Welcome to NEU's Webinar!

NEU's monthly webinars are part of our commitment to education on sustainable practices and climate adaptive strategies.

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The NEU Low-Carbon Concrete Materials Guide Overview

Mary Christiansen, PhD
University of Minnesota Duluth

January 29, 2026

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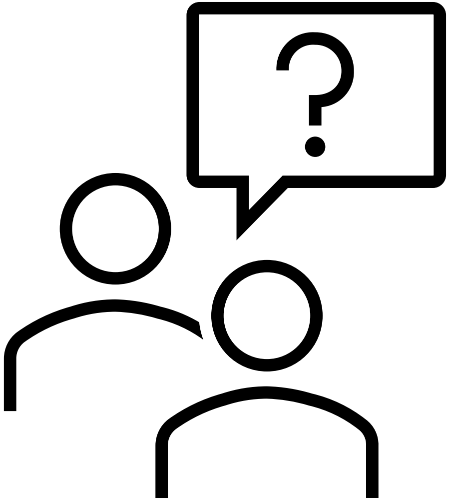
www.neuconcrete.org

Presentation Notes

- Find presentation slides and post event recording at:
  - https://www.neuconcrete.org/events-and-education
- Attendees are in listen only mode.
- Ask questions via the Q&A dialog box in the zoom platform



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Disclaimer

As with all concrete mixtures, trial batches should be performed to verify concrete properties. Results may vary due to a variety of circumstances, including temperature and mixture components, among other things.

You should consult your materials, cement, and concrete professionals for design assistance. Nothing contained herein shall be considered or construed as a warranty or guarantee, either expressed or implied, including any warranty of fitness for a particular purpose.

Today's Speaker

Dr. Mary Christiansen is an Associate Professor in the Department of Civil and Environmental Engineering at the University of Minnesota Duluth. She earned her BS and MS degrees in Architectural and Structural Engineering from the Milwaukee School of Engineering in 2008 and her PhD in Civil Engineering from Michigan Technological University in 2013.

Dr. Christiansen teaches courses in concrete materials, structural design, and sustainability. Her research focuses on the development and characterization of low-carbon concrete and high-performance materials aimed at improving the sustainability and resiliency of concrete infrastructure.

She was the founding chair of ACI Committee 242, Alternative Cements, and is a member of ACI Committees 232, Fly Ash in Concrete, and 240, Pozzolans.

The NEU Low-Carbon Concrete Materials Guide Overview

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Purpose of the Guide

- Provide a structure, big-picture overview of the low-carbon concrete materials landscape
- Make the guide useful across audiences: students, engineers, architects, owners, contractors, decision makers
- Organize the vocabulary and "language" of low-carbon concrete materials
- Present materials in context: what's used today, what's emerging, and what's on the horizon

Photo courtesy of Bailee Coughlin.

Organization of the Guide

- Part I: Understanding the Carbon Footprint of Concrete
- Part II: Exploring Low-Carbon Alternatives to Portland Cement
- Part III: Exploring Low-Carbon Alternatives to Non-Binder Concrete Materials
- Part IV: Advanced Design Strategies for Low-Carbon Concrete

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Part I: Understanding the Carbon Footprint of Concrete

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Understanding the Carbon Footprint of Concrete

7-8% Global Annual Carbon Emissions!?

Statistic from Miller et al. (2016) and UNIDO 2023.

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Understanding the Carbon Footprint of Concrete

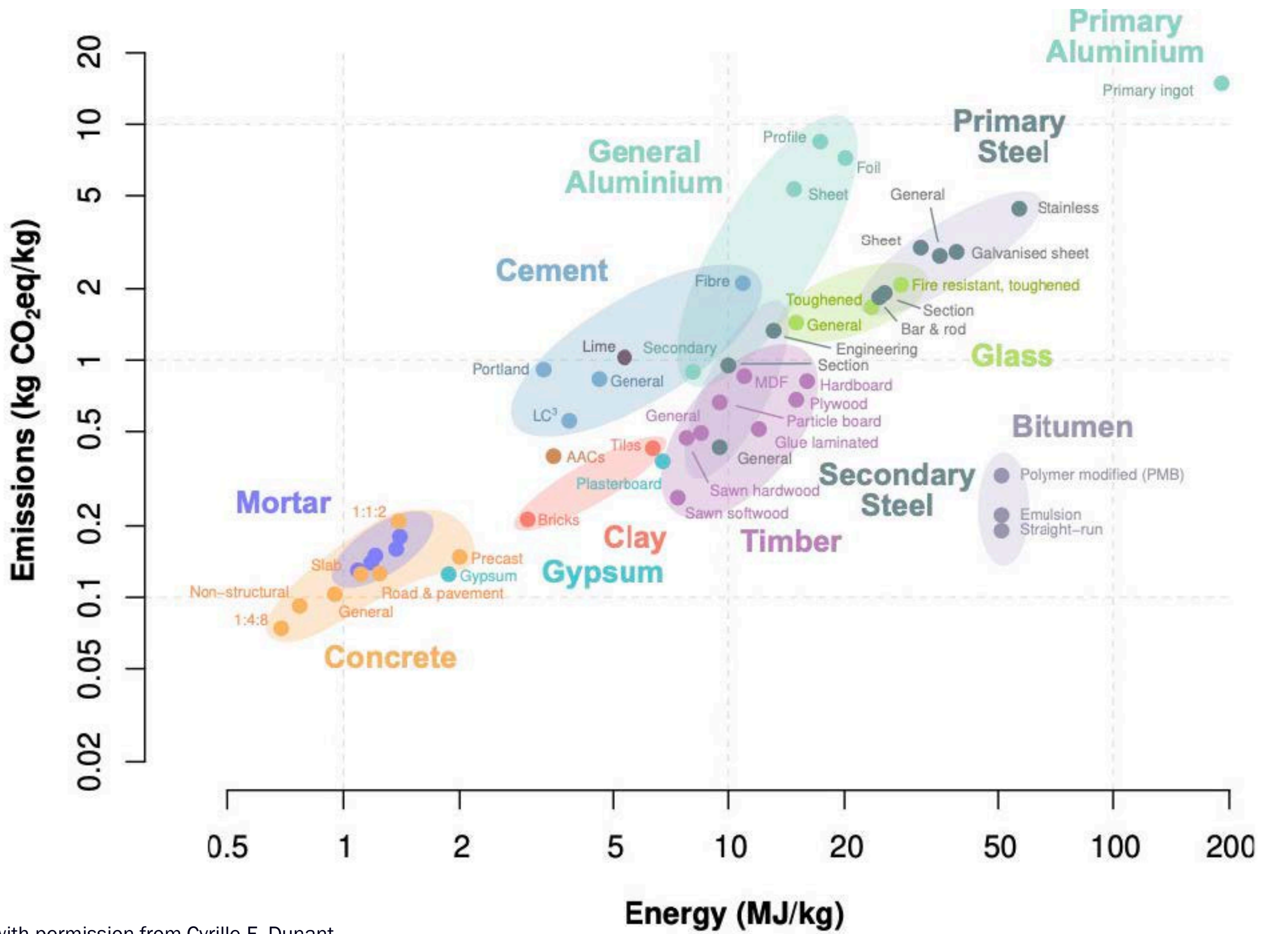
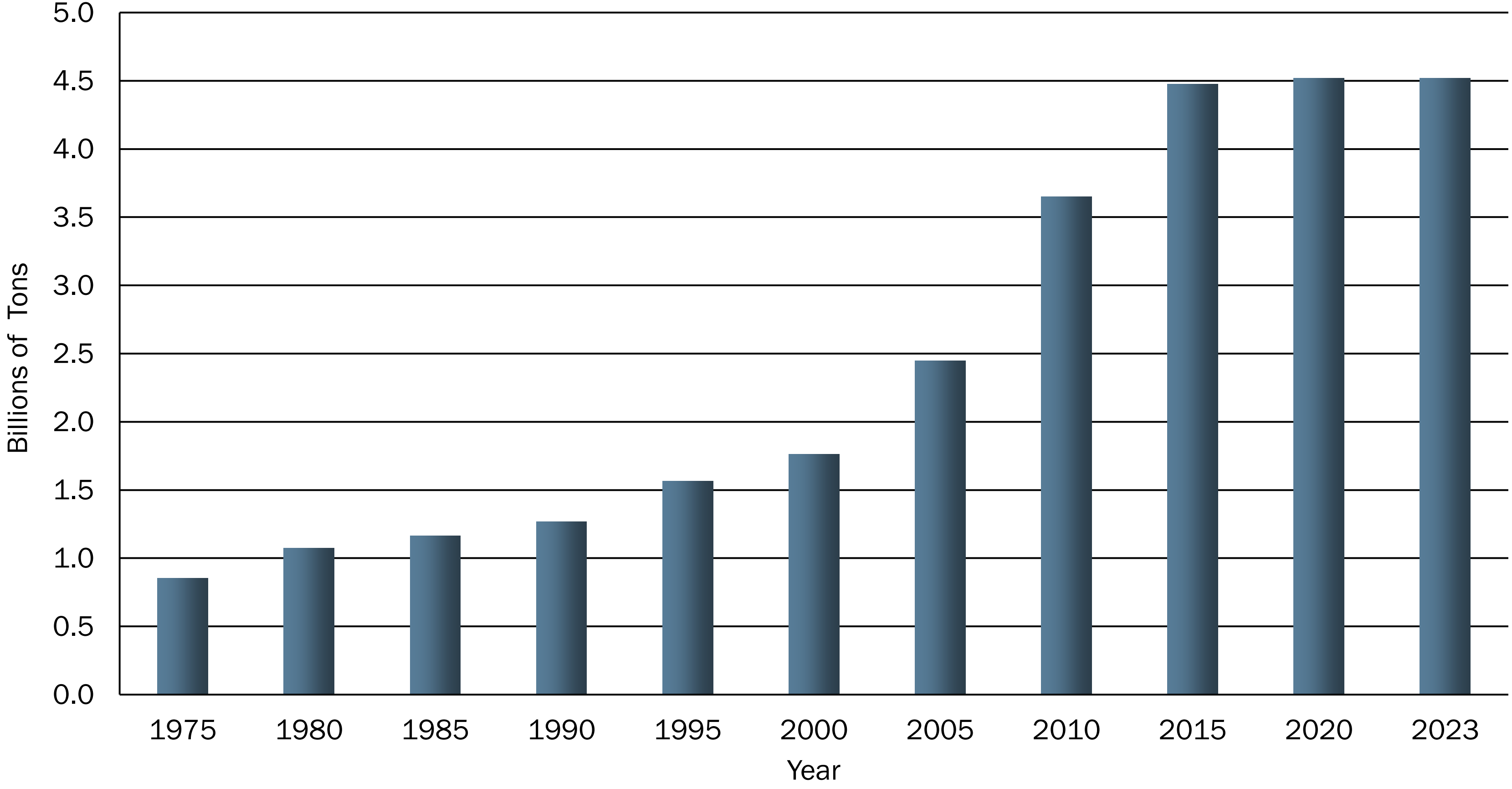


