1300 SYCAMORE

"BUILDING INNOVATION DESIGN ASSISTANCE:
EMBODIED CARBON LIFECYCLE ANALYSIS ASSISTANCE"

GRANT TEAM

Holly Lennihan
Former, Director of Sustainability
HICKOK COLE

Elba Morales
Associate Principal
Director of Design - HICKOK COLE

Kerron Miller
Senior Associate
Sr Project Architect - HICKOK COLE

Linda Toth
Associate
Senior Sustainability Director - ARUP

Spencer Schrandt
Graduate Engineer
Structural - ARUP

Matt O'Malley
Precontruction & Commercial
Market Lead - DPR

TABLE OF CONTENTS

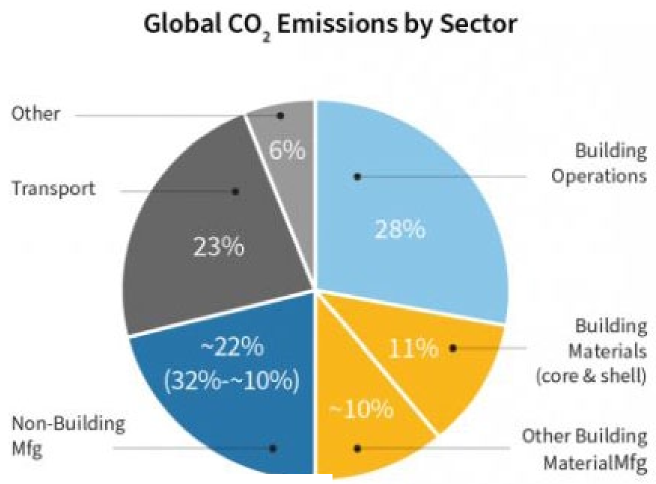
A. WHAT IS EMBODIED CARBON?

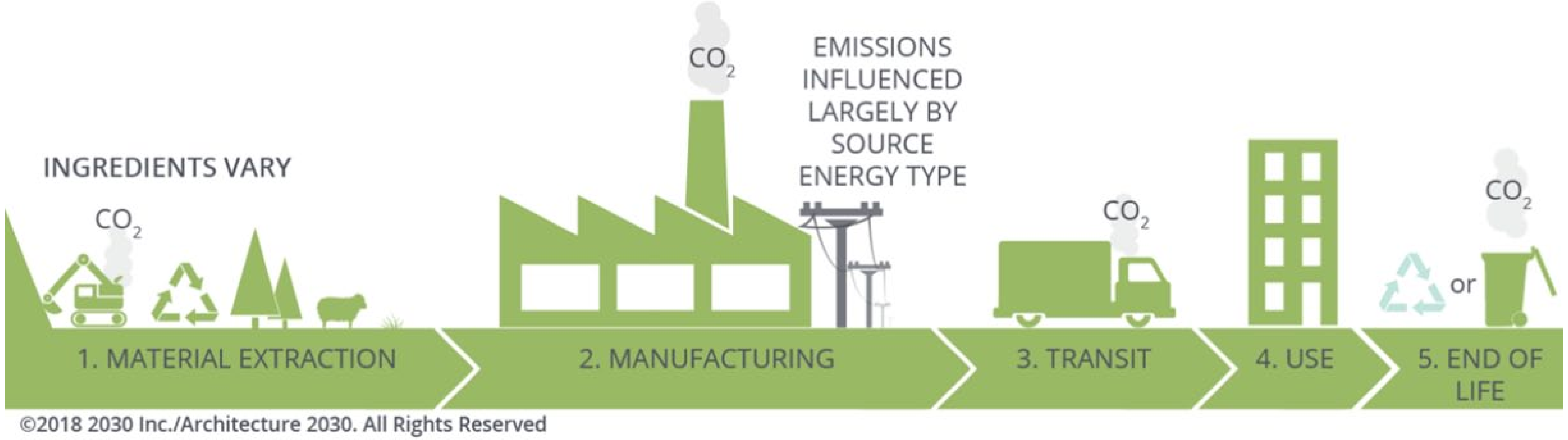
Embodied carbon is a metric of how much carbon is associated with products.

In this graphic, we can see where CO2 comes from, at different stages for concrete.

Embodied carbon is the sum of all of these amounts of CO2 that are produced along the way.

This tells us how much greenhouse gases are released into the atmosphere and how much a project contributes to global warming.





UPFRONT IMPACTS FROM MANUFACTURING, TRANSPORTATION AND INSTALLATION OF CONSTRUCTION MATERIALS

A. **SOURCES OF EMBODIED CARBON**
ACROSS THE CONSTRUCTION LIFECYCLE (EN STANDARD)

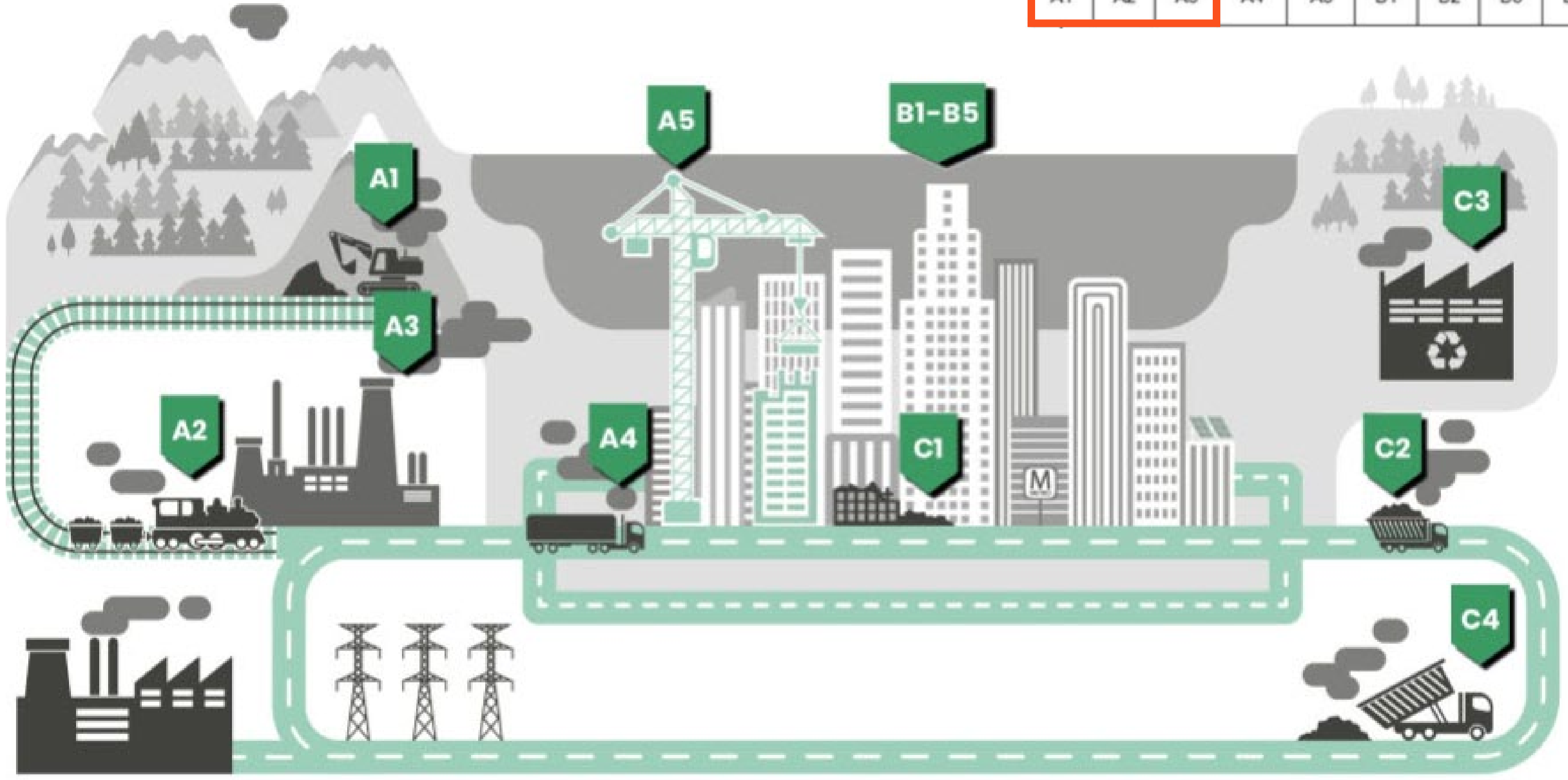
"Building life cycle stages are the different periods of a building's lifetime.

For instance: raw material harvesting, manufacturing of products, use phase of the building, end of life.

In the European markets, the building life cycle stages are defined by EN 15978 and EN 15804 standards, which can be included in LCAs."

SCOPE OF STUDY

Product Stage			Construction Process Stage		Use Stage							End-of-Life Stage				Benefits and loads beyond the system boundary		
Raw material supply	Transport	Manufacturing	Transport to building site	Installation into building	Use/application	Maintenance	Repair	Replacement	Refurbishment	Operational energy use	Operational water use	Deconstruction/demolition	Transport	Waste processing	Disposal	Reuse	Recovery	Recycling
A1	A2	A3	A4	A5	B1	B2	B3	B4	B5	B6	B7	C1	C2	C3	C4	D	D	D



SOURCE: ONE CLICK LCA, https://oneclicklca.zendesk.com/

A. **WHAT IS A "GOOD" LCA?**

LCA AND LEED

LEED v4.1 lays out guidelines for how to get between 1 and 4 points for doing lifecycle assessment of the structure and enclosure.

Greater reduction in environmental impacts means more points.

For all 4 points, LCA would need to show a 20% reduction in CO2 and a 10% reduction in two other categories.

INTENT

"Updates in v4.1 include a greater focus on reducing embodied carbon of buildings structures and enclosures. Changes to this credit are intended to incentivize reuse of existing buildings and components, as well as make building reuse calculations simpler. Further, if buildings or building elements cannot be re-used significantly, changes to the lifecycle analysis option of the credit encourage projects to conduct whole builing life cycle assessment as an integral design component for many more buildings" (source: LEED V4.1 Building Design and Construction)

LEED Life-Cycle Impact Reduction – Up to 4 points

- 4 points – CO2 ⬇20% and two other impact categories ⬇10%
- 3 points – CO2 and two other impact categories ⬇10%

*** For this study, Path 3 should be targeted to reduce at least 3 categories by 10% for 3 points, but further analysis is required**

A. **PURPOSE OF THE GRANT**

VS

1

6 STORIES
- 10'-10", TYP. FLR-FLR HEIGHT
- 24,892 SF, TYP. FLR
- 164,531 SF (INCL. PH)
- BAU CONCRETE
- BOD CWALL / WWALL
- BOD ROOF MEMBRANE

2

6 STORIES
- 10'-10", TYP. FLR-FLR HEIGHT
- 24,892 SF, TYP. FLR
- 164,531 SF (INCL. PH)
- LOW CARBON CONCRETE
- LOW CARBON CWALL / WWALL
- LOW CARBON ROOF MEMBRANE

3

5 STORIES
- 13'-0", TYP. FLR-FLR HEIGHT
- 27,545 SF, TYP. FLR
- 157,760 SF (INCL. PH)
- CLT STRUCTURE
- LOW CARBON CWALL / WWALL
- LOW CARBON ROOF MEMBRANE

A. PURPOSE OF THE GRANT
& ACTIVITIES FUNDED

TARGET AUDIENCES

The target audiences for this project include the owners and project team designing and constructing the building, District non-profit real estate developers, the District government, the design and construction industry and affiliated non-profits, such as the Building Innovation Hub and DC/MD/VA Net-Zero Energy Coalition

1

Attachment 1: Activities Funded

Grantee: Hickok Cole Architects, Inc.
Grant number: #2021-2101-USA-4
Grant Name: Building Innovation Design Assistance – Embodied Carbon Lifecycle Analysis Assistance

This grant funds the following grantee activities for the following property and target populations. The property is Building Number 2 on Parcel 17 at the Saint Elizabeth's campus.

A. Target Population

The target audiences for this project include the owners and project team designing and constructing the property, District non-profit real estate developers, the District government, the design and construction industry and affiliated non-profits, such as the Building Innovation Hub and DC/MD/VA Net-Zero Energy Coalition.

B. Specific Service Requirements

Activity #1 – Provide a training session

a. Prior to start of the grant work, Hickok Cole Architects, Inc. will providea training session on the "One Click LCA" software for the property's owners and design and construction team.

Activity #2 – Facilitate a working session for the property's owners and design and construction team, the outputs of which include:

a. Provide a venue and event for open discussion with the property's structural engineer, general contractor and owners;
b. Define the building assembly options including how, if at all, they affect the current plan layout;
c. Create architectural background drawings and model in the Revit software;
d. Generate a conceptual LCA using Revit inputs with generic assumptions, adding the scenarios as variables;
e. Compare to the business as usual scenario by compiling a list of the alternate, lower carbon materials needed in each of the scenarios identified; and
f. Package working session documentation with a materials matrix, for the purpose of pricing.

Activity #3 – Pricing exercise

a. Generate cost comparisons between the three structural floor assembly options; and
b. Review pricing with the design team and the client.

Activity #4 – Wrap Up Session

a. The grant team will conduct a final conversation among key project team members prior to submission of the grant final report to DOEE; and
b. The conversation will result in a list of key takeaways and next steps for use of the LCA among the project team members during the balance of their project. The grantee will include the list in the final report.

Activity #5 – Report on work performed and results

a. Meet with DOEE staff monthly to discuss project progress;
b. Submit a Work Plan by the end of the third (3rd) week after the Grantee is notified of the award. See Attachment 2 for the format;
c. Provide a Progress Report for the preceding quarter in accordance with the standardized progress-reporting template (Attachment 3) by July 15;
   i. The Grantee shall attach to the Progress Report a revised Work Plan if requested;
   ii. Comply with the tracking and reporting requirements of the DC Language Access Act of 2004 by submitting the LEP/NEP Data Collection Sheet (Attachment 6)
d. Provide DOEE a draft Final Report in Microsoft Word format, (See Attachment 4) two (2) weeks before the end of the grant period:
   i. The following information should be included:
      1. A clear listing of the activities conducted and an evaluation of their effectiveness in supporting the project's pursuit of lower embodied carbon;
      2. Documentation confirming that the activities have been completed prior to the end of the grant period.
      3. Details on the activities conducted to support a case study;
      4. A basic proforma project budget, if completed as part of this analysis;
      5. A copy of the energy model outputs, if completed as part of this analysis; and
      6. Status of the development project and anticipated completion date.
   ii. Receive and review DOEE's comments and redraft accordingly; and
   iii. Submit the Final Report within two (2) weeks after the expiration of the grant period.

Activity #6 – Maintain good practices.

a. Maintain electronic mail (email) capabilities;
b. Observe proper and safe cybersecurity practices, particularly with respect to materials and communications to be shared with the District Government; and
c. Periodically review Appendices to the RFA, for continuing terms and conditions and for continuing promises, certifications, assertions and assurances.

Filename: 00 5296 att. 1 - activities funded_hickok coleec.docx

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B. EXECUTIVE SUMMARY

This grant team is committed to advance our knowledge of high performance design. In this case, we sought to quantify the embodied carbon in a current project and analyze the cost implications.

At this moment, all of us working in the builtt environment, must quickly learn how to lessen the impact of what we do. This grant is one important step in helping us adopt a more nuanced means of selecting the systems and materials that we put into our buildings.

As building efficiency becomes better, our focus shifts toward the amount of energy that goes into the building materials and systems. The main goal of this study is to investigate the embodied energy in the structure and envelope of a new, speculative commercial office building on Parcel 17 of the St. Elizabeths Campus.

The grant team includes: Hickok Cole, Arup, and DPR Construction

METHODOLOGY: THE ADVANTAGE OF EARLY ANALYSIS

The grant team analyzed and priced 3 alternates:

(1) design 1 reflects the embodied carbon in the cast-in-place (CIP) post-tensioned (PT) concrete structure, and the basis of design envelope systems.

(2) design 2 studies a low carbon concrete and a low carbon envelope.

(3) design 3 includes cross-laminated timber (CLT) as an alternate structure, and proposes the same low-carbon envelope as design 2.

The Hickok Cole and Arup teams input the system assemblies, material selections, and areas onto a life cycle carbon software (OneClick LCA) to analyze the embodied carbon impact of the design selections.

This software allows for analysis at a very early stage in the design process when teams need the agility to make multiple system and material comparisons for selection.

The basis of design scheme is at a 50% Schematic Design level, while the CLT scheme is at a Concept/Massing level of development.

DPR provided a cost estimate for the LCA data. The grant team sought to determine whether there is a cost premium for the lower embodied carbon materials. Cost is always a consideration and could be a determinant in the specification of materials with lower greenhouse emissions.

