SH13 CO Overlay
Picture Source: ACPA

COLORADO
Department of Transportation

CDOT Industry Stakeholder EPD Workshop

Concrete Industry Perspective

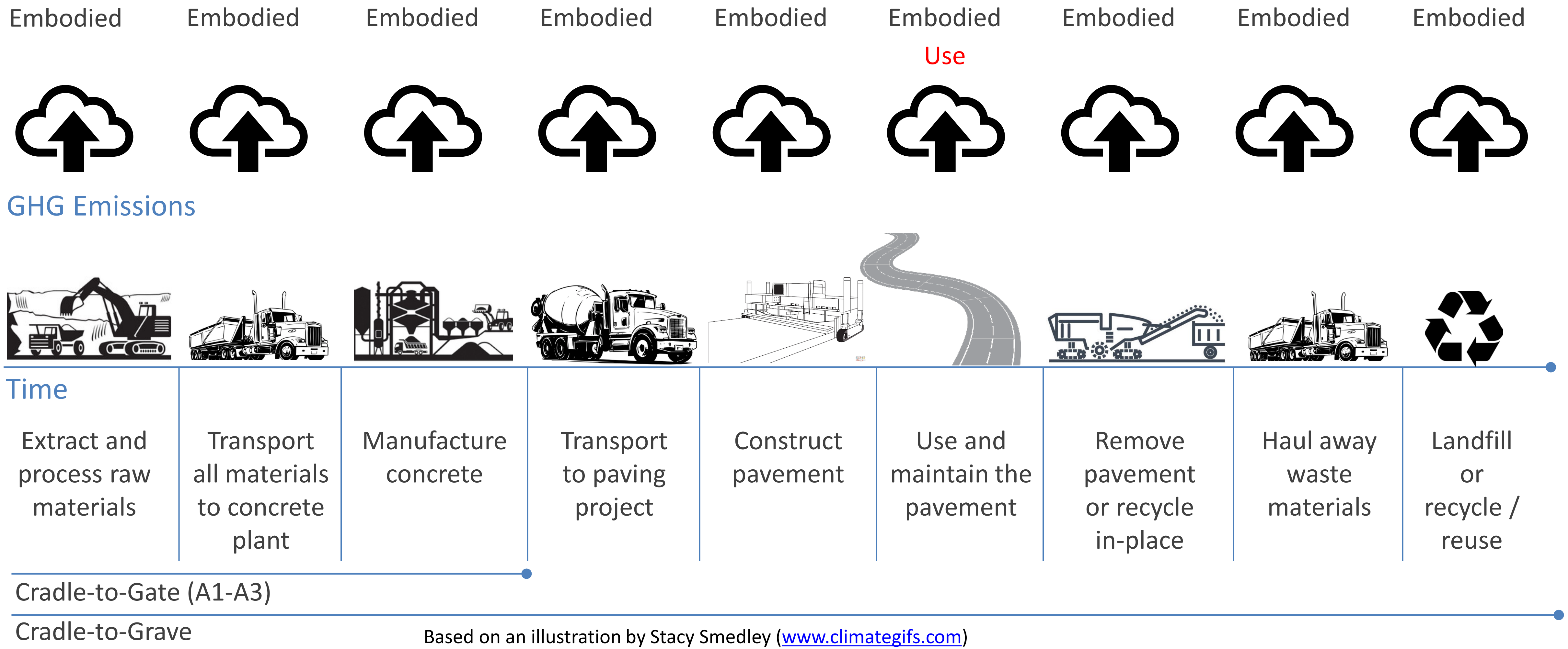
ACPA

NRMCA

PCA

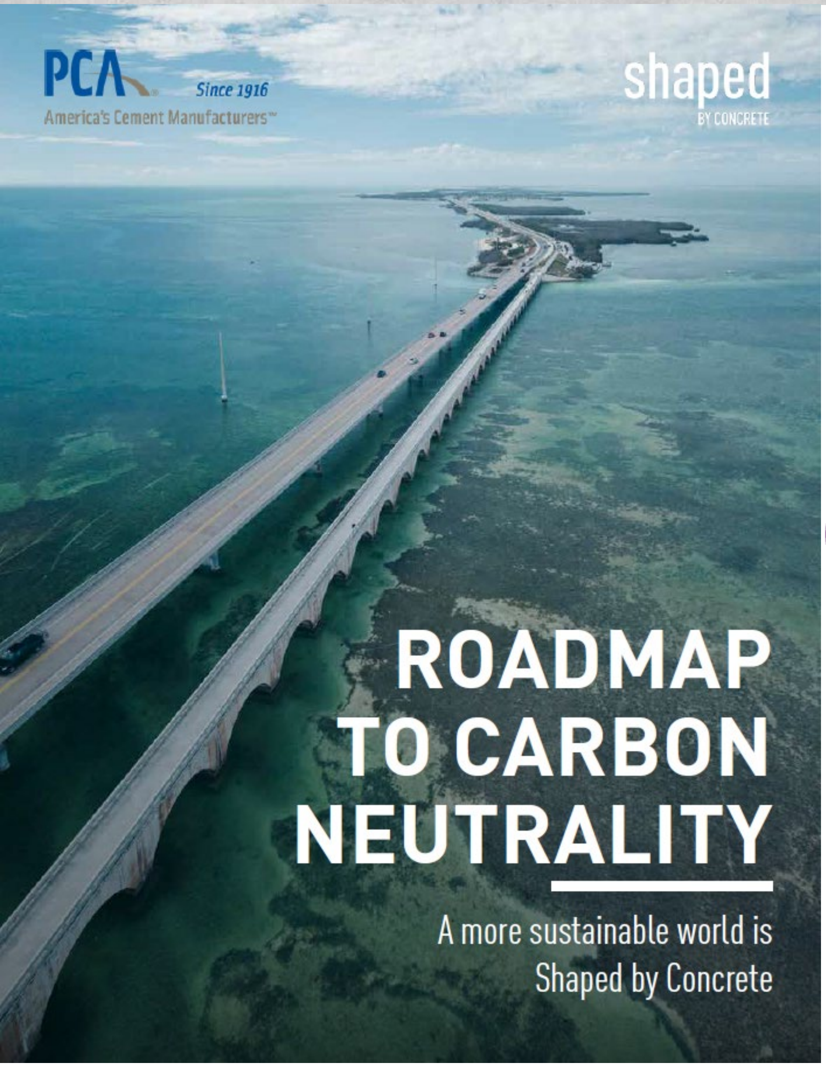
Embodied and Operational (Use) GHG Emissions

Concrete Pavement Life-Cycle



Based on an illustration by Stacy Smedley (www.climategifs.com)

