

Lowering The Carbon Footprint of Cement

Using Portland Limestone Cement and Other Blended Cements

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2025 Construction Symposium
February 11, 2025

Today's Discussion

- History of Portland Limestone Cement
- Portland Limestone Cement Basics
- Sustainability & Measuring CO₂
- Why Portland Limestone (PLC) Cements

History of Portland Limestone Cement

PLC has a Long History in Europe and Canada

Cement with 20% limestone in Germany for specialty applications

1965

CSA 5 (Canada) allows up to 5% limestone in Portland cement

1983

UK specs allows up to 20% in limestone cement

1992

EN 197-1 creates CEM II/A-L (6-20%) and CEM II/B-L (21-35%)

2000

French cement standards allows limestone additions.

1979

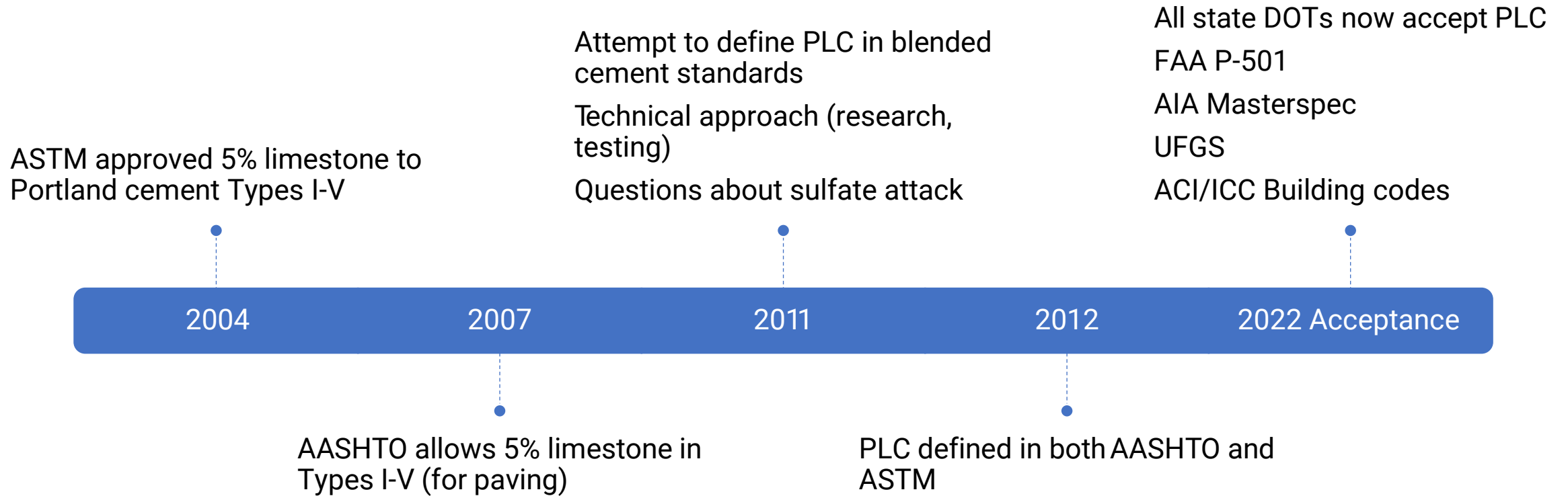
15±5% limestone blended cements routinely used in Germany

1990

EN 197-1 allows 5% in all 27 common cements, as was commonly practiced in various European cement standards prior

2000

Brief History of Limestone in US Standards



VERSATILITY

AVAILABILITY

DURABILITY

STRENGTH

FIRE RESISTANCE

SUSTAINABILITY

Portland Limestone Cement Basics

Most cement plants in the US produce a clinker that meets the specifications for Type II (moderate sulfate resistant) ASTM C150 cement

Type II cement can be adjusted to meet specifications for

- Type I (I/II)
- Type V (II/V) Cements

Alumina content is the main difference between Type I, II & V

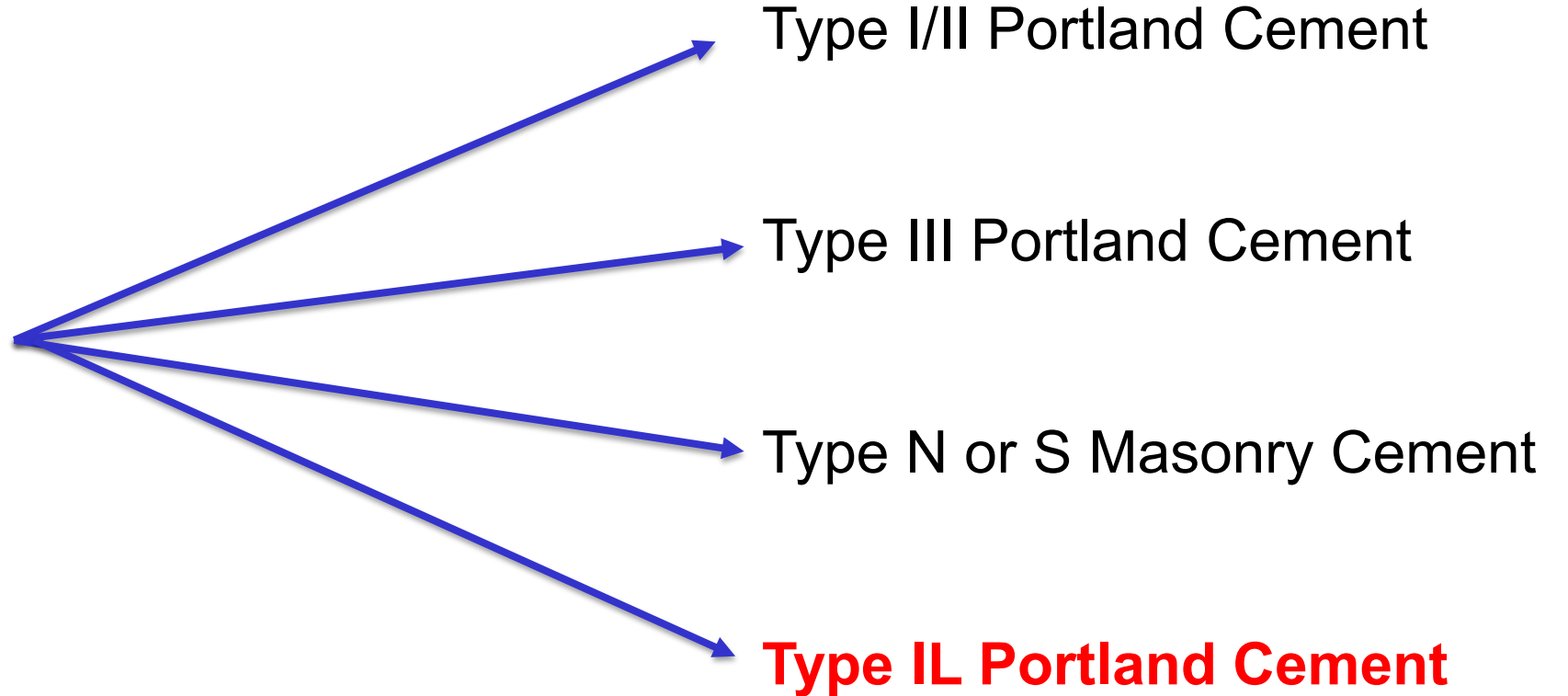
- Type I - no C3A limit
- Type II - C3A limit < 8%
- Type V - C3A limit < 5%



Cemex Brooksville Cement Plant

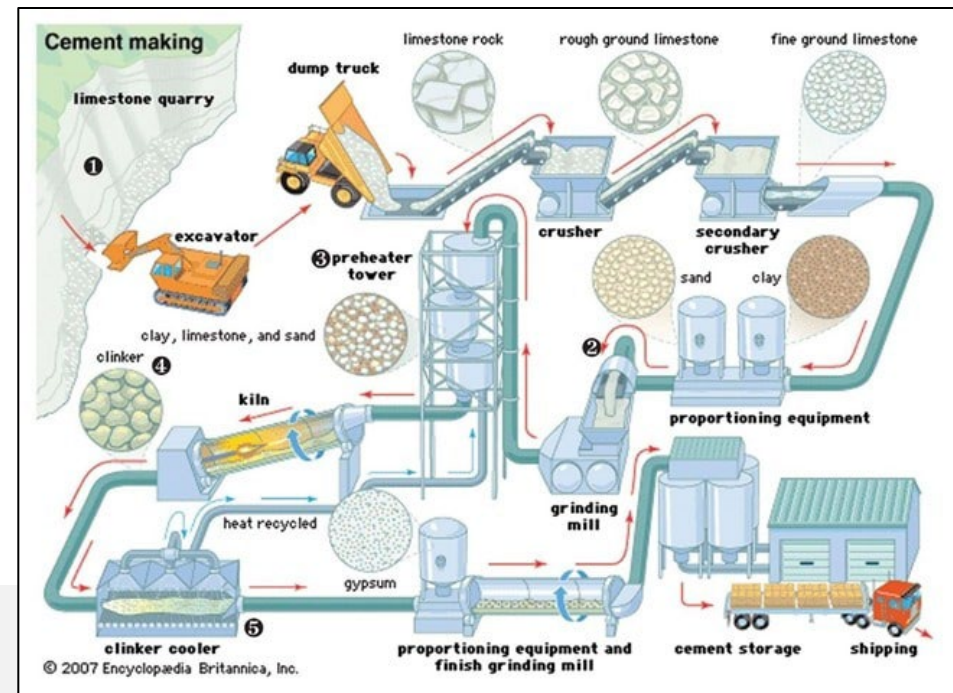
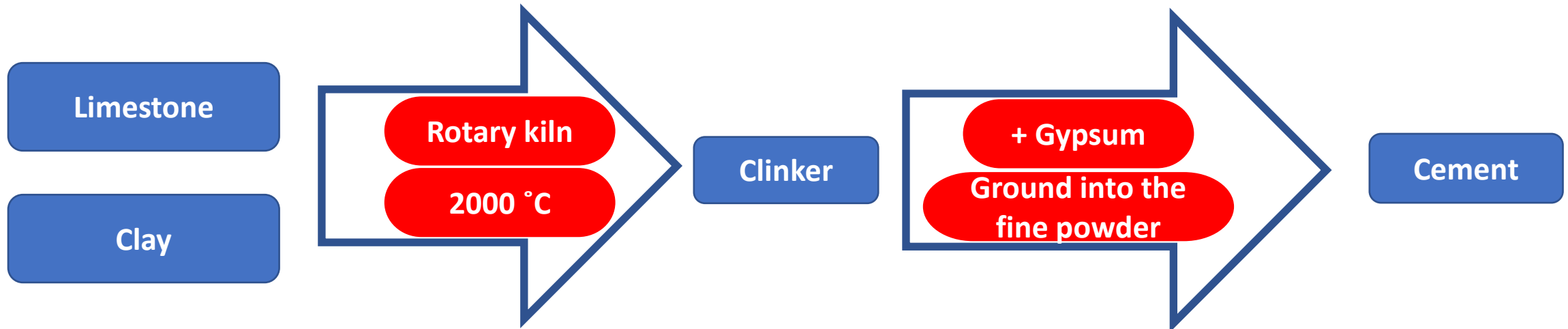
The same Type II Clinker
May be Used to produce a
number of Cement
Products

