Slag Cement's Role in Sustainable Concrete

Slag School April 21, 2025
Houston, TX
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Heidelberg Materials

SCA
SLAG CEMENT ASSOCIATION

Sustainability Basics

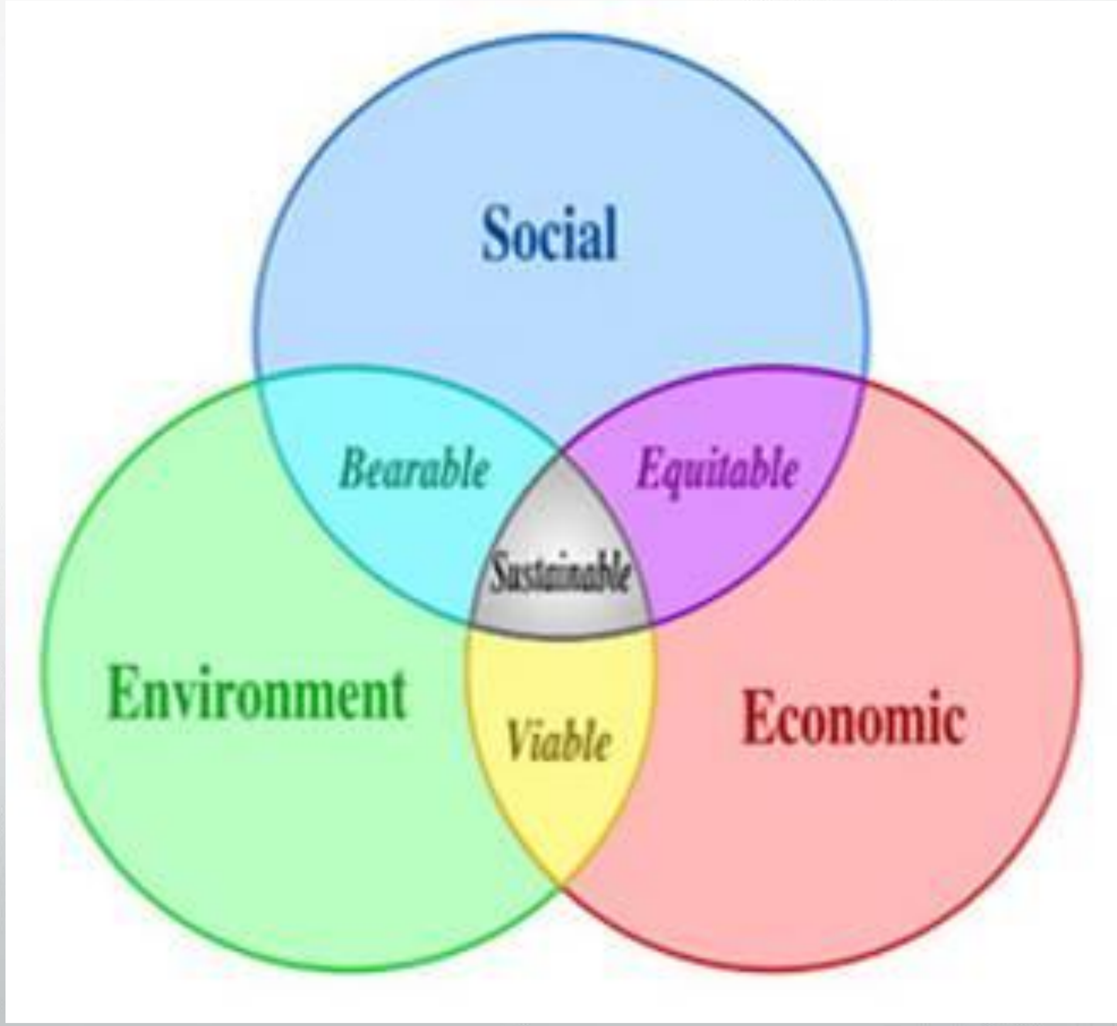
"We do not inherit the earth from our ancestors; we borrow it from our children"

Wendell Berry

The Triple-Bottom-Line

- Social
- Environmental
- Economic

… Sustainability is in the Overlap



Architectural &Engineering community were early adopters

Construction Practices & Building Design in…

- Material Impacts
- Health and Safety
- Resilience and Durability
- Longevity / Service Life
- Energy Performance
- Suitability for use

… Each Impact the Environment & Communities

Concrete meets sustainable criteria and is world's material of choice

After Water, Concrete is the Most Used Material on Earth

"Each year more than three tons of concrete are made and used for every person on the Globe…"

Over 20 billion tons/year

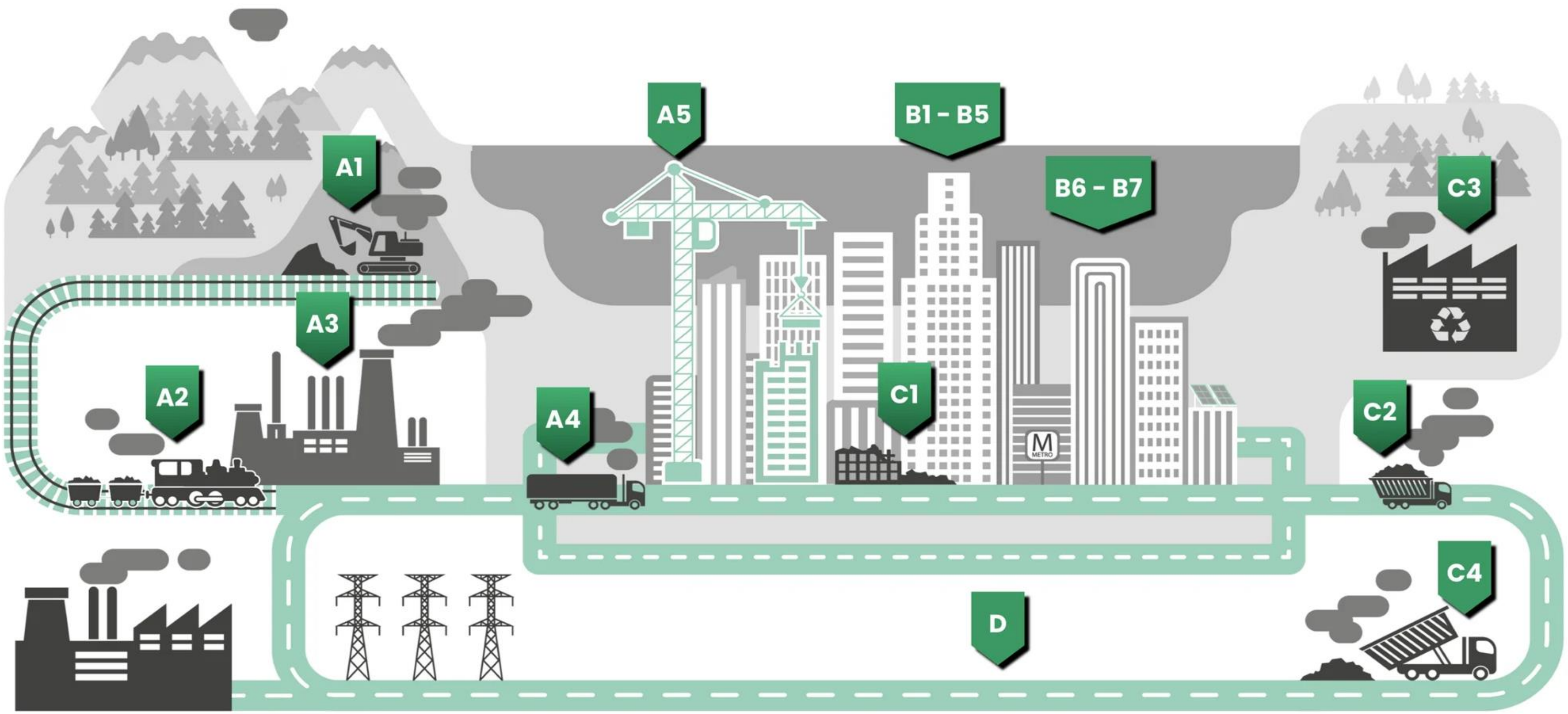
Demand is growing we are seeing

- 40% +/- increase in building construction
- Building stock will double in 30-years
- To add 280 billion square feet by 2040

What makes a material more or less sustainable?

- Sustainable Constituents — LCA Production Module **A1**
- CO_2 / Energy Efficient Production — LCA Production Module A3
- Durability and Resilience — LCA Use Stage, Modules B1 – B5
- Long Service Life, Easily Recycled — LCA Use Modules **B1 – B5** & *End of Use Stages*, Module **C1-C4**

Life Cycle Assessments (LCA)



A1 - A3 Product stage

- **A1** Raw material extraction
- **A2** Transport to manufacturing site
- **A3** Manufacturing

A4 - A5 Construction stage

- **A4** Transport to construction site
- **A5** Installation / Assembly

B1 - B5 Use stage

- **B1** Use
- **B2** Maintenance
- **B3** Repair
- **B4** Replacement
- **B5** Refurbishment
- **B6** Operational energy use
- **B7** Operational water use

C1 - C4 End of life stage

- **C1** Deconstruction & demolition
- **C2** Transport
- **C3** Waste processing
- **C4** Disposal

D - Benefits and loads beyond system boundary

Reuse, recovery and/or recycling potentials, expressed as net impacts and benefits

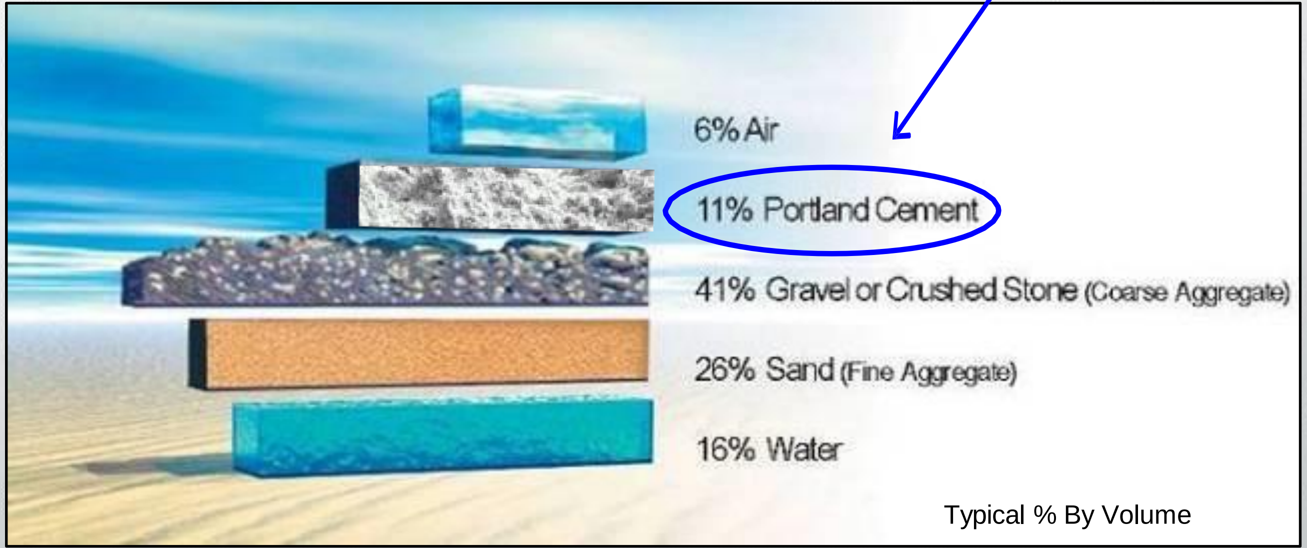
https://oneclicklca.com/en-us/resources/articles/life-cycle-assessment-examples-and-lca-defined/

Common Elements = Sustainable Material

Concrete uses common elements

- Rock aka coarse aggregate
- Sand aka fine aggregate
- Cement as a binder
- Optional SCMs
- Water
- Admixtures

Cement and Supplementary Cementitious Materials hold concrete together & give strength



Constituent Materials - Aggregate

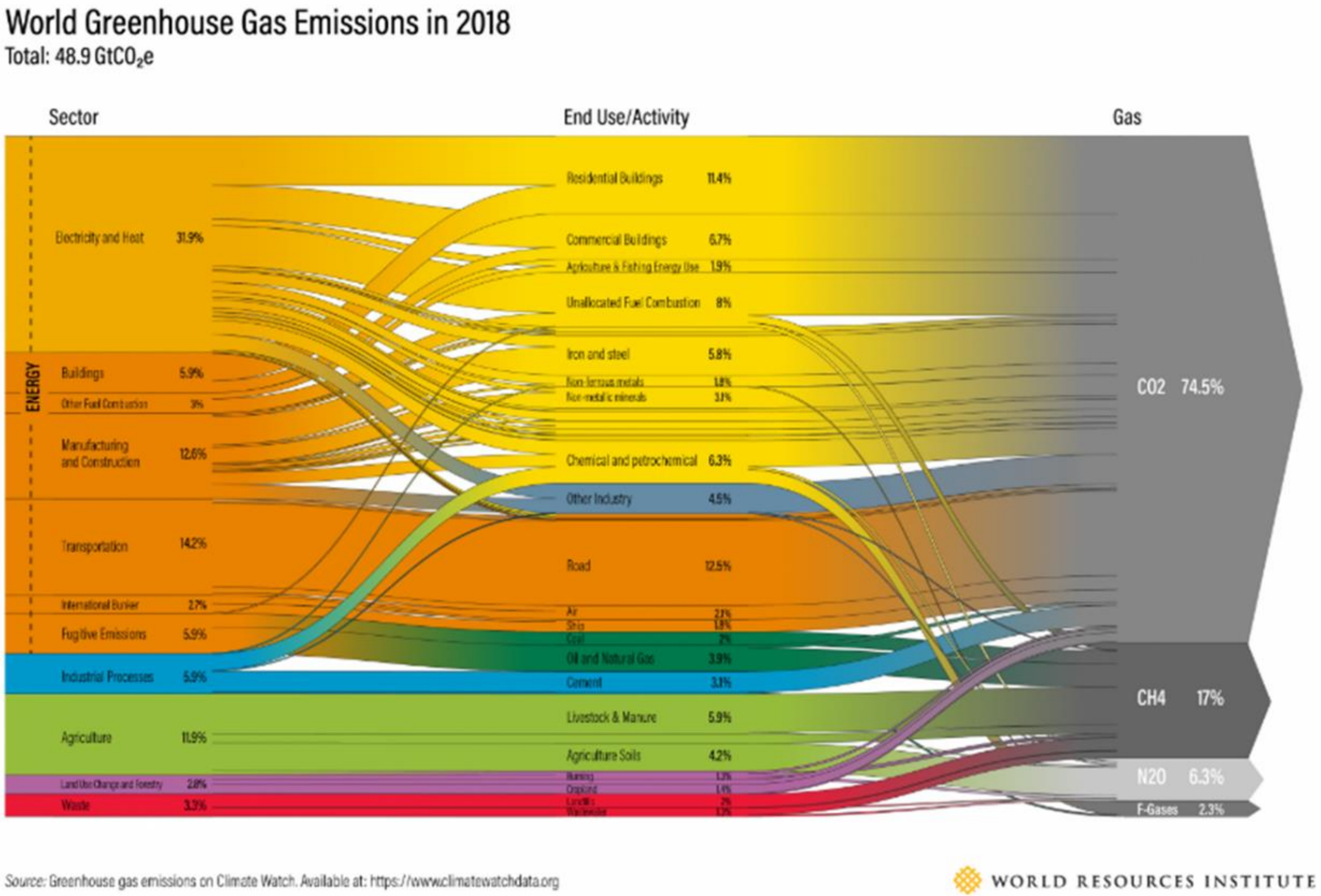
~ 2/3 of the Concrete Mix

- Low Embodied Energy
- Little or No Mining Waste
- Easily Recycled
- Durable
- Local