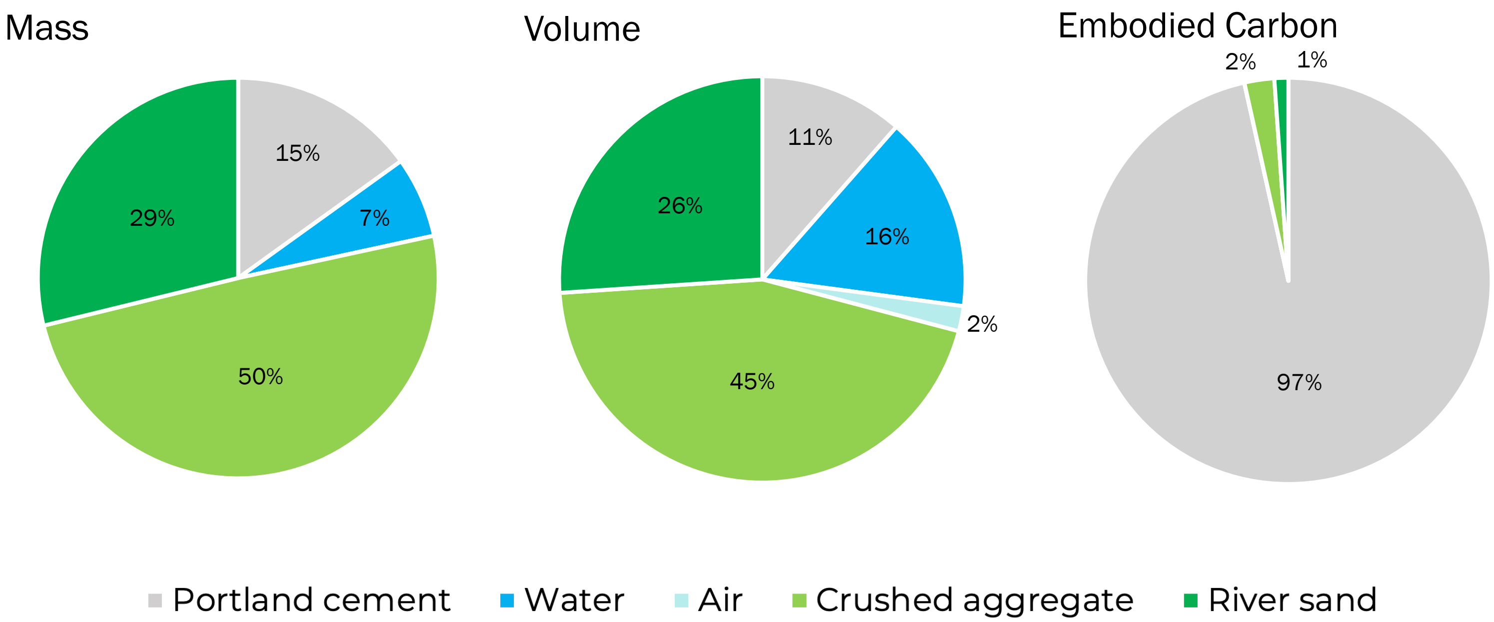
Figure used with permission from Cyrille F. Dunant.

Understanding the Carbon Footprint of Concrete



Statistics from USGS (2024), Miller et al. (2016), and UNIDO 2023.

Understanding the Carbon Footprint of Concrete



Statistics from Adesina (2020).

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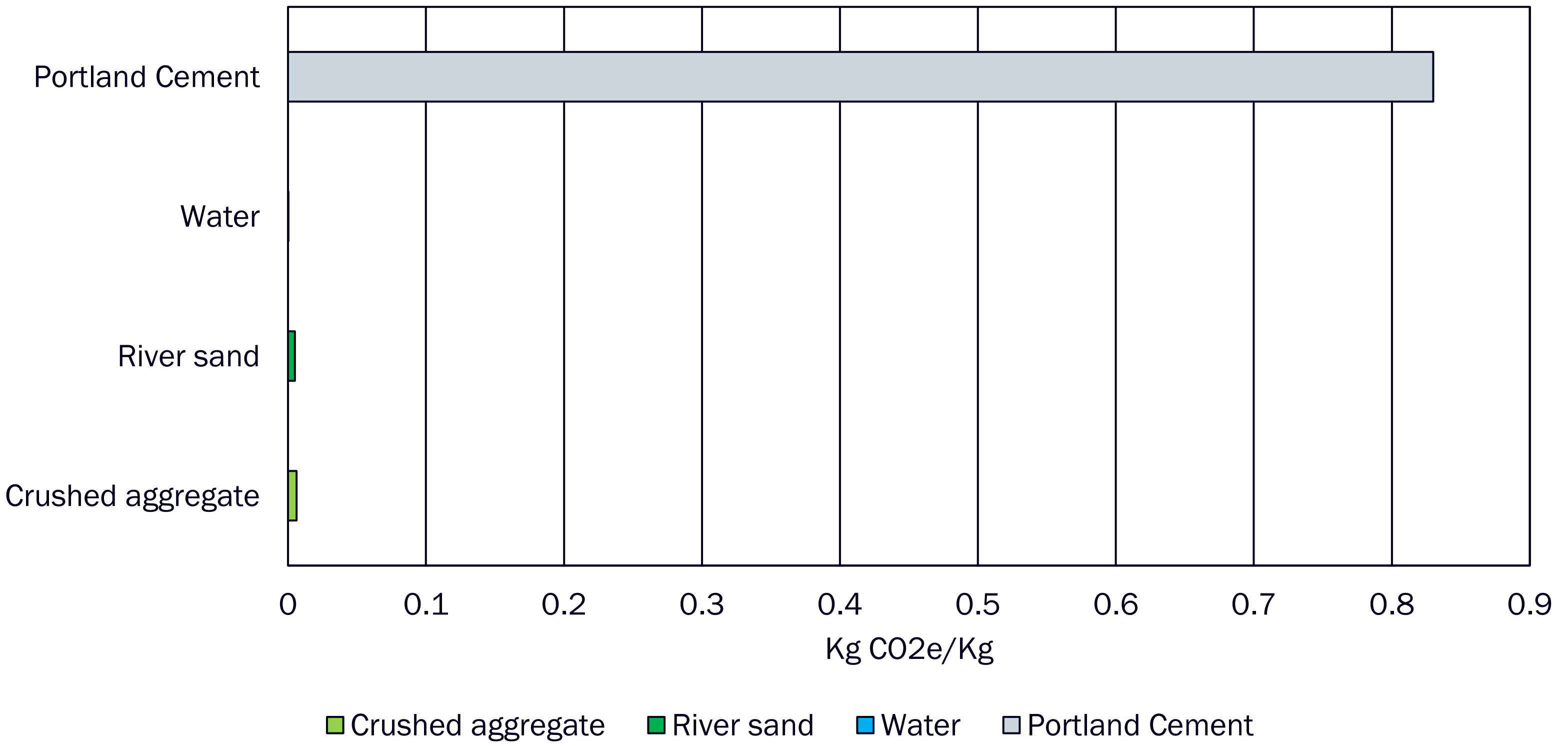
Understanding the Carbon Footprint of Concrete



Statistics from Adesina (2020).

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Traditionally Produced Portland Cement Concrete

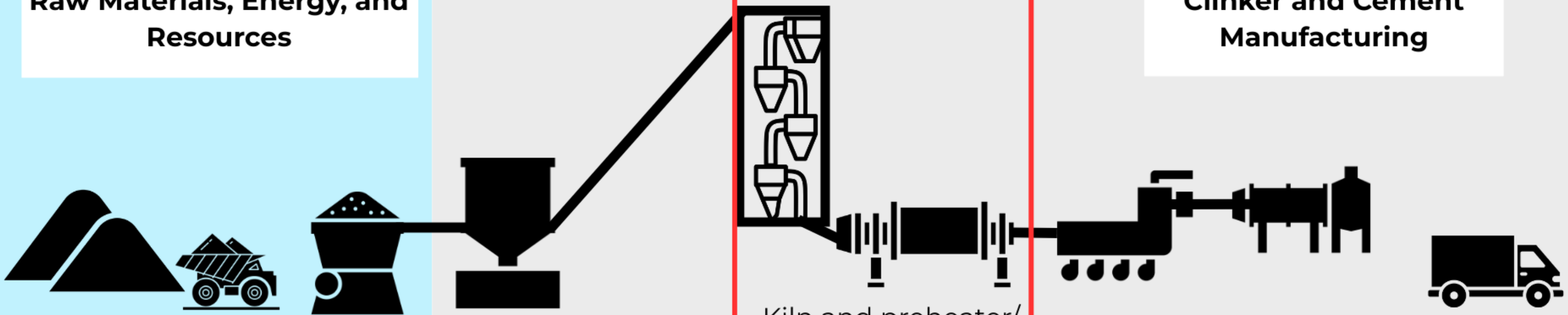
Part I: 1 2 3 4
Part II: 5 6 7 8 9
Part III: 10 11 12
Part IV: 13 14

Photo courtesy of Jeff Hook.

