Sustainable Concrete

Graniterock®

Tech Talk Series 2021

March 18th, 2021

Agenda

- Introduction to the CNCA
- Sustainability & Climate Change
- Cement Production & CO2
- GHG Mitigation Strategies Now & in the Future
- Quantifying Impacts & Performance

California Nevada Cement Association

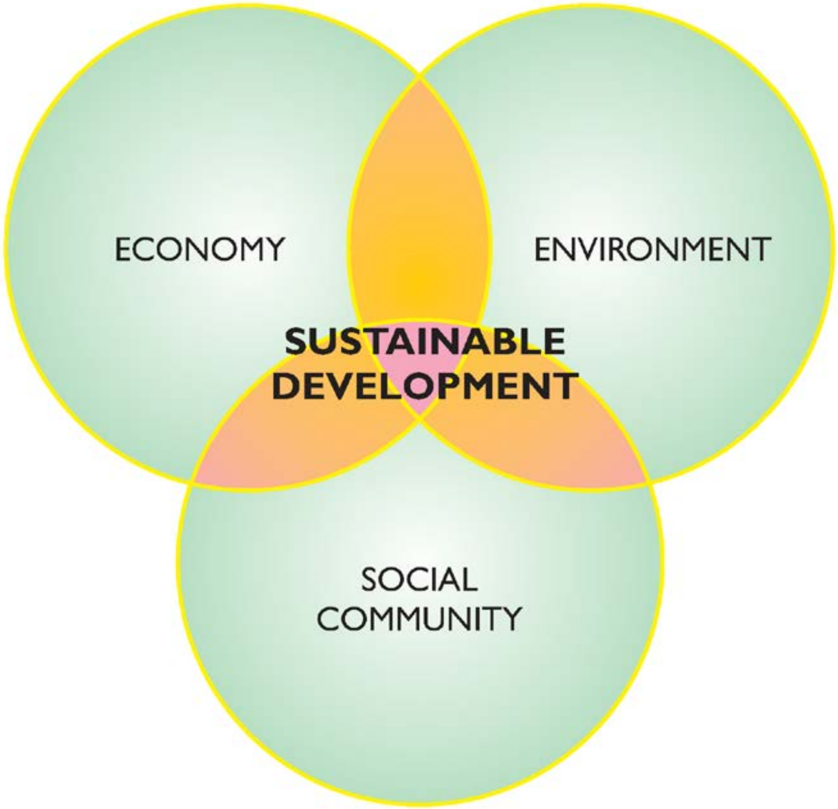
WHO WE ARE

- A non-profit trade association
- Funded by the 7 producers and distributors of portland cement
- Advocates for infrastructure funding
- In partnership with agencies/owners, consultants, and contractors to provide:
    - Technical expertise
    - Research
    - Educational opportunities
    - Design assistance
    - Construction feasibility

What is Sustainability?

ASCE Definition:

ASCE defines sustainability as a set of environmental, economic, and social conditions – the “Triple Bottom Line” – in which all of society has the capacity and opportunity to maintain and improve its quality of life indefinitely, without degrading the quantity, quality, or the availability of natural, economic, and social resources.



The Triple Bottom Line

Perceptions on Climate Change

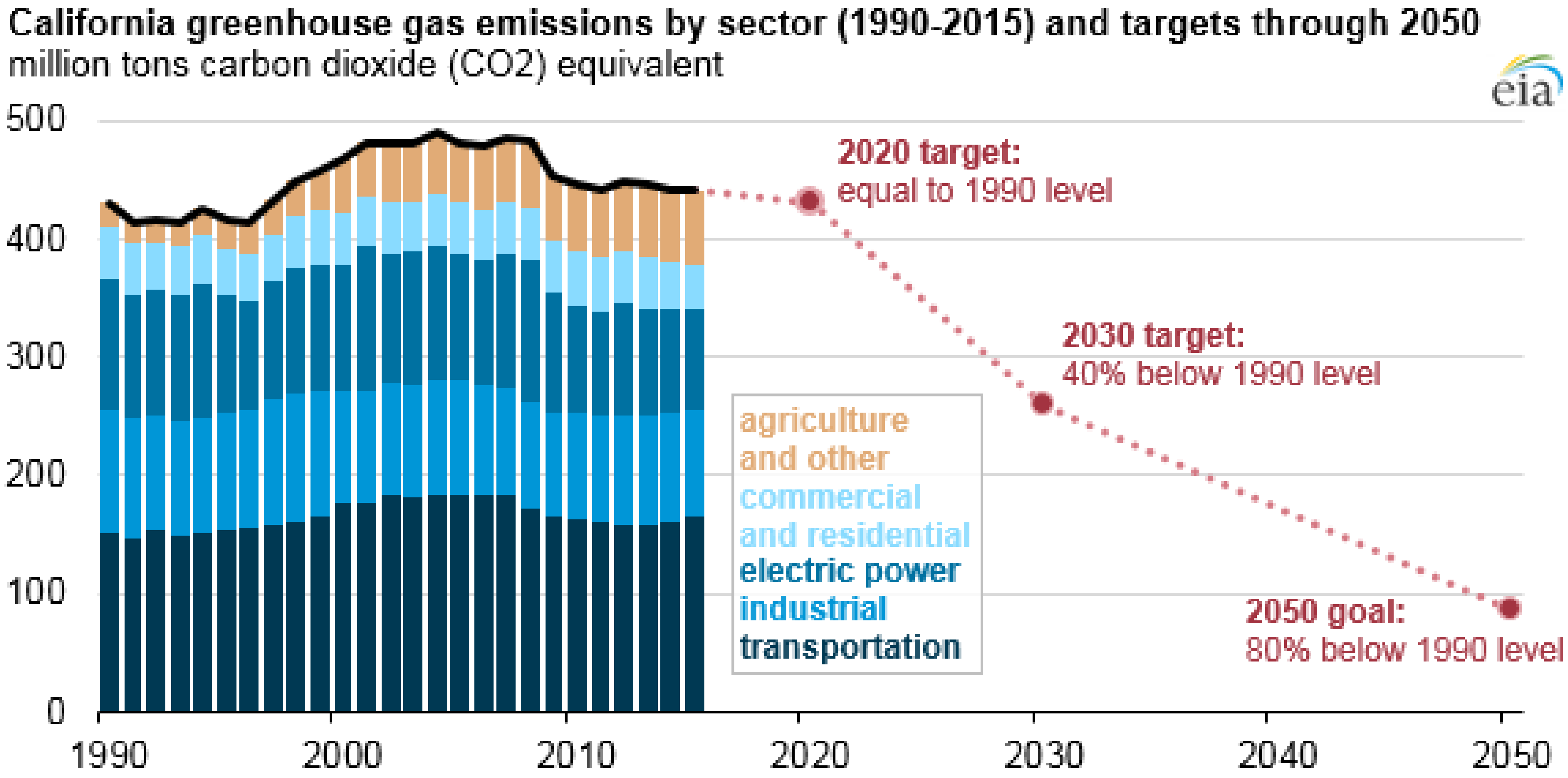
Limestone quarries and cement factories are often sources of air pollution. Photograph: Zoonar GmbH/Alamy

Guardian concrete week

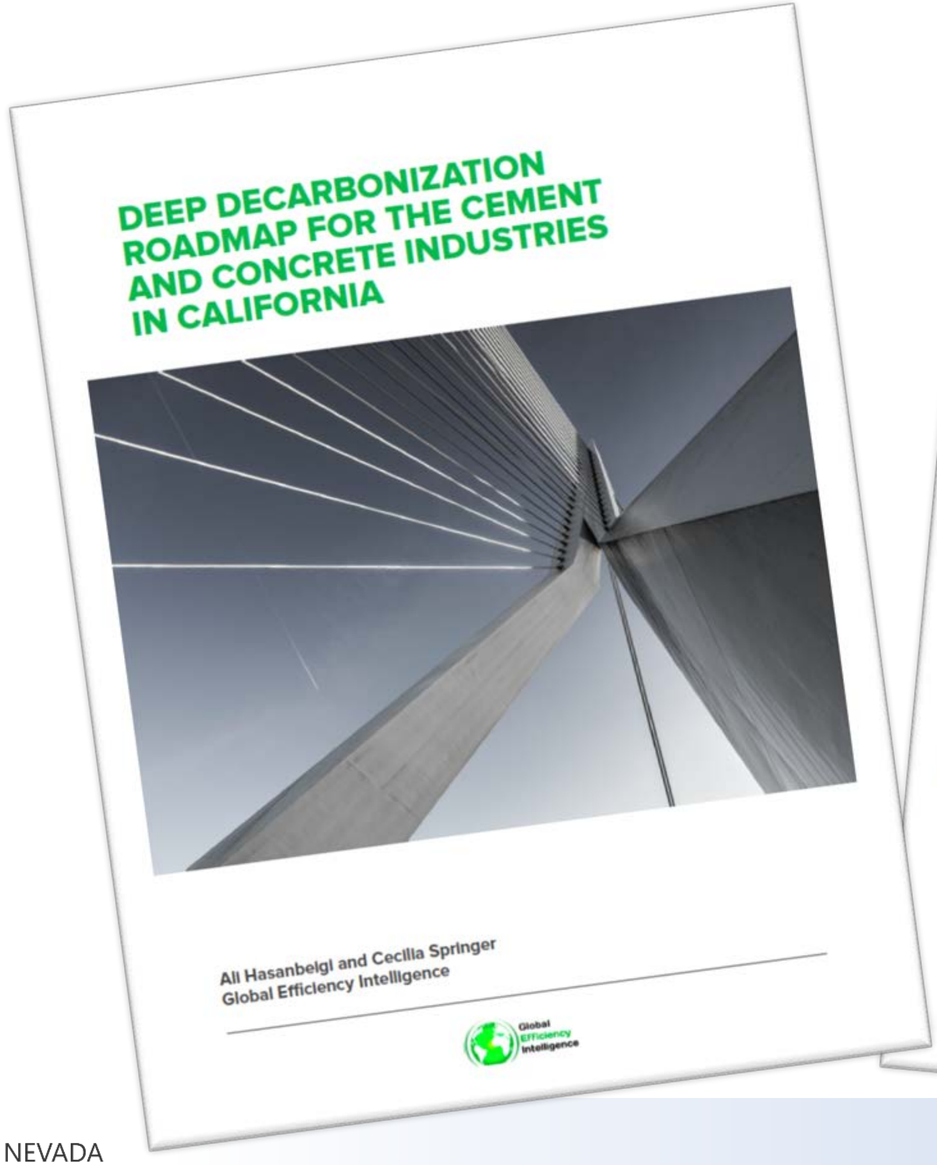
Concrete: the most destructive material on Earth

