NET-ZERO EMBODIED CARBON STRUCTURES: *THE SE 2050 COMMITMENT*

Michael C. Gryniuk, P.E.
Principal, LeMessurier
Chair, SE 2050
mgryniuk@lemessurier.com

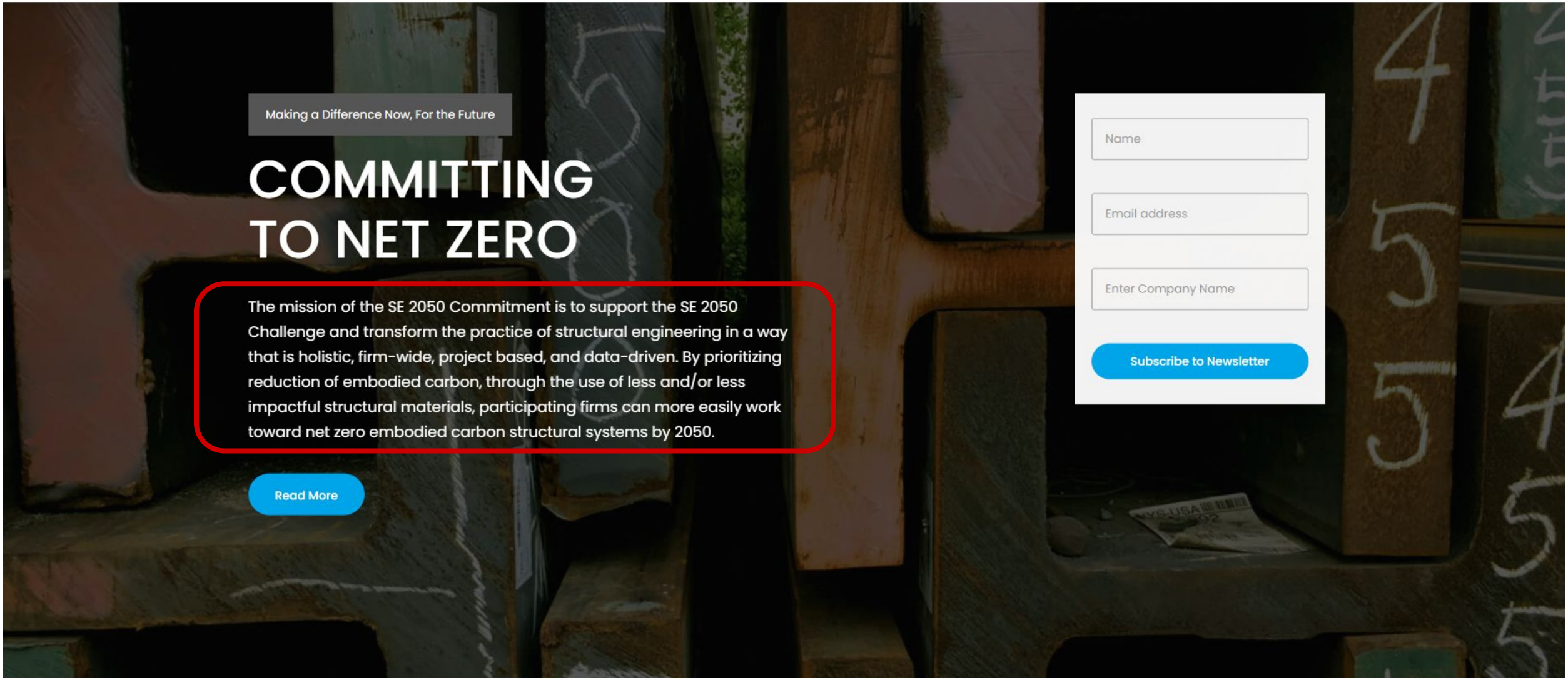
v. 22.00

SEI ASCE STRUCTURAL ENGINEERING INSTITUTE

SE2050 COMMITTING TO NET ZERO

Firms Committed	2022 Goal
~~73~~	200

*Program Launched November, 2020



www.SE2050.org

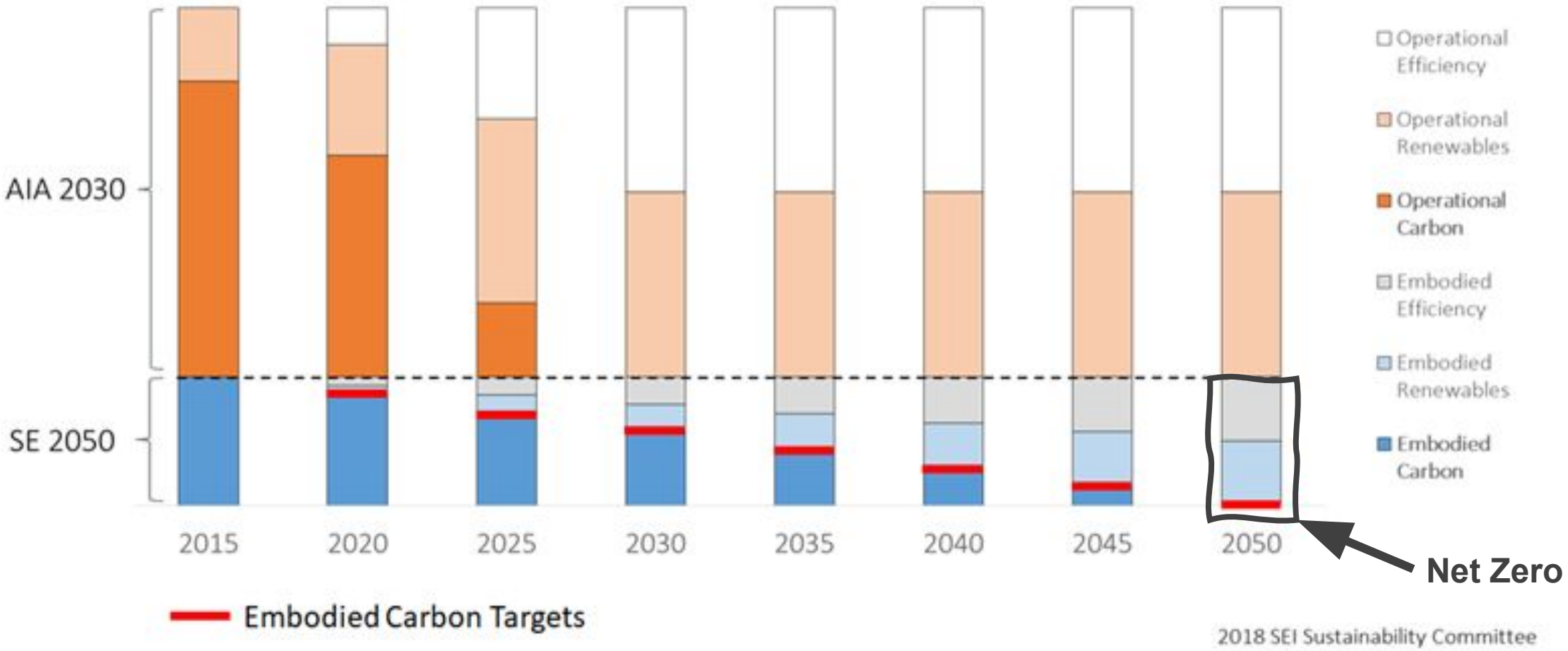
Summer 2019

SE 2050 *Challenge*

“All structural engineers shall understand, reduce and ultimately eliminate embodied carbon in their projects by 2050”

December 2019

SE 2050 + AIA 2030



2018 SEI Sustainability Committee

“Can you include some language in your proposal for embodied carbon?”

“Do you know what embodied carbon is?”

“Does everything have to be timber now?”

“How much embodied carbon in a ‘typical’ floor frame?”

“Will our design be impacted?”

“Isn’t this going to impact my schedule?”

“…[confused look]…”

“How much will this cost?”

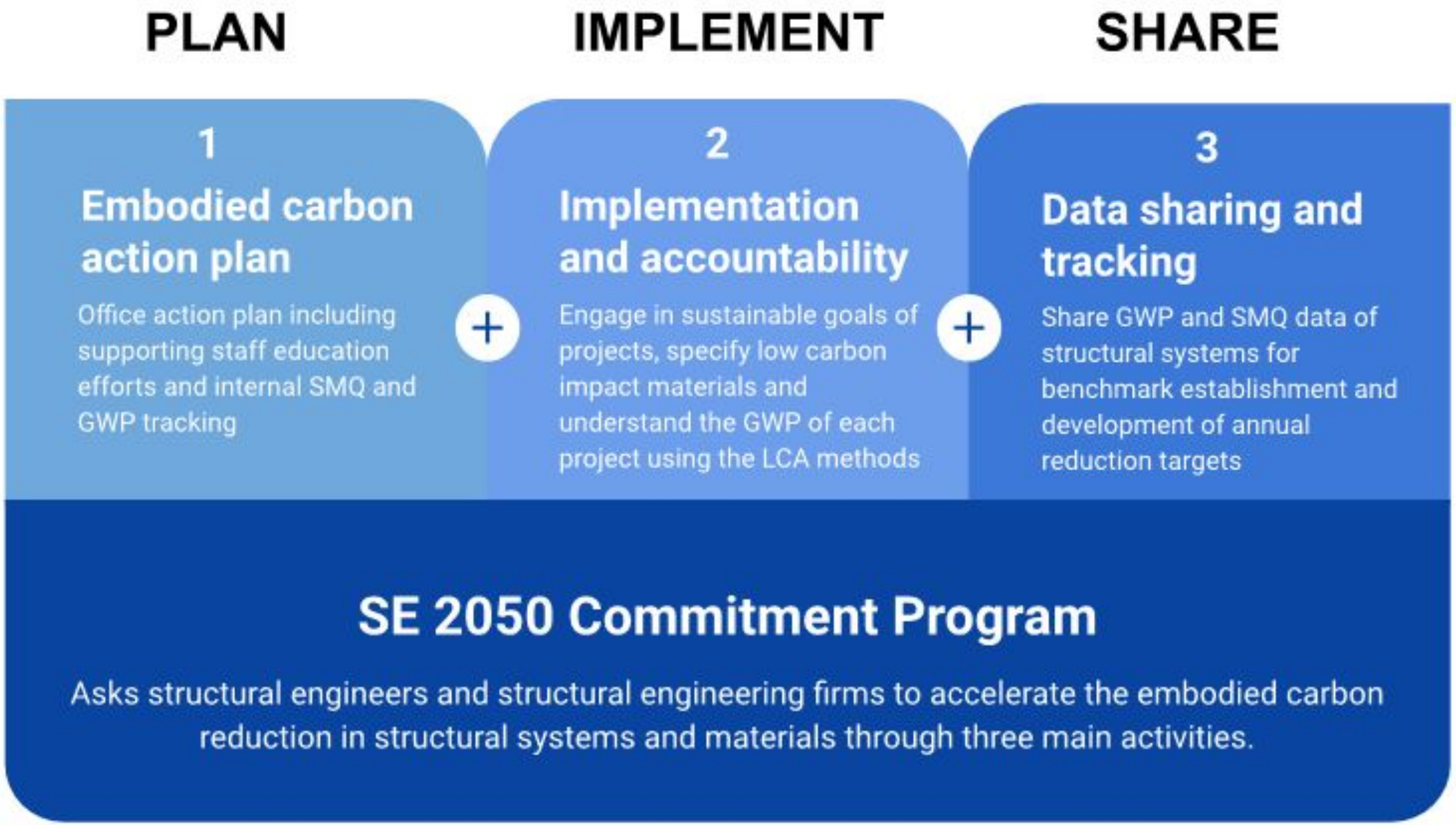
“What’s the best way to reduce embodied carbon on this project?”

“Do these embodied carbon numbers look right?”

“There’s NO WAY you can get to zero by 2050”

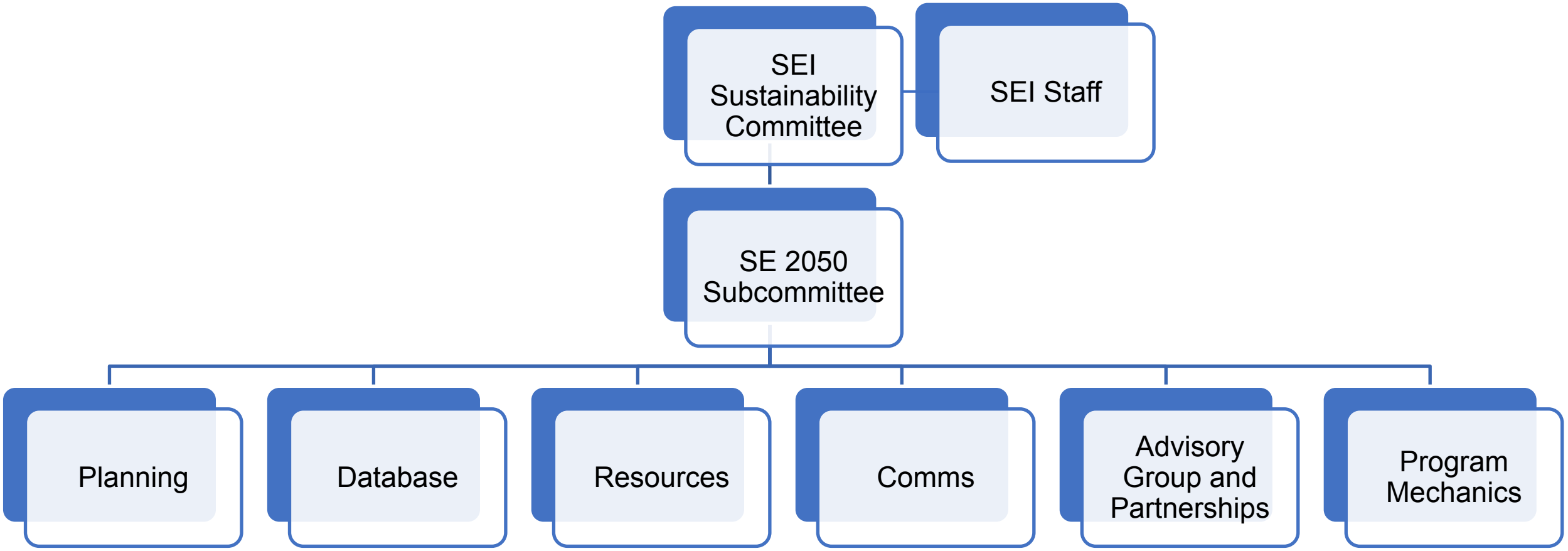
“Is that just about adding more fly ash to the mix?”