Traditionally Produced Portland Cement Concrete

Raw Materials, Energy, and Resources

Clinker and Cement Manufacturing



	Quarry	Crusher	Raw Mill	Transport	Kiln and preheater/ precalcinator	Cooler	Cement Mill	Logistics	**Total**
Energy *(MJ)*	*40*	*5*	*40*	*100*	*3,100*	*160*	*285*	*115*	***3,845***
Carbon Produced *(kg/metric tonne)*	*3*	*1*	*7*	*17*	*479* *319*	*28*	*49*	*22*	***925***

Adapted from Czigler et al. (2020).

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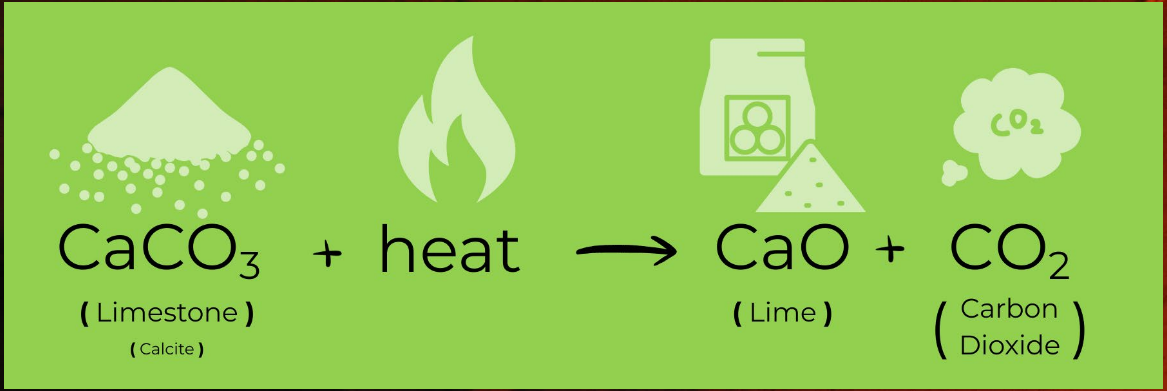
Traditionally Produced Portland Cement Concrete



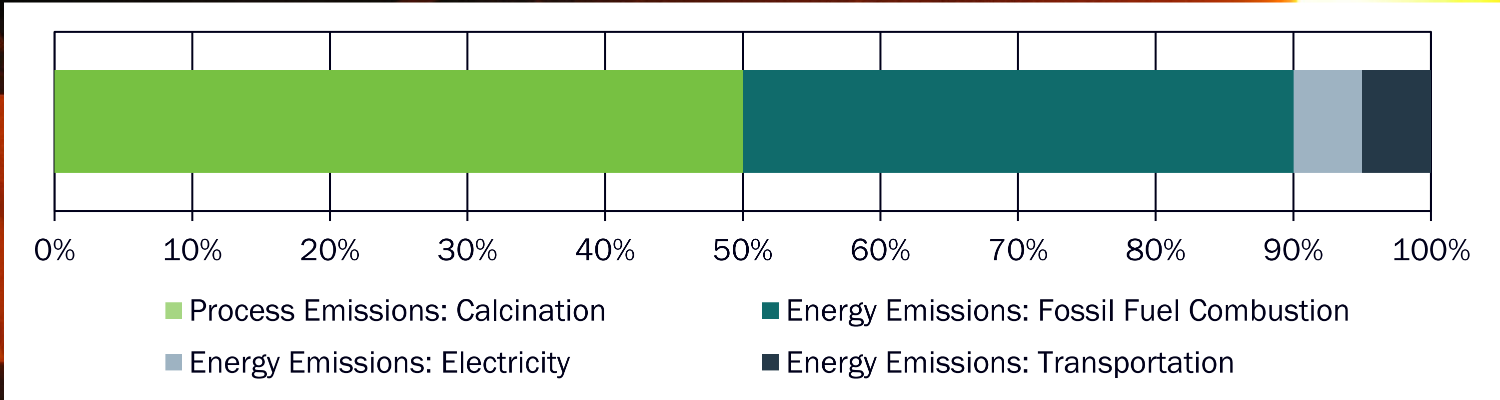
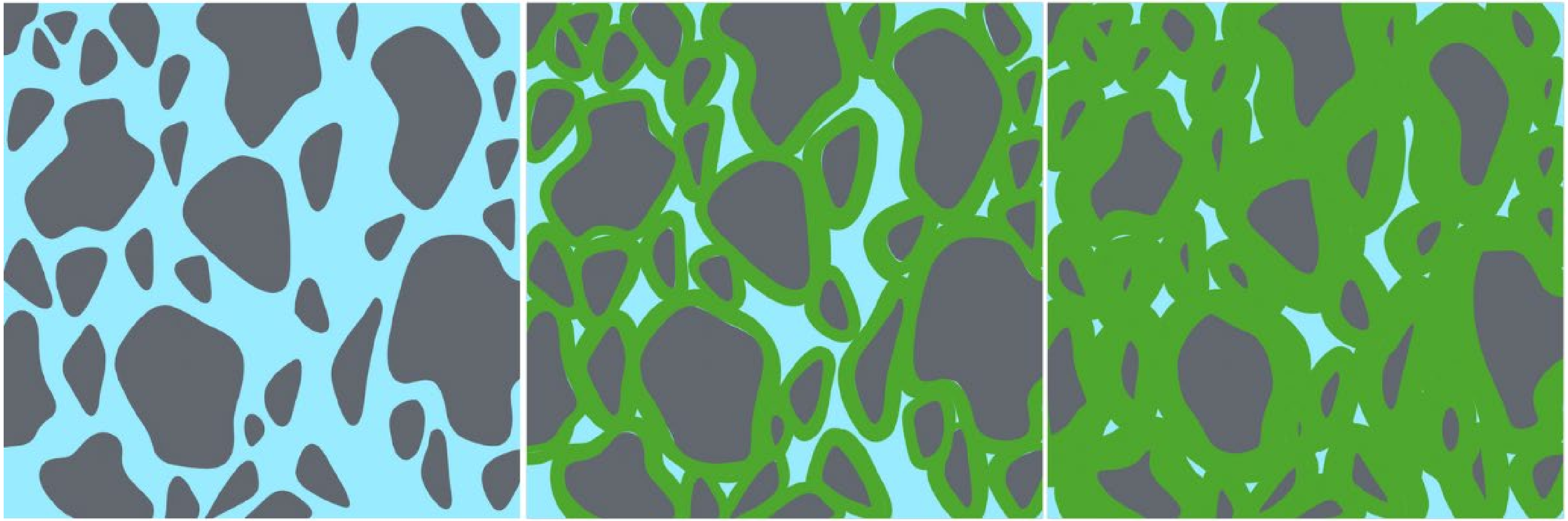


Photo courtesy of Larry Rowland. Statistics from Summerbell et al. (2016).

Traditionally Produced Portland Cement Concrete



Unhydrated Cement | Hydration | Hardened Concrete

$C_3S + H \longrightarrow C\text{-}S\text{-}H + CH$

(Alite) (Water) (Calcium Silicate Hydrate) (Calcium Hydroxide)

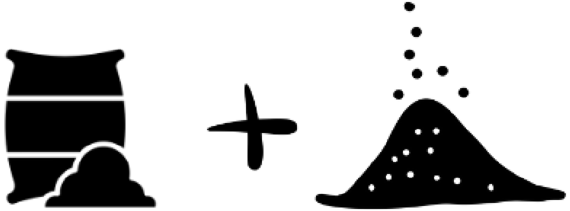
$C_2S + H \longrightarrow C\text{-}S\text{-}H + CH$

(Belite) (Water) (Calcium Silicate Hydrate) (Calcium Hydroxide)

Adapted from Scrivener et al. (2018).

Life Cycle Carbon: Frameworks, Metrics, and Benchmarks

Life Cycle Carbon: Frameworks, Metrics, and Benchmarks



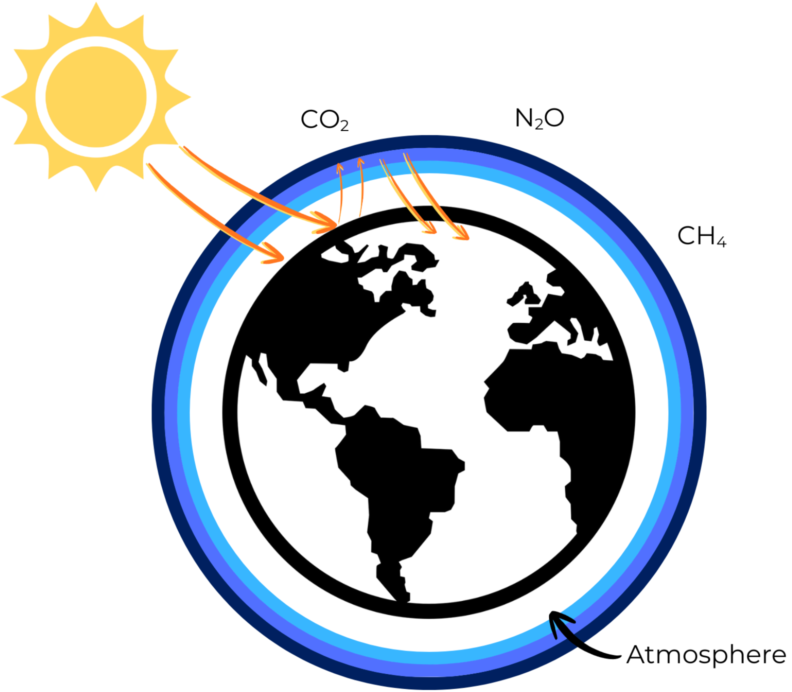
Partial replacement of portland cement with supplementary cementitious materials

More resilient structure

Embodied Carbon + Downstream Carbon

Whole-Life Carbon

Life Cycle Carbon: Frameworks, Metrics, and Benchmarks



GHG Emissions		Apply GWP Factors		Sum Total
800 kg CO_2	×	GWP for CO_2 1	=	800 kg CO_{2e}
				+
2 kg CH_4	×	GWP for CH_4 25	=	50 kg CO_{2e}
				+
0.5 kg N_2O	×	GWP for N_2O 298	=	149 kg CO_{2e}
		Total Carbon Dioxide Equivalent	=	999 kg CO_{2e}

Life Cycle Carbon: Frameworks, Metrics, and Benchmarks

PCA Since 1916
America's Cement Manufacturers™

ASTM INTERNATIONAL

ENVIRONMENTAL PRODUCT DECLARATION
PORTLAND CEMENT

Life cycle assessment results

The cradle-to-gate (A1 to A3) EPD results for producing one metric ton of portland cement are presented in Table 4.

