BUILDINGENERGY BOSTON

A Revolution in Embodied Carbon: Four Pivotal Materials

Jim D'Aloisio (Klepper, Hahn and Hyatt)
Jodi Smits Anderson (New Buildings Institute)

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Northeast Sustainable Energy Association (NESEA) | March 19, 2024

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Why Concrete, Glass, Steel, and Asphalt?

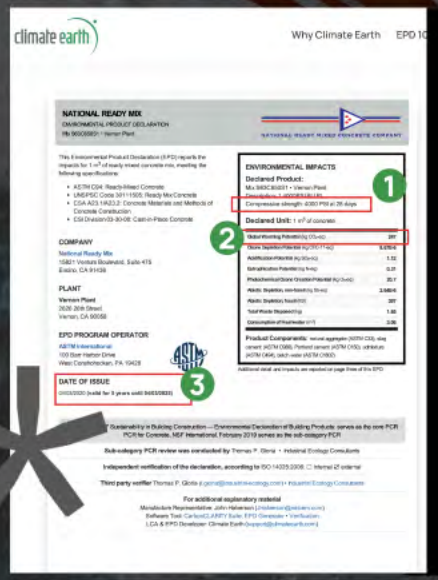
These are the most carbon-intensive building materials, and used in significant amounts.

Steel -
The steel industry produces about **3 billion metric tons** of CO2e per year. Arc furnaces in China averaged 3 tons of CO2e per ton of new steel. Globally 7.2 - 11% of emissions.

Concrete -
In 2022, cement emitted **1.6 billion metric tons** of CO2e, and the industry's impacts doubled from 2002-2021. Globally, 8% of emissions.

Glass -
In 2022 flat glass clocked in at over **95 million metric tons** of emissions for $100 billion of demand.

Asphalt -
~20 million metric tons in USA in 2019. 94% of roadways in USA are asphalt. Increasing RAP (reclaimed asphalt pavement) by 1% would reduce by .14 mmt)



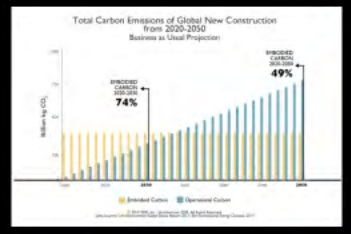
Simple shifts, NOW

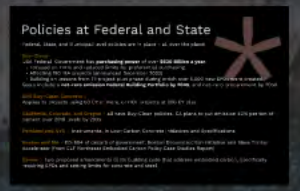
1) Compare Performance (should match)
2) Compare GWP
3) Check expiration date!
4) Confirm uncertainty of methodology (industry average or manufacturer, fuel sources, location?)
5) Compare Primary Sources (should match)

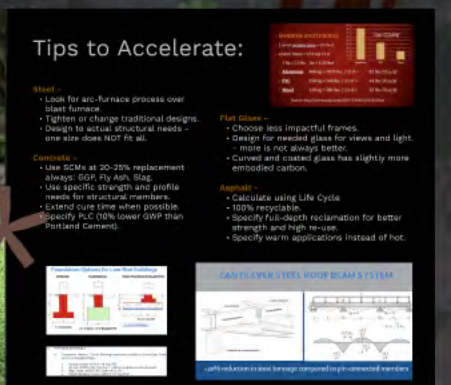
from climate earth

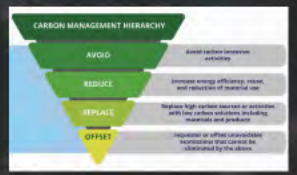
Also, EPDs are about MORE than GWP. Never stop learning!

Embodied Energy is AS IMPORTANT as Operational Energy regarding emissions.









Start by doing what is necessary, then what is possible, and suddenly you are doing the impossible.
St. Francis of Assisi

Thank you!

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Also Note

Soil excavation (yikes)

Finishes, especially with fast churn

Aluminum

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The **EPA** is working on a label program for Low Embodied Carbon (LEC) materials, starting with....

these fabulous four!

A $100 million investment.
Written comments accepted until March 18, 2024.

Phased approach, on-line registry, labeling, tiered rating system.

?

Example Building CO_2e from Structure

36 psf

30 psf

(-10) psf Incl. biogenic C

20 psf w/o biogenic C

Conventional Construction

Incremental Changes

Transformative Changes

An Example - 100,000 sf "typical" mixed use building.

100,000 sf, 10-Story Mixed-Use Building
Conventional Construction – structure only`

MATERIAL							lbs. CO2e/lb.	lbs. CO2e	
20 ga. steel roof decking	10,000	sf	2.2	psf	22,000	lbs.	2.61	57,420	
Open-web steel roof joists	10,000	sf	2.7	psf	27,000	lbs.	1.52	41,040	
Structural steel framing (incl. shear conn's)	100,000	sf	8.7	psf	870,000	lbs.	1.38	1,200,600	
Composite steel floor decking	90,000	sf	2.3	psf	207,000	lbs.	2.61	540,270	
Cold-formed steel wall studs	150,000	sf	0.4	psf	60,000	lbs.	2.53	151,800	
Shear walls, 80 lf, 12"t, 4000 psi	9,600	sf	356	cy	1,386,667	lbs.	0.23	318,933	
2-10th fl. conc - 3.5" eff. t, 4000 psi	90,000	sf	972	cy	3,791,667	lbs.	0.23	872,083	
1st floor conc slab - 5" 4000 psi	10,000	sf	154	cy	601,852	lbs.	0.23	138,426	
Strip ftgs, fd'n walls, 4000 psi	2,704	sf	160	cy	623,362	lbs.	0.23	143,373	
Int. ft'gs, piers 12 x 8'x8'x18", 4000 psi	768		51	cy	199,680	lbs.	0.23	45,926	
Steel rebar, assume 0.7% conc vol.	2.6	cy	69	cf	34,733	lbs.	0.94	32,649	
								3,542,522	lbs. CO_2e
								35.43	psf

100,000 sf, 10-Story Mixed-Use Building
EZPZ Incremental – structure only

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Structural steel framing (19% optimized)	100,000	sf	7.9	psf	790,000	lbs.	1.38	1,090,200	
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Shear walls, 80 lf, 12"t, 4000 psi, 20% fly ash	9,600	sf	356	cy	1,386,667	lbs.	0.19	263,467	
2-10th fl. conc - 3.5" eff. t, 3000 psi, 20% fly ash	90,000	sf	972	cy	3,791,667	lbs.	0.16	606,667	
1st floor conc slab - 4" 3000 psi, 20% fly ash	10,000	sf	123	cy	481,481	lbs.	0.16	77,037	
Strip ftgs, FPSF fd'n walls, 3500 psi, 20% fly ash	1,664	sf	82	cy	319,673	lbs.	0.17	54,344	
Int. ft'gs, 12 x 8'x8'x18", 3500 psi, 20% fly ash	768	sf	43	cy	166,400	lbs.	0.17	28,288	
Steel rebar, assume 0.7% conc vol.	8.5	cy	231	cf	116,012	lbs.	0.94	109,051	
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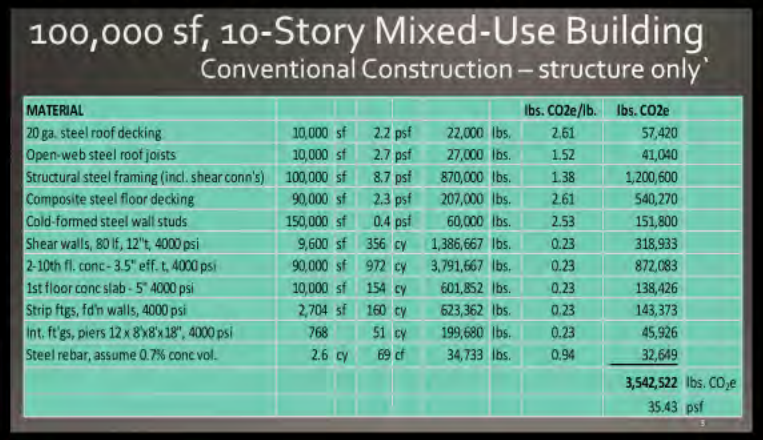