SEI ASCE STRUCTURAL ENGINEERING INSTITUTE | SE2050 COMMITTING TO NET ZERO

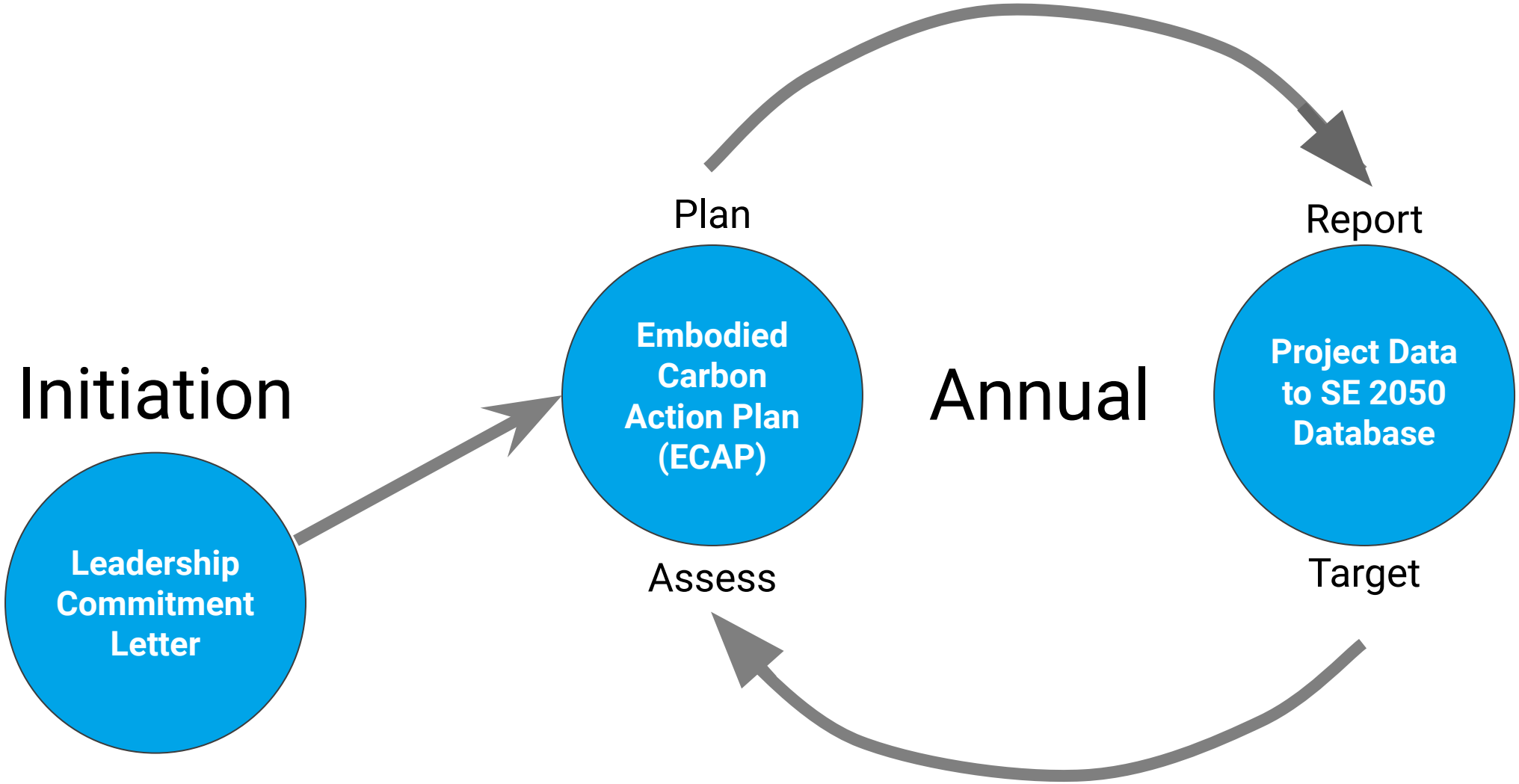


Education, advocacy, accountability, firm culture

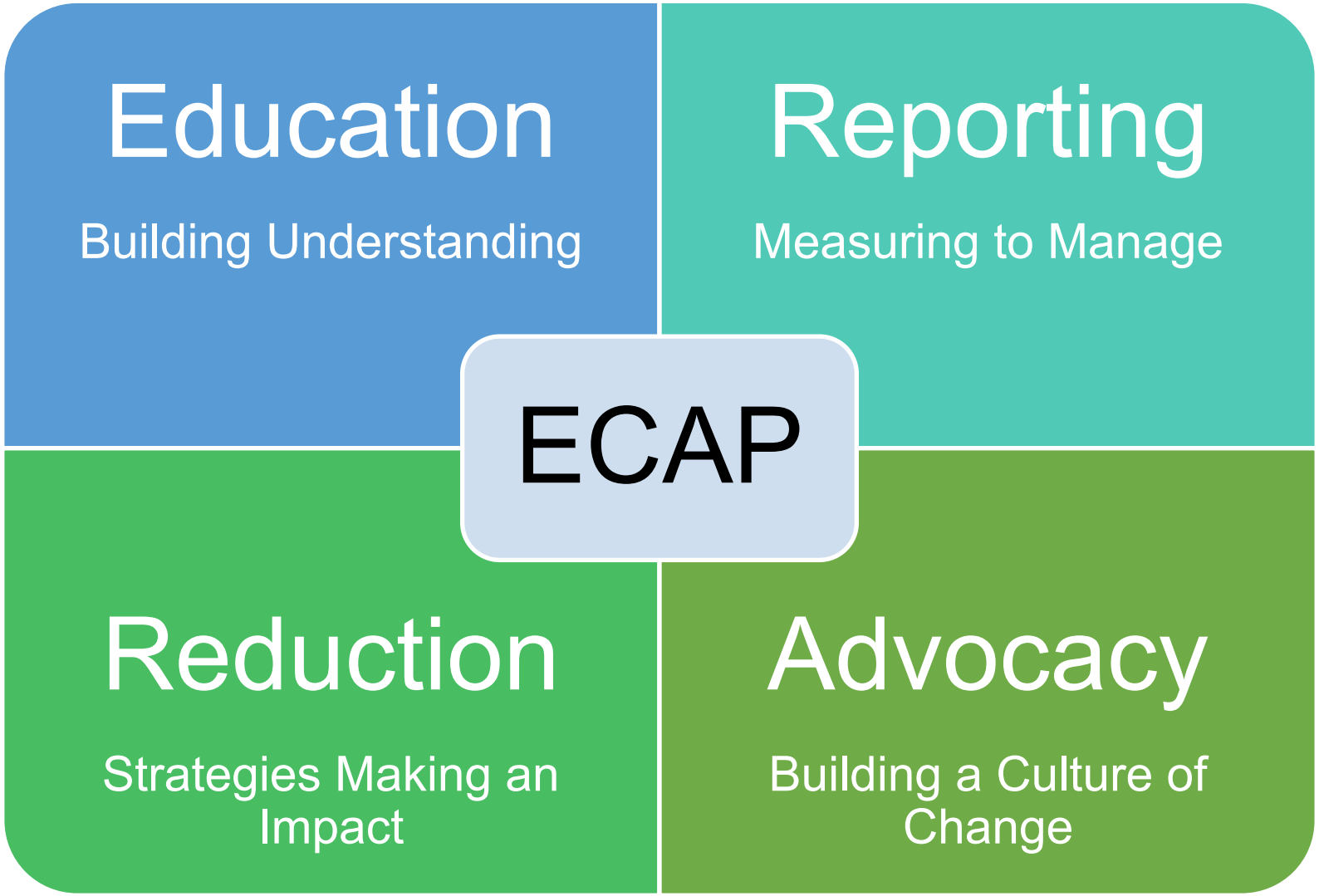
Volunteer Management Structure



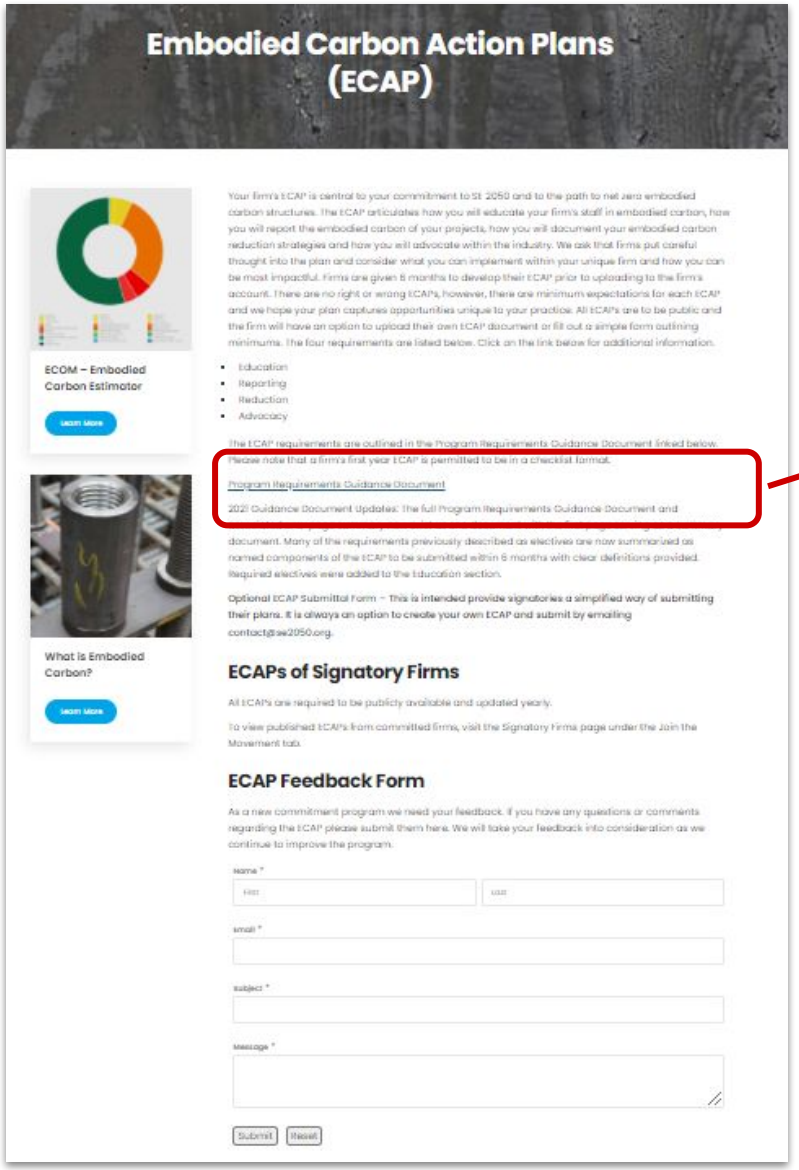
Program Mechanics - How it works

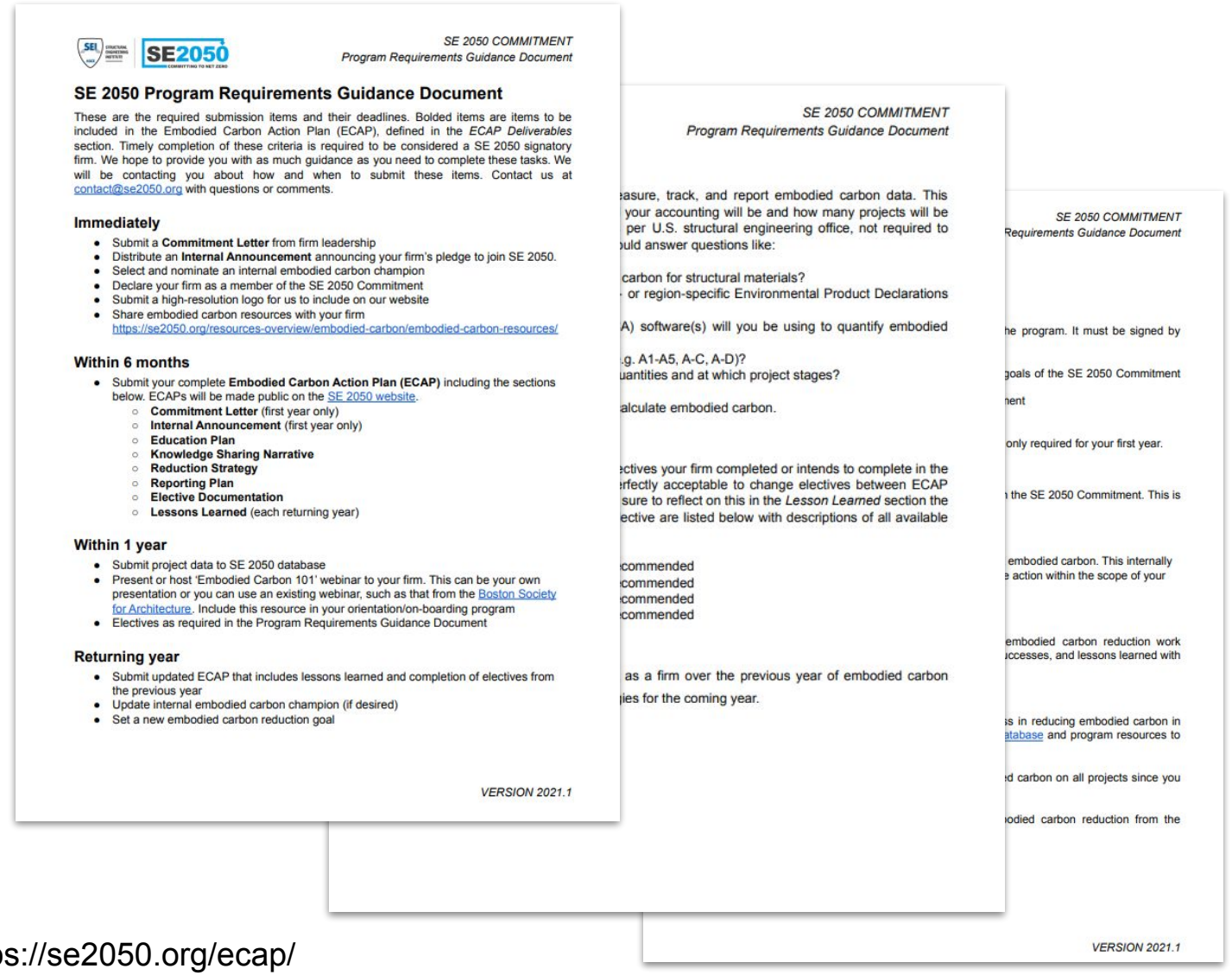


Embodied Carbon Action Plan (ECAP)



Program Mechanics - How it works





https://se2050.org/ecap/

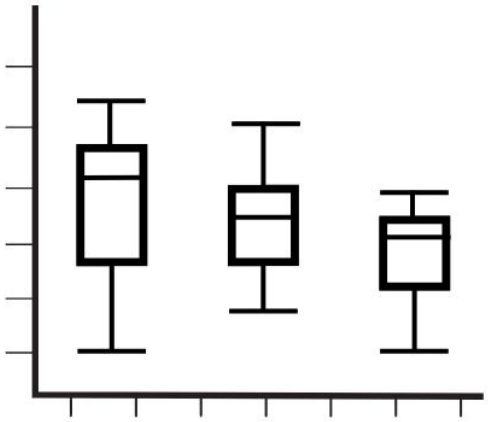
ECAP - Education

- Designate Firmwide Embodied Carbon Champion
- Narrative of Education Plan
- Embodied Carbon 101 Presentation/Webinar

ECAP - Reporting

- Initial Reporting Minimums to Database

  2x number of firm offices
  but not more than
  5 Projects



ECAP - Reduction Strategies

- Set a Goal and Report on Progress
- Discuss what strategies worked, and what didn’t

ECAP - Advocacy

- Share your commitment
- Educate clients
- Engage in groups like CLF

CLF Carbon Leadership Forum

ECAP - Accountability

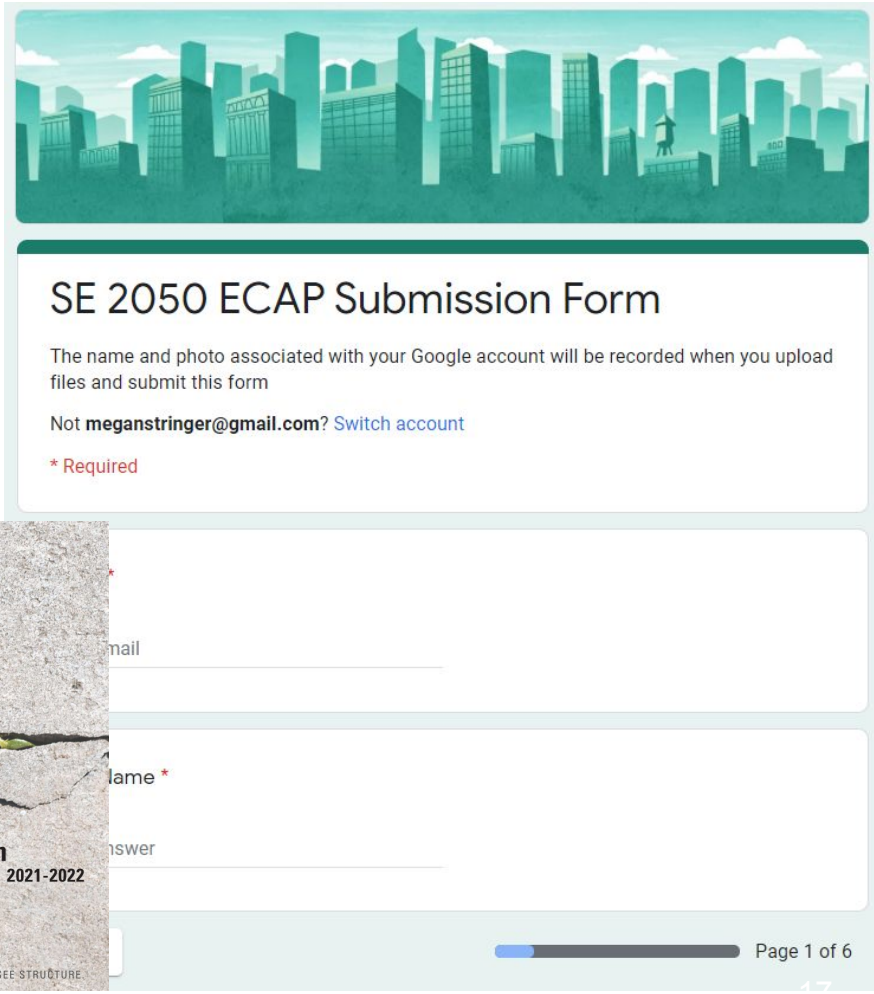
ANNUAL Updates to ECAP
PUBLISHED on SE 2050 Website

Firm Name	Embodied Carbon Champion	Submitted ECAPs	Start Year	Next ECAP due	Next Data due
Ai-Alt Structural Engineering	Alvin Tabar	-	2021	2022-01	2022-07
Armstrong-Douglass Partners	Scott Douglass	2021 Submitted	2021	2022-07	2022-01
Arup (North America)	Frances Yang	2021 Submitted	2020	2022-06	2021-12
Aspect Structural Engineers	Ross Jardine	2021 Submitted	2021	2022-08	2022-02
Black Box Engineering	David Bueno	-	2021	2022-02	2022-08
Buehler	Ryan Miller	2021 Submitted	2021	2023-01	2022-07
Buro Happold	Stephen Curtis	-	2021	2022-04	2022-10
Bush, Bohlman & Partners	Trevor Whitney	-	2021	2021-10	2022-04

https://se2050.org/signatory-firms/

ECAP - How to start

- Review other firm's ECAP's
- Reference website: https://se2050.org/ecap/
- Use Googleform on website



SE 2050 DATABASE (BETA)

Why a database?

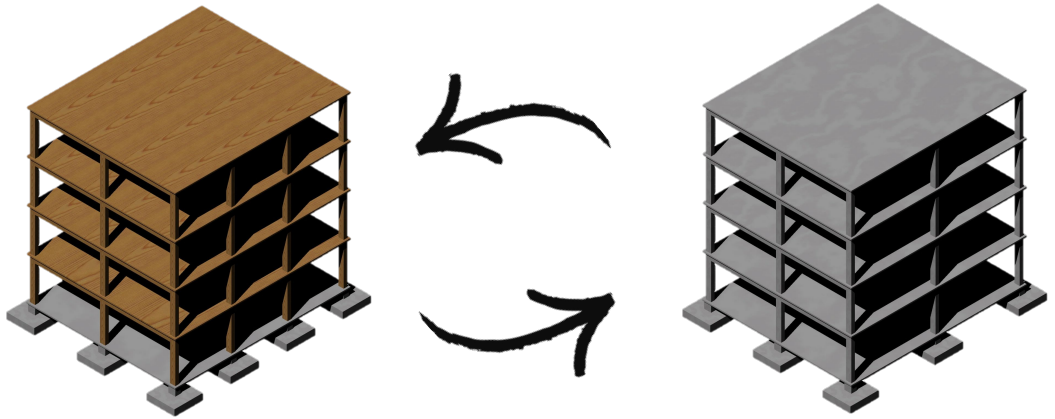
Embodied Carbon Data

using As-Designed and Reference building

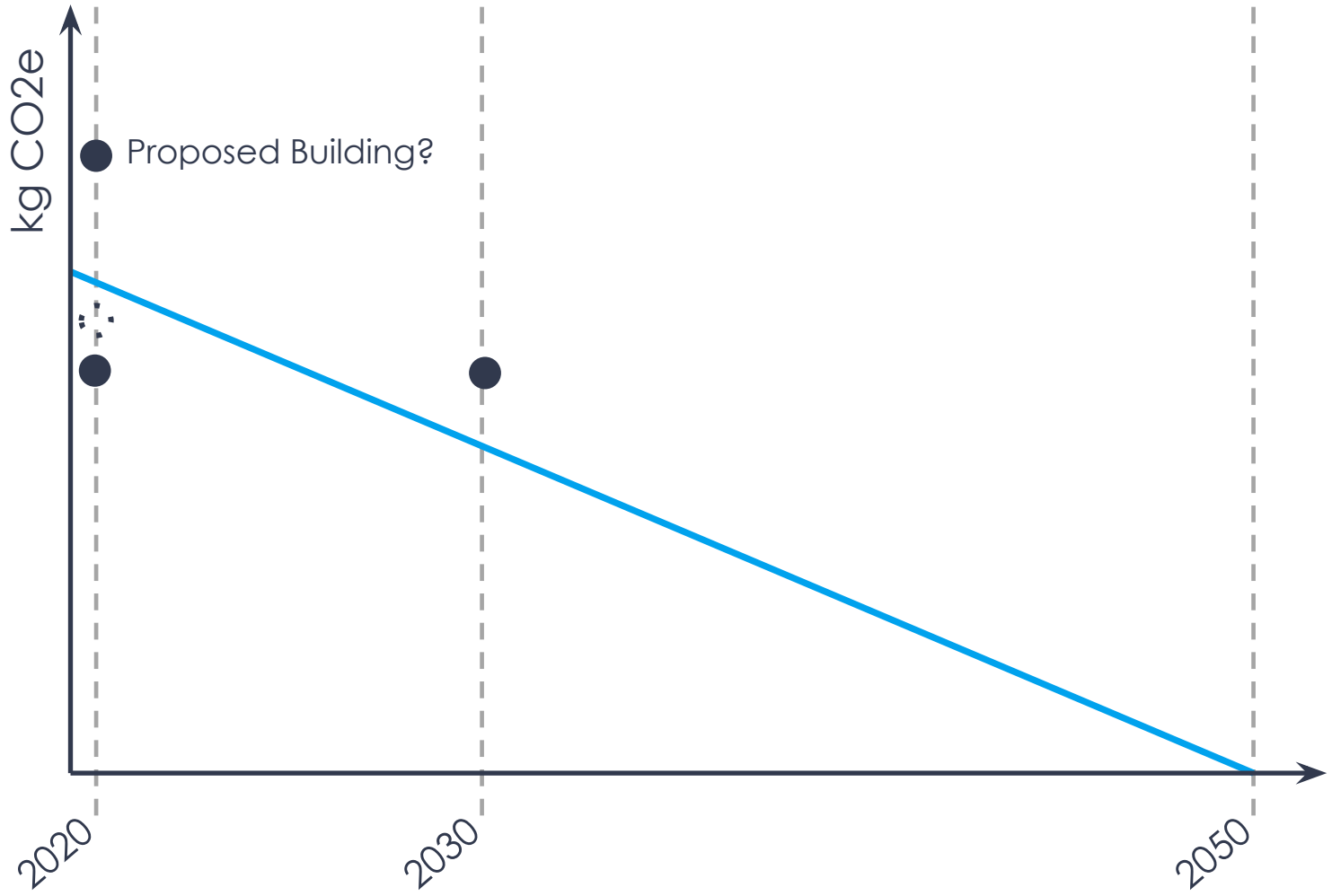
Current approach (e.g., as used by green building rating systems):

