

NRMCA Concrete Carbon Calculator:

How to quantify and specify carbon

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National Ready Mixed Concrete Assoc.



How to Quantify and Specify Carbon

Historically:

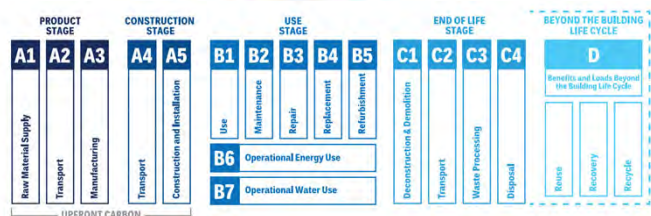
- Prescriptive measures
 - "maximum cement content"
 - "minimum SCM content"
- Byproduct:
 - Not producer-specific solutions
 - Inefficient mix design
 - Increase in cost



How to Quantify and Specify Carbon

Present Day:

- Life Cycle Assessment
 - Benchmark vs. Proposed Low Carbon
 - Concrete-scope embodied carbon
 - Project-wide Whole Building LCA
- Byproduct:
 - Quantifiable reductions
 - Producer specific solutions
 - Flexibility in execution



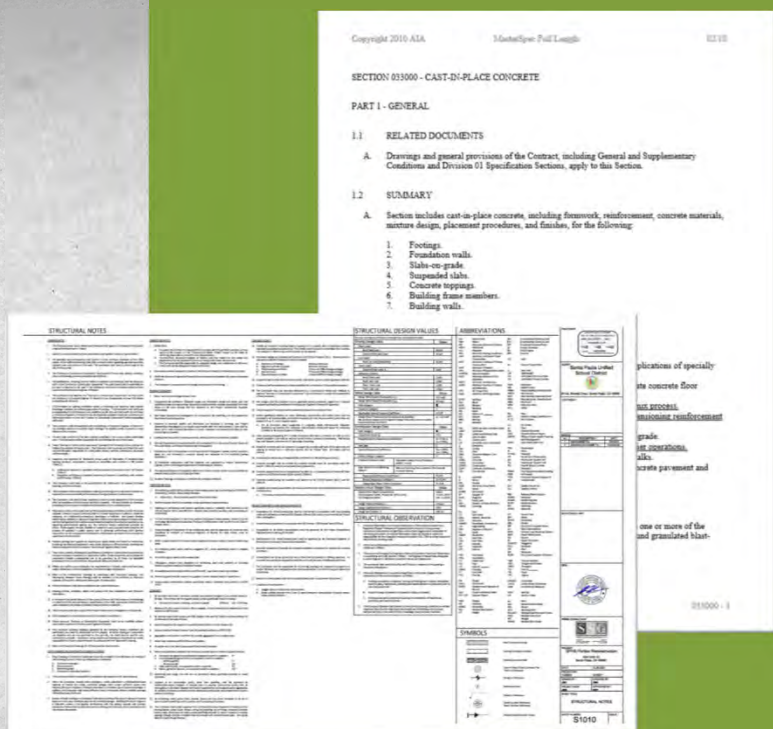
Division 03 Section 033000 Cast-In-Place Concrete

Step #1:

Performance-Based Improvements

Step #2:

Carbon Accounting and Targets



Step #1 – Performance Based Improvements

Goal:

Prescription  Performance

Methods:

- Emphasize ACI 318 Exposure Classes
- Alt testing for durability/design
 - Shrinkage, MOE, RCP, ASR
- Expand acceptable materials
- Extended strength development

Results:

Efficient and Optimized Mix Designs



Performance Specs

They allow for sustainable mix designs, but don't require it!



Step #2 – Carbon Accounting and Targets

Goal:

Trigger the use of low carbon materials

Methods:

- Collect EPDs
- Establish a Carbon Budget

Results:

- Procurement of low carbon concrete
- Flexibility for the contractor and producer
- Buffer for as-built conditions



Specifications for Sustainability

Member	Mix ID	Durability Exposure				Specified Strength, f'_c , psi	Max w/cm or Performance Alternative	Nom. max. Aggregate, in.	Air Content	Slump/ Slump Flow	Chloride Limit	Temp. Limits
		F	S	W	C							
Footings												
Foundation Walls												
Slabs-on-grade												
Exterior slabs												
Suspended slabs (interior)												
Suspended slabs (exterior)												
Frame members												
Columns (interior)												
Columns (exterior)												
Walls (interior)												
Concrete toppings												