Constituent Materials – Portland Cement

- Embodied Energy
  - Fossil Fuel Combustion
- Concrete's primary CO_2 source
  - ~ 60% from Calcining $CaCO_3 \rightarrow CaO + CO_2(g)$
  - ~ 40% from Fuel Combustion & Electrical
- With No Supplementary Cementitious Materials…
  Cement Can Represent 96% of Total Emissions

Global CO_2 emissions from cement



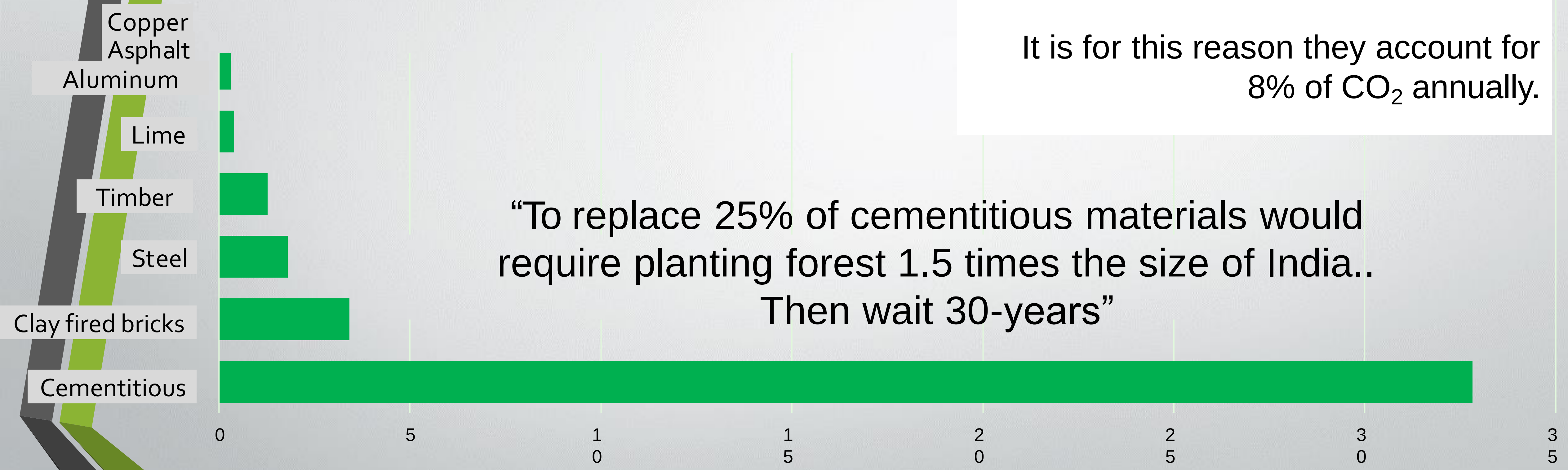
Cement's Impacts Well Documented

- Cement global GHG ~ 8% of CO_2
- Large emissions source globally
- Target due to high profile industry
- Carbon intensive process

Global CO_2 emissions from cement

Cementitious materials make up >50% of everything we produce.

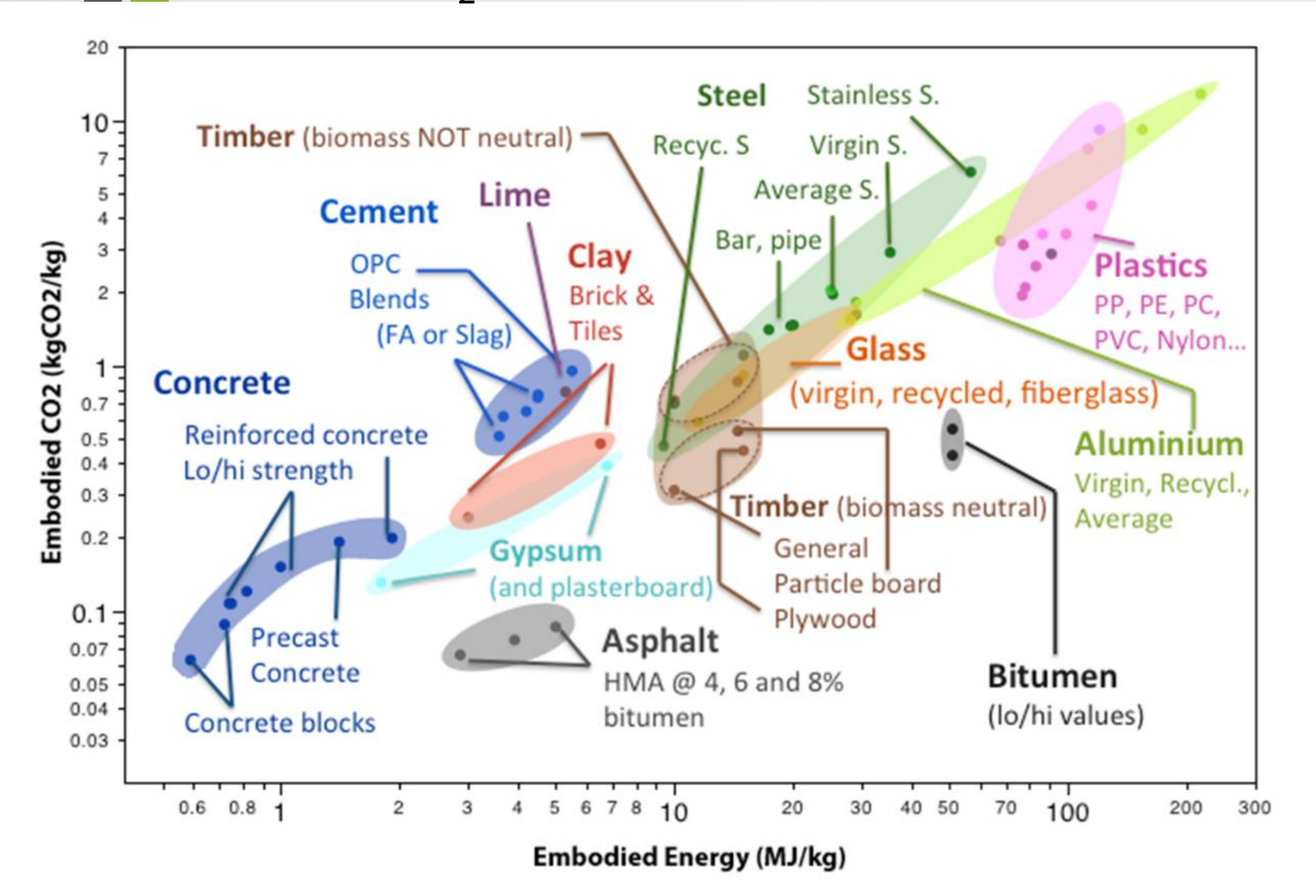
It is for this reason they account for 8% of CO_2 annually.



"To replace 25% of cementitious materials would require planting forest 1.5 times the size of India.. Then wait 30-years"

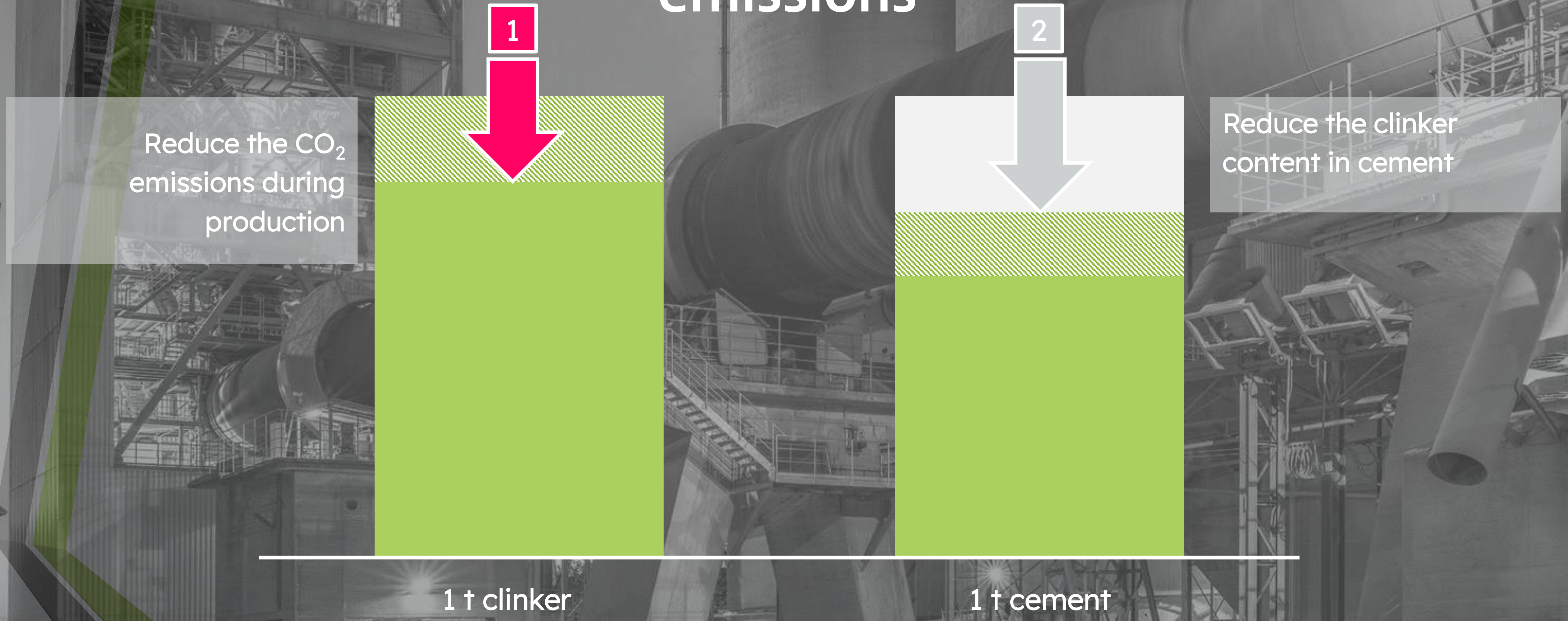
Slide adapted from LC3 presentation 3.31.2023 by Prof. Karen Scrivener

Global CO_2 emissions from cement

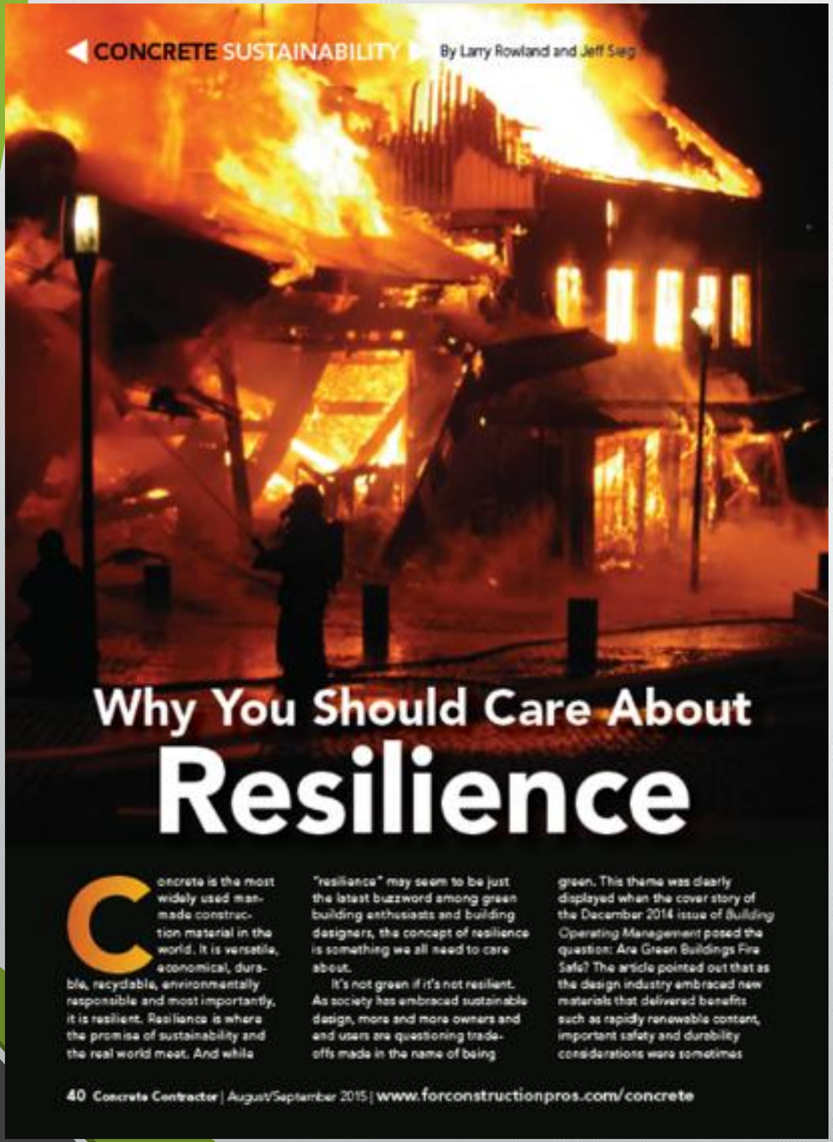


- Cement is a very sustainable material with relatively low environmental impacts.
- Concrete is the global sustainable building material of choice.

Two fundamental approaches for minimising the CO_2 emissions



Concrete is Resilient


CONCRETE SUSTAINABILITY By Larry Rowland and Jeff Sieg

Why You Should Care About

Resilience

Concrete is the most widely used man-made construction material in the world. It is versatile, economical, durable, recyclable, environmentally responsible and most importantly, it is resilient. Resilience is where the promise of sustainability and the real world meet. And while "resilience" may seem to be just the latest buzzword among green building enthusiasts and building designers, the concept of resilience is something we all need to care about.