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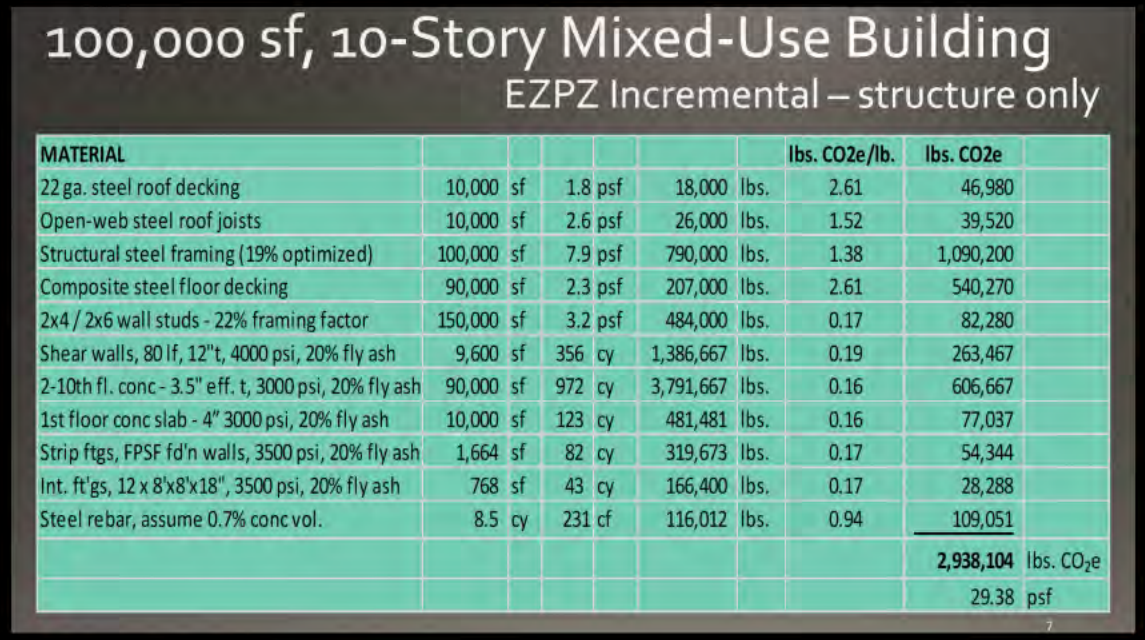

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100,000 sf, 10-Story Mixed-Use Building

Transformative – structure only

MATERIAL							lbs. CO2e/lb.	lbs. CO2e	
5-ply CLT (6 7/8") roof and floor decking	100,000	sf	17.8	psf	1,776,042	lbs.	0.28	497,292	
7-ply CLT (9 5/8) wall panels 20% WWR	39,936	sf	24.9	psf	992,992	lbs.	0.28	278,038	
Glulam roof and floor beams - 5 1/2" x 14"	12,000	lf	20.9	plf	250,250	lbs.	0.37	92,593	
Glulam columns - est. 12 int, avg. 5 1/2" X 16"	1,440	lf	22.2	plf	31,964		0.37	11,827	
Steel composite floor ties	90,000	sf	1.2	psf	108,000		2.53	273,240	
Steel conn hardware for glulam, 10 lbs. ea.	1,680	pcs	10	lbs.	16,800		1.62	27,216	
2-10th fl. conc - 2" t, 3000 psi, 30% slag	90,000	sf	556	cy	2,166,667	lbs.	0.12	260,000	
Shear walls, 80 lf, 12"t, 4000 psi, 30% slag	9,600	sf	356	cy	1,386,667	lbs.	0.19	263,467	
1st floor conc slab - 4" 2500 psi, 30% slag	10,000	sf	123	cy	481,481	lbs.	0.11	52,963	
Strip ftgs, FPSF fd'n walls, 3500 psi, 30% slag	2,704	sf	133	cy	519,468	lbs.	0.13	67,531	
Int. ft'gs, optimized 3500 psi, 30% slag	768	sf	34	cy	133,120	lbs.	0.13	17,306	
Steel rebar, assume 0.7% conc vol.	8.4	cy	227	cf	114,261	lbs.	0.94	107,405	
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Transformational!!

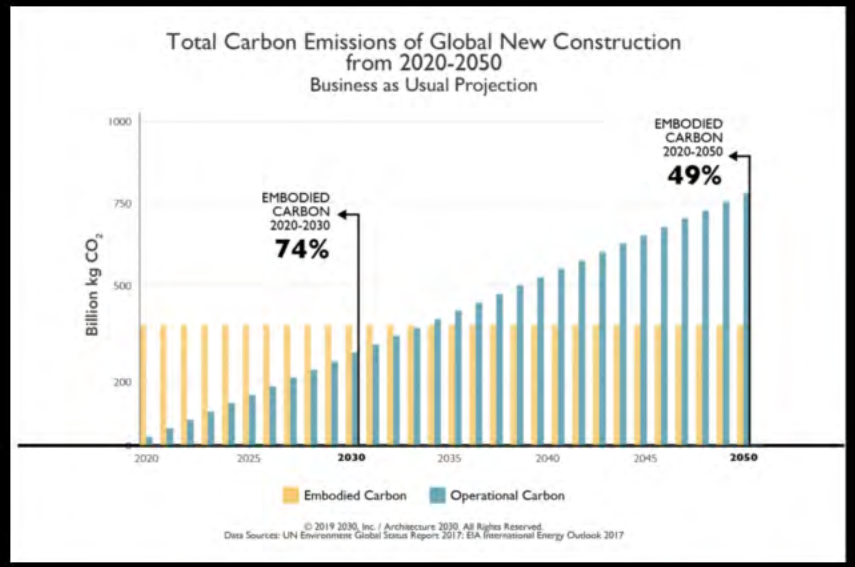
Still using steel and concrete, but in more deliberate and essentialized approaches.

Grown materials are gaining prominence.

Down to under 20 pounds CO2e psf even without calculating the biogenic storage.

We have the power!

Embodied Energy is AS IMPORTANT as Operational Energy regarding emissions.



Policies at Federal and State

Federal, State, and Municipal-level policies are in place - all over the place!