Max. GWP (kg/yd ³ CO ₂ e)
250
250
250
250
300
300
300
300
250
250

Collaborative carbon budget **vs.** GWP limit per mix class

Preferred

Specifications for Sustainability

Project Budget

TOTAL GWP: 4.30×10^6



VS

Individual Mix Limits

TOTAL GWP: 4.30×10^6

Shear Walls:
180 kg CO₂ eq/m³

Columns:
190 kg CO₂ eq/m³

Floors 2-18:
240 kg CO₂ eq/m³

Floors B2-1:
225 kg CO₂ eq/m³

Basement Walls:
190 kg CO₂ eq/m³

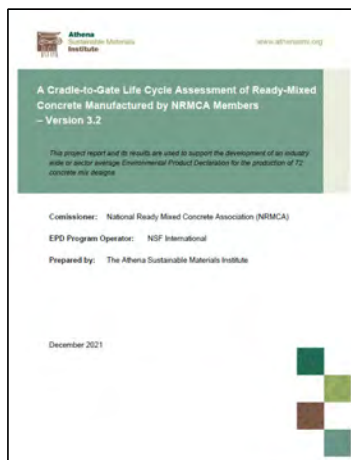
Foundation:
175 kg CO₂ eq/m³



Establishing a Carbon Budget

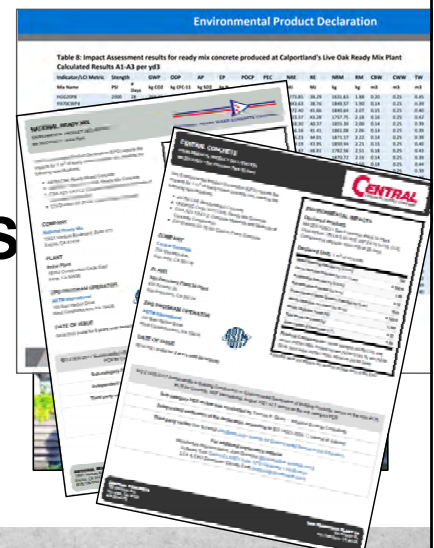


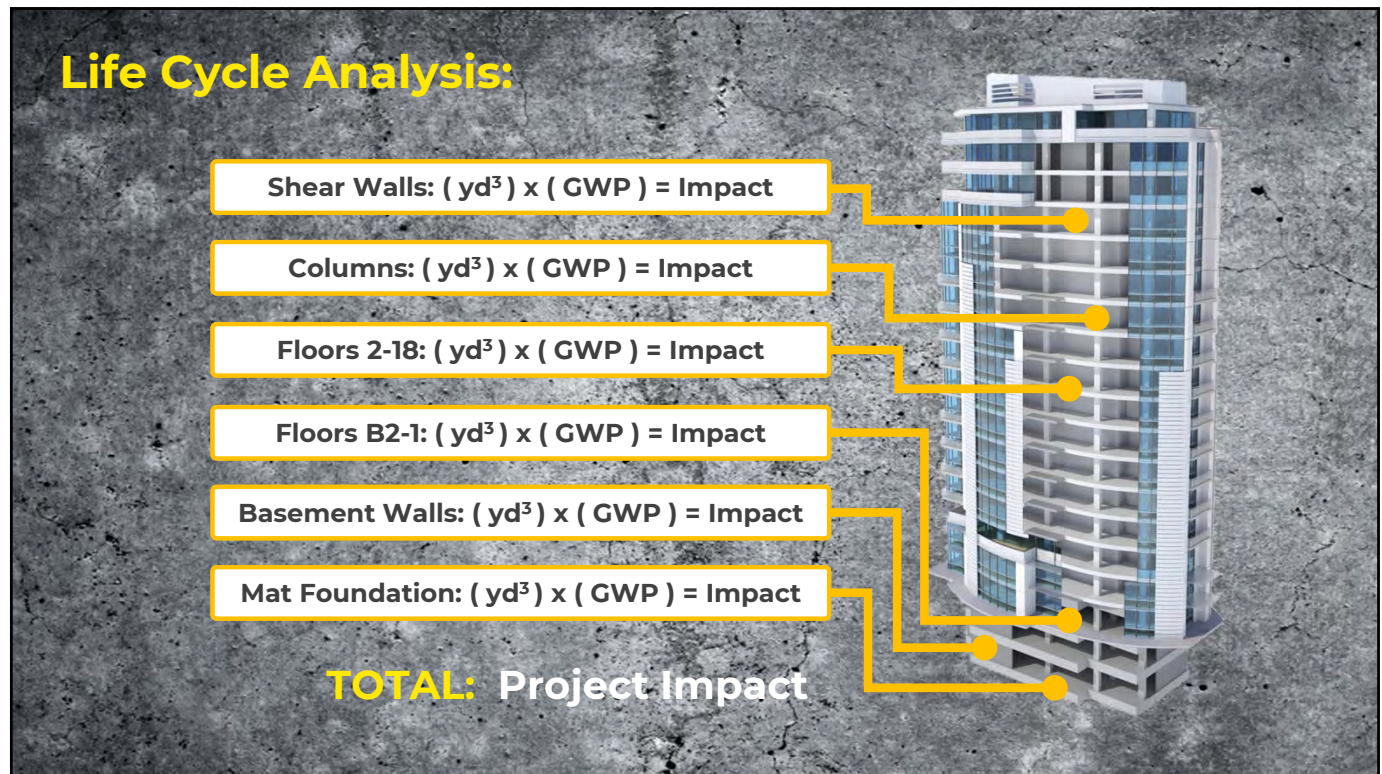
Benchmark Project



VS

Proposed Project





Estimating Quantities and Properties

Concrete Element	Concrete Volume (yd^3)	Benchmark Mixes (benchmark)*	Proposed Mixes (IW-EPD)*
Shear Walls	7,630	6,000 psi	6,000 psi 30% slag, 20% fly ash
Columns	366	8,000 psi	8,000 psi 40% fly ash
Floors 2-18	4,533	5,000 psi	5,000 psi 30% slag
Floors B2-1	1,067	5,000 psi	5,000 psi 40% fly ash