ARUP

The structural materials in the LCA consist of concrete, rebar, structural steel and mass timber components. The baseline structure includes concrete mixes aligned with regional National Ready Mix Concrete Association environmental product declarations and rebar with 97% recycled content, which is typical of rebar in the United States.

Alternatives designs included swapping the concrete mixes for low carbon design mixes with higher supplementary cementitious materials (SCMs) such as slag and fly ash, and a mass timber design and the low carbon concrete mixes. Mass timber inputs used Nordic, and accounted for impacts from the manufacturing facility in Quebec.

- Low carbon concrete mix designs increase the slag and fly ash quantities by 20% to reduce the amount of cement.
- Most greenhouse gas emissions from structural materials occur during the product life cycle stage (A1-A3) that includes raw material extraction, transportation to factory and manufacturing. The mass timber option does have greatly reduced product lifecycle emissions but has significantly higher end of life (C1-C4) impacts.
- Efforts to reduce embodied carbon should focus on material replacement with lower-embodied carbon, and potentially carbon storing materials.

Overall, the baseline structure contains 2.5 million kg CO_2e. The low carbon concrete option provides an opportunity for a 17% reduction, while the mass timber option reduces further for a total of 32% as compared to the baseline.

HICKOK COLE

The base scheme (design 1) includes:
(a) Kawneer window wall (aluminum-framed window system supported at each slab edge), and curtain wall (aluminum framed system that bypasses the slab edge);

(b) insulated aluminum metal panels at the slab edges, as vertical design elements in the facade, and as the primary cladding for the penthouse walls;

(c) hot-fluid applied membrane roofing

Garage doors were not available in the OneClick data set and were included as additional metal panel.

As a means to test how a different material selection can change the amount of embodied carbon, an alternate selection was made for the curtain wall and window wall systems, as well as for the roofing membrane. The delta is illustrated clearly in the tabulations and graphs.

A. EXECUTIVE SUMMARY
CONTINUED

DPR provided a cost estimate for the LCA data. The grant team sought to determine whether there is a cost premium for the lower embodied carbon materials. Cost is always a consideration and could be a determinant in the specification of materials with lower greenhouse emissions.

OBSERVATIONS
The following are observations about using an embodied carbon calculator, specifically One Click LCA:

- This software's data set is skewed toward Europe where it was developed, but the company is working toward collecting EPD's for products used in the US.
- The ability to compare --with the click of a mouse-- the embodied carbon content between building envelope systems and elements, is an invauable tool and one which architects and engineers must leverage now.
- Design teams should strongly encourage that the manufacturers of products and systems we specify, provide embodied carbon data in this platform.

DPR CONSTRUCTION
DPR Construction provided cost and schedule analysis for the structural options on the DOEE Grant effort.

Embodying its ever forward spirit, DPR Construction has utilized mass timber on a number of projects. As with any new technology, there exists a component of "learning by doing," and mass timber is no exception. DPR has collected some valuable lessons learned from the people doing the actual work of building mass timber projects, lessons that fall into these categories: Design, Procurement and Operational Considerations.

MASS TIMBER VS CIP CONCRETE
In preparation of the cost analysis, DPR was provided with the structural narratives for the options prepared by ARUP. Our preconstruction team pulled quantities from the Revit model and performed traditional 2D quantity survey to ensure that the structural components were properly quantified.

The HCA/ARUP design took into account a slightly different building configuration for the Mass Timber option vs the CIP concrete option. The CIP option was 6 levels above grade with a penthouse, and the Mass Timber option was 5 levels with a penthouse. The floor plates were slightly different, which yielded an overall GSF that was approximately the same in each option. ARUP detailed the variance in footing sizes (footings were smaller for the timber option because the structure is lighter), and this was considered in our cost analysis. We also reviewed the skin area and found that the variance between the two options was minimal. There are more floors but a shorter floor to floor height in the CIP option.

DPR also engaged several trade partners for pricing input for both the CIP structure and the Mass Timber Structure. Hardesty Concrete provided pricing for the concrete option, and Nordic Structures provided and estimate for the Mass Timber Structure. DPR reviewed and compared quantities with each of the trade partners to ensure and accurate estimate.

The result was an approximate cost premium of $20/GSF for the Mass Timber structure over the CIP Concrete Structure. This was based on the quantity survey and trade partner pricing that is described above.

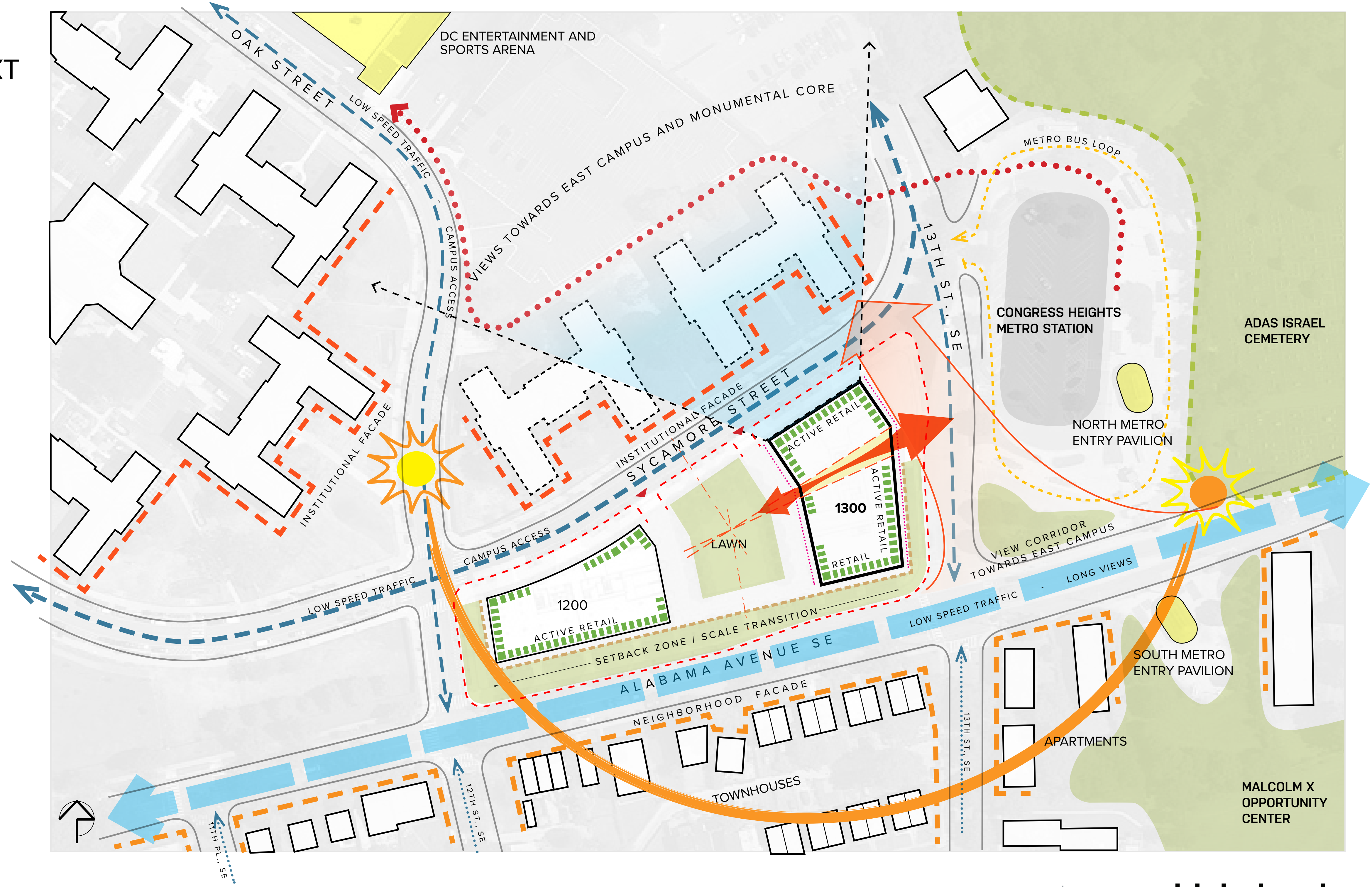
The premium was somewhat larger than the team anticipated. This is largely due to rapid material cost escalation over the past 6 months in the timber and wood products. While pricing has stabilized, there has been significantly more cost escalation in wood products than cast in place concrete. This is reflected in the result.

We do think that with additional study of the timber configuration and working with a supplier such as Nordic, we could explore options to reduce the cost of the timber option and ultimately narrow that gap.

C. SITE
PARCEL 17, IN CONTEXT

C. SITE

PARCEL 17, IN CONTEXT



E. **STRUCTURAL ELEMENTS**

QUANTITIES FOR CONCRETE + CLT OPTIONS

When comparing the material inputs, it's key to note that low carbon concrete has the same quantities as the BAU option.

The only difference is that the mix designs for the low carbon concrete have higher SCM quantities to offset the amount of Portland cement.

The CLT option takes advantage of the low carbon concrete for its design and that the amount of concrete and steel decrease by 50%.

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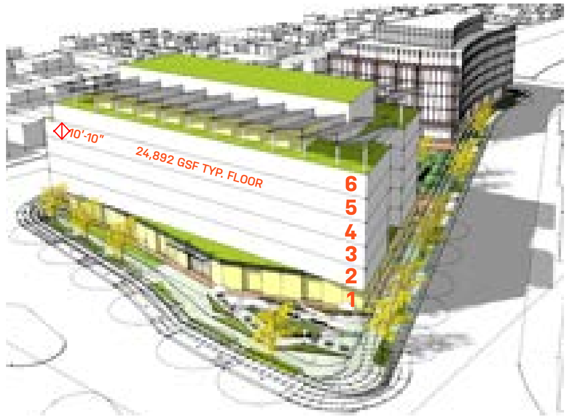

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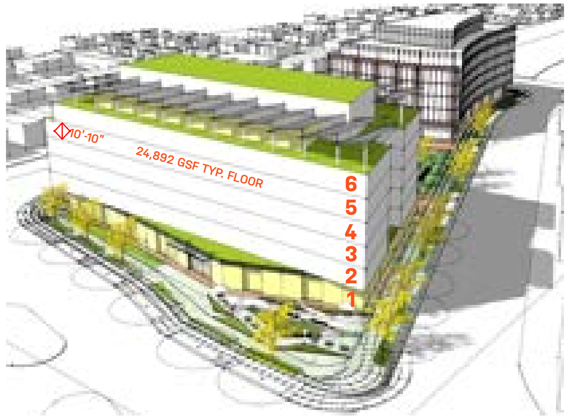

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Material	BAU Concrete Basis of Design	Low Carbon Concrete	Mass Timber
Concrete, CY	10k	10k	5k
Steel, lbs	1M	1M	400k
Timber, CY	--	--	6k

CY = cubic yards
BAU = business as usual

E. **STRUCTURAL ELEMENTS**

LOW CARBON CONCRETE MIX

LOW CARBON CONCRETE

The low carbon concrete mixes used for this study have 20% higher GGBS than BAU ("business as usual") mix design.

Conc. Mix Strength	4000 psi	5000 psi	6000 psi	8000 psi	6000 ES
Portland Cement	380	468	496	597	645
Fly Ash	47	59	62	75	0
Slag Cement (GGBS)	177	218	231	278	161
Mixing Water	171	177	192	192	293
Coarse Aggregate	1634	1552	1602	1520	1539
Fine Aggregate	1345	1278	1318	1251	1302

ALL MEASURED IN PCY (POUNDS PER CUBIC YARD)

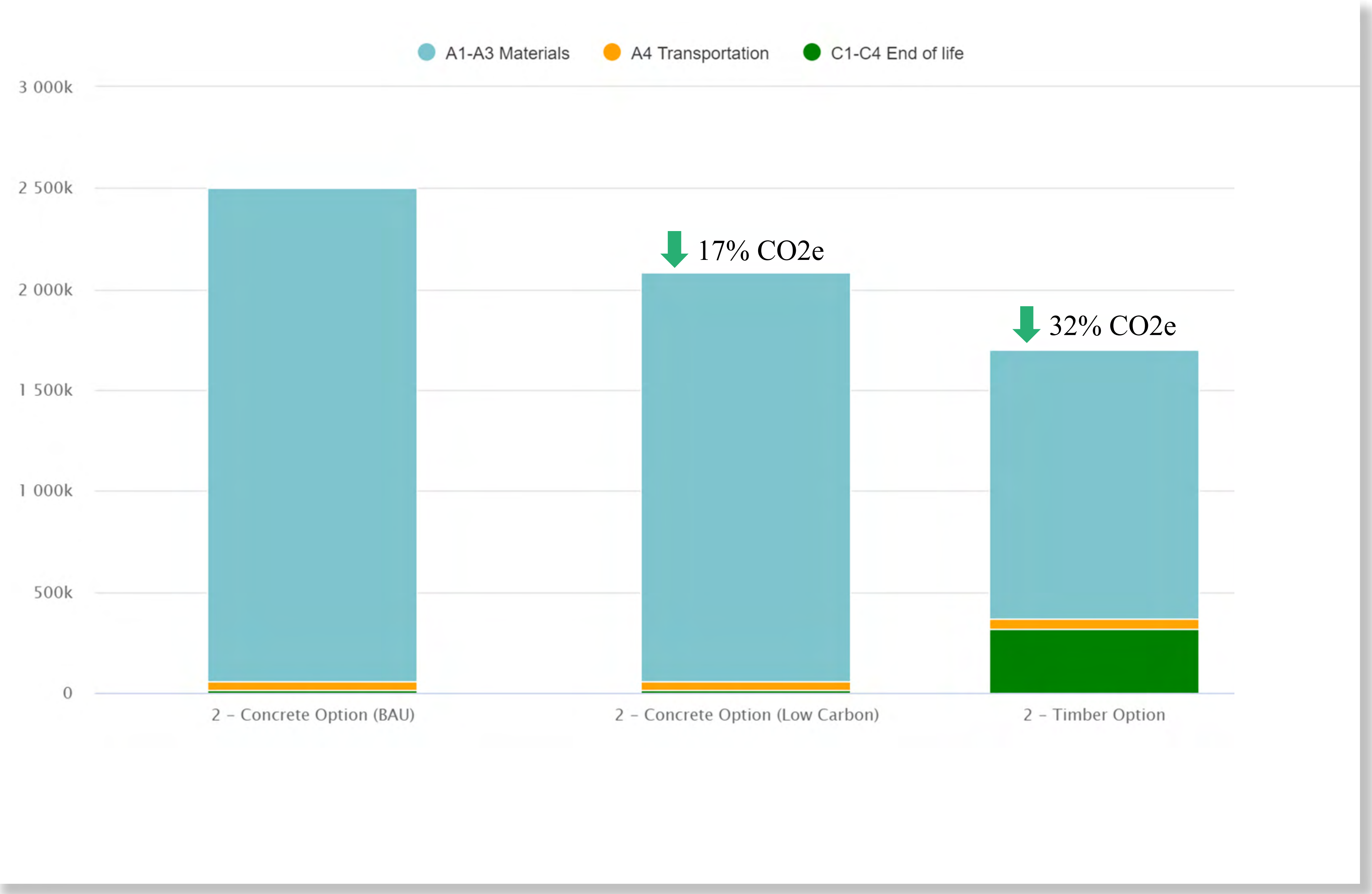
E. STRUCTURAL ELEMENTS

ONE CLICK LCA RESULTS

The low carbon concrete decreases the embodied carbon by 17% when compared to BAU.