Roadmap to Carbon Neutrality: Cement & Concrete



CLINKER
Key chemically reactive ingredient

- -------------
- -------------
- -----------------
- ------------

CEMENT
The binder

- -------------
- -------------
- -----------------
- ------------

CONCRETE
Critically useful material to society

- -------------
- -------------
- -----------------
- ------------

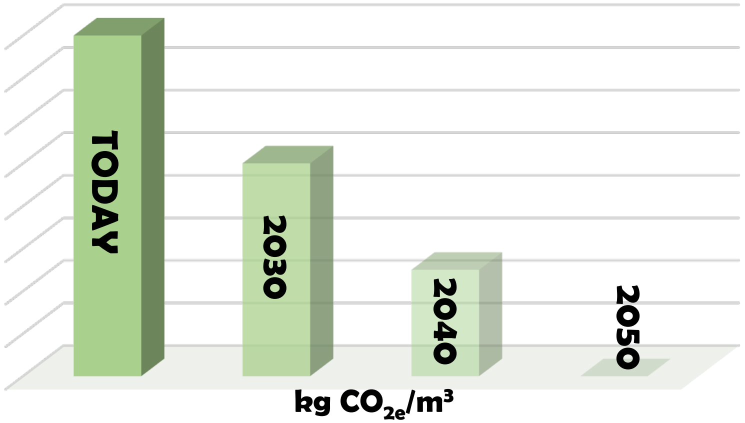
CONSTRUCTION
Service life / use phase impacts

- -------------
- -------------
- -----------------
- ------------

CARBONATION
Concrete is a CO_2 sink

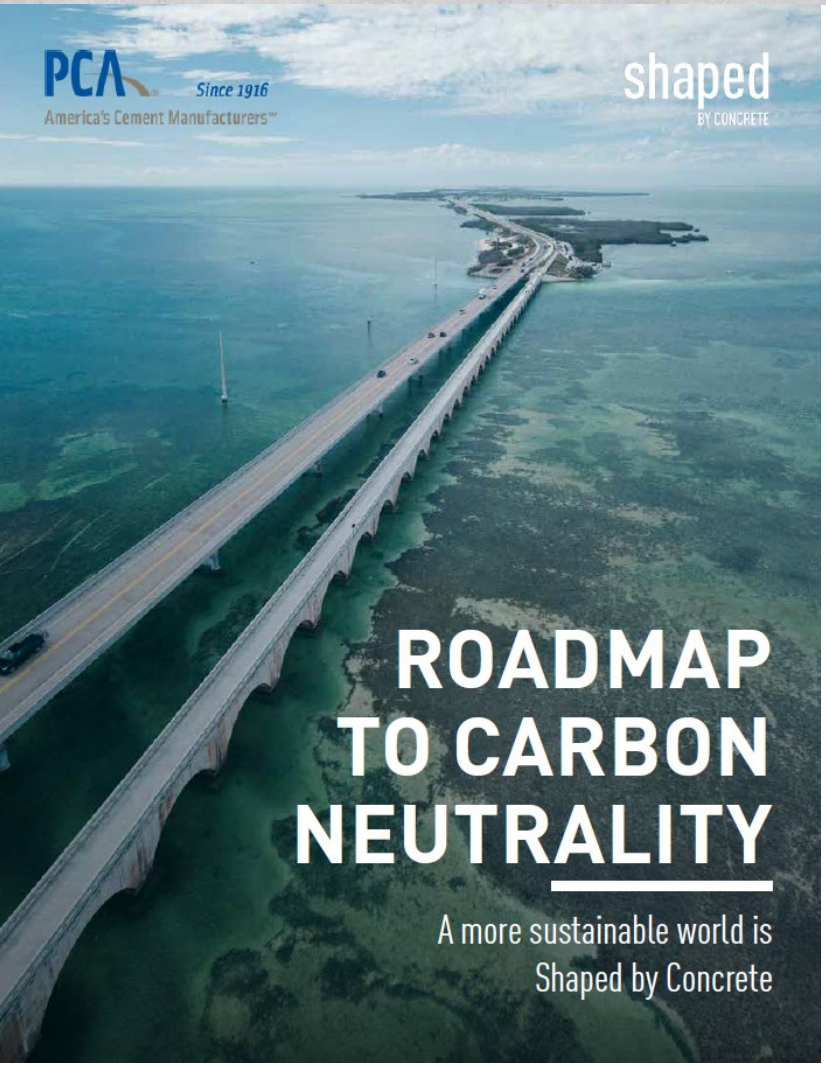
- -------------
- -------------
- -----------------
- ------------

NEAR-TERM — **MID-TERM** — **LONG-TERM**



Count on CONCRETE
PAVE AHEAD
DURABLE. SUSTAINABLE. CONCRETE.
shaped
BY CONCRETE

Roadmap to Carbon Neutrality: Cement & Concrete



CLINKER – Key chemically reactive ingredient

CEMENT – The binder

CONCRETE – Critically useful material to society

CONSTRUCTION – Service life / use phase impacts

CARBONATION – Concrete is a CO_2 sink

AT THE CEMENT PLANT

- Increase the use of decarbonated raw materials
- Decrease the use of traditional fossil fuels by 5X
- Increase the use of alternative fuels
- Push efficiency and decrease energy intensity for one metric ton of clinker
- Utilize carbon capture to avoid the release of CO_2 emissions
- Reduce clinker production emissions

OPTIMIZING THE DESIGN AND CONSTRUCTION OF THE BUILT ENVIRONMENT

- Lower concrete manufacturing emissions to zero at the plant
- Transition to zero emission fleets
- Optimize concrete mixes
- Reduce overdesign
- Construct concrete structures for durability, resiliency, stiffness, and thermal mass benefits

CONCRETE IN USE

- 10% – The amount of CO_2 that concrete buildings, structures, and pavements can permanently absorb from the air is 10%
- A reduction of 46.5 million metric tons of GHG emissions per year could be realized if the entire U.S. road system used concrete pavement according to the MIT Concrete Sustainability Hub (MIT CSHUB)

Reducing Concrete's Embodied Carbon Emissions (In-Use to Near-Term)

- **Optimized Pavement Designs & Rehabilitations**
  - Use of Pavement ME and other innovative methods (e.g., short or long [jointless] slab designs, concrete o/l, FDR).
- **Use of Type IL Cement**
  - Portland-limestone cement containing more than 5% but less than or equal to 15% by mass of limestone.
- **Alternative & Blended Cements / Clinkers**
  - The use of low CO_2 clinker and blended cements.
- **Supplementary Cementitious Materials (SCMs)**
  - Fly Ash, Slag, other pozzolans to reduce the amount of cement in the concrete.
- **Aggregate Optimization**
  - Use well graded mixes to reduce paste and improve workability & durability. On-site concrete recycling.
- **Enhanced Carbonation**
  - Technologies to use CO_2 emissions (e.g., injected CO_2).