Basement Walls	444	5,000 psi	5,000 psi 30% slag, 20% fly ash
Foundation	3,844	6,000 psi	6,000 psi 40% slag, 30% fly ash

*Should be augmented with local data, knowledge, capabilities

NRMCA Benchmark Mixes

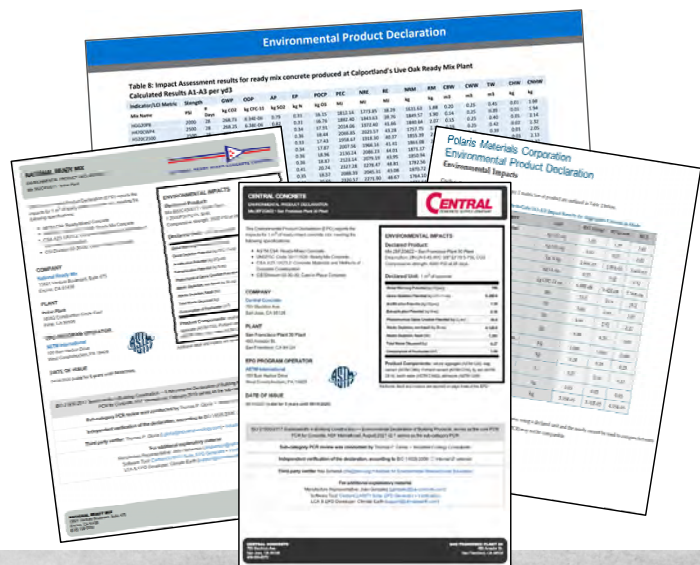
Results Table E2-Eastern LCA Results (per cubic yard)										
Strength	psi @28 days	2,500	3,000	4,000	5,000	6,000	8,000	3000LW	4000LW	5000LW
Core Mandatory Impact Indicator										
GWP	kg CO ₂ e	183.29	201.48	240.22	289.03	305.26	360.51	395.35	437.90	480.10
ODP	kg CFC11e	5.91E-06	6.36E-06	7.32E-06	8.52E-06	8.96E-06	1.03E-05	1.47E-05	1.58E-05	1.69E-05
AP	kg SO ₂ e	0.67	0.71	0.81	0.93	0.98	1.12	2.10	2.22	2.33
EP	kg Ne	0.24	0.26	0.30	0.36	0.37	0.44	0.69	0.74	0.79
SFP	kg O ₃ e	14.31	15.21	17.18	19.61	20.57	23.34	29.65	31.81	33.89
ADPf	MJ, NCV	400.61	412.16	442.07	482.50	503.70	548.75	2,225.23	2,290.96	2,344.41
ADPe	kg Sbe	1.28E-04	1.30E-04	1.36E-04	1.42E-04	1.48E-04	1.55E-04	1.71E-04	1.79E-04	1.87E-04