It's not green if it's not resilient. As society has embraced sustainable design, more and more owners and end users are questioning trade-offs made in the name of being green. This theme was clearly displayed when the cover story of the December 2014 issue of *Building Operating Management* posed the question: Are Green Buildings Fire Safe? The article pointed out that as the design industry embraced new materials that delivered benefits such as rapidly renewable content, important safety and durability considerations were sometimes

40 Concrete Contractor | August/September 2015 | www.forconstructionpros.com/concrete

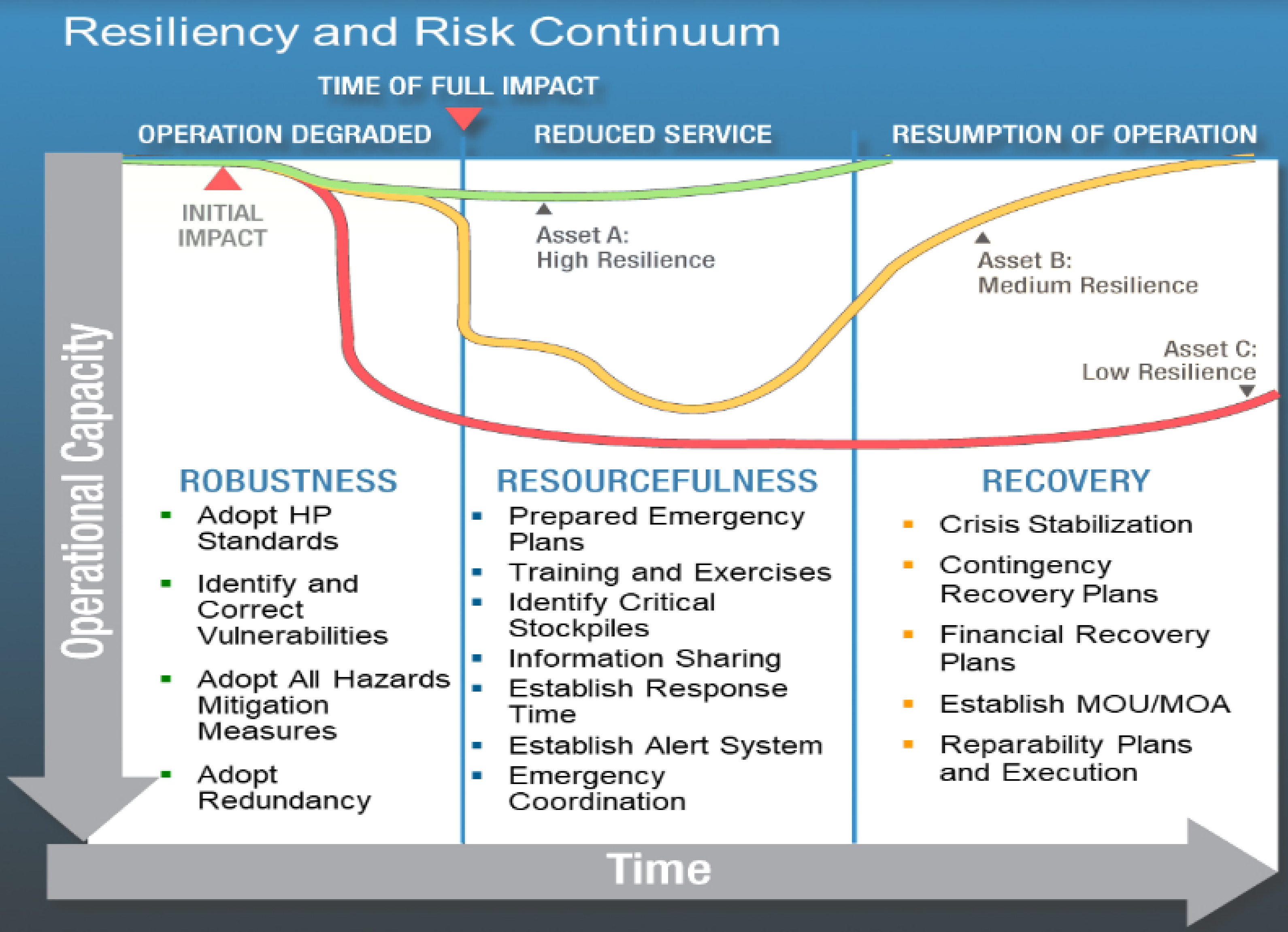
What do you want your home to be made of?

- Will it burn?
- Does it provide passive resistance to file?
- Is it pressurized water dependent
- Will it rot or be eaten by insects or mold?
- Will it blow away?
- Is it worth the risk?

HP Resilience Program Overview

Infrastructure resilience is the ability to reduce the effects of the magnitude and duration of disruptive events on the physical environment

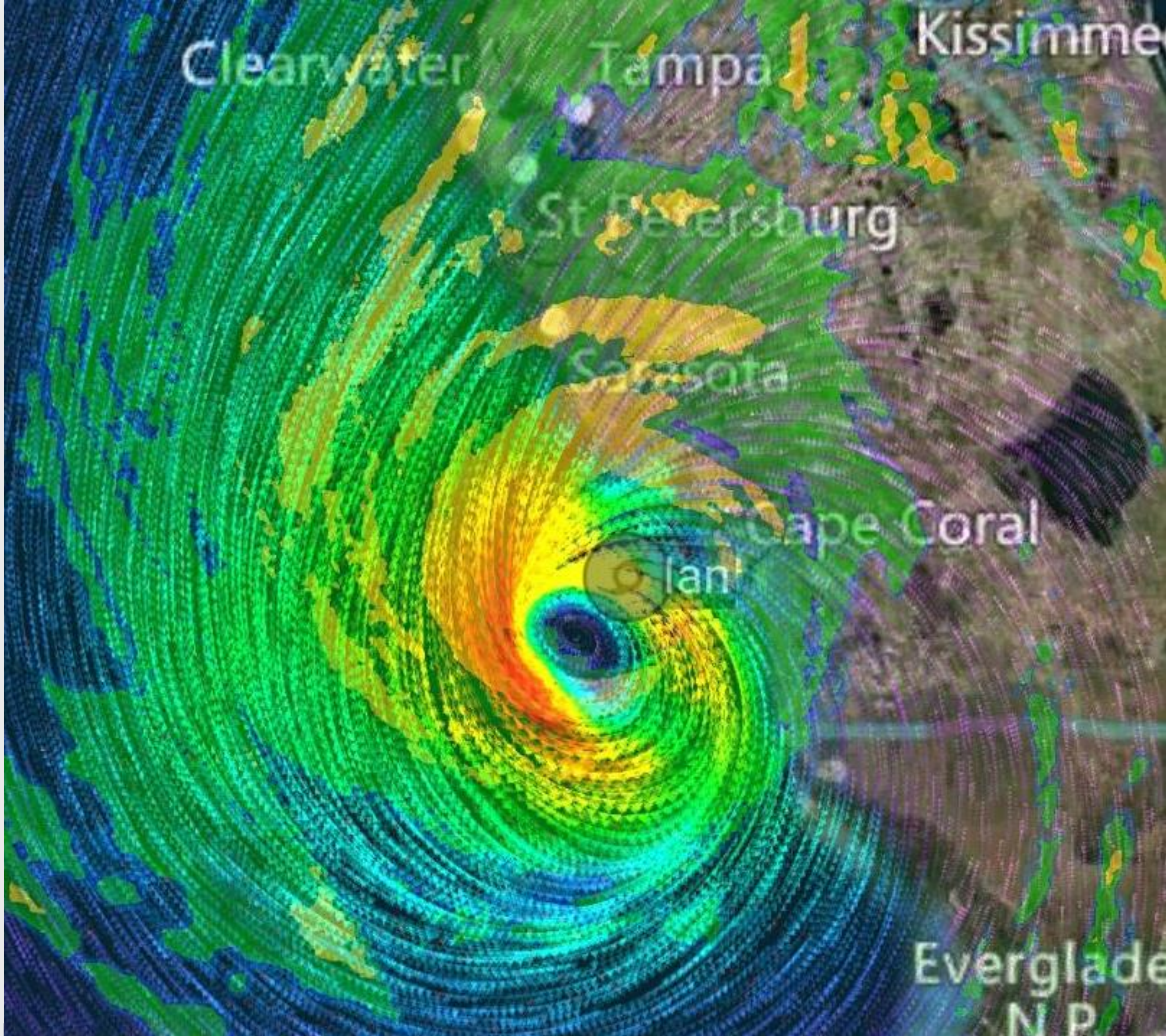
The effectiveness of a resilient enterprise depends upon its ability to anticipate, absorb, adapt to, and/or rapidly recover from a potentially disruptive event



Concrete…

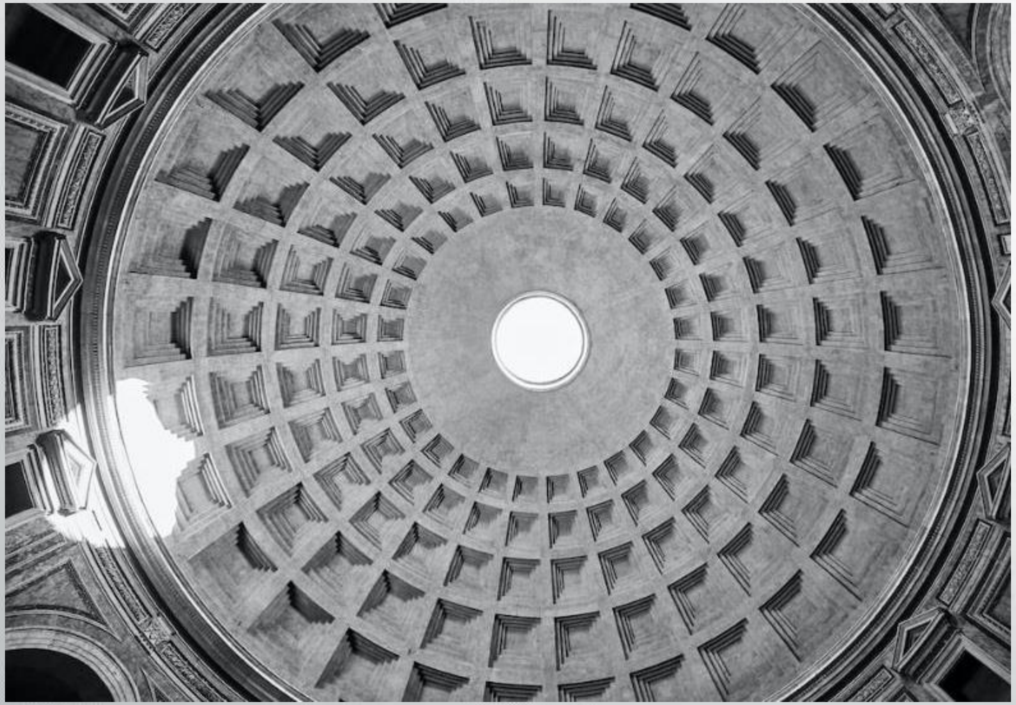
Naturally Resilient & Sustainable

- Mitigates risk
- Highly durable
- Significant safety advantages for…
    - Hurricane
    - Tornado
    - Wildfire / Structural fire
    - Floods
    - Mayhem



Concrete has a Long Service Life

Do it Once… Do it Right with Concrete



The Pantheon in Rome. Circa 126

Photo by Mathew Schwartz on Unsplash

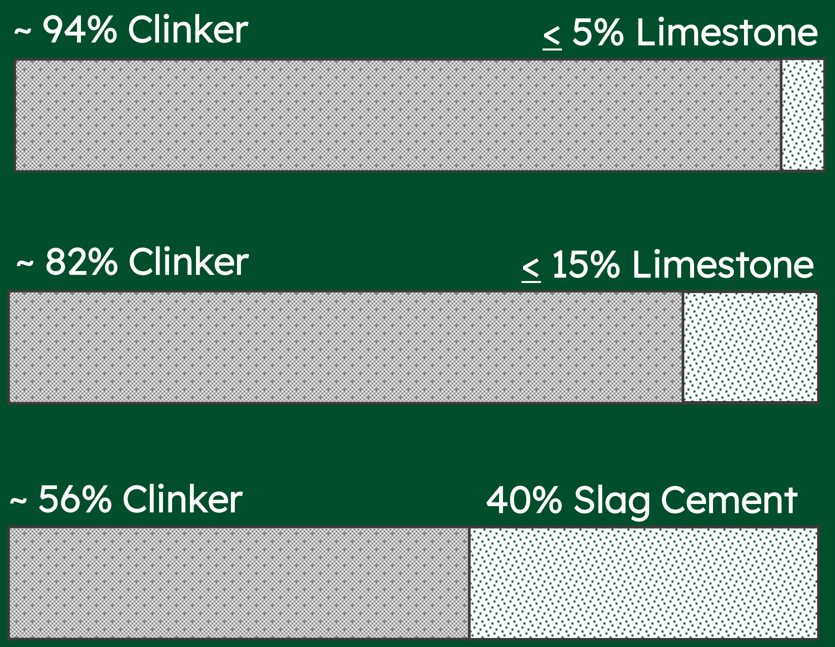
The Baha'i Temple, Wilmette, IL Circa 1930

Photo by Larry Rowland

OPC / Portland

PLC Type IL / GUL

Blended Cements Type IS(40)



Innovative Products

Low Carbon Cements and Concrete Mixes

Clinker reduction

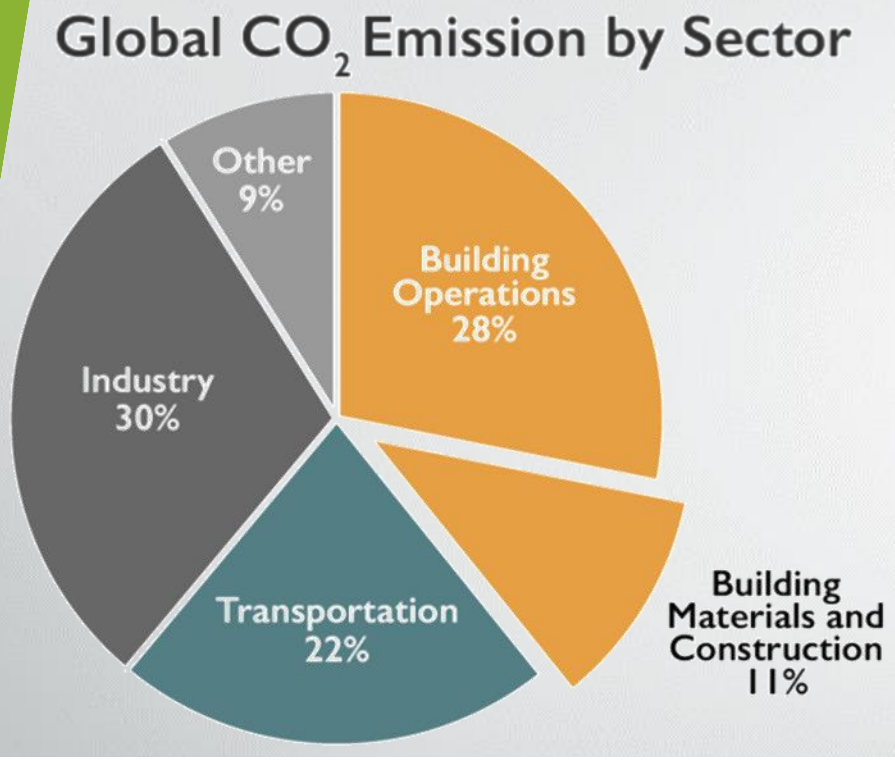
- Key strategy for reducing embodied CO_2 aka GWP
- Performance Specifications enable use
- Significant reduction potential depending on available materials and type of application

Current technologies at the cement plant

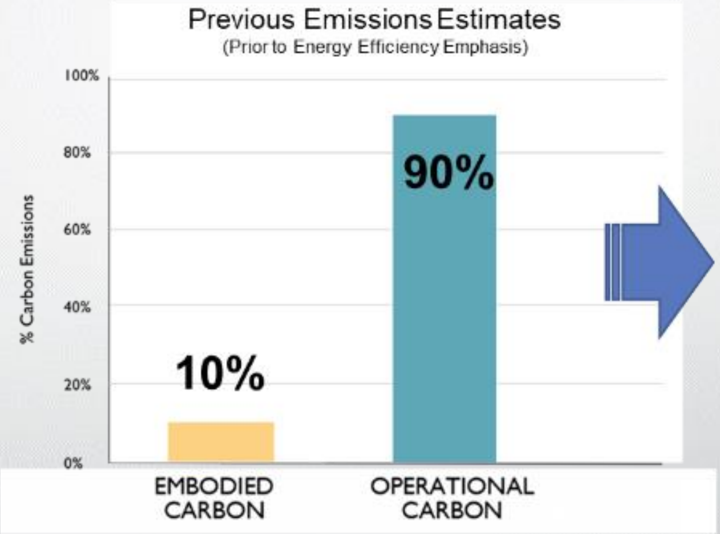
- Interground limestone and SCM incorporation
- Recycled raw materials for clinker production
- Alternative fuels and heat recovery technologies