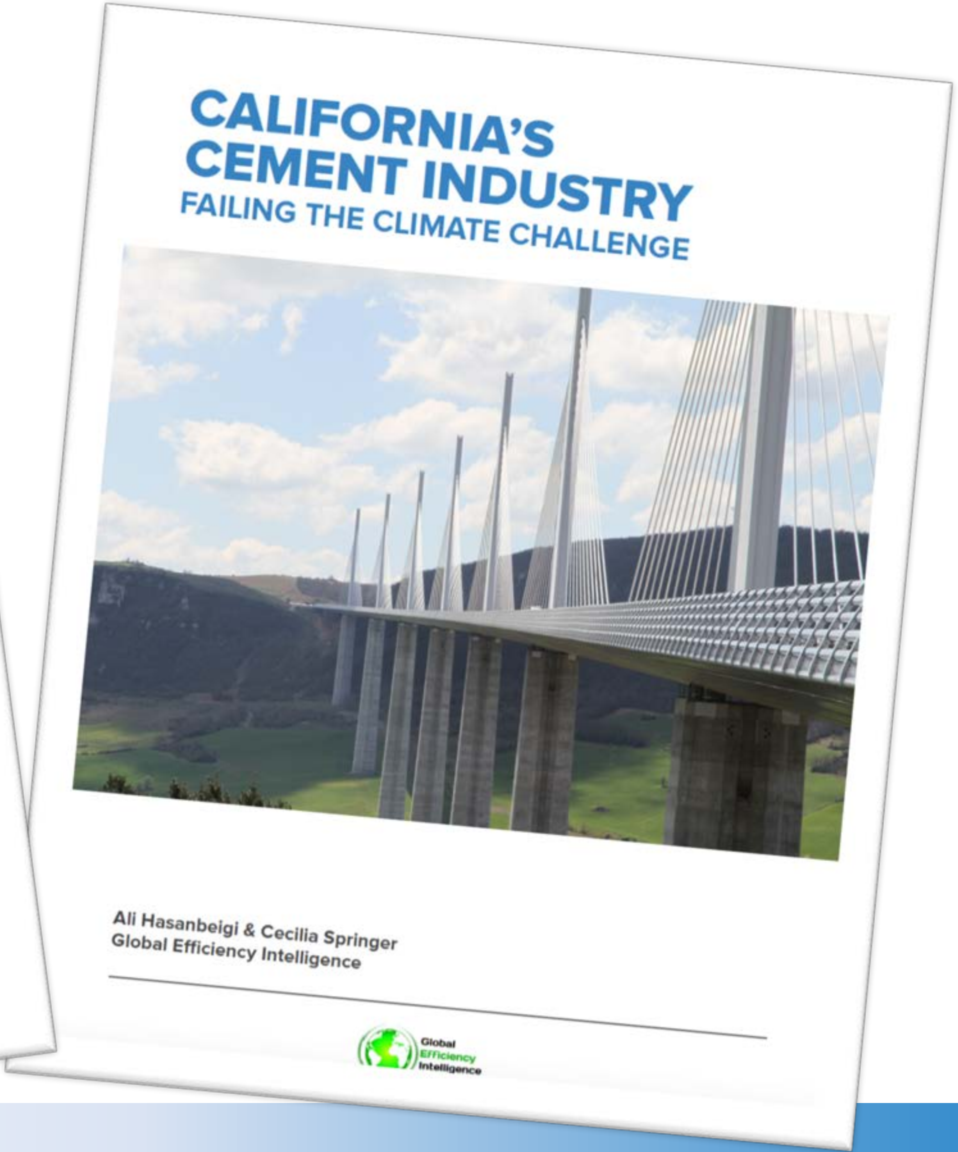
After water, concrete is the most widely used substance on the planet. But its benefits mask enormous dangers to the planet, to human health - and to culture itself

California-Specific Climate Change Goals



Perceptions on Climate Change





Proposals/Actions on Climate Change

BUY CLEAN

AB 262

LA County Sustainability Plan

GREEN
CALIFORNIA GREEN BUSINESS NETWORK
MARIN COUNTY

Bay Area Low-Carbon Concrete Building Code

City of LA's sustainability pLAn, the "Green New Deal"

Current Status of Portland Cement Production in California

- 8 Plants Operating
- 10.3 MMT production
- 10.7 MMT demand
- 12.4 MMT capacity
  - +/- 11.5% of US capacity

* 2018 numbers courtesy PCA

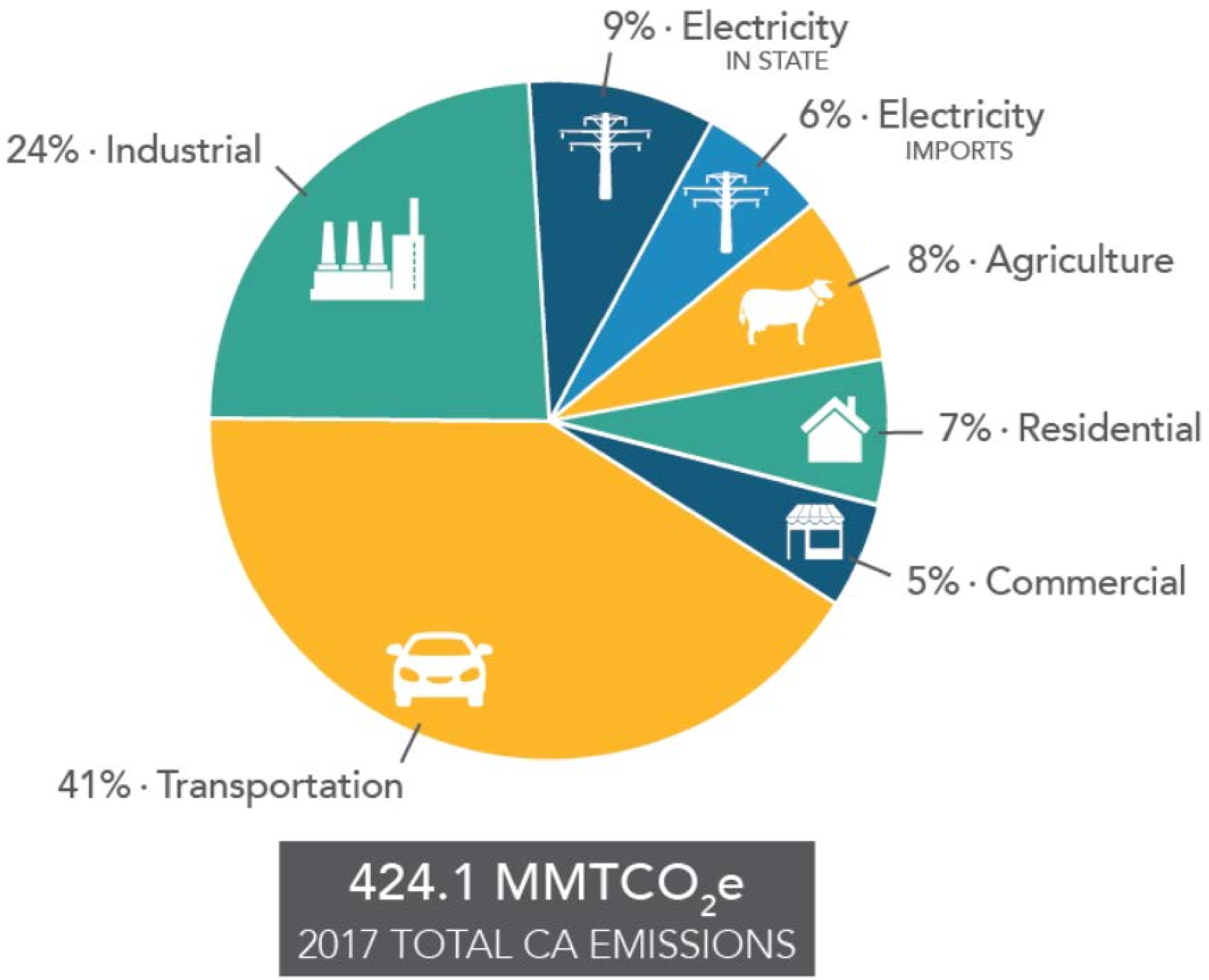
Current Status of energy use and emissions in California

- 1,340 GWh of electricity used
- 900,000 tons of coal and coke burned
- 7.9 MMt of CO2 emitted
  - 61% from process
  - 39% from combustion

* 2015 numbers courtesy CARB

Let’s keep things in perspective

- The CA cement industry’s 7.9 MMT of CO2 is less than 2% of CO2 emissions in California