Table 4. Production stage EPD results for portland cements.

Impact category and inventory indicators	Unit	Portland Cements 1 metric ton
Global warming potential, GWP 100, IPCC 2013	kg CO_2 eq	919
Ozone depletion potential, ODP	kg CFC-11 eq	2.05E-05
Acidification potential, AP	kg SO_2 eq	1.74
Eutrophication potential, EP	kg N eq	1.02
Smog formation potential, SFP	kg O_3 eq	32.8
Abiotic depletion potential for non-fossil mineral resources, ADP elements*	kg Sb eq	1.56E-04
Abiotic depletion potential for fossil resources, ADP fossil*	MJ LHV	4365
Renewable primary resources used as an energy carrier (fuel), RPR_E*	MJ LHV	138
Renewable primary resources with energy content used as material, RPR_M*	MJ LHV	3.55
Non-renewable primary resources used as an energy carrier (fuel), $NRPR_E$*	MJ LHV	4361
Non-renewable primary resources with energy content used as material, $NRPR_M$*	MJ LHV	4.75
Secondary materials, SM*	kg	95.8
Renewable secondary fuels, RSF*	MJ LHV	54.3
Non-renewable secondary fuels, NRSF*	MJ LHV	523
Net use of freshwater, NFW*	m^3	1.2
Hazardous waste disposed, HWD*	kg	0.013
Non-hazardous waste disposed, NHWD*	kg	5.23
High-level radioactive waste, conditioned, to final repository, HLRW*	kg	x[1)]
Intermediate- and low-level radioactive waste, conditioned, to final repository, ILLRW*	kg	x[1)]
Components for re-use, CRU*	kg	0
Materials for recycling, MFR*	kg	0.52
Materials for energy recovery, MER*	kg	0
Recovered energy exported from the product system, EE*	MJ LHV	1.94
Global warming potential - biogenic, GWP_{bio}*	kg CO_2 eq	0.34
Emissions from calcination*	kg CO_2 eq	480
Emissions from combustion of waste from renewable sources*	kg CO_2 eq	0.260
Emissions from combustion of waste from non-renewable sources*	kg CO_2 eq	51.1
Removals and emissions associated with biogenic content of bio-packaging	kg CO_2	-0.38

[1)] x – Not all LCA datasets for upstream materials include these impact categories and thus results may be incomplete.
[*)] Use caution when interpreting results for these categories

IN-LB Inch-Pound Units

Low-Carbon Concrete—Code Requirements and Commentary

Reported by ACI Committee 323

ACI CODE-323-24

aci American Concrete Institute
Always advancing

Figures courtesy of Athena Sustainable Materials Institute and ASTM International (2023) (left) and ACI (2023) (right).

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Material Selection Considerations

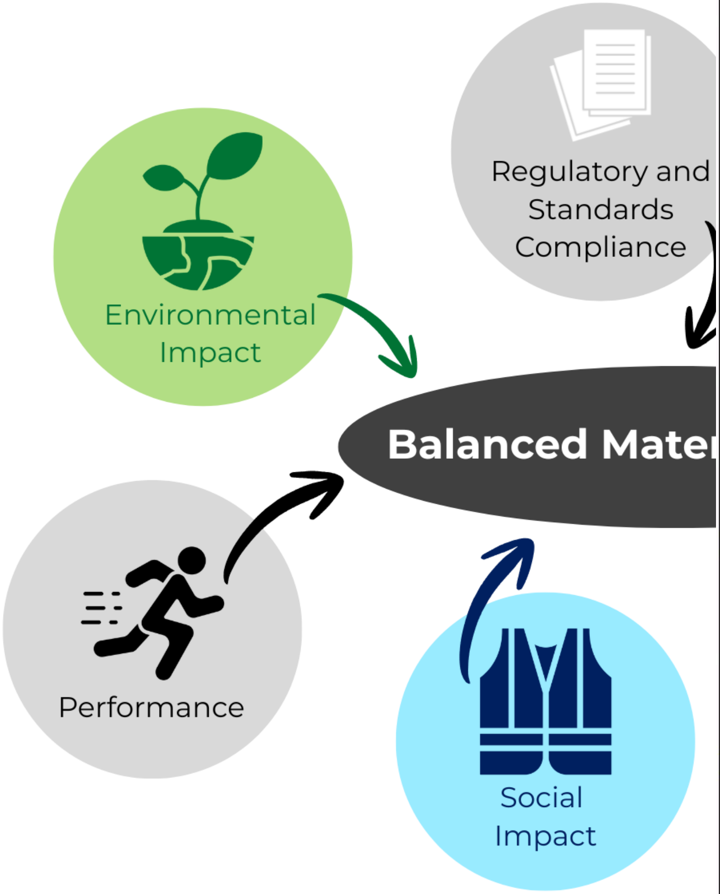

Table 20 Compliance Documents Influencing Material Selection and Adoption

Organization	Key Document(s)	Primary Focus	Relevance to Low-Carbon Materials
Codes			
ACI	ACI CODE 318, Building Code for Structural Concrete—Code Requirements and Commentary	Structural safety, durability	Establishes structural and durability requirements; prescriptive provisions shape material acceptance.
ACI	ACI CODE-562, Assessment, Repair, and Rehabilitation of Existing Concrete Structures—Code Requirements and Commentary	Repair and rehabilitation of existing structures	Governs repair materials and methods; applies to alternative binders and repair mortars.
ACI	ACI CODE-323, Low-Carbon Concrete—Code Requirements and Commentary	Performance-based mixture acceptance	Introduces explicit performance- and carbon-based provisions for concrete mixtures.
AASHTO	AASHTO LRFD Bridge Design Specifications	Transportation structures	Governs bridge design in the U.S.; acceptance provisions influence the use of SCMs and alternative binders.
Specifications			
ACI	ACI CODE-301, Specifications for Concrete Construction	Contract-level construction requirements	Provides prescriptive limits that often restrict SCM or alternative binder use unless modified.
ASTM International	ASTM material specifications and test methods	Standardized classification and testing	Provide acceptance criteria for portland cements, blended cements, performance cements, SCMs, and durability performance.
AASHTO	AASHTO material specifications and test methods	SCMs for transportation projects	Define acceptance criteria for SCMs and binders used in state-level transportation projects.
Technical Reports and Guides			
ACI	ACI technical reports and guides	Material-specific evaluation	Provide technical evaluation and guidance for SCMs, alternative cements, mixture proportioning, and other materials to support acceptance of low-carbon innovations.
RILEM	Technical committee recommendations	Research-driven test methods	Provide consensus-based test methods and recommendations, often research-driven, that help fill gaps where no ASTM/ACI equivalents exist.
International Standards			
CEN (Europe)	European standards	European concrete and cement frameworks	Allow wider use of blended systems and performance-based acceptance than U.S. counterparts.
ISO	ISO standards for EPDs and LCAs	Environmental declarations and LCAs	Establish frameworks for environmental product declarations and enable carbon-based material comparisons.

Part II: Exploring Low-Carbon Alternatives to Portland Cement

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Readiness Levels

Readiness Level	Definition
Proven	Widely adopted in industry practice with established specifications, abundant field data, and well-understood performance characteristics.
Emerging	Demonstrated in field projects or regionally available but not yet standardized or broadly adopted. Data and specifications may be limited, under development, or region-specific.
Experimental	Primarily in research or pilot stages. Limited field experience, uncertain long-term performance, and significant scale-up challenges remain before commercial adoption.

Strategies for Reducing the Carbon Footprint of the Binder

Part I	1
	2
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	4
Part II	5
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Part III	10
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	12
Part IV	13
	14

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Supplementary Cementitious Materials

Photo courtesy of Mindy Granley.

Supplementary Cementitious Materials

Photos courtesy of Laura Nurczyk (top) and Harsh Jain (bottom).

Supplementary Cementitious Materials

Photos courtesy of Briana Gross.