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

Reducing Concrete's Embodied Carbon Emissions (In-Use to Near-Term)

- Communicate Carbon Reduction Goals
- Ensure Good Quality Control and Assurance
- Optimize Concrete Designs & Mixtures
- Specify Innovative Cements
- Specify Supplementary Cementitious Materials
- Specify Admixtures
- Don't Limit Ingredients
- Set Targets for Carbon Footprint
- Sequester Carbon Dioxide in Concrete
- Encourage Innovation

The embodied CO_2 footprint of a typical concrete paving mixture today is as much as 40 percent lower than just a few decades ago.

Reducing Concrete's Embodied Carbon Emissions (Mid- to Long-Term)

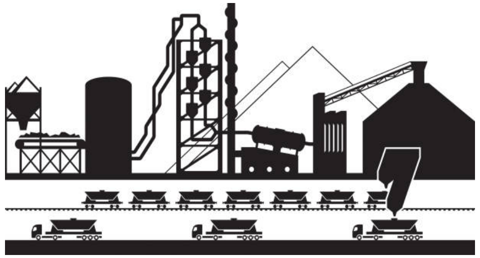
- **Increase Use of Alternative Fuels at Cement Plants**
  - Utilize transformative fuels and technologies: hydrogen, plasma heating, oxyfuel/oxy-calcination, electric calcination, agriculture and sorted disposed waste…
- **Zero or Low Emissions During Cement and Concrete Manufacturing and Transportation**
  - Move to renewable energy sources and alternative fuels (e.g., hydrogen) or electric power for transportation.
- **Development of New Cements**
  - Use low CO_2 clinker and blended cements, new binders, etc.
- **Carbon Capture Utilization & Storage**
  - Further develop technologies to capture, store, and use CO_2 emissions (e.g., underground storage, enhanced carbonation cement and aggregates, etc.).

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

Public Agency Collaboration: Key Policy Levers

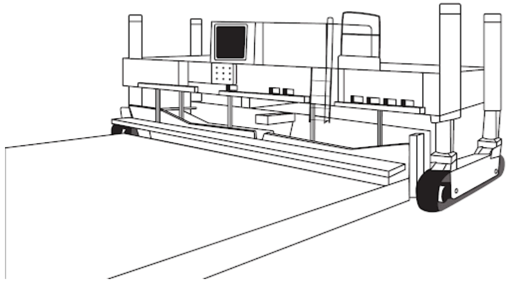
- Research, Development & Innovation
- Regulations, Permitting & Guidance
- Financial Incentives & Support
- Performance-Based Material Standards
- Market-Based Carbon Pricing
- Market Acceptance
- Community Acceptance
- Cradle-to-Cradle Life Cycle-Based Procurement
- Low-Carbon Infrastructure
- Level Playing Field

Industry Partnering:
Working Together to Meet Sustainability Goals



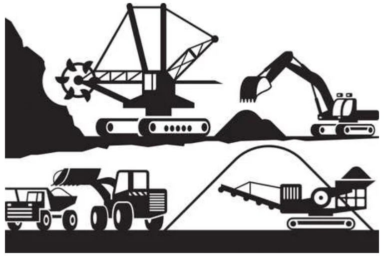
Cement Suppliers

Equipment Manufacturers

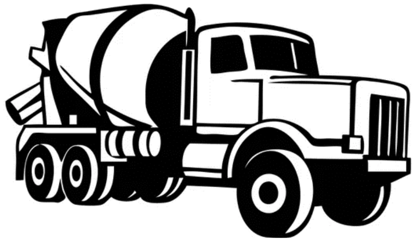


Concrete Contractors

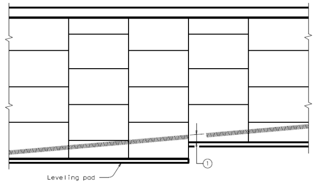
Concrete Producer Partners



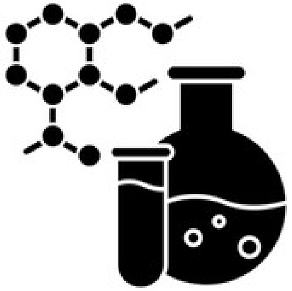
Aggregate Suppliers



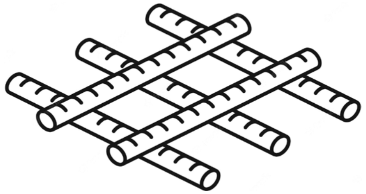
Truck Manufacturers



Precast Suppliers



Admixture / Additive Suppliers



Steel Suppliers

Concrete Materials

Transparency Initiatives

ACPA NRMCA PCA

Concrete Industry EPD Process

1. Submitting Company Selects a Program Operator.
2. Choose Product and Related Product Category Rule (PCR) and Gather Data per PCR.
3. Conduct Life-Cycle Assessment (LCA) by In-House Staff or LCA Consultant.
4. Conduct Independent Review of LCA.
5. Develop Draft EPD by In-House Staff or LCA Consultant.
6. Submit the LCA Report and Draft EPD to Program Operator for Initial Verification.
7. Program Operator Engages Independent Verifier Who Reviews the LCA Report and Draft EPD.
8. Program Operator Certifies EPD for Submitting Company.

Common EPD Program Operators for Concrete

Program Operator	LCA / EPD Practitioner
NSF®	MASTER® BUILDERS SOLUTIONS
NRMCA™	Athena Sustainable Materials Institute & climate earth™
ASTM	Athena Sustainable Materials Institute & climate earth™

Concrete Product Category Rule (PCR) – Revision History

Version	Date issued
Version 1 (published by Carbon Leadership Forum)	November 2012
Version 1.1 (published by Carbon Leadership Forum)	December 2013
Version 2 (published by NSF International)	February 2019
Version 2.1 (published by NSF International)	August 2021 Valid through February 22, 2024

Version 2.x (published by NSF International) August 2022(?) Consideration of Mobile Mixers

Concrete PCR Revisions: Consideration of Mobile Batch Plants

- PCR Committee recently voted to include a one-year deviation:
  - Informative annex to the PCR;
  - Allows for data collection and analysis of data from portable mixing equipment;
  - Data would be basis for paving project EPDs using mobile batch plants.
- Committee will evaluate need to add language specific to paving vs. building mobile batch plant impacts.
  - Subcommittee could be assigned and propose expanded language, if necessary.
- Roller Compacted Concrete Paving Industry
  - Seeking clarification whether deviation is applicable to continuous (pugmill) mixers.