Download at <https://www.nrmca.org/sustainability>

Environmental Product Declaration (EPD)

3rd party verified & registered documents that communicate transparency

ENVIRONMENTAL IMPACTS	
Declared Product: Mix 2EFZG8Z2 • San Francisco Plant 30 Plant Description: 2IN LN 0.45 W/C 3/8" EF70 5-7SL CO2 Compressive strength: 4000 PSI at 28 days	
Declared Unit: 1 m ³ of concrete	
Global Warming Potential (kg CO ₂ -eq)	190
Ozone Depletion Potential (kg CFC11e)	5.91E-06
Acidification Potential (kg SO ₂ -eq)	1.59
Eutrophication Potential (kg N-eq)	0.16
Photochemical Ozone Creation Potential (kg O ₃ -eq)	36.6
Abiotic Depletion, non-fossil (kg Sb-eq)	4.12E-5
Abiotic Depletion, fossil (MJ)	1,393
Total Waste Disposed (kg)	0.27
Consumption of Freshwater (m ³)	1.69
Product Components: natural aggregate (ASTM C33), slag cement (ASTM C989), Portland cement (ASTM C150), fly ash (ASTM C618), batch water (ASTM C1602), admixture (ASTM C494)	



NRMCA Proposed Industry Wide EPD Mixes

Table 10b. Summary Results (A1-A3): 5001-6000 psi (34.5-41.4 MPa) RMC product mix design, per cubic yard

		Minimum	Maximum	5001-6000-00-FA/SL	5001-6000-20-FA	5001-6000-30-FA	5001-6000-40-FA	5001-6000-30-SL	5001-6000-40-SL	5001-6000-50-SL	5001-6000-50-FA/SL
Core Mandatory Impact Indicator											
GWP	kg CO ₂ e	231.47	377.44	377.44	322.63	293.01	261.73	290.83	261.97	233.11	231.47
ODP	kg CFC11e	6.50E-06	9.71E-06	9.16E-06	7.90E-06	7.22E-06	6.50E-06	9.49E-06	9.60E-06	9.71E-06	6.24E-06
AP	kg SO ₂ e	0.81	1.10	1.07	0.95	0.88	0.81	1.08	1.09	1.10	0.97
EP	kg Ne	0.30	0.45	0.45	0.39	0.35	0.32	0.37	0.34	0.32	0.30
SFP	kg O ₃ e	17.76	23.30	22.81	20.42	19.13	17.76	23.10	23.20	23.30	20.73
ADPF	MJ, NCV	503.28	575.31	575.31	541.31	522.84	503.28	550.69	542.48	534.27	515.21
ADPe	kg Sbe	1.21E-04	1.50E-04	1.50E-04	1.36E-04	1.29E-04	1.21E-04	1.36E-04	1.31E-04	1.27E-04	1.22E-04

Download at <https://www.nrmca.org/sustainability>

Identifying Global Warming Potential

Concrete Element	Concrete Volume (yd ³)	Benchmark Mixes GWP (Eastern Region)	Proposed Mixes GWP (IW-EPD)*
Shear Walls	7,630	305	232 30% slag, 20% fly ash
Columns	366	361	303 40% fly ash
Floors 2-18	4,533	289	277 30% slag
Floors B2-1	1,067	289	249 40% fly ash
Basement Walls	444	289	220 30% slag, 20% fly ash
Foundation	3,844	305	166* 40% slag, 30% fly ash

*Should be augmented with local data, knowledge, capabilities

NRMCA Concrete Carbon Calculator

Producer

NRMCA

Designer

Access at <https://www.nrmca.org/sustainability>

Concrete Budget Report

Contractor: ABC Construction
Ready Mix Producer: NRMCA Member
Prepared by: bway@nrmca.org
Fruit Technology Inc. - New Office Campus
Sunny, California