Cement Type I/II
Clinker

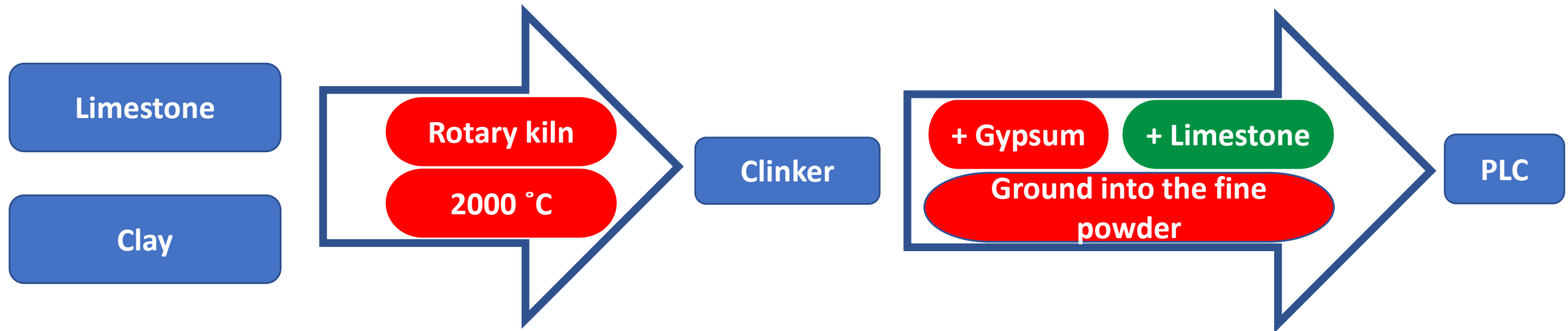


Finish mill > Clinker + grinding aid + additions = cement products

Portland Cement Production Process



Portland Limestone Cement Production Process



- Type IL Portland Limestone Cement (PLC) is a cement made with the same clinker as typical Type I/II (or II/V) Ordinary Portland Cement (OPC).
- Limestone is added to the finish mill and blended with the clinker and gypsum.
 - ASTM C595 / AASHTO M240 allows 5%-15% limestone to be added

How does PLC differ from OPC?

PLC is ground finer than OPC.

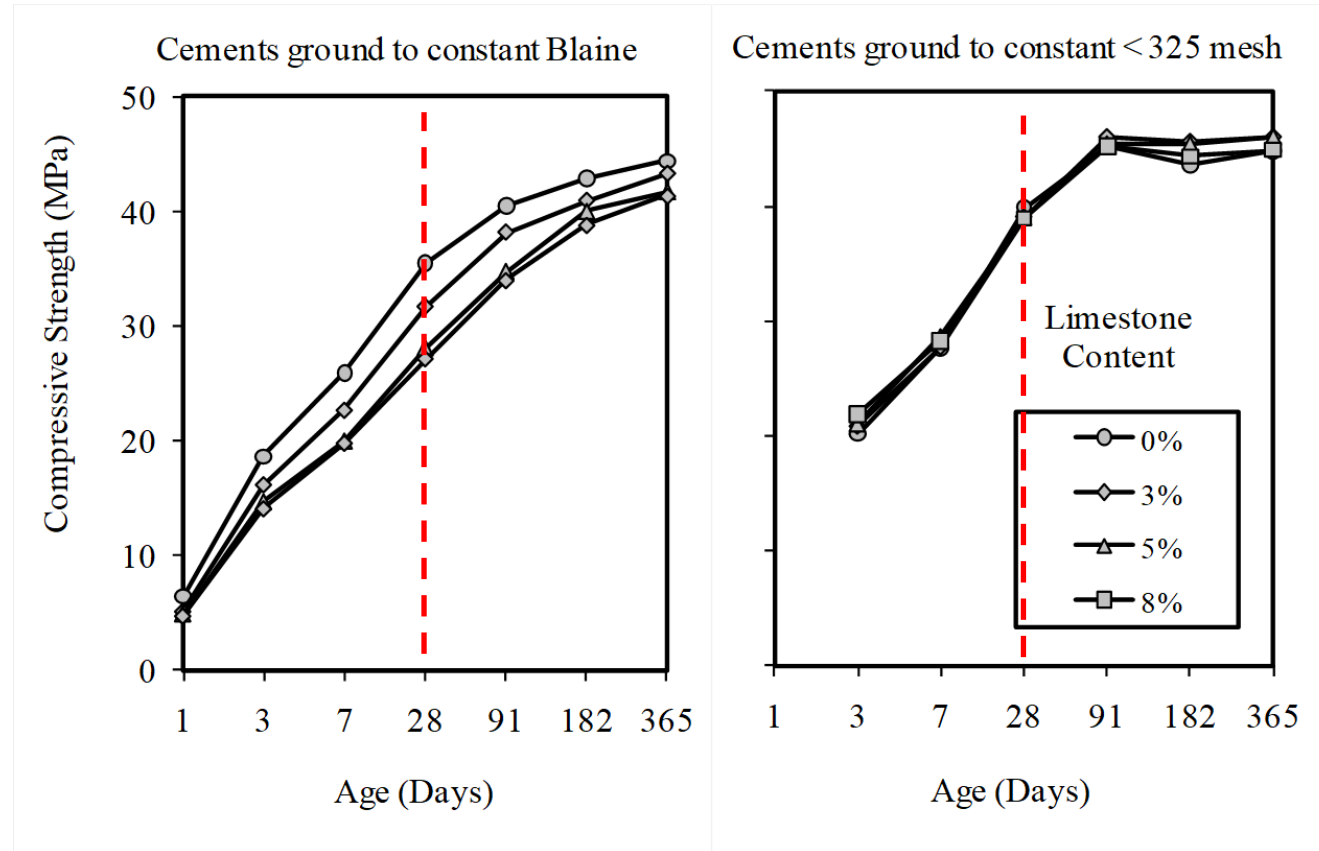
The Blaine for PLC is about 5000-5500, as opposed to OPC at about 4000 ($\text{cm}^2 / \text{gram}$)

- The higher Blaine is mainly due to the soft limestone grinding very fine

The #325 sieve is targeted to be the same as it is for OPC.

- Ensures the clinker portion of the PLC has about the same sizing as OPC.
- Most cements have about 92-99% passing #325 sieve.

Strength Comparisons #325 Mesh Size is the Key



Source: State-of-the-art report on use of limestone in cements at levels of up to 15%, Portland Cement Assn