Supplementary Cementitious Materials

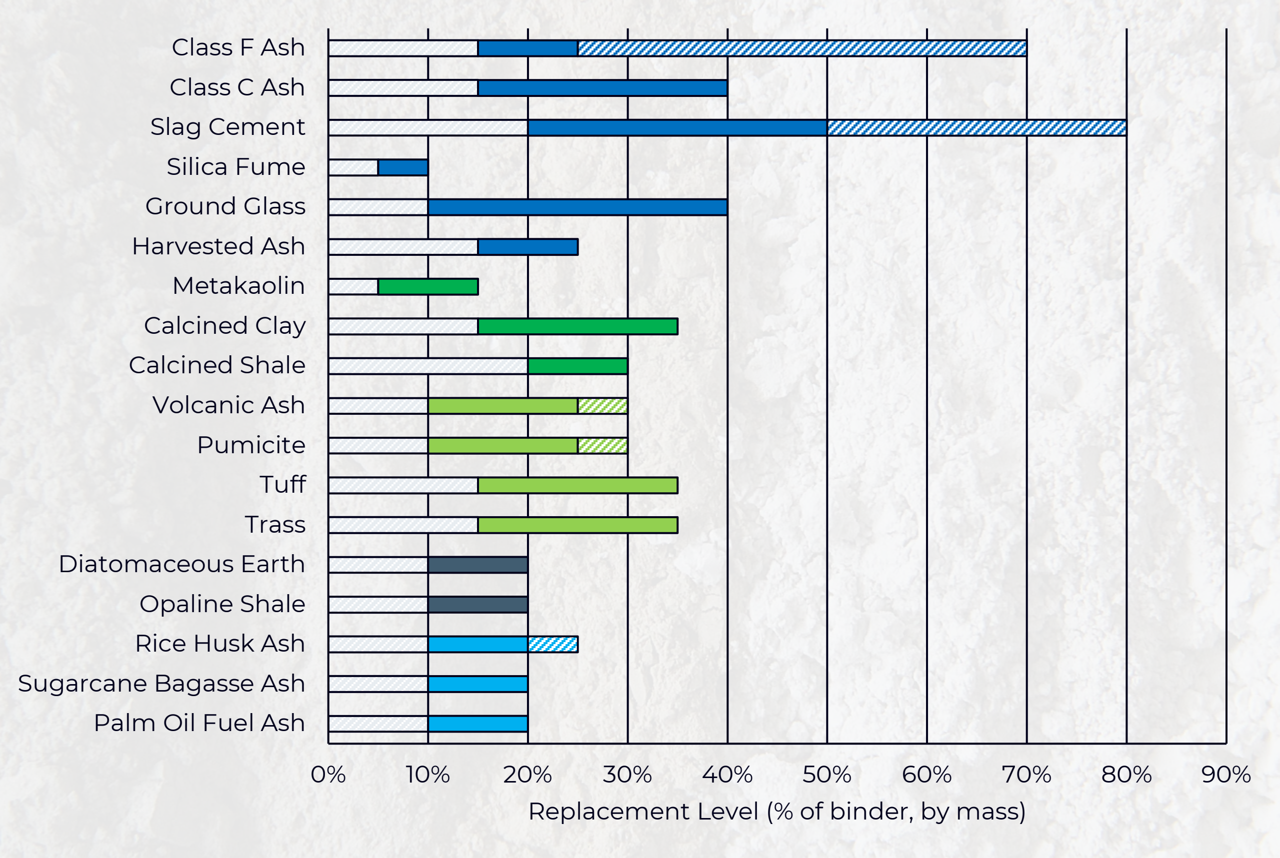
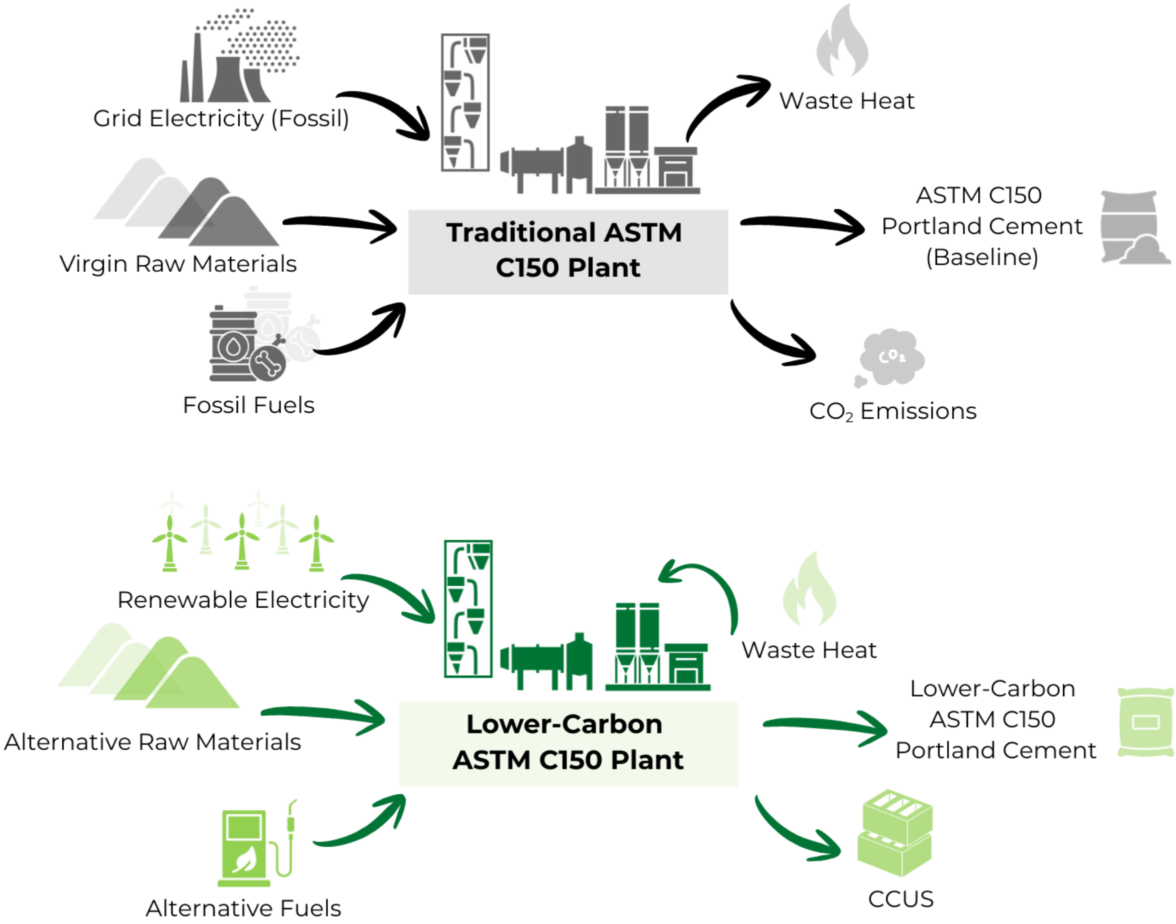


Photo courtesy of Kate McCabe.

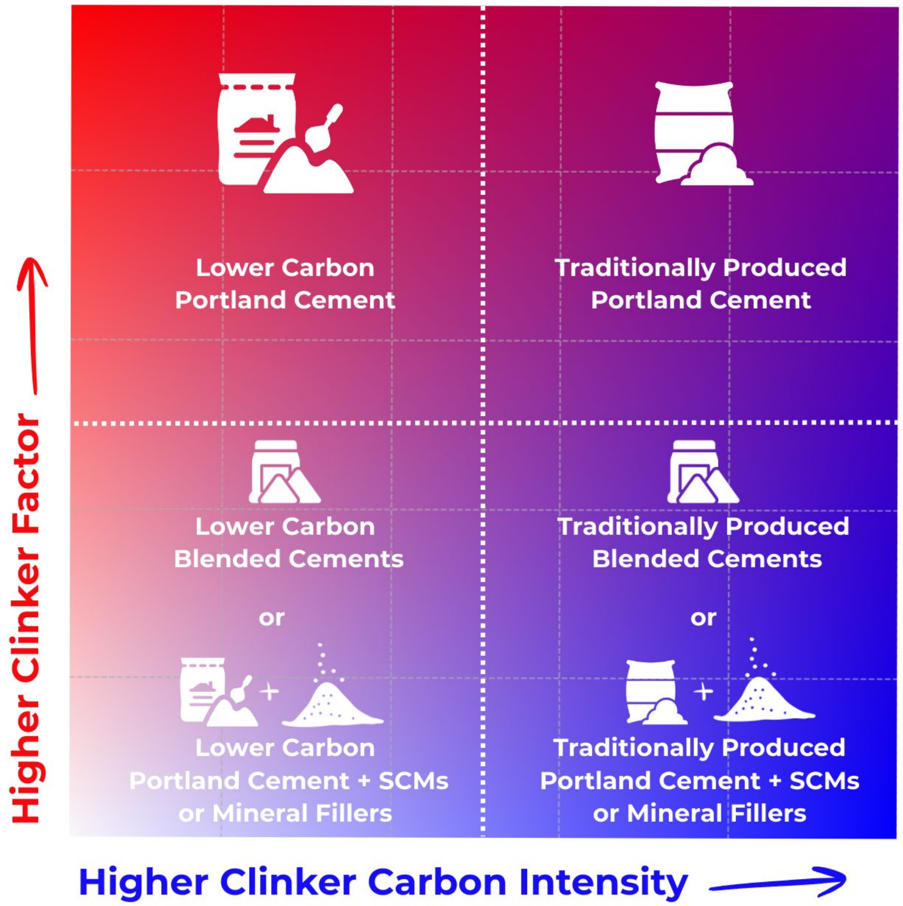
Mineral Fillers

Photo courtesy of Kate McCabe.