Concrete Environmental Product Declarations


Environmental Product Declaration (EPD) for Concrete

Holliday Rock
1401 N Benson Ave
Upland, California
91786 888-273-2200
www.hollidayrock.com

Environmental Product Declaration

Ready-Mix Concrete

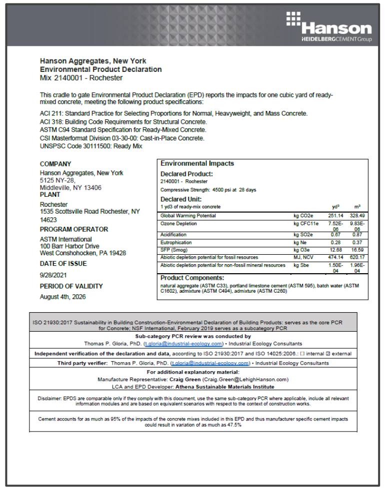
(per ISO 14025 and ISO 21930)

Holliday Rock has been a constant presence in the Southern California construction market for over eighty years and is one of the largest independent producers of aggregate, ready mix concrete and hot mix asphalt in the United States. Started by Otha and Ethel Holliday in 1937 during the Great Depression, Holliday Rock has allowed three successive generations of the Holliday family to thrive and expand in an ever more challenging and competitive industry.

Holliday Rock holds the beliefs that long-term success requires common goals, adaptability shared values, and most importantly safety.

Authors of the Life Cycle Assessment:
A. Grosse-Sommer and D. Green BASF

Certified Environmental Product Declaration
www.nsf.org


Hanson
HEIDELBERGCEMENT Group

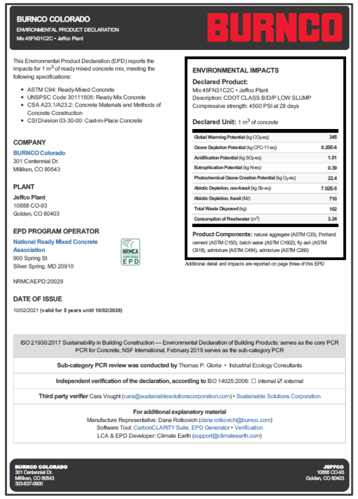
Hanson Aggregates, New York
Environmental Product Declaration
Mix 2140001 - Rochester

This cradle to gate Environmental Product Declaration (EPD) reports the impacts for one cubic yard of ready-mixed concrete, meeting the following product specifications:
ACI 211: Standard Practice for Selecting Proportions for Normal, Heavyweight, and Mass Concrete.
ACI 318: Building Code Requirements for Structural Concrete.
ASTM C94 Standard Specification for Ready-Mixed Concrete.
CSI Masterformat Division 03-30-00: Cast-in-Place Concrete.
UNSPSC Code 30111500: Ready Mix

- **Over 38,000+* product specific EPDs have been published by concrete producers since 2013 in U.S. and Canada (~40,000+* globally)**
  - **Largest number published by any industry**
  - Concrete GWP Values (from EC3 Tool):
    - Conservative (Baseline set @ 80^{th} percentile): 366 $kgCO_{2e}/yd^3$
    - Average ("Typical" @ Arithmetic Mean & Std Dev): 302 $kgCO_{2e}/yd^3$ ± 27.5%
    - Achievable ("Low-Carbon" set @ 20^{th} percentile): 234 $kgCO_{2e}/yd^3$

*Based on Embodied Carbon in Construction Calculator (EC3) Tool Published by Building Transparency which is very comprehensive but not exhaustive.

Colorado Concrete EPDs



BURNCO COLORADO
ENVIRONMENTAL PRODUCT DECLARATION
Mix 45FN31C2C • Jeffco Plant

This Environmental Product Declaration (EPD) reports the impacts for 1 m^3 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
BURNCO Colorado
301 Centennial Dr.
Milliken, CO 80543

PLANT
Jeffco Plant
10888 CO-93
Golden, CO 80403

EPD PROGRAM OPERATOR
National Ready Mixed Concrete Association
900 Spring St
Silver Spring, MD 20910

NRMCAEPD:20029

DATE OF ISSUE
10/02/2021 (valid for 5 years until 10/02/2026)

ENVIRONMENTAL IMPACTS
Declared Product:
Mix 45FN31C2C • Jeffco Plant
Description: CDOT CLASS B/D/P LOW SLUMP
Compressive strength: 4500 PSI at 28 days

Declared Unit: 1 m^3 of concrete

Global Warming Potential (kg CO_2-eq)	345
Ozone Depletion Potential (kg CFC-11-eq)	8.20E-6
Acidification Potential (kg SO_2-eq)	1.01
Eutrophication Potential (kg N-eq)	0.39
Photochemical Ozone Creation Potential (kg O_3-eq)	22.4
Abiotic Depletion, non-fossil (kg Sb-eq)	7.02E-5
Abiotic Depletion, fossil (MJ)	710
Total Waste Disposed (kg)	102
Consumption of Freshwater (m^3)	3.24

Product Components: natural aggregate (ASTM C33), Portland cement (ASTM C150), batch water (ASTM C1602), fly ash (ASTM C618), admixture (ASTM C494), admixture (ASTM C260)

Additional detail and impacts are reported on page three of this EPD

ISO 21930:2017 Sustainability in Building Construction — Environmental Declaration of Building Products: serves as the core PCR
PCR for Concrete, NSF International, February 2019 serves as the sub-category PCR

Sub-category PCR review was conducted by Thomas P. Gloria • Industrial Ecology Consultants

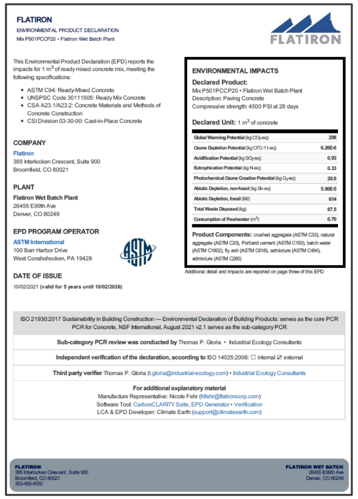
Independent verification of the declaration, according to ISO 14025:2006: ☐ internal ☑ external

Third party verifier Cara Vought (cara@sustainablesolutionscorporation.com) • Sustainable Solutions Corporation

For additional explanatory material
Manufacture Representative: Dana Rotkovich (dana.rotkovich@burnco.com)
Software Tool: CarbonCLARITY Suite, EPD Generator • Verification
LCA & EPD Developer: Climate Earth (support@climateearth.com)

BURNCO COLORADO
301 Centennial Dr.
Milliken, CO 80543
303-637-0900

JEFFCO
10888 CO-93
Golden, CO 80403



FLATIRON
ENVIRONMENTAL PRODUCT DECLARATION
Mix P501PCCP20 • Flatiron Wet Batch Plant