Sustainability & Measuring CO₂

Sustainability

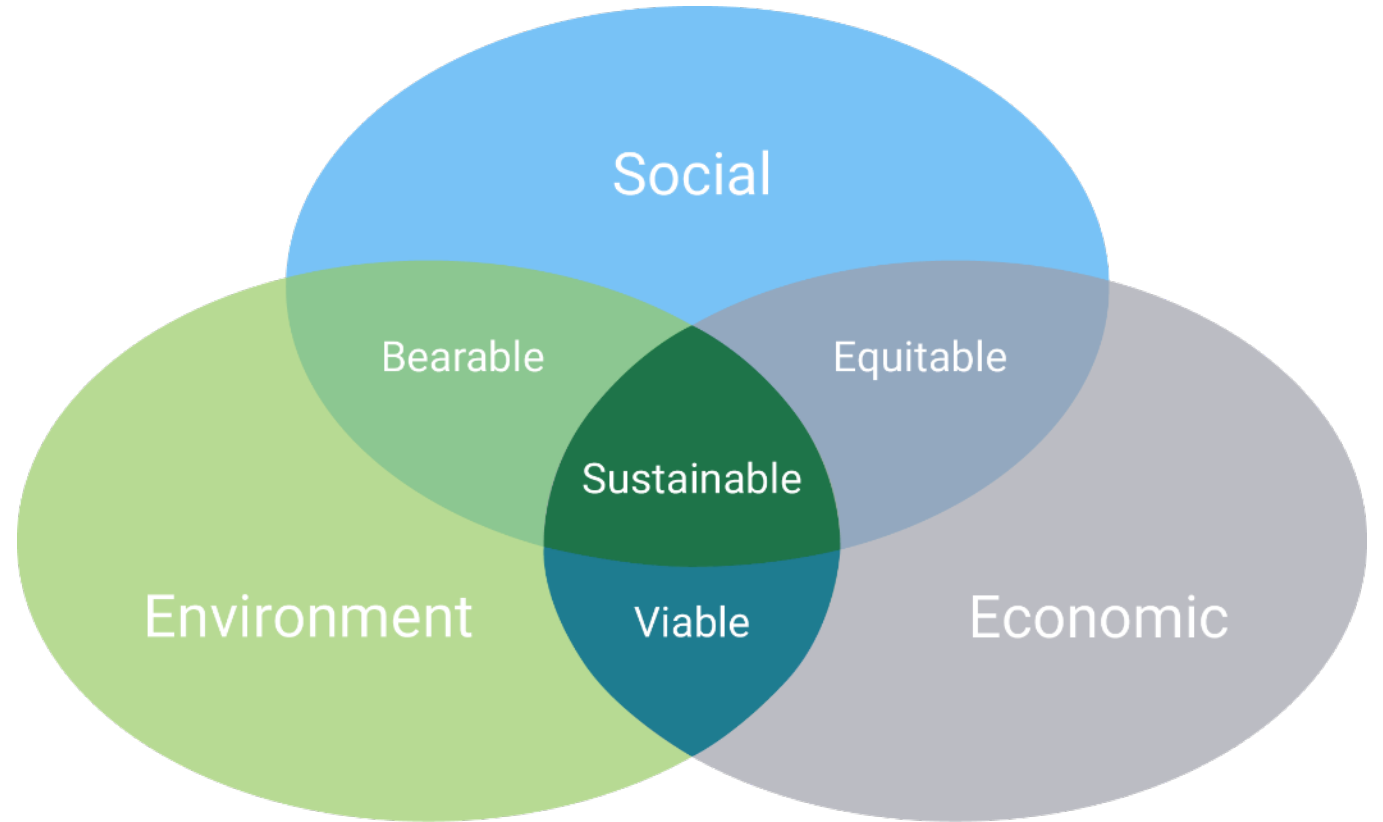
Development that meets the needs of the present without compromising the ability of future generations to meet their own needs.¹

Being sustainable really means being better.
Do less “bad” and more “good.”

Source:

1. UN Report of the World Commission on Environment and Development: Our Common Future, 1987

Triple Bottom Line



While sustainability is supposed to focus on social, environmental and financial performance, most of the attention is on the **Environmental /CO2 Aspects**

Which home is more sustainable? Which would you rather live in?



Low CO₂
No running water, no bathroom, no insulation



Higher CO₂
Running water, bathroom, insulation, higher safety, etc.

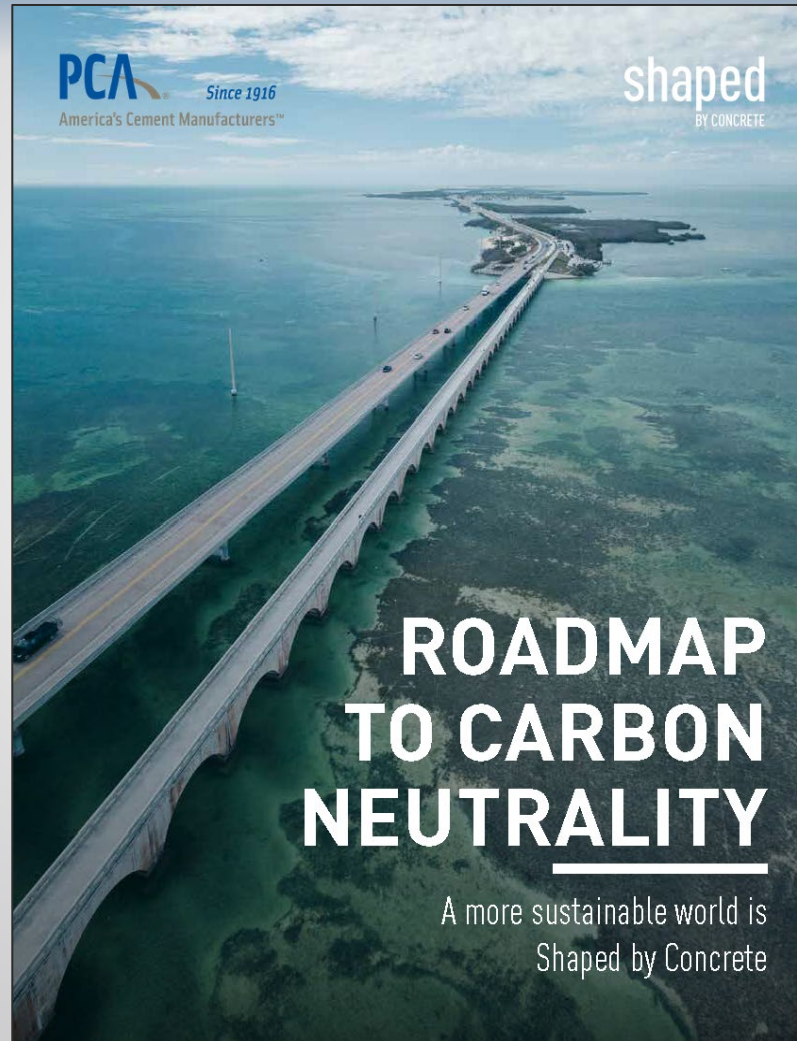
PCA ROADMAP TO CARBON NEUTRALITY

Developed in Cooperation, collaboration, coordination of the entire industry

Highlights the entire value chain based on the 5 “C’s”

- Clinker to cement
- Cement to concrete
- Concrete to construction
- Construction to carbonation
- Carbonation back to clinker

Available at
<https://www.cement.org/sustainability/roadmap-to-carbon-neutrality>



EPD use is being driven by a Combination of Regulatory Requirements, Certification Schemes, and a Growing Awareness

Federal “Buy Clean” Policies

- Executive Order 14057 - Net Zero Goal in Federal Procurement
- Inflation Reduction Act
- USDOT & General Services Administration Buy Clean Initiative
 - prioritize the use of lower-carbon construction materials

State & City “Buy Clean” Policies

- CA, CO, & OR – Legislated
- WA, MN, IL, VA, MD, NJ & DE – Considering
- Portland OR, San Francisco Bay Area, Marian County, CA, others

Green Building Certification

- LEED, BREEAM, and others require or award points for products with EPDs
- Incentivizes construction companies to ask for EPDs

Life Cycle Assessment (LCA)

- The use of LCA in the construction industry is increasing
- EPDs provide a standardized and consistent way to report results for building products.

Increased awareness

- Growing awareness of the environmental impact of construction, both in terms of operational energy use and embodied carbon.

Sustainability Goals

- Building owners / developers are increasingly setting ambitious goals,
- EPDs provide a transparent and credible way to evaluate products.

EPDs are a Business Continuity Requirement in order to Provide Transparent & Credible Information on the Environmental Performance of Building Products

**Government
Agencies are
requiring
reduced
carbon
emissions.**

California Governor commits to net-zero cement CO2 strategy by 2045

California Governor Gavin Newsom has signed a bill requiring the California Air Resources Board (CARB) to develop a plan by mid-2023 for the state's cement procedures to achieve **net zero emissions of greenhouse gases by the end of 2045**.

A **40% reduction compared to 2019** levels would also be required by the end of **2035** with interim targets set beforehand.

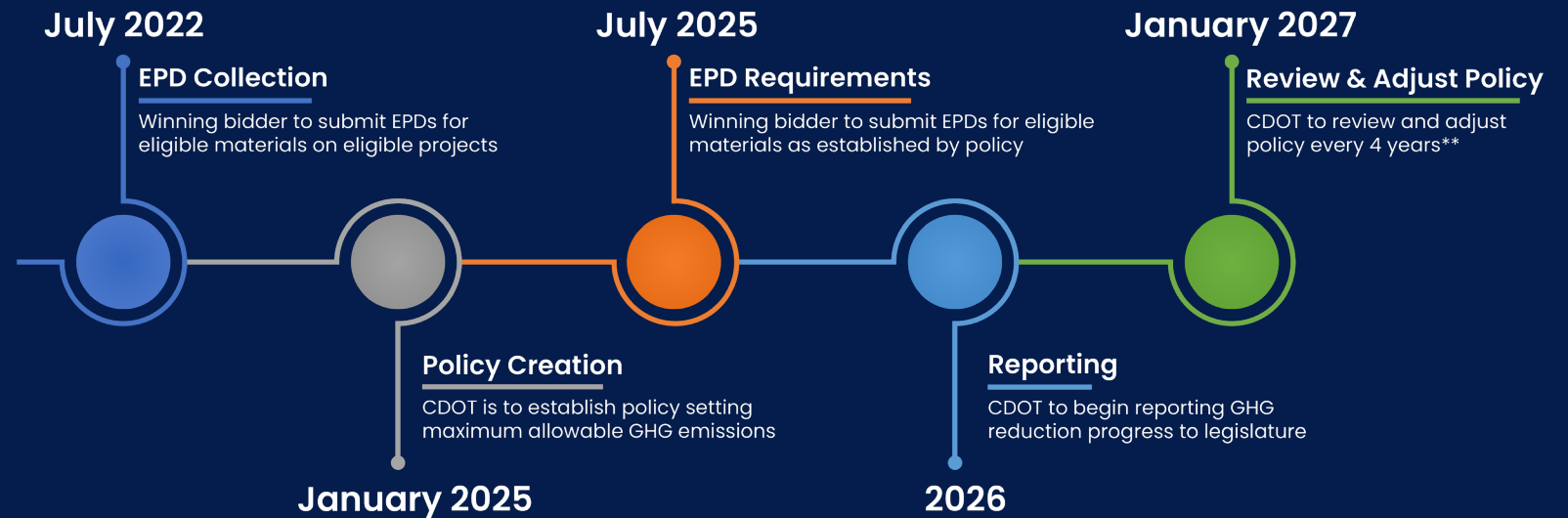
CARB will also be obliged to 'define a metric for greenhouse gas intensity,' monitor emissions data, set a baseline to measure emissions reduction progress, evaluate measures to support market demand and financial incentives to encourage the production and use of low-carbon cement amongst other actions, according to the report.