Comparative Structural System LCA

using As-Designed and Reference building

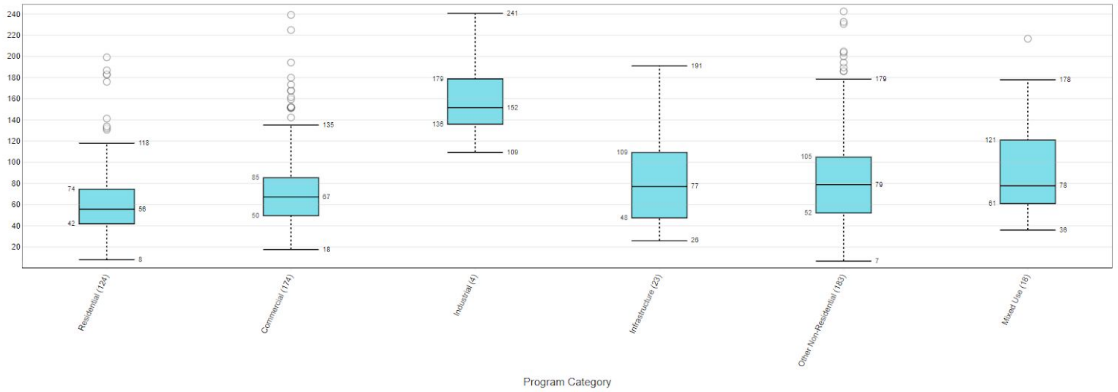


Embodied Carbon Targets

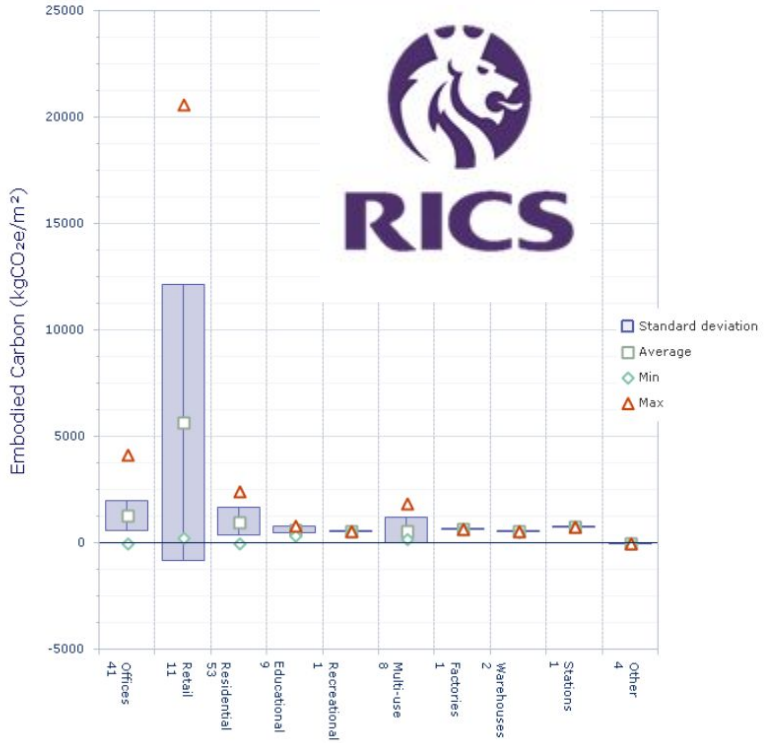


Beta Database Precedents

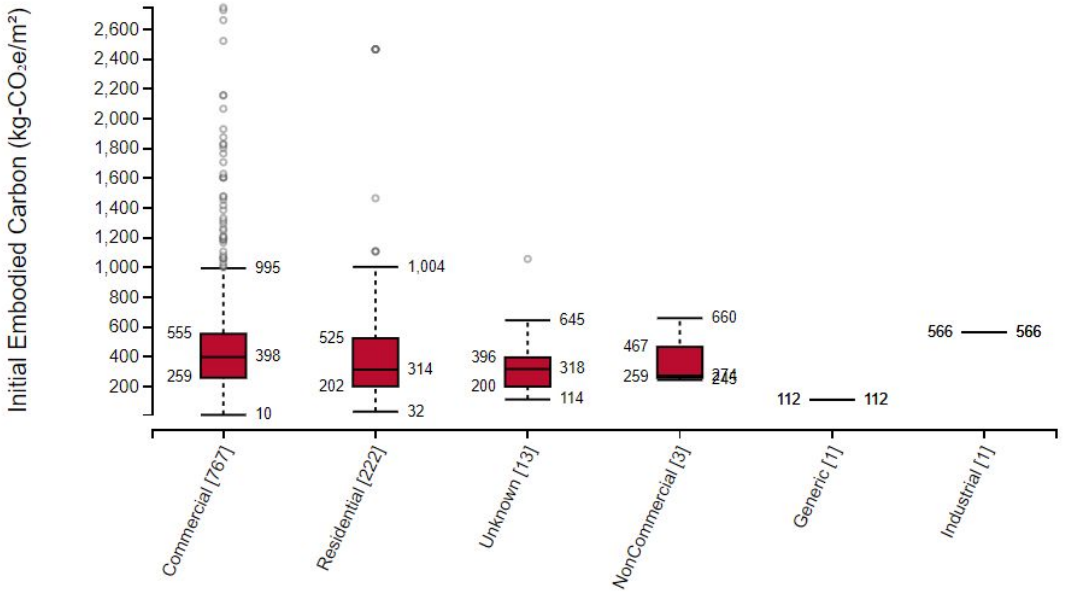
deQo



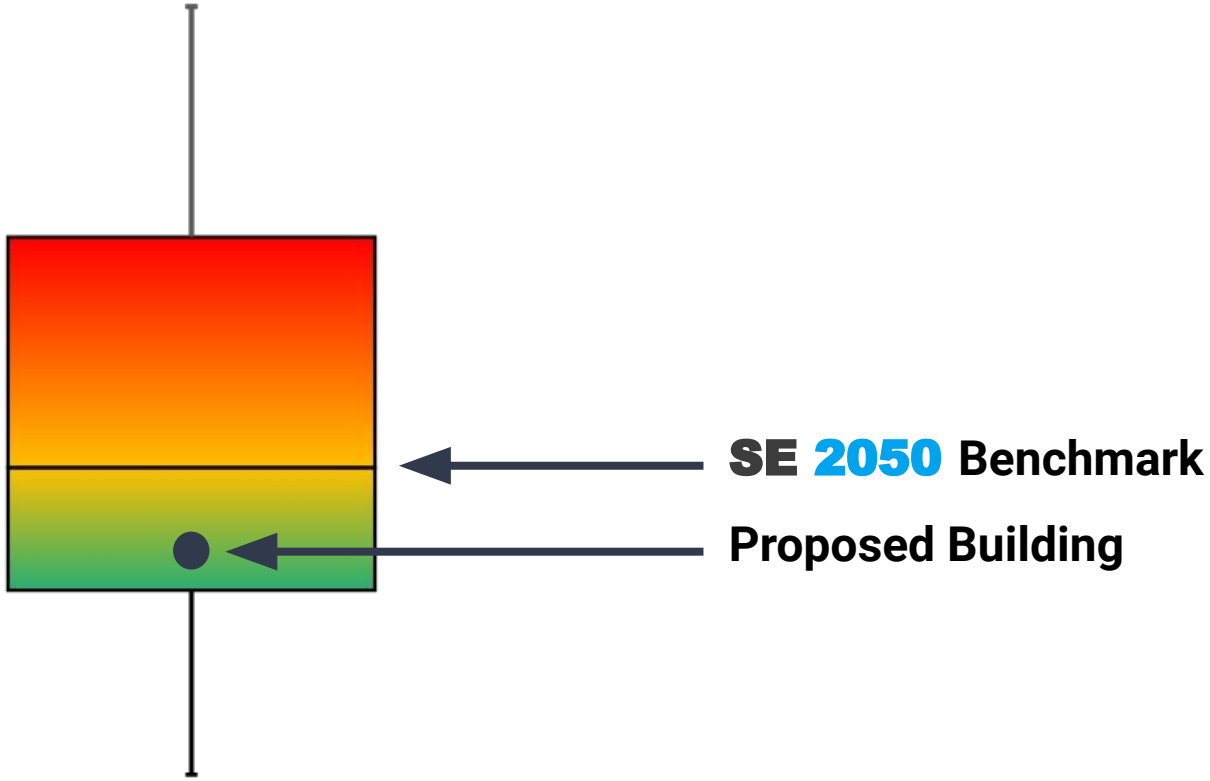
RICS Building Carbon Database Results Summary



CLF Carbon Leadership Forum



Embodied Carbon Benchmarks



SE 2050 Beta Database

Priorities:

Familiarize structural firms with embodied carbon reporting

Collect GWP results at minimum

Increase visibility of need for embodied carbon benchmarks

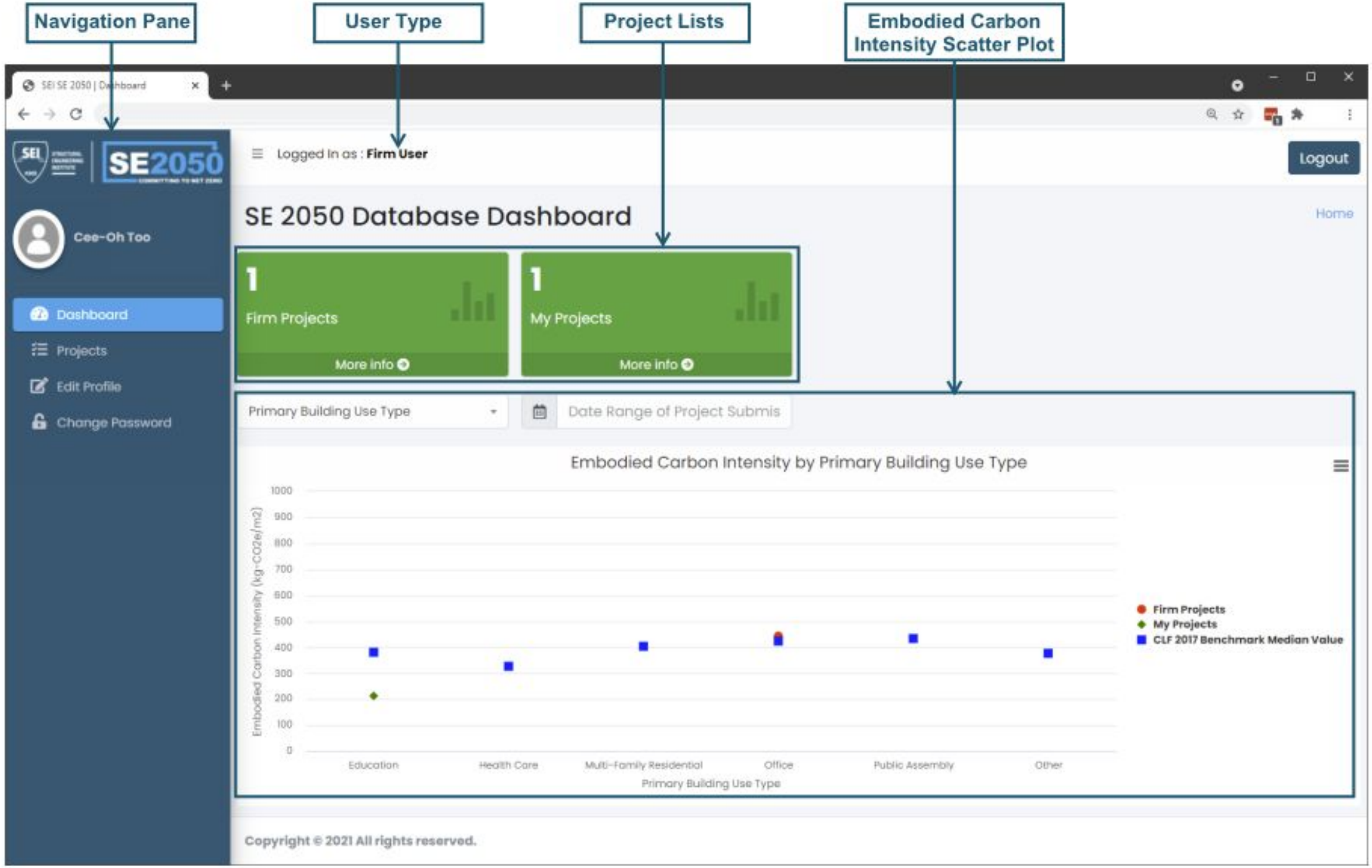
What data is being collected?

Structural System Descriptors, including:
- Risk category
- Seismic design category
- Typical floor live load
- Typical column grid
- Primary gravity, lateral systems
- Allowable bearing pressure

Project Descriptors, including:
- Building use type
- Project phase
- Expected building life
- Gross square footage

LCA Data, including:
- LCA tool used
- LCA stages included
- Biogenic carbon
- Components included
- GWP results

Embodied Carbon Intensity
kg-CO2e/m2


Navigation Pane
User Type
Project Lists
Embodied Carbon Intensity Scatter Plot
SEI SE 2050 | Dashboard
SE2050
Logged In as : Firm User
Logout
Cee-Oh Too
Dashboard
Projects
Edit Profile
Change Password
SE 2050 Database Dashboard
Home
1
Firm Projects
More info
1
My Projects
More info
Primary Building Use Type
Date Range of Project Submis
Embodied Carbon Intensity by Primary Building Use Type
Embodied Carbon Intensity (kg-CO2e/m2)
1000
900
800
700
600
500
400
300
200
100
0
Education
Health Care
Multi-Family Residential
Office
Public Assembly
Other
Primary Building Use Type
Firm Projects
My Projects
CLF 2017 Benchmark Median Value
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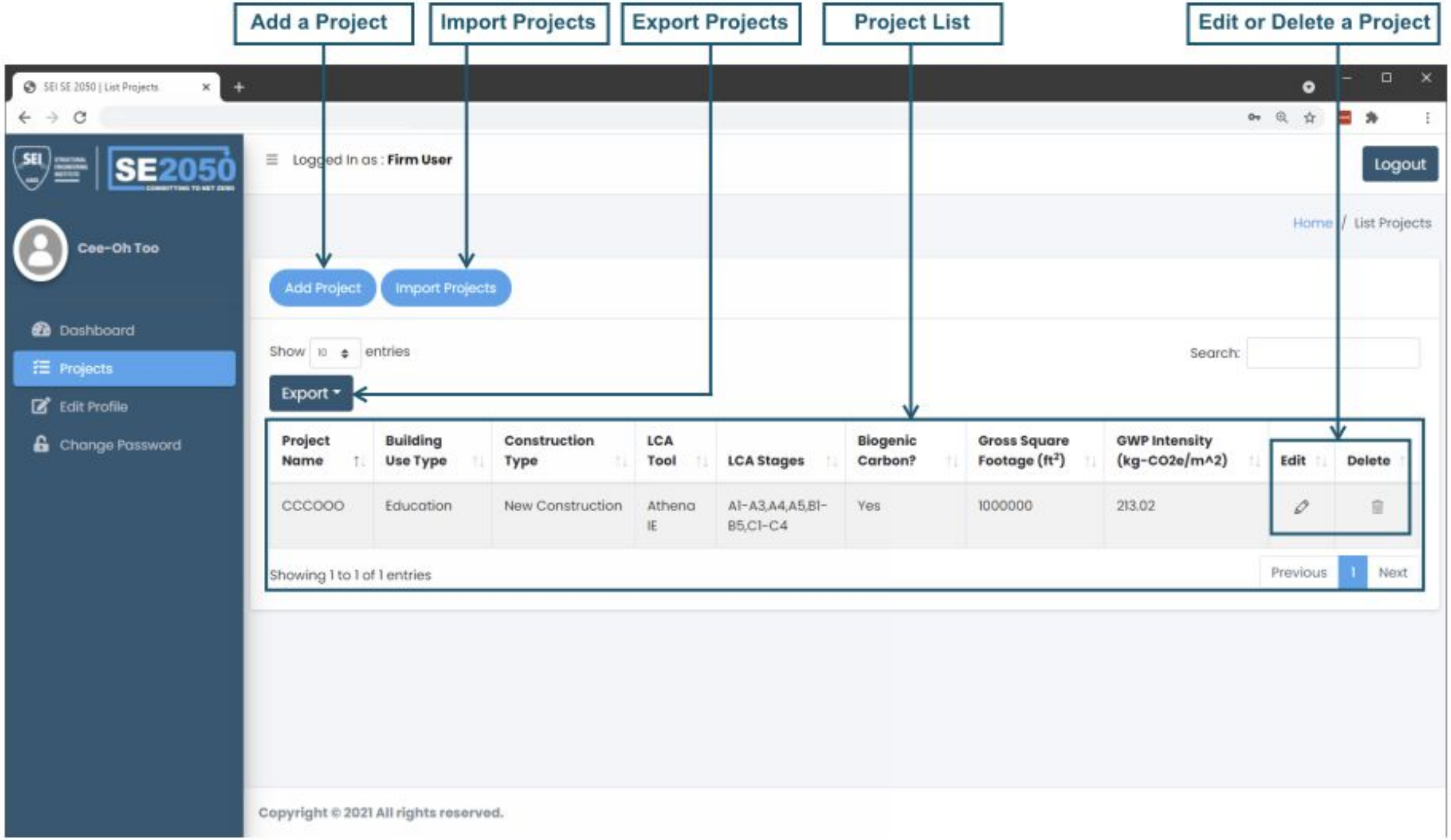
Add a Project
Import Projects
Export Projects
Project List
Edit or Delete a Project
SEI SE 2050 | List Projects
SE2050
Logged In as : Firm User
Logout
Cee-Oh Too
Dashboard
Projects
Edit Profile
Change Password
Home / List Projects
Add Project
Import Projects
Show 10 entries
Search:
Export
Project Name
Building Use Type
Construction Type
LCA Tool
LCA Stages
Biogenic Carbon?
Gross Square Footage (ft²)
GWP Intensity (kg-CO2e/m^2)
Edit
Delete
CCCOOO
Education
New Construction
Athena IE
A1-A3,A4,A5,B1-B5,C1-C4
Yes
1000000
213.02
Showing 1 to 1 of 1 entries
Previous
1
Next
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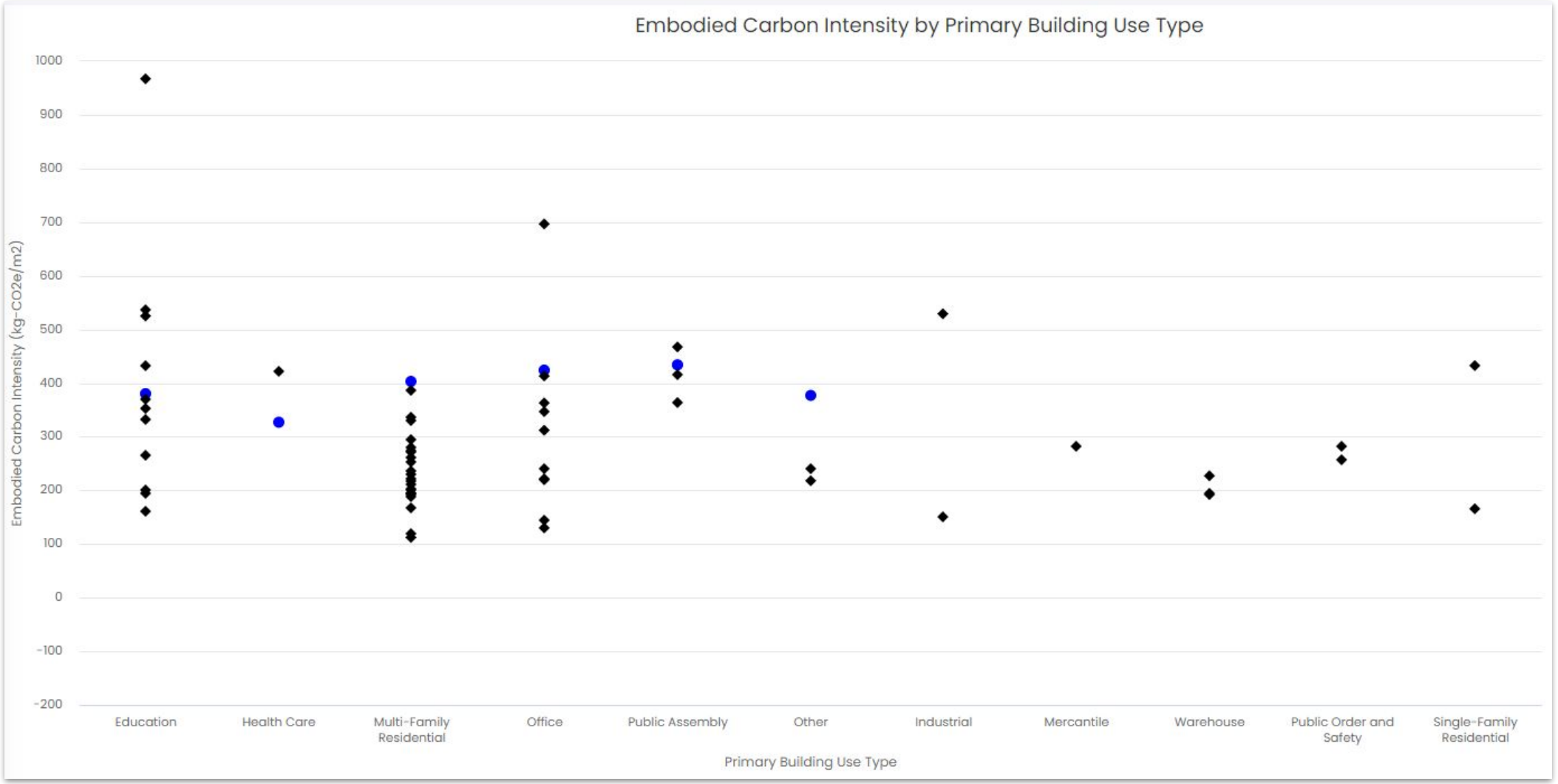
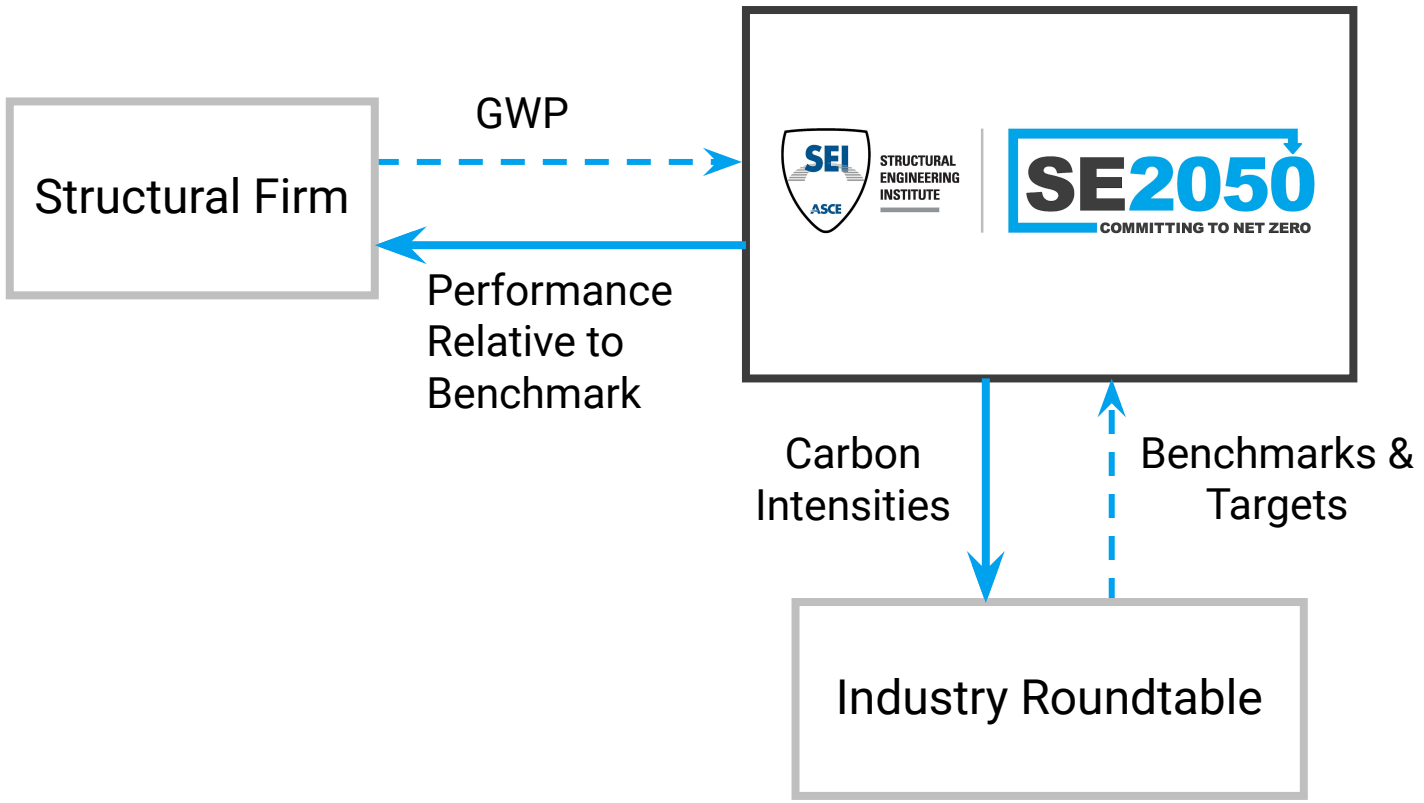
SE 2050 Beta Database Snapshot