This Environmental Product Declaration (EPD) reports the impacts for 1 m^3 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
Flatiron
385 Interlocken Crescent, Suite 900
Broomfield, CO 80021

PLANT
Flatiron Wet Batch Plant
26455 E99th Ave
Denver, CO 80249

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

DATE OF ISSUE
10/02/2021 (valid for 5 years until 10/02/2026)

ENVIRONMENTAL IMPACTS
Declared Product:
Mix P501PCCP20 • Flatiron Wet Batch Plant
Description: Paving Concrete
Compressive strength: 4500 PSI at 28 days

Declared Unit: 1 m^3 of concrete

Global Warming Potential (kg CO_2-eq)	298
Ozone Depletion Potential (kg CFC-11-eq)	6.26E-6
Acidification Potential (kg SO_2-eq)	0.93
Eutrophication Potential (kg N-eq)	0.33
Photochemical Ozone Creation Potential (kg O_3-eq)	20.6
Abiotic Depletion, non-fossil (kg Sb-eq)	5.90E-5
Abiotic Depletion, fossil (MJ)	614
Total Waste Disposed (kg)	87.5
Consumption of Freshwater (m^3)	0.70

Product Components: crushed aggregate (ASTM C33), natural aggregate (ASTM C33), Portland cement (ASTM C150), batch water (ASTM C1602), fly ash (ASTM C618), admixture (ASTM C494), admixture (ASTM C260)

Additional detail and impacts are reported on page three of this EPD

ISO 21930:2017 Sustainability in Building Construction — Environmental Declaration of Building Products: serves as the core PCR
PCR for Concrete, NSF International, August 2021 v2.1 serves as the sub-category PCR

Sub-category PCR review was conducted by Thomas P. Gloria • Industrial Ecology Consultants

Independent verification of the declaration, according to ISO 14025:2006: ☐ internal ☑ external

Third party verifier Thomas P. Gloria (t.gloria@industrial-ecology.com) • Industrial Ecology Consultants

For additional explanatory material
Manufacture Representative: Nicole Fehr (Nfehr@flatironcorp.com)
Software Tool: CarbonCLARITY Suite, EPD Generator • Verification
LCA & EPD Developer: Climate Earth (support@climateearth.com)

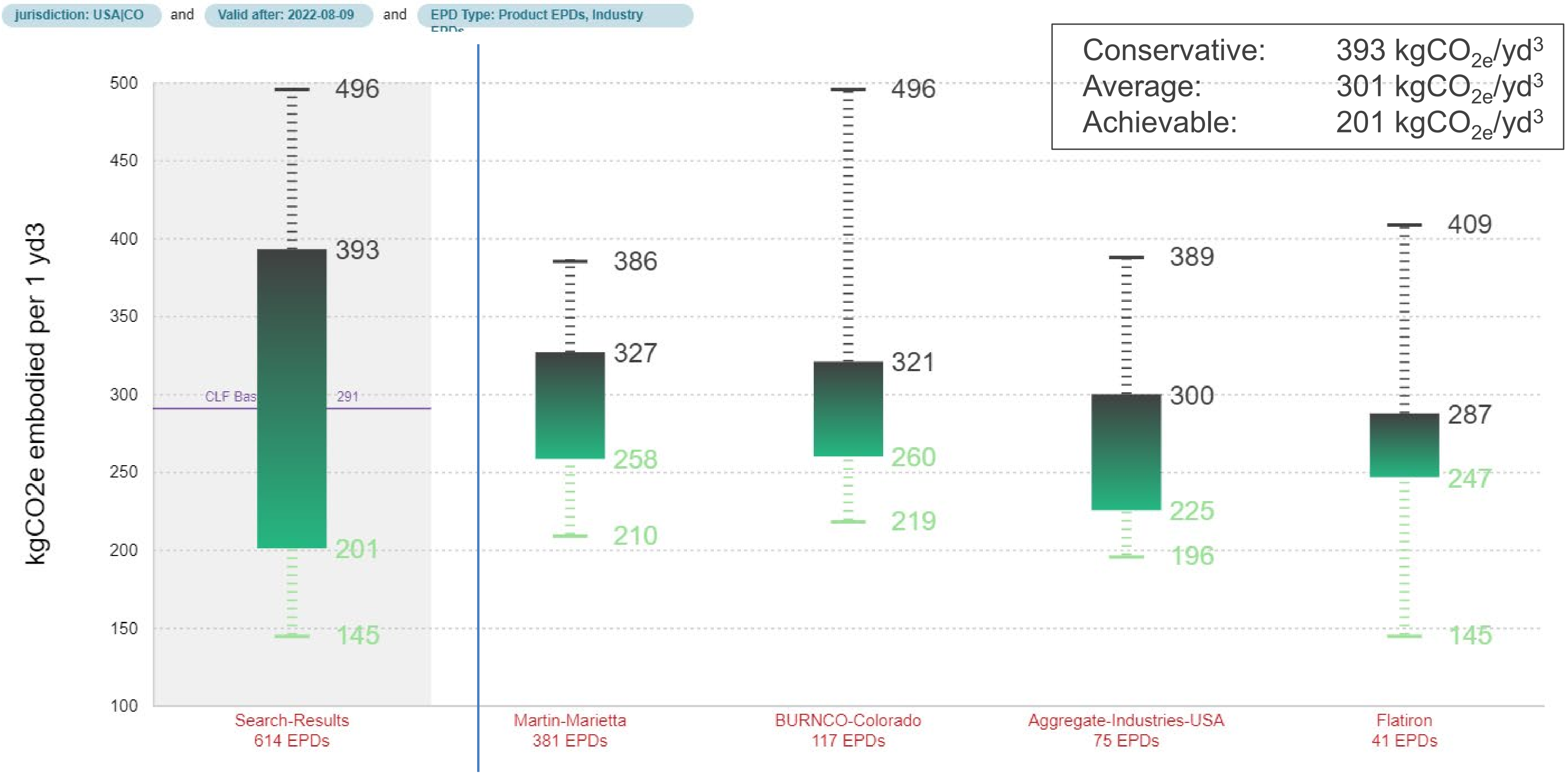
FLATIRON
385 Interlocken Crescent, Suite 900
Broomfield, CO 80021
303-485-4050

FLATIRON WET BATCH
26455 E99th Ave
Denver, CO 80249

- **Currently 614* concrete EPDs Published for CO**
  - Concrete GWP Values (from EC3 Tool):
    - Conservative (Baseline set @ 80th percentile): 393 $kgCO_{2e}/yd^3$
    - Average ("Typical" @ Arithmetic Mean & Std Dev): 301 $kgCO_{2e}/yd^3 \pm 39.5\%$
    - Achievable ("Low-Carbon" set @ 20th percentile): 201 $kgCO_{2e}/yd^3$