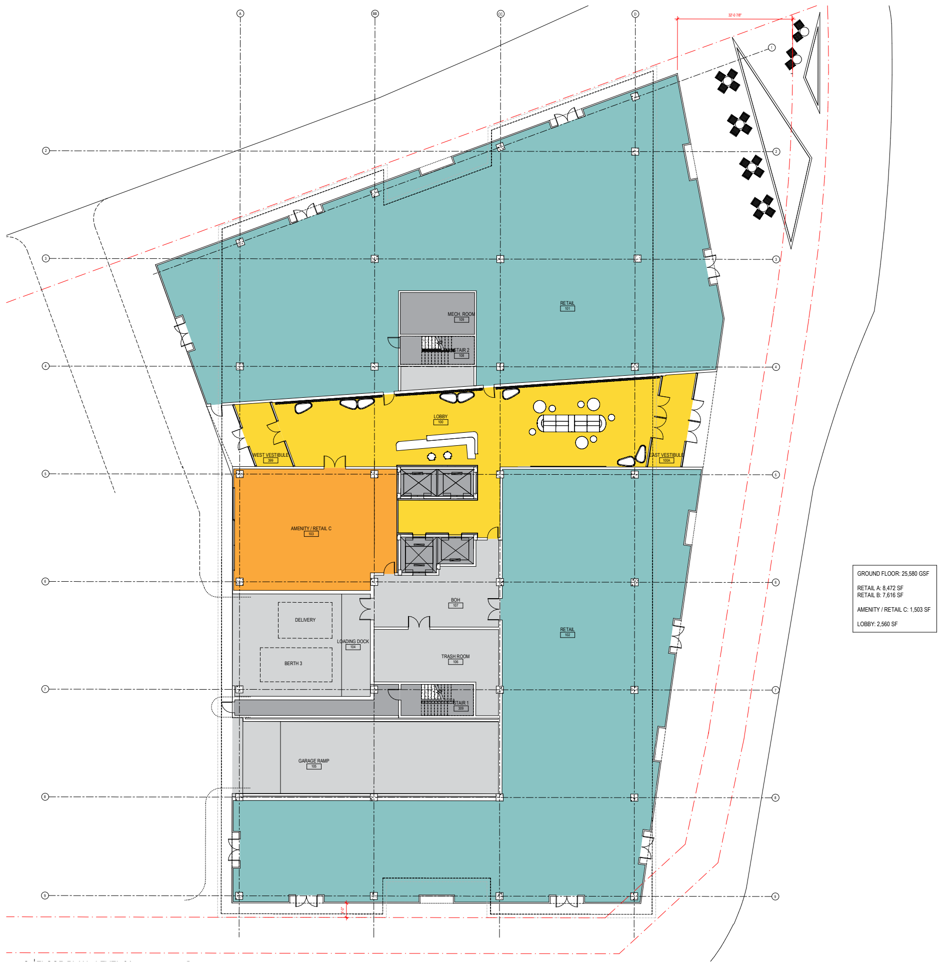
The C02 reduction from the CLT is nearly double that.

It is important to note that sequestered carbon is not substracted from the building's embodied carbon. This is indicated by the "end of life" region.

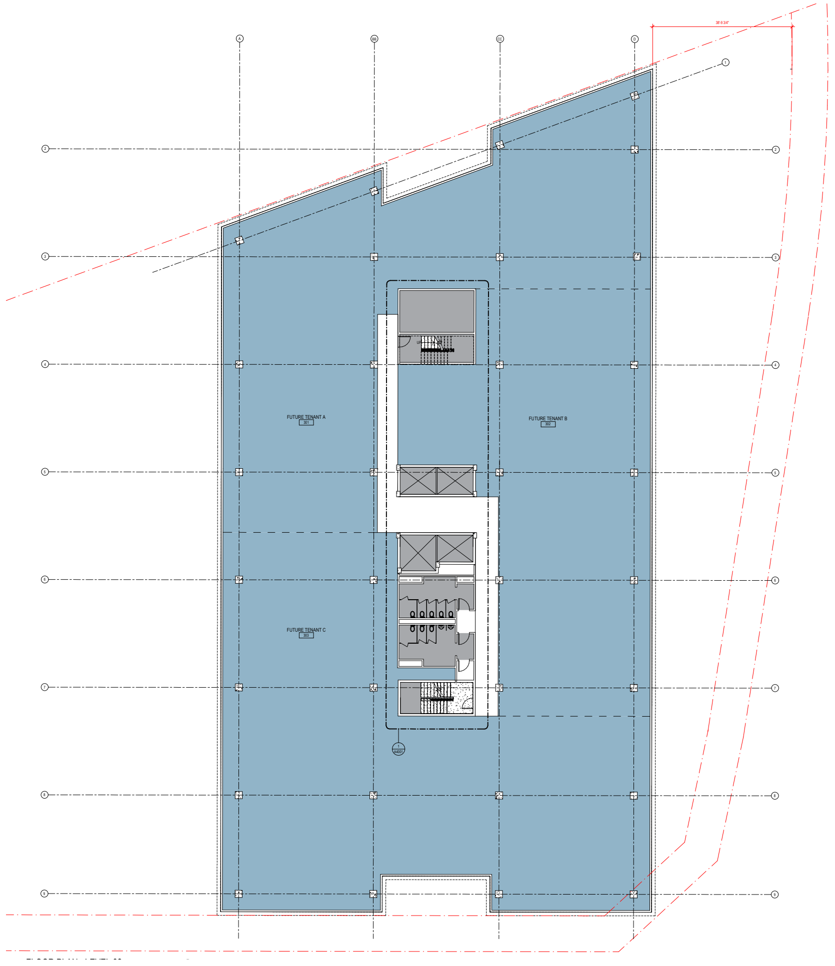


D. **ARCHITECTURAL ENVELOPE**

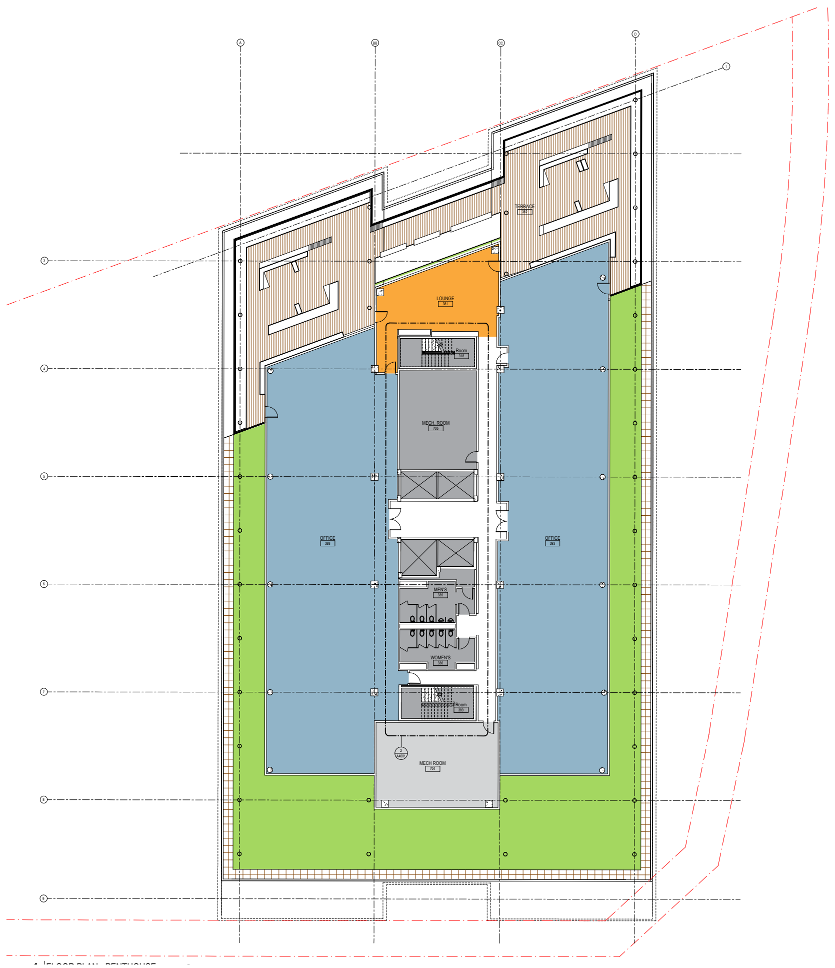
BASE SCHEME (& LOW CARBON CONCRETE), FLOOR PLANS



GROUND FLOOR



TYPICAL FLOOR: 2ND - 5TH



PENTHOUSE FLOOR

D. **ARCHITECTURAL ENVELOPE**
FACADE - DELINEATION OF ELEMENTS

GENERAL NOTES:

1. CW-1, WW-1 AND THE METAL PANEL WERE ALL INPUT INTO ONE CLICK LCA.

2. THE GROUND FLOOR WAS TREATED AS A SINGLE ELEMENT, NAMELY CW-1 AND METAL PANEL. NO OVERHEAD DOOR EXISTED IN THE ONE CLICK DATA BASE.

EAST ELEVATION

D. **ARCHITECTURAL ENVELOPE**

FACADE - DELINEATION OF ELEMENTS

WEST ELEVATION

GENERAL NOTES:

1. CW-1, WW-1 AND THE METAL PANEL WERE ALL INPUT INTO ONE CLICK LCA.

2. THE GROUND FLOOR WAS TREATED AS A SINGLE ELEMENT, NAMELY CW-1 AND METAL PANEL. NO OVERHEAD DOOR EXISTED IN THE ONE CLICK DATA BASE.

D. ARCHITECTURAL ENVELOPE

FACADE - DELINEATION OF ELEMENTS

NORTH ELEVATION

GENERAL NOTES:

1. CW-1, WW-1 AND THE METAL PANEL WERE ALL INPUT INTO ONE CLICK LCA.

2. THE GROUND FLOOR WAS TREATED AS A SINGLE ELEMENT, NAMELY CW-1 AND METAL PANEL. NO OVERHEAD DOOR EXISTED IN THE ONE CLICK DATA BASE.

D. ARCHITECTURAL ENVELOPE

FACADE - DELINEATION OF ELEMENTS

SOUTH ELEVATION

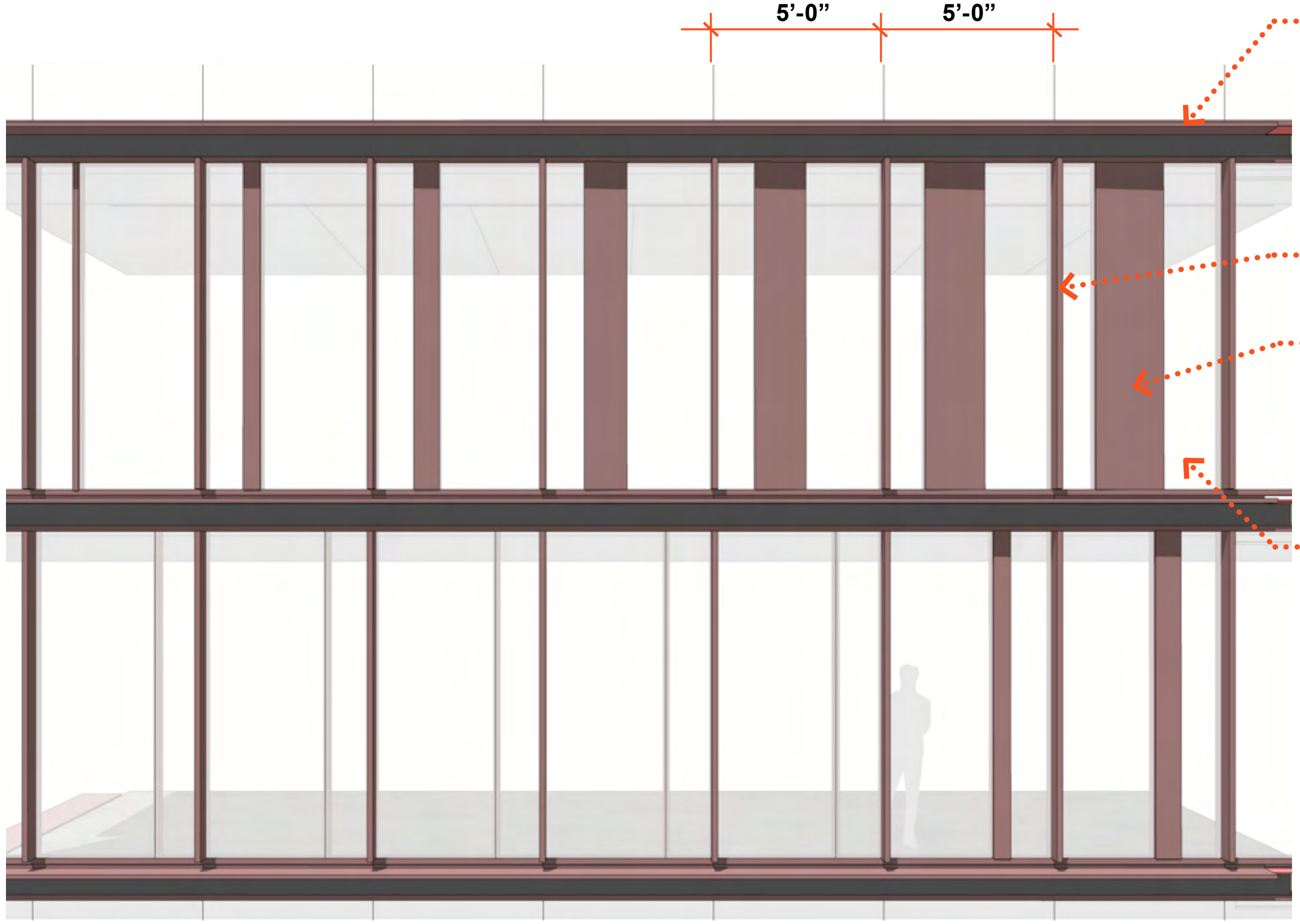
GENERAL NOTES:

1. CW-1, WW-1 AND THE METAL PANEL WERE ALL INPUT INTO ONE CLICK LCA.

2. THE GROUND FLOOR WAS TREATED AS A SINGLE ELEMENT, NAMELY CW-1 AND METAL PANEL. NO OVERHEAD DOOR EXISTED IN THE ONE CLICK DATA BASE.

D. ARCHITECTURAL ENVELOPE

QUANTIFYING WINDOW WALL + METAL PANEL



ENLARGED, TWO-STORY ELEVATION

8" PT CONCRETE SLAB

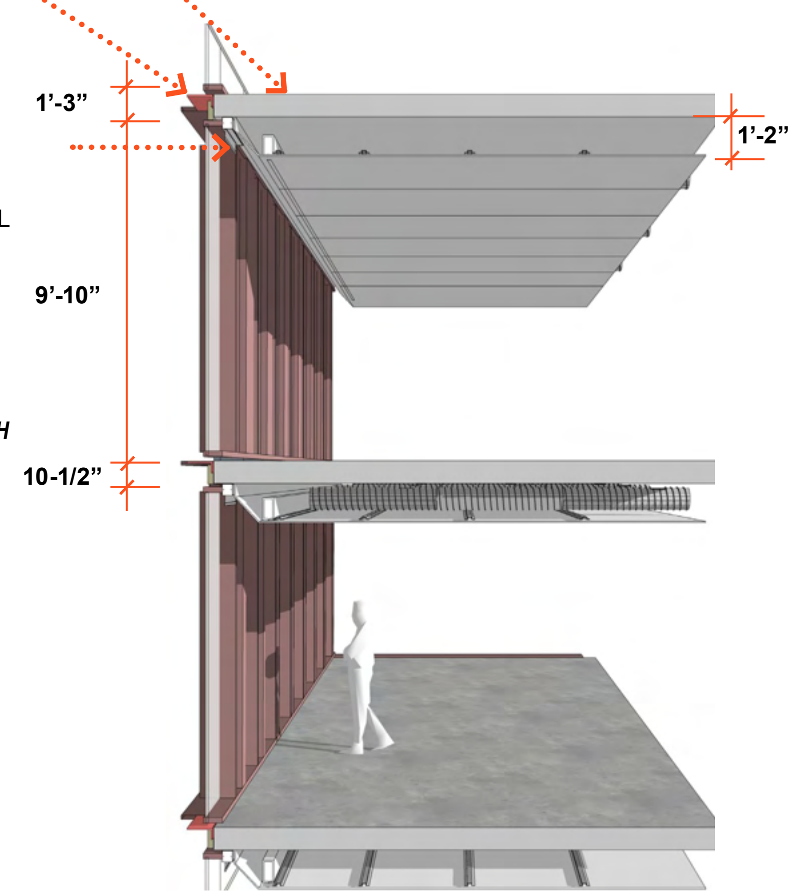
12" DEEP ALUMINUM BRAKE METAL SLAB EDGE COVER

SUSPENDED CEILING WITH EDGE POCKET FOR ROLL UP SHADE

7.5" DEEP SNAP CAP ON VERTICAL MULLION OF WINDOW WALL

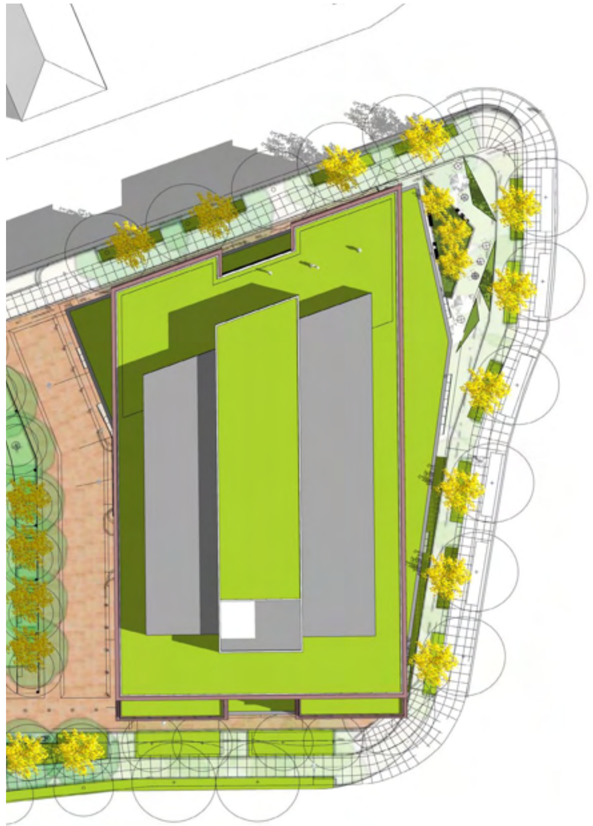
FLAT PLATE ALUMINUM METAL PANEL (WIDTH VARIES: **2'-6"** AT WIDEST).
TO FACILITATE ONE CLICK LCA INPUT, THIS MATERIAL WAS SUBSTITUTED WITH A CENTRIA WALL PANEL.