Buy-Clean -
USA Federal Government has **purchasing power** of over **$630 Billion a year**.
- Focused on EPDs and reduced limits for preferential purchasing.
- Affecting 150 IRA projects (announced December 2023)
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Goals include a **net-zero emission Federal Building Portfolio by 2045**, and net-zero procurement by 2050

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Applies to projects using 50 CY or more, or DOT projects at 300 CY plus

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All Over the Place -

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CLF Carbon Leadership Forum

Embodied Carbon Policy Toolkit

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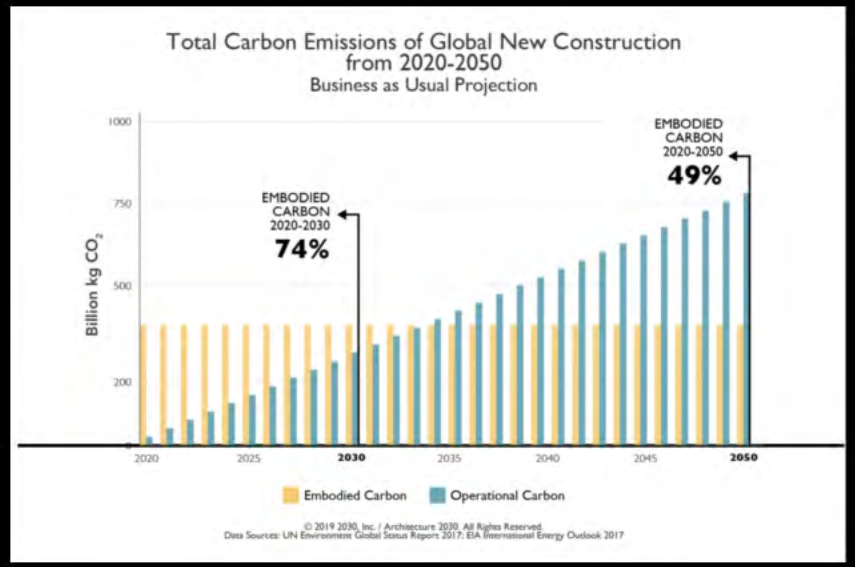

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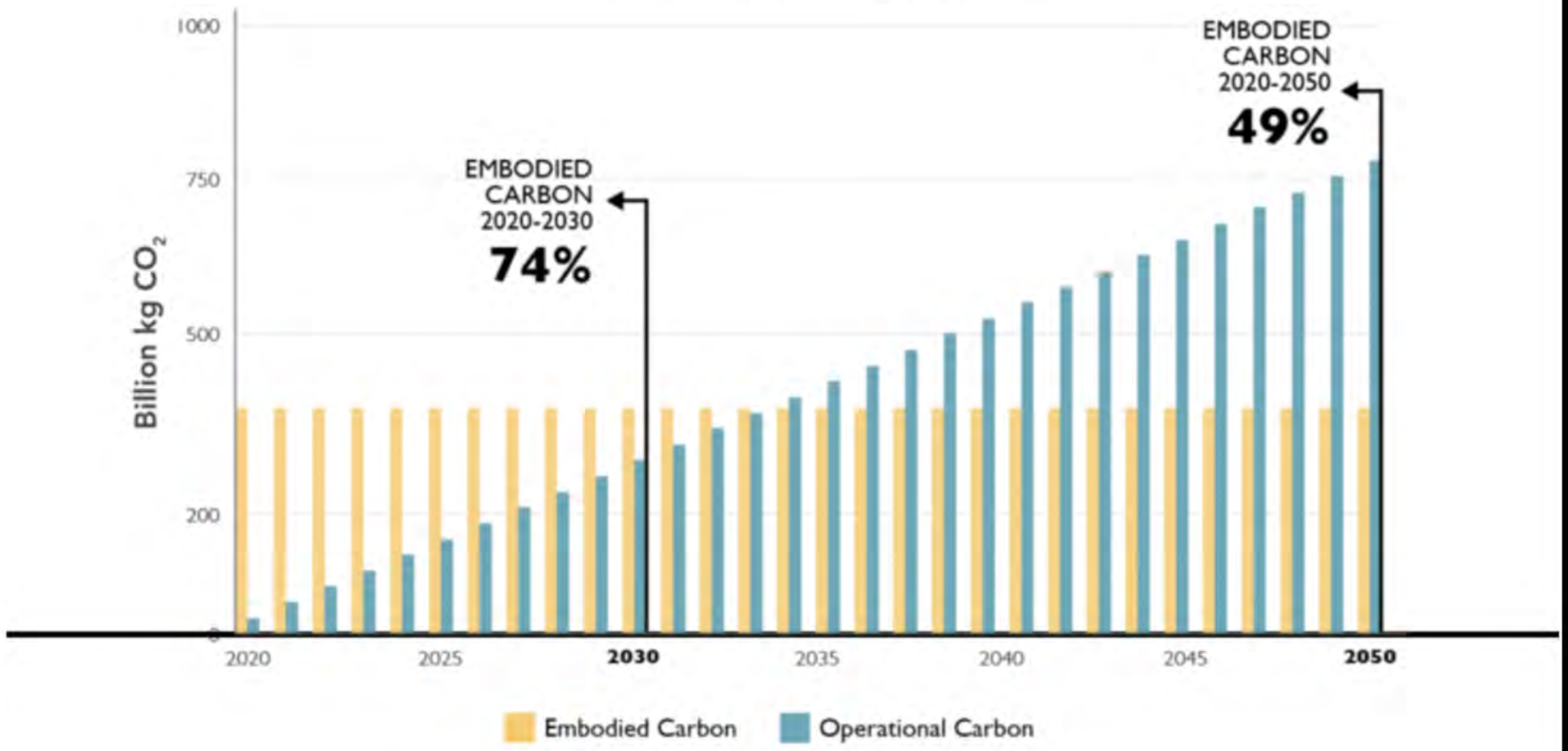
Total Carbon Emissions of Global New Construction from 2020-2050

Business as Usual Projection



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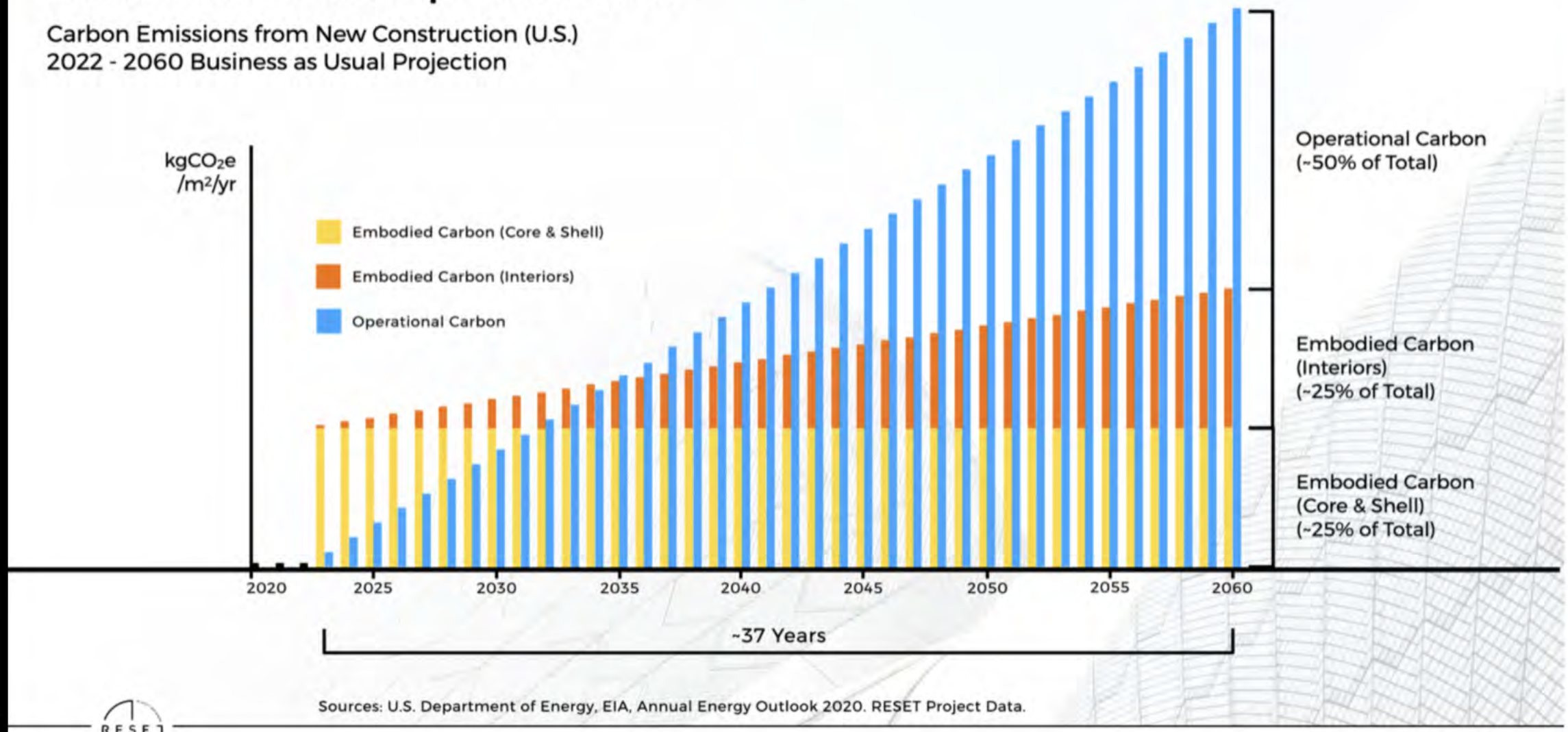
Data Sources: UN Environment Global Status Report 2017; EIA International Energy Outlook 2017