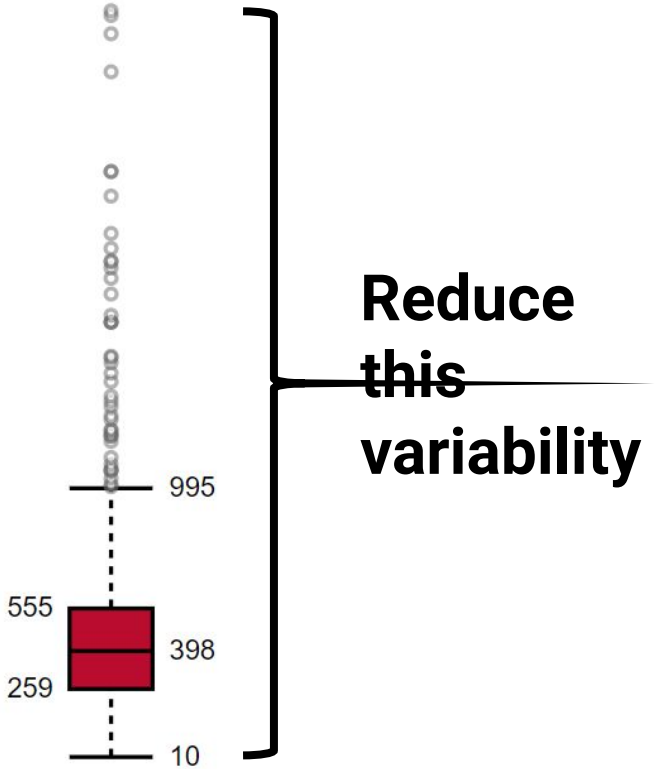
***Beta Database Launched November, 2021**

SE 2050 Beta Database: Stakeholder Interaction

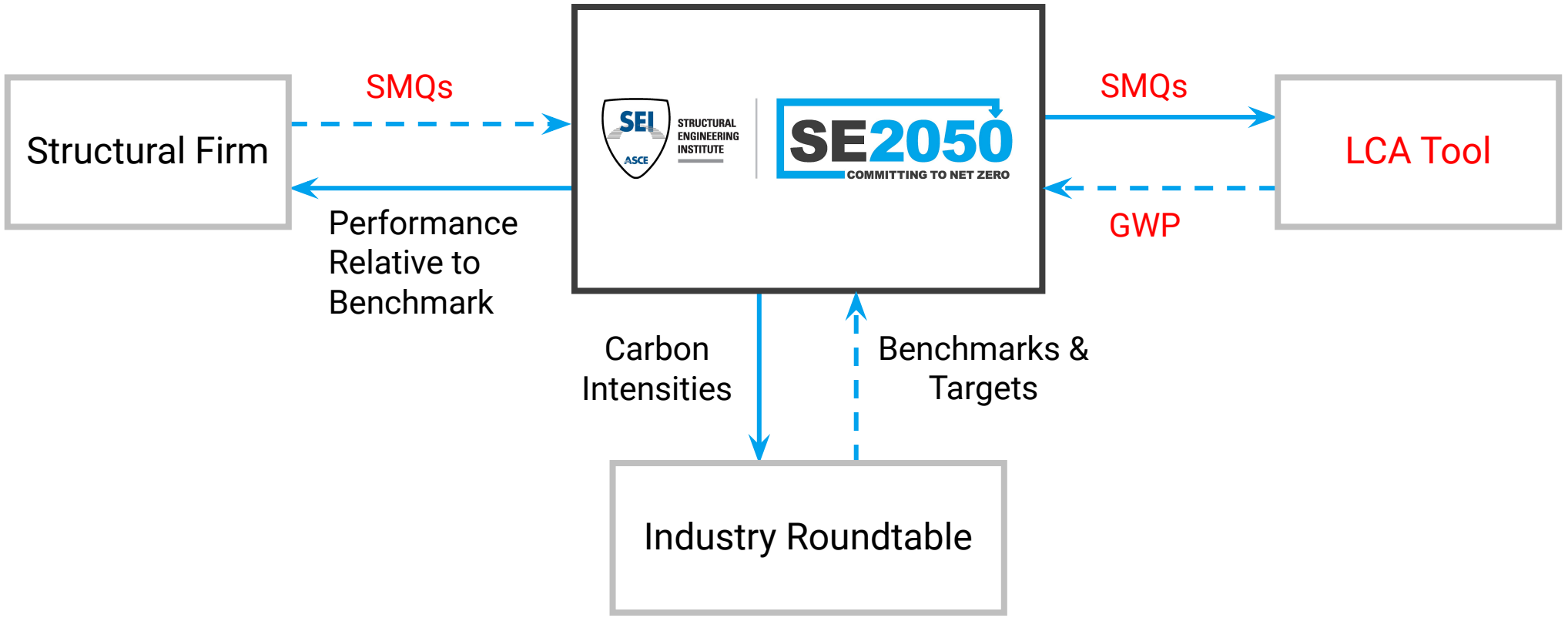


SE 2050 Database: Future

- Collect structural material quantities (“SMQs”)
- Focus on reducing data variability
- Establish industry benchmarks and targets using aggregated data



SE 2050 Database: Future



PROGRAM STATS – SIGNATORY FIRMS

Firms Committed

73

Projects Submitted to Database (Public)

91

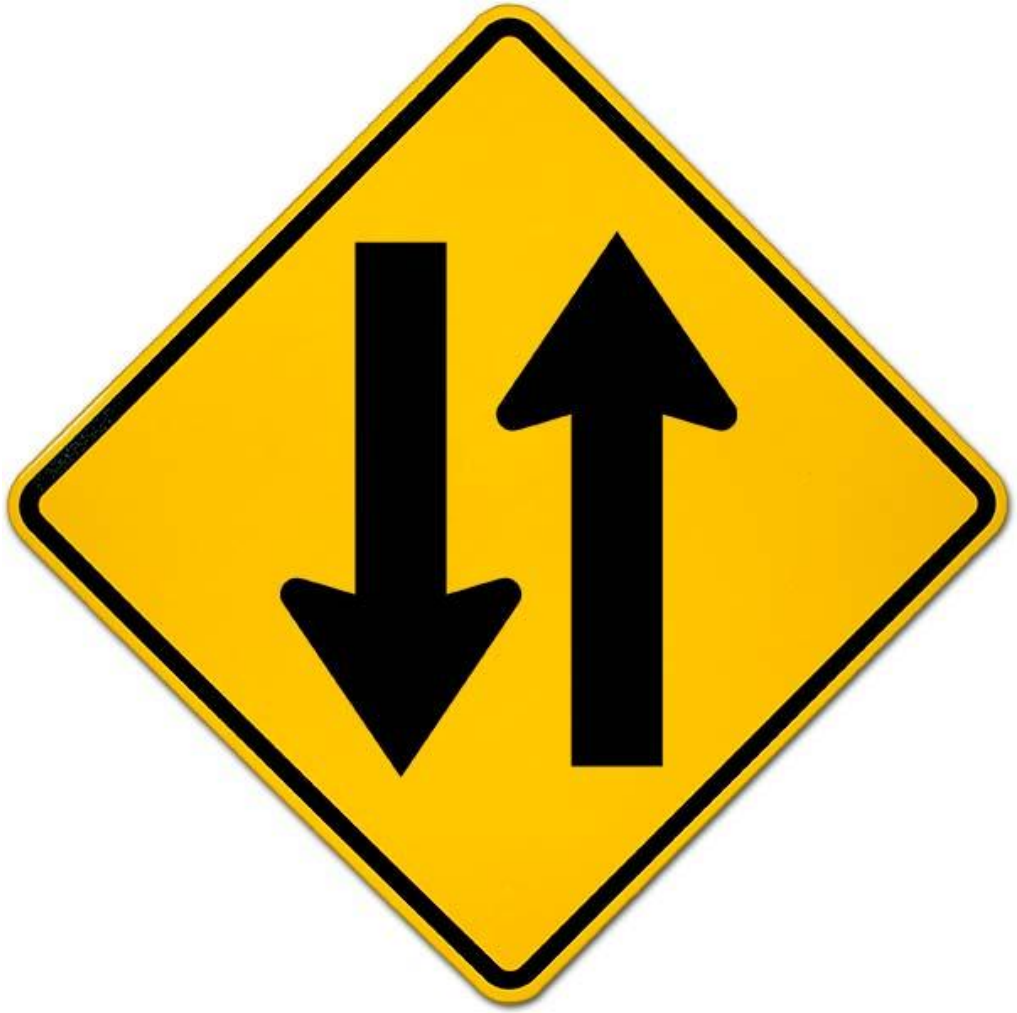
ECAPs Received

42

RESOURCES

TWO-WAY STREET COMMITMENT

- Our ask *of* the Profession
- We Commit to Providing Resources and Support *to* the Profession

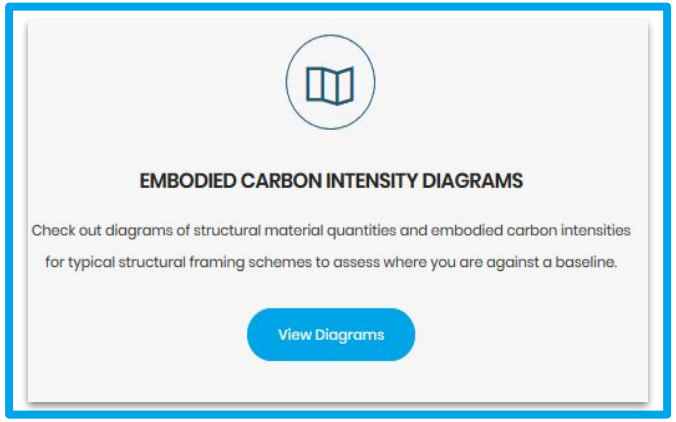


SE 2050 RESOURCES

Embodied Carbon

Structural Materials

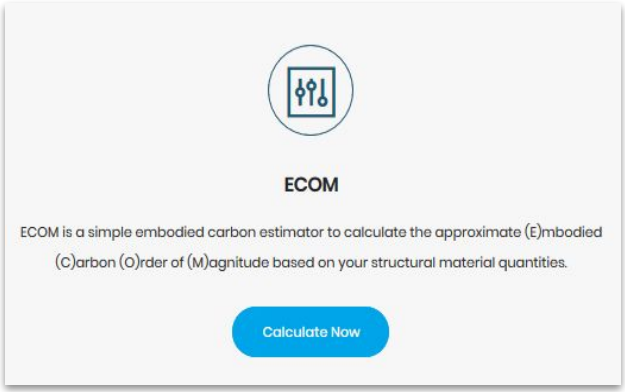
Strategies



Tools and Data

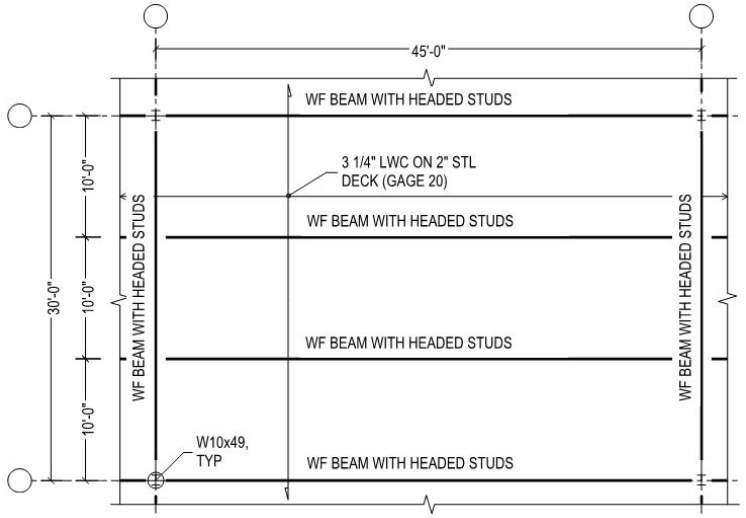
Case Studies

U.S. Green Rating Systems

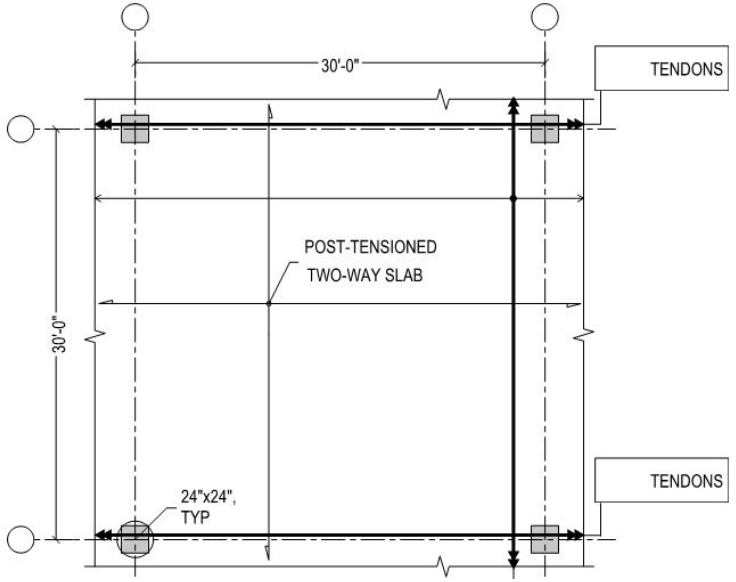


EMBODIED CARBON INTENSITY DIAGRAMS (ECID)

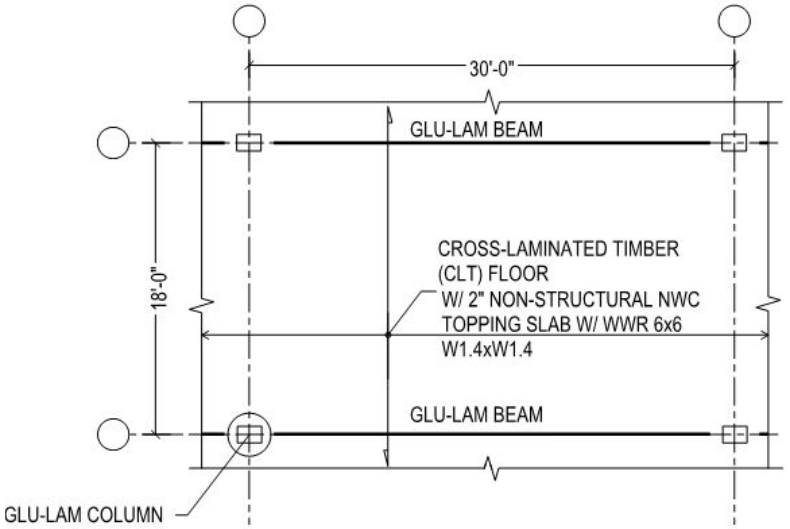
Intent: Start to establish fluency in EC metric