2-SIDED SSG WINDOW WALL (SIMILAR TO KAWNEER METROVIEW FG 601T PW SSG), WITH 1 IN. LOW-E, CLEAR IGU, FT (SIM. TO VNE 1-63 BY VIRACON)



ENLARGED, SECTION- PERSPECTIVE

D. ARCHITECTURAL ENVELOPE
BASE SCHEME



ROOF PLAN VIEW

FROM NORTHEAST CORNER

D. ARCHITECTURAL ENVELOPE
PENTHOUSE ARTICULATION

METAL WALL PANEL: FLAT PLATE, ALUMINUM, CONCEALED FASTENERS
TO FACILITATE ONE CLICK LCA INPUT, THIS MATERIAL WAS SUBSTITUTED WITH A CENTRIA WALL PANEL.

WINDOW WALL: 2-SIDED SSG WINDOW WALL (SIMILAR TO KAWNEER METROVIEW FG 601T PW SSG), WITH 1 IN. LOW-E, CLEAR IGU, FT (SIM. TO VNE 1-63 BY VIRACON)

GUARD RAIL: LAMINATED, LOW IRON GLASS; STAINLESS STEEL "SHOE" SYSTEM

TERRACE. FROM EAST, LOOKING NW

D. CLT SCHEME
MASSING & PLANS

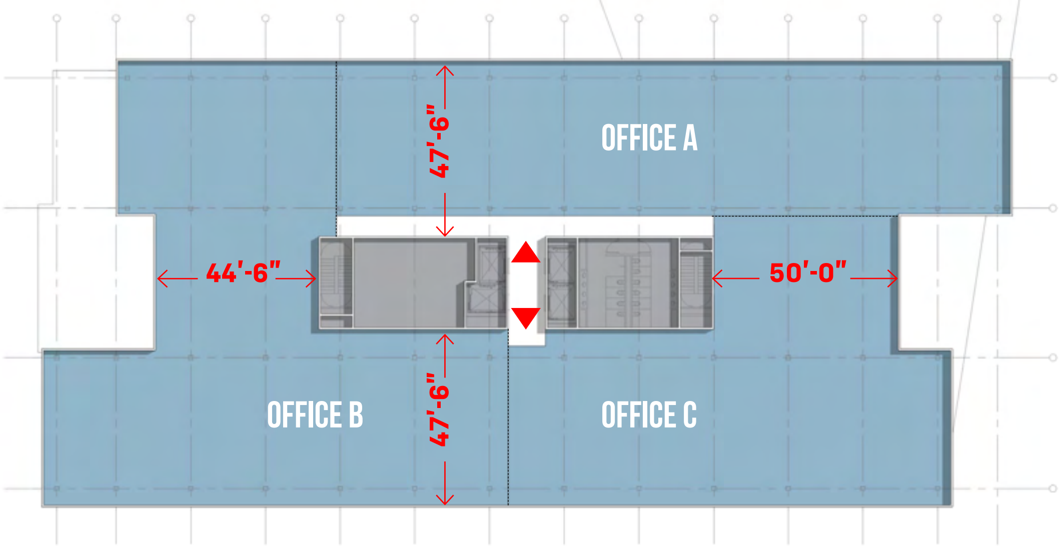
GROUND FLOOR: 31, 705 GSF

TYPICAL FLOOR: 27,545 GSF

TOTAL GSF: 141, 885 GSF

PH: 15,875 SF

TOTAL SF INCL. PH: 157,760 SF

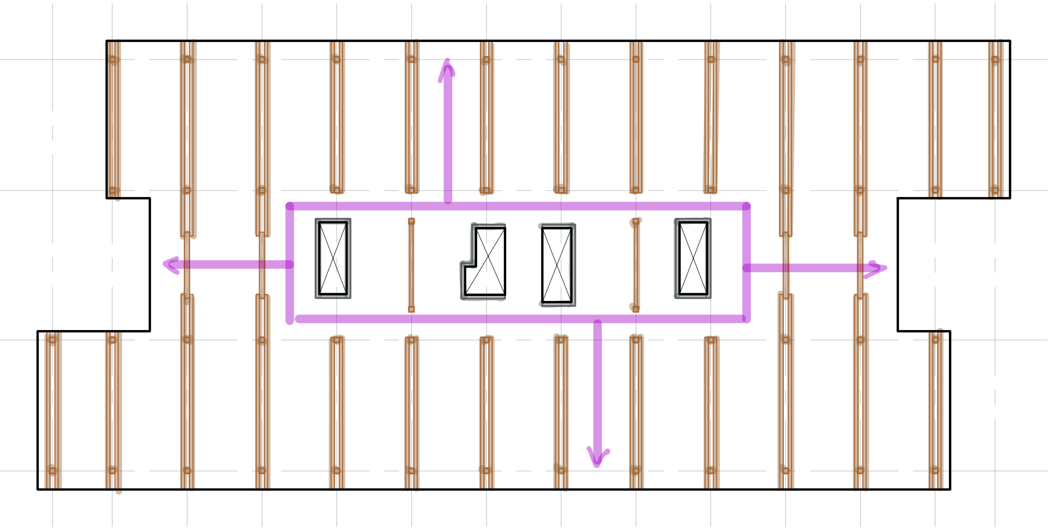


ARCHITECTURAL - MULTI-TENANT DEMISING

40' X 20' COLUMN GRID

DOUBLE 10.5X34.375 GLULAM BEAMS

7 PLYC LT PANEL



STRUCTURAL FRAMING

AERIAL, FROM NORTHEAST

D. **LCA DATA + OUTPUTS**

TAKE OFFS FOR DATA ENTRY

AREA TAKEOFFS: DPR & HCA

DPR's area takeoffs include all facade components (metal panel, window frames, and glazing) added and summarized together for 3 general locations: (a) ground floor, (b) office floors, (c) penthouse.

The metal panel area takeoffs here are used in conjunction with DPR's "Exterior Skin Area", to add more fidelity to the One Click LCA input.

Building Envelope System	Skin Area (SF): PT Concrete	Skin Area: Factor	Skin Area (SF): CLT Mass Timber	
GROUND FLR - Glazing/Metal Panel	11,839	1.26	14,917	
OFFICE - Glazing	46,156	1.05	48,464	
OFFICE - Metal Panel	9,756	1.05	10,244	
PENTHOUSE - Metal Panel	7,090	1.00	7,090	
PENTHOUSE (+ all other) - Roofing	32,593	1.04	33,897	
PENTHOUSE (+ all other) - Pavers	4,593	1.04	4,777	

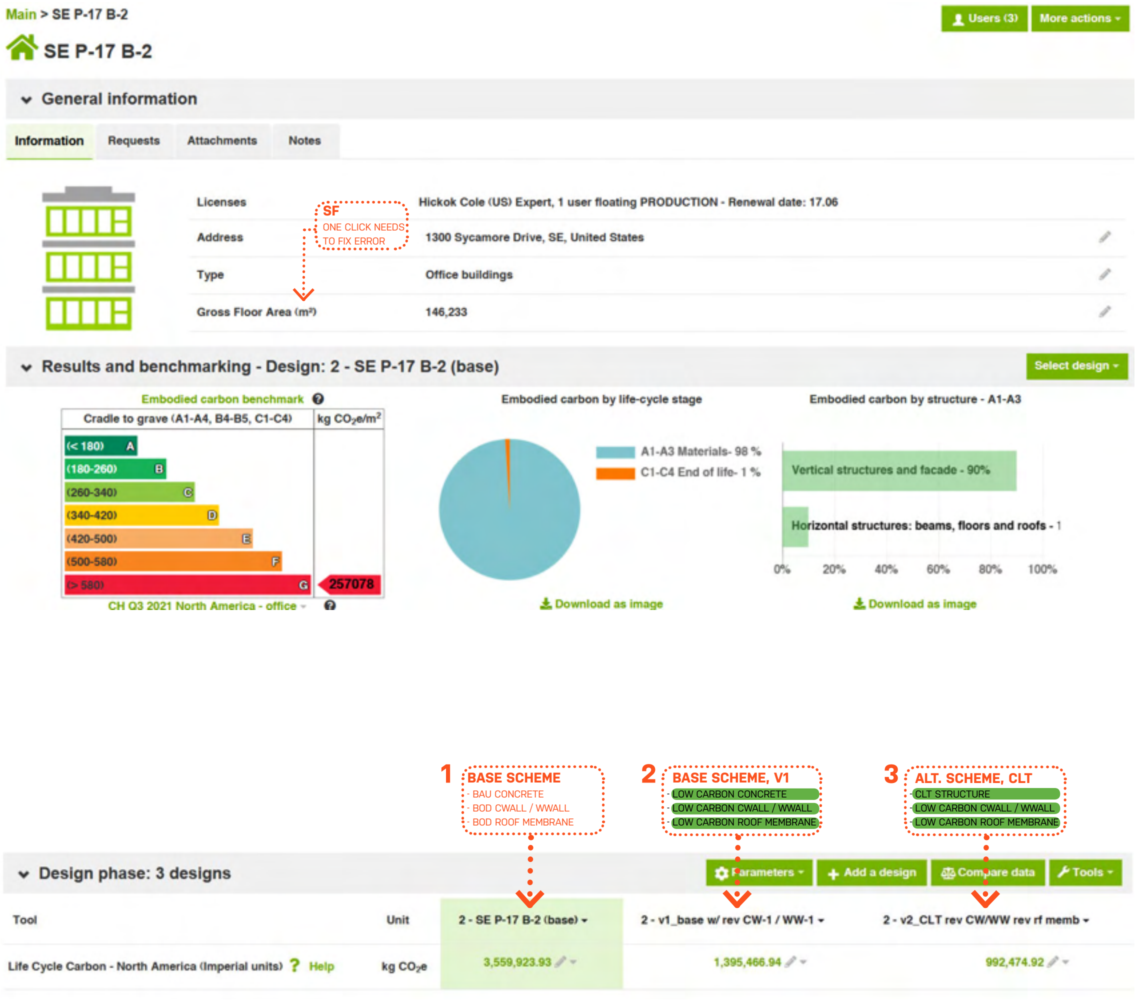
Metal Panel Areas	OA Height	Dimensions	Dimensions in Decimals	Perimeter - LF	Perimeter Metal Panel	Area - SF	Location	OneClick Specification
Ground Floor		1'3"	1.25	483		603.75	Slab Edge	Centria Vistawall
	16'-4"	15'-1"	15.08	40		603.33	Garage Doors	Centria
		1'3"	1.25	40		50.00	Slab Edge	Centria Vistawall
Level 02	10'-10"	9'-7"	9.58		50.5	483.96	Vertical façade panels	Centria Vistawall
		1'3"	1.25	523		653.75	Slab Edge	Centria Vistawall
Level 03	10'-10"	9'-7"	9.58		93.5	896.04	Vertical façade panels	Centria Vistawall
		1'3"	1.25	523		653.75	Slab Edge	Centria Vistawall
Level 04	10'-10"	9'-7"	9.58		76.3	731.21	Vertical façade panels	Centria Vistawall
		1'3"	1.25	523		653.75	Slab Edge	Centria Vistawall
Level 05	10'-10"	9'-7"	9.58		100	958.33	Vertical façade panels	Centria Vistawall
		1'3"	1.25	523		653.75	Slab Edge	Centria Vistawall
Level 06	10'-10"	10'-0"	10		71.8	718.00	Vertical façade panels	Centria Vistawall
		1'3"	1.25	523		653.75	Slab Edge	Centria Vistawall

Metal Panel Areas	Total Metal Panel Doors	Total Slab Edge Cover	Total Vertical Façade Panel			
Ground Floor	603.33	653.75				
Level 02-06		3268.75	3,787.54			
Penthouse			7,090.00			
TOTAL AREAS	603.33	3922.50	10877.54			15,403.37

DPR CONSTRUCTION ARUP hickok cole

D. ARCHITECTURAL ENVELOPE
ONE CLICK LCA REPORT

- ***Design 1*** *reflects the embodied carbon in the current design.*
- ***Design 2*** *shows the carbon "savings" if the curtain wall, window wall, and roofing membrane are replaced by similar products (YKK in lieu of Kawneer, and Sarnafil G410 in lieu of Henry/Hydrotech hot fluid applied membrane).*
- ***Design 3*** *outlines an alternate design that holds the modifications made on no.2, and replaces the structure with cross laminated timber.*



Screenshots, OneClick LCA Report

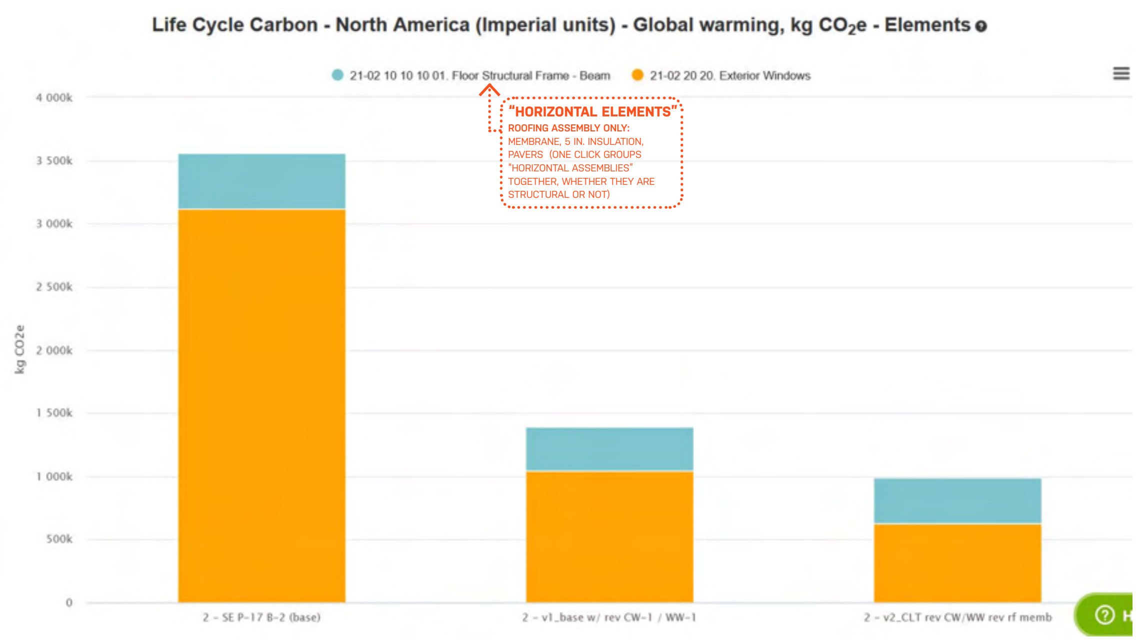
D. **ARCHITECTURAL ENVELOPE**

ONE CLICK LCA REPORT, CONTINUED

- ***Design 1*** *reflects the embodied carbon in the current design.*

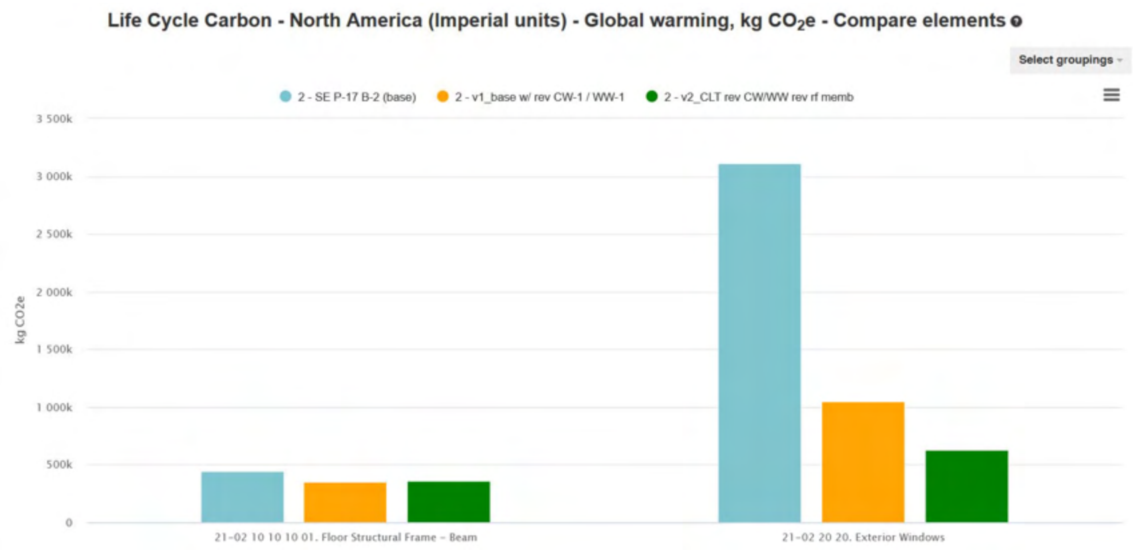
- ***Design 2*** *shows the carbon "savings" if the curtain wall, window wall, and roofing membrane are replaced by similar products (YKK in lieu of Kawneer, and Sarnafil G410 in lieu of Henry/Hydrotech hot fluid applied membrane).*