Embodied vs. Operational

Carbon Emissions from New Construction (U.S.)
2022 - 2060 Business as Usual Projection



Sources: U.S. Department of Energy, EIA, Annual Energy Outlook 2020. RESET Project Data.

GIGA © 2022

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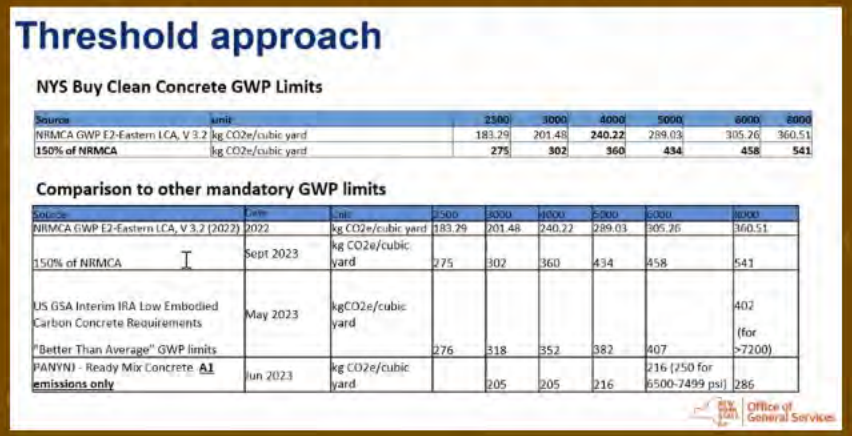
NYS Jan 2025 - Mandatory documentation on GWP of concrete used.



Threshold approach

NYS Buy Clean Concrete GWP Limits

Source	unit	2500	3000	4000	5000	6000	8000
NRMCA GWP E2-Eastern LCA, V 3.2	kg CO2e/cubic yard	183.29	201.48	**240.22**	289.03	305.26	360.51
150% of NRMCA	kg CO2e/cubic yard	**275**	**302**	**360**	**434**	**458**	**541**

Comparison to other mandatory GWP limits

Source	Date	Unit	2500	3000	4000	5000	6000	8000
NRMCA GWP E2-Eastern LCA, V 3.2 (2022)	2022	kg CO2e/cubic yard	183.29	201.48	240.22	289.03	305.26	360.51
150% of NRMCA	Sept 2023	kg CO2e/cubic yard	275	302	360	434	458	541
US GSA Interim IRA Low Embodied Carbon Concrete Requirements "Better Than Average" GWP limits	May 2023	kgCO2e/cubic yard	276	318	352	382	407	402 (for >7200)
PANYNJ - Ready Mix Concrete **A1 emissions only**	Jun 2023	kg CO2e/cubic yard		205	205	216	216 (250 for 6500-7499 psi)	286

Office of General Services

Phase 1 - Voluntary limits + EPDs from Jan 2024
Phase 2 - Mandatory for both from Jan 2025
Phase 3 - Revised mandatory limits from Jan 2027

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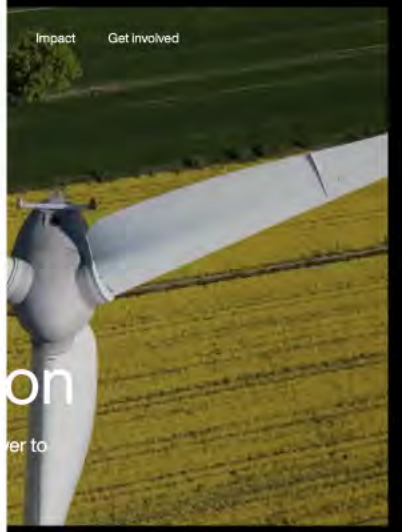
licy Toolkit

ASHRAE/ICC 240P

Purpose: The purpose of this standard is to provide a methodology to quantify and document greenhouse gas emissions associated with buildings, building systems, and building equipment and their sites over their life cycle.

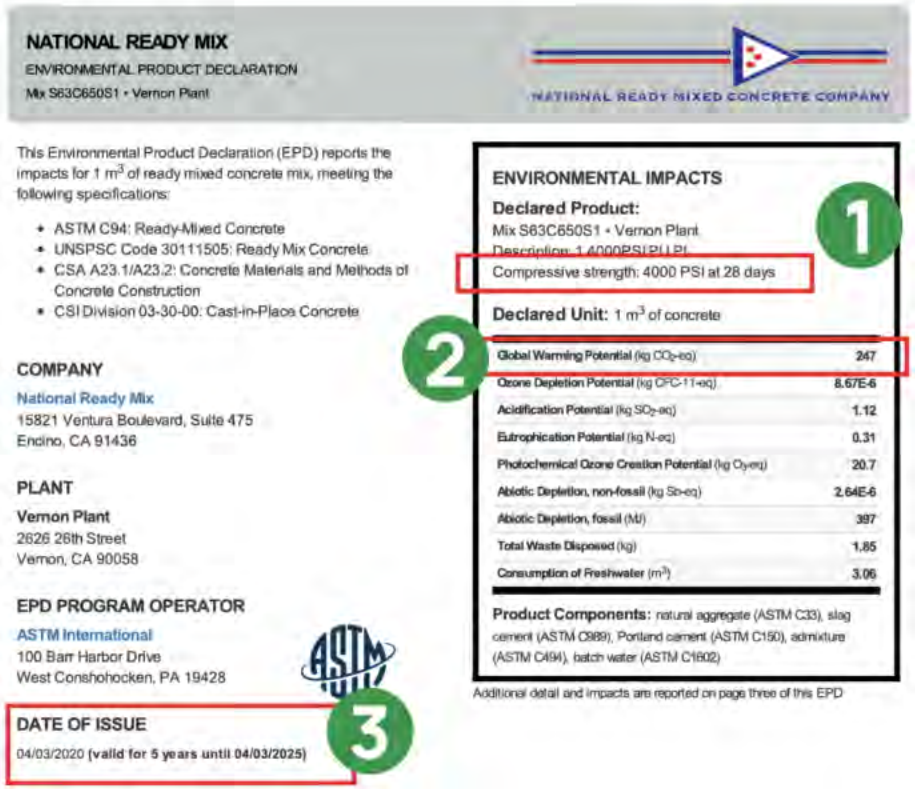
SEI PreStandard

Purpose: The purpose of <this Prestandard> is to establish a standard of practice for assessing the embodied carbon of structural systems and making comparisons between structural systems. As components of a building or similar structure.