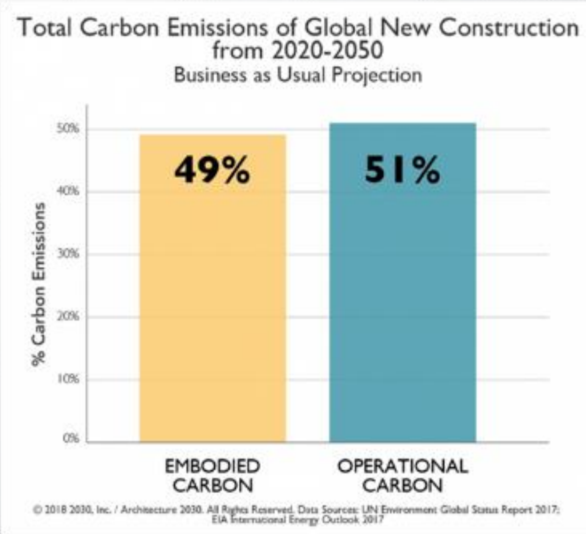
Slag Cement's Role in Sustainable Concrete Mixes

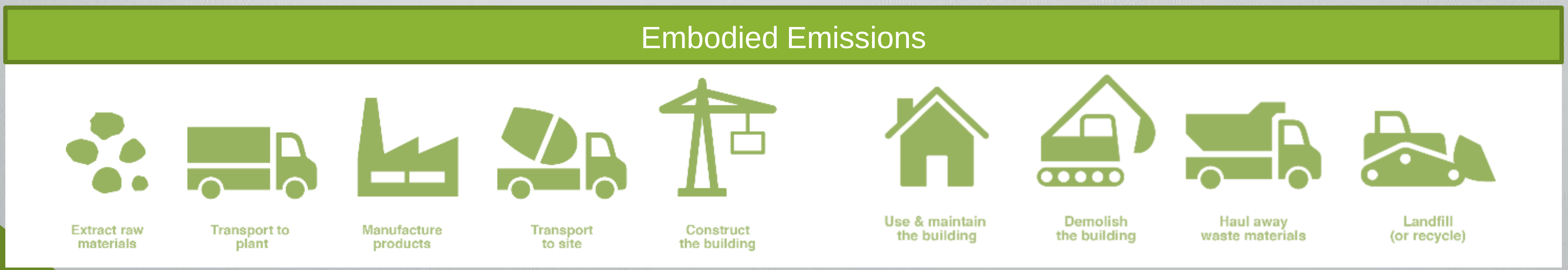
How it all fits together, then…



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



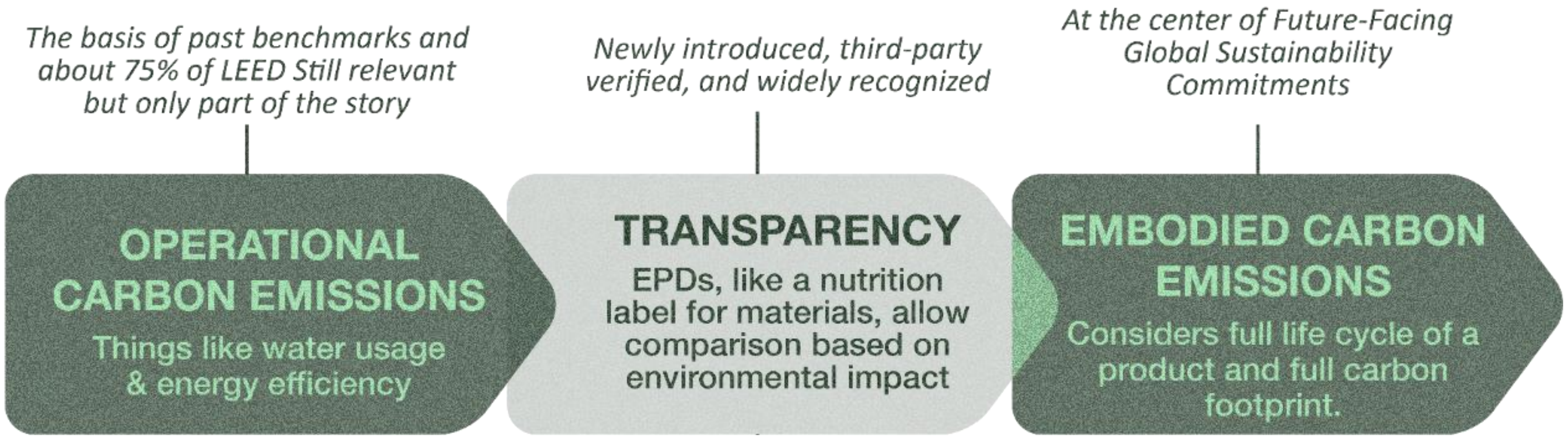




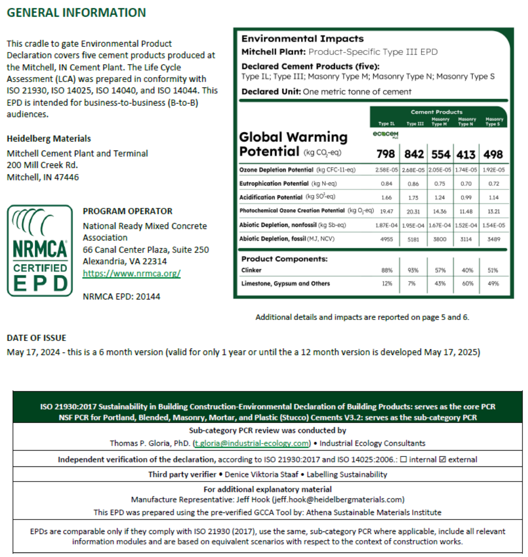
Transparency and the Development of Environmental Product Declarations (EPDs)

Understanding carbon reduction levers is important but, having a way to uniformly measure a product's environmental impact is just as crucial.

EPDs make an accounting, furthering the transparency of our claims.



"M" Plant EPD



GENERAL INFORMATION

This cradle to gate Environmental Product Declaration covers five cement products produced at the Mitchell, IN Cement Plant. The Life Cycle Assessment (LCA) was prepared in conformity with ISO 21930, ISO 14025, ISO 14040, and ISO 14044. This EPD is intended for business-to-business (B-to-B) audiences.

Heidelberg Materials
Mitchell Cement Plant and Terminal
200 Mill Creek Rd.
Mitchell, IN 47446

NRMCA CERTIFIED EPD

PROGRAM OPERATOR
National Ready Mixed Concrete Association
66 Canal Center Plaza, Suite 250
Alexandria, VA 22314
https://www.nrmca.org/

NRMCA EPD: 20144

Environmental Impacts
Mitchell Plant: Product-Specific Type III EPD
Declared Cement Products (five):
Type IL; Type III; Masonry Type M; Masonry Type N; Masonry Type S
Declared Unit: One metric tonne of cement

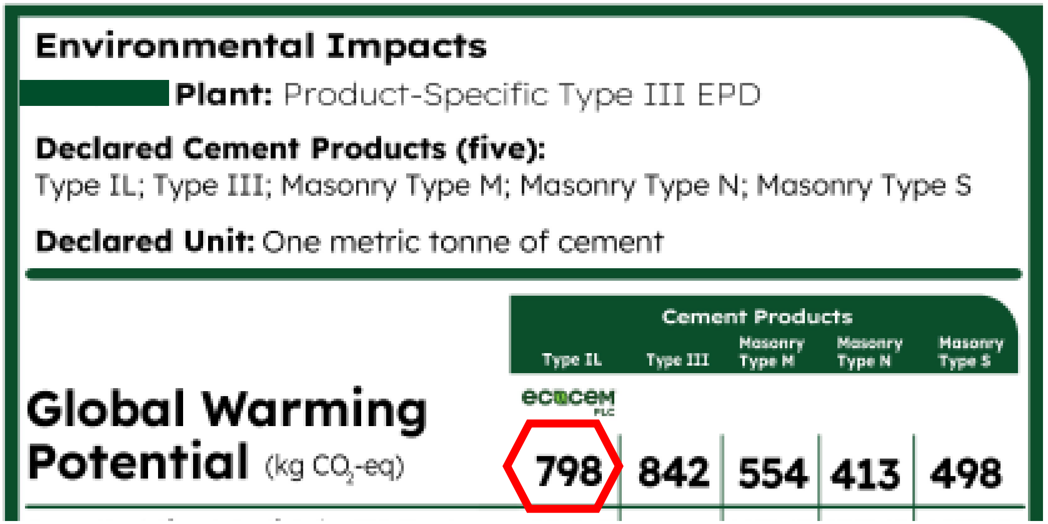
	Cement Products				
	Type IL	Type III	Masonry Type M	Masonry Type N	Masonry Type S
Global Warming Potential (kg CO_2-eq)	ecocem PLC 798	842	554	413	498
Ozone Depletion Potential (kg CFC-11-eq)	2.58E-05	2.68E-05	2.05E-05	1.74E-05	1.92E-05
Eutrophication Potential (kg N-eq)	0.84	0.86	0.75	0.70	0.72
Acidification Potential (kg SO^2-eq)	1.66	1.73	1.24	0.99	1.14
Photochemical Ozone Creation Potential (kg O_3-eq)	19.47	20.31	14.36	11.48	13.21
Abiotic Depletion, nonfossil (kg Sb-eq)	1.87E-04	1.95E-04	1.67E-04	1.52E-04	1.54E-05
Abiotic Depletion, fossil (MJ, NCV)	4955	5181	3800	3114	3489
Product Components:					
Clinker	88%	93%	57%	40%	51%
Limestone, Gypsum and Others	12%	7%	43%	60%	49%

Additional details and impacts are reported on page 5 and 6.

DATE OF ISSUE
May 17, 2024 - this is a 6 month version (valid for only 1 year or until the a 12 month version is developed May 17, 2025)

ISO 21930:2017 Sustainability in Building Construction-Environmental Declaration of Building Products: serves as the core PCR NSF PCR for Portland, Blended, Masonry, Mortar, and Plastic (Stucco) Cements V3.2: serves as the sub-category PCR
Sub-category PCR review was conducted by Thomas P. Gloria, PhD. (t.gloria@industrial-ecology.com) • Industrial Ecology Consultants
Independent verification of the declaration, according to ISO 21930:2017 and ISO 14025:2006.: ☐ internal ☑ external
Third party verifier • Denice Viktoria Staaf • Labelling Sustainability
For additional explanatory material Manufacture Representative: Jeff Hook (jeff.hook@heidelbergmaterials.com) This EPD was prepared using the pre-verified GCCA Tool by: Athena Sustainable Materials Institute
EPDs are comparable only if they comply with ISO 21930 (2017), use the same, sub-category PCR where applicable, include all relevant information modules and are based on equivalent scenarios with respect to the context of construction works.

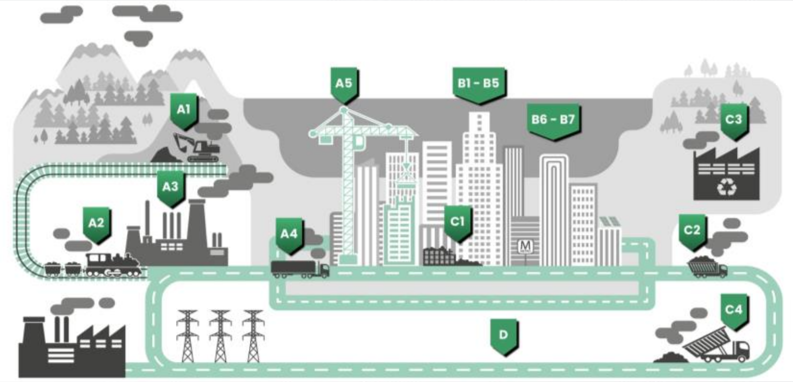
"M" Plant EPD



Life Cycle Assessments (LCA)

Cradle

Gate

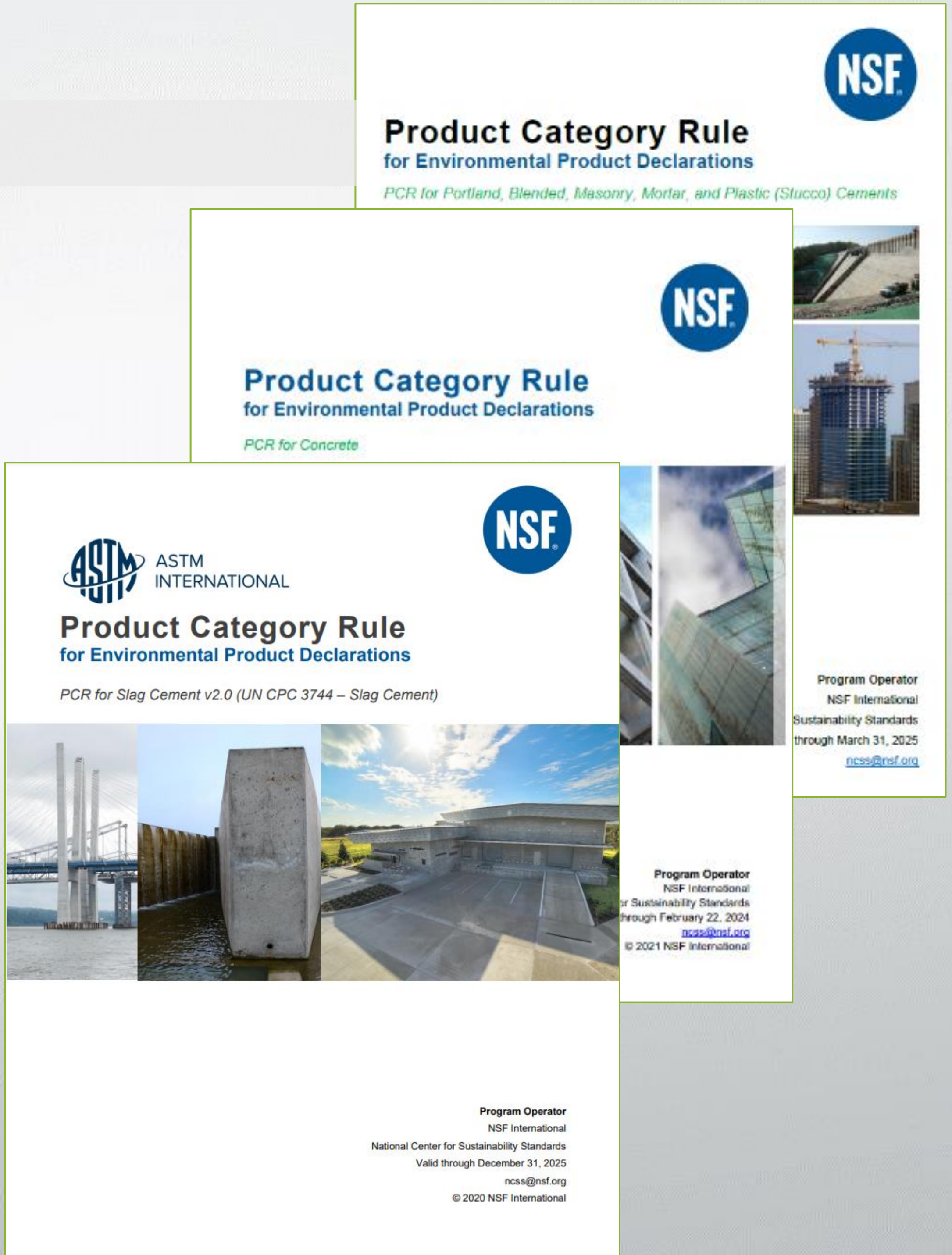


Production Stage			Construction Stage		Use Stage
Extraction And Upstream Production	Transport To Factory	Manufacturing	Transport To Factory	Installation	
A1	A2	A3	A4	A5	
x	x	x	MND	MND	