- ***Design 3*** *outlines an alternate design that holds the modifications made on no.2, and replaces the structure with cross laminated timber.*



Chart

Category	21-02 10 10 10 01. Floor Structural Frame - Beam	21-02 20 20. Exterior Windows
2 - SE P-17 B-2 (base)	444086.18570650485	3115837.746292203
2 - v1_base w/ rev CW-1 / WW-1	350482.01091134606	1044984.9329769152
2 - v2_CLT rev CW/WW rev rf memb	364510.42261081433	627964.5016723629



Chart

Category	2 - SE P-17 B-2 (base)	2 - v1_base w/ rev CW-1 / WW-1	2 - v2_CLT rev CW/WW rev rf memb
21-02 10 10 10 01. Floor Structural Frame - Beam	444086.18570650485	350482.01091134606	364510.42261081433
21-02 20 20. Exterior Windows	3115837.746292203	1044984.9329769152	627964.5016723629

D. **ARCHITECTURAL ENVELOPE**

REPORT, CONTINUED

- ***Design 1*** *reflects the embodied carbon in the current design.*

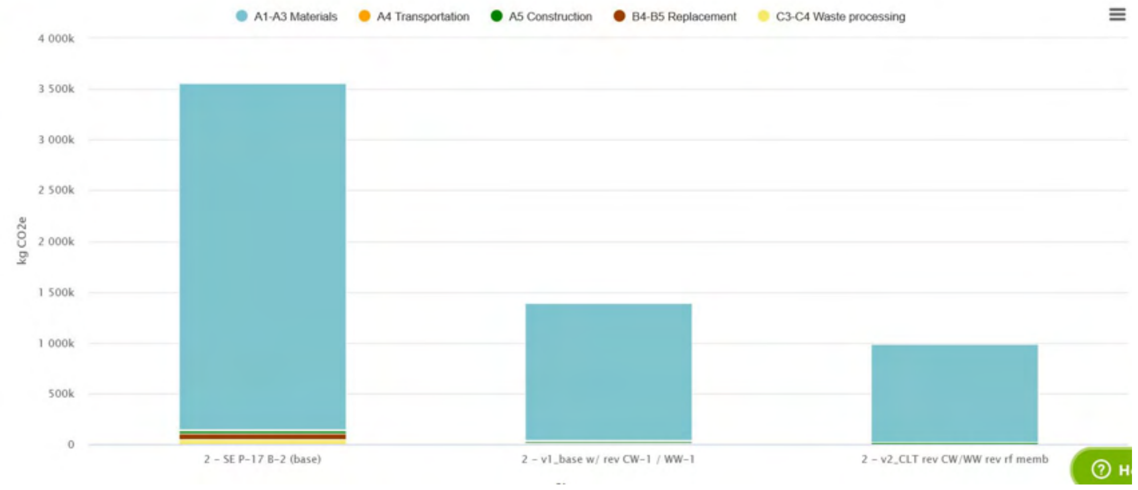
- ***Design 2*** *shows the carbon "savings" if the curtain wall, window wall, and roofing membrane are replaced by similar products (YKK in lieu of Kawneer, and Sarnafil G410 in lieu of Henry/Hydrotech hot fluid applied membrane).*

- ***Design 3*** *outlines an alternate design that holds the modifications made on no.2, and replaces the structure with cross laminated timber.*

Life Cycle Carbon - North America (Imperial units) - Global warming, kg CO_2e - Elements and life-cycle stages

Select elements to show: Deselect all / Select all

☑ 21-02 10 10 10 01. Floor Structural Frame - Beam ☑ 21-02 20 20. Exterior Windows



Chart

Category	A1-A3 Materials	A4 Transportation	A5 Construction	B4-B5 Replacement	C3-C4 Waste processing
2 - SE P-17 B-2 (base)	3415484.9038601764	9107.608575910563	30091.291956844525	53750.28395902228	51489.843646754314
2 - v1_base w/ rev CW-1 / WW-1	1357055.3667435013	5202.5354171325935	26468.210971741202	0	6740.830755886063
2 - v2_CLT rev CW/WW rev rf memb	973477.1873081981	3801.4367214481103	10412.928052506073	0	4783.372201024854

E. ENVELOPE

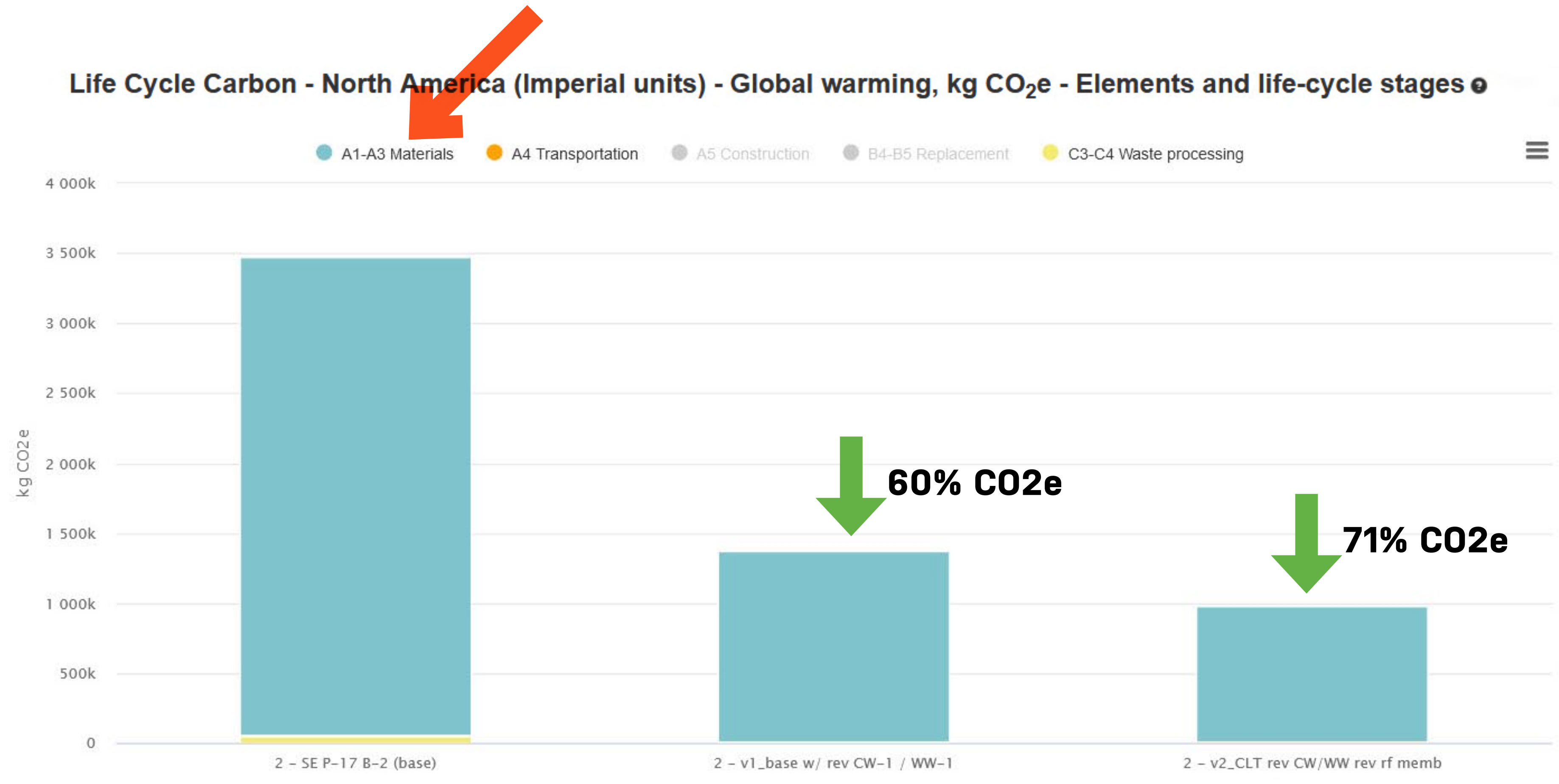
ONE CLICK LCA RESULTS

CO2e SAVINGS

Design 2: *reflects a 60% CO2e savings when compared to the Basis of Design (Design 1).*

The alternates include revisions to: window wall, curtain wall, and roofing membrane

Design 3: *reflects a 71% CO2e savings. The difference between 2 and 3 is the generic change in structure (CIP concrete for CLT) that is quantified with more fidelity in the Structure Analysis.*



Chart

Category	A1-A3 Materials	A4 Transportation	C3-C4 Waste processing
2 - SE P-17 B-2 (base)	3415484.9038601764	9107.608575910563	51489.843646754314
2 - v1_base w/ rev CW-1 / WW-1	1357055.3667435013	5202.5354171325935	6740.830755886063
2 - v2_CLT rev CW/WW rev rf memb	973477.1873081981	3801.4367214481103	4783.372201024854

D. CWALL / WWALL COMPARISON

ONE CLICK LCA DATA FOR BOTH MANUFACTURERS

REPORTING - LACK OF UNIFORMITY

Because of the lack of uniformity in how manufacturers declare data for their products, it seems at a glance that a substitution of the "basis of design" Kawneer systems for YKK results in significant embodied carbon savings.

At a closer look however, we see that YKK's data is an average that ecompasses different systems (punched windows, ribbon windows, and window wall). We also see in the more detailed EPD, that because the typical "lite" is not clearly defined, it is difficult to ascertain the "frequency" and quantity of mullions and therefore the amount of aluminum in the facade.

Ideally the One Click LCA software would allow users to control the average width of the "lites" to account for the project specific frequency and quantity of vertical and horizontal mullions.

There are significant differences in the "density" and "thickness" in the EPD of both manufacturers.

Another difference is that, for the purposes of the EPD, Kawneer includes a default float glass IGU, while YKK values are for the "frame only" and require the addition of glass to the input data.

KAWNEER

Traditional curtain wall, 1.5m x 1.6m, 35.6 kg/piece, 1600 1, 1600 2, 1600 3, 1600 4, 1600 5, 1600 SS, 1600 UT 1, 1600 UT 2, 1620/1620 SSG, 1630 SS IR, 2250 IG, 2250 LR, 7500 and Clearwall Curtain Wall Systems (Kawneer)

Add to input | Add to compare | Download EPD

Show empty rows

General information	
Country	North America
Manufacturer	Kawneer
Commercial name	1600 1, 1600 2, 1600 3, 1600 4, 1600 5, 1600 SS, 1600 UT 1, 1600 UT 2, 1620/1620 SSG, 1630 SS IR, 2250 IG, 2250 LR, 7500 and Clearwall Curtain Wall Systems
Material type	Alumium frame windows
Warning	Datapoint may be expired
Datapoint background information	
EPD number	47868332121.105.1
EPD program	UL Environment
Year	2015
Product Category Rules (PCR)	PCR Cradle to Gate Window, September 2015
Standard	ISO14040
Data source	Traditional curtain wall system, Kawneer 2015
Verification	Third-party verified (as per ISO 14025)
Upstream database	GaBi
Technical characteristics	
Technical specification	1.5m x 1.6m, 35.6 kg/piece
Density	133.33 kg/m²
Default thickness	267.0 mm
Available units	kg, ton, m³, m²
Environmental profile	
Global warming potential (A1-A3) before local compensation	9.93 kg CO_2e / kg 1324.0 kg CO_2e / m³ 353.51 kg CO_2e / m²
Impact categories (A1-A3)	Show
Performance in group	Alumium frame windows
Performance ranking	CO_2 TRACI: 25 / 31 See full ranking Datapoint impacts are unusual, however data matches its issue document. Avoid datapoint when seeking typical product.
Q Metadata	+/- 28.35 % variation in dataset
Default scenarios and assumptions	
Transportation distance	430
Transportation method	Trailer combination, 40 ton capacity, 100% fill rate: 0.0559 kg CO_2e / tonmile
Default service life	As building
Product-specific service life	As building
Others	
Notes about PCR	Biogenic CO_2 separated
Properties	Third-party verified (as per ISO 14025)

ASSUMED SIZE: DETERMINES FREQUENCY AND QUANTITY OF HORIZONTAL AND VERTICAL MULLIONS. INCLUDES GENERIC FLOAT GLASS IGU TO QUANTIFY THE ENTIRE ASSEMBLY

Window wall curtain wall system, 1.5m x 1.3m, 40.5 kg/piece, MetroView FG 501T, FG 623, TR-700 Window Walls and PG123 Framing (Kawneer)

Add to input | Add to compare | Download EPD

Show empty rows

General information	
Country	North America
Manufacturer	Kawneer
Commercial name	MetroView FG 501T, FG 623, TR-700 Window Walls and PG123 Framing
Material type	Alumium frame windows
Warning	Datapoint may be expired
Datapoint background information	
EPD number	47868332121.110.1
EPD program	UL Environment
Year	2015
Product Category Rules (PCR)	PCR Cradle to Gate Window, September 2015
Standard	ISO14040
Data source	Window wall, Kawneer 2015
Verification	Third-party verified (as per ISO 14025)
Upstream database	GaBi
Technical characteristics	
Technical specification	1.5m x 1.3m, 40.5 kg/piece
Density	318.9 kg/m²
Default thickness	127.0 mm
Available units	kg, ton, m³, m²
Environmental profile	
Global warming potential (A1-A3) before local compensation	11.3 kg CO_2e / kg 3603.54 kg CO_2e / m³ 457.65 kg CO_2e / m²
Impact categories (A1-A3)	Show
Performance in group	Alumium frame windows
Performance ranking	CO_2 TRACI: 31 / 31 See full ranking Datapoint impacts are unusual, however data matches its issue document. Avoid datapoint when seeking typical product.
Q Metadata	+/- 28.35 % variation in dataset
Default scenarios and assumptions	
Transportation distance	430
Transportation method	Trailer combination, 40 ton capacity, 100% fill rate: 0.0559 kg CO_2e / tonmile
Default service life	As building
Product-specific service life	As building
Others	
Notes about PCR	Only with ISO14040

ASSUMED SIZE: DETERMINES FREQUENCY AND QUANTITY OF HORIZONTAL AND VERTICAL MULLIONS. INCLUDES GENERIC FLOAT GLASS IGU TO QUANTIFY THE ENTIRE ASSEMBLY

YKK

AVERAGE OF DIFFERENT SYSTEMS: PUNCHED WINDOW, RIBBON WINDOW, AND WINDOW WALL SYSTEMS

Window wall curtain wall aluminum framing, 5.9 kg/m², YCN 40, YCN 40 T, YWE 60 T, YWW 40 T, YWW 45 T, YWW 45 FI, YWW 45 FS, YWW 5 T, and YWW 45 TU Window Wall System (YKK AP)

Add to input | Add to compare | Download EPD

Show empty rows

General information	
Country	United States
Manufacturer	YKK AP
Commercial name	YCN 40, YCN 40 T, YWE 60 T, YWW 40 T, YWW 45 T, YWW 45 FI, YWW 45 FS, YWW 5 T, and YWW 45 TU Window Wall System
Material type	Alumium frame windows
Warning	Datapoint may be expired
Datapoint background information	
EPD number	4786832322.106.1
EPD program	UL Environment
Year	2015
Product Category Rules (PCR)	IBU/UL PCR Part A: Calculation Rules for the LCA and Requirements Project Report, (V1.3, 06.19.2014), Part B: Requirements on the EPD for Curtain Walling (IBU, V1.6, Jul. 2014), Part B Addendum: IBU PCR for Curtain Walling (UL E, V1.0 Nov. 2015). Berlin: Institut Bauen & Umwelt.
Standard	ISO14040
Data source	Aluminum Window Wall Systems, YKK AP America 2015
Verification	Third-party verified (as per ISO 14025)
Upstream database	GaBi
Technical characteristics	
Technical specification	5.9 kg/m²
Density	52.68 kg/m³
Mass per unit	5.9 kg/m²
Default thickness	112.0 mm
Available units	m², kg, ton, m³
Environmental profile	
Global warming potential (A1-A3)	11.59 kg CO_2e / kg 610.71 kg CO_2e / m³ 68.4 kg CO_2e / m²
Impact categories (A1-A3)	Show
Performance in group	Alumium frame windows
Performance ranking	CO_2 TRACI: 1 / 31 See full ranking
Q Metadata	+/- 28.35 % variation in dataset
Default scenarios and assumptions	
Transportation distance	430
Transportation method	Trailer combination, 40 ton capacity, 100% fill rate: 0.0559 kg CO_2e / tonmile
Default service life	As building
Product-specific service life	As building

SIZE? ASSUMPTION FOR SIZE AND/OR QUANTITY OF HORIZONTAL AND VERTICAL MULLIONS IS NOT CLEAR. DOES NOT INCLUDE GENERIC IGU TO QUANTIFY THE ENTIRE ASSEMBLY

"DENSITY" VALUE IS ABOUT 1/6 OF THE KAWNEER WINDOW WALL DENSITY

"DEFAULT THICKNESS" IS ABOUT 12% LESS THAN THE KAWNEER WWALL THICKNESS

D. **CWALL / WWALL EPD**

KAWNEER (BASIS OF DESIGN)

ENVIRONMENTAL PRODUCT DECLARATION

WINDOW WALL

ALUMINUM CURTAIN WALL SYSTEMS

Window Wall offers the look of a true curtain wall with a slab-to-slab aluminum frame design with a slab edge cover option to conceal the floor slab. Kawneer products are comprised of extrusions made from one of the earth's most plentiful recyclables — aluminum. Durable and lasting the extruded products also boast aesthetically appealing design features that can help contribute to energy efficiency and long term sustainability.