Government Agencies are requiring reduced carbon emissions.

COLORADO TO REQUIRE EPDs FOR CONSTRUCTION PRODUCTS

- Colorado legislation mandated construction materials manufacturers to label their products with their embodied carbon starting in 2025.
- The law charges CDOT with setting benchmarks for now, and then with creating policies to lower the carbon footprint of the purchased goods as much as possible, starting in 2025.

HB 21-1303 Timeline



Understanding the terms

PCR = Product Category Rules

Rules for developing product EPDs / LCAs for similar products

EPD = Environmental Product Declaration

A partial LCA of a product or material that enables comparisons between products fulfilling the same function (aka a Type III environmental declaration)

LCA = Life Cycle Assessment

Analysis technique to quantify the environmental impacts (e.g. CO₂eq) associated with all the stages of a product's life from material extraction through the end of life

Product Category Rules

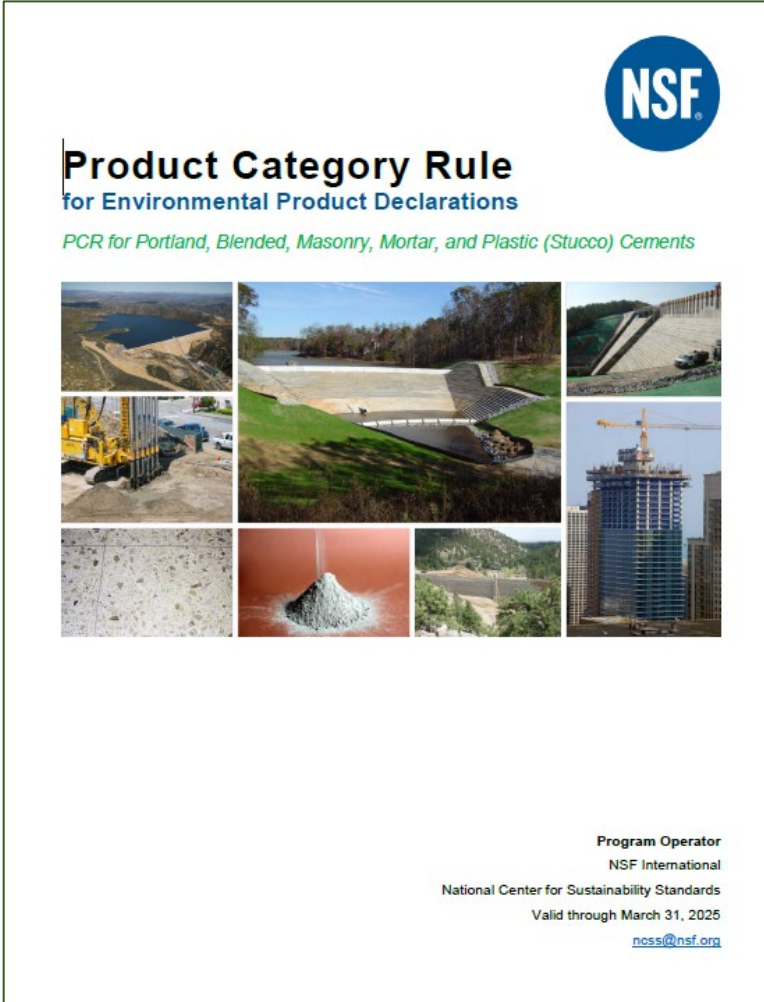
Provides the instructions for how to develop EPDs and do Life Cycle Assessment (LCA)

- Ensures data, models, system boundaries, functional units, allocation rules, etc. are compatible
- ISO 14025 establishes the procedure for developing PCRs, required content & requirements for comparability
- Enables fair comparison among products of the same category

Limited collaboration between program operators

- Different rules across PCR categories (concrete, steel, asphalt, wood, etc.) means that Global harmonization of PCR standards remains a challenge

Cement



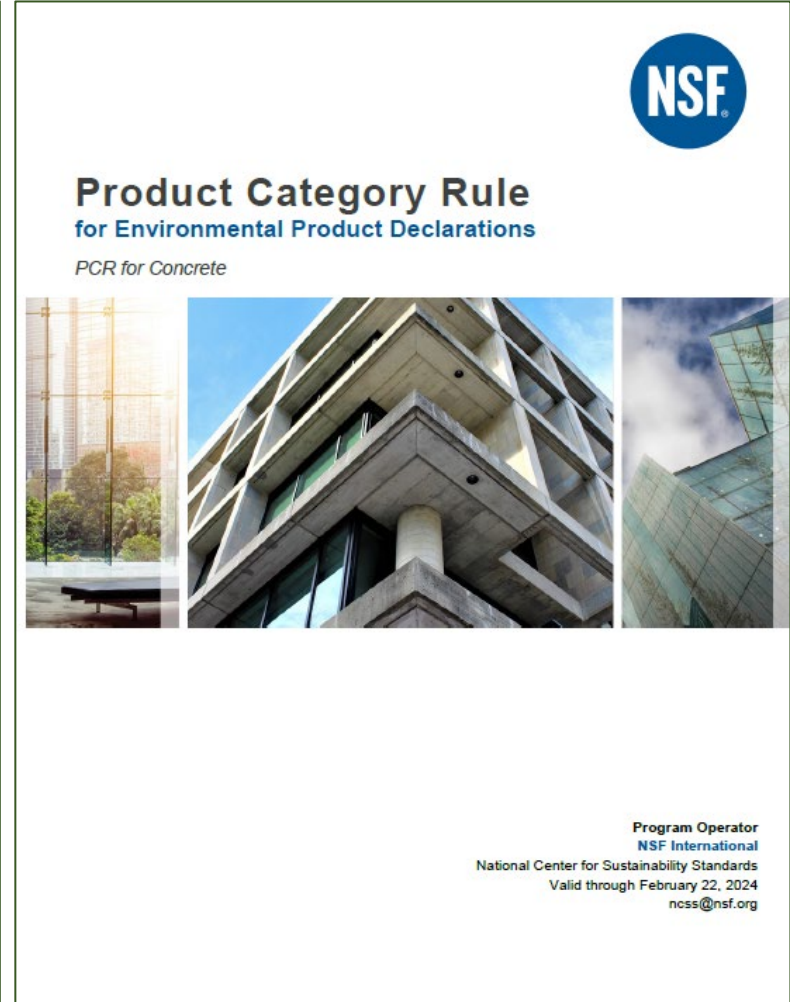
NSF

Product Category Rule
for Environmental Product Declarations

PCR for Portland, Blended, Masonry, Mortar, and Plastic (Stucco) Cements

Program Operator
NSF International
National Center for Sustainability Standards
Valid through March 31, 2025
ness@nsf.org

Concrete



NSF

Product Category Rule
for Environmental Product Declarations

PCR for Concrete

Program Operator
NSF International
National Center for Sustainability Standards
Valid through February 22, 2024
ncss@nsf.org

Environmental Product Declaration (EPD)

In general, Concrete EPDs are Plant and Mix Specific

They are NOT supply chain or Material Specific

They use the specific materials; transportation distance, energy use, etc. for that plant.

- EPD's at a specific plant are NOT component specific.
 - They do not change if the cement or other materials source changes on any given day
 - Based on the quantity of components in the mix
- EPD's are Based on the
 - weighted average of materials used +
 - weighted average of transportation distances for the materials +
 - weighted average of plant operation energy / emissions.
- Collected & based on the past 12-months of data.
- Updated on annual basis, as a minimum (can be done sooner if needed / desired)

Environmental Product Declaration EPD

Nutrition Facts	
Serving Size 1 cup Servings Per Container	
Amount Per Serving	
Calories 100	Calories from Fat 15
	% Daily Value*
Total Fat 1.5g	2%
Saturated Fat 0g	0%
Trans Fat 0g	
Cholesterol 0mg	0%
Sodium 160mg	7%
Total Carbohydrate 21g	7%
Dietary Fiber 3g	12%
Sugars 1g	
Protein 3g	
Vitamin A 15% • Vitamin C 10%	
Calcium 10% • Iron 50%	
*Percent Daily Values are based on a 2,000 calorie diet. Your daily values may be higher or lower depending on your calorie needs:	
	Calories: 2,000 2,500
Total Fat	Less than 65g 80g
Saturated Fat	Less than 20g 25g
Cholesterol	Less than 300mg 300mg
Sodium	Less than 2,400mg 2,400mg
Total Carbohydrate	300g 375g
Dietary Fiber	25g 30g
Calories per gram: Fat 9 • Carbohydrate 4 • Protein 4	



CEMEX
ENVIRONMENTAL PRODUCT DECLARATION
Mix 1618915 • Santa Clara Plant

This Environmental Product Declaration (EPD) reports the impacts for 1 m³ of ready mixed concrete mix, meeting the following specifications:

- ASTM C94: Ready-Mixed Concrete
- UNSPSC Code 30111505: Ready Mix Concrete
- CSA A23.1/A23.2: Concrete Materials and Methods of Concrete Construction
- CSI Division 03-30-00: Cast-In-Place Concrete

COMPANY
CEMEX
10100 Katy Freeway, Suite 300
Houston, TX 77043

PLANT
Santa Clara Plant
1555 Russell Avenue
Santa Clara, CA 95054

EPD PROGRAM OPERATOR
ASTM International
100 Barr Harbor Drive
West Conshohocken, PA 19428

DATE OF ISSUE
12/03/2020 (valid for 5 years until 12/03/2025)

ENVIRONMENTAL IMPACTS

Declared Product:
Mix 1618915 • Santa Clara Plant
A4GRC 658 C+S 30% BL AIR WR
Compressive strength: 5000 PSI at 28 days