Steel

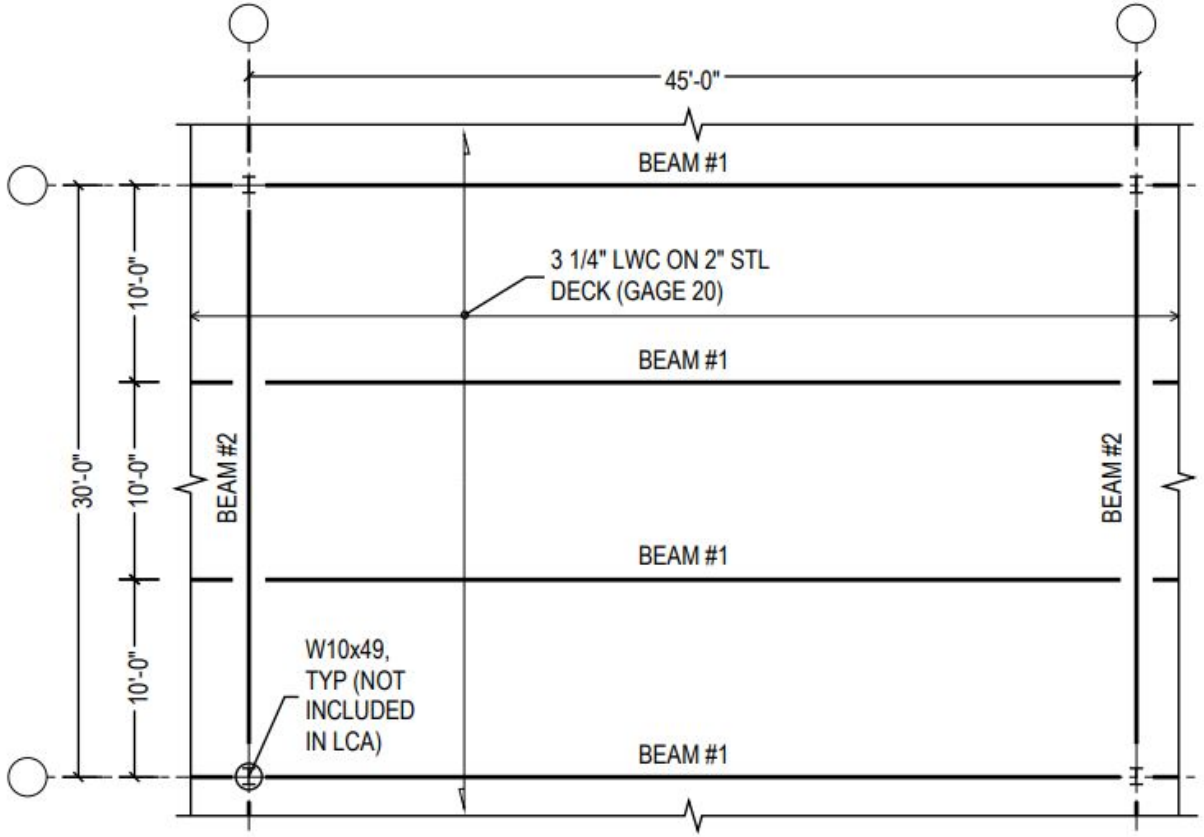


Concrete

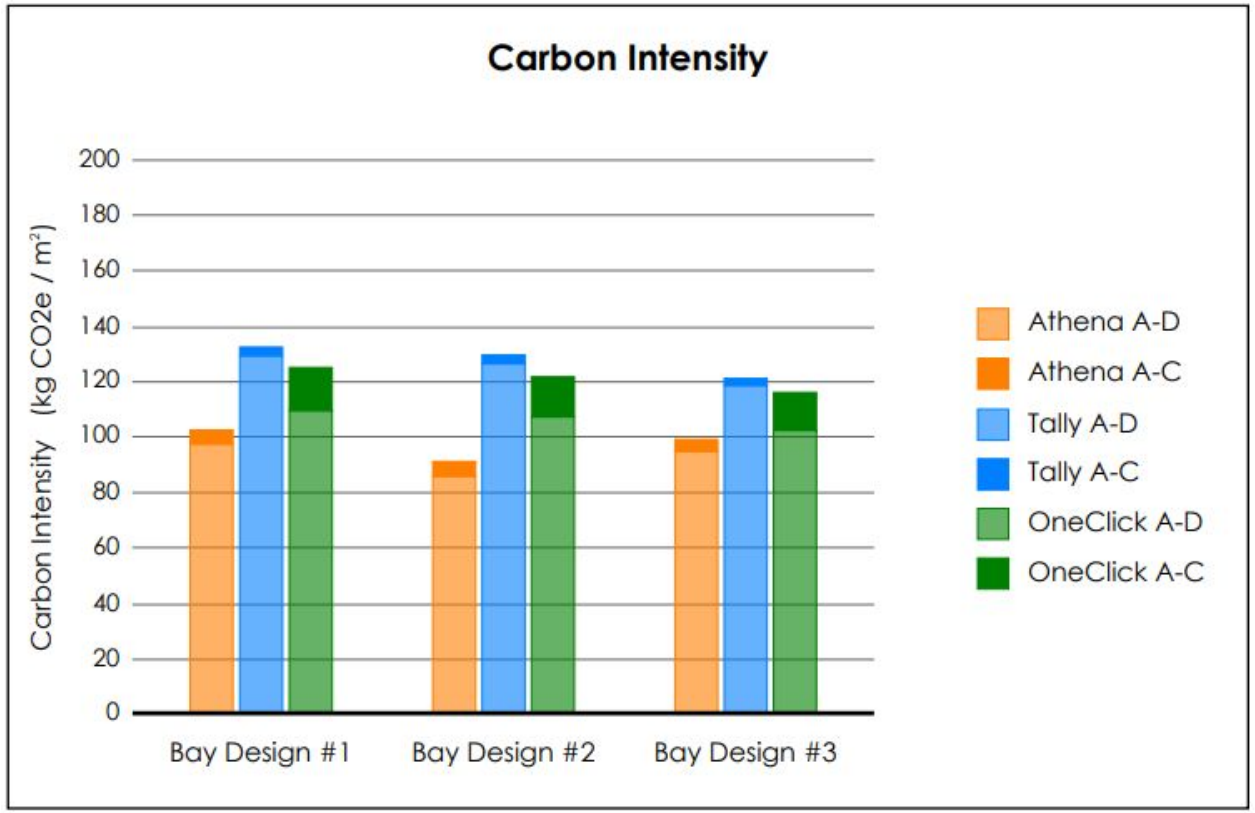


Timber

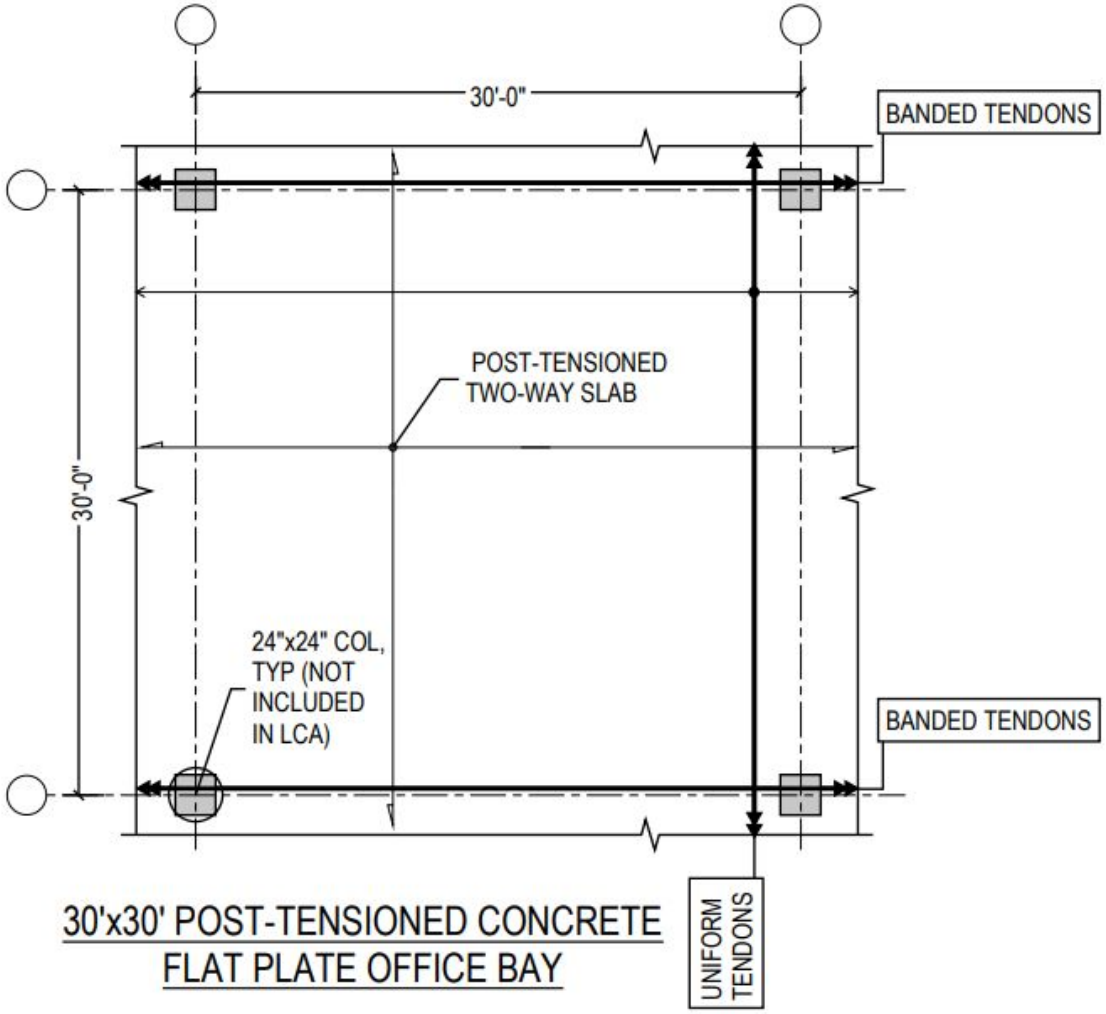
COMPOSITE STEEL OFFICE ECID



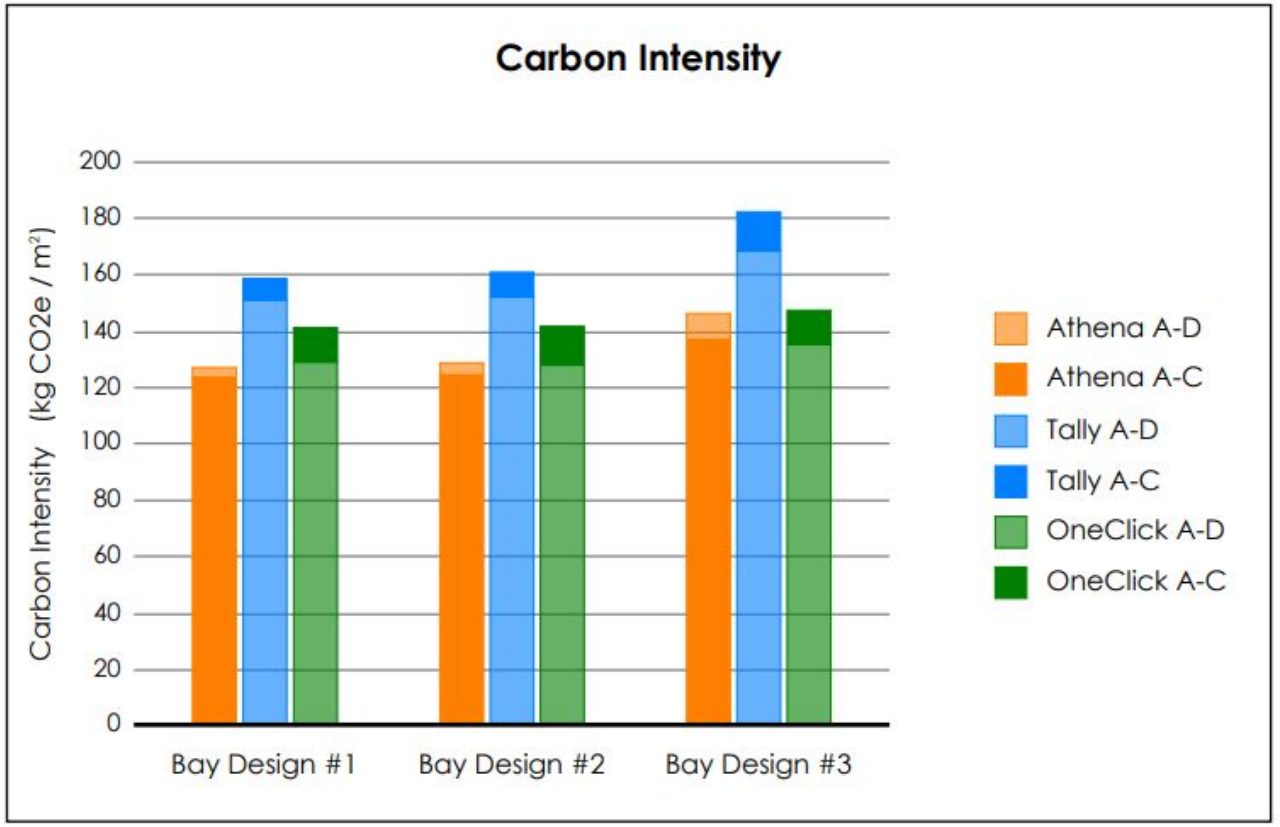
30'x45' COMPOSITE STEEL OFFICE BAY



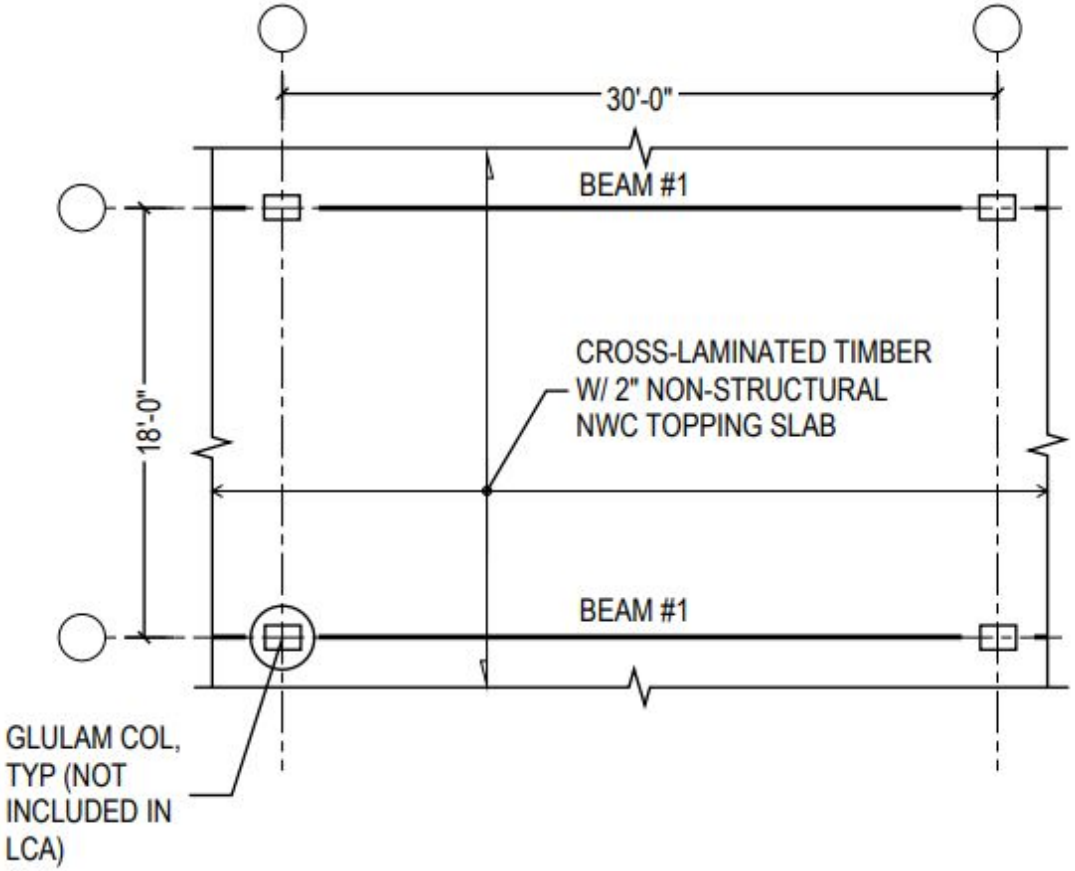
CONCRETE POST-TENSIONED FLAT PLATE OFFICE ECID



30'x30' POST-TENSIONED CONCRETE FLAT PLATE OFFICE BAY



MASS TIMBER (CLT) OFFICE ECID



18'x30' MASS TIMBER
POST-AND-BEAM OFFICE BAY

INCLUDED IN LCA:

MASS TIMBER

(1) BEAM #1 *24F-V4 (DF) - 8.75"x31.5" TO 10.25"x30"*
CLT *V2 OR E1 (SPF) - 5-PLY (6.90") TO 7-PLY (7.56")*

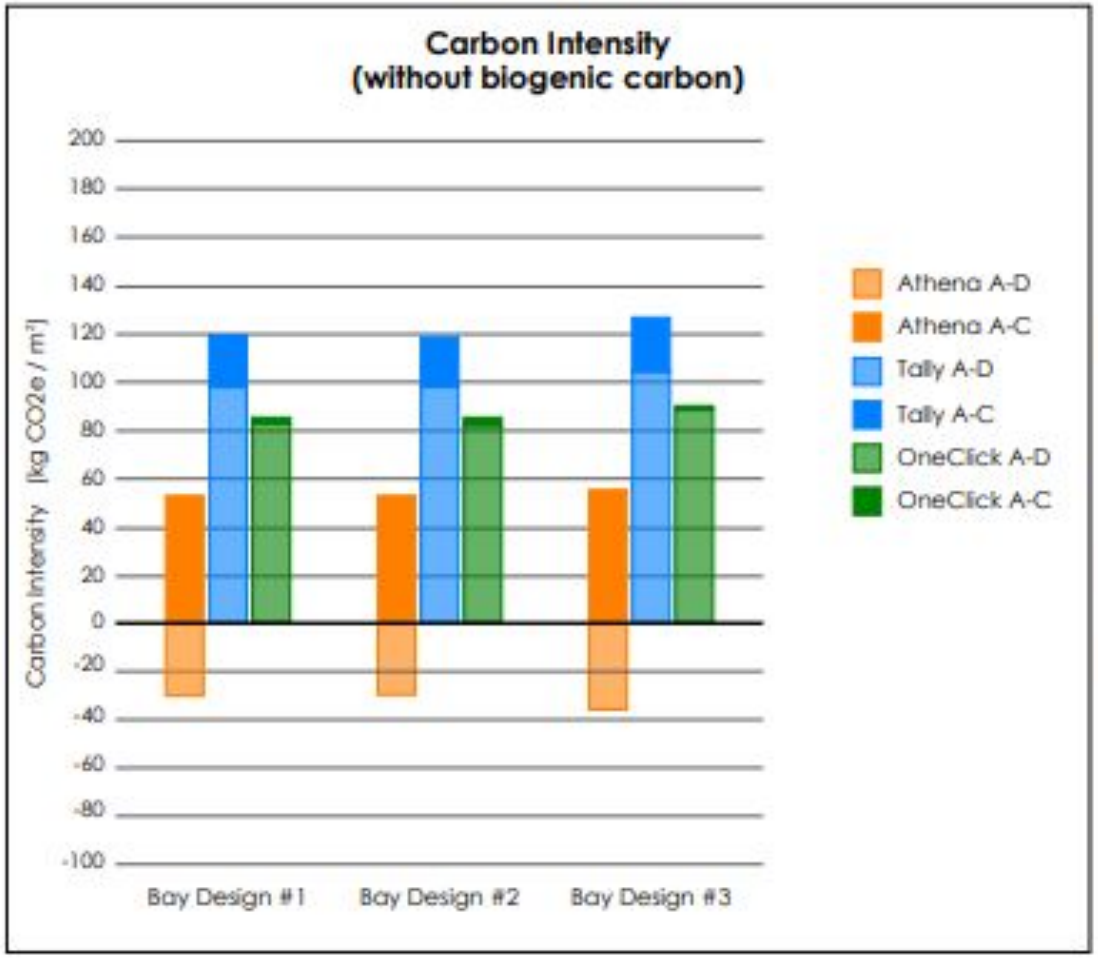
(1) STEEL BEAM-COL CONNECTION *125 TO 200 LBS*

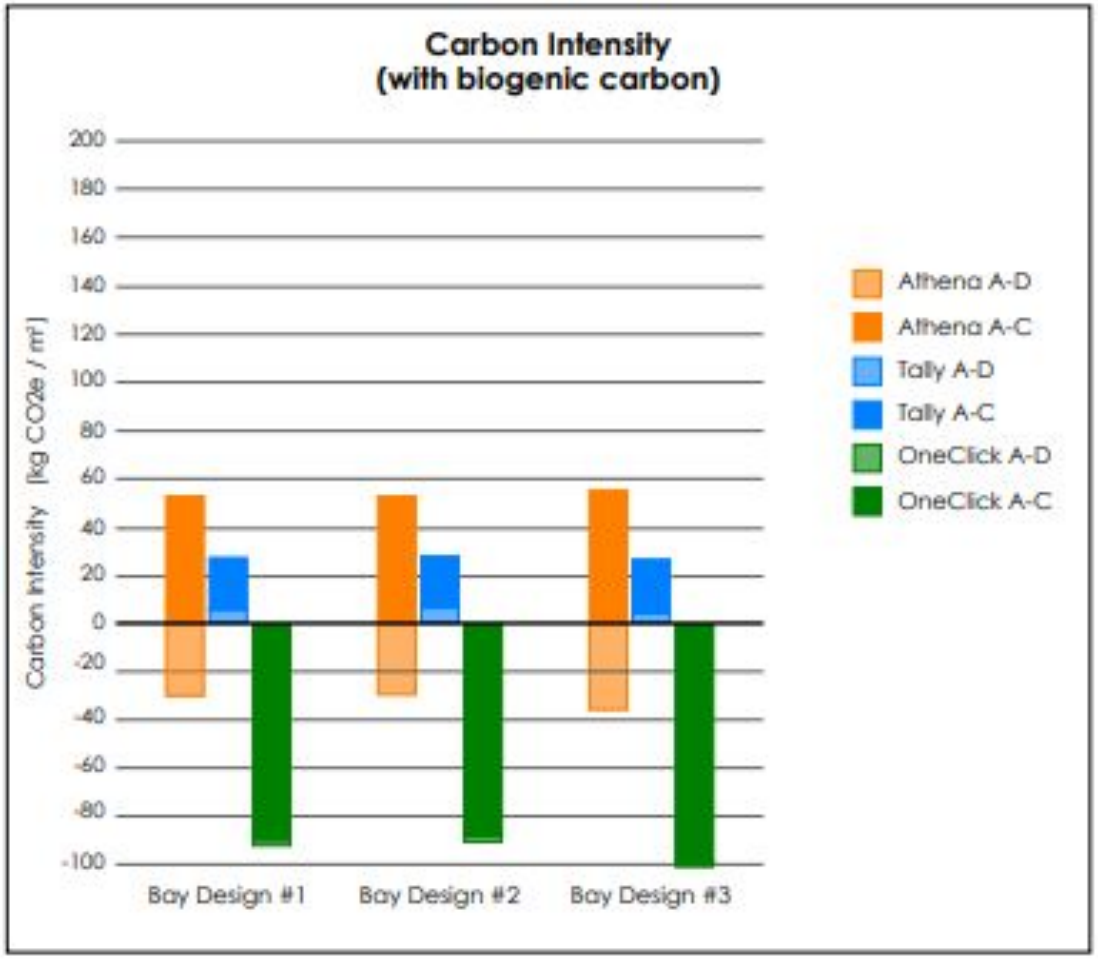
CONCRETE TOPPING

3,000 PSI NORMALWEIGHT, 20-29% SCMs

WWR 6x6 W1.4xW1.4

MASS TIMBER (CLT) OFFICE ECID (CONT.)