climate earth

Why Climate Earth EPD 10



NATIONAL READY MIX

ENVIRONMENTAL PRODUCT DECLARATION

Mix S63C650S1 • Vernon Plant

NATIONAL READY MIXED CONCRETE COMPANY

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

National Ready Mix
15821 Ventura Boulevard, Suite 475
Encino, CA 91436

PLANT

Vernon Plant
2626 26th Street
Vernon, CA 90058

EPD PROGRAM OPERATOR

ASTM International
100 Barr Harbor Drive
West Conshohocken, PA 19428

DATE OF ISSUE

04/03/2020 **(valid for 5 years until 04/03/2025)**

ENVIRONMENTAL IMPACTS

Declared Product:
Mix S63C650S1 • Vernon Plant
Description: 4,000PSI PLUPL
Compressive strength: 4000 PSI at 28 days

Declared Unit: 1 m^3 of concrete

Global Warming Potential (kg CO_2-eq)	247
Ozone Depletion Potential (kg CFC-11-eq)	8.67E-6
Acidification Potential (kg SO_2-eq)	1.12
Eutrophication Potential (kg N-eq)	0.31
Photochemical Ozone Creation Potential (kg O_3-eq)	20.7
Abiotic Depletion, non-fossil (kg Sb-eq)	2.64E-6
Abiotic Depletion, fossil (MJ)	397
Total Waste Disposed (kg)	1.85
Consumption of Freshwater (m^3)	3.06

Product Components: natural aggregate (ASTM C33), slag cement (ASTM C989), Portland cement (ASTM C150), admixture (ASTM C494), batch water (ASTM C1602)

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

1

2

3

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

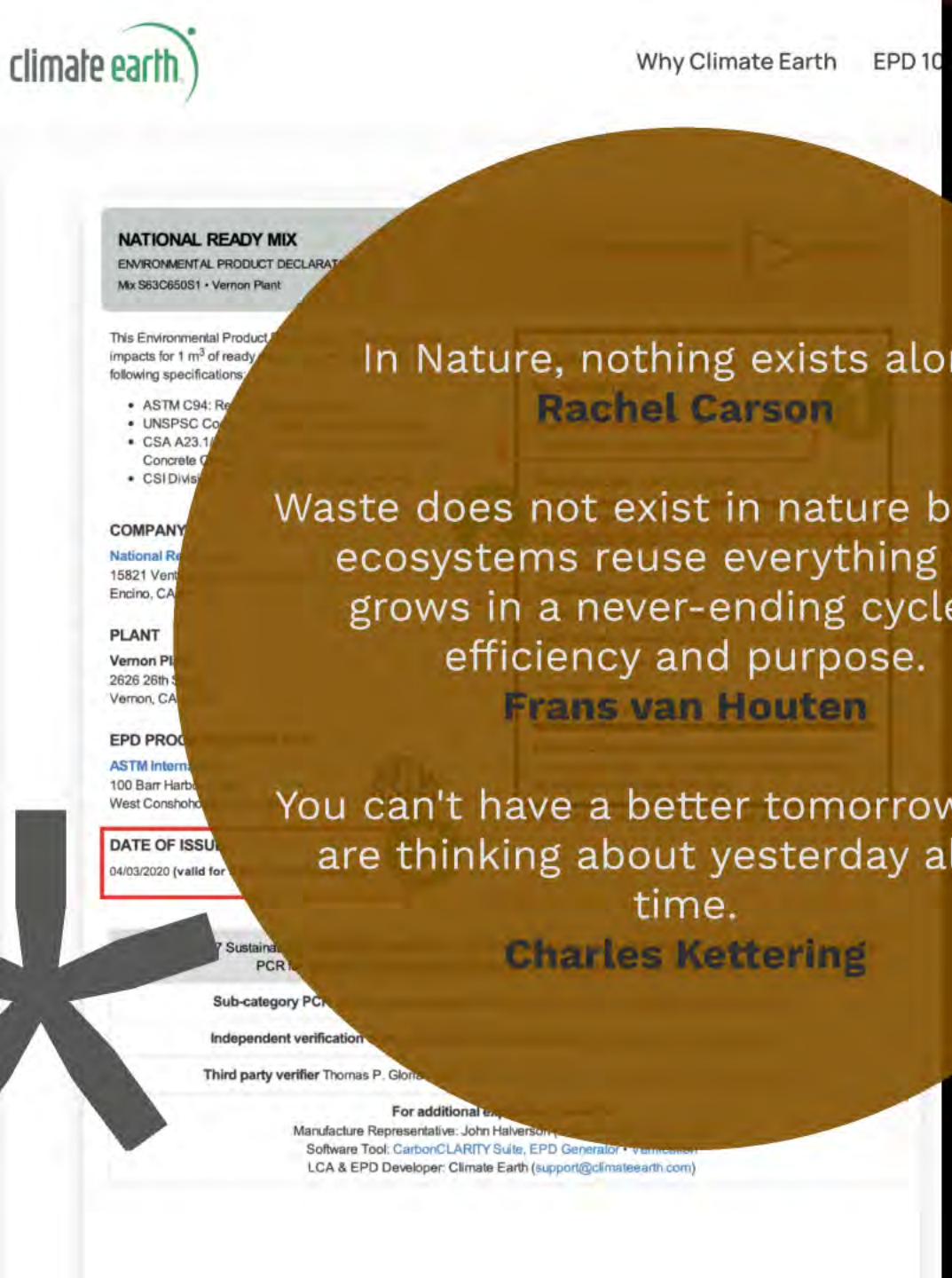
For additional explanatory material
Manufacture Representative: John Halverson (JHalverson@natcem.com)
Software Tool: CarbonCLARITY Suite, EPD Generator • Verification
LCA & EPD Developer: Climate Earth (support@climateearth.com)

Simple shifts, NOW

1) Compare Performance (should match)
2) Compare GWP
3) Check expiration date!
4) Confirm uncertainty of methodology (industry average or manufacturer, fuel sources, location?)
5) Compare Primary Sources (should match)

from climate earth

Also, EPDs are about MORE than GWP.
Never stop learning!



In Nature, nothing exists alone.
Rachel Carson

Waste does not exist in nature because ecosystems reuse everything that grows in a never-ending cycle of efficiency and purpose.
Frans van Houten

You can't have a better tomorrow if you are thinking about yesterday all the time.
Charles Kettering

Simple shifts, NOW

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Tips to Accelerate:

Steel -
- Look for arc-furnace process over blast furnace.
- Tighten or change traditional designs.
- Design to actual structural needs - one size does NOT fit all.

Concrete -
- Use SCMs at 20-25% replacement always: GGP, Fly Ash, Slag.
- Use specific strength and profile needs for structural members.
- Extend cure time when possible.
- Specify PLC (10% lower GWP than Portland Cement).

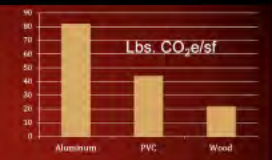
Move from steel studs to wood studs -
- A steel stud is 400 times as thermally conductive as a wood stud.
- A steel stud has 12 times the embodied carbon as a wood stud!