End Of Life Stage

Product Category Rules (PCRs)

- Life Cycle Assessments help level the playing field and report estimated impacts
- Product Category Rules (PCRs) set the baseline requirements for reporting impacts
  - Set scope, and framework of how to do **LCAs for EPDs**
  - PCRs define what is measured and reported
  - They are product specific
  - Individual PCRs for…
    - Cement valid through March 2025
    - Concrete through Feb. 2024
    - Slag Cement through Dec. 2025


NSF
Product Category Rule
for Environmental Product Declarations
PCR for Portland, Blended, Masonry, Mortar, and Plastic (Stucco) Cements
Program Operator
NSF International
Sustainability Standards
through March 31, 2025
ncss@nsf.org

NSF
Product Category Rule
for Environmental Product Declarations
PCR for Concrete
Program Operator
NSF International
r Sustainability Standards
hrough February 22, 2024
ncss@nsf.org
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NSF
Product Category Rule
for Environmental Product Declarations
PCR for Slag Cement v2.0 (UN CPC 3744 – Slag Cement)
Program Operator
NSF International
National Center for Sustainability Standards
Valid through December 31, 2025
ncss@nsf.org
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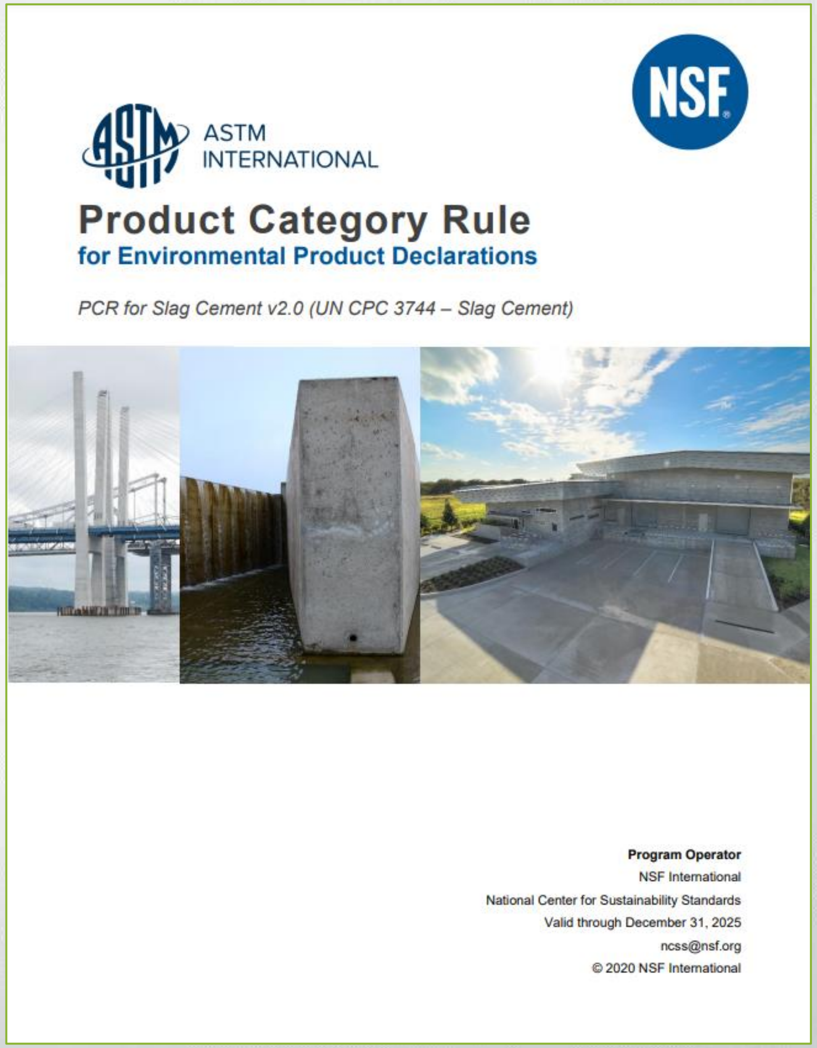
Product Category Rules (PCRs)

- **The PCR for Slag Cement**
- From cradle-to-gate for life cycle stage Modules A1-A3.
  - For Slag produced to ASTM C 988, AASHTO M 302, CSA A3001
  - Declared unit shall be one metric tonne (1,000 kg) of slag cement
- Blast-furnace slag shall be considered a recovered material
- Allows for Average EPDs
  - An industry-average EPD shall be comprised of at least three companies operating three different manufacturing locations
  - Only manufacturers who participated in the industry average may benchmark individual type of cement EPDs against an industry average


ASTM INTERNATIONAL

NSF

Product Category Rule
for Environmental Product Declarations

PCR for Slag Cement v2.0 (UN CPC 3744 – Slag Cement)

Program Operator
NSF International
National Center for Sustainability Standards
Valid through December 31, 2025
ncss@nsf.org
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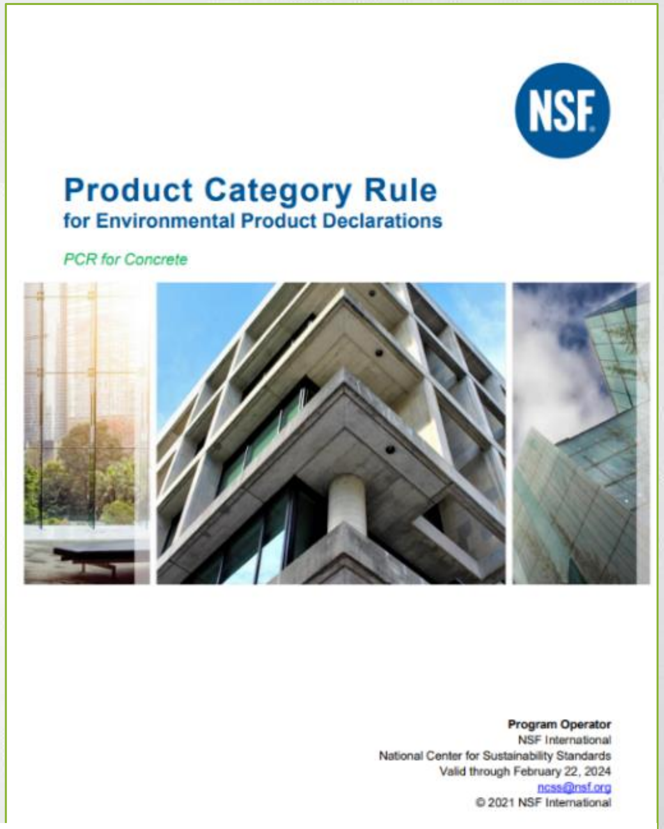
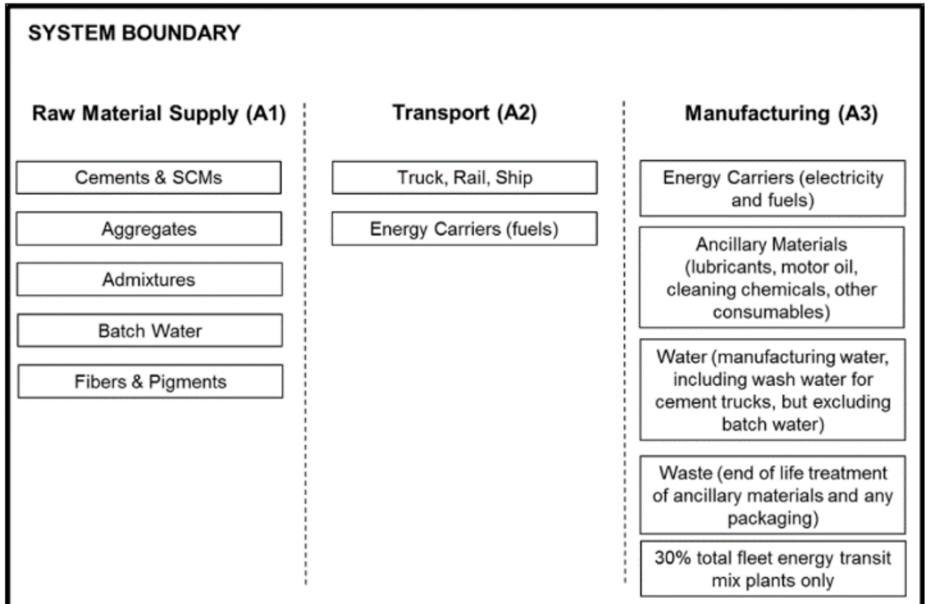
Product Category Rules (PCRs)

- The "Concrete" PCR is for Ready Mixed Concrete
- NRMCA was the sponsor of this PCR
- Limited to Ready Mix so it is a subproduct category rule
- PCR
  - Metric units to be used m^3, but can include both US yd3 and metric units
  - Gives optional System Boundary diagram
  - Allows for option to include LCA Construction Sta
    - A4 Transport to site
    - A5 for concrete placement activities



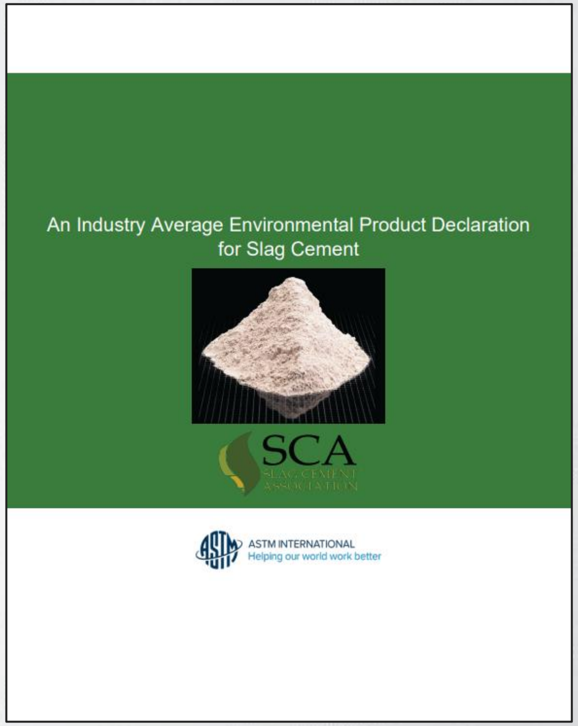


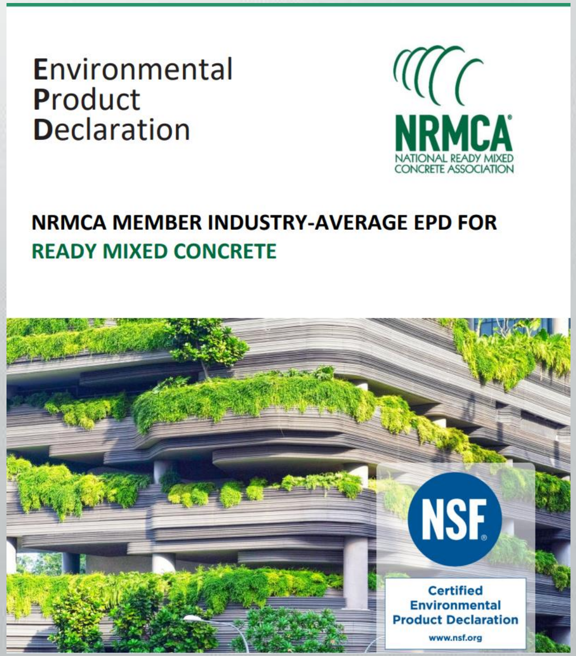
Environmental Product Declarations (EPDs)

What is an EPD?

"Environmental Product Declarations (EPDs) are comparable to a "nutrition label" for products which report a selection of environmental impacts."

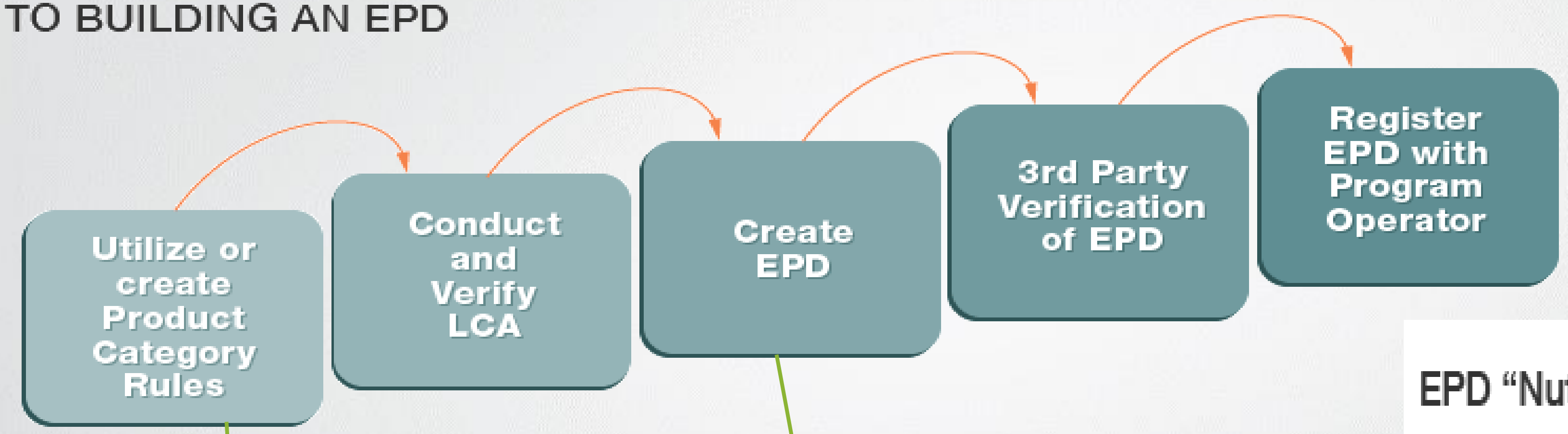
- Provide a summary of LCA Results
- Give environmental information on products.
- EPDs are science and evidence-based tool
  - Provides visibility into Impact Categories set by PCR
  - Example: list GWP of Mton of slag cement or M^3 of concrete





Steps to building an EPD?