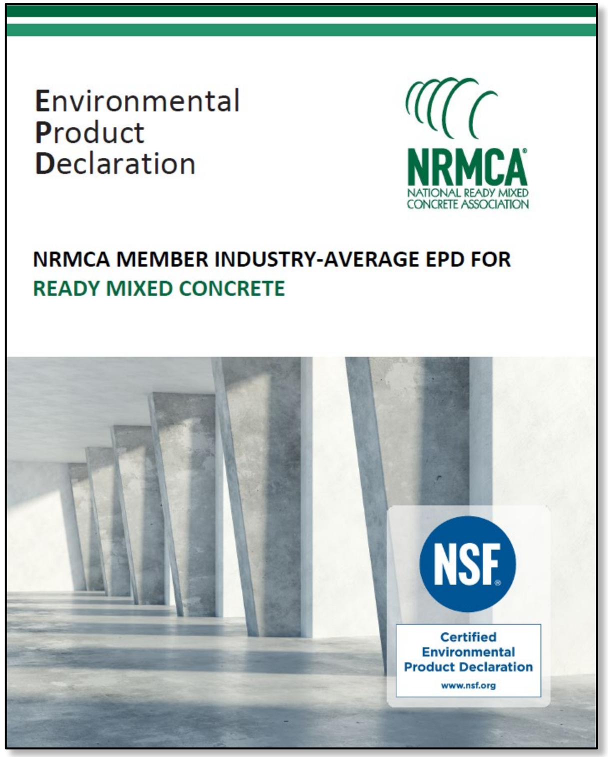
*based on Embodied Carbon in Construction Calculator (EC3) Tool Published by Building Transparency which is very comprehensive but not exhaustive.

Colorado Concrete EPDs



Conservative: 393 $kgCO_{2e}/yd^3$
Average: 301 $kgCO_{2e}/yd^3$
Achievable: 201 $kgCO_{2e}/yd^3$

Industry Wide Environmental Product Declaration



https://www.nrmca.org/wp-content/uploads/2020/02/NRMCA_EPD10294.pdf

- Ready Mixed Concrete Industry Wide EPD (v3.2) Jan 2022 – Nov 2024
- From NRMCA Member Data (100+ Companies & ~2,000 Plants)
- Concrete GWP Values from IW EPD (calculated at ↑strength & ↓SCM ranges):

Industry Average EPD (Published January 3rd, 2022)										
28-day f'c, psi	Minimum	Maximum	0% FA/SL	20% FA	30% FA	40% FA	30% SL	40% SL	50% SL	50% FA/SL
Conventional Concrete GWP (per yd^3)										
0 - 2,500	136.6	213.7	213.7	184.7	169.1	152.6	168.0	152.8	137.5	136.6
2,501 - 3,000	150.7	238.1	238.1	205.2	187.4	168.8	186.1	168.9	151.7	150.7
3, 001 - 4,000	182.5	293.3	293.3	251.7	229.1	205.5	227.5	205.6	183.7	182.5
4,001 - 5,000	220.3	358.5	358.5	306.6	278.6	249.0	276.5	249.2	221.8	220.3
5,001 - 6,000	231.5	377.4	377.4	322.6	293.0	261.7	290.8	262.0	233.1	231.5
6,001 - 8,000	266.9	438.9	438.9	374.4	339.5	302.6	336.9	302.9	268.9	266.9
Lightweight Aggregate Concrete GWP (per yd^3)										
0 - 3,000	303.0	426.4	426.4	367.2	335.2	360.0	305.7	340.8	303.0	321.6
3,001 -4,000	343.6	491.2	491.2	424.0	385.0	414.7	348.2	390.3	343.6	362.5
4,001 - 5,000	373.6	547.6	547.6	468.5	422.4	455.3	380.1	427.5	373.6	394.4

Supplementary Cementitious Material (SCM) Ranges:
0-19% Fly Ash and/or Slag, 20-29% Fly Ash, 30-39% Fly Ash, 40-49% Fly Ash, 30-49% Slag, 40-39% Slag, ≥ 50% Slag, ≥ 20% Fly Ash and ≥ 30% Slag

- **NRMCA members decreased their carbon footprint by 21% in 7 years**

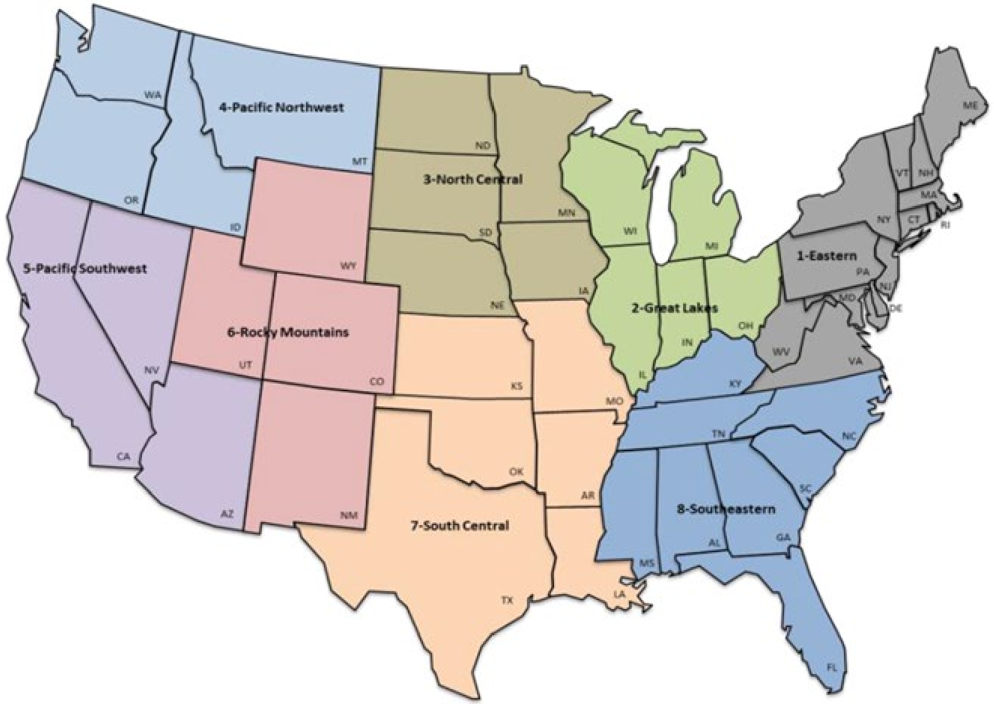
NRMCA Member Regional LCA Benchmark Report