Carbon Footprint Summary

Category	Baseline (tCO ₂ e)	Proposed (tCO ₂ e)	Reduction (tCO ₂ e)	Reduction (%)
Mix Concrete	1,000,000	950,000	50,000	-5.0%
Slabs and Beams	500,000	480,000	20,000	-4.0%
Shear Walls and Columns	300,000	280,000	20,000	-6.7%
Slabs on Grade	100,000	95,000	5,000	-5.0%
Wall Foundation	50,000	45,000	5,000	-10.0%
Carbonation	10,000	10,000	0	0.0%
Total	1,960,000	1,860,000	100,000	-5.1%

This report was generated using the NRMCA's Concrete Carbon Calculator, powered by Climate Earth. The results of this analysis indicate that an estimated -25.11% reduction in embodied carbon could be achieved for the concrete scope on Fruit Technology Inc. - New Office Campus*. The baseline used to calculate this reduction is based on NRMCA v3.2 Pacific SW.

*This study includes the following life cycle stages:

NRMCA Carbon Tool

Project
Start New Project

1 Basic Information
2 Project Settings
3 Project Data
4 Online Report

Project Basic Information

Name *

Description *

Project type *

Residential Tower - Boston

18 Story CIP Frame

Building

Project Address

Street

City *

State *

Zip Code *

123 Main Street

Boston

Massachusetts (MA)

02114

Project Complementary Information

Contractor name

Ready Mix Producer


Plant Name

ABC Contracting

NRMCA Producer

Downtown Boston

NRMCA Carbon Tool



Project

Start New Project

1 Basic Information

2 Project Settings

Basic Settings

Unit of Measure System *

imperial

Total Project Area *

500000

Carbon Budget Source Settings

Source for carbon budget *

I will use an industry or local policy baseline

Source for baseline *

NRMCA v3.2 Eastern

Reset

Cancel


< Previous

Next >

- NRMCA Benchmarks v3.2
 - National
 - 8 Regions
- GSA (General Services Administration)
- City of Portland
- CLF Baseline (Carbon Leadership Forum)

More to be added in the future

NRMCA Carbon Tool



Project



















Edit Project

1 Basic Information

2 Project Settings

3 Project Data

4 Online Report

Mix ID	Strength PSI	Mix Type	Application	Total Volume yd³	Proposed Mix GWP kgCO2e/yd³	Carbonation Factor kgCO2e/yd³	Baseline GWP kgCO2e/yd³	Baseline GWP Budget kgCO2e/project	Proposed Project GWP kgCO2e/project	Total Achievable Carbonation kgCO2e/project
 1	6000	Norm... ▼	Shear Walls	7630	232 	-7.6 	305.3	2,329,439	1,770,160	-57,988
 2	8000	Norm... ▼	Columns	366	303 	-17.8 	360.5	131,943	110,898	-6,515
 3	5000	Norm... ▼	Floors 2-18	4533	277 	-12.4 	289	1,310,037	1,255,641	-56,209
 4	5000	Norm... ▼	Floors B2-1	1067	249 	-17.7 	289	308,363	265,683	-18,886
 5	5000	Norm... ▼	Basement V	444	220 	18.6 	289	128,316	97,680	-8,258
 6	6000	Norm... ▼	Foundation	3844	166.4 	11.7 	305.3	1,173,573	639,642	-2,691
TOTALS				17,884				5,381,671	4,139,704	-150,547

NRMCA Carbon Tool

Project

Edit Project

Basic Information

Online Report

Portland Limestone Cement (Type IL)/ASTM C595 - Domestic

282

✓

LB

Slag Cement/ASTM C989 - Imported

170

✓

LB

Fly Ash

112

✓

LB

Crushed Coarse Aggregate/ Crushed Fine Aggregate

1650

✓

LB

Natural Fine Aggregate

1400

✓

LB

Plasticizer and Superplasticizer

24

✓

FL.OZ

Cancel

Download Mix Design File

Calculate

✕

Project

Edit Project

Basic Information

Online Report

Important information

This result is NOT an EPD. This GWP was calculated using the same LCI data sources as prescribed in Table A1 of the PCR for Concrete, NSF International, August 2021 v2.1. A3 is assumed to be 9.04 kg CO₂e/m³ per NRMCA's Benchmark Report v3.2. This GWP is strictly an estimate and is based on industry averages, regional data, and average transportation impacts and should be used for estimation purposes only. For more accurate results, it is recommended that a Type III Third-Party Verified Product Specific EPD be developed.