STEPS TO BUILDING AN EPD



PCR = Guideline

EPD = Communication "Nutrition label"

EPD "Nutrition" Label

Your Building Product

Amount per Unit

LCA IMACT MEASURES	TOTAL
Primary Energy (MJ)	12.4
Global Warming Potential (kg CO^2 eq)	0.96
Ozone Depletion (kg CFC- 11 eq)	1.80E-08
Acidification Potential (mol H^+ eq)	0.93
Eutrophication Potential (kg N- eq)	6.43E-04
Photo-Oxidant Creation Potential (kg 03 eq)	0.121

Your Product's Ingredients: Listed Here

Environmental Product Declarations (EPDs)

Slag Cement Industry Average EPD

- Eight Slag Cement Association Members took part…
- 2-dozen Impact Categories recorded, i.e. Ozone depletion
- GWP Cradle to Gate total is **<u>147 kg CO2</u>** eq. per metric ton

PCA likewise has published an industry average EPD

- GWP Cradle to Gate total is **<u>922 kg CO2</u>** eq. per metric ton

An Environmental Product Declaration (EPD)
In accordance with ISO 14025 and ISO 21930

SCA SLAG CEMENT ASSOCIATION

Transparency	Activity and LCI datasets are transparently disclosed in the project report, including data source.
Uncertainty	A *sensitivity check* was conducted to assess the reliability of the EPD results and conclusions by determining how they are affected by uncertainties in the data or assumptions on calculation of LCIA and energy indicator results. The sensitivity check includes the results of both a *sensitivity and Monte Carlo analysis.*

Life Cycle Impact Assessment Results

This section summarizes the *production stage* life cycle impact assessment (LCIA) results including resource use and waste generated metrics based on the cradle-to-gate life cycle inventory inputs and outputs analysis. The results are calculated based on 1 metric ton of slag cement type as manufactured and distributed by Slag Cement Association members. *It should be noted that LCIA results are relative expressions and do not predict impacts on category endpoints, the exceeding of thresholds, safety margins or risks [4], [5]. Further, a number of LCA impact categories and inventory items are still emerging or under development and can have high levels of uncertainty that preclude international acceptance pending further development. Use caution when interpreting results for these categories – identified with an "*"* [2].

EPDs based on cradle-to-gate and cradle-to-gate with options information modules shall not be compared. Further, EPDs based on a declared unit shall not be used for comparisons [2]. Environmental declarations from different programs may not be comparable [7]. EPDs are comparable only if they comply with ISO 21930, use the same, sub-category PCR where applicable, include all relevant information modules and are based on equivalent scenarios with respect to the context of construction works [3].

Production stage EPD Results for one metric ton of Slag Cement

Impact category and inventory indicators	Unit	A1, Extraction and upstream production	A2, Transport to factory	A3, Manufacturing	Total
Global warming potential, GWP 100[1)], AR5	kg CO_2 eq	1.8	62.7	82.6	**147.0**
Ozone depletion potential, ODP[2)]	kg CFC-11 eq	2.9E-07	1.4E-05	1.0E-05	**2.4E-05**
Smog formation potential, SFP[2)]	kg O_3 eq	0.19	33.1	4.28	**37.6**
Acidification potential, AP[2)]	kg SO_2 eq	8.7E-03	1.7	2.6E-01	**2.0**
Eutrophication potential, EP[2)]	kg N eq	2.9E-03	0.08	2.4E-01	**0.33**
Abiotic depletion potential for non-fossil mineral resources, ADP elements[3)]*	kg Sb eq	1.7E-06	2.4E-06	6.8E-05	**7.2E-05**

ARGOS | ASH GROVE A CRH COMPANY | CEMEX | Heidelberg Materials | HOLCIM | OZINGA | SKYWAY SLAG CEMENT | st marys cement VOTORANTIM cimentos

Current Industry EPD's for OPC, GUL and Slag cement

LCA Results - Type OPC/PLC/Slag one metric ton - absolute basis				
Category Indicator	Unit	Total		
TRACI v.2.1 Category Indicators		OPC	PLC	Slag
Global Warming Potential (GWP)	kg CO_2eq	922	798	147.0
Acidification Potential (AP)	kg N eq.	1.75	1.64	2.0
Eutrophication Potential (EP)	kg O_2 eq.	1.02	0.94	0.33
Smog Creation Potential (POCP)	kg O_3 eq.	32.9	30.2	37.6
Ozone Depletion Potential (ODP)	kg CFC -11 eq.	2.10E-05	2.17 E-05	2.4E-05

Interpreting Concrete EPDs Cement/Binders are Primary GWP Contributors

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https://www.nrmca.org/

NRMCA EPD: 20144

Environmental Impacts

Mitchell Plant: Product-Specific Type III EPD

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	Type IL (ecocem PLC)	Type III	Masonry Type M	Masonry Type N	Masonry Type S
Global Warming Potential (kg CO_2-eq)	798	842	554	413	498
Ozone Depletion Potential (kg CFC-11-eq)	2.58E-05	2.68E-05	2.05E-05	1.74E-05	1.92E-05
Eutrophication Potential (kg N-eq)	0.84	0.86	0.75	0.70	0.72
Acidification Potential (kg SO^2-eq)	1.66	1.73	1.24	0.99	1.14
Photochemical Ozone Creation Potential (kg O_3-eq)	19.47	20.31	14.36	11.48	13.21
Abiotic Depletion, nonfossil (kg Sb-eq)	1.87E-04	1.95E-04	1.67E-04	1.52E-04	1.54E-05
Abiotic Depletion, fossil (MJ, NCV)	4955	5181	3800	3114	3489
Product Components:					
Clinker	88%	93%	57%	40%	51%
Limestone, Gypsum and Others	12%	7%	43%	60%	49%

Additional details and impacts are reported on page 5 and 6.

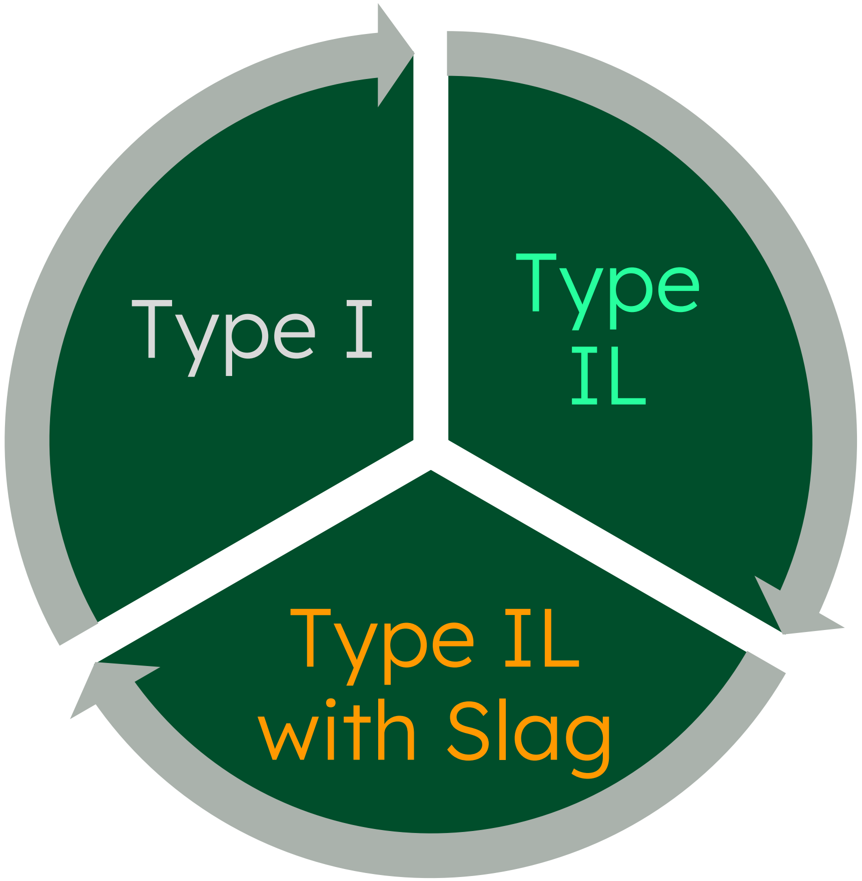
DATE OF ISSUE

May 17, 2024 - this is a 6 month version (valid for only 1 year or until the a 12 month version is developed May 17, 2025)

ISO 21930:2017 Sustainability in Building Construction-Environmental Declaration of Building Products: serves as the core PCR **NSF PCR for Portland, Blended, Masonry, Mortar, and Plastic (Stucco) Cements V3.2: serves as the sub-category PCR**
Sub-category PCR review was conducted by Thomas P. Gloria, PhD. (t.gloria@industrial-ecology.com) • Industrial Ecology Consultants
Independent verification of the declaration, according to ISO 21930:2017 and ISO 14025:2006.: ☐ internal ☑ external
Third party verifier • Denice Viktoria Staaf • Labelling Sustainability
For additional explanatory material Manufacture Representative: Jeff Hook (jeff.hook@heidelbergmaterials.com) This EPD was prepared using the pre-verified GCCA Tool by: Athena Sustainable Materials Institute
EPDs are comparable only if they comply with ISO 21930 (2017), use the same, sub-category PCR where applicable, include all relevant information modules and are based on equivalent scenarios with respect to the context of construction works.

Product Stage		
Extraction and upstream production	Transport to factory	Manufacturing
A1	A2	A3
Disproportionately driven by cement (clinker) content	Dependent on haul distances and mode of transport. How close are aggregate and cement resources?	Dependent on energy sources – climate and electricity (hydroelectric or coal fired)?

Example of GWP for Concrete Mix calculation using, EPD Data



Compare Type I, Type IL, and Type IL with Slag Cement (350 kg/m3 total for cement design

1. Type I GWP from an Industry Average Type I / GU @ 922 GWP
2. Type IL GWP from actual cement plant @ 798 GWP
3. Type IL and Slag Cement from actual cement plant and industry average slag cement

Apply GWP values to Generic Mix for all mix components

- Binder, 350 kg/m^3 “Average” Type I cement
- Reference with no SCM’s
- “Generic” course and fine aggregate
- Water reducing & Air-entraining admixtures

Calculating Concrete GWP Calculations by Leveraging EPD Data from Type I Industry Avg.

Apply GWP values to Generic Mix for all mix components

- Binder, 350 kg/m^3 "Average" Type I cement
- No SCMs
- "Generic" course and fine aggregate
- Water reducing & Air-entraining admixtures.
  - **This Baseline Mix has GWP of 374.8**
  - Note inclusion of A1 – A3 LCA Modules
    - GWP for A1 331.3
    - GWP for A2 34.1
    - GWP for A3 9.4

Mix GWP Total **374.8 CO2 eq.**

SCM, Aggregate and Admixture Data via FHWA Report No. FHWA-HIF-22-032, LCA Pave

Generic Concrete Mix Global Warming Potential A1 - A3			
Generic Concrete Mix Raw Materials A1	**Quantity kg/m^3**	**GWP / Metric ton (1,000 kg)**	**GWP in Mix**
Industry Average Portland Cement (GU / Type I)	350	922	322.7
Generic Fly Ash	0	14.7	0.0
Generic Slag Cement	0	146.6	0.0
Generic Crushed Stone Course Aggregate	1,046	4.6	4.8
Generic Concrerte Sand Fine Aggregate	791	2.8	2.2
Water	156	0.0	0.0
Generic Water Reducing Admixture	0.80	1880.6	1.5
Generic Air-Entrainer	0.05	524.7	0.03
Raw Materials Production CO_2 Footprint - Total A1			**331.3**
Material Transport to Concrete Plant A2			
Summary for Transport to BC Ready Mix CO_2 Footprint - Total A2			**34.1**
Concrete Manufacturing @ RM Plant			
Material Handling, Batching & Misc. Operations CO_2 Footprint - Total A3			**9.4**
	Total A1 + A2 + A3		**374.8**

Type IL Cement Delivers more than Type I CO_2 Reductions, LCA Data

Compare industry average vs. high performing plant in Generic Mix

- Industry Average Portland Cement Type I / GU @ 922 GWP
- Compared to actual EPD Data →
- "M" Plant
  - Preheater/Precalciner
  - Vertical Mill
- Type IL @ 798 GWP

Environmental Impacts

Mitchell Plant: Product-Specific Type III EPD

Declared Cement Products (five):
Type IL; Type III; Masonry Type M; Masonry Type N; Masonry Type S

Declared Unit: One metric tonne of cement

	Type IL (ecocem)	Type III	Masonry Type M	Masonry Type N	Masonry Type S
Global Warming Potential (kg CO_2-eq)	798	842	554	413	498
Ozone Depletion Potential (kg CFC-11-eq)	2.58E-05	2.68E-05	2.05E-05	1.74E-05	1.92E-05
Eutrophication Potential (kg N-eq)	0.84	0.86	0.75	0.70	0.72
Acidification Potential (kg SO^2-eq)	1.66	1.73	1.24	0.99	1.14
Photochemical Ozone Creation Potential (kg O_3-eq)	19.47	20.31	14.36	11.48	13.21
Abiotic Depletion, nonfossil (kg Sb-eq)	1.87E-04	1.95E-04	1.67E-04	1.52E-04	1.54E-05
Abiotic Depletion, fossil (MJ, NCV)	4955	5181	3800	3114	3489

Product Components:

	Type IL	Type III	Masonry Type M	Masonry Type N	Masonry Type S
Clinker	88%	93%	57%	40%	51%
Limestone, Gypsum and Others	12%	7%	43%	60%	49%

Generic Concrete Mix Global Warming Potential A1 - A3 using PLC

Generic Concrete Mix Raw Materials A1	Quantity kg/m^3	GWP / Metric ton (1,000 kg)	GWP in Mix
Portland Limestone Cement (Type IL)	350	798	279.3

Calculating Concrete GWP with EPD Data for "M" plant Type IL cement in concrete mix

Apply GWP values to Generic Mix for all mix components

- Binder is 350 kg/m^3 Type IL
- No SCMs
- "Generic" course and fine aggregate
- Water reducing & Air-entraining admixtures
- **"M" plant Type IL = - 11.6% vs Baseline Mix**
- Note inclusion of A1 – A3 LCA Modules
  - GWP for A1 287.9
  - GWP for A2 34.1
  - GWP for A3 9.4

Mix GWP Total **331.4 CO2 eq.**

Generic Concrete Mix Global Warming Potential A1 - A3 using PLC			
Generic Concrete Mix Raw Materials A1	**Quantity kg/m^3**	**GWP / Metric ton (1,000 kg)**	**GWP in Mix**
Portland Limestone Cement (Type IL)	350	798	279.3
Generic Fly Ash	0	14.7	0.0
Generic Slag Cement	0	146.6	0.0
Generic Crushed Stone Course Aggregate	1,046	4.6	4.8
Generic Concrerte Sand Fine Aggregate	791	2.8	2.2
Water	156	0.0	0.0
Generic Water Reducing Admixture	0.80	1880.6	1.5
Generic Air-Entrainer	0.05	524.7	0.03
Raw Materials Production CO_2 Footprint - Total A1			**287.9**
Material Transport to Concrete Plant A2			
Summary for Transport to BC Ready Mix CO_2 Footprint - Total A2			**34.1**
Concrete Manufacturing @ RM Plant			
Material Handling, Batching & Misc. Operations CO_2 Footprint - Total A3			**9.4**
	Total A1 + A2 + A3		**331.4**

SCM, Aggregate and Admixture Data via FHWA Report No. FHWA-HIF-22-032, LCA Pave

Type IL and Slag Cement Delivers Significant CO_2 Reductions, LCA Data

Compare Type IL and Slag Cement in Generic Mix

Type IL @ 798 GWP

Slag Cement @ 147 GWP

Production stage EPD Results for one metric ton of Slag Cement

Impact category and inventory indicators	Unit	A1, Extraction and upstream production	A2, Transport to factory	A3, Manufacturing	Total
Global warming potential, GWP 100[1], AR5	kg CO_2 eq	1.8	62.7	82.6	**147.0**
Ozone depletion potential, ODP[2]	kg CFC-11 eq	2.9E-07	1.4E-05	1.0E-05	**2.4E-05**
Smog formation potential, SFP[2]	kg O_3 eq	0.19	33.1	4.28	**37.6**
Acidification potential, AP[2]	kg SO_2 eq	8.7E-03	1.7	2.6E-01	**2.0**
Eutrophication potential, EP[2]	kg N eq	2.9E-03	0.08	2.4E-01	**0.33**
Abiotic depletion potential for non-fossil mineral resources, ADP elements[3]*	kg Sb eq	1.7E-06	2.4E-06	6.8E-05	**7.2E-05**