Region	28-Day Compressive Strength, psi								
	2,500	3,000	4,000	5,000	6,000	8,000	3,000LW	4,000LW	5,000LW
	Global Warming Potential (per yd^3)								
National	183.5	200.6	235.6	279.0	294.6	341.3	376.4	412.9	449.8
Eastern	183.3	201.5	240.2	289.0	305.3	360.5	395.4	437.9	480.1
Great Lakes Midwest	177.6	194.8	231.4	277.6	293.1	345.3	381.6	421.6	461.3
North Central	184.2	201.9	238.8	284.7	301.5	351.8	372.1	410.7	451.7
Pacific Northwest	180.0	199.8	242.0	295.2	311.9	372.7	396.2	439.7	483.4
Pacific Southwest	196.5	213.5	247.3	288.9	306.4	349.0	382.2	417.5	453.9
Rocky Mountains	177.5	194.6	229.8	273.4	289.6	336.7	369.8	406.5	443.5
South Central	172.4	187.7	218.6	257.2	272.2	312.8	357.7	390.2	424.5
South Eastern	188.9	204.6	236.5	275.5	292.1	332.2	365.6	398.7	429.4

Table B1-NRMCA U.S. National Benchmark Mix Designs (per cubic yard)

Compressive Strength	psi	2500	3000	4000	5000	6000	8000	3000 LW	4000 LW	5000 LW
Portland Cement	lbs	354	394	475	576	610	719	394	475	556
Fly Ash	lbs	62	69	83	101	107	126	69	83	97
Slag Cement	lbs	17	19	23	28	30	35	19	23	27
Mixing Water	lbs	305	305	305	315	341	341	308	308	308
Crushed Coarse Aggregate	lbs	1,126	1,115	1,083	1,029	1,061	1,018	0	0	0
Natural Coarse Aggregate	lbs	553	547	531	505	521	499	0	0	0
Crushed Fine Aggregate	lbs	169	167	162	154	159	152	161	149	136
Natural Fine Aggregate	lbs	1,282	1,270	1,233	1,171	1,208	1,159	1,225	1,130	1,035
Man.Lightweight Aggregate	lbs	0	0	0	0	0	0	980	990	1,000
Air %	%	6%	6%	6%	6%	6%	0	6%	6%	2%
Air Entraining Admixture	oz	1	1	1	1	1	1	1	1	0
Plasticizer & Superplasticizer	oz	3	3	3	7	3	3	3	7	7
Set Accelerator	oz	25	20	15	10	25	20	15	10	10
Total Weight	lbs	3,867	3,886	3,895	3,878	4,037	4,049	2,178	2,168	2,159

- Published July 2022 (v3.2)
- Region Specific Mixtures For:
  - 6 Conventional Concrete Mixtures &
  - 3 Lightweight Concrete Mixtures



EPD Software Tools

- EPDs developed utilizing pre-verified EPD software becoming more prevalent.
  - Athena
  - Climate Earth
  - GCCA / Quantis
  - One-Click LCA

Reproducibility and Alignment of LCA Models

- Concrete PCR v2 requires verification and validity of an EPD
- Two (of five) conditions state:
  - EPD calculations by software systems should be verified using similar procedures as verifying and EPD.
  - When EPDs are aligned to an industry average, there should be consistency of results between product specific EPDs and industry average.
    - Use same LCA software version and background data, or
    - *test representative samples of the regionally specific industry average benchmark data and include report of the maximum percent difference.*

Reproducibility and Alignment of LCA Models

Appendix A: Summary of Reproducibility Results

Results of alignment for the NRMCA Eastern Region Benchmark.

April 2021

Impact category	ABB	Athena	Climate Earth	Unit	Results		Difference
		Method Used	Method Used		Athena	Climate Earth	
Global warming	GWP	TRACI 2.1 V1.02	TRACI 2.1 v 1.04	kg CO2 eq	202.80	201.02	-0.88%
Ozone depletion	ODP	TRACI 2.1 V1.02	TRACI 2.1 v 1.04	kg CFC-11 eq	6.18E-06	5.98E-06	-3.28%
Eutrophication	EP	TRACI 2.1 V1.02	TRACI 2.1 v 1.04	kg N eq	0.29	0.2799	-2.79%
Acidification	AP	TRACI 2.1 V1.02	TRACI 2.1 v 1.04	kg SO2 eq	0.74	0.7245	-2.17%
Smog	SFP	TRACI 2.1 V1.02	TRACI 2.1 v 1.04	kg O3 eq	15.20	14.959	-1.57%

EPD Misunderstandings, Misconceptions, and Misuses and Other Considerations

- Comparing EPDs across categories is tempting but improper.
- Life-cycle inventory data quality is critical for accurate analysis and EPD results.
- EPDs can lead to a “how low can we go” mentality, unintentionally affecting other properties.
- There is more to environmental stewardship than green house gas emissions.
- Producer-contractor collaboration may not be fully realized when only considering EPDs.
- Whole pavement EPD would provide for better decision making.
- Individual EPDs do not account for uncertainty, but a collection of within category EPDs can.
- There are costs that could potentially inhibit some producers from bidding on projects.

Concrete Materials

Beyond EPDs

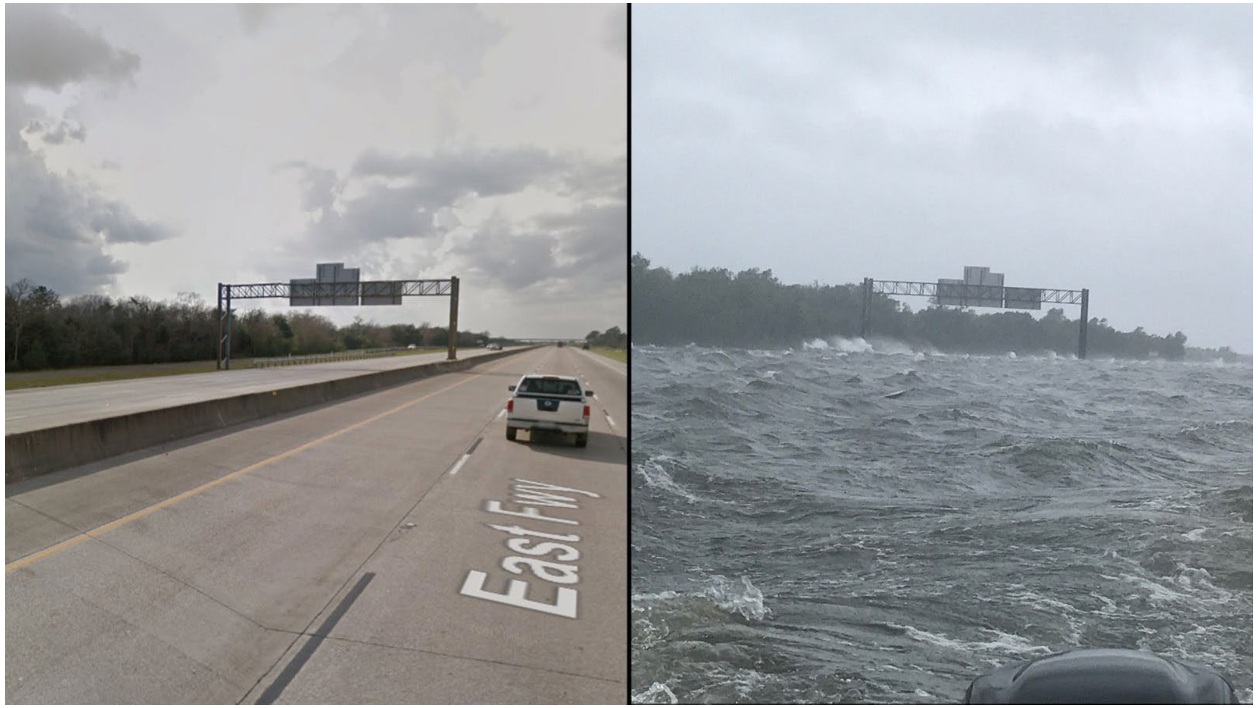
Strategies BEYOND the Embodied Footprint