Plant-Level Innovations in Producing Lower-Carbon Cements

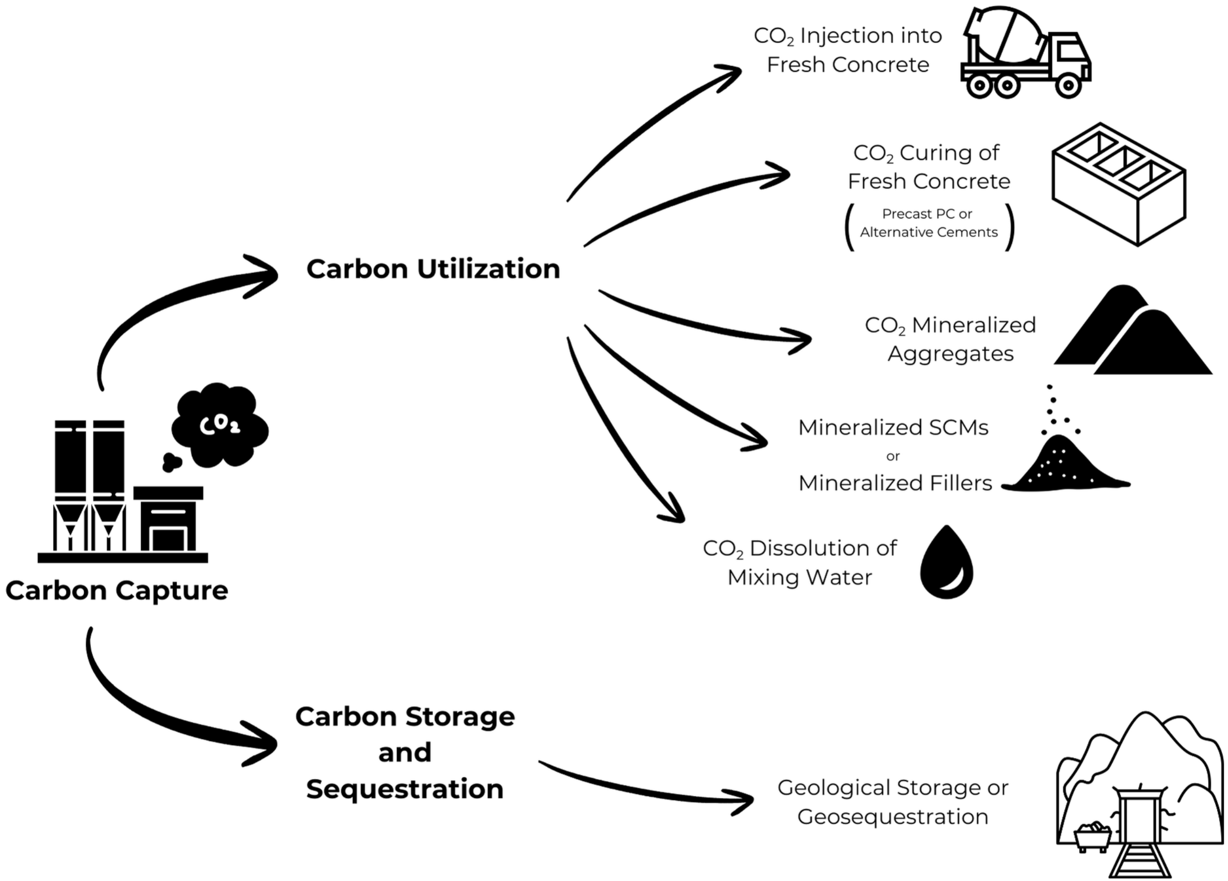


Plant-Level Innovations in Producing Lower-Carbon Cements



Photos courtesy of Kenny Allen (top) and Rachel Clement (bottom).

Carbon Capture, Utilization, and Storage



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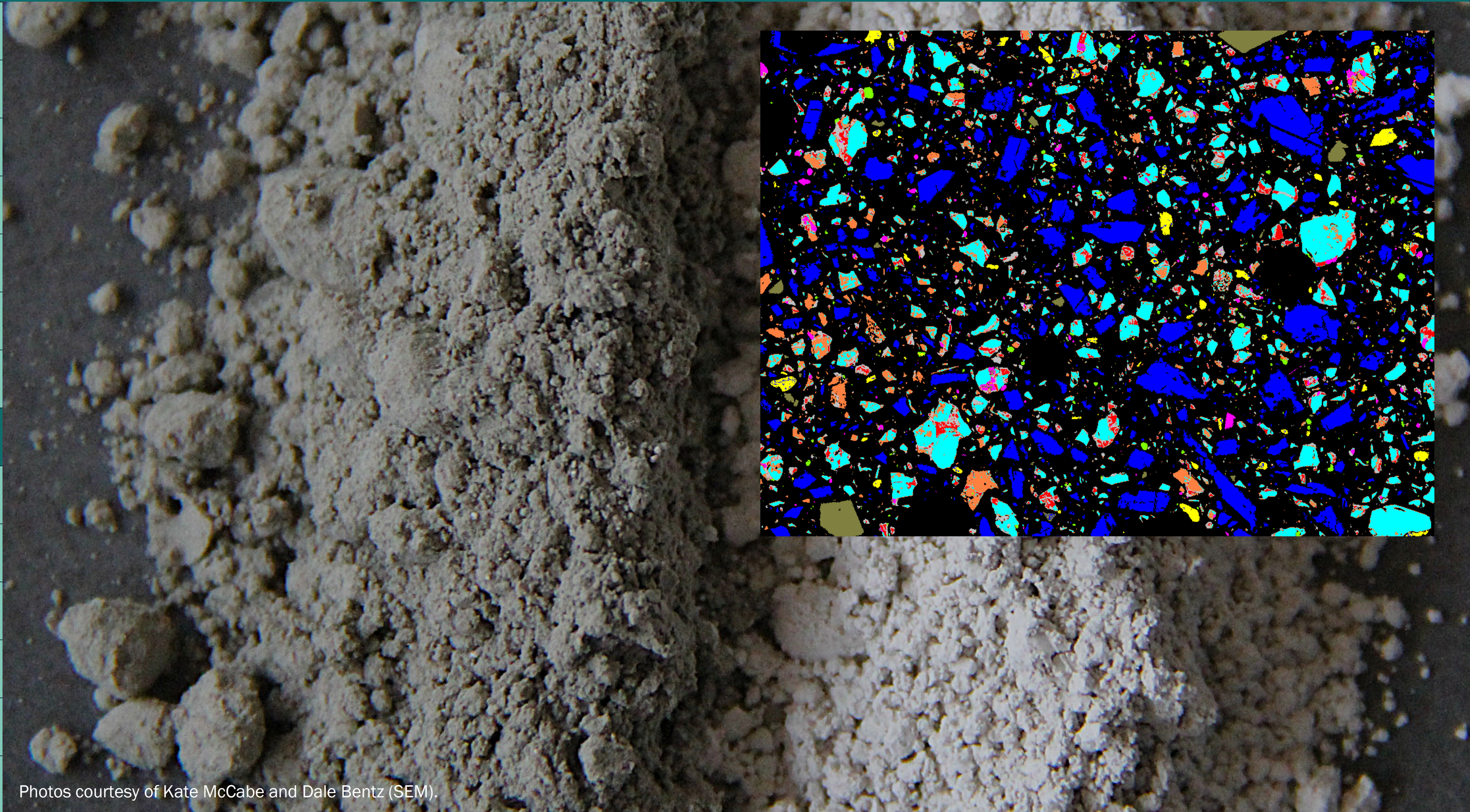
Portland Limestone Cement (Type IL)

Part I: 1 2 3 4
Part II: 5 6 7 8 9
Part III: 10 11 12
Part IV: 13 14



Photos courtesy of Kate McCabe and Dale Bentz (SEM).

LC^3 Cement: Limestone Calcined Clay Cement

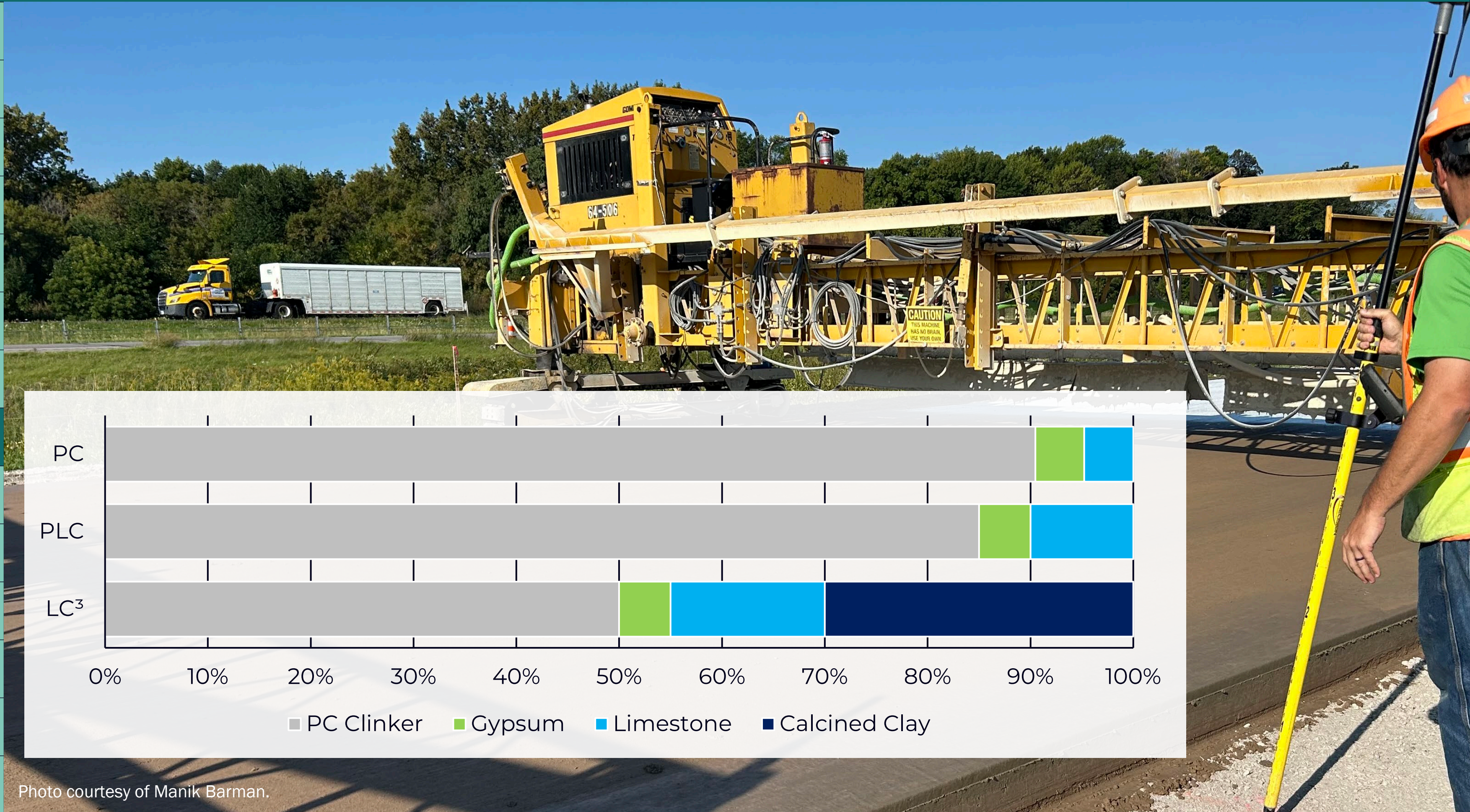


Photo courtesy of Manik Barman.