SE 2050 RESOURCES

Embodied Carbon

Structural Materials

Strategies

EMBODIED CARBON INTENSITY DIAGRAMS

Check out diagrams of structural material quantities and embodied carbon intensities for typical structural framing schemes to assess where you are against a baseline.

View Diagrams

Tools and Data

Case Studies

U.S. Green Rating Systems

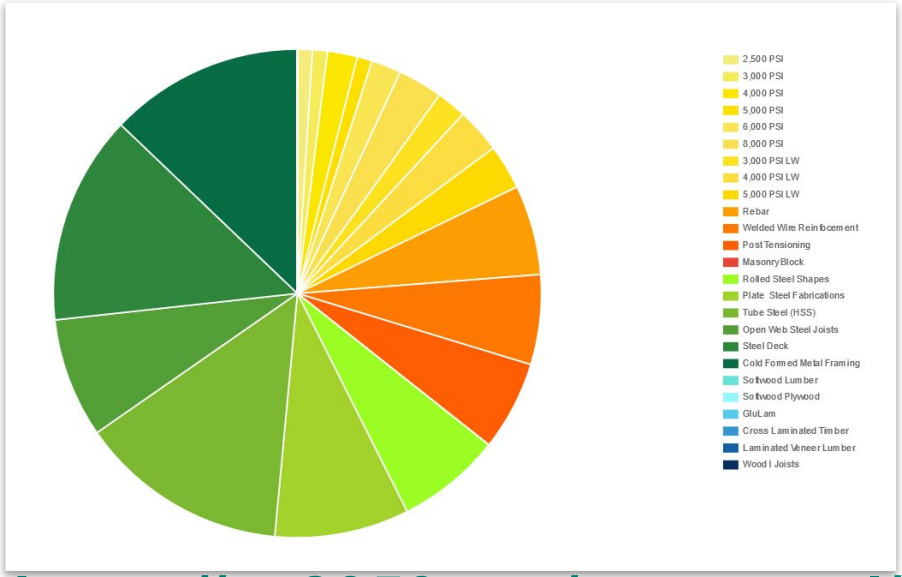
ECOM

ECOM is a simple embodied carbon estimator to calculate the approximate (E)mbodied (C)arbon (O)rder of (M)agnitude based on your structural material quantities.

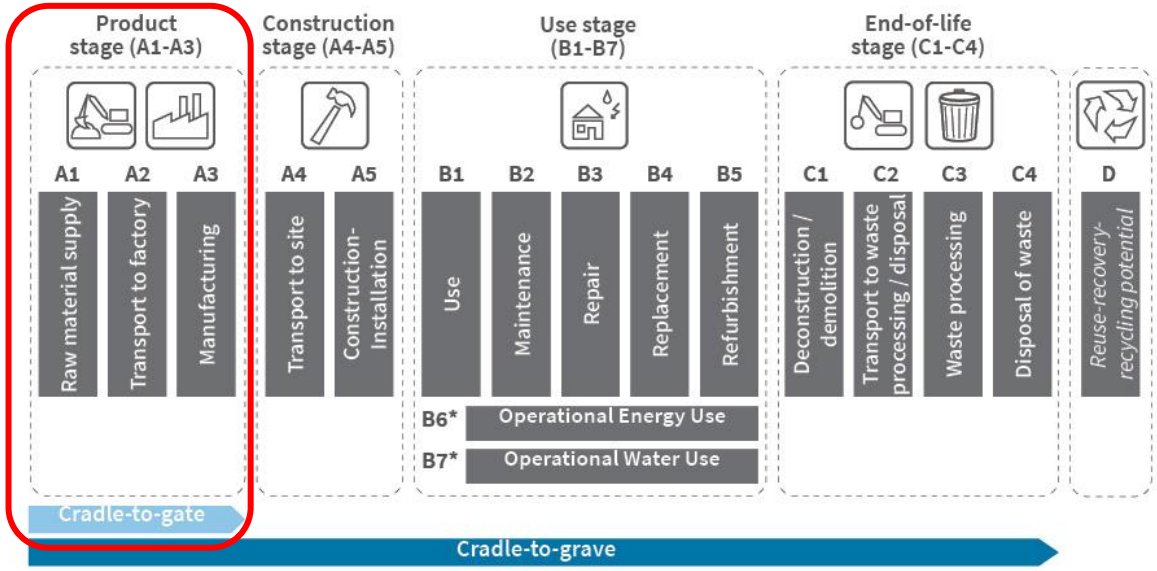
Calculate Now

ECOM TOOL

- **E**mbodied **C**arbon **O**rder of **M**agnitude Tool
- A simple product tool that calculates global warming potential
- Designers can identify hot spots



https://se2050.org/ecom-tool/



*Operational carbon stages that are typically excluded from life cycle assessments focused on embodied carbon.

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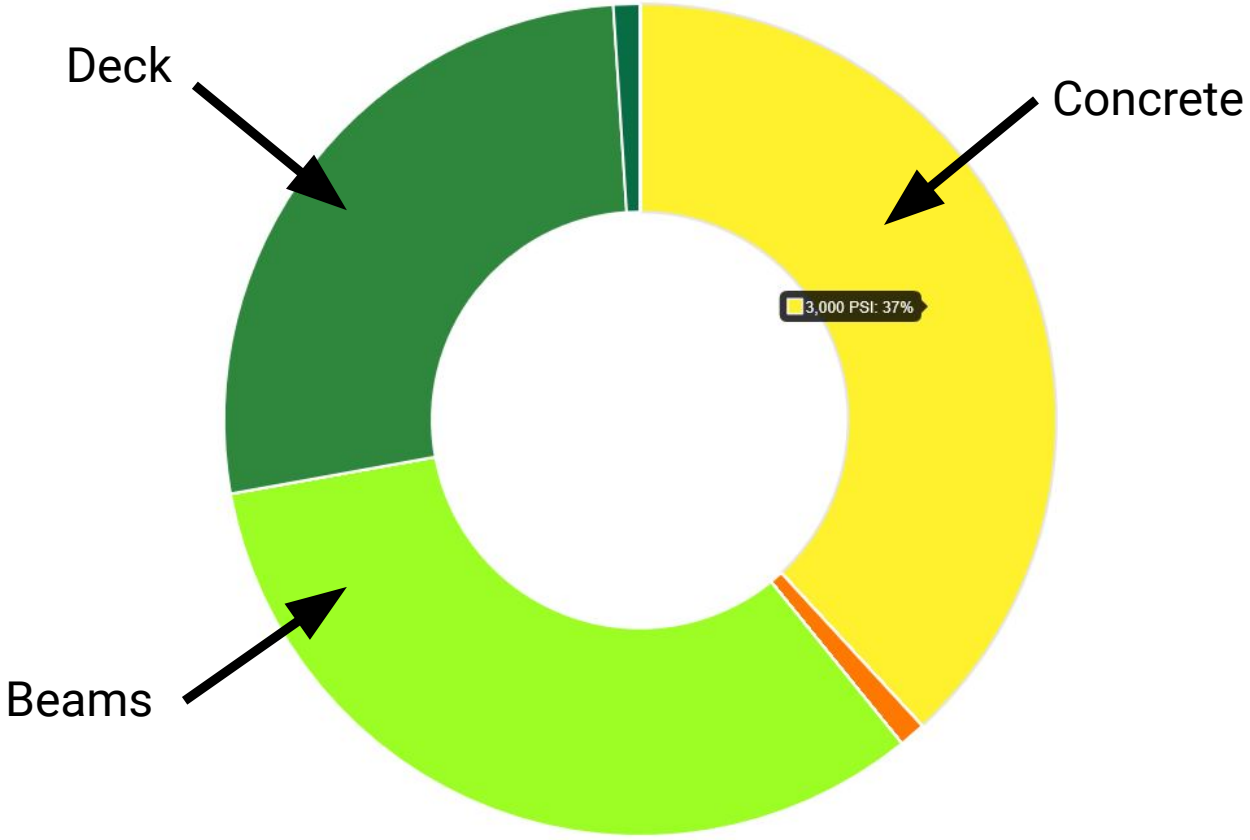
SE 2050 – ECOM OUTPUT



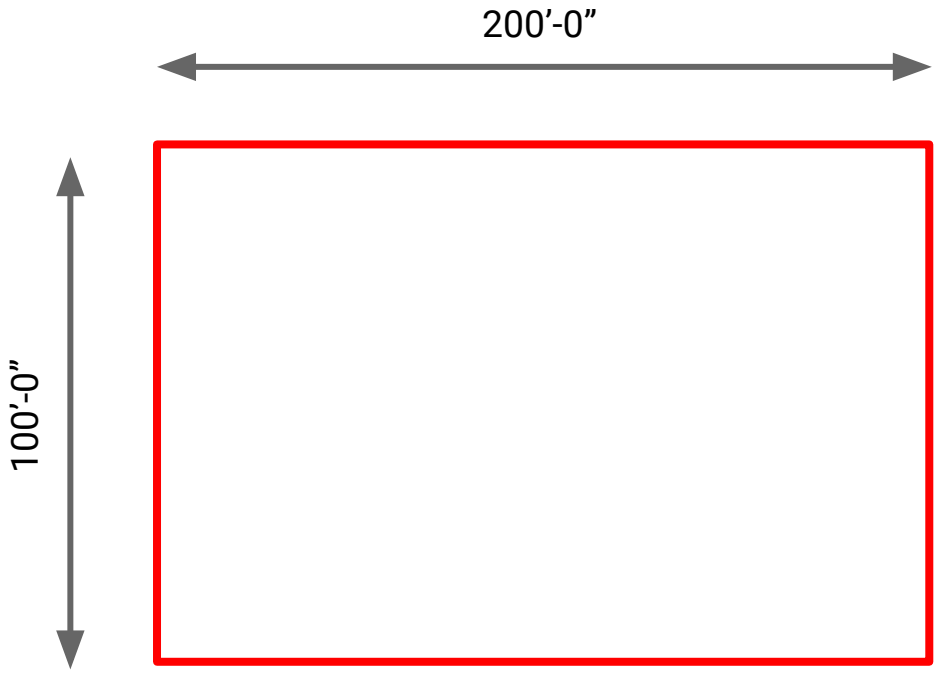
Embodied Carbon Totals	
Total Impact (lb CO_2e)	602,573
Total Impact (kg CO_2e)	273,322

Embodied Carbon Intensities	
Intensity (lb CO_2e/ ft^2)	20.78
Intensity (kg CO_2e/ m^2)	101.45

https://se2050.org/ecom-tool/

ECOM - Exercise

- What is the embodied carbon intensity in $kgCO_2e/m^2$?
  - Structural Steel = 70 tons
  - Structural Concrete (3ksi NW) = 370 CY
  - Concrete Rebar = 5 tons
  - Concrete Welded Wire Reinf = 5 tons
  - Composite Steel Decking = 25 tons
  - Perimeter Steel Bent Plate = 20 lb/ft



https://se2050.org/ecom-tool/

FUTURE SE 2050 RESOURCES

In Development:

- Case Studies of Structural System WBLCAs Using LCA Tools for Designers
- Updates to ECOM
- LCA Guidelines for Structural Engineers
- More Embodied Carbon Intensity Diagrams!

QUESTIONS?

STRUCTURAL ENGINEERING INSTITUTE

SE2050 COMMITTING TO NET ZERO

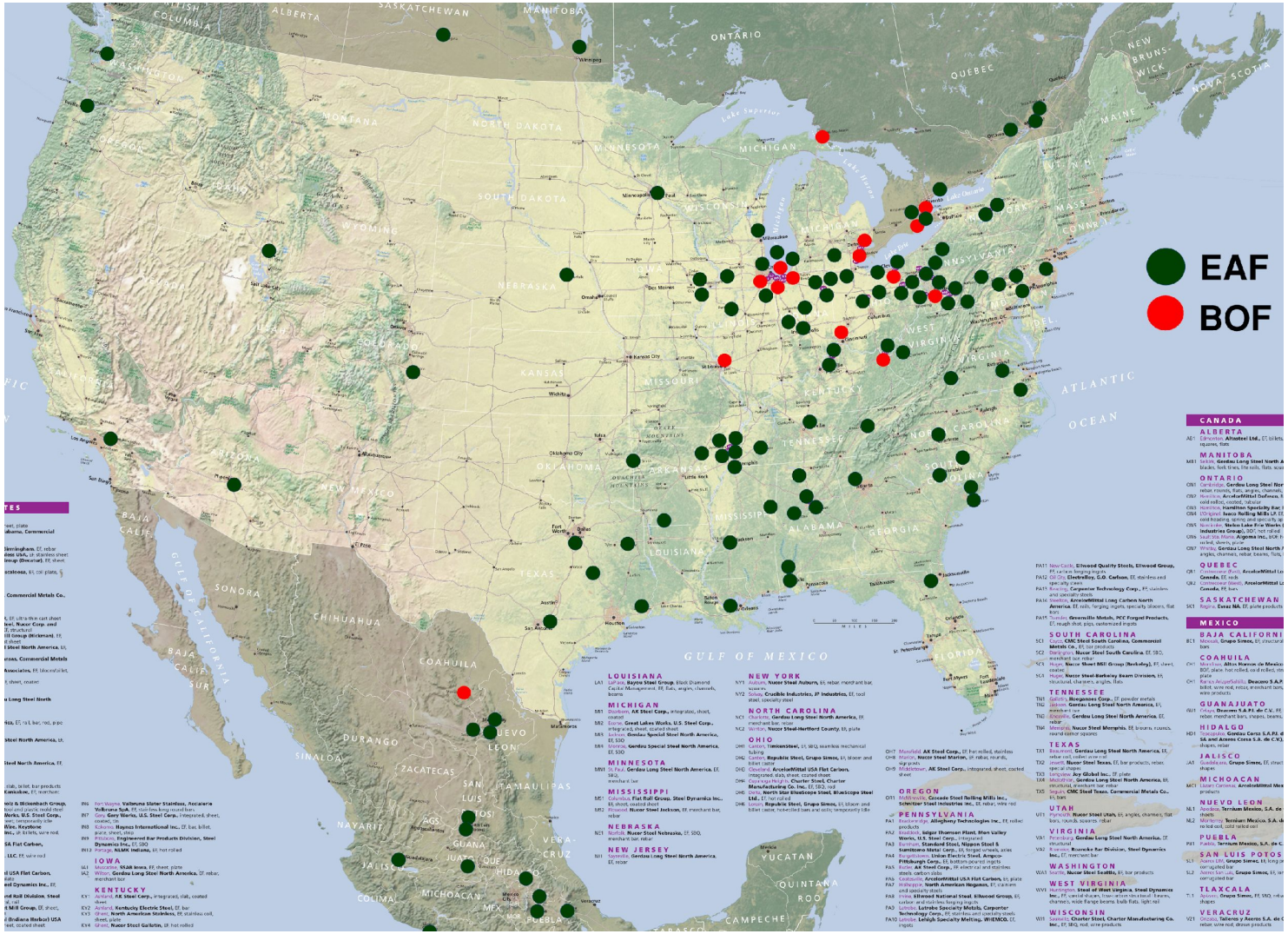
Are you ready to join the movement?

https://se2050.org/sign-up/

THANK YOU!

REDUCING EMBODIED CARBON IN STRUCTURAL STEEL SYSTEMS

North American Steel Production 2018



Source: www.amm.com

- <u>Vast majority</u> of structural steel for U.S. building industry is North American
- Over 65% of U.S. Domestic Steel is EAF
- Some BOF plants have been idled
- Is specifying furnace type appropriate?

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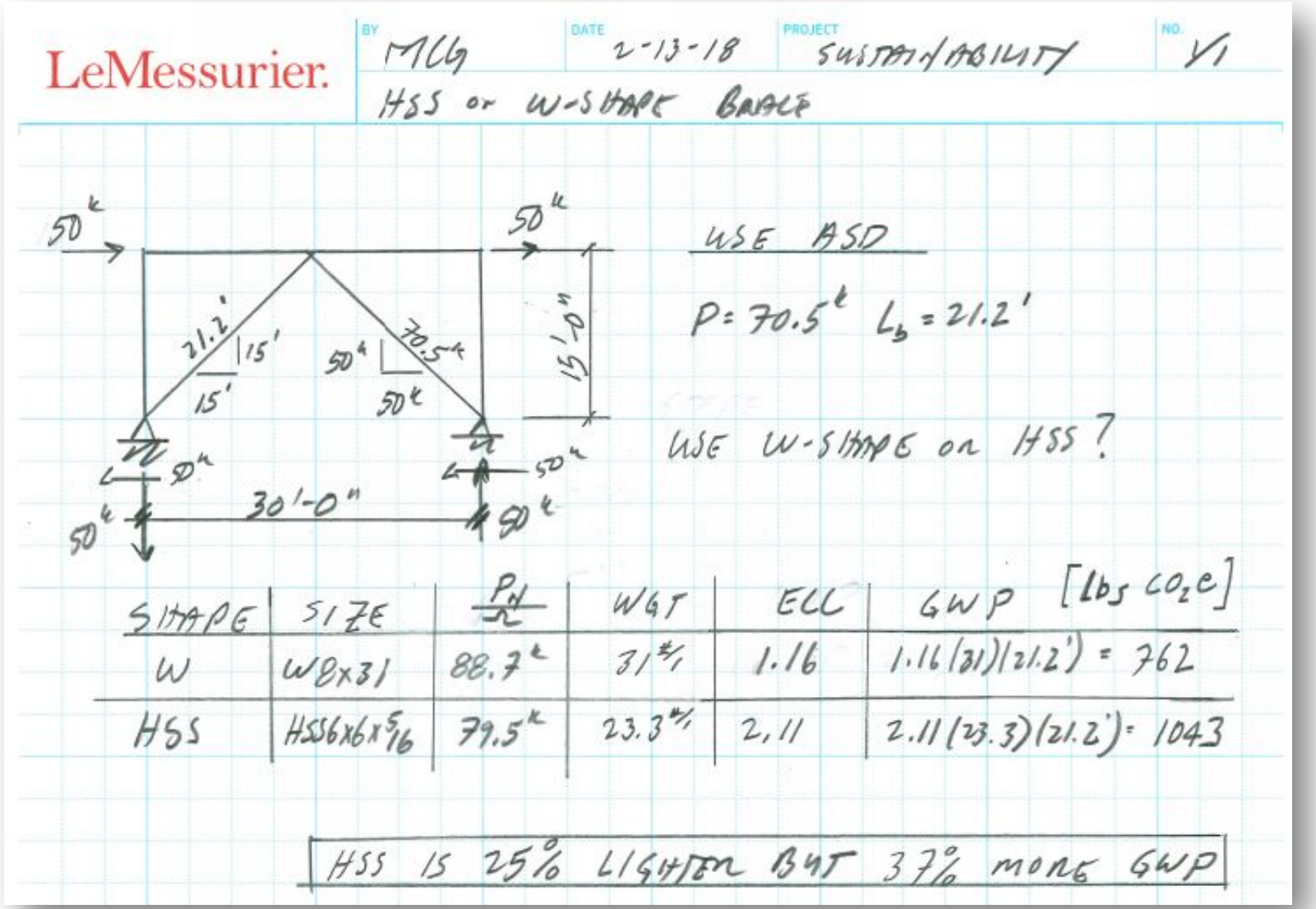
AISC Industry-Wide EPDs (A1-A3)

Structural Element	Ton CO2e / Ton
Fabricated Hot-Rolled Structural Sections	1.16
Fabricated Steel Plate	1.47
Fabricated Hollow Structural Sections (HSS)	2.39

- **All EPDs for domestic steel only**
- **Small number of [BIG] producers**
  - **(4 for hot-rolled; 3 for plate; 10 for HSS)**

Steel the System

Use Fewer HSS members?