WINDOW FOOTPRINTS

1 m^2 of window pane = 10.76 sf

add for frame = 12.9 say 13 sf

1 kg = 2.2 lbs. 1m = 3.28 feet

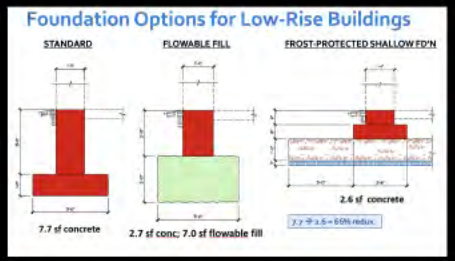


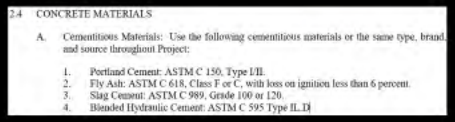
- **Aluminum** 486 kg = 1070 lbs. /13 sf = 82 lbs. CO_2e/sf
- **PVC** 258 kg = 568 lbs. / 13 sf = 44 lbs. CO_2e/sf
- **Wood** 130 kg = 286 lbs. / 13 sf = 22 lbs. CO_2e/sf

Source: http://www.mdpi.com/2075-5309/2/4/542/htm

Flat Glass -
- Choose less impactful frames.
- Design for needed glass for views and light. - more is not always better.
- Curved and coated glass has slightly more embodied carbon.

Asphalt -
- Calculate using Life Cycle
- 100% recyclable.
- Specify full-depth reclamation for better strength and high re-use.
- Specify warm applications instead of hot.




2.4 CONCRETE MATERIALS

A. Cementitious Materials: Use the following cementitious materials of the same type, brand, and source throughout Project:

1. Portland Cement: ASTM C 150, Type I/II.
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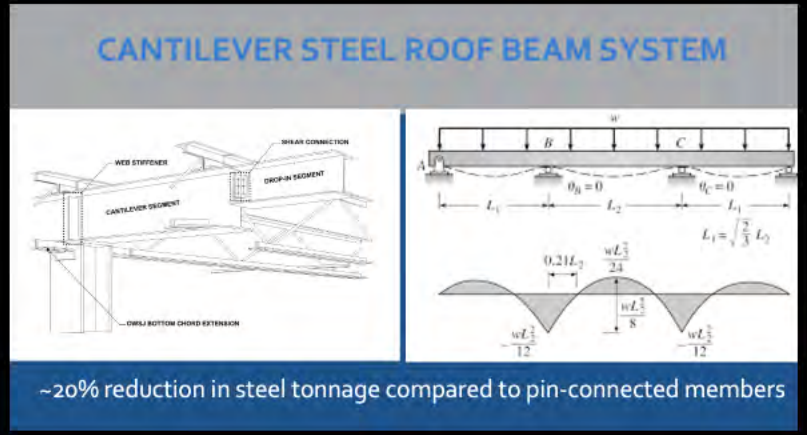
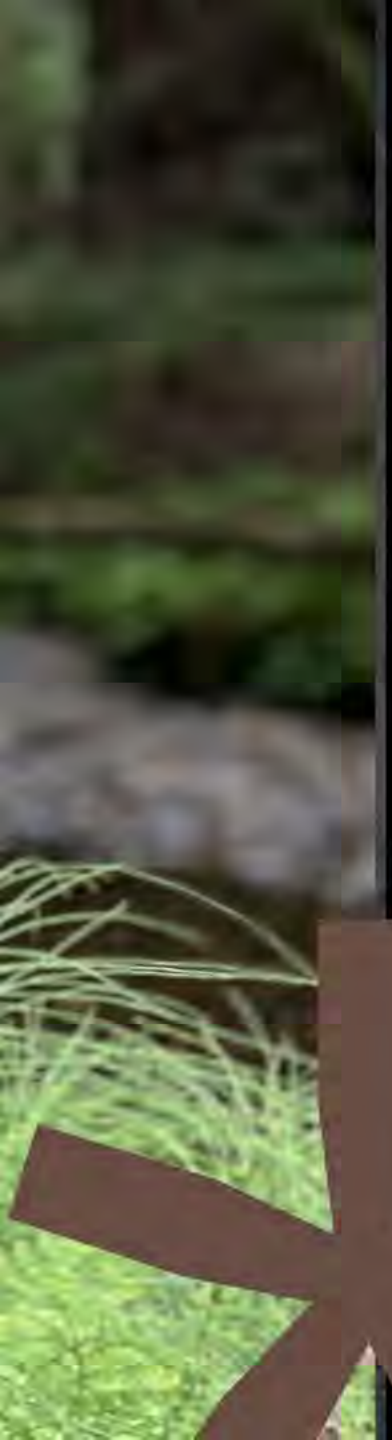


~20% reduction in steel tonnage compared to pin-connected members



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Flat Glass -

- Choose
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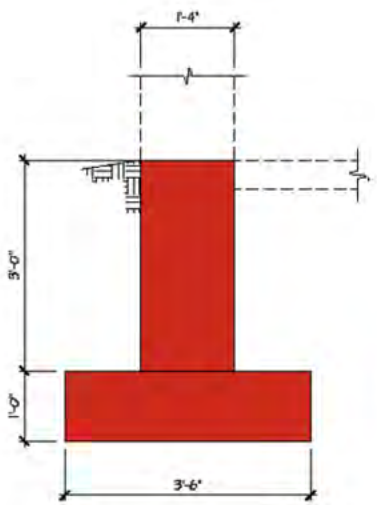
  - more i
- Curved a
  embodie

Asphalt -

- Calculat
- 100% re
- Specify
  strength
- Specify

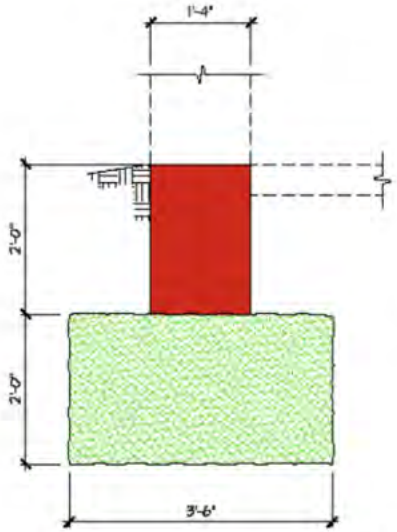
Foundation Options for Low-Rise Buildings