Alternative Cements

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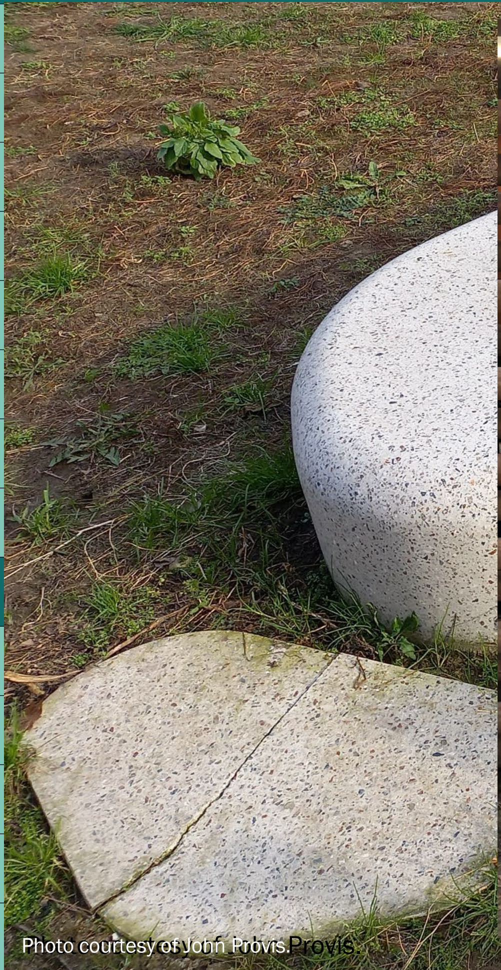

Photo courtesy of John Provis.

Photo courtesy of Maria Juenger.

Strategies for Reducing the Carbon Footprint of the Binder

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Part III
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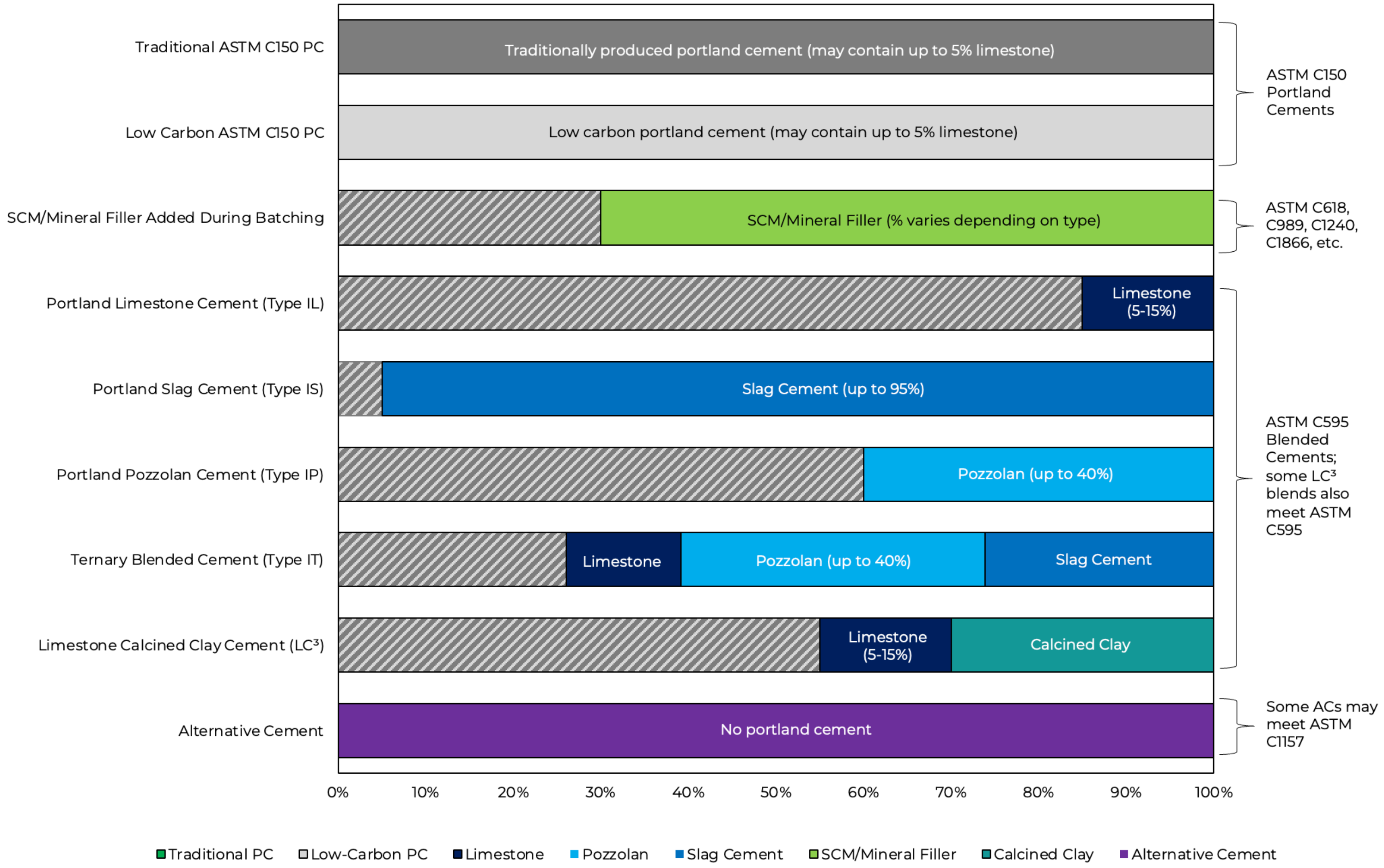

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Part III: Exploring Low-Carbon Alternatives to Non-Binder Concrete Materials

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Aggregates

Photo courtesy of Mary Christiansen.

Aggregates

Photos courtesy of Karl Peterson (top) and Jodi Slick (bottom).

Reinforcement

Photo courtesy of Kate McCabe.

Reinforcement

Photos courtesy of Kate McCabe, Ben Dymond, Grant Magnuson, Mario Ratnaraj (clockwise from top left).

Water in Concrete

Part I 1 2 3 4
Part II 5 6 7 8 9
Part III 10 11 12
Part IV 13 14

- Where water is used in concrete
- Reducing water demand in mixing
- Alternative water sources
- Efficient curing techniques
- Water-conscious construction practices
- CO_2 mineralization of process water

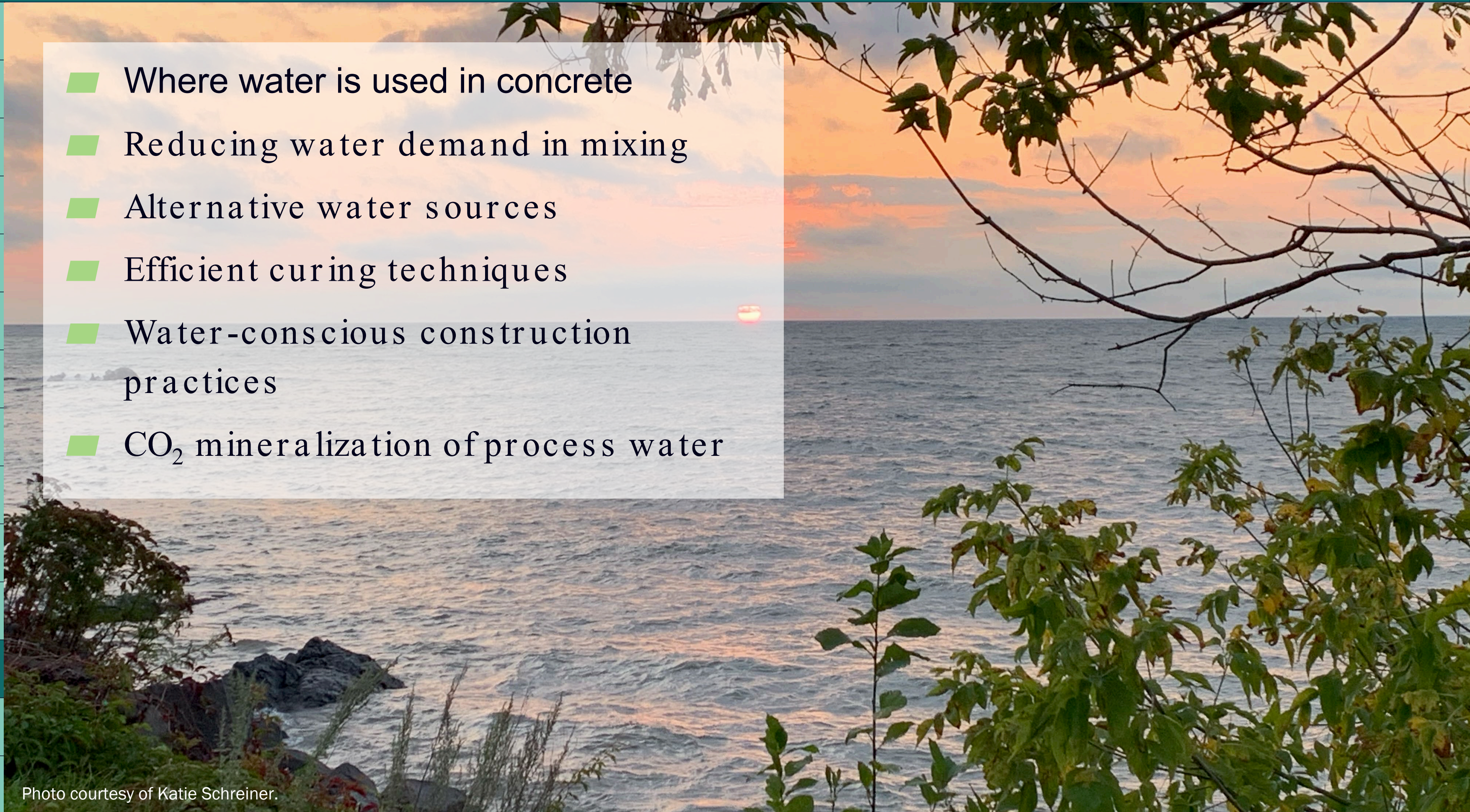

Photo courtesy of Katie Schreiner.