- **HSS members are efficient in axial – good bracing members**
- **Less steel but higher GWP**
- **Carbon Budget and the Decision Matrix**

Material Specifications

051200-Structural Steel

PART 2 - **PRODUCTS**

2.2 MATERIALS

N. Structural Steel Global Warming Potential (GWP):

1. The design intent for the structural steel contribution to the Project Carbon Budget is that the total CO_2e of the product for life-cycle assessment stages A1-A3 does not exceed industry-wide average values. To meet this criterion all hot-rolled structural steel shall be produced domestically using Electric Arc Furnaces (EAFs).

2. Third-party verified Environmental Product Declarations (EPDs) in accordance with ISO 14025 shall be submitted for each product confirming the A1-A3 contribution of GWP.

N. Structural Steel Global Warming Potential (GWP):

1. The design intent for the structural steel contribution to the Project Carbon Budget is that the total CO_2e of the product for life-cycle assessment stages A1-A3 does not exceed values listed in the table below. The intent is that 75% of the product tonnage meets the requirements listed.

Product	Ton CO_2e / short ton
W-Shape Rolled (Fy=50ksi)	0.870
W14-Shape Rolled (Fy=65ksi)	0.870
Plate	1.100
HSS	1.790

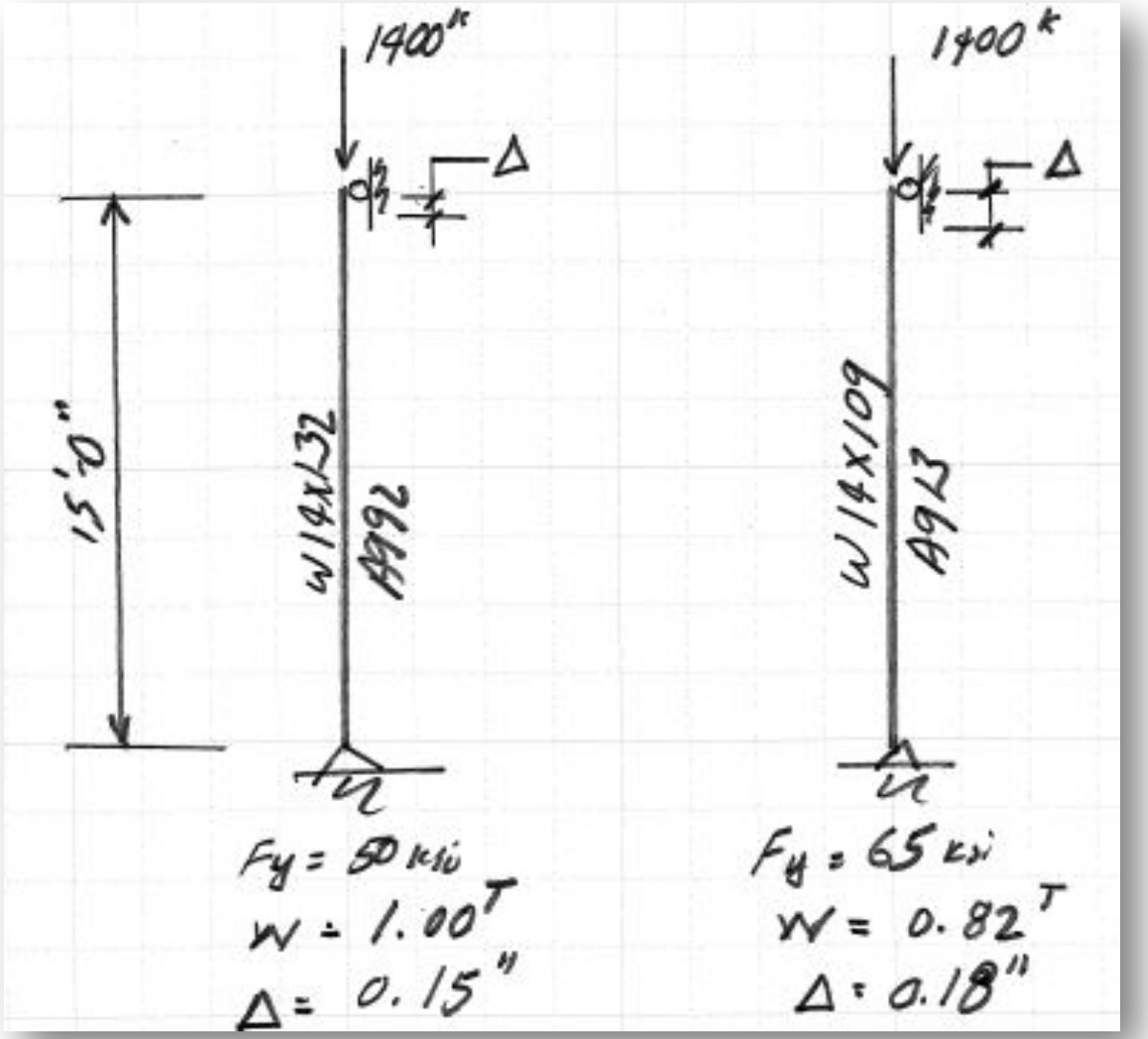
2. Third-party verified Environmental Product Declarations (EPDs) in accordance with ISO 14025 shall be submitted for each product confirming the A1-A3 contribution of GWP.

- **Specifications get everyone's attention**
- **Get GWP requirements in the Specification EARLY**
- **Engage the Owner, CM and SE EARLY in this process**
- **Specifying EAF only may be limiting; not all EAFs treated equal**
  - **Do you know the electricity source?**
- **Consider specifying limits of CO2e instead; easier conversation (maybe)**
- **Let the CM manage the sourcing with clear Project Specifications – be prepared for many conversations! (it's a good thing)**

High(er) Material Strength

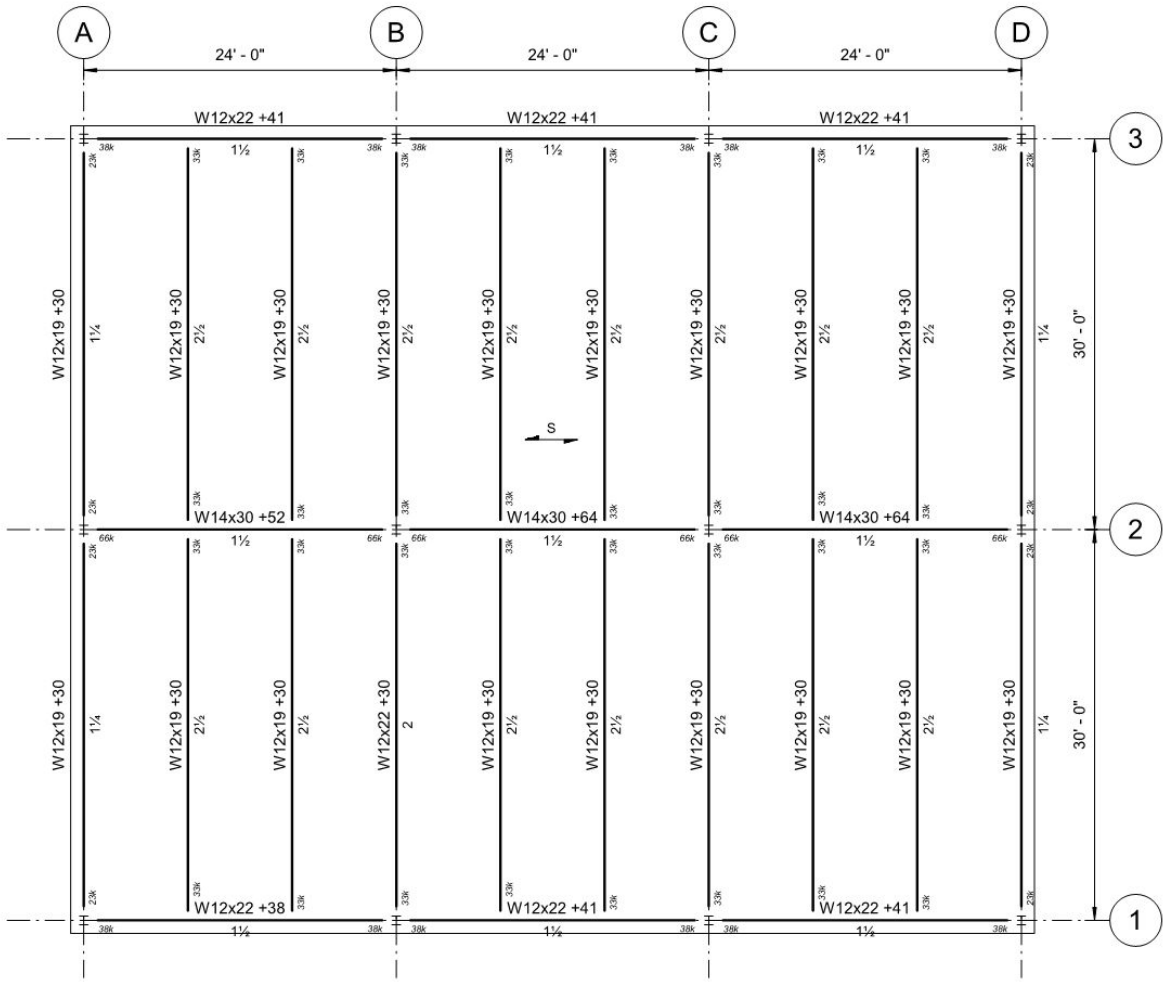
Another Option for W14s

- ASTM A913 (Gr 65 and 70)
- Quenching and Self-Tempering process increases strength
- Carbon Budget
  - Reduced GWP per ton (maybe)
  - Tonnage Reduction
- W14 ‘jumbo’ sections ONLY
- Serviceability may still ‘control’ design
- Ask for EPDs to confirm
- Different weld wire
- Rolling schedules



Composite Floor Framing

Maximizing Deck Span



3-Span Deck

Structural Element	Quantity
Structural Steel Pieces	29
Structural Steel	9 T
Metal Deck	5 T
Concrete topping	80 CY
Concrete reinforcement	3 T
Headed Shear Connectors	1038
Connection Angle Pieces	58
Connection Angles	0.26 T
Bolts	486
GWP (kg CO2e) [not including bolts, angles, headed shear connectors]	58,151

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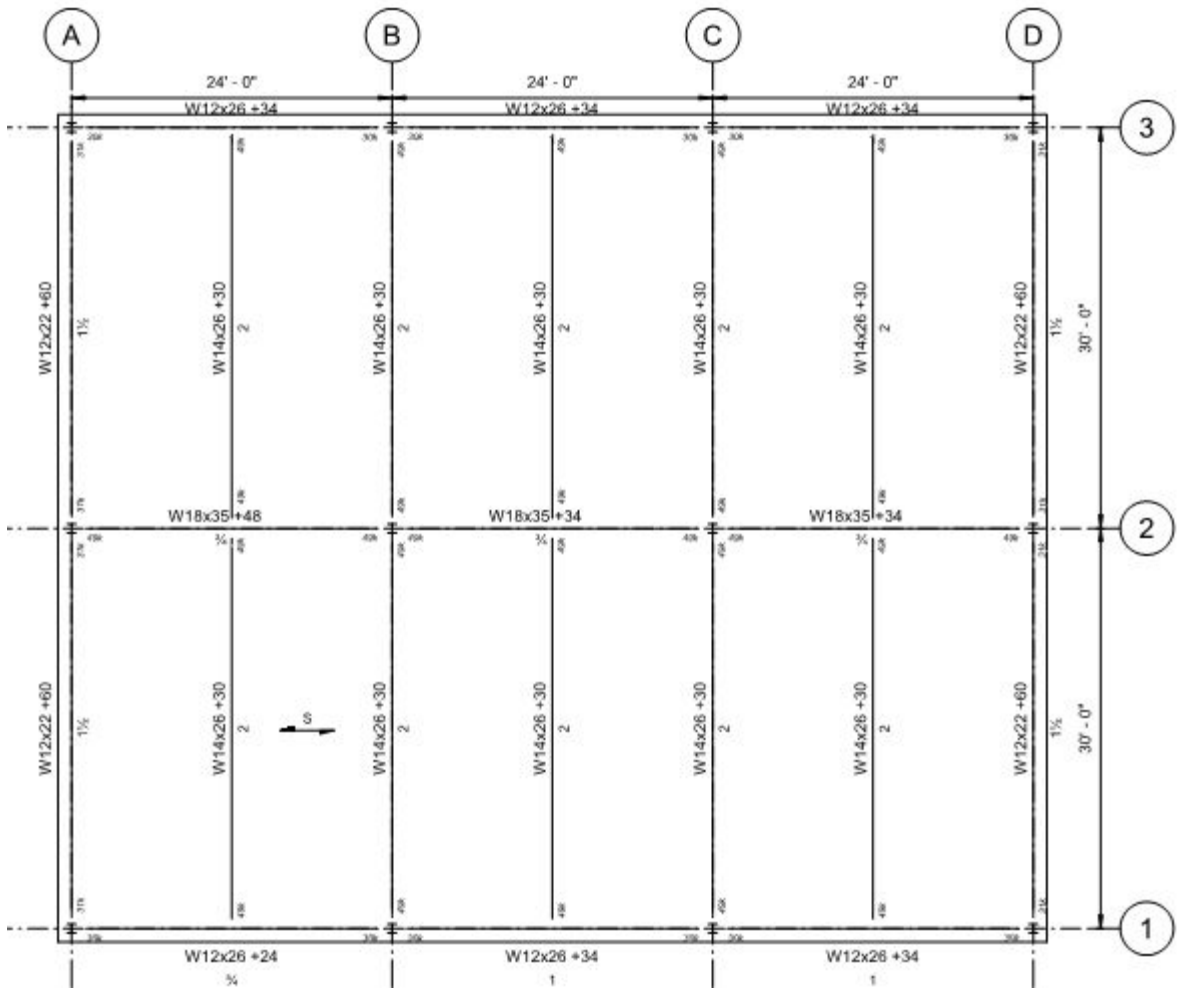
Composite Floor Framing

Maximizing Deck Span



2-Span Deck

Structural Element	Quantity
Structural Steel Pieces	23 (-20%)
Structural Steel	8 T (-12%)
Metal Deck	8 T (+60%)
Concrete topping	80 CY
Concrete reinforcement	3 T
Headed Shear Connectors	846 (-20%)
Connection Angle Pieces	46 (-20%)
Connection Angles	0.20 T (-20%)
Bolts	320 (-35%)
GWP (kg CO2e) [not including bolts, angles, headed shear connectors]	60,684 (+4%)

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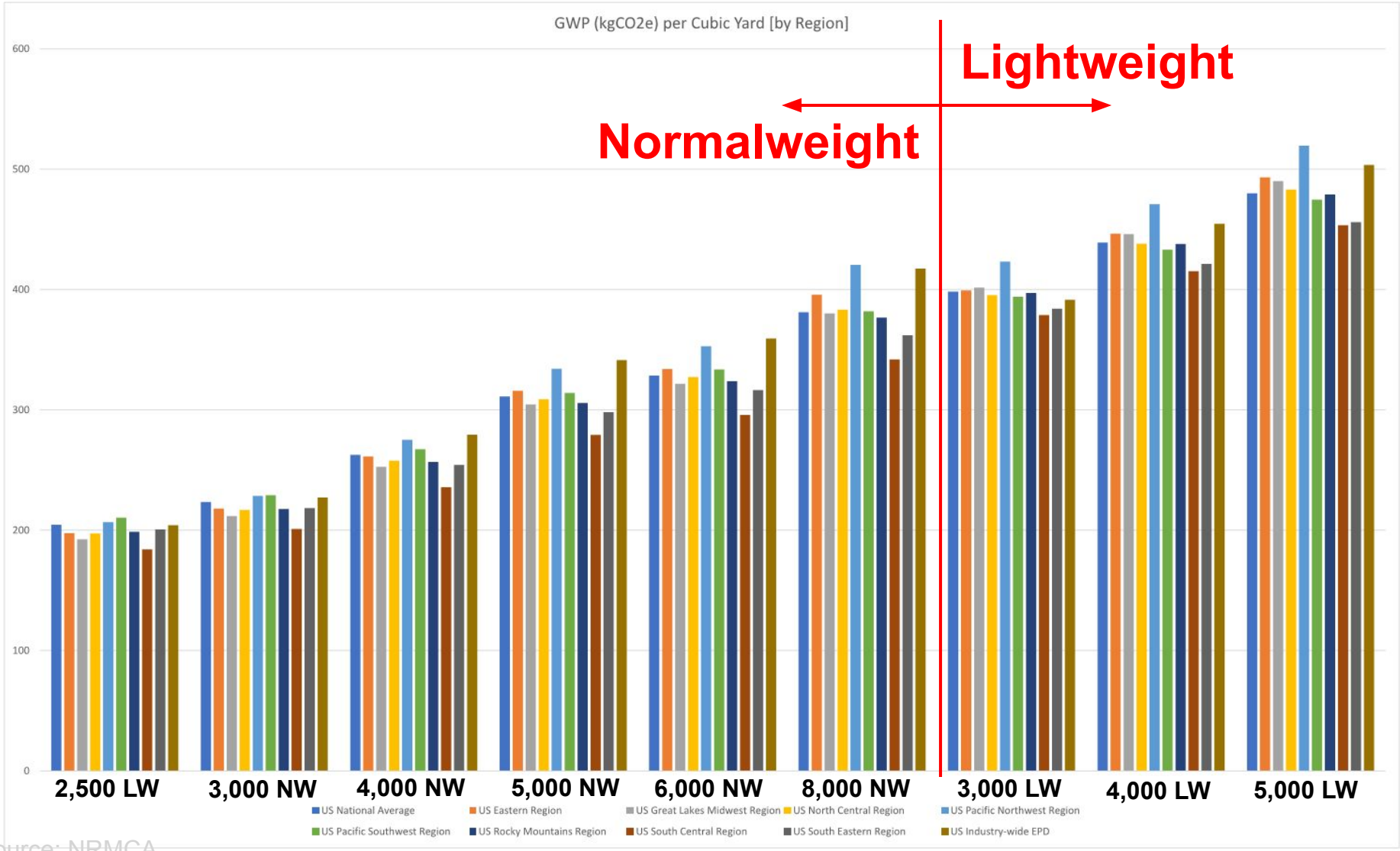
Concrete Topping Matters