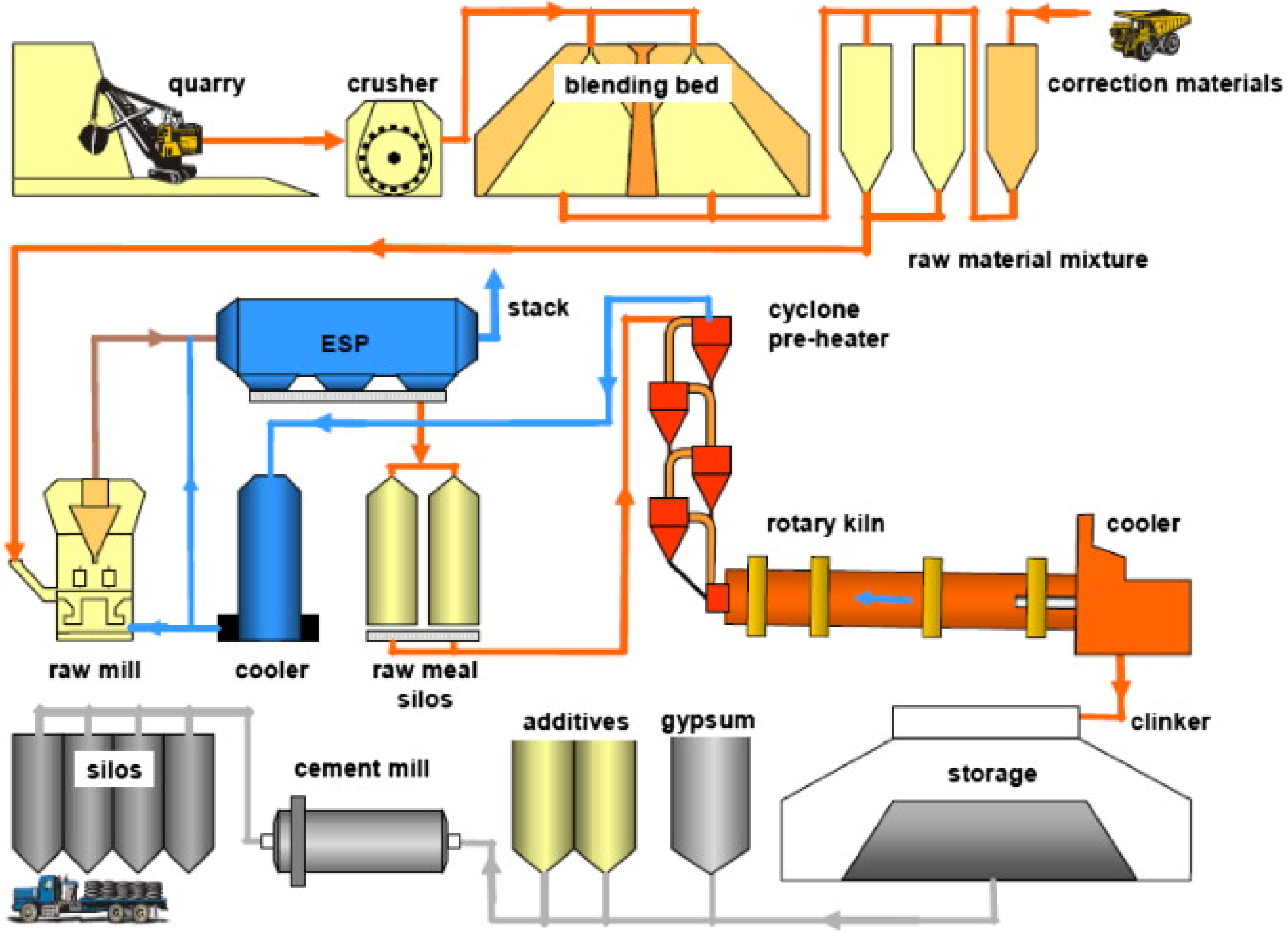


* 2017 numbers courtesy CARB

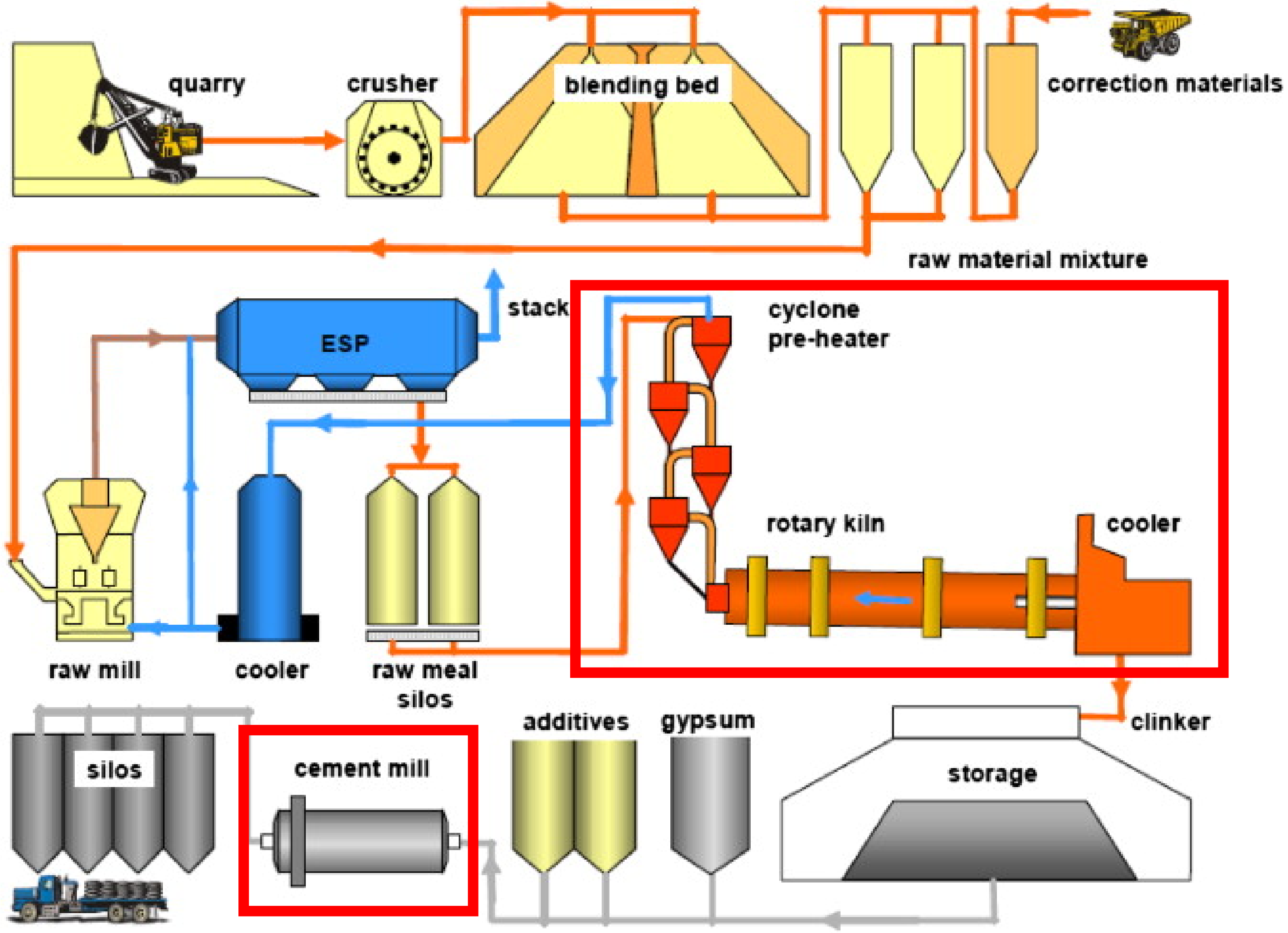
What can be done?

- At the cement plant
- At the ready-mix plant
- With design & specification
- In the future

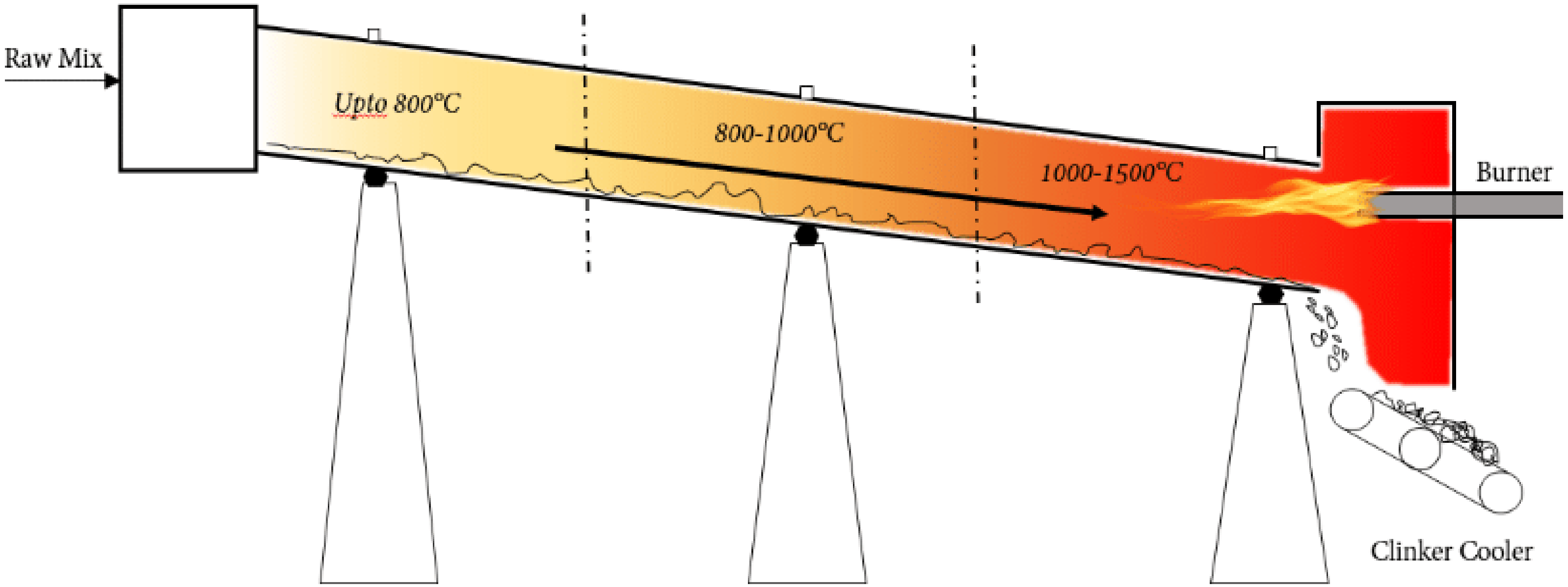
Cement Manufacturing:

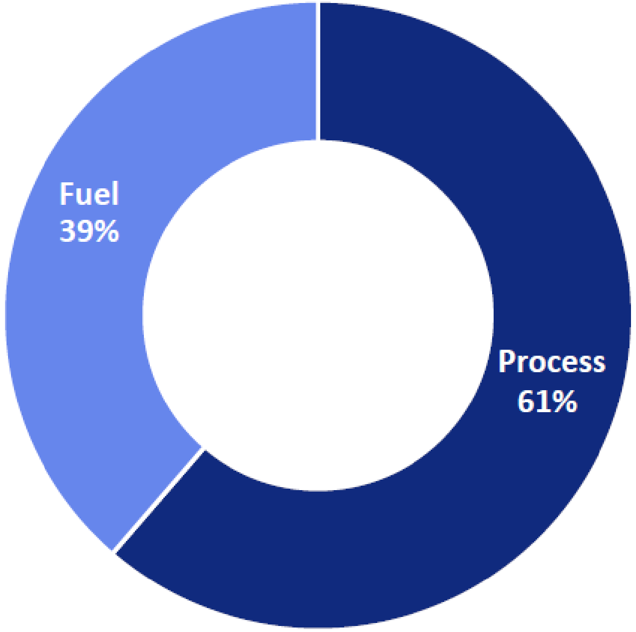


Cement Manufacturing:



Cement Manufacturing – 2 Main CO_2 Sources:

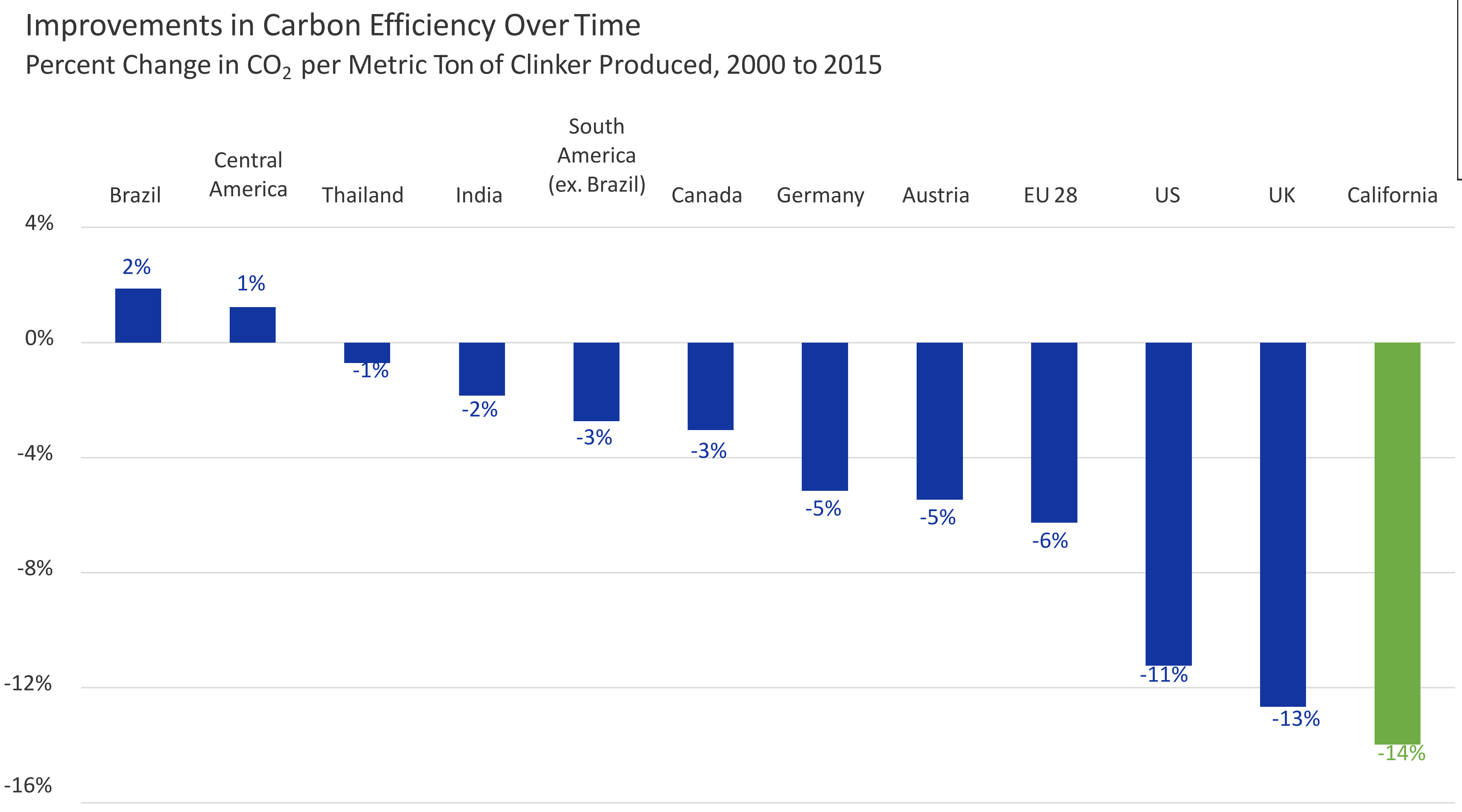




Fuel: California plants use advanced and energy efficient production technology
Process: PLC helps reduce these emissions

1. Thermal energy related: peak temperatures of 1400–1450 °C (2550 – 2650 °F) are required for calcining reaction: +/- 39% of CO_2 emissions
2. Material related (process) emissions: ($CaCO_3$ -> $CaO + CO_2$): +/- 61% of CO_2 emissions

Cement Plant Efficiencies



Portland Limestone Cement

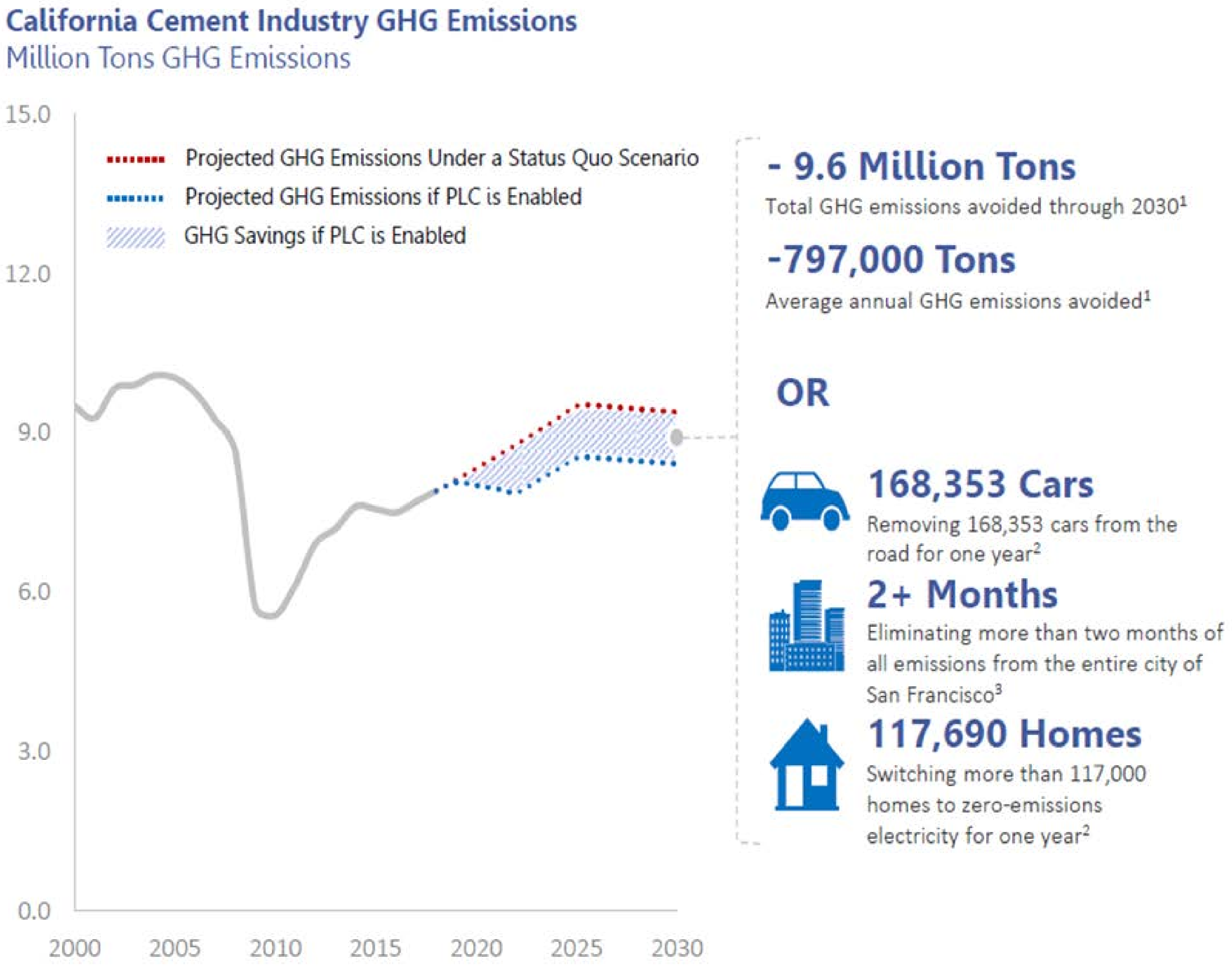
- PLC (ASTM C595 Type IL) contains up to 15% interground limestone in finished cement product

  (ASTM C 150 Portland cements contains up to 5%)
- Limestone addition happens during cement grinding at the cement plant

PLC's Impact

When adopted in the California market, PLC has the potential to generate almost 10 million metric tons in GHG savings by 2030

- PLC allows an additional 10% of limestone to be added to the final product at cement facilities
- PLC reduces the cement industry's GHG emissions by as much as 10%



Sources: (1) analysis by CNCA using historical production data from USGS and emissions data from CARB; (2) EPA GHG Equivalencies Calculator (Last Updated May 2016); (3) San Francisco Department of the Environment.

Notes: Projections assume that increased limestone blending displaces cement clinker on a one-for-one basis; increased limestone blending is enabled in 2018 and adopted gradually by the market in subsequent years, with the average industry blending rate increasing by three percentage points each year until reaching 12% in 2022.

Low-Carbon Fuels

Waste fuels:

- Shredded tires
- Waste oils
- Plastics
- Textiles
- Paper residues
- Municipal Solid Waste

Biogenic fuels:

- Agricultural waste
- Biomass crops

Supplementary Cementitious Materials (SCMs)

- Fly Ash
  - Class C
  - Class F
- Ground Granulated Blast Furnace Slag
- Silica Fume
- Natural Pozzolans
- Limestone
- Calcined clays
- Calcined Shale
- Metakaolin