KAWNEER
AN ALCOA COMPANY

Kawneer Company, Inc., part of Alcoa's global Building and Construction Systems (BCS) business, has provided the commercial construction industry with best-in-class architectural aluminum products and service for more than 100 years. Its extensive range of solutions — from curtain walls and windows, to entrances and framing systems — help build infinite possibilities for thermal performance, hurricane resistance, blast mitigation and sun control.

Kawneer's commitment to social and environmental responsibility is rooted in high performing, sustainable solutions that extend beyond energy efficiency to elements like daylighting, acoustical efficiency, recyclability, occupant security and occupant comfort. In fact, sustainability is at the heart of Kawneer's product line, which is comprised of one of the earth's most plentiful recyclables — aluminum.

Kawneer offers architects a new way to look at the building façade, placing endless design and sustainability options at their fingertips.

For more information visit www.kawneer.com

CERTIFIED
ENVIRONMENTAL PRODUCT DECLARATION
UL.COM/EPD

ENVIRONMENTAL PRODUCT DECLARATION

KAWNEER
AN ALCOA COMPANY

Window Wall
Featuring MetroView™ FG 501T Window Wall

According to ISO 14025

This declaration is an environmental product declaration (EPD) in accordance with ISO 14025. EPDs rely on Life Cycle Assessment (LCA) to provide information on a number of environmental impacts of products over their life cycle. Exclusions: EPDs do not indicate that any environmental or social performance benchmarks are met, and there may be impacts that they do not encompass. LCAs do not typically address the site-specific environmental impacts of raw material extraction, nor are they meant to assess human health toxicity. EPDs can complement but cannot replace tools and certifications that are designed to address these impacts and/or set performance thresholds – e.g. Type 1 certifications, health assessments and declarations, environmental impact assessments, etc. Accuracy of Results: EPDs regularly rely on estimations of impacts, and the level of accuracy in estimation of effect differs for any particular product line and reported impact. Comparability: EPDs are not comparative assertions and are either not comparable or have limited comparability when they cover different life cycle stages, are based on different product category rules or are missing relevant environmental impacts. EPDs from different programs may not be comparable.

PROGRAM OPERATOR	UL Environment	
DECLARATION HOLDER	Kawneer North America	
DECLARATION NUMBER	4786833212.110.1	
DECLARED PRODUCT	Window Wall featuring FG 501T Window Wall	
REFERENCE PCR	Earthsure. Cradle to Gate Window Product Category Rule. September 2015	
DATE OF ISSUE	December 7, 2015	
PERIOD OF VALIDITY	5 Years	
CONTENTS OF THE DECLARATION	Product definition and information about building physics Information about basic material and the material's origin Description of the product's manufacture Indication of product processing Information about the in-use conditions Life cycle assessment results Testing results and verifications	
The PCR review was conducted by:		PCR Review Panel Chair: Thomas P. Gloria Industrial Ecology Consultants
This declaration was independently verified in accordance with ISO 14025 by Underwriters Laboratories ☐ INTERNAL ☒ EXTERNAL		Wade Stout, UL Environment
This life cycle assessment was independently verified in accordance with ISO 14044 and the reference PCR by:		Thomas Gloria, Industrial Ecology Consultants

Environment

D. **CWALL / WWALL EPD**

KAWNEER (BASIS OF DESIGN)

KAWNEER
AN ALCOA COMPANY

Window Wall
Featuring MetroView™ FG 501T Window Wall

According to ISO 14025

Product Information

Product Description

Window wall applications have been growing in popularity for many years. They were predominantly specified on large condominium projects, but have begun to be used in medium size projects and are becoming the preferred method for commercial projects where the aluminum framing design is from slab to slab.

Window Wall featuring:
MetroView™ FG 501T Window Wall, FG 623 Window Wall, TR-700 – Window Wall and PG 123™ Framing

Sleek, efficient and versatile Window Wall provides the desired aesthetics of a curtain wall into a cost-efficient window wall system. Ideal for mid-rise commercial projects and sophisticated multi-family housing, Window Wall delivers the refined design features that are so popular in today's urban and near-urban cityscapes.

For thermal performance, a product is considered thermally broken if the separation between the interior and exterior metal is 0.21 inches or greater. Thermally improved systems are generally defined as having a separation between the interior and exterior metal of less than 0.21 inches but not less than 1/16 inch.

MetroView™ FG 501T Window Wall

Performance Standards

Kawneer products are tested, certified and labeled for the following performance standards:

- AAMA/WDMA/CSA 101/IS2/A440 (NAFS-North American Fenestration Standard/Specification for windows, doors, and skylights) for the most current version
- AAMA E283/NFRC 400 Air Infiltration
- ASTME330/1 and AAMA 501 Methods of Test
- AAMA 1503, AAMA 507 and NFRC 100 Thermal Transmittance – U-Factors
- AAMA 1503, CSA A440.2 and NFRC 500 Condensation Resistance (CRF,I,CR)
- AAMA 507 and NFRC 200 Overall Solar Heat Gain Coefficient and Visible Transmittance (SHGC) & (VT)
- AAMA 1801, ASTM E90 and ASTM E1425 Sound Transmission (STC, OITC)

Life Cycle Assessment

Declared Unit

The declared unit of the underlying life cycle assessment study was one square meter (1 m²) of window (including frame) meeting the performance standards noted below. The reference flow is 40.5 kg of window unit with framing, with a frame to glazing ration of 31.4% to 68.6% by mass. The 1.5m x 1.3m ribbon window standard size was used to derive the declared unit.

KAWNEER
AN ALCOA COMPANY

Window Wall
Featuring MetroView™ FG 501T Window Wall

According to ISO 14025

System Boundary

The system boundary for the declaration is cradle-to-gate per the guiding PCR. The product life cycle stages included within this boundary are illustrated in Figure 1.

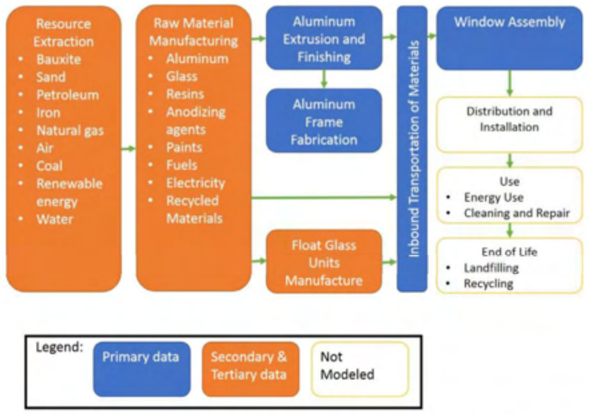


Figure 1: Life cycle stage diagram for cradle-to-gate production of traditional curtain wall by Kawneer

Data Sources

To cover these requirements and to ensure reliable results, first-hand industry data were used in combination with consistent background LCA information from the GaBi ts 2014 database. The data for aluminum billet, as well as externally sourced aluminum extrusions, are based on 2010 Aluminum Association studies and are the best available. Other LCI datasets were sourced from the GaBi LCA databases and are representative of years 2010-2013.

Assumptions

The manufacturing process and end product is essentially the same in all manufacturing sites. Impacts and inventories for traditional curtain wall are calculated with a mass-based production-weighted average of each manufacturer's impacts and inventories.

Float glass is insulated, laminated, or tempered and added to the finished assembly. At this time data does not include granularity to differentiate between insulate, laminated and tempered glass. As such, all glass is treated the same. Glass is only processed at the Cranberry facility. The remaining facilities produce and sell only the aluminum frames. For these facilities, the glass produced at the Cranberry facility was used as a proxy for the window glazing.

D. **CWALL / WWALL EPD**

KAWNEER (BASIS OF DESIGN)

KAWNEER
AN ALCOA COMPANY

Window Wall
Featuring MetroView™ FG 501T Window Wall

According to ISO 14025

No significant assumptions have been made beyond the aforementioned. All of the raw materials and energy inputs have been modeled using processes and flows that closely follow actual production raw materials and processes. All of the material and energy flows have been accounted.

Sensitivity Analysis

Sensitivity analyses was performed because primary data from more than one location is averaged for a unit process.

In order to better understand the variation of impacts across locations for the manufacturing process, the coefficient of variation was calculated for the environmental impact categories. As shown in Table 1, the impacts were seen to vary between 1% and 3%, depending on location for the production of window wall. These variations are likely due primarily to the different scales of operations at each location, the different proportions of finishes used, as well as due to energy mixes used at each location.

Table 1: Coefficient of variation for environmental impacts of window wall

Impact Category	CoV
TRACI 2.1	
Global warming potential	1%
Ozone depletion potential	1%
Acidification potential	3%
Eutrophication potential	1%
Smog formation potential	1%

The coefficient of variation for each impact category was calculated by first determining the weighted standard deviation (σ_w) and the weighted average ($\bar{x}_w$) and then applying

$$CoV = \frac{\sigma_w}{\bar{x}_w}.$$

The weighted average was calculated via

$$\bar{x}_w = \frac{\sum_{i=1}^{n} w_i x_i}{\sum_{i=1}^{n} w_i},$$

while the weighted standard deviation is determined by

$$\sigma_w = \sqrt{\frac{\sum_{i=1}^{n} w_i (x_i - \bar{x}_w)^2}{\sum_{i=1}^{n} w_i}},$$

where w_i is the weight, i.e. annual production, for each company and x_i is the particular input or output for each location.

Environment

KAWNEER
AN ALCOA COMPANY

Window Wall
Featuring MetroView™ FG 501T Window Wall

According to ISO 14025

Life Cycle Impact Assessment Results

Table 1: Cradle-to-gate (manufacturing, glazing and frame) LCIA results of Kawneer Window Wall

	Units (per $1m^2$)	Manufacturing Impact (cradle to gate)	Glazing Impact (cradle to gate)	Frame Impact (cradle to gate)
Life Cycle Impact Assessment Results (TRACI 2.1)				
Global Climate Change Potential (excluding biogenic carbon)	kg CO_2 equivalent	2.30E+02	1.80E+02	4.95E+01
Acidification Potential	kg SO_2 equivalents	1.25E+00	8.69E-01	3.84E-01
Eutrophication Potential	kg N equivalents	3.32E-02	2.23E-02	1.09E-02
Stratospheric Ozone Depletion Potential	kg CFC-11 equivalents	9.92E-08	8.98E-08	9.44E-09
Photochemical Smog Formation Potential	kg O_3 equivalents	1.11E+01	7.97E+00	3.09E+00
Use of Material and Energy Resources				
Fresh Water Consumption (excluding 143 L rain water)	Liters	3.14E+03	2.90E+03	2.46E+02
Non-Renewable Primary Energy Demand	MJ (HHV)	2.89E+03	2.22E+03	6.70E+02
Renewable Primary Energy Demand	MJ (HHV)	7.61E+02	6.72E+02	8.91E+01
Non-Renewable Material Resources*	kg	6.95E+02	6.02E+02	9.31E+01
Renewable Material Resources*	kg	8.61E+05	7.10E+05	1.51E+05
Waste Production				
Non-hazardous Waste Generated	kg	4.55E+01	4.07E+01	4.81E+00
Hazardous Waste Generated	kg	1.11E-02	1.09E-02	1.36E-04

Environment

DPR CONSTRUCTION ARUP hickok cole

D. **CWALL / WWALL EPD**

KAWNEER (BASIS OF DESIGN)

KAWNEER
AN ALCOA COMPANY

Window Wall
Featuring MetroView™ FG 501T Window Wall

According to ISO 14025

Additional Information

Disclosure of Windows Hazardous Content

There are no materials present in at least 0.1% of the window wall that are known to be hazardous to human health and the environment nor on the Candidate List Substances of Very High Concern [IERE 2015].

Recyclable Content

Aluminum is a highly efficient sustainable building material. Aluminum is 100% recyclable and can be recycled repeatedly. Recycled aluminum is identical to smelted aluminum but requires only 1/20 of the energy to manufacture. In building and construction aluminum scrap has a recycling rate of 95% [AA]. The remaining 5% is sent to landfill.

References

AA. 2013	Aluminum Association. "The Environmental Footprint of Semi-finished Aluminum Products in North America: A Life Cycle Assessment Report." 2013
Bare, J. 2012	Tool for the Reduction and Assessment of Chemical and other Environmental Impacts (TRACI) - Software Name and Version Number: TRACI version 2.1 - User's Manual. Washington, D.C.: U.S. EPA.
Earthsure 2015	Earthsure. "Cradle to Gate Window Product Category Rule. September 2015." Earthsure PCR Cradle-to-Gate 30171600:2015. A Program of the Institute for Environmental Research and Education. Vashon WA. 2015
EN 15804 2012	European Committee for Standardization (CEN). "EN15804:2012. Sustainability of construction works – Environmental product declarations— Core rules for the product category of construction products"
ISO 14040	International Standard Organization. ISO 14040:2006-10, Environmental management – Life cycle assessment – Principles and framework (ISO 14040:2006)." German and English version EN ISO 14040:2006 Geneva. 2006
ISO 14044	International Standard Organization. "ISO 14044:200610, Environmental management – Life cycle assessment – Requirements and guidelines (ISO 14044:2006)." German and English version EN ISO 14044:2006 Geneva. 2006
thinkstep. 2014	GaBi LCA Database Documentation. Retrieved from thinkstep AG: http://database-documentation.gabi-software.com

The Life Cycle Assessment was conducted by thinkstep (formerly PE INTERNATIONAL) using GaBi data.

thinkstep

Environment

UL

D. CWALL / WWALL EPD

YKK (LOW CARBON ALTERNATE)

ENVIRONMENTAL PRODUCT DECLARATION

ALUMINUM WINDOW WALL SYSTEMS

YKK AP AMERICA

Window wall systems are commonly used in ribbon window configurations or punched openings as shown here on the Plaza Midtown building in Atlanta, GA.

All YKK AP® products are manufactured, finished, and inspected for quality in the YKK AP environmentally certified, state-of-the-art facility in Dublin, GA.

YKK AP Quality inspires®

YKK AP America is taking positive steps toward sustainable manufacturing helping to balance ecology and economy—improving the environment and society over the long term. YKK AP® is the proud manufacturer of architectural products, including aluminum window wall systems, which provide safe and comfortable environments for building occupants and help reduce energy usage.

A dedicated partner in green building design and sustainability, YKK AP helps create innovative, high quality architectural systems that add to the strength, energy efficiency and longevity of the building envelope.

All YKK AP® products are created in a facility that is a model of environmental responsibility. YKK AP's U.S. manufacturing plant in Dublin, GA, is ISO 14001 certified and has been recognized by the U.S. Department of Energy for exceptional leadership in industrial energy efficiency.

For additional information, visit commercial.ykkap.com.

UL CERTIFIED ENVIRONMENTAL PRODUCT DECLARATION UL.COM/EPD

ENVIRONMENTAL PRODUCT DECLARATION

YKK AP Quality inspires®

YKK AP America
Aluminum Window Wall Systems

According to ISO 14025

This declaration is an environmental product declaration (EPD) in accordance with ISO 14025. EPDs rely on Life Cycle Assessment (LCA) to provide information on a number of environmental impacts of products over their life cycle. Exclusions: EPDs do not indicate that any environmental or social performance benchmarks are met, and there may be impacts that they do not encompass. LCAs do not typically address the site-specific environmental impacts of raw material extraction, nor are they meant to assess human health toxicity. EPDs can complement but cannot replace tools and certifications that are designed to address these impacts and/or set performance thresholds – e.g. Type 1 certifications, health assessments and declarations, environmental impact assessments, etc. Accuracy of Results: EPDs regularly rely on estimations of impacts, and the level of accuracy in estimation of effect differs for any particular product line and reported impact. Comparability: EPDs are not comparative assertions and are either not comparable or have limited comparability when they cover different life cycle stages, are based on different product category rules or are missing relevant environmental impacts. EPDs from different programs may not be comparable.