Part IV: Advanced Design Strategies for Low-Carbon Concrete

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Advanced Mixture Optimization for Low-Carbon Concrete

Part I
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Part II
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Part III
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Part IV
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- **Lower clinker content** - water reducers, accelerators, retarders, rheology modifiers, strength enhancing admixtures
- **Reduce total paste volume** - mid- and high-range water reducers, viscosity-modifying admixtures
- **Design for durability** - air-entraining agents, permeability reducers, shrinkage and crack reducers, corrosion inhibitors, ASR inhibitors
- **Improve construction efficiency** - extended-set control admixtures, workability retaining admixtures, viscosity modifying admixtures

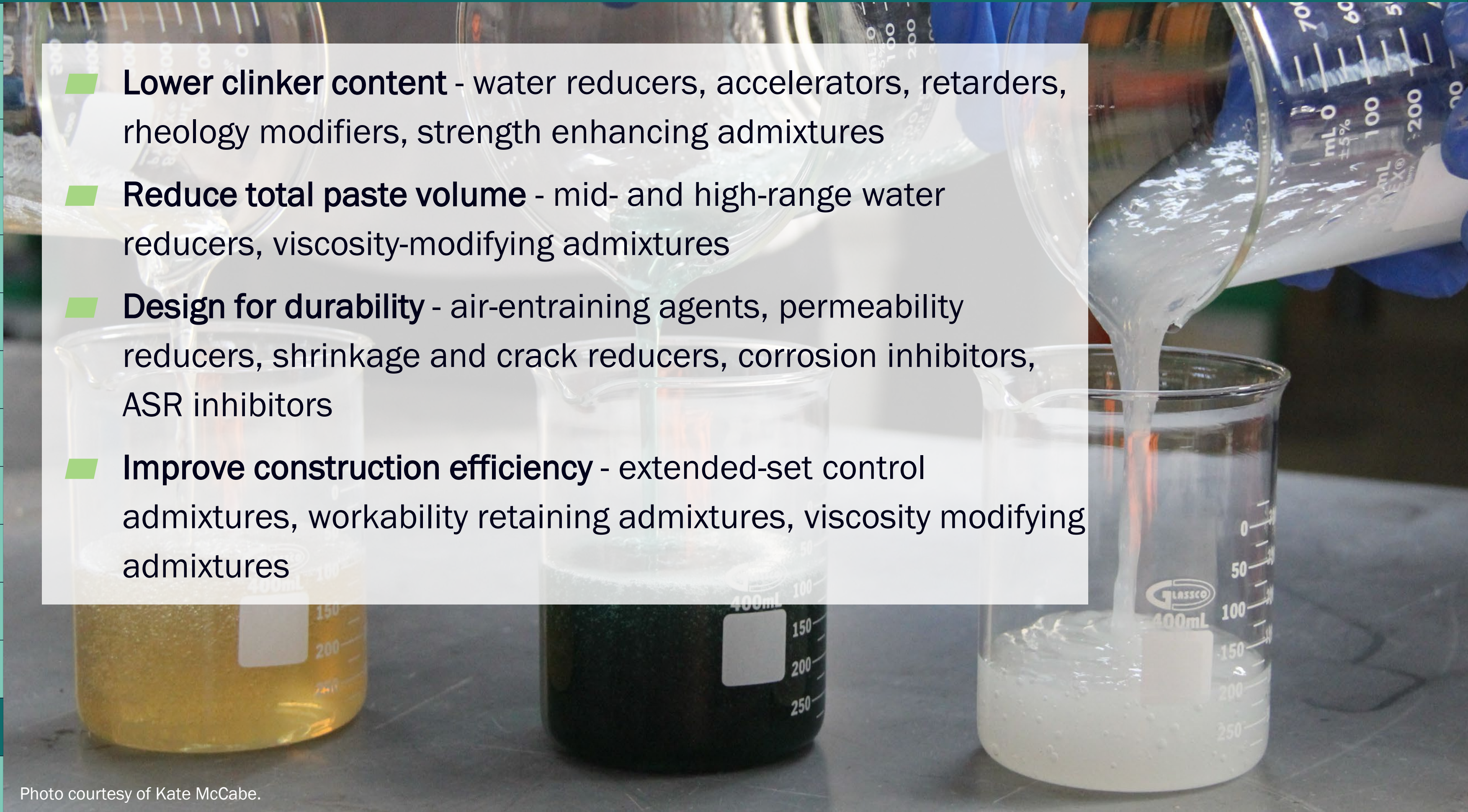


Photo courtesy of Kate McCabe.

Advanced Concretes and Their Role in Low-Carbon Construction

- High-performance concretes
- Construction-efficiency concretes
- Environment- and system-driven concretes

Photos courtesy of Mario Ratnaraj (left) and Mary Vancura (right).

Achieving durable, verifiable reductions in concrete's carbon footprint will require:

- Life-cycle thinking
- Balanced decision-making
- Collaboration across the value chain
- Adopting proven practices while embracing innovation

Photos courtesy of Najeeb Jindeel.

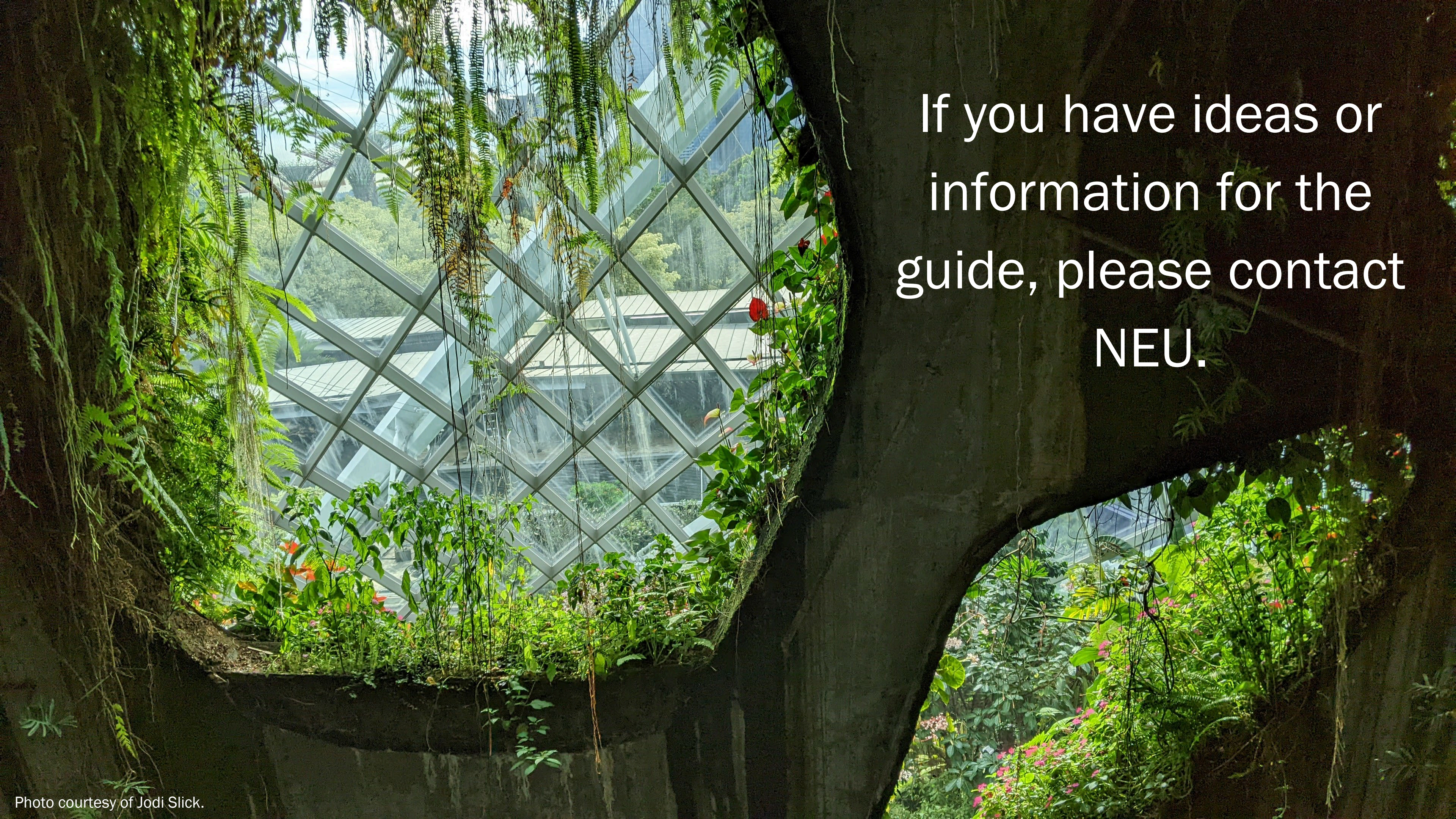
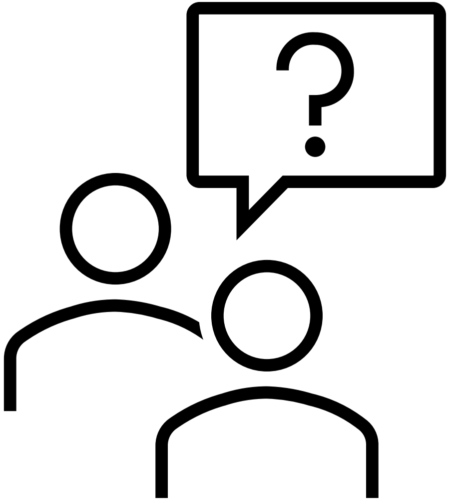


Photo courtesy of Jodi Slick.

Questions?

- Ask questions via the Q&A dialog box in the zoom platform



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NEU is Here to Help You!

Ask us about:

NEU's *The Low-Carbon Concrete Guide: Materials.* Strategies for reducing the carbon emissions of concrete with an emphasis on material/mixture decisions made at the project level. Available for purchase at the ACI Store. Scan the QR code!

NEU's Validation and Verification program. Provides third-party validation or verification of the environmental claims of both existing and innovative new products/technologies associated with low-carbon cement, concrete, and concrete products, following the requirements of international standards.
www.neuconcrete.org/validation-verification

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Thank you!

NEU's next webinar is February 26 at 1 PM Eastern Time. Nathan Forrest from the California Nevada Cement Association presents *Utilizing ACI Code 323 – Low-Carbon Concrete: Real World Implementation and Examples*. Register today: https://ow.ly/4o9750XTbt2

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Low-Carbon Concrete Guide: Materials

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