Declared Unit: 1 m³ of concrete

Global Warming Potential (kg CO ₂ -eq)	392
Ozone Depletion Potential (kg CFC-11-eq)	1.1E-5
Acidification Potential (kg SO ₂ -eq)	2.06
Eutrophication Potential (kg N-eq)	0.46
Photochemical Ozone Creation Potential (kg O ₃ -eq)	45.5
Abiotic Depletion, non-fossil (kg Sb-eq)	1.4E-6
Abiotic Depletion, fossil (MJ)	695
Total Waste Disposed (kg)	2.71
Consumption of Freshwater (m ³)	1.01

Product Components: crushed aggregate (ASTM C33), natural aggregate (ASTM C33), Portland cement (ASTM C150), slag cement (ASTM C989), batch water (ASTM C1602), admixture (ASTM C494), admixture (ASTM C260)

Global Warming Potential (kg CO₂-eq) 392

An Environmental Product Declaration (EPD) is analogous to a Nutrition Facts food label

An EPD is developed using a LCA process and each EPD is an independently verified & registered document that communicates the life-cycle environmental impact of a product

While an EPD is analogous to a Nutrition Facts Food Label it does not give the final impact

Nutrition Facts	
Serving Size 1 cup	
Servings Per Container	
Amount Per Serving	
Calories 100	Calories from Fat 15
% Daily Value*	
Total Fat 1.5g	2%
Saturated Fat 0g	0%
Trans Fat 0g	
Cholesterol 0mg	0%
Sodium 160mg	7%
Total Carbohydrate 21g	7%
Dietary Fiber 3g	12%
Sugars 1g	
Protein 3g	
Vitamin A 15%	• Vitamin C 10%
Calcium 10%	• Iron 50%
*Percent Daily Values are based on a 2,000 calorie diet. Your daily values may be higher or lower depending on your calorie needs:	
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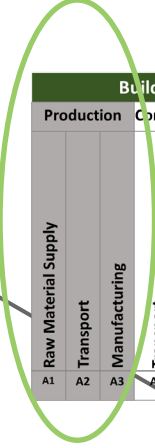
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Building and Infrastructure Life Cycle Assessment Stages																
Production	Construction			Use					End-of-Life		Beyond					
Raw Material Supply	Transport	Manufacturing	Transport	Construction / Installation	Use	Maintenance	Repair	Replacement	Refurbishment	Operational Energy Use	Operational Water Use	De-construction/Demolition	Transport	Waster Processing	Disposal	Credit for Reuse, Recycling & Recovery Potential
A1	A2	A3	A4	A5	B1	B2	B3	B4	B5	B6	B7	C1	C2	C3	C4	D



A concrete EPD provides the upstream environmental impact (i.e. “cradle to gate”) information in order to do a full LCA (i.e. cradle-to-grave) of the building or infrastructure project

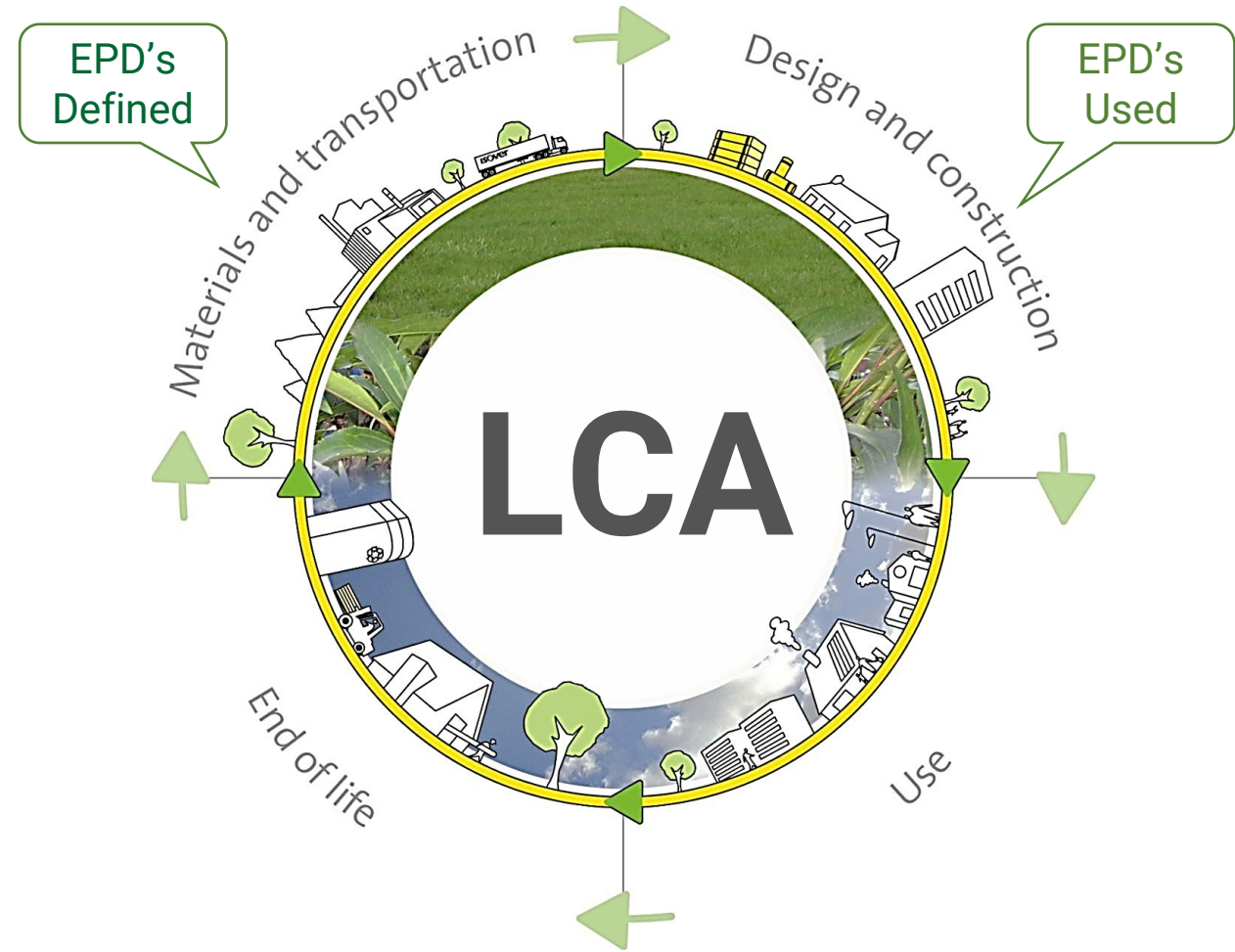
Environmental Product Declaration (EPD)

EPDs of the different materials are used to build the LCA of the final product (building, pavement, etc.)

- Cement EPD \Rightarrow Concrete's EPD
- Concrete's EPD \Rightarrow Element GWP (e.g. Column)
- Σ Element GWPs = embodied GWP of the final building / project

Comparisons must be made on a full product LCA that includes:

- Materials
- Construction
- Use
- End of Life



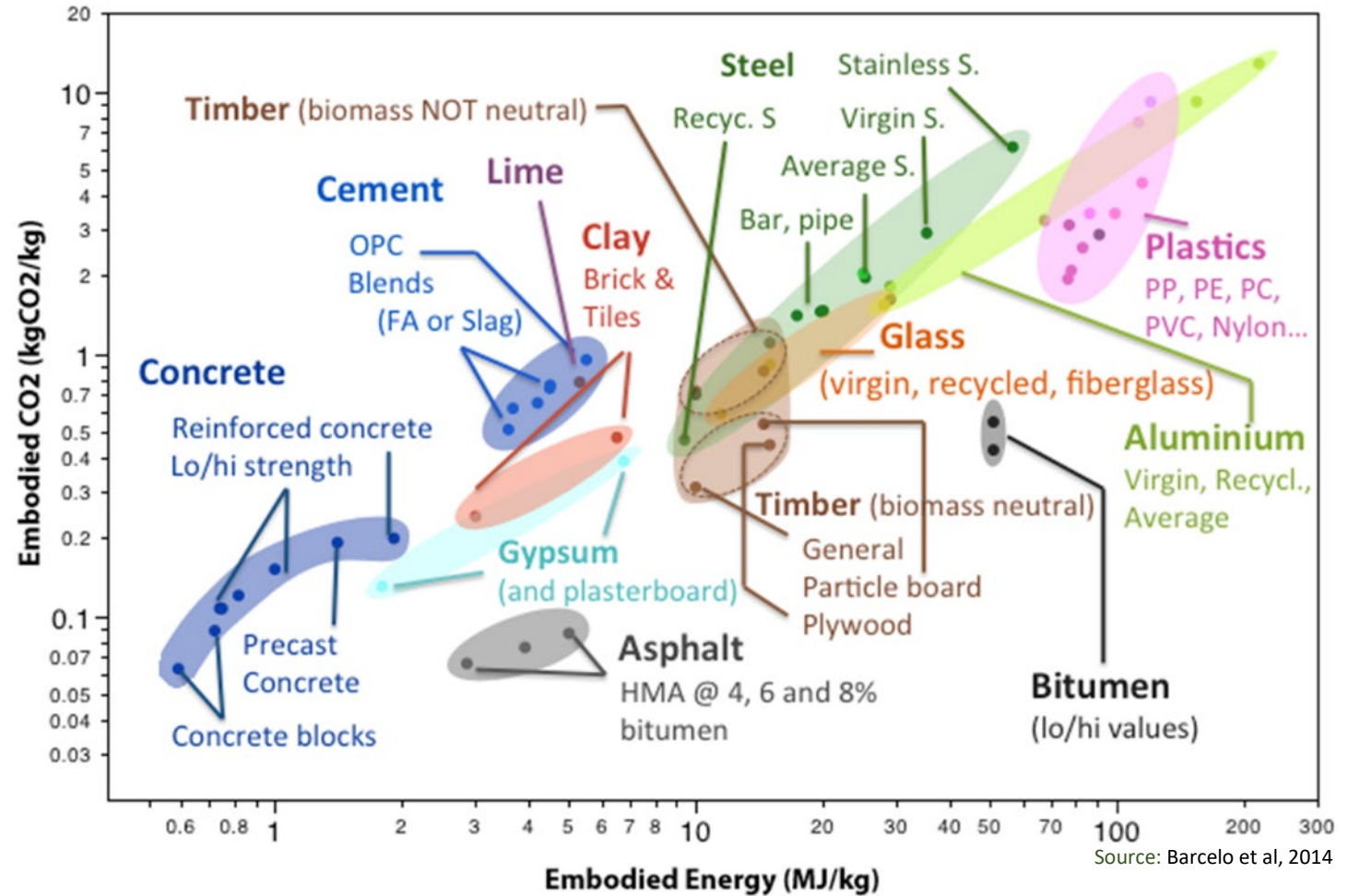
To improve sustainability, use LCA in an iterative manner to balance trade-offs in the final product. Ensures the lowest lifetime impacts of the alternatives being considered

Why Portland Limestone Cement (PLC)

CO₂ Emissions

While Concrete's total CO₂ level is high, its Embodied CO₂ and Embodied Energy (per unit basis) are low compared to other materials.