For a more accurate plant specific estimate, use your EPD tool provider's EPD estimator.

Proposed Mix GWP for 'Foundation'

✕

Portland Limestone Cement (Type IL)/ASTM C595 - Domestic

282

✓

LB

✕

Slag Cement/ASTM C989 - Imported

170

✓

LB

✕

Fly Ash

112

✓

LB

✕

Crushed Coarse Aggregate/ Crushed Fine Aggregate

1650

✓

LB

✕

Natural Fine Aggregate

1400

✓

LB

✕

Plasticizer and Superplasticizer

24

✓

FL.OZ

Cancel

Download Mix Design File

Calculate

NRMCA Carbon Tool

Project
Edit Project

Basic Information **2 Project Settings** 3 Project Data Online Report

Mix ID	Strength PSI	Mix Type	Application	Total Volume yd³	Proposed Mix kgCO2e/yd³	Carbonation Factor kgCO2e/yd³	Baseline GWP kgCO2e/yd³	Baseline GWP Budget kgCO2e/project	Proposed Project GWP kgCO2e/project	Total Achievable Carbonation kgCO2e/project
1	6000	Norm...	Shear Walls	7630	232	-7.6	305.3	2,329,439	1,770,160	-57,988
2	8000	Norm...	Columns	366	303	-17.8	360.5	131,943	110,898	-6,515
3	5000	Norm...	Floors 2-18	4533	277	-12.4	289	1,310,037	1,255,641	-56,209
4	5000	Norm...	Floors B2-1	1067	249	-17.7	289	308,363	265,683	-18,886
5	5000	Norm...	Basement V	444	220	-18.6	289	128,316	97,680	-8,258
6	6000	Norm...	Foundation	3844	166.4	-0.7	305.3	1,173,573	639,642	-2,691
TOTALS				17,884				5,381,671	4,139,704	-150,547

NRMCA Carbon Tool

Basic Information

Online Report

Mix ID	Strength PSI	Mix Type	Baseline GWP Budget CO ₂ e/project	Proposed Project GWP kgCO ₂ e/project	Total Achievable Carbonation kgCO ₂ e/project
1	6000	Norm...	2,329,439	1,770,160	-57,988
2	8000	Norm...	131,943	110,898	-6,515
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4	5000	Norm...	308,363	265,683	-18,886
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6	6000	Norm...	1,173,573	639,642	-2,691
TOTALS			5,381,671	4,139,704	-150,547