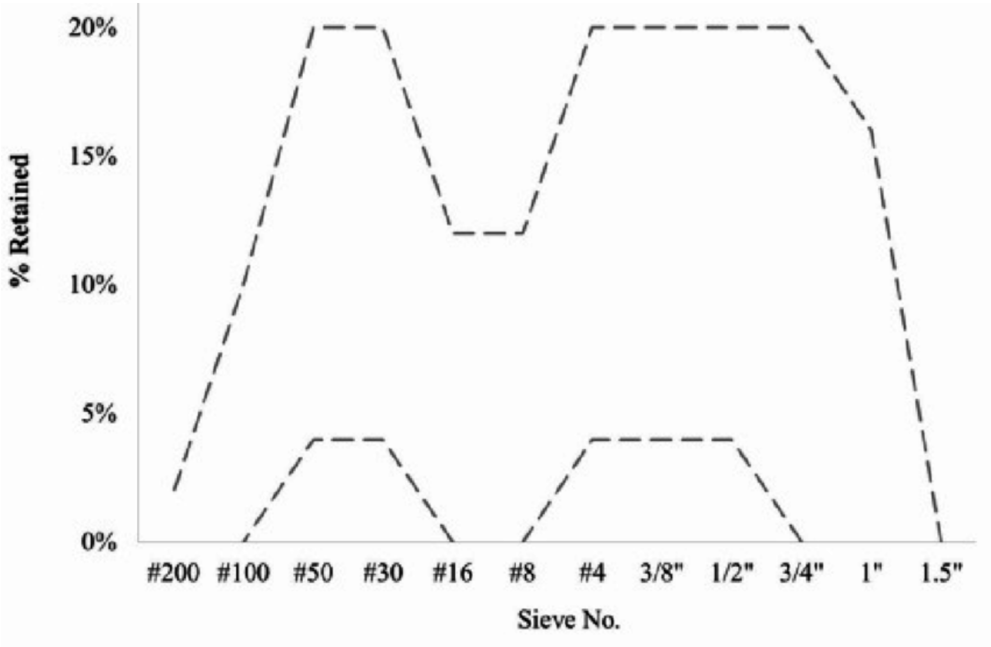
Optimized Aggregate Gradation

Less shrinkage

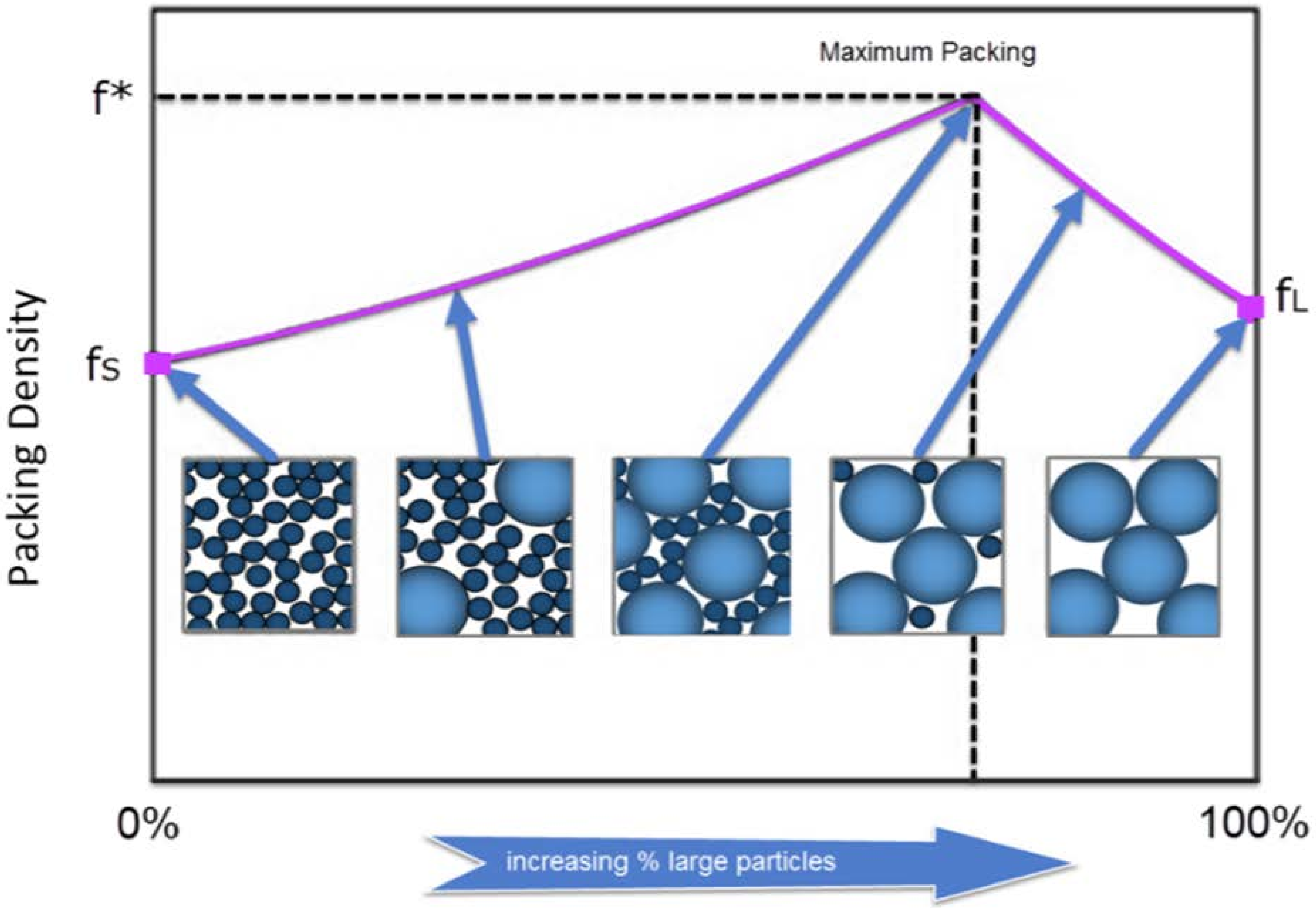
More durable (lower permeability)

Less cement

Lower Cost



Tyler Ley's "Tarantula Curve"



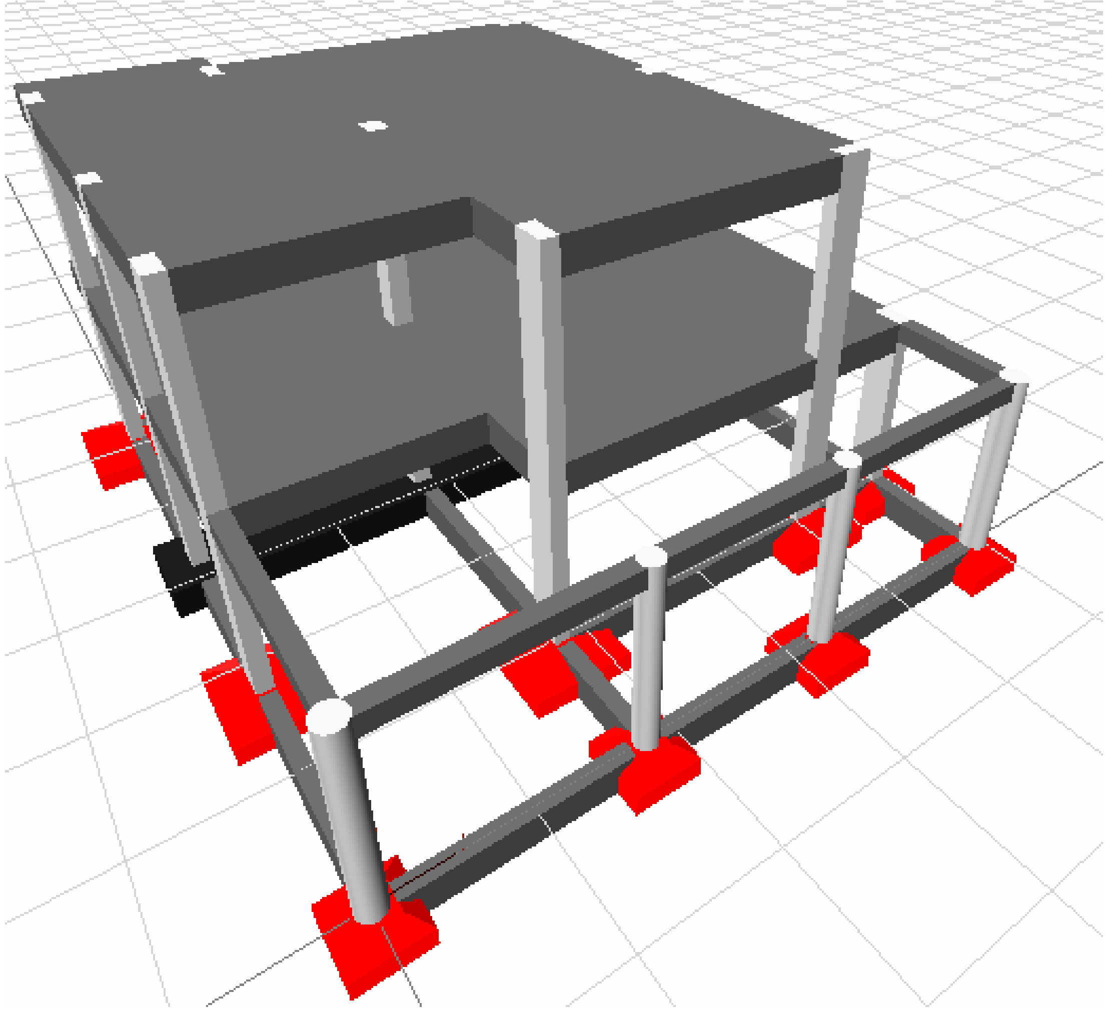
Carbon Capture and reuse with CarbonCure

- Liquid CO2 is injected in fresh concrete during batching process
- C02 turns into solid calcium carbonate
- Results in stronger concrete
- Typical dosage of CO_2 is 1/2 – 1 lb/yd^3

CarbonCure Equipment

Design Keys for Reducing Carbon

- Consider project schedule
- Engineer member size vs concrete volume needed
  - Potential floor-space benefits
- Consider precasting
- Consider lightweight members
- Use high-strength reinforcing steel



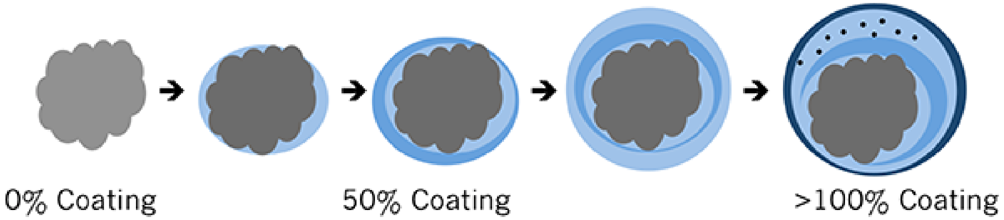
Specification Do’s and Don’ts

- Don’t:
  - Require minimum cement contents
  - Restrict SCM usage (min or max)
  - Require specific aggregate gradations
  - Limit compressive strength to 28 days
  - Require specific w/cm ratios
  - Keep thinking that cement = strength

- Do:
  - Determine required performance
  - Specify metrics and require testing to ensure that performance

Further Horizon Solutions – Process Carbon Capture in aggregate with Blue Planet

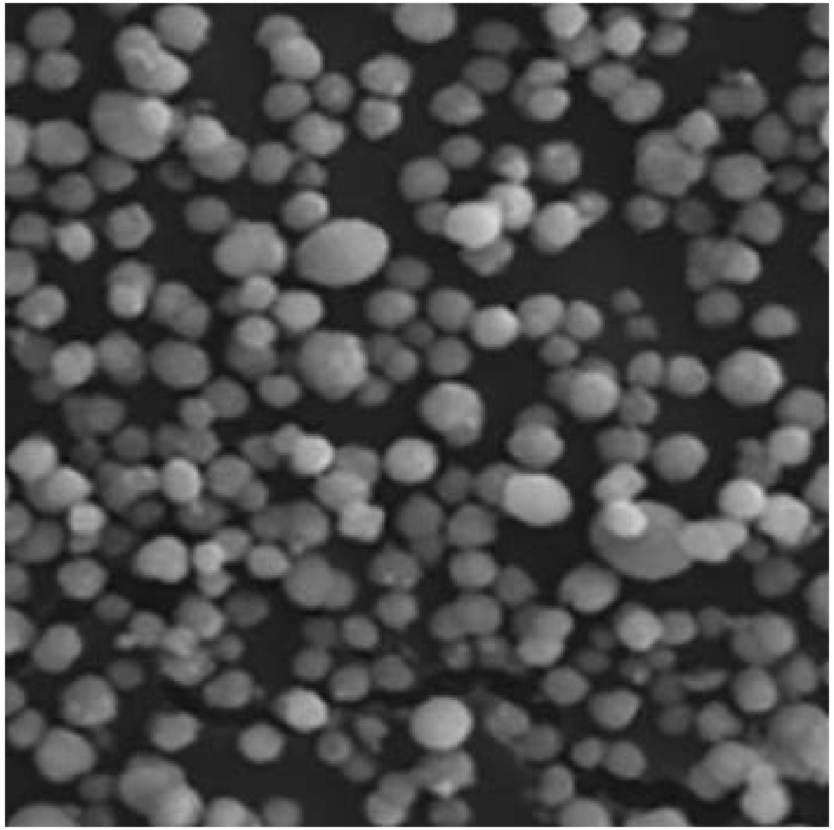
- Uses CO2 as a raw material for making carbonate aggregate,
- Forming a carbon-sequestering coating that is 44% by mass CO2
- Potential for carbon-negative concrete by capturing and sequestering up to 1,920 lbs of CO2/CY:
  - 1,320 lbs in aggregate and 600 lbs removed from flue gas



Blue Planet CO2 Aggregate

Further Horizon Solutions – Fortera Reactive Calcium Carbonate

- Recarbonated Calcium Oxide (CaO)
- Reacted in a kiln exhaust CO2-rich environment
- Finished product is 43% CO2 by weight and is an SCM



Fortera Reactice CaCO3

Further Horizon Solutions– Solar heated kilns and calciners - Heliogen

- Uses concentrated solar energy to heat the kiln or calciner
- Current technology allows for calcination of limestone (+/- 1,000°C)
- Future technology may allow for full cement production (+/- 1,500°C)
- Potential for elimination of fossil fuels from cement production process