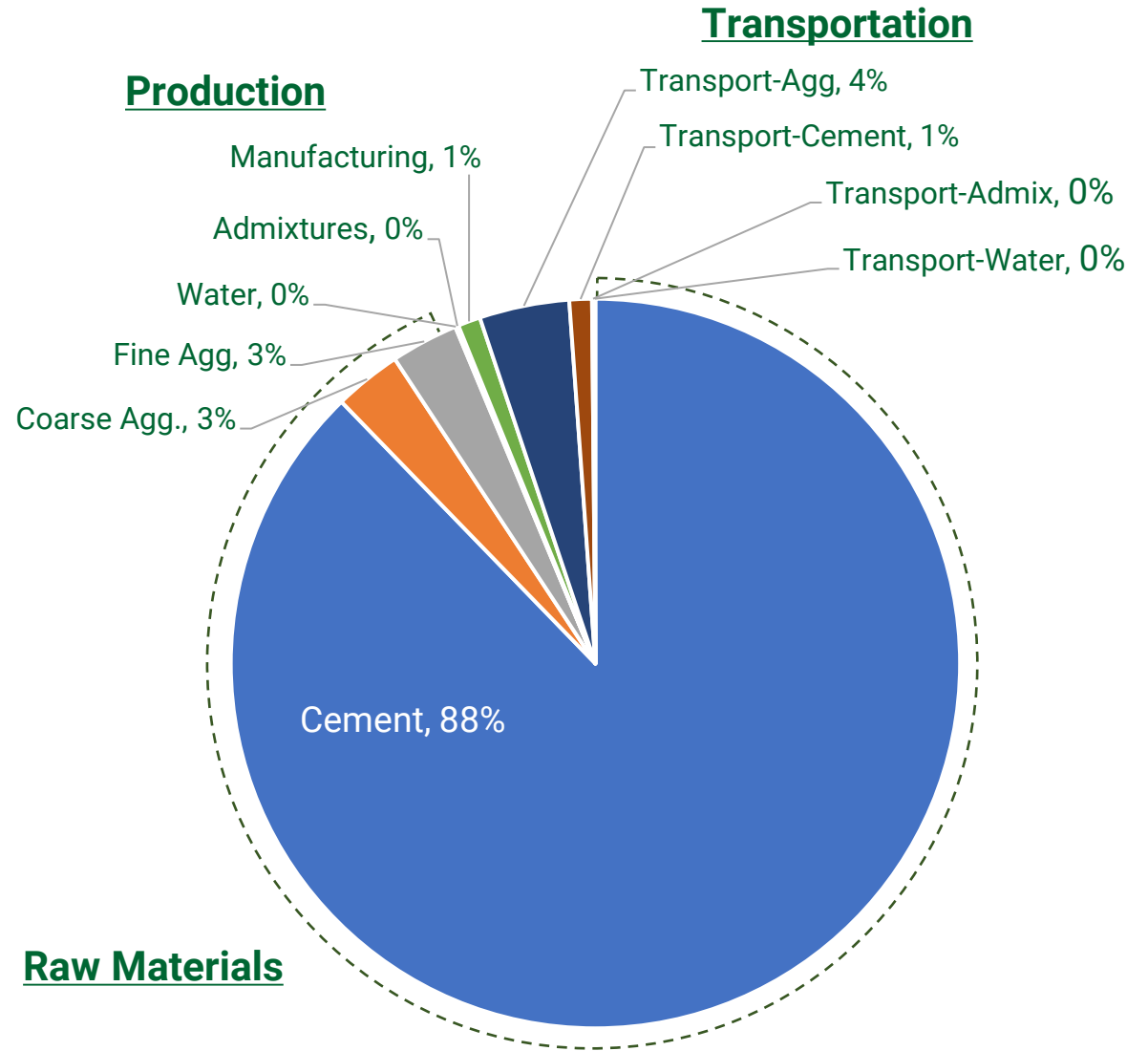
Materials used in the construction industry



Concrete will continue to play a critical role in a low-carbon economy. There are no substitutes for its cost effectiveness, strength & resilience.

Many Items Impact a Concrete's Carbon Footprint

CO₂ footprint from Cement ~75 to 90% of GWP



Levers to Reduce Concrete CO₂

- **Use of Type IL cement**

Type IL cement is a Portland-limestone cement containing more than 5% but less than or equal to 15% by mass of limestone

- **Supplementary Cementitious Materials (SCMs)**

Fly Ash, Slag, other pozzolans to reduce the amount of cement in the concrete

- **Alternative & Blended Cements / Clinkers**

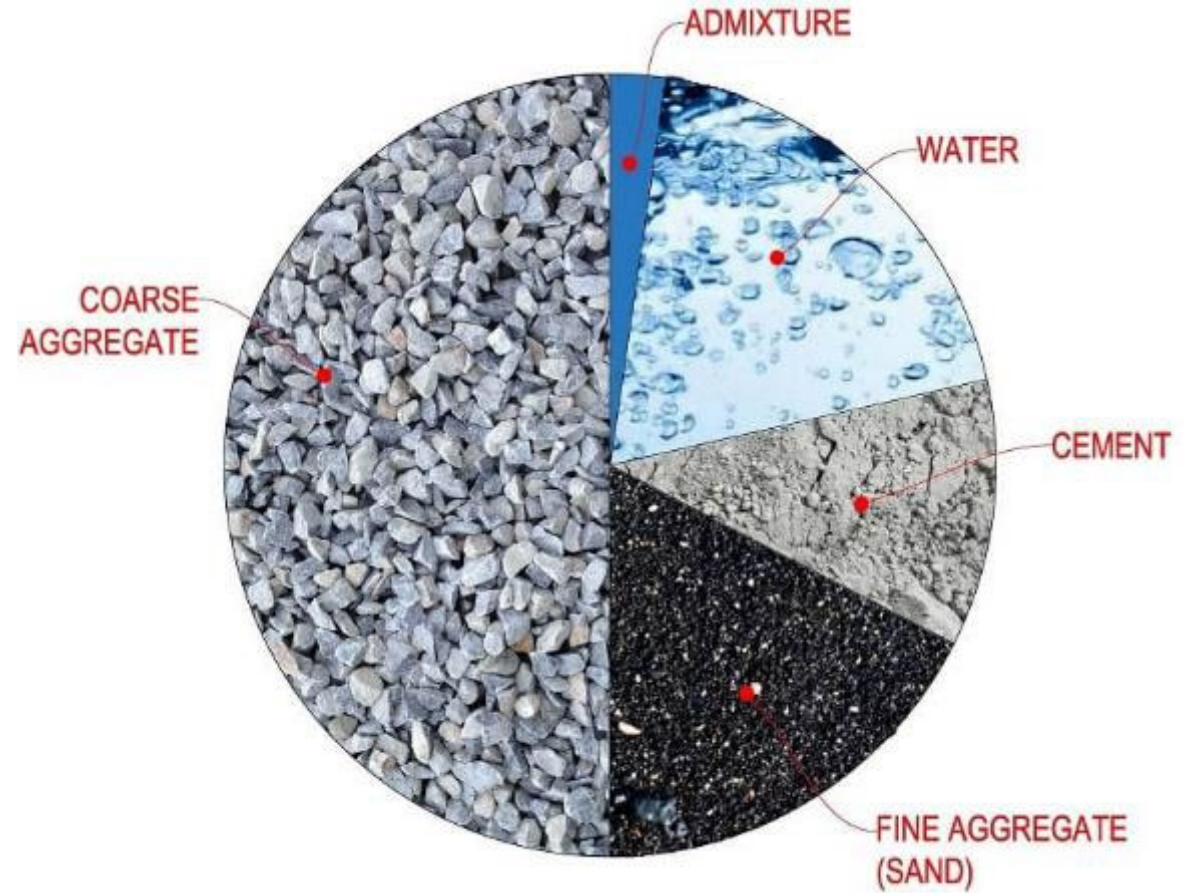
The use of low CO₂ clinker and blended cements

- **Aggregate Optimization**

Use Well Graded Mixes to reduce paste and improve workability & durability

- **Carbon Capture Utilization & Storage**

Technologies to capture & store CO₂ emissions (e.g. underground, concrete, aggregates, etc.)