Environmental Impacts

Mitchell Plant: Product-Specific Type III EPD

Declared Cement Products (five):
Type IL; Type III; Masonry Type M; Masonry Type N; Masonry Type S

Declared Unit: One metric tonne of cement

	Cement Products				
	Type IL	Type III	Masonry Type M	Masonry Type N	Masonry Type S
Global Warming Potential (kg CO_2-eq)	798	842	554	413	498
Ozone Depletion Potential (kg CFC-11-eq)	2.58E-05	2.68E-05	2.05E-05	1.74E-05	1.92E-05
Eutrophication Potential (kg N-eq)	0.84	0.86	0.75	0.70	0.72
Acidification Potential (kg SO_2-eq)	1.66	1.73	1.24	0.99	1.14
Photochemical Ozone Creation Potential (kg O_3-eq)	19.47	20.31	14.36	11.48	13.21
Abiotic Depletion, nonfossil (kg Sb-eq)	1.87E-04	1.95E-04	1.67E-04	1.52E-04	1.54E-05
Abiotic Depletion, fossil (MJ, NCV)	4955	5181	3800	3114	3489
Product Components:					
Clinker	88%	93%	57%	40%	51%
Limestone, Gypsum and Others	12%	7%	43%	60%	49%

Calculating Concrete GWP with EPD Data for "M" plant portland/ Slag Cement in Mix

Apply GWP values to Generic Mix for all mix components

- Binder is 350 kg/m^3 Type IL and 40% Slag Cement
- "Generic" course and fine aggregate
- Water reducing & Air-entraining admixtures
- **IL with 40% Slag Cement = - 35.9% vs Baseline Mix**
- Note inclusion of A1 – A3 LCA Modules
    - GWP for A1 194.4
    - GWP for A2 34.1
    - GWP for A3 9.4

Mix GWP Total **240.2 CO2 eq**.

Generic Concrete Mix Global Warming Potential A1 - A3 w/ PLC (IL) + Slag			
Generic Concrete Mix Raw Materials A1 using Mitchell PLC & SCMs	**Quantity kg/m^3**	**GWP / Metric ton (1,000 kg)**	**GWP in Mix**
Portland Limestone Cement (Type IL)	210	798	167.6
Generic Slag Cement	140	146.6	20.5
Generic Crushed Stone Course Aggregate	1,046	4.6	4.8
Generic Concrerte Sand Fine Aggregate	791	2.8	2.2
Water	156	0.0	0.0
Generic Water Reducing Admixture	0.80	1880.6	1.5
Generic Air-Entrainer	0.05	524.7	0.03
Raw Materials Production CO_2 Footprint - Total A1			**196.7**
Material Transport to Concrete Plant A2			
Summary for Transport to BC Ready Mix CO_2 Footprint - Total A2			**34.1**
Concrete Manufacturing @ RM Plant			
Material Handling, Batching & Misc. Operations CO_2 Footprint - Total A3			**9.4**
	Total A1 + A2 + A3		**240.2**

SCM, Aggregate and Admixture Data via FHWA Report No. FHWA-HIF-22-032, LCA Pave

EPDs provide transparency

Summary of Example of GWP for Concrete Mix calculation using, EPD Data

Type I

Type IL

Type IL with Slag

GWP Calculated Total (kg CO2 eq)

374.8

331.4

240.2

GWP reduction

-11.6%

-35.9%

Carbon Accounting Tools – **SCAs LCA Calculator**

Counting GWP is a simple way to see the impacts are to compare like mixes

- The Slag Cement Association has an excellent, free LCA Calculator

SCA
SLAG CEMENT ASSOCIATION

HOME About SCA Why Slag Cement? Sustainability Resources

Slag Cement Life Cycle Assessment Calculator

The Slag Cement Association (SCA) commissioned the Athena Institute to produce this Ready Mixed Concrete Life Cycle Assessment (LCA) Calculator for Slag Cement - Version 1.0 to show the impacts of using slag cement in ready mixed concrete.

The LCA calculator allows you to enter custom concrete mixes and then substitute varying amounts of slag cement through a simple dashboard interface. You simply select a preset mix or enter the details of a custom mix and the calculator will allow you to increase or decrease the percentage of slag cement and calculate LCA results in real time. The tool also allows you to compare custom mixes against region-specific industry average mixes and to substitute these mixes into a generic whole building to calculate cumulative whole-building results.

Download the Calculator Here

Carbon Accounting Tools – SCAs LCA Calculator

The calculator is separated into four worksheets:

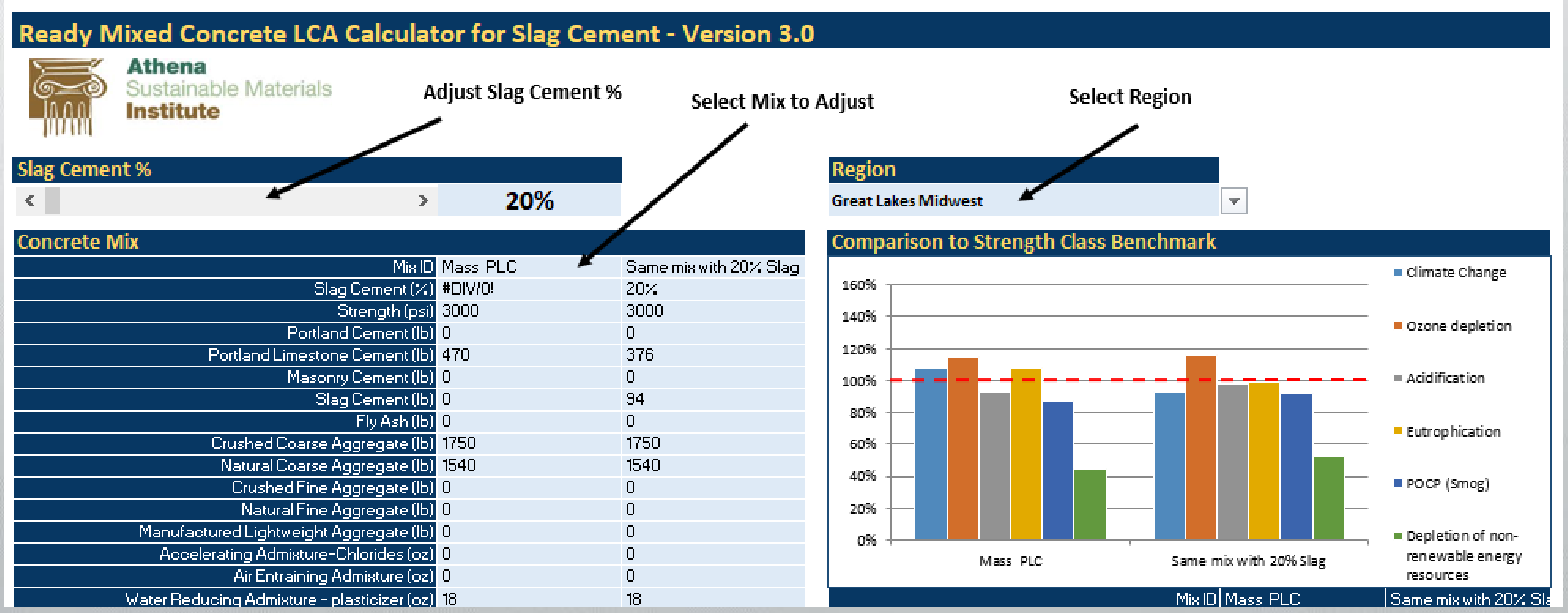
1. **Slag Substitution:** main dashboard tab allows you to select from a list of preset concrete mixes and to then alter the percentage of slag cement in that mix.
2. **Custom Mixes:** enter up to 10 custom mixes, have drop-down list on the "Slag Substitution" tab. Environmental impacts of these mixes are calculated.
3. **Comparison to Benchmark:** environmental impacts of the entered "Custom Mixes" in absolute terms and as a percentage of region-specific industry average benchmarks.
4. **Impacts in Whole Building:** enter amounts for each of the "Custom Mixes" used in a given project to calculate the cumulative whole-building impact. The calculator adds in non-concrete impacts (i.e. steel, glazing, insulation, etc.) in amounts proportional to the amount of concrete. … the results in this tab are not considered a whole-building LCA, but do give you a realistic look at how concrete selection effects whole building impacts.

Carbon Accounting Tools – SCAs LCA Calculator

The calculator is separated into 4 worksheets:

Slag Substitution: tab allows you to select from a list of preset concrete mixes and to then alter the percentage of slag cement in that mix. The user picks:

- What baseline mix to use (What Mix to Adjust)
- The % replacement
- Region i.e. Great Lakes Midwest



Mix ID	Mass PLC	Same mix with 20% Slag
Slag Cement (%)	#DIV/0!	20%
Strength (psi)	3000	3000
Portland Cement (lb)	0	0
Portland Limestone Cement (lb)	470	376
Masonry Cement (lb)	0	0
Slag Cement (lb)	0	94
Fly Ash (lb)	0	0
Crushed Coarse Aggregate (lb)	1750	1750
Natural Coarse Aggregate (lb)	1540	1540
Crushed Fine Aggregate (lb)	0	0
Natural Fine Aggregate (lb)	0	0
Manufactured Lightweight Aggregate (lb)	0	0
Accelerating Admixture-Chlorides (oz)	0	0
Air Entraining Admixture (oz)	0	0
Water Reducing Admixture - plasticizer (oz)	18	18

Mix ID	Mass PLC	Same mix with 20% Sla

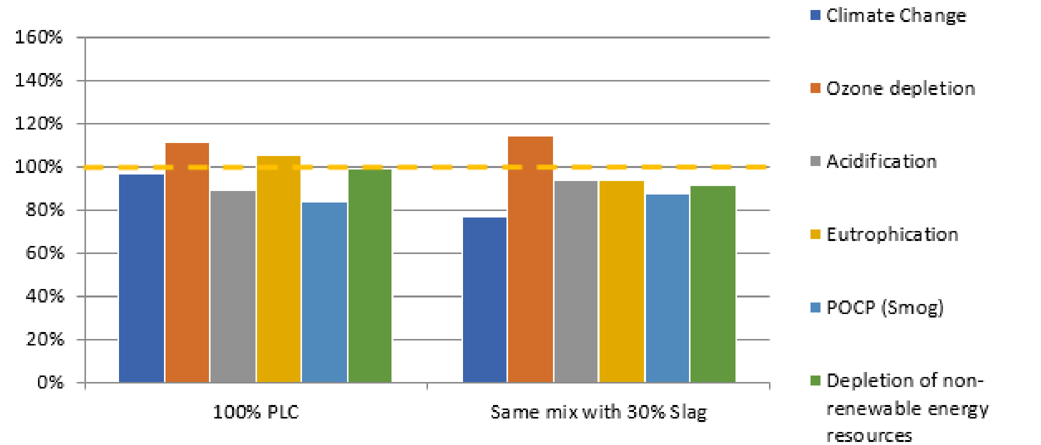
Carbon Accounting Tools – SCAs LCA Calculator

Using the "**Slag Substitution**" tab & 4,000 psi OPC mix at 30% & 40% substitution

Adjust **Select Region**

Region
North Central

Comparison to Strength Class Benchmark



Mix ID	100% PLC	Same mix with 30% Slag
Strength (PSI) of Relevant Benchmark	4000	4000
Climate Change	96%	77%
Ozone depletion	112%	114%
Acidification	89%	94%
Eutrophication	106%	93%
POCP (Smog)	83%	88%
Depletion of non-renewable energy resources	99%	91%

Life Cycle Assessment Results

Mix ID	100% PLC	Same mix with 30% Slag
Climate Change (kg CO2-eq)	230.36	183.44

A 30% Slag Substitution in this mix yields:

- ~ 47 kg CO_2 eq. / yd^3 Savings
- ~ 20% reduction in GWP

A 40% Slag Substitution in this mix yields:

- ~ 63 kg CO_2 eq. / yd^3 Savings
- ~ 27% reduction in GWP

Carbon Accounting Tools – SCAs LCA Calculator

The "**Custom Mixes**" tab allows comparison of up to 10 mixes at once

The user picks a strength class then manually enters the names and the specific quantities from their mixes. This example is for six 4,000 psi mixes for 50 % 30% slag

Ready Mixed Concrete LCA Calculator for Slag Cement - Version 3.0

Athena
Sustainable Materials
Institute

Enter Data for Custom Mixes on a per yd3 basis

Concrete Mix (per yd3)

Mix ID	100% OPC	100% PLC	50% PLC / Slag	470# OPC	50/50 @ 470	30% Sag & PLC
Strength for Benchmarking (psi)	4000	4000	4000	4000	4000	4000
Portland Cement (lb)	500			470		
Portland Limestone Cement (lb)		500	250		235	330
Masonry Cement (lb)						
Slag Cement (lb)			250		235	140
Fly Ash (lb)						
Crushed Coarse Aggregate (lb)	1800	1800	1800	1800	1800	1800
Natural Coarse Aggregate (lb)						
Crushed Fine Aggregate (lb)						
Natural Fine Aggregate (lb)	1400	1400	1400	1450	1450	1450
Manufactured Lightweight Aggregate (lb)						
Accelerating Admixture-Chlorides (oz)						
Air Entraining Admixture (oz)	0					
Water Reducing Admixture - plasticizer (oz)	30	30	30	30	30	30
High Range Water Reducing Admixture - superplasticizer (oz)						
Water (gal)	225.00	225.00	225.00	220.00	220.00	220.00

Carbon Accounting Tools – SCAs LCA Calculator

The "**Custom Mixes**" tab allows comparison of up to 10 mixes at once

Ready Mixed Concrete LCA Calculator for Slag Cement - Version 3.0

Athena Sustainable Materials Institute

Enter Data for Custom Mixes on a per yd3 basis

Concrete Mix (per yd3)

Mix ID	100% OPC	100% PLC	50% PLC / Slag	470# OPC	50/50 @ 470	30% Sag & PLC
Strength for Benchmarking (psi)	4000	4000	4000	4000	4000	4000
Portland Cement (lb)	500			470		
Portland Limestone Cement (lb)		500	250		235	330
Masonry Cement (lb)						
Slag Cement (lb)			250		235	140
Fly Ash (lb)						
Crushed Coarse Aggregate (lb)	1800	1800	1800	1800	1800	1800
Natural Coarse Aggregate (lb)						
Crushed Fine Aggregate (lb)						
Natural Fine Aggregate (lb)	1400	1400	1400	1450	1450	1450
Manufactured Lightweight Aggregate (lb)						
Accelerating Admixture-Chlorides (oz)						
Air Entraining Admixture (oz)	0					
Water Reducing Admixture - plasticizer (oz)	30	30	30	30	30	30
High Range Water Reducing Admixture - superplasticizer (oz)						
Water (gal)	225.00	225.00	225.00	220.00	220.00	220.00

Steps to enter custom mixes to compare:

- Type in Mix id
- Pick mix strength class from dropdown
- Type in mix proportions
- Multiple mix classes can be entered in the custom mixes tab
- Mixes will be populated in the comparison to benchmark tab, impacts in whole building tab and a drop down selection in slag substitution tab.