Heliogen Mirror Array in Lancaster

Further Horizon Solutions– Direct Air Capture

- Capture and sequester CO2 from the air (not at a plant)
- Current technology is estimated to cost $600/ton to capture
- IRS Section 45Q:
  - Current tax credit of $35 per ton of captured and sequestered CO2 ($50 in 2026)
    - (Geological sequestration)

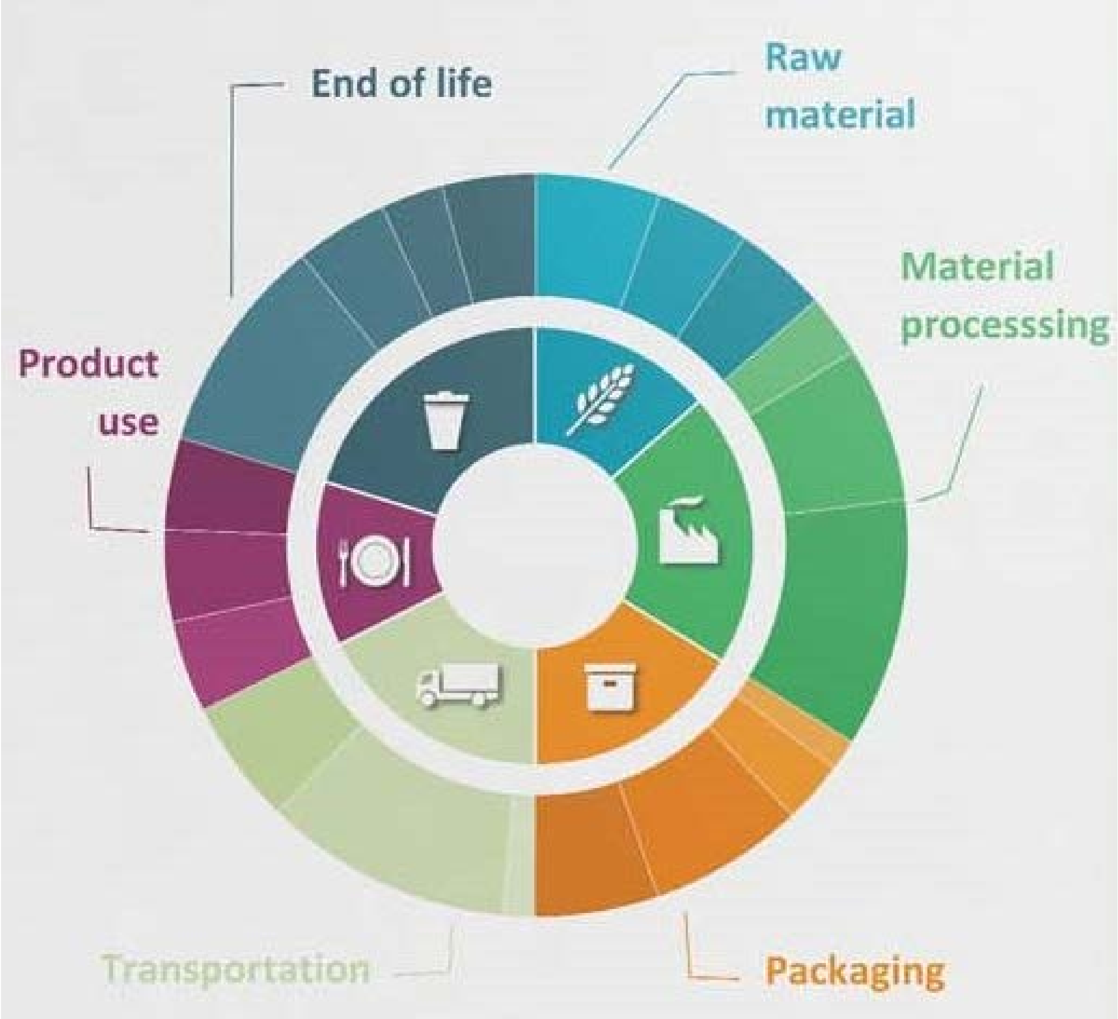
Carbon Engineering facility in British Columbia captures 1 ton/day

Quantifying Environmental Performance

Environmental Product Declarations

Rating Systems

Lifecycle Assessments

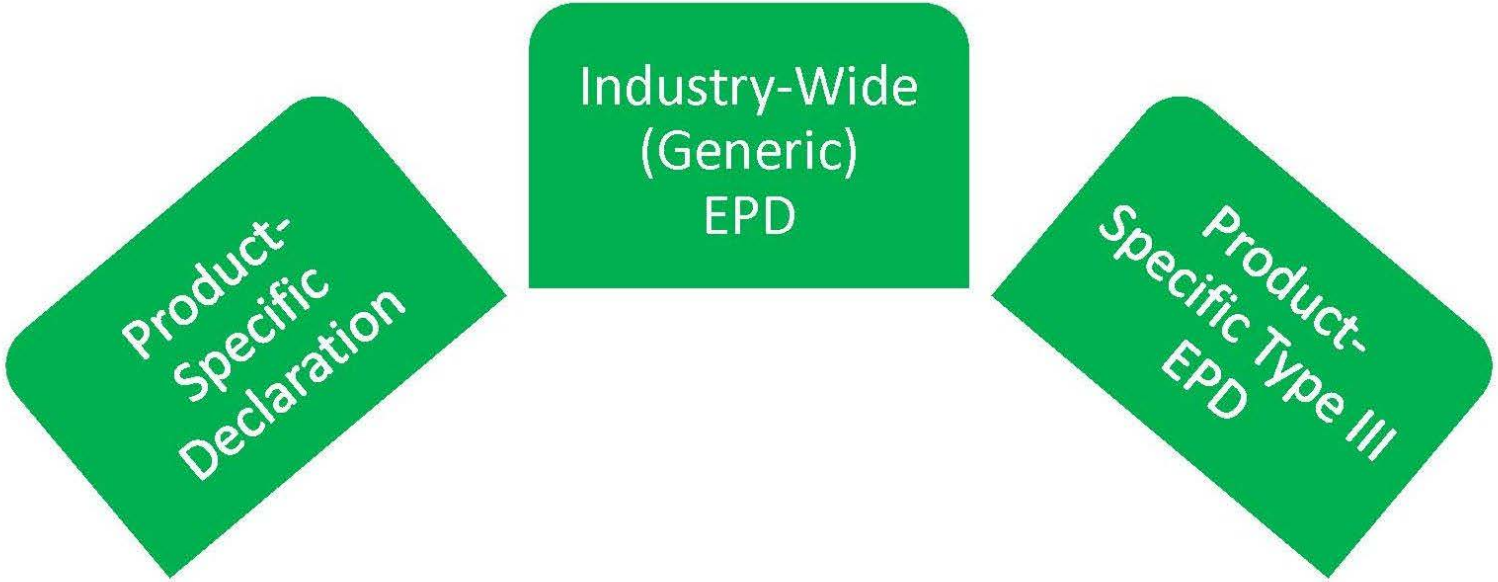


Environmental Product Declarations

EPDs

Environmental Product Declarations

The 3 Types of EPDs



Hydraulic Cements – each type is a product

- Portland cement (ASTM C150 / AASHTO M 85)
  - Type I – general use
  - Type II – moderate sulfate resistance
  - Type III – high early strength
  - Type V – sulfate resistance

- Blended cements (ASTM C595 / AASHTO M 240)
  - IS - Portland blast-furnace slag cement (e.g., Type IS(35))
  - IP - Portland-pozzolan cement
  - IL - Portland-limestone cement
  - IT - Ternary blended cement (3 cementitious materials)

- Performance specification for hydraulic cements (ASTM C1157)
  - Type GU - General Use
  - Type HE - High Early-Strength
  - Type MS - Moderate Sulfate Resistance
  - Type HS - High Sulfate Resistance
  - Type MH - Moderate Heat of Hydration
  - Type LH - Low Heat of Hydration

- Rapid hardening hydraulic cement (ASTM C1600)
  - Type URH - ultra rapid hardening
  - Type VRH - very rapid hardening
  - Type MRH - medium rapid hardening
  - Type GRH – general rapid hardening

Cement EPDs – Standard Cement: Avg. & Specific

Metric	Cradle-to-gate total per metric tonne of production	Unit
Environmental impact		
Global warming potential (100 years)	1040	kg CO2-eq.
Acidification potential	2.45	kg SO2-eq.
Eutrophication potential	1.22	kg N-eq.
Formation potential of tropospheric ozone	48.8	kg O3-eq
Ozone depletion potential	2.61E-05	kg CFC 11-eq.
Total primary energy consumption		
Non-renewable primary energy: Fossil	5250	MJ
Non-renewable primary energy: Nuclear	345	MJ
Renewable primary energy: Solar, wind, hydroelectric, geothermal	127	MJ
Renewable primary energy: Biomass	165	MJ
Material resources consumption		
Non-renewable material resources	1420	kg
Renewable material resources	7.64	kg
Net fresh water[a]	9700	L
Total waste generation[b]		
Non-hazardous waste generated	8.99	kg
Hazardous waste generated	0.0518	kg

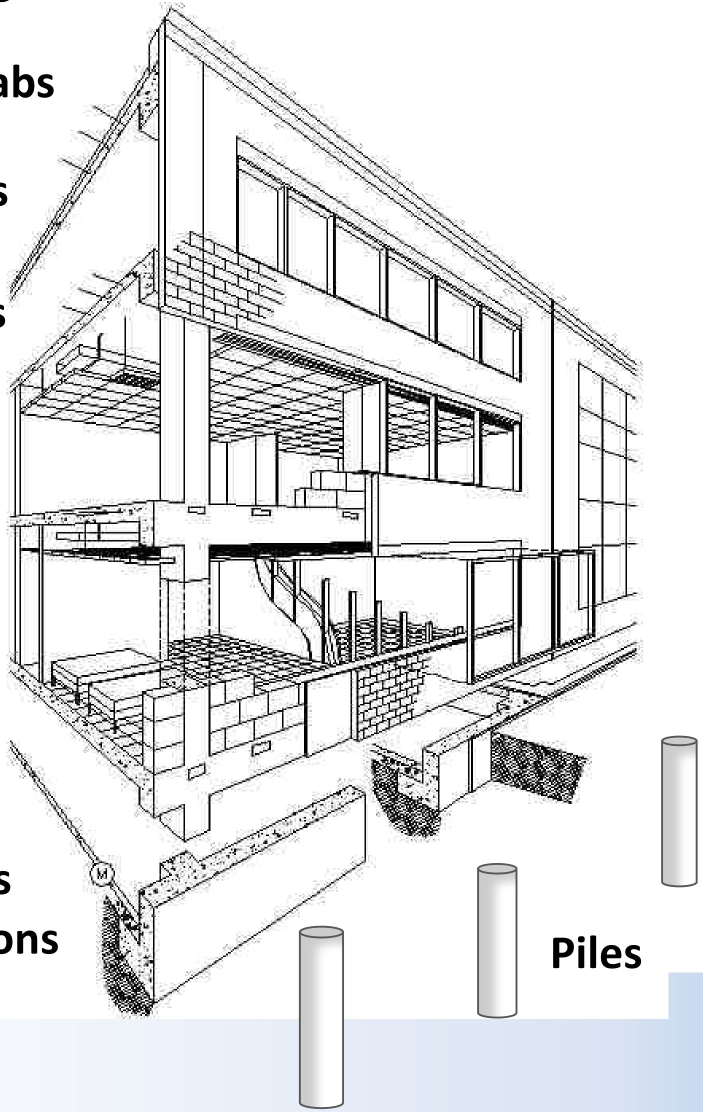
Environmental Indicator	Unit	Riverside Type I/II/V	Riverside Type III	Riverside Plastic
TRACI 2.1 impact categories				
Global warming potential (GWP)	kg CO_2 eq.	969	962	823
Acidification potential	kg SO_2 eq.	1.70	1.71	1.48
Eutrophication potential	kg N eq.	0.0874	0.0910	0.0742
Smog creation potential	kg O_3 eq.	38.6	38.6	32.8
Ozone depletion potential	kg CFC-11 eq.	9.82E-07	1.27E-06	7.70E-07
Total primary energy consumption				
Non-renewable fossil	MJ (HHV)	5,502	5,490	4,736
Non-renewable nuclear	MJ (HHV)	142	143	130
Renewable (solar, wind, hydroelectric, and geothermal)	MJ (HHV)	143	143	133
Renewable (biomass)	MJ (HHV)	0.92	1.18	0.75
Material resources consumption				
Non-renewable material resources	kg	1,599	1,574	1,490
Renewable material resources	kg	0.0291	0.0390	0.0236
Net fresh water (inputs minus outputs)	l	666	820	576
Waste generated				
Non-hazardous waste generated	kg	2.75	2.73	2.47
Hazardous waste generated	kg	0.00709	0.00708	0.00632