STANDARD



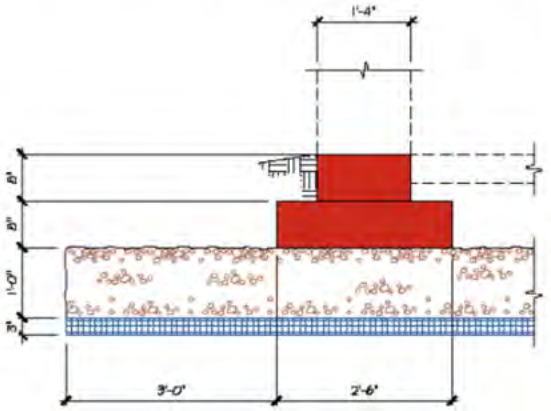
7.7 sf concrete

FLOWABLE FILL



2.7 sf conc; 7.0 sf flowable fill

FROST-PROTECTED SHALLOW FD'N



2.6 sf concrete

7.7 → 2.6 = 66% redux

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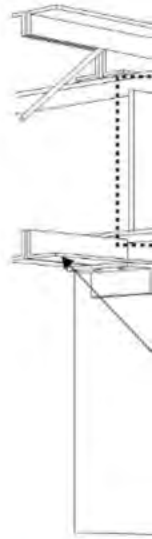
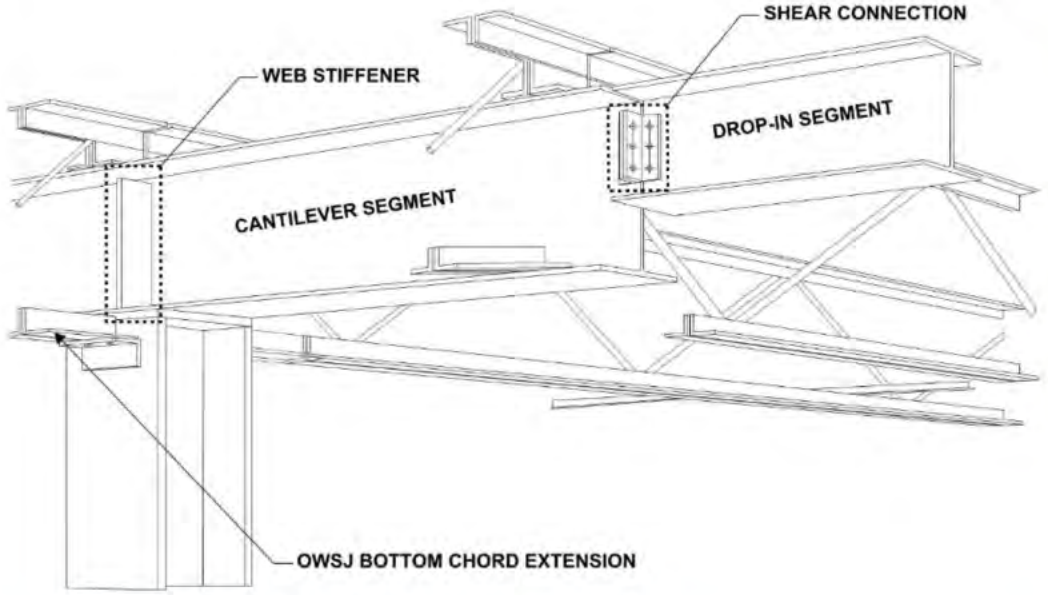
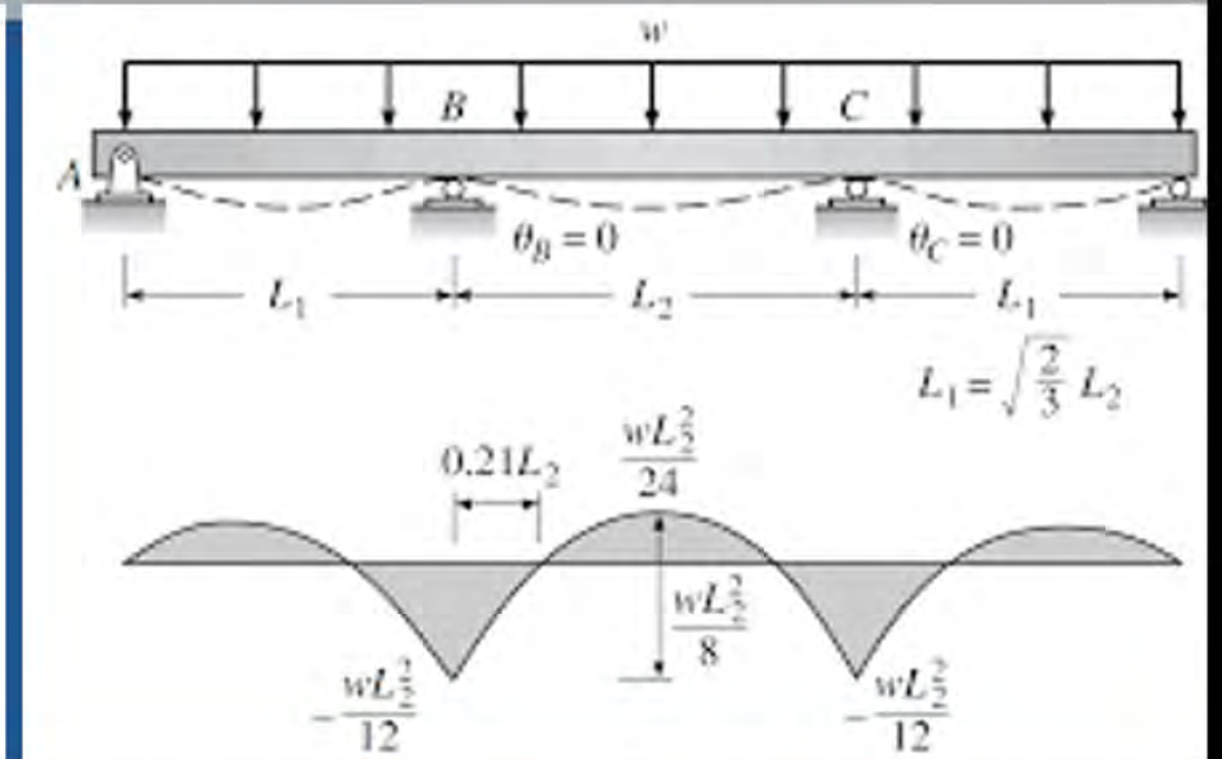


~20

CANTILEVER STEEL ROOF BEAM SYSTEM





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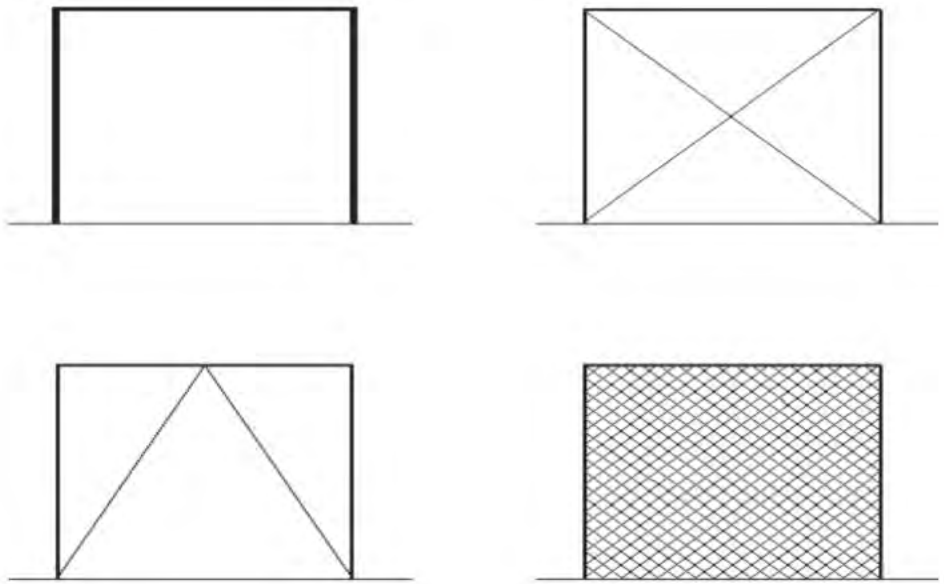
STEEL LATERAL BRACING SYSTEMS

Steel Moment Frames require more steel material per service unit than braced frames.

Braced Frames can be designed in a variety of configurations.

Consider Hybrid Masonry/Steel Frames.