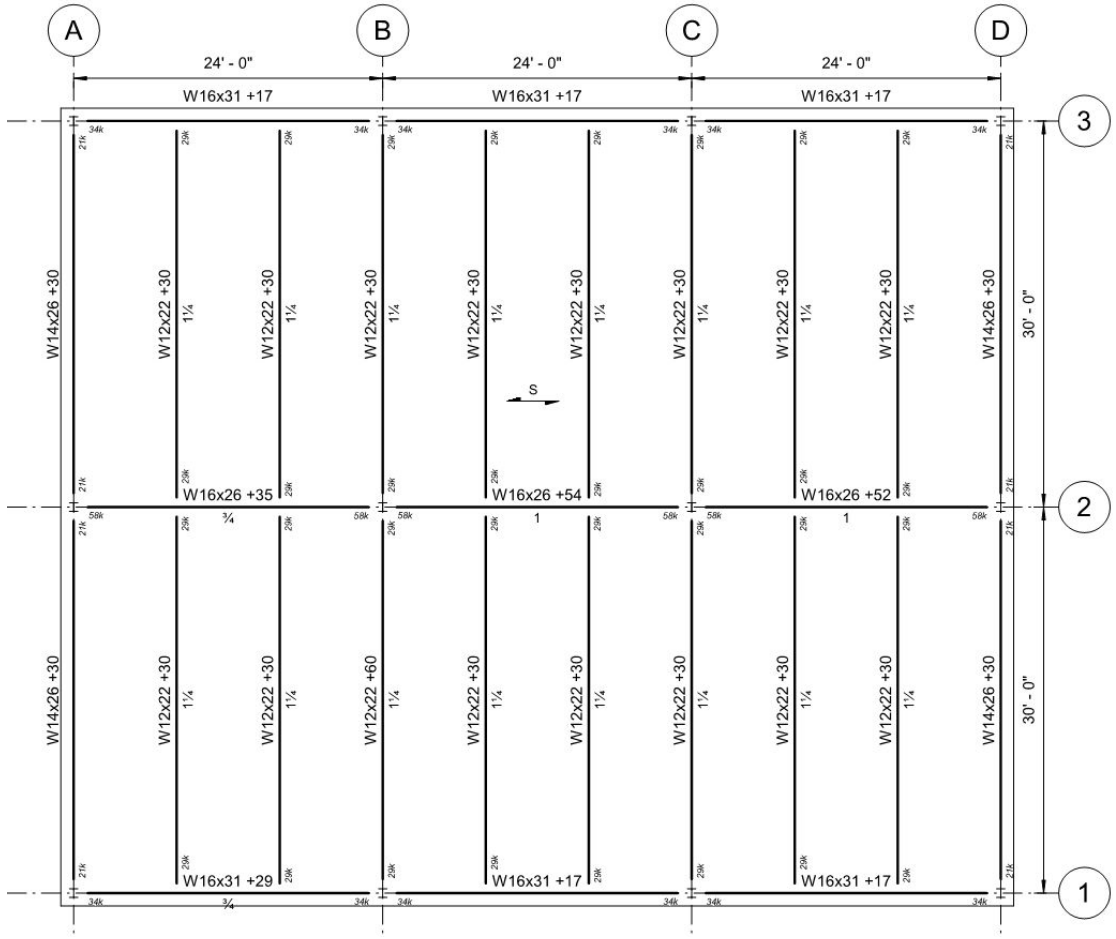
Be Careful with Lightweight Concrete



Source: NRMCA

Concrete Topping Matters

Be Careful with Lightweight Concrete



3-Span Deck – LWC

Structural Element	Quantity
Structural Steel Pieces	29
Structural Steel	10 T (+10%)
Metal Deck	5 T
Concrete topping	80 CY
Concrete reinforcement	3 T
Headed Shear Connectors	858 (-19%)
Connection Angle Pieces	58
Connection Angles	0.26 T
Bolts	486
GWP (kg CO2e) [not including bolts, angles, headed shear connectors]	101,149 (+73%)

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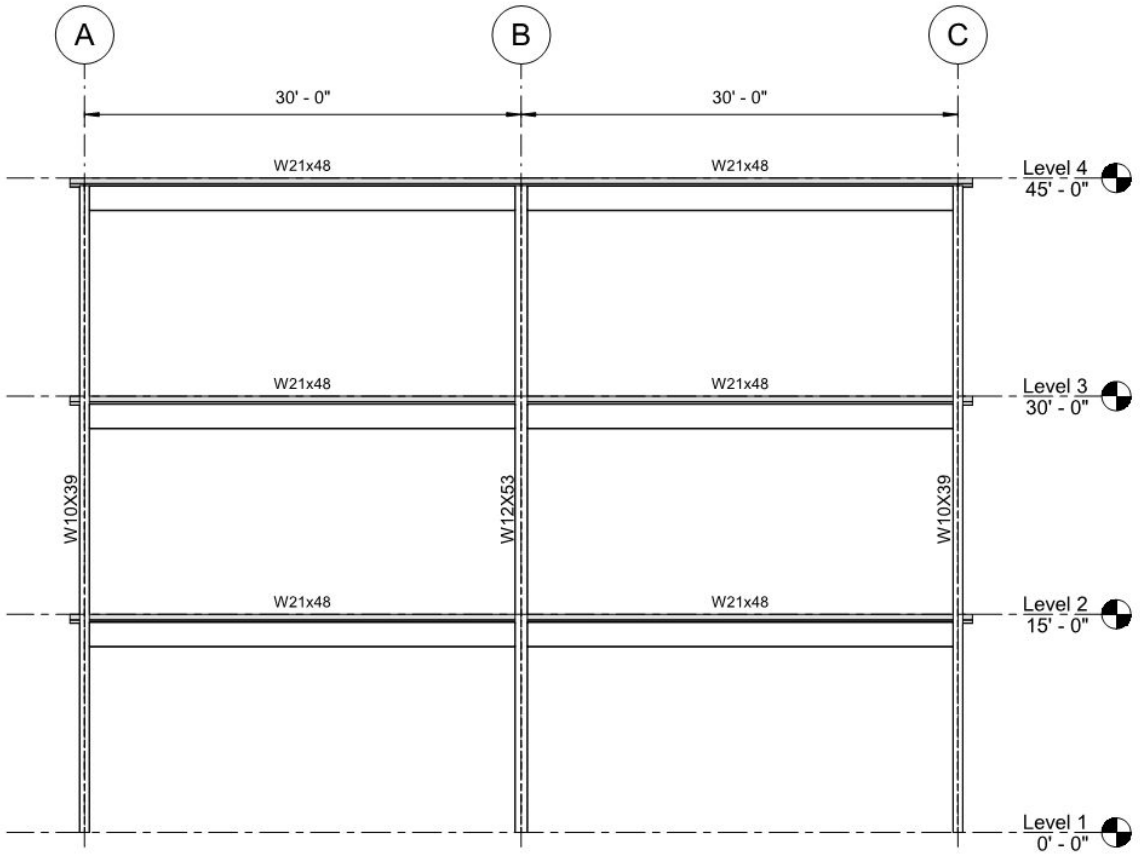
Steel the System

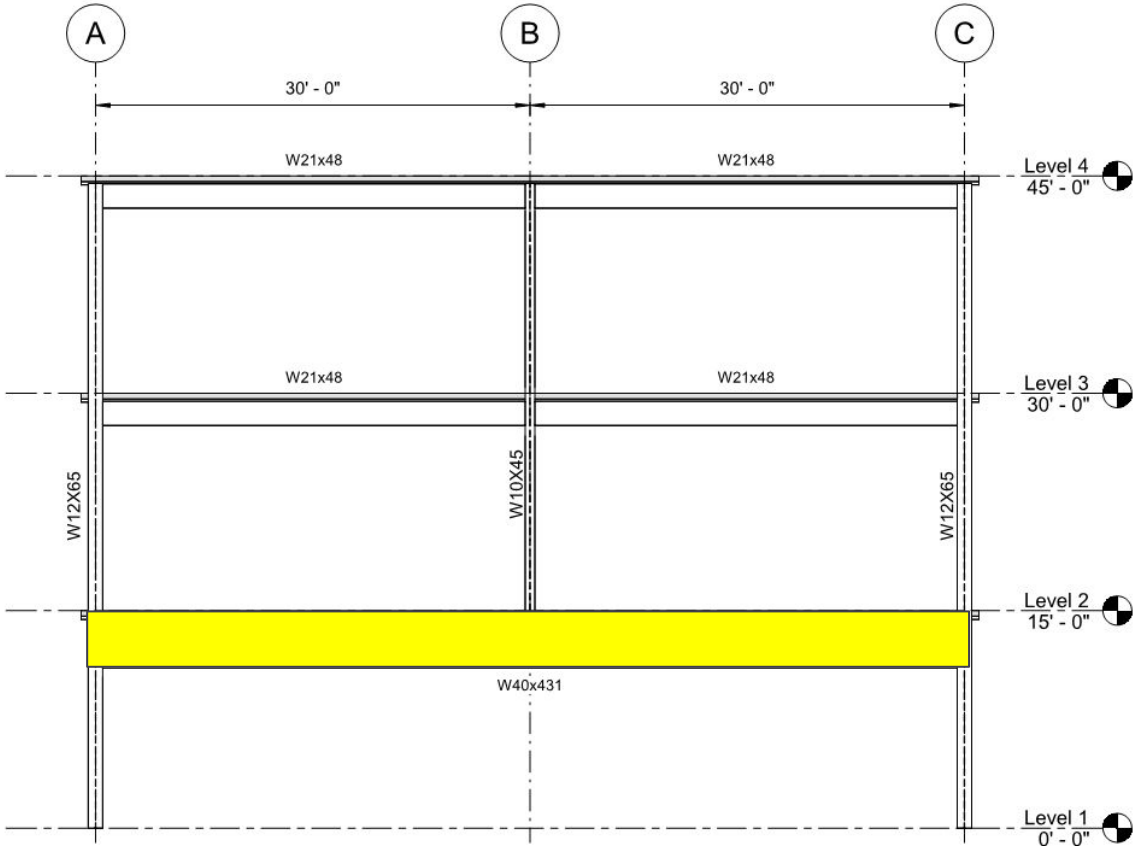
Transfer Girders

No Transfer



Structural Steel	45 T

With Transfer



Structural Steel	57 T

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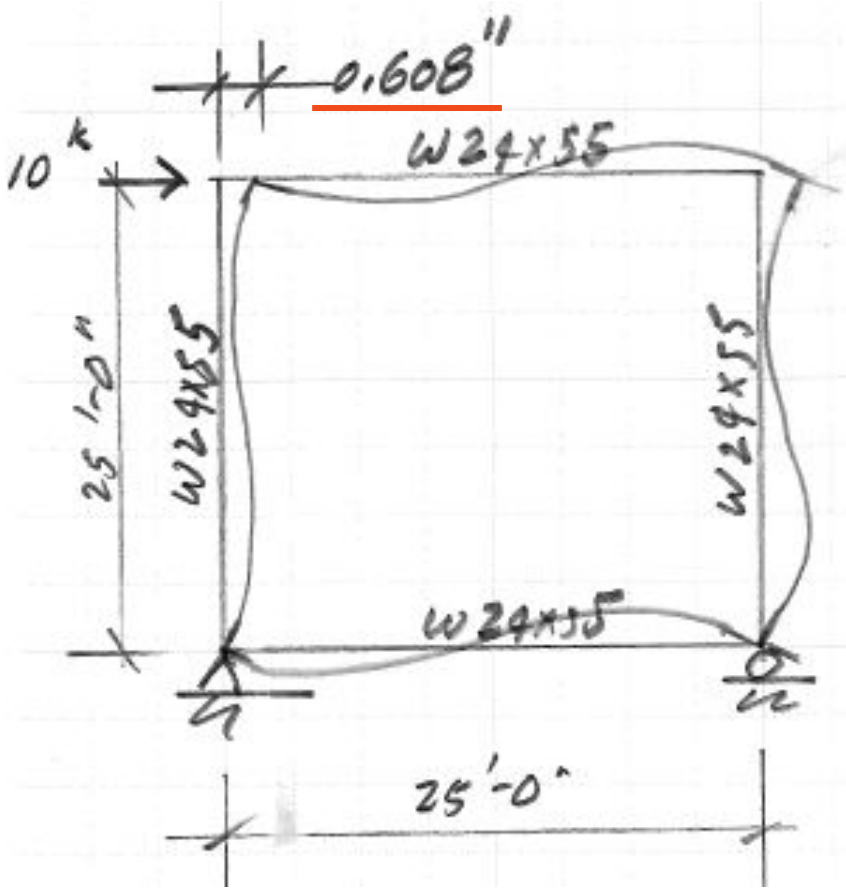
Steel the System

Transfer Girders

Steel the System

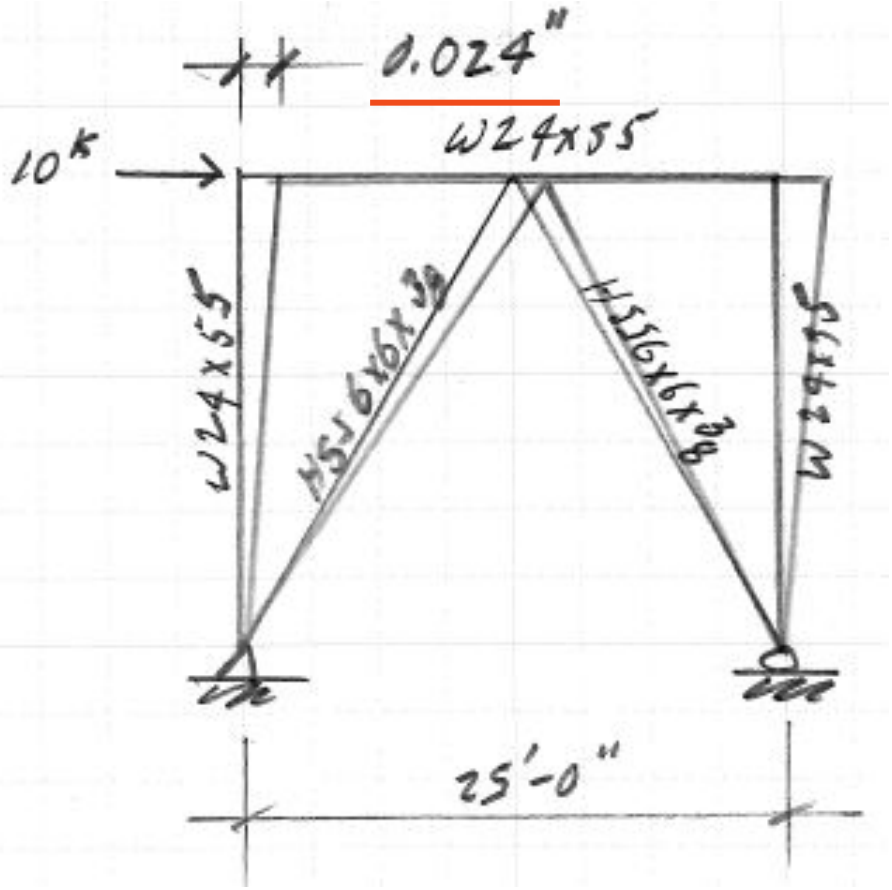
Lateral Force Resisting System Type

Moment Frame



2.80 Tons LFRS Steel

Braced Frame



2.80 Tons LFRS Steel

Steel the System

Cementitious Fireproofing

LeMessurier.

Steel the System

Cementitious Fireproofing

- **Cementitious FP Impact can be substantial**
- **Performance based fire design**
- **Targeted Cementitious FP approach**
- **‘Restrained’ v ‘Unrestrained’**
- **Minor adjustments to end connections**

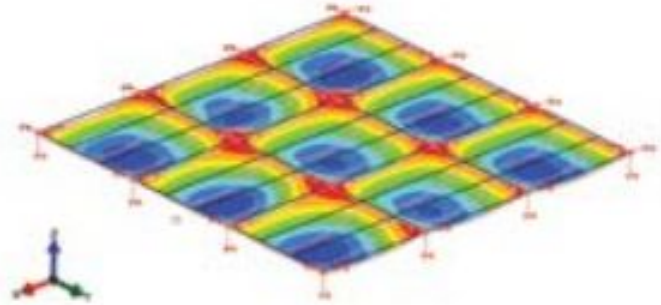
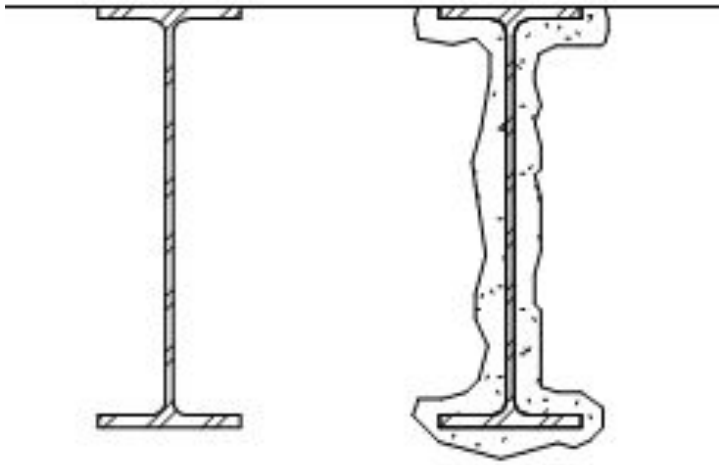


Figure 1 - Modeling Structural Behavior Under Fire Exposure (Vertical Displacement Contour Plot), Simpson Gumpertz & Heger Inc. image

	Standard Fire Resistance Design (circa 1918)	Structural Fire Engineering (circa 2018)
Structural Design	Optimized for Ambient Loads	Optimized for Ambient + **Fire** Loads
Structural Fire Protection Design	**Blanket** Structure with Insulation	**Target** Insulation Where Necessary
Steel Cost	Least Expensive	Slightly More Expensive
Fire Protection Cost	High	Moderate
Total Cost	**High**	**Moderate**
(Design Freedom)	***(Low)***	***(High)***

W18x35



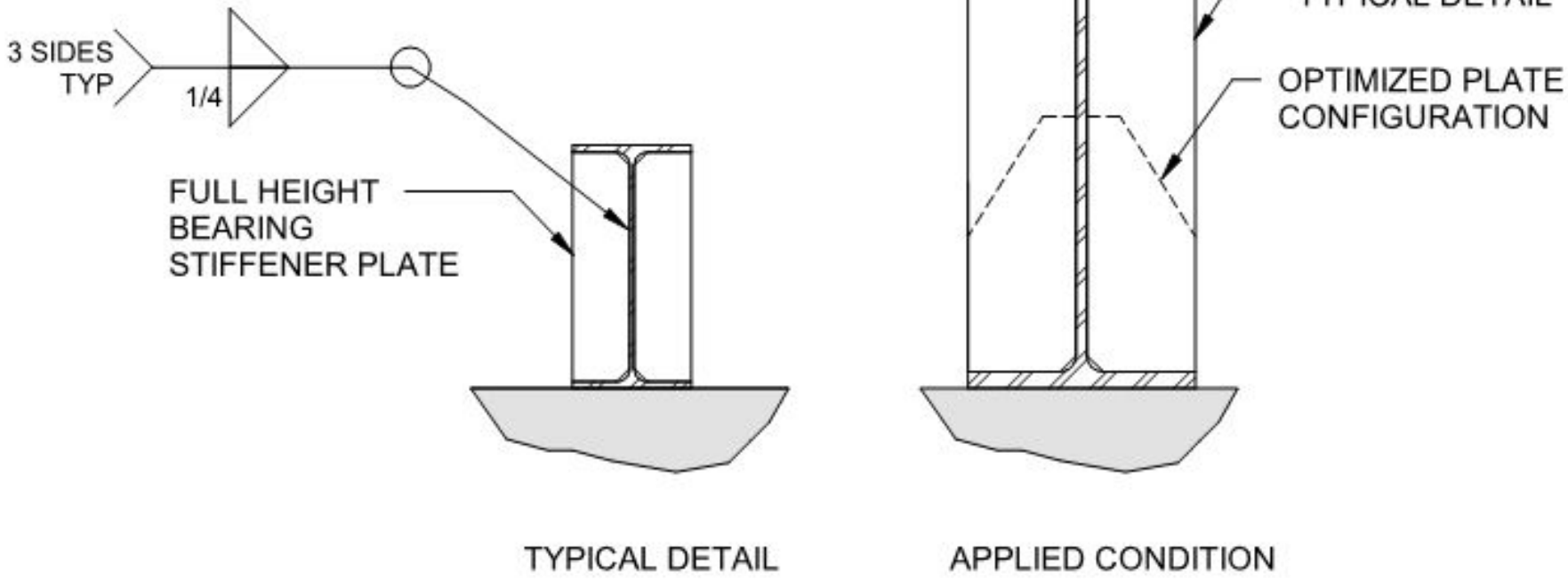
522.0 kg CO2e

770.2 kg CO2e

Source: LaMalvia

Steel the System

Be Aware of 'Typical' Details – They Multiply!



Steel the System

Other Items to Consider

- Building Reuse
- Drift limitations for CW
- Brick deflection limits
- Efficient Grid System
- Precast Façade – Col-to-Col Support
- Performance-Based Wind Design
- Bolts v Welds
- Staggered Truss System
- Explore proprietary moment connections
- Explore open-web steel joists
- Brick relief close to floor levels
- Column splice locations
- Tuned-Mass Dampers
- Castellated Beams
- Placement of LFRS Elements

"There isn't much you can do with Steel Systems"