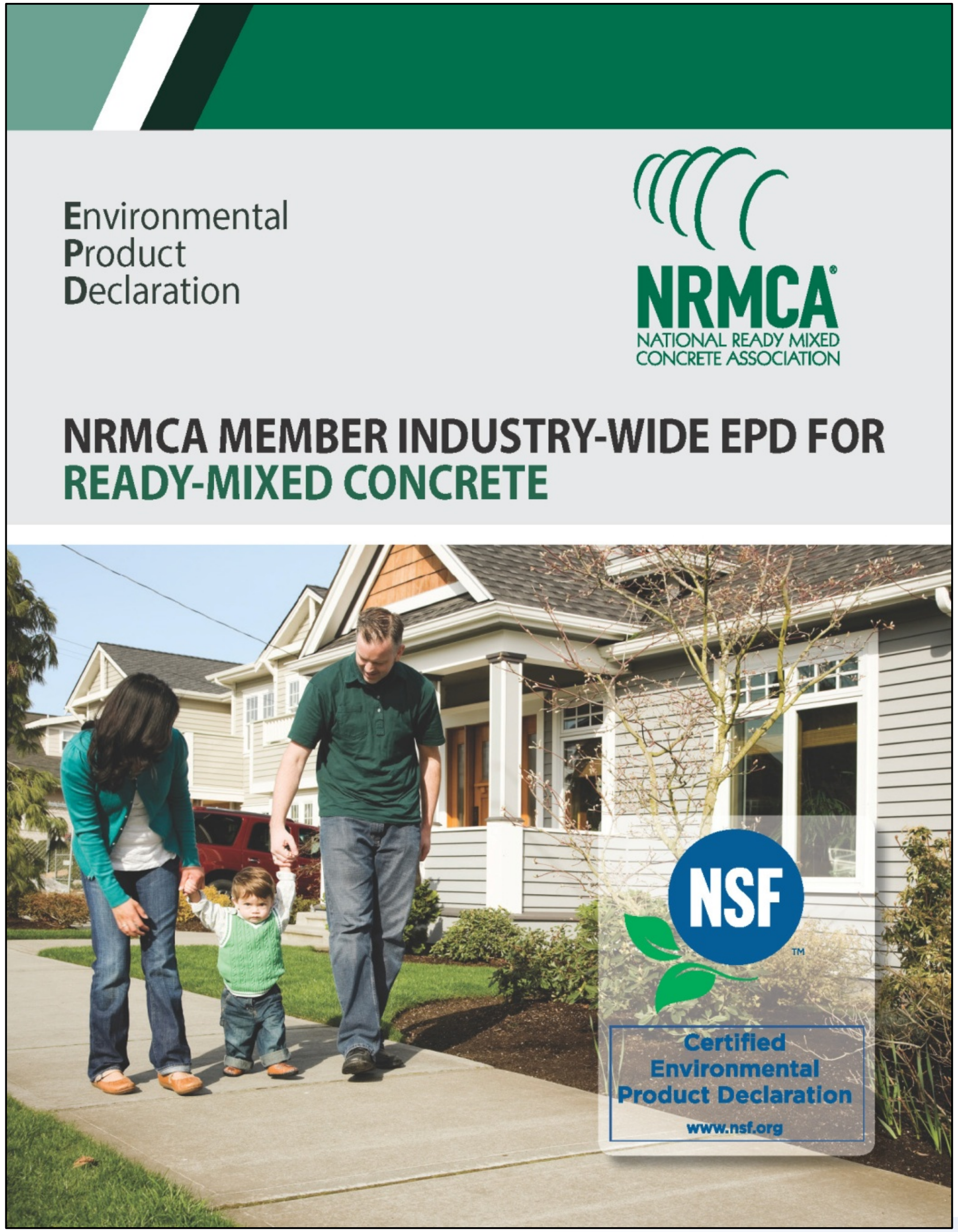
Cement EPD – PLC: CalPortland Oro Grande

- CA PLC is 16% 'Greener' than average US Portland cement
  - 871 kg/ton vs 1040 kg/ton
- CA PLC is 10% 'Greener' than CA Portland cement
  - 871 kg/ton vs 969 kg/ton

Category Indicator	Unit	Total A1-A3
TRACI 2.1 impact categories		
Global warming potential (GWP)	kg CO_2 eq.	871
Acidification potential	kg SO_2 eq.	1.56
Eutrophication potential	kg N eq.	0.0739
Smog creation potential	kg O_3 eq.	34.8
Ozone depletion potential	kg CFC-11 eq.	1.09E-06
Total primary energy consumption		
Non-renewable fossil	MJ (HHV)	5,010
Non-renewable nuclear	MJ (HHV)	136
Renewable (solar, wind, hydroelectric, and geothermal)	MJ (HHV)	136
Renewable (biomass)	MJ (HHV)	0.883
Material resources consumption		
Non-renewable material resources	kg	1,530
Renewable material resources	kg	0.0282
Net fresh water (inputs minus outputs)	l	335
Waste generated		
Non-hazardous waste generated	kg	2.59
Hazardous waste generated	kg	0.00658

Each unique concrete mix design is a product




Environmental
Product
Declaration
NRMCA
NATIONAL READY MIXED CONCRETE ASSOCIATION
NRMCA MEMBER INDUSTRY-WIDE EPD FOR
READY-MIXED CONCRETE
NSF
Certified Environmental Product Declaration
www.nsf.org


Admix
Aggregate
SCMs
Cement
Environmental
Product
Declaration
NRMCA
A cradle-to-gate EPD of five cement products according to ISO 14025 and ISO 21930
Type I
Type III
EcoMent Endure ®
EcoMent Spec ®
Type N&S
CAPITOL
AGGREGATES INC
Supplier EPDs
CEMEX
NRMCA
CERTIFIED
EPD
Environmental Product Declaration
This Environmental Product Declaration (EPD) covers twelve concrete mixes
produced by CEMEX at the Pier 92 plant in San Francisco, California.

Industry Average EPD – 4,001 – 5000 psi

Table 9. Summary Results (A1-A3): 4001-5000 psi (27.59-34.47 MPa) RMC product, per cubic meter															
Indicator/LCI Metric	GWP	ODP	AP	EP	POCP	PEC	NRE	RE	NRM	RM	CBW	CWW	TW	CHW	CNHW
Unit (equivalent)	kg CO2	kg CFC-11	kg SO2	kg N	kg O3	MJ	MJ	MJ	kg	kg	m3	m3	m3	kg	kg
Minimum	305.8	8.80E-6	1.15	0.38	23.97	2268	2222	43	1983	2.44	0.13	0.12	0.28	0.43	4.72
Maximum	511.7	1.30E-5	1.55	0.61	31.75	3173	3110	63	2377	3.73	0.13	0.12	0.29	0.49	6.77
5000-00-FA/SL	511.7	1.30E-5	1.55	0.61	31.75	3173	3110	63	2377	3.73	0.13	0.12	0.29	0.44	6.77
5000-20-FA	436.3	1.10E-5	1.36	0.52	28.07	2752	2699	53	2196	3.18	0.13	0.12	0.28	0.43	6.12
5000-30-FA	395.5	9.90E-6	1.26	0.47	26.07	2525	2476	48	2099	2.88	0.13	0.12	0.28	0.43	5.77
5000-40-FA	352.5	8.80E-6	1.15	0.42	23.97	2285	2241	43	1995	2.56	0.13	0.12	0.28	0.43	5.40
5000-30-SL	388.2	1.20E-5	1.47	0.48	28.18	2714	2658	56	2175	3.03	0.13	0.12	0.29	0.47	5.54
5000-40-SL	347.1	1.10E-5	1.45	0.44	27.00	2561	2508	53	2107	2.79	0.13	0.12	0.29	0.48	5.13
5000-50-SL	305.8	1.10E-5	1.42	0.39	25.80	2407	2356	51	2039	2.56	0.13	0.12	0.29	0.49	4.72
5000-50-FA/SL	306.2	9.60E-6	1.28	0.38	24.31	2268	2222	46	1983	2.44	0.13	0.12	0.29	0.47	4.83

