FLY ASH

- Description
  - By-product from coal fired power generation
- Limitations
  - Maximum replacement level around 50%, typical max 30%
  - Not accepted in all specifications
  - Can have strength gain and finishability implications
  - Coal fired power plants shutting down
- Potential
  - 10 to 20% depending on replacement level
- Status and Viability
  - Long term history of use
  - Limited future

LOWER CARBON CONCRETE SCM – SLAG

- Description
  - By-product from iron manufacturing
- Limitations
  - Maximum replacement level around 80%, typical max 50%
  - Can have strength gain and finishability implications
  - Not accepted in all specifications
- Potential
  - 20 to 30% depending on replacement level
- Status and Viability
  - Long term history of use

LOWER CARBON CONCRETE SCM – OTHER TYPES

- Description
  - Ground glass, silica fume (up to 10%), natural pozzolans, recovered fly ash
- Limitations
  - Familiarity with use by ready mix producers
  - Material availability – regionally specific
  - Limits of use dependent on material
  - Not accepted in all specifications
- Potential
  - Variable depending on material
- Status and Viability
  - New material sources being identified

PRESCRIPTIVE VS PERFORMANCE SPECIFICATIONS

PRESCRIPTIVE ELEMENTS

Strength based

Defined w/cm ratio

Limits on cement type and amount

Limits on SCM type and content

Limits on admixture and additives

Primary risk with Owner/Designer

Builds on the history of construction and empirical relationships

Does not permit creativity and innovation

PERFORMANCE ELEMENTS

- Flexible
- Functional Performance Criteria of Element/Structure
- Plastic and Hardened Requirements
- Other Measureable Requirements
- Primary risk with Producer/Contractor

Offers suppliers and contractors flexibility to achieve project goals

Shrinking Carbon Emissions Through Innovative Cement and Concrete Technologies

Kevin Davis
CarbonCure Technologies

CARBON CURE™

Simply better concrete.


CO_2: An Ally, Not An Enemy
Blue Planet
SOLIDIA®
Svante
Carbon Engineering
CARBON CURE™

What is CarbonCure?

CO_2 Utilization in Concrete

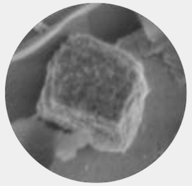
- CarbonCure is a **retrofit technology** installed in ready mix concrete plants that **injects CO_2** into wet concrete in order to improve its **strength and performance**.
- These improvements enable concrete producers to **realize cost savings** through **mix optimization** while **growing their business** with the green design community.

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)



- Reverse calcination reaction occurs
- CO_2 converts into **$CaCO_3$ (solid limestone)**