Optimizing concrete mixes using these tools allows the Industry to create low carbon ready-mix concrete

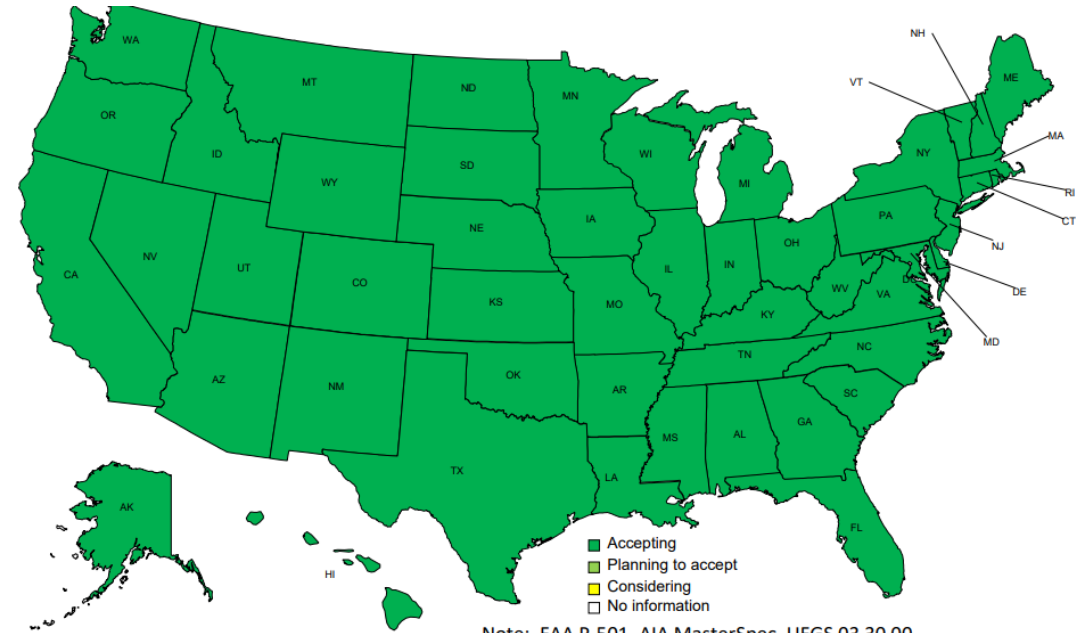
Type 1L / Portland Limestone Cement (PLC)

A Greener Cement Option

- A blended cement with additional limestone content
 - ASTM C595 / AASHTO M240 allows 5%-15%
 - Most producers use 10%-12% addition rate
- Carbon reduction ~ 7%
- Designed to perform equal to Ordinary Portland Cement (OPC)
 - PLC is ground finer
 - Water demand may be slightly higher
 - Early strengths may be higher
 - Set time should be equal
 - Color is slightly lighter
- Suitable for all applications

State DOT Acceptance of Portland-Limestone Cement

Tentative Data: February 2024



Note: FAA P-501, AIA MasterSpec, UFGS 03 30 00, and ACI and ICC building codes permit use of PLC



<https://www.greencement.com>

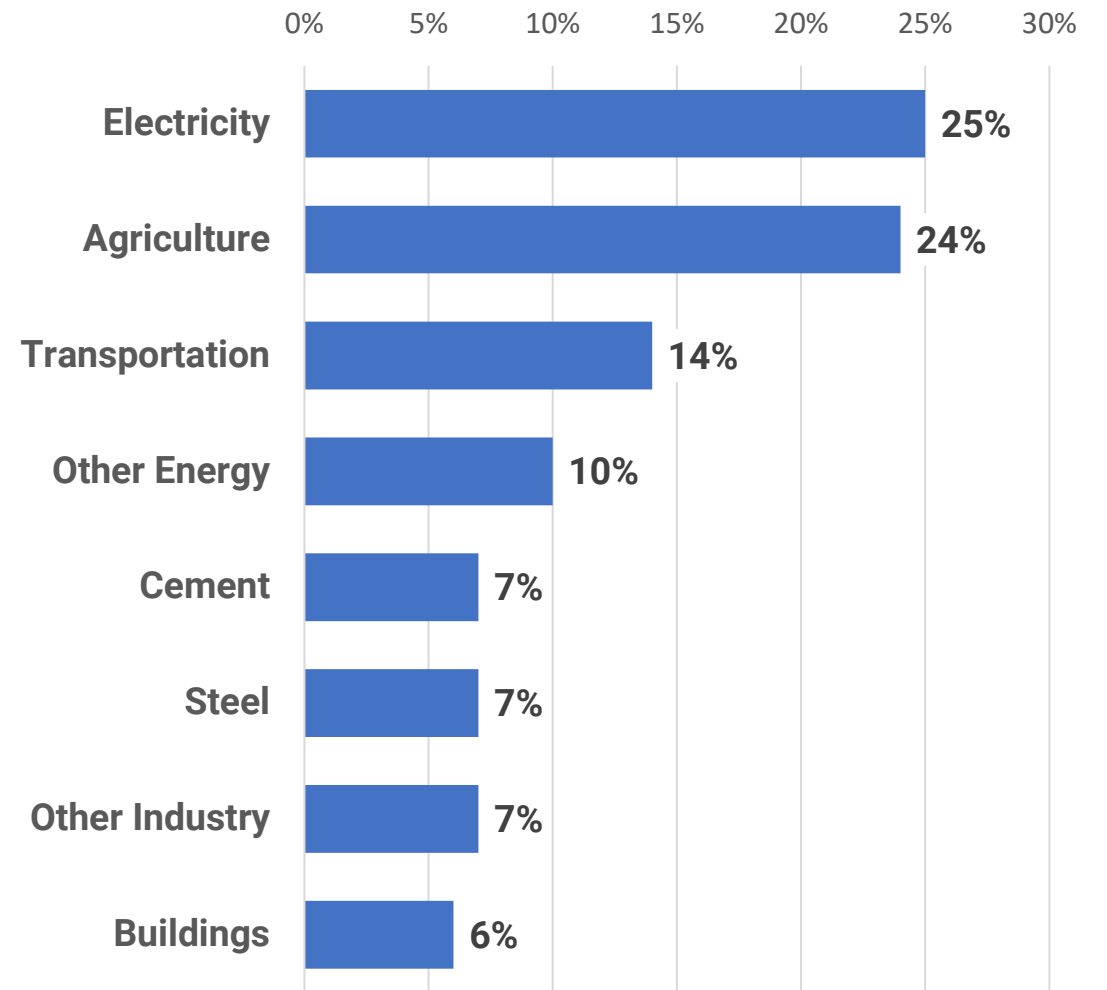
Type 1L / Portland Limestone Cement (PLC)

A Greener Cement Option

Why Should (and why are) Cement Manufacturers Producing PLC?

The cement / concrete industry is one of the larger contributors of CO2 emissions and is under tremendous pressure to become more environmentally friendly.

% CO2 Emissions by Sector



Use Supplementary Cementitious Materials

- **Fly Ash**
Fine powder retrieved from the dust-control systems of electric power plants burning coal and lignite
- **GGBFS (Slag)**
A by-product of the production of iron, requires grinding
- **Silica Fume**
A by-product of silicon and ferrosilicon industries
- **Natural Pozzolans**
Natural clay, calcined clay, calcined shale and metakaolin, requires grinding



Benefits

- Recycled industrial waste (reduction)
- Reduce CO2 Emissions
- Increase long term strength
- Mitigate ASR
- Increase durability
- Reduce heat of hydration
- Lower cost

Global Warming Potential (GWP) of Cementitious Materials, Metric Ton

- **CEMENT – 2016***: 1044 kg CO2-eq
- **CEMENT – 2021***: 922 kg CO2-eq

- **Ty 1L Cement – 2021**: 846 kg CO2-eq

- **GGBFS (Slag)**: 146 kg CO2-eq

- **FLY ASH**: 0 kg CO2-eq

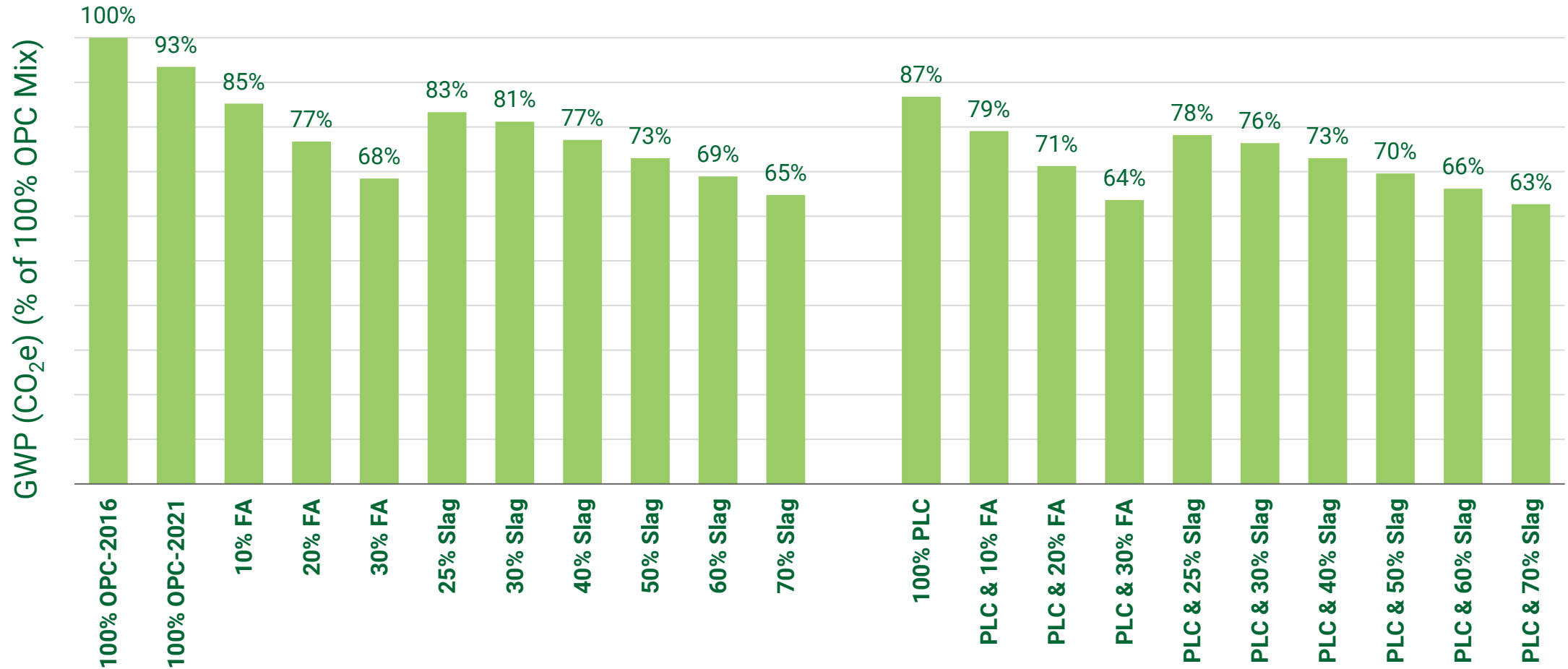
- **Plus, transportation to the RMX plants** – including truck, rail, marine or a combination of all three.