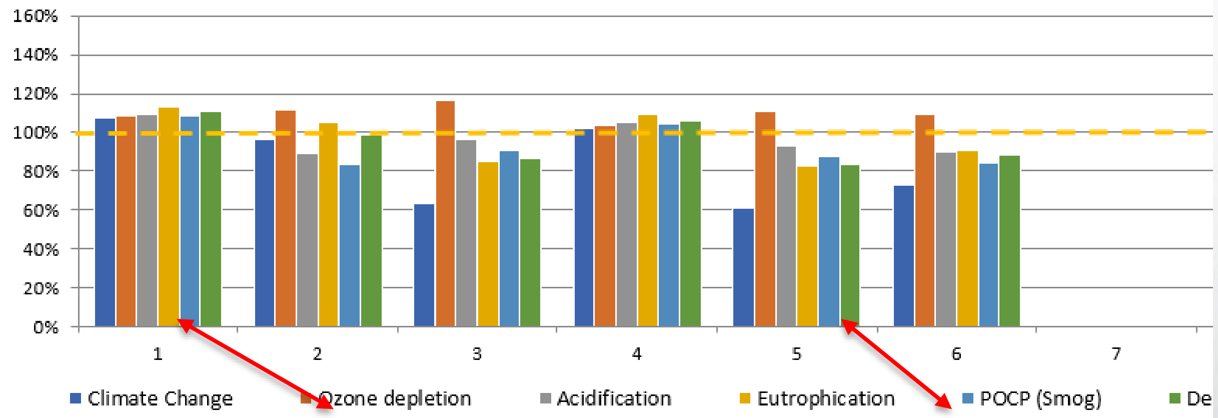
Carbon Accounting Tools – SCAs LCA Calculator

The **Custom Mixes** info populates the info into the "**Comparison Benchmark"** tab

Ready Mixed Concrete LCA Calculator for Slag Cement - Version 3.0

Athena Sustainable Materials Institute

Comparison of Entered Mixes to Strength Class Benchmarks



Mix in Graph	1	2	3	4	5	6
Mix ID	100% OPC	100% PLC	50% PLC / Slag	470# OPC	50/50 @ 470	30% Sag & PLC
Strength (PSI) of Relevant Benchmark	4000	4000	4000	4000	4000	4000
Climate Change	108%	96%	64%	102%	61%	73%
Ozone depletion	109%	112%	116%	104%	111%	109%
Acidification	109%	89%	97%	105%	93%	90%
Eutrophication	113%	106%	85%	109%	83%	91%
POCP (Smog)	108%	83%	91%	104%	87%	85%
Depletion of non-renewable energy resources	111%	99%	87%	106%	84%	88%

Life Cycle Assessment Results

Mix ID	100% OPC	100% PLC	50% PLC / Slag	470# OPC	50/50 @ 470	30% Sag & PLC
Climate Change (kg CO2-eq)	256.96	230.36	152.17	243.75	145.25	174.96

Results shown in the table and plotted graphically

- The GWP or (Climate Change) values are plotted in dark blue
- In this example the GWP values range from:
  - a high of **~257 kg CO2 eq.** / yd3

    for the 500# OPC mix, no slag, Mix 1

  to

  - a low of **~145 kg CO2 eq.** / yd3

    for the 470# PLC mix @ 50% slag, Mix 5

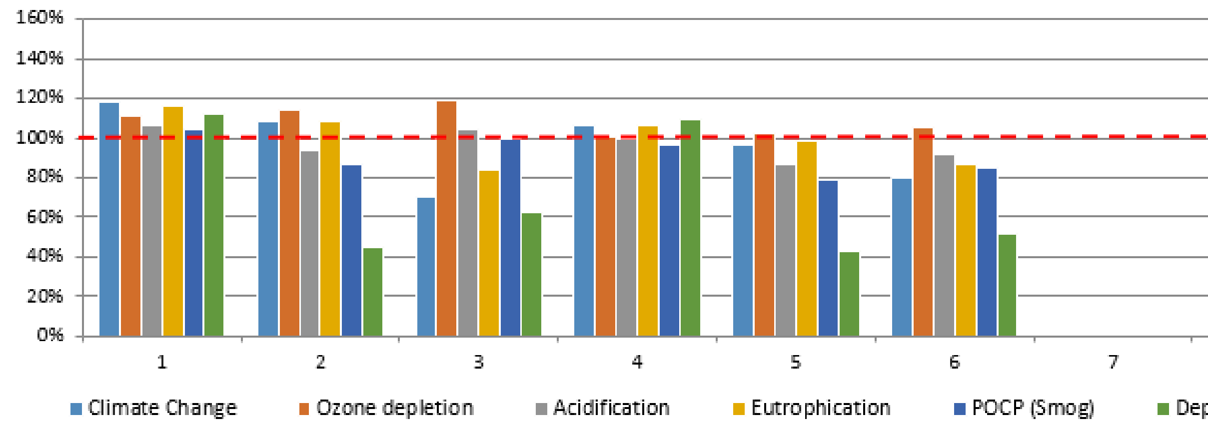
Using the SCA Calculator

The **Comparison to Benchmark** tab will show the environmental impacts compared to the NRMCA Industry EPD.

Ready Mixed Concrete LCA Calculator for Slag Cement - Version 3.0

Athena Sustainable Materials Institute

Comparison of Entered Mixes to Strength Class Benchmarks



Mix in Graph	1	2	3	4	5	6
Mix ID	Mass OPC	Mass PLC	Mass slag	Floor OPC	Floor PLC	Floor slag
Strength (PSI) of Relevant Benchmark	3000	3000	3000	5000	5000	5000
Climate Change	118%	108%	71%	106%	97%	80%
Ozone depletion	112%	114%	119%	100%	103%	105%
Acidification	106%	93%	104%	100%	87%	92%
Eutrophication	116%	108%	84%	106%	99%	87%
POCP (Smog)	105%	87%	100%	96%	79%	85%
Depletion of non-renewable energy resources	112%	45%	63%	110%	43%	51%

Life Cycle Assessment Results

Mix ID	Mass OPC	Mass PLC	Mass slag	Floor OPC	Floor PLC	Floor slag
Climate Change (kg CO2-eq)	230.37	210.33	137.63	295.05	269.00	221.67
Ozone depletion (kg CFC-11-eq)	6.21E-06	6.36E-06	6.60E-06	7.51E-06	7.70E-06	7.86E-06
Acidification (kg SO2-eq)	0.65	0.57	0.64	0.79	0.69	0.73
Eutrophication (kg N-eq)	0.30	0.28	0.22	0.37	0.35	0.31
Photochemical Ozone Creation/Smog (kg O3-eq)	12.71	10.57	12.11	15.18	12.40	13.40
Abiotic Depletion Potential ADPf (MJ)	373.25	319.85	333.96	514.94	445.52	454.71
Abiotic Depletion Potential ADPe (kg Sb eq.)	1.89E-04	1.88E-04	1.75E-04	3.37E-04	3.36E-04	3.28E-04
Use of renewable primary energy (MJ)	11.75	38.77	30.94	25.55	60.67	55.57
Use of non-renewable primary energy (MJ)	1,406.18	563.35	785.23	1,791.34	695.67	840.13
Fresh water consumption (m3)	0.42	0.41	0.33	0.51	0.91	0.83

Introduction | Slag Substitution | Custom Mixes | Comparison to Benchmark | Impacts in Wh

Example of benchmark concrete for whole building aspect

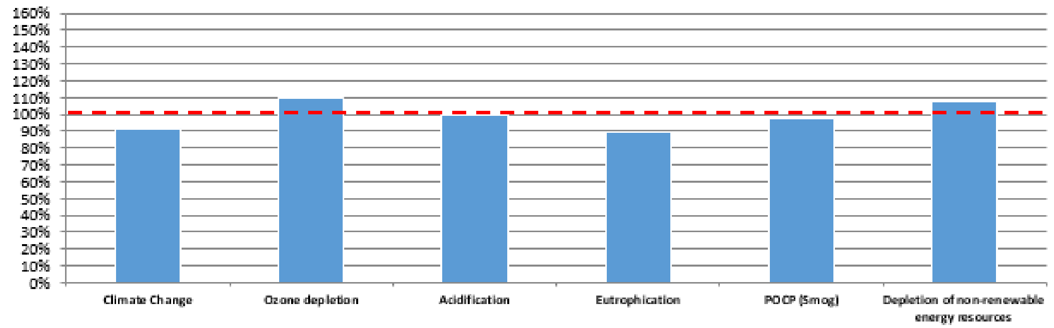
The **Impacts in Whole Building** is an easy tool for designers to apply when evaluating the impact of slag for their project compared to the NRMCA Industry EPD.

Using original PLC& Slag mix values

PLC 235 lbs/ slag 235 lbs on Mass Conc. (50% Slag for 470# mix)

PLC 458 lbs / slag 153 lbs on Floors, Columns (25% Slag for 611# mix)

Comparison of Entered Mixes to Building Constructed with Benchmark Concrete



% of Impacts of Building with Default Concrete	
Climate Change	91%
Ozone depletion	110%
Acidification	99%
Eutrophication	89%
POCP (Smog)	98%
Depletion of non-renewable energy resourc	107%

Life Cycle Assessment Results	Total Impacts		Impacts of Individual Mixes					
Mix ID	Benchmark Building	Custom Building	Mass OPC	Mass PLC	Mass slag	Floor OPC	Floor PLC	Floor slag
Climate Change (kg CO2-eq)	8,264,168.39	7,529,645.22			825,793.49			1,551,678.94
Ozone depletion (kg CFC-11-eq)	9.35E-02	1.02E-01			3.96E-02			5.50E-02
Acidification (kg SO2-eq)	38,915.95	38,619.09			3,827.33			5,112.71
Eutrophication (kg N-eq)	5,318.12	4,739.95			1,326.89			2,143.51
hotochemical Ozone Creation/Smog (kg O3-eq)	704,534.81	687,858.59			72,654.52			93,788.12
letion of non-renewable energy resources (MJ)	69,356,415.02	74,543,085.20			2,003,732.70			3,182,937.47

Introduction | Slag Substitution | Custom Mixes | Comparison to Benchmark | Impacts in Whole Building

Mass concrete 33% GWP reduction using PLC and Slag

Floor and Columns 15% GWP reduction

Key Messages / Takeaways

1. **Concrete is the Sustainable Building Material!**
    - Meets the criteria: Sustainable constituents, Low CO2 & Energy, Resilient, Long Lasting
    - No viable alternative; true sustainability needs to account for full project life cycle

2. **We have the tools to improve, key levers include:**
    - Clinker reduction in our cements & SCMS to reduce Portland Cement in our mixes
    - Slag Cement is an exceptionally good SCM due to high replacement levels

3. **The SCA's LCA Calculator is Good Tool for Comparing Environmental Impacts**
    - Relies on EPDs for environmental impact accounting
    - Four tabs work together:
        - **Slag Substitution**: Sets Region for other tabs, quick comparison of standard mixes
        - **Custom Mixes**: Compares up to 10 custom mixes that will then be available from the drop-down list on the "Slag Substitution" tab.
        - **Comparison to Benchmark**: Shows impacts of "Custom Mixes"
        - **Impacts in Whole Building**: Uses Custom Mixes to compare impacts

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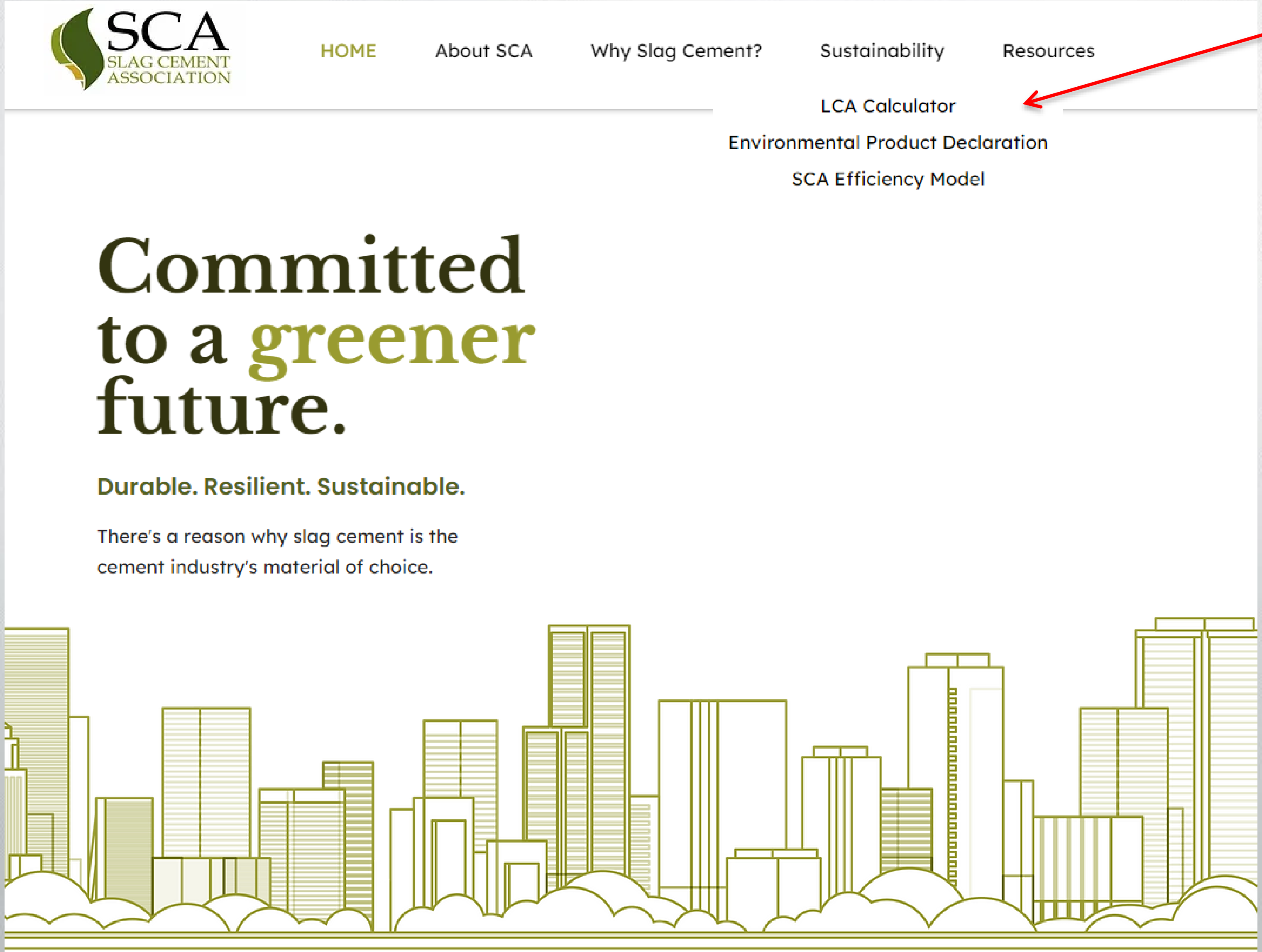
SLAG CEMENT ASSOCIATION

Carbon Accounting Tools – SCAs LCA Calculator

Accessing the Slag Cement Association free LCA Calculator is Easy and its a Quick Useful Tool



Questions?

…Thank You

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