Carbonation Factor

Use type *
Building Interior - Structural elements

Reference Service Life (RSL) (years) *

60

Exposed surface (yd²/yd³) *

5.5

Exposure category *

Without cover

Cement content (lb/yd³) *

470

Percent clinker in cement (%) *

93

Percent limestone in concrete (%) *

0

Percent silica fume in concrete (%) *

0

Percent fly ash in concrete (%) *

20

Cancel

Calculate

NRMCA Carbon Tool

Basic Information

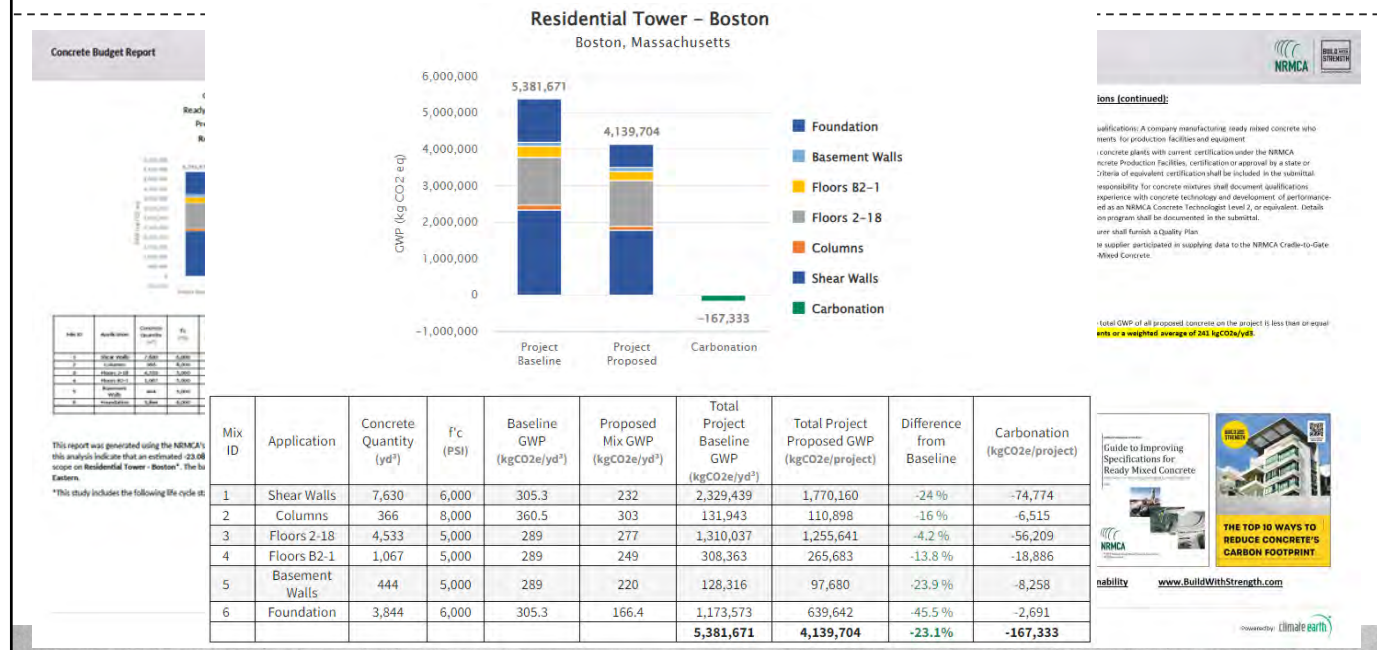
Project Settings

Project Data

Online Report

Mix ID	Strength PSI	Mix Type	Application	Total Volume yd ³	Proposed Mix GWP kgCO ₂ e/yd ³	Carbonation Factor kgCO ₂ e/yd ³	Baseline GWP kgCO ₂ e/yd ³	Baseline GWP Budget kgCO ₂ e/project	Proposed Project GWP kgCO ₂ e/project	Total Achievable Carbonation kgCO ₂ e/project
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NRMCA Carbon Tool



Final Results

Project	Project GWP (kg)	Weighted GWP (kg/yd ³)	GWP Reduction
Benchmark Mixes	5,382,000	301	0
Proposed with Fly Ash and Slag Mixes	4,140,000	232	- 23%
Establish Carbon Budget	4,300,000	240	- 20%*

* Consider added buffer/tolerance

Set Targets for Carbon Footprint

Concrete Materials:

A. Supply concrete mixtures such that the total Global Warming Potential (GWP) of all concrete on the project is less than or equal to **4,300,000 kg** of CO₂ equivalents or a weighted average of **240 kgCO₂e/yd³**



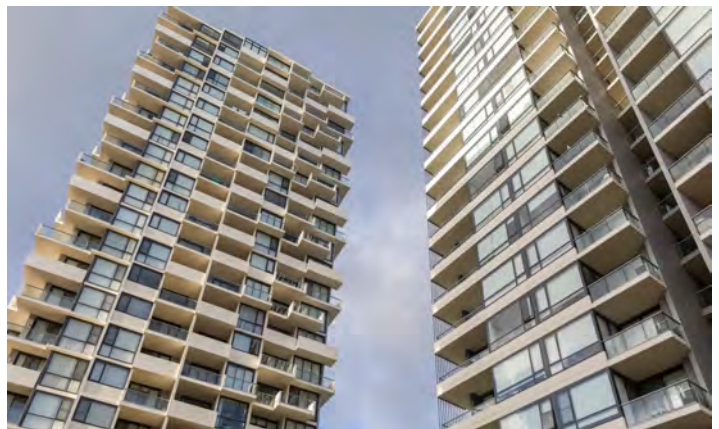
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How to quantify and specify carbon

Brandon Wray

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Director, Building Innovations
National Ready Mixed Concrete Assoc.



Questions?
Thank You!