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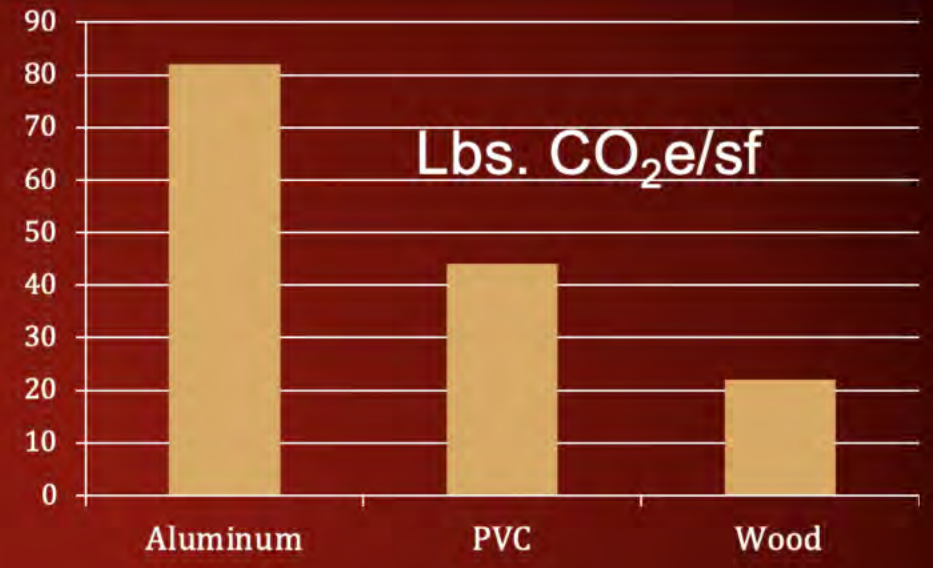

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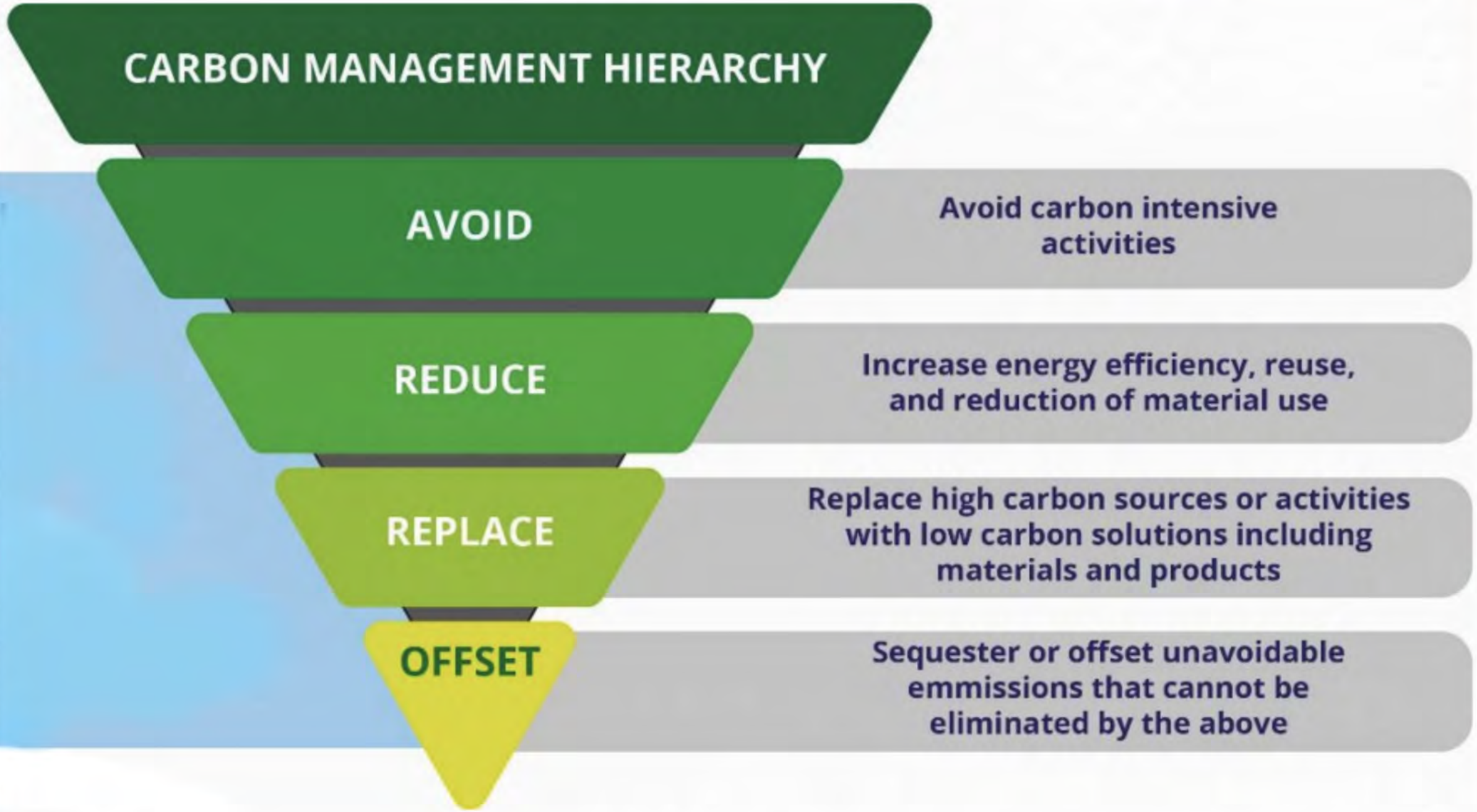
CARBON MANAGEMENT HIERARCHY
AVOID
Avoid carbon intensive activities
REDUCE
Increase energy efficiency, reuse, and reduction of material use
REPLACE
Replace high carbon sources or activities with low carbon solutions including materials and products
OFFSET
Sequester or offset unavoidable emmissions that cannot be eliminated by the above

Start by doing what is necessary, then what is possible, and suddenly you are doing the impossible.

St. Francis of Assisi

Thank you!

Jodi Smits Anderson, FAIA
New Buildings Institute
jodi@newbuildings.org
518-229-3215

Jim D'Aloisio, PE, Principal
Klepper, Hahn & Hyatt
JAD@khhpc.com
315-446-9201

nbi new buildings institute

Klepper, Hahn & Hyatt
STRUCTURAL ENGINEERING
LANDSCAPE ARCHITECTURE
BUILDING ENVELOPE SYSTEMS

Start by doing what is necessary, then what is possible, and suddenly you are doing the impossible.

100,000 sf, 10-Story Mixed-Use Building

Transformative – structure only

INCLUDING BIOGENIC CARBON and END-OF-LIFE IMPACTS

MATERIAL							lbs. CO2e/lb.	lbs. CO2e	
5-ply CLT (6 7/8") roof and floor decking	100,000	sf	17.8	psf	1,776,042	lbs.	-0.67	(1,189,948)	
7-ply CLT (9 5/8) wall panels 20% WWR	39,936	sf	24.9	psf	992,992	lbs.	-0.67	(665,305)	
Glulam roof and floor beams - 5 1/2" x 14"	12,000	lf	20.9	plf	250,250	lbs.	-0.72	(180,180)	
Glulam columns - est. 12 int, avg. 5 1/2" X 16"	1,440	lf	22.2	plf	31,964		-0.72	(23,014)	
Steel composite floor ties	90,000	sf	1.2	psf	108,000		2.53	273,240	
Steel conn hardware for glulam, 10 lbs. ea.	1,680	pcs	10	lbs.	16,800		1.62	27,216	
2-10th fl. conc - 2" t, 3000 psi, 50% SCM	90,000	sf	556	cy	2,166,667	lbs.	0.12	260,000	
Shear walls, 80 lf, 12"t, 4000 psi, 50% SCM	9,600	sf	356	cy	1,386,667	lbs.	0.19	263,467	
1st floor conc slab - 4" 2500 psi, 50% SCM	10,000	sf	123	cy	481,481	lbs.	0.11	52,963	
Strip ftgs, FPSF fd'n walls, 3500 psi, 50% SCM	2,704	sf	133	cy	519,468	lbs.	0.13	67,531	
Int. ft'gs, optimized 3500 psi, 50% SCM	768	sf	34	cy	133,120	lbs.	0.13	17,306	
Steel rebar, assume 0.7% conc vol.	8.4	cy	227	cf	114,261	lbs.	0.94	107,405	
								(989,320)	lbs. CO_2e
								(9.89)	psf

Start by doing what is necessary, then what is possible, and suddenly you are doing the impossible.

St. Francis of Assisi

Thank you!

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