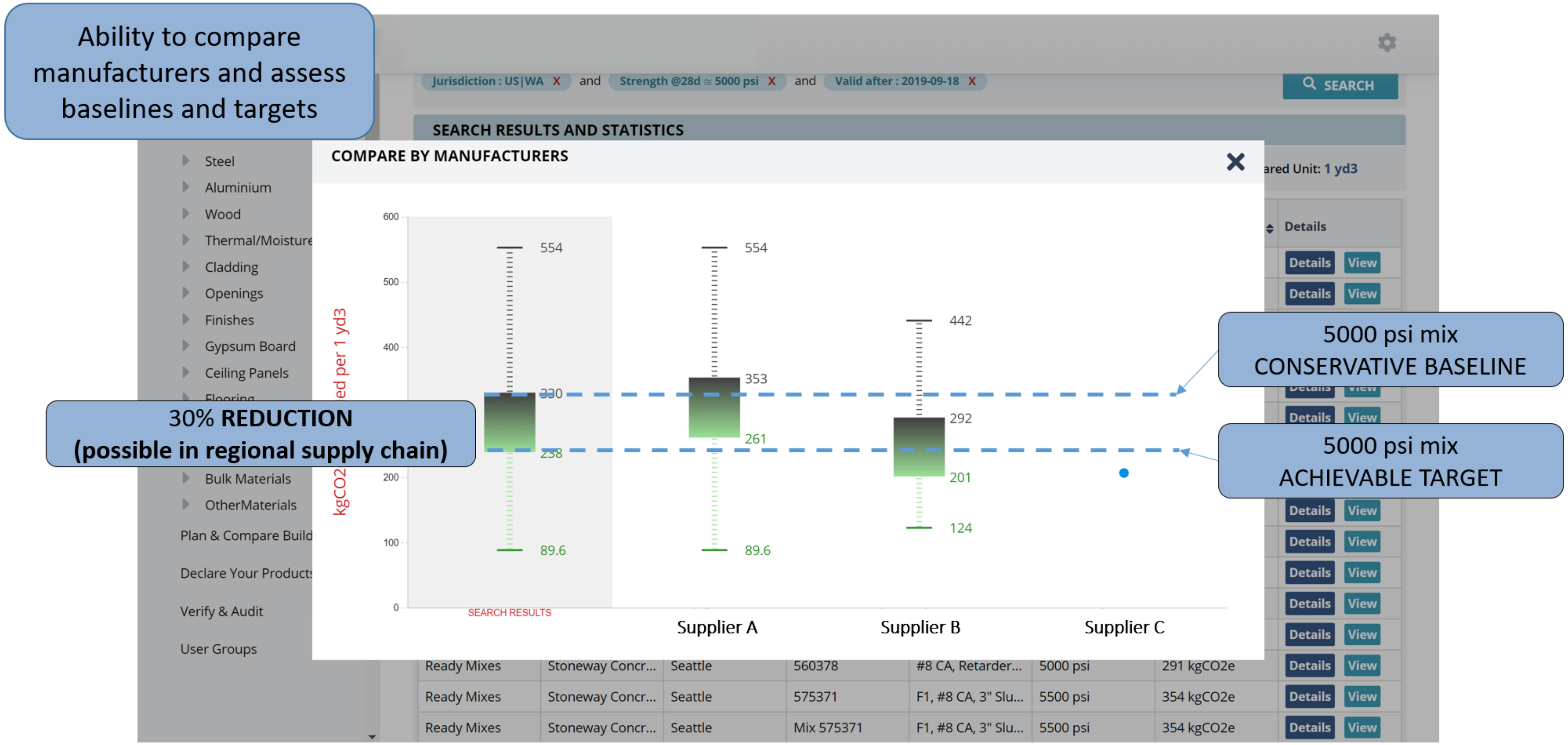
Plant Specific EPD – 5000 psi

- Description: 50% SCM (Slag) Gen. Use 4" Line Perf 5000
- 28-day compressive strength: 5,000 psi

Impact name	Unit	Impact per m^3	Impact per cyd
Global warming potential	kg CO_2-eq	378	289
Ozone depletion	kg CFC-11-eq	1.78×10^{-5}	1.36×10^{-5}
Acidification	kg SO_2-eq	1.92	1.46
Eutrophication	kg N-eq	0.25	0.19
Photochemical oxidation	kg O_3-eq	12.2	9.3
Primary energy consumption	MJ	4,173	3,191
Batch freshwater consumption	gal	17.3	13.2
Process freshwater consumption	gal	3.69	2.82

Estimating Impacts – EC3 tool

Comparison of 5000 psi ready mix concretes in a region



Rating System - Buildings Market

LEED v4

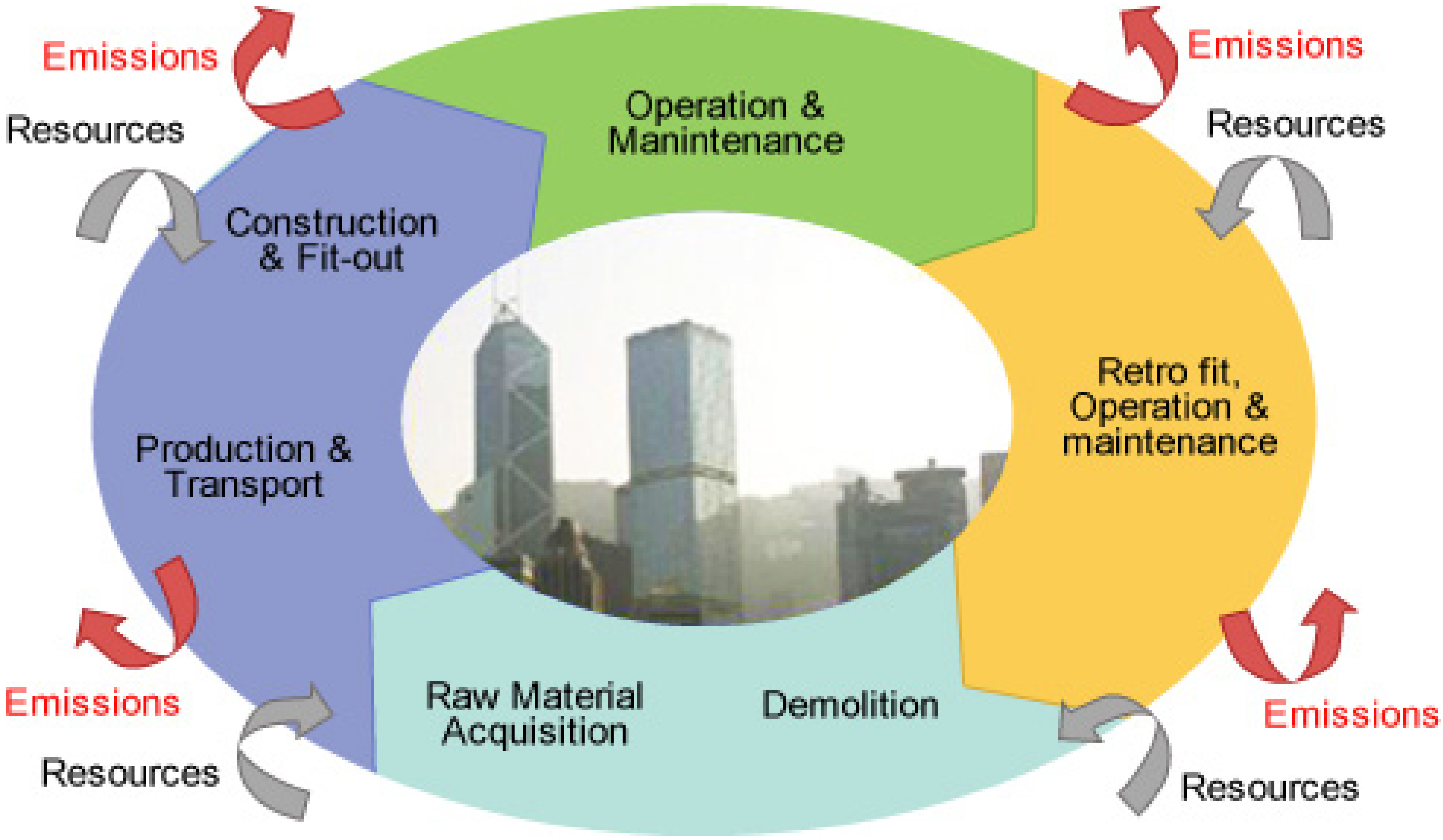
Infrastructure Market Rating Systems

- Envision
  - ISI - ASCE, APWA,
- Invest
  - Federal Highways Administration (FHWA)
- Greenroads

Rating System Commonalities

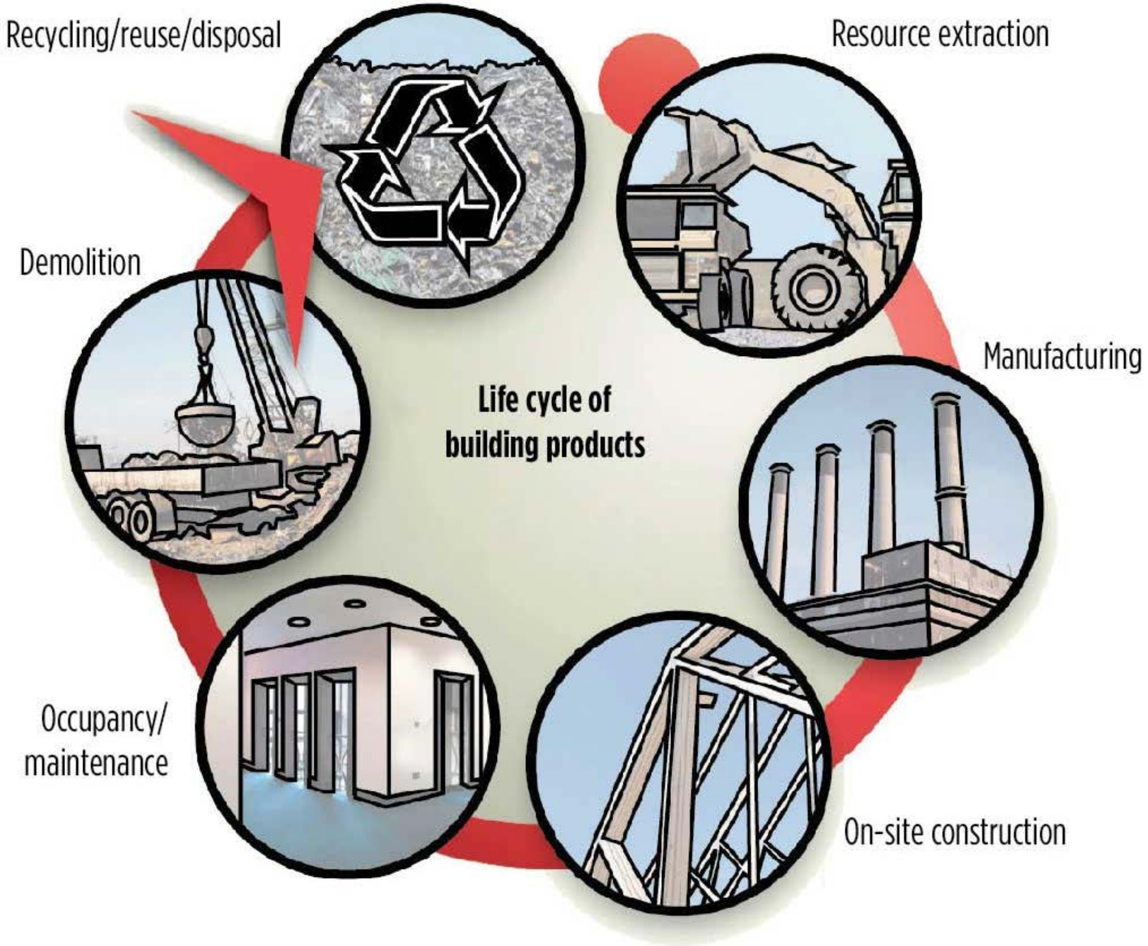
- Typically voluntary
- Whole Life Consideration
  - Planning, Design, Construction, Operations, End of Life
- Incentivize improved performance
- Tiered certification levels
- Awards Innovation

Life Cycle Assessment



Take Aways:

- Sustainability is an important topic
  - Becoming more so every day
- CO_2 is inherent Portland cement production
- Many strategies exist to mitigate impacts
- LCAs and Rating Systems allow us to quantify our decisions



Questions?

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