PROGRAM OPERATOR	UL Environment
DECLARATION HOLDER	YKK AP America
DECLARATION NUMBER	4786832322.106.1
DECLARED PRODUCT	Aluminum Window Wall Systems
REFERENCE PCR	Part A: Calculation Rules for the LCA and Requirements Project Report, (IBU/UL E, V1.3, 06.19.2014), Part B: Requirements on the EPD for Curtain Walling (IBU, V1.6, Jul. 2014), Part B Addendum: IBU PCR for Curtain Walling (UL E, V1.0 Nov. 2015). Berlin: Institut Bauen & Umwelt.
DATE OF ISSUE	November 13, 2015
PERIOD OF VALIDITY	5 Years
CONTENTS OF THE DECLARATION	Product definition and information about building physics Information about basic material and the material's origin Description of the product's manufacture Indication of product processing Information about the in-use conditions Life cycle assessment results Testing results and verifications

The PCR review was conducted by:	IBU The Independent Expert Committee
This declaration was independently verified in accordance with ISO 14025 by Underwriters Laboratories ☐ INTERNAL ☒ EXTERNAL	Wade Stout, UL Environment
This life cycle assessment was independently verified in accordance with ISO 14044 and the reference PCR by:	Thomas Gloria, Industrial Ecology Consultants

D. **CWALL / WWALL EPD**

YKK (LOW CARBON ALTERNATE)

ENVIRONMENTAL PRODUCT DECLARATION

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Aluminum Window Wall Systems

According to ISO 14025

Product Definition

Category Description

Window wall systems are commonly used in ribbon window configurations or punched openings. The framing system spans from slab-to-slab and can be installed from the building's interior to improve logistics and reduce installation costs. Window wall systems can also employ floor slab edge covers that enable the system to mimic the look of a curtain wall system at a significantly reduced cost.

All YKK AP® products are manufactured, finished and inspected for quality in YKK AP's environmentally certified, state-of-the-art facility in Dublin, GA. As a result, YKK AP® products fit together without a lot of jobsite re-work. YKK AP offers a complete suite of tools and engineering services to assist in proper system selection, specification and installation.

Materials & Coatings

Aluminum Alloys: 6063 T5, 6063 T6, 6061 T6

Available Finishes: ANODIZED PLUS®, AAMA 2604/2605 Painted Finishes

Product Description

The following YKK AP America aluminum window wall systems are covered by this EPD (glazing is excluded from this study):

YCN 40 2" x 4-3/8" Front Loaded Ribbon Window

YCN 40 is an offset, front loaded ribbon window framing system designed for a clean, open look without exposed fasteners.

YCN 40 T 2-1/4" x 4-3/8" Thermally Broken Front Loaded Ribbon Window

YCN 40 T is a thermally broken, offset, front loaded ribbon window framing system designed for a clean, open look without exposed fasteners.

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YWE 60 T 2-1/4" x 6" High Performance Window Wall System

YWE 60 T is a thermally improved window wall system designed and engineered to meet the design challenges of today's new buildings. The system is capable of spanning from floor to floor, even at higher design loads.

YWE 60T (with **ssg vertical mullions**) is comparable to the BOD Kawneer window wall

YWW 40 T 2-1/4" x 4" Thermally Broken Window Wall System

The YWW 40 T system is designed specifically to meet the performance requirements of window walls for multi-story buildings.

YWW 45 T 2-1/4" x 4-1/2" Thermally Broken Window Wall System

The YWW 45 T system is designed specifically to meet the performance requirements of window walls for multi-story buildings. Glass is set to the front of the system to maximize thermal performance and may be glazed from either the interior of the building for labor savings or from the exterior at column line applications.

YWW 45 FI 2-1/4" x 4-1/2" High Performance Window Wall System

YWW 45 FI is designed specifically to meet the performance requirements of window walls for multi-story buildings. YWW 45 FI may be installed with head and sill members running continuously or with the head and sill members cut in between the vertical members. Sill flashing is only required when the head and sill members are cut in between the verticals; in addition, sill members are anchored without penetrating the sill flashing.

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YWW 45 FS 1-3/4" x 4-1/2" High Performance/Flush Glazed Window Wall System

The YWW 45 FS system is designed specifically to meet the performance requirements of window walls for multi-story buildings. Glass is set to the front of the system, and may be glazed from either the interior of the building for labor savings or from the exterior at column line applications. The system may be installed with head and sill members running continuously or with the head and sill members cut in between the vertical members. Sill flashing is only required when the head and sill members are cut in between the verticals; in addition, sill members are anchored without penetrating the sill flashing.

YWW 50 T 2-1/4" x 5" Thermally Broken Window Wall System with Optional Slab Edge Cover

YWW 50 T is a Window Wall glazing system designed for use in multi-story applications. It includes an innovative slab edge cover that yields the beauty and appearance of a curtain wall application. The glass plane is set to the front to maximize thermal performance. YWW 50 T is designed to accommodate 1" glazing infill and, with the use of adapters, can also accommodate 1/4" infill. The system has mullion options that allow glazing from the interior or the exterior. Structural Silicone Glazing is also an option. Thermal performance is enhanced by YKK AP's patented Mega-Therm® thermal break technology that also provides the system with dual finish capability. The screw spline assembly design makes fabrication and installation more efficient.

YWW 45 TU 2-1/4" x 4-1/2" Thermally Broken Window Wall System

YWW 45 TU is designed specifically to meet the performance requirements of window walls for multistory buildings. Glass is set to the front of the system to maximize thermal performance and may be glazed from either the interior of the building for labor savings or from the exterior at column line applications. YWW 45 TU is designed specifically to meet the performance requirements of window walls for multistory buildings. Glass is set to the front of the system to maximize thermal performance and may be glazed from either the interior of the building for labor savings or from the exterior at column line applications.

Environment

ENVIRONMENTAL PRODUCT DECLARATION

YKK AP America
Aluminum Window Wall Systems

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Technical Performance

Name	Notes*	Value	Unit
Thermal Transmittance (U-Factor) AAMA 1503.1, AAMA 507, and NFRC 100	1, 2, 4	0.33 – 0.39	Btu/hr• ft²•°F
Solar Heat-Gain Coefficient (SHGC) NFRC 200	1, 2, 4	0.23 – 0.24	
Condensation Resistance Factor (CRFf) AAMA 1503.1	2, 3, 4	57 – 70	
Water Infiltration ASTM E 331 and AAMA 501.1	2	10 – 15	psf
Air Infiltration ASTM E283 at 6.24 psf	2	0.06	cfm/ft²

* (1) - Calculated based on U (COG) = 0.20 and SHGC (COG) = 0.25 (2) - Varies by product type (3) - Dependent on glazing specified (4) - Based on products tested

** Predominantly describes the framing

Industry Standards

AAMA 1801, ASTM E1425, ASTM E90, ASTM E413, ASTM E1332, ASTM E2235, ASTM E283, ASTM E330, AAMA 507, AAMA 1503, NFRC 100, NFRC 102, NFRC 200, NFRC 500, ASTM E331

YKK AP® does not test or rate the declared products for extraordinary effects, i.e., performance under unforeseeable influence of fire, water or mechanical destruction.

Delivery Status

YKK AP® window wall systems vary in size depending on the application. They are commonly used in ribbon window configurations or punched openings. The framing system spans from slab-to-slab and can be installed from the building's interior to improve logistics and reduce installation costs. Window wall systems can also employ floor slab edge covers that enable the system to mimic the look of a curtain wall system at a significantly reduced cost.

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Base and Ancillary Materials

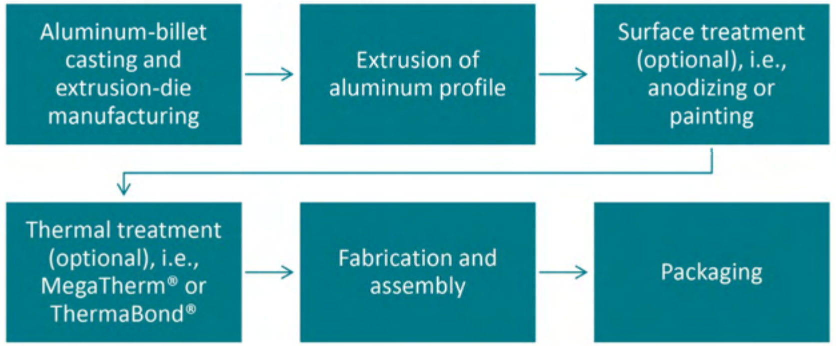
Material	Mass [kg]	Mass [%]
Aluminum 6063	5.28 – 5.33	89.3 – 90.2
Anodizing coat, optional	0 – 3.23E-02	<1
Paint coat, optional	0 – 1.76E-02	<1
MegaTherm (Nylon 6.6/Glass fiber)	3.36E-02	<1
ThermaBond (Polyurethane)	1.38E-01	2.3
EPDM	3.65E-01	6.2
EVA	4.35E-05	<1
Nylon 6	6.08E-03	<1
Polyurethane foam	1.48E-03	<1
PVC	5.06E-03	<1
PVC foam	5.86E-05	<1
Stainless steel	4.22E-03	<1
Steel	2.66E-02	<1

Note: Glazing is excluded from this study.

Manufacturing

All YKK AP® products are manufactured, finished and inspected for quality in our environmentally certified, state-of-the-art facility in Dublin, GA.

The manufacturing process comprises the following production stages:



Environment UL

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According to ISO 14025

The main material input into the YKK AP manufacturing process is aluminum ingot. The ingot is first alloyed to the desired grade and cast into billets. Subsequently, the billets are extruded into profiles using steel dies that are manufactured on-site. The extruded profiles may then be anodized or painted. Optional thermal treatment, whereby a system is thermally broken, leads into the product's fabrication and assembly. In a last step, the complete assemblies are packed for shipment.

Packaging

YKK AP® products are primarily packaged using corrugated cardboard and wood components prior to shipping to installation sites.

Product Processing/Installation

Outside of the scope of this EPD (installation stage excluded).

Reference Service Life, Condition of Use

Outside of the scope of this EPD (use stage excluded).

End of Life: Recycling and Disposal (C4)

Name	Value	Unit
Recycling	4.94E+00	kg
Landfilling (non-recycled Aluminum, other materials)	9.69E-01	kg

Aluminum extrusions are a highly efficient sustainable building material. Aluminum is 100% recyclable and can be recycled repeatedly. Recycled aluminum is identical to smelted aluminum but requires only 1/20 of the energy to manufacture. In building and construction, aluminum scrap has a recycling rate of 95% [AA]. The remaining 5% is sent to landfill.

AA. (2013). The Environmental Footprint of Semi-finished Aluminum Products in North America: A Life Cycle Assessment Report. Aluminum Association.

Environment and Health

Product manufacturing: Plant emissions to air/soil/water are monitored (if applicable) and comply with local laws.

Product use: YKK AP® products are not expected to create exposure conditions that exceed safe thresholds for health impacts to humans or flora/fauna under normal operating conditions. Use stage is outside of the scope of this EPD.

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Life Cycle Assessment – Product System and Modeling

A "cradle-to-gate with options" analysis using life cycle assessment (LCA) techniques was conducted for this EPD. The analysis was done according to the product category rule (PCR) for Curtain Walling and followed LCA principles, requirements and guidelines laid out in the ISO 14040/14044 standards. As such, EPDs of construction products may not be comparable if they do not comply with the same PCR. While the intent of the PCR is to increase comparability, there may still be differences among EPDs that comply with the same PCR (e.g., due to differences in system boundaries, background data, etc.).

Declared Unit

The declared unit for an EPD is one square meter (1 m^2) of window wall product.

Name	Value	Unit
Declared unit	1	m^2
Conversion factor to 1 kg	1/5.9	-

System Boundaries

Per the PCR, this "cradle-to-gate with options" analysis provides information on the Product Stage of the aluminum product life cycle, comprising modules A1–A3, and on the "options" Disposal and Credits, i.e., modules C4 and D:

DESCRIPTION OF THE SYSTEM BOUNDARY (X = INCLUDED IN LCA; MND = MODULE NOT DECLARED)																
PRODUCT STAGE			CONSTRUCTION PROCESS STAGE		USE STAGE							END OF LIFE STAGE				BENEFITS AND LOADS BEYOND THE SYSTEM BOUNDARIES
Raw material supply	Transport	Manufacturing	Transport	Construction-installation process	Use	Maintenance	Repair	Replacement	Refurbishment	Operational energy use	Operational water use	De-construction demolition	Transport	Waste processing	Disposal	Reuse-Recovery-Recycling-potential
A1	A2	A3	A4	A5	B1	B2	B3	B4	B5	B6	B7	C1	C2	C3	C4	D
X	X	X	MND	MND	MND	MND	MND	MND	MND	MND	MND	MND	MND	MND	X	X

Time coverage: Primary data were collected on production within calendar year 2014. Background data for upstream and downstream processes (i.e., raw materials, energy resources, transportation and ancillary materials) were obtained from the GaBi 2014 databases.

Technology coverage: Data were collected for the production of aluminum window wall products at YKK AP's manufacturing facility in the United States.

Geographical coverage: All YKK AP® products are manufactured in Dublin, Georgia, USA. As such, the geographical coverage for this study is based on United States system boundaries for all processes and products. Whenever US background data were not readily available, European data or global data were used as proxies.

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Assumptions

This study was performed based on primary YKK AP data for the production of a production-weighted average curtain wall system. However, up to fabrication and assembly, where a bill of materials (BoM) specifies the parts which comprise an individual product, the underlying model was created to describe YKK AP® aluminum extrusions as generic intermediates. Thus, it was assumed that the same annual average split for surface treatments—i.e., 50% anodized, 18% painted, 32% remain mill finish—apply to extrusions going into window wall control products as well as extrusions going into other products, e.g., windows (see separate EPD).

Another assumption was made in accounting for packaging materials, i.e., wood and corrugated cardboard. Due to a lack of data granularity, which is, at least partially, owed to the realities on the factory floor, packaging materials were scaled with the aluminum content as identified in the BoM.

Beyond that, no significant assumptions have been made. All of the raw materials and energy inputs were modeled using processes and flows that closely follow actual production raw materials and processes. All of the material and energy flows have been accounted.

Allocation

No multi-output (i.e., co-product) allocation was performed in this study. Allocation of background data (energy and materials) taken from the GaBi 2014 databases is documented online at http://www.gabi-software.com/support/gabi/gabi-6-lci-documentation/.

Cut-off Criteria

As required by EN 15804, in case of insufficient input data or data gaps for a unit process, the cut-off criteria were 1% of renewable and non-renewable primary energy usage and 1% of the total mass input of that unit process. The total of neglected input flows per module was a maximum of 5% of energy usage and mass.

In practice, all inputs and outputs, for which data are available, have been included in the calculation. Data gaps have been filled by conservative assumptions with average or generic data. Capital items for the production processes (machines, buildings, etc.) were not taken into consideration.

Background Data

In order to model the life cycle for the production and recycling of the extruded aluminum, the GaBi Professional software system developed by thinkstep AG was used. All relevant background data necessary for the production of extruded aluminum were taken from the GaBi 2014 databases.

LCA Practitioner

This EPD and the underlying LCA model were developed by thinkstep, Inc.

thinkstep

Environment

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D. **CWALL / WWALL EPD**

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Life Cycle Assessment – Results and Analysis

Results given per declared unit: 1m² of window wall system.