CO_2 Utilization : Admixture Analogy

Batch Controller

Admix Supply

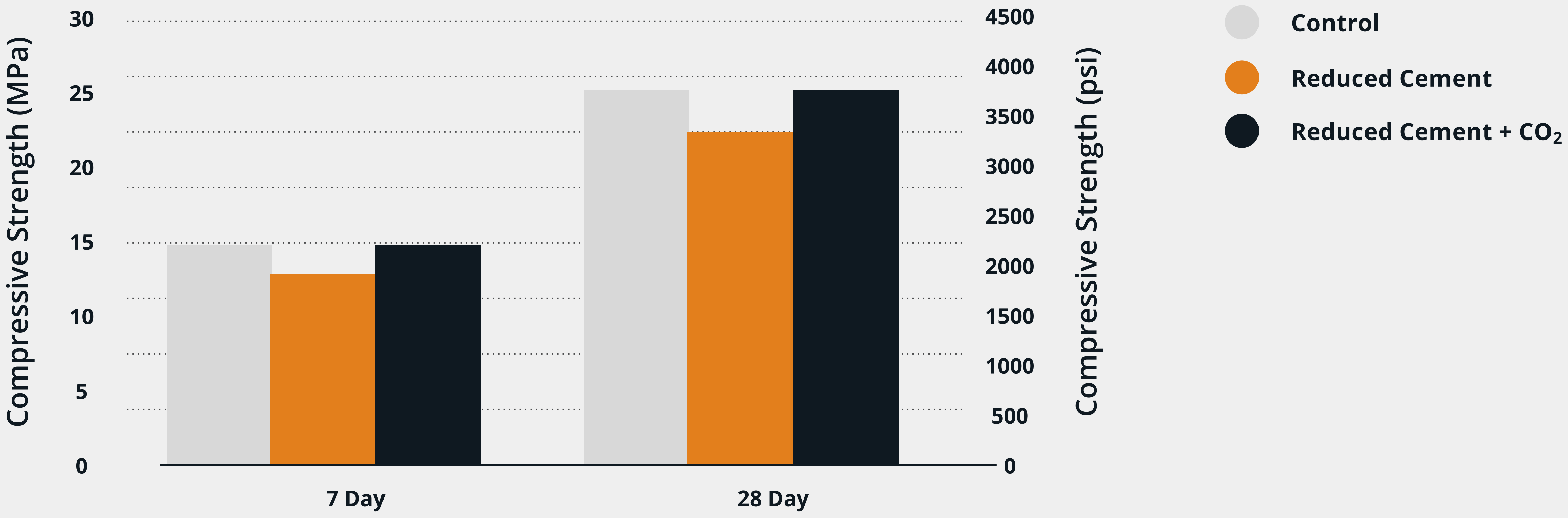
Admix Dispensing

CO_2 Supply

Valve Box

Product

Mix Optimization Potential



Conclusion: *CarbonCure enables concrete producers to* ***reduce cement content*** *without sacrificing strength.*
Source: *"Ready Mix Technology Trial Results" (2015)*

Economics

Generic 28 MPa (4,000 psi) Mix
NRMCA Benchmark Report

Factor	Value	Unit
Baseline cement	282	kg/m³
Cement reduction	14	kg/m³
One load	8	m³/load
Cement savings	113	kg/load
Monetary saving	$14.66	$/load
CO_2 usage	2.1	kg/load
Cost of CO_2	$0.94	kg/load
Net CO2 Benefit	119	kg/load

Savings are 14 x Costs

Net value of $5,398 per t CO_2 utilized

Net CO_2 benefit is 56 × utilization

Assumptions: *Cement price $110 USD/ton • Merchant CO_2 cost $400 USD/ton • CO_2 emissions intensity of the cement 1.04 (PCA EPD) • CO_2 mineralization rate 90% • Process emissions proportion of dose 13%*

CarbonCure for Ready Mix

How Much CO_2 Can Be Saved?

15-20 kg CO_2 saved per yd^3

20-35 lbs CO_2 saved per yd^3

CO_2 saved = CO_2 mineralized + CO_2 avoided by reducing cement

The CarbonCure Advantage

- **Positive impact for a conservative industry**
  - Working with innovators
  - Easy to implement in largest market segment (ready mixed concrete)
  - Retrofit (same equipment and materials) and scalable

- **CO_2 utilization drives value versus simply “green” aspects**
  - Improved concrete performance
  - Act sustainably and save money

- **Improved cement efficiency**
  - Avoided CO_2 unlocks carbon benefits
  - Carbon utilization is not carbon sequestration