- Prioritizing means reducing our embodied carbon – in cement and in concrete – right now.
- The industry has embraced EPDs to benchmark and measure progress.
- <u>The industry has made huge strides already… optimizing mixtures (PEM), reducing cement content, SCMs, PLC, ternary blends, etc.</u>
- However… embodied carbon is only a PORTION of the carbon footprint.

How Concrete Properties Can Lower Use Phase CO_2

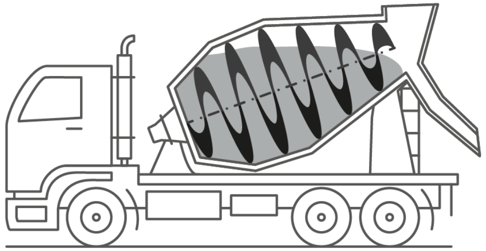
- **Durability and Resilience**
  - Concrete's durability reduces future rehabilitation and reconstruction activities.
  - Concrete's strength and resiliency allows it to better withstand natural disasters and their aftermath.
- **Improved Fuel Efficiency**
  - Fuel consumption of trucks on concrete is improved because concrete pavements are stiffer and stay smoother longer.
- **Highly Reflective**
  - Concrete's light color lowers lighting requirements and UHI impacts; and increases Radiative Forcing that can offset 20% to 40+% of concrete CO_2 used to make the pavement (dependent on thickness)
- **Increased Carbonation**
  - Re-carbonation absorbs ~10-11% of the CO_2 emitted in the A1-A3 phase and 25% of the total potential CO_2 that could be sequestrated.

Resilience and Sustainability:
Not having to rebuild after natural disasters saves CO_2



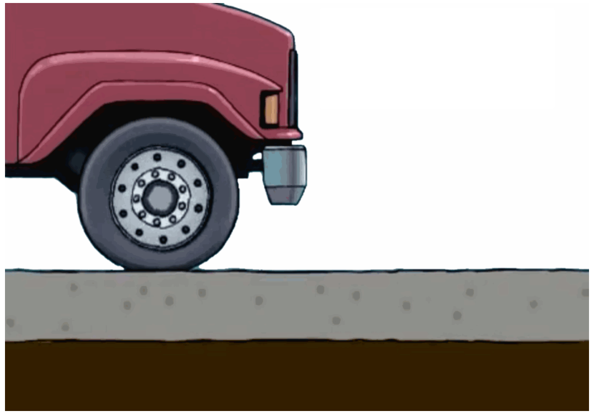
I-10 South of Beaumont, TX During Hurricane Harvey 2017
Source: Logan Wheat

Combining Methods to Decarbonize Pavements

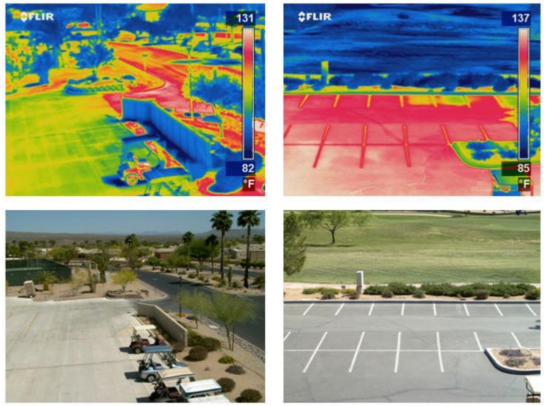


Use Low Carbon & Performance Based Materials

Build & Maintain Smooth Pavements For Better Fuel Efficiency



Build Low Deflection Pavements For Better Fuel Efficiency



Build High Albedo Pavement To Reduce Urban Heat Island

Plus Others…

Infrastructure Decision Making: Considering Sustainability and Resilience

Planning/Goals

Use scoring systems (i.e., INVEST) to evaluate a project's potential environmental impact and set specific sustainability goals.

Design

Use whole pavement, full life cycle to understand a project's cradle-to-grave cost and environmental impacts and select designs with the lowest impacts.

Procurement

Use environmental product declarations (EPDs) to set benchmarks and procure materials that meet sustainability goals.

Operation

Use life cycle cost and environmental modeling for asset management treatment optimization and selection. Network analyses will provide the largest CO_2 reductions.

Summary & Key Take-Aways

- **The cement and concrete industries worldwide are committed to combat climate change, but we cannot do it ourselves**
  - We need support from government, agencies, designers, engineers and all groups throughout the value chain.
- **There are a variety of levers <u>in-use</u> and <u>immediately</u> available to lower concrete's CO_2 emissions**
  - Portland Limestone Cement (Type 1L), Supplementary Cementitious Materials (SCMs), Alternative & Blended Cements / Clinkers, and Aggregate Optimization are just some examples.
  - The industry seeks assistance and leadership from the public sector with implementing these levers.
- **The emissions of the pavement system are the most important**
  - Cement and concrete are not the end products - the concrete pavement is the end-product – so whole pavement LCA is appropriate.
  - Eliminating "over-design," better pavement management, and selection of where to use concrete because of its inherent properties (i.e., stiffness and maintaining long-term smoothness) will lower the network CO_2.
- **Results from a full life cycle perspective should drive decisions**
  - Concrete's strength, durability, and resilience lower the operational and use phase impacts.
  - Models are available now to assess use phase impacts and account for uncertainty.

Thank You

Brian Killingsworth, P.E.
NRMCA
bkillingsworth@nrmca.org

ACPA

NRMCA™

PCA®