* Base = US Default Industry Average for Portland Cement, Portland Cement Assn, 2016

** Vertua Mixes based of US Default Industry Average for Portland Cement, Portland Cement Assn, 2021 or plant specific data

Use of Supplementary Cementitious Materials lowers CO₂ of the mix Using Portland Limestone Cements lowers the CO₂ impacts some more

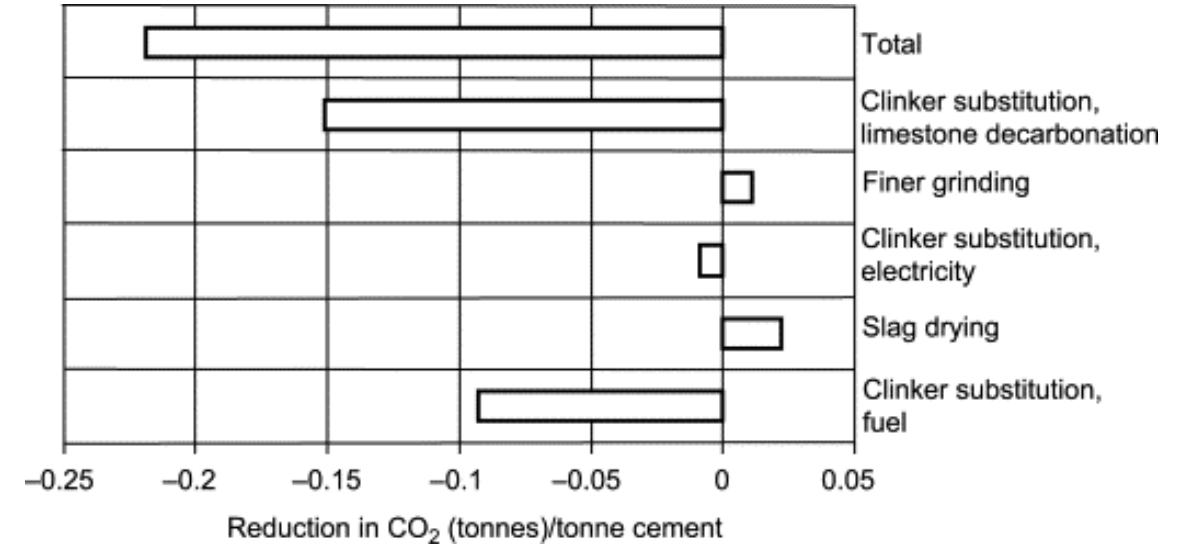


Other Blended Cements

- **Blended cements are cements where part of the clinker is substituted with other materials.**
 - Granulated slag
 - Fly ash
 - Uncalcined limestone.
- **Blended hydraulic cements must conform to the requirements of ASTM C595 (or AASHTO M 240)**
 - Type IL, Portland-limestone cement
 - Type IP, Portland-pozzolan cement
 - Type IS, Portland blast-furnace slag cement
 - Type IT, Ternary blended cement
- **Blended cements are used in all aspects of concrete construction in the same manner as Portland cements.**

Changes in CO₂ emissions from producing a blended cement.

The example is for CEM IVB-S 32.5 cement with 35% granulated slag
(Eco serve Network, 2004a).

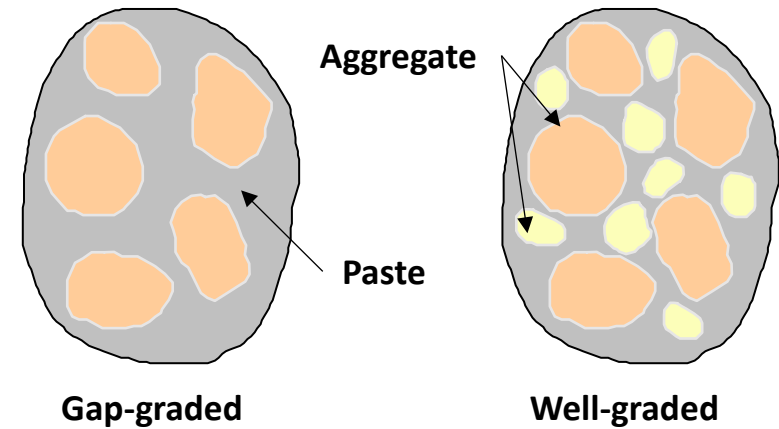


The difference between concrete with blended cements & concrete with SCM's is where the SCM is added

In the USA – use OPC and add SCM at RMix plant
Rest of the world – Add SCM at the Cement Plant

Aggregate Optimization

- Historically most concrete's use a "Gap-graded" mixes
- Well graded mixes reduce the paste content:
 - Lower cement contents (~ +/- 10%)
 - Reduced water demand
 - Decreased shrinkage
 - Increased concrete density
 - Improves durability
 - Improves workability
 - Improved response / flow due to vibration



Vertua[®]
Low carbon by design

Vertua[®] is a family of low-carbon concretes, each offering incrementally greater levels of CO₂ reduction compared to 100% ordinary Portland cement-based mix.

Vertua[®] | classic
Low carbon by design
30-49% reduction

Vertua[®] | plus
Low carbon by design
50-69% reduction

Vertua[®] | ultra
Low carbon by design
>70% reduction

Many cement & concrete companies are developing low CO2 cement & concrete products

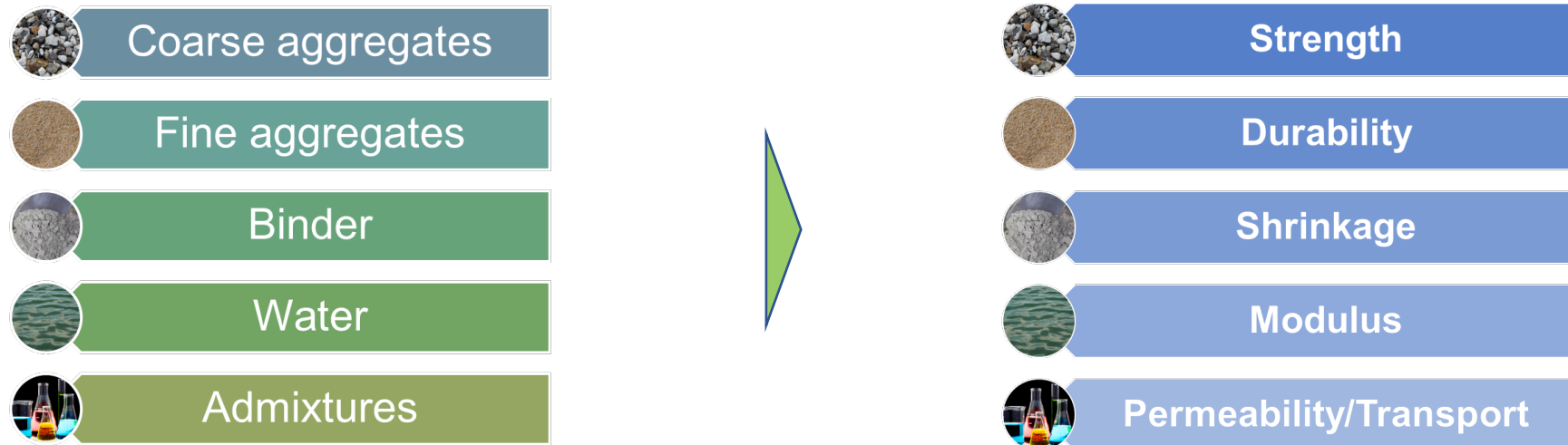
Lehigh Hanson
HEIDELBERGCEMENT Group



Performance-based specifications are the best way to spur innovation in low-impact concrete

Optimize concrete mixtures to meet performance specifications for cost and environmental impact targets

- Design multiple concrete mixtures that meet performance specifications



Transitioning to performance-based specifications requires collaboration to share planning and risk among all stakeholders (architects, engineers, owners, DOTs, etc.)

Expected Cement Production Evolution

Current

ASTM C 150

TY I
TY I / II
TY II/V
TY III

Short Term

0-2 years

ASTM C 595

TY IL – Limestone
Cement

Long Term

4-10 years

ASTM C 595

TY 1P – Pozzolan Cement
TY 1S – Slag Cement
TY IT – Ternary Blends

- Pozzolan + LS
- Slag + LS

We are moving to a market where SCM will be blended at the cement plant instead of Ready Mix Plant

Cement & Concrete are not the end products

Cement is used to make concrete.

Concrete is used to make the:

- Homes
- Buildings
- Hospitals
- Schools
- Bridges, pavements and other infrastructure
- Water treatment plants
- Etc.

...that make our lives & society better.



Q&A