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

CO_2 Supply in the PNW

Cherry Point Refinery
Bellingham, WA

Pacific Ethanol Refinery
Boardman, OR

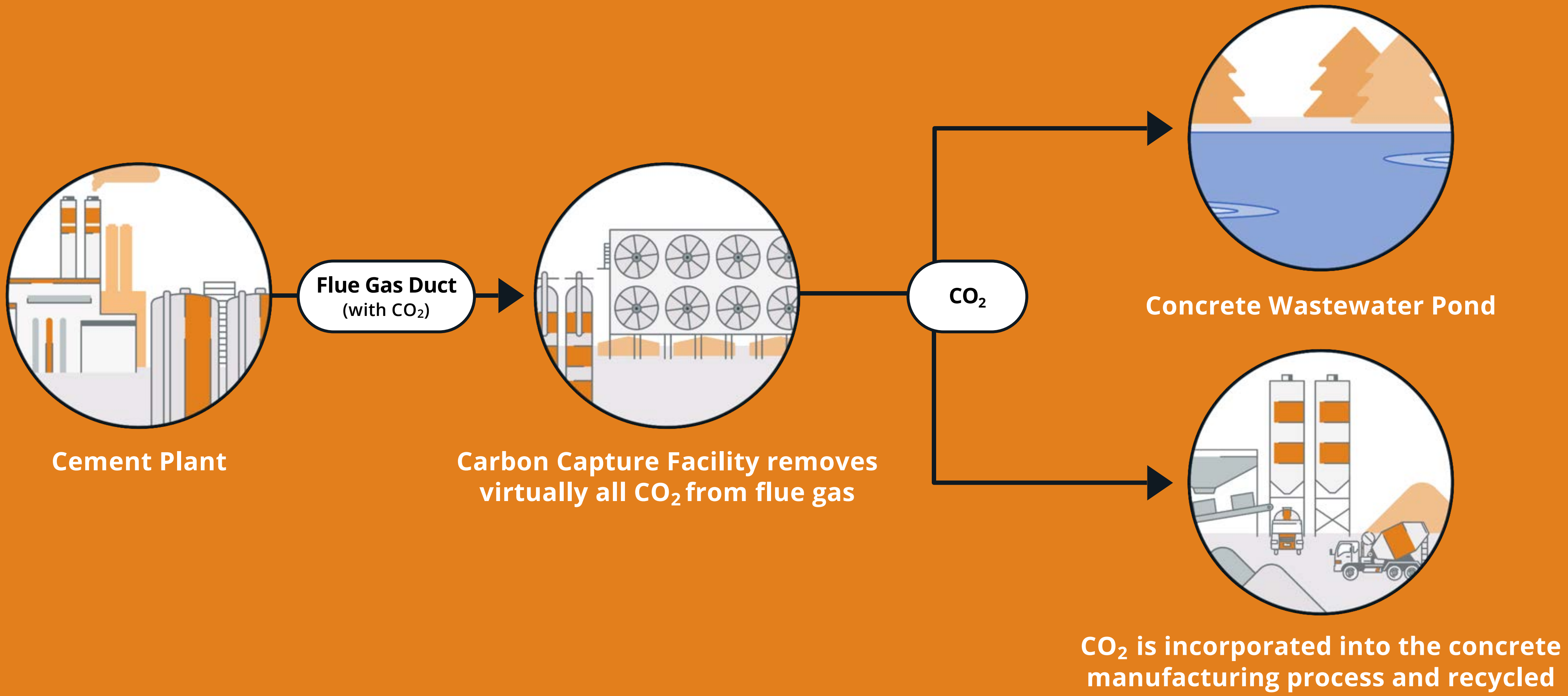
an Air Liquide company

Pacific Ethanol, Inc.

CO_2 : The Bigger Picture

CarbonCure has demonstrated the world's only integrated CO_2 capture and utilization solution from cement in 2018 for the Carbon XPRIZE competition.

Integrated CO_2 Capture & Use Model



CARBON CURE™

Many local governments are reducing their CO_2 emissions through energy efficiency, renewable energy and cleaner transportation

- Technologies and best practices are already being used to reduce the carbon footprint of concrete such as the use of Portland limestone cement or solid waste materials, like fly ash and steel slag
- New innovations like the treatment of concrete with post-industrial waste CO_2 are being specified by architects and engineers around the world. Known as CO_2 mineralization, this process permanently traps CO_2 inside concrete.
- These methods meet current standards for strength, safety, and durability. Better yet, they are cost-competitive. They are also fully compatible, and by deploying them together CO_2-reducing benefits can be combined to achieve greater emissions reductions.

Thank You!

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