ENVIRONMENTAL IMPACTS

CML 2001 (Apr 2013)

		Manufacturing	Disposal	Credits
Parameter	Unit	A1-A3	C4	D
GWP	kg CO_2 eq	6.84E+01	4.86E-02	-5.05E+01
ODP	kg CFC-11 eq	4.93E-09	1.11E-12	-2.14E-09
AP	kg SO_2 eq	4.59E-01	2.16E-04	-3.60E-01
EP	kg PO_4^3 eq	2.44E-02	2.73E-05	-1.49E-02
POCP	kg C_2H_4 eq	3.15E-02	2.16E-05	-1.81E-02
ADPE	kg Sb eq	7.88E-05	1.91E-08	-2.70E-05
ADPF	MJ	7.57E+02	7.56E-01	-4.64E+02

TRACI 2.1

		Manufacturing	Disposal	Credits
Parameter	Unit	A1-A3	C4	D
GWP	kg CO_2 eq	6.84E+01	4.86E-02	-5.05E+01
ODP	kg CFC-11 eq	5.24E-09	1.18E-12	-2.27E-09
AP	kg SO_2 eq	4.43E-01	2.32E-04	-3.32E-01
EP	kg N eq	1.02E-02	1.27E-05	-5.33E-03
SP	kg O_3 eq	4.16E+00	4.50E-03	-2.57E+00
FF	MJ	6.05E+01	9.74E-02	-3.07E+01

RESOURCE USE

		Manufacturing	Disposal	Credits
Parameter	Unit	A1-A3	C4	D
PERE	[MJ]	3.25E+02	4.23E-02	-2.99E+02
PERM	[MJ]	-	-	-
PERT	[MJ]	3.25E+02	4.23E-02	-2.99E+02
PENRE	[MJ]	7.95E+02	7.78E-01	-4.76E+02
PENRM	[MJ]	-	-	-
PENRT	[MJ]	7.95E+02	7.78E-01	-4.76E+02
SM	[kg]	3.86E-01	-	-
RSF	[MJ]	-	-	-
NRSF	[MJ]	-	-	-
FW	[m³]	1.42E+00	-7.20E-04	-1.30E+00

OUTPUT FLOWS AND WASTE CATEGORIES

		Manufacturing	Disposal	Credits
Parameter	Unit	A1-A3	C4	D
HWD	[kg]	5.16E-03	1.50E-07	-4.77E-03
NHWD	[kg]	1.79E+01	1.09E+00	-1.61E+01
RWD	[kg]	1.51E-02	8.65E-06	-5.02E-03
CRU	[kg]	-	-	-
MFR	[kg]	-	6.76E+00	-
MER	[kg]	-	-	-
EEE	[MJ]	-	-	-
EET	[MJ]	-	-	-

Glossary

Environmental Impacts

- GWP Global warming potential
- ODP Depletion potential of the stratospheric ozone layer
- AP Acidification potential of land and water
- EP Eutrophication potential
- POCP Formation potential of tropospheric ozone photochemical oxidants
- ADPE Abiotic depletion potential for non-fossil resources
- ADPF Abiotic depletion potential for fossil resources
- FF Fossil fuel consumption

Resource Use

- PERE Use of renewable primary energy excluding renewable primary energy resources used as raw materials;
- PERM Use of renewable primary energy resources used as raw materials
- PERT Total use of renewable primary energy resources
- PENRE Use of non-renewable primary energy excluding non-renewable primary energy resources used as raw materials
- PENRM Use of non-renewable primary energy resources used as raw materials
- PENRT Total use of non-renewable primary energy resources
- SM Use of secondary material
- RSF Use of renewable secondary fuels
- NRSF Use of non-renewable secondary fuels
- FW Use of net fresh water

Output Flows and Waste Categories

- HWD Hazardous waste disposed
- NHWD Non-hazardous waste disposed
- RWD Radioactive waste disposed
- CRU Components for re-use
- MFR Materials for recycling
- MER Materials for energy recovery
- EE Exported energy per energy carrier

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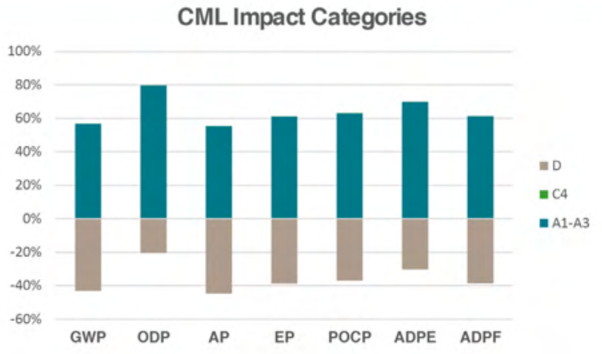
Interpretation



The results represent the cradle-to-gate and disposal environmental performance of the evaluated window wall system. As shown in the figure to the right, the results indicate that the impacts are driven by the product stage (modules A1-A3). The primary impact is derived from upstream aluminum production in module A1 (raw material supply). The YKK AP manufacturing processes account for a relatively small part of the manufacturing impact in comparison.

As module D (material credit at the end of life) clearly impacts the results, it is important to note that the applied recycling rate of 95% represents a defensible rate for aluminum extrusion products in the building and transportation sector. This is based on a conservative calculation for global aluminum recycling from these sectors. If a higher rate is used, the credit will increase, thus lowering the total life-cycle impacts. Similarly, a lower recycling rate would raise the total life cycle impacts. As new information becomes available (e.g., the Aluminum Association publishes regional-specific recycling rates), this EPD should be modified to reflect the most current industry conditions.

Data Quality Assessment

Temporal representativeness: All primary data were collected for the year 2014. All secondary data come from the GaBi 2014 databases and are representative of the years 2010-2013. Therefore, temporal representativeness is warranted. Geographical representativeness: All primary and secondary data were collected specific to the countries or regions under study. Where country-specific or region-specific data were unavailable, proxy data were used. Geographical representativeness is considered to be high. Technological representativeness: All primary and secondary data were modeled to be specific to the technologies or technology mixes under study. Where technology-specific data were unavailable, proxy data were used. Technological representativeness is considered to be high. Precision: As the majority of the relevant foreground data are measured data or calculated based on primary information sources of the owner of the technology, precision is considered to be high. All background data are sourced from GaBi databases with the documented precision.

References

IBU. (2014). *PCR for Building-Related Products and Services - Part A: Calculation Rules for the LCA and Requirements Project Report, (IBU/UL E, V1.3, 06.19.2014), Part B: Requirements on the EPD for Curtain Walling (IBU, V1.6, Jul. 2014), Part B Addendum: IBU PCR for Curtain Walling (UL E, V1.0 Nov. 2015).* Berlin: Institut Bauen & Umwelt.

ISO. (2006). *ISO 14025: Environmental labels and declarations — Type III environmental declarations — Principles and procedures.* Geneva: International Organization for Standardization.

EN. (2013). *EN 15804:2012-04+A1 2013: Sustainability of construction works — Environmental Product Declarations — Core rules for the product category of construction products.*

Environment

D. **KAWNEER CWALL**

ONE CLICK LCA - BENCHMARK DATA

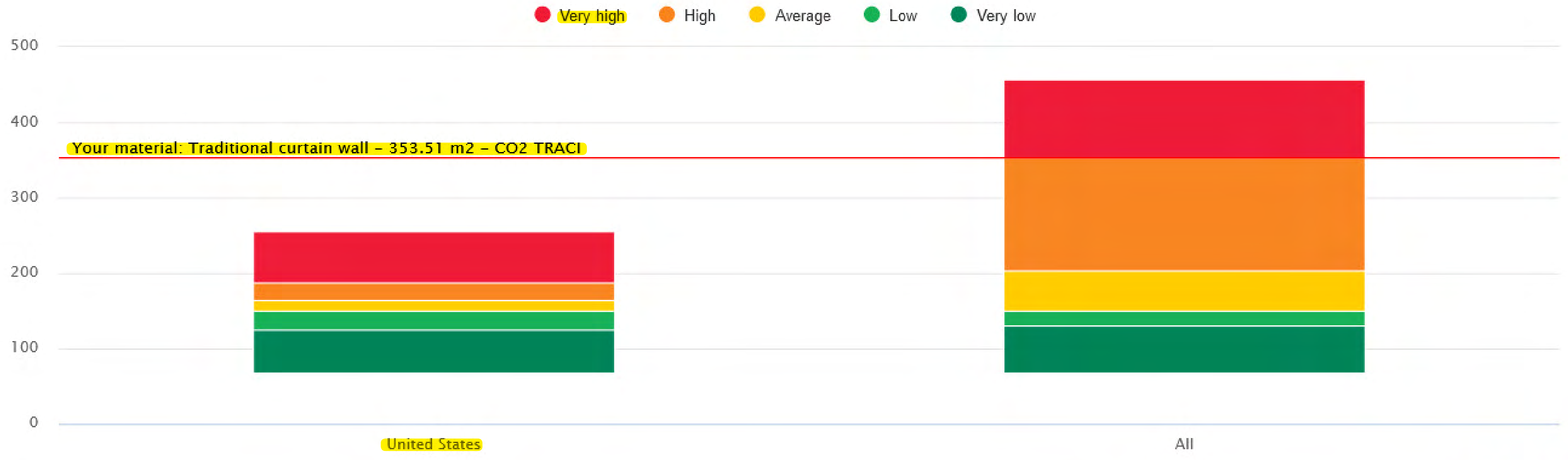
We are unable to explain why the values for Kawneer appear so large against US and International benchmark data. We cannot ascertain the uniformity in the reporting.

Benchmark for Alumium frame windows, 71 products, M2 - CO2 TRACI

The benchmark data does not consider local compensation. Results after compensation may vary.

Select threshold : No cut off

To narrow down visualised ranges, click names of undesirable quintiles to remove them from the graph



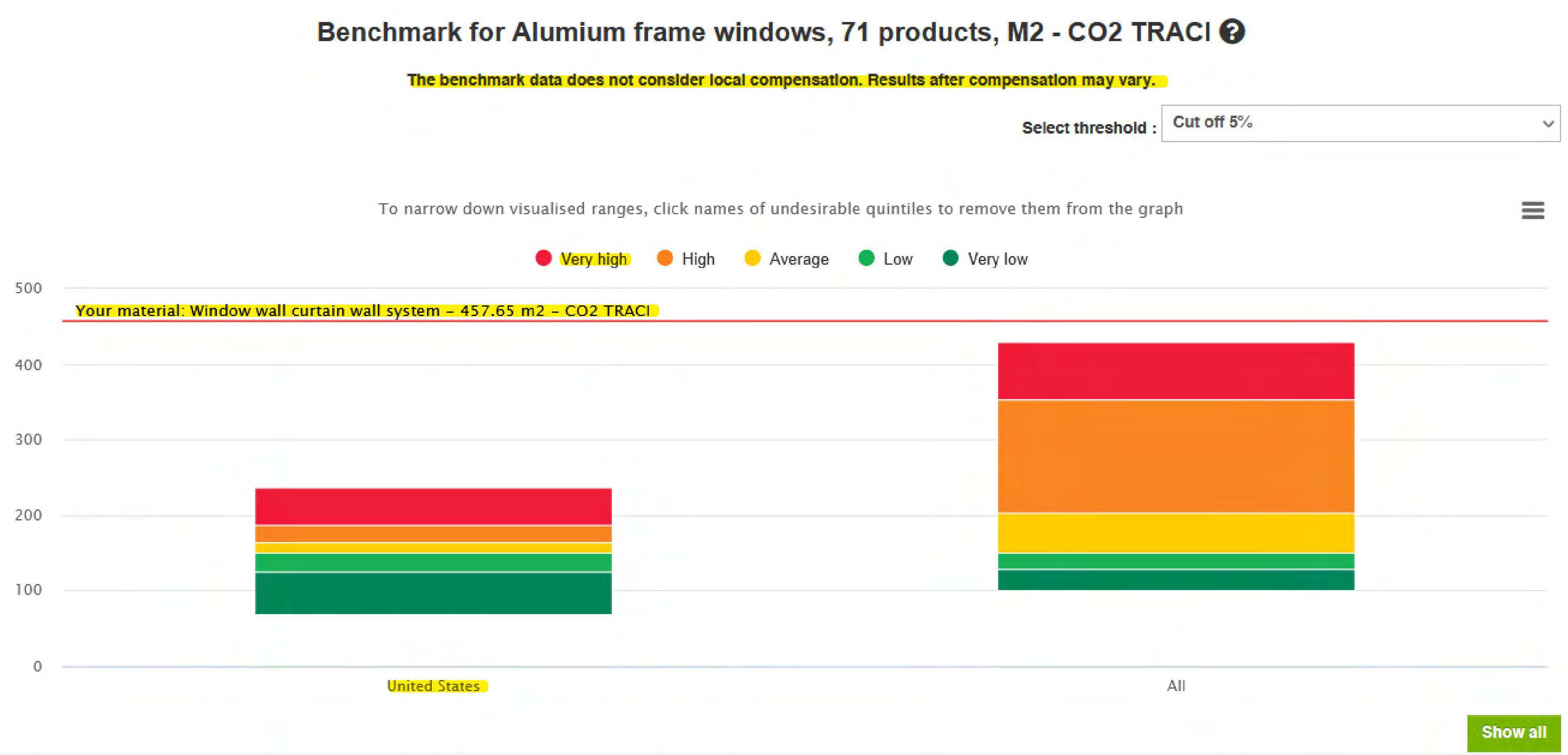
Show all

Factor	Unit	District of Columbia	United States	Neighbouring countries	All
Products in area	product	0	21	1	31
80th percentile	kg CO2e/m2	0	187.58 - Use as benchmark	136.0	353.508 - Use as benchmark
Average	kg CO2e/m2	0	158.927 - Use as benchmark	136.0	227.455 - Use as benchmark
Median	kg CO2e/m2	0	150.0 - Use as benchmark	136.0	180.0 - Use as benchmark

D. **KAWNEER WWALL**

ONE CLICK LCA - BENCHMARK DATA

We are unable to explain why the values for Kawneer appear so large against US and International benchmark data. We cannot ascertain the uniformity in the reporting.



Factor	Unit	District of Columbia	United States	Neighbouring countries	All
Products in area	product	0	21	1	31
80th percentile	kg CO2e/m2	0	187.58 - Use as benchmark	136.0	353.508 - Use as benchmark
Average	kg CO2e/m2	0	158.927 - Use as benchmark	136.0	227.455 - Use as benchmark
Median	kg CO2e/m2	0	150.0 - Use as benchmark	136.0	180.0 - Use as benchmark

E. COMBINED LCA DATA
ARCHITECTURE + STRUCTURAL

The calculations for the combined results for Envelope and Structure are shown here in detail, and graphed in the following page.

Structure

Category	A1-A3 Materials	A4 Transportation	C1-C4 End of life	Total kg CO2	
2 - Concrete Option (BAU)	2448730	42291	13396	2504417	
2 - Timber Option	1329005	55169	316149	1700324	804094
2 - Concrete Option (Low Carbon)	2030947	42291	13396	2086634	417783

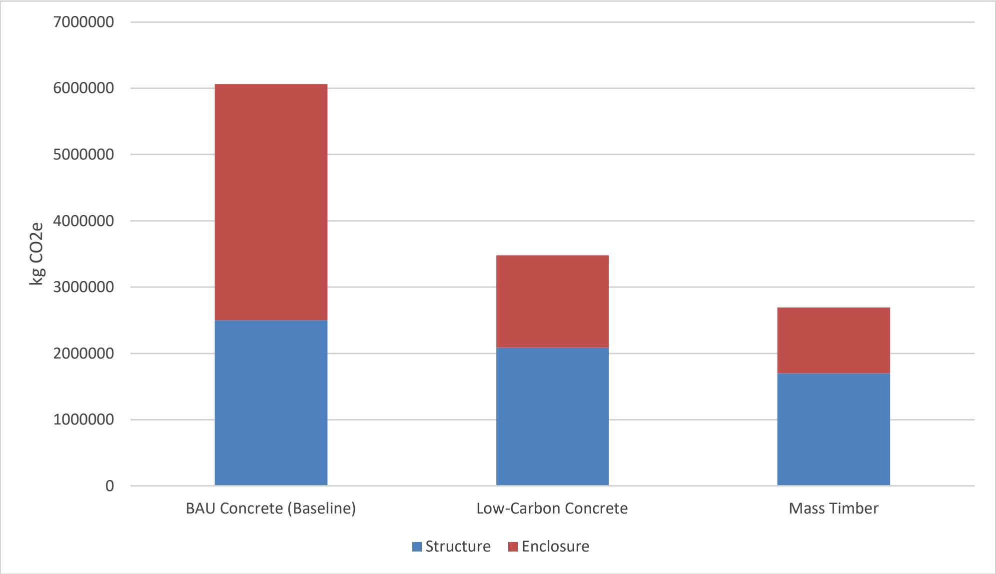
Enclosure

Category	A1-A3 Materials	A4 Transportation	A5 Construction	B3 Repair	B4-B5 Replacement	B6 Energy	B7 Water	C3-C4 Waste processing	B1 Use Phase	Total kg CO2
2 - SE P-17 B-2 (base)	3415485	9108	30091	0	53750	0	0	51490	0	3559924
2 - v1_base w/ rev CW-1 / WW-1	1357055	5203	26468	0	0	0	0	6741	0	1395467
2 - v2_CLT rev CW/WW rev rf memb	973477	3801	10413	0	0	0	0	4783	0	992475

Combined

	A1-A3 Materials	A4 Transportation	C1-C4 End of life	Total kg CO2	Reduction from baseline	
BAU Concrete (Baseline)	5864215	51399	64886	5980500	0	
Low-Carbon Concrete	3388003	47494	20137	3455633	2524867	42%
Mass Timber	2302482	58971	320933	2682386	3298114	55%

	Structure	Enclosure
BAU Concrete (Baseline)	2504417	3559924
Low-Carbon Concrete	2086634	1395467
Mass Timber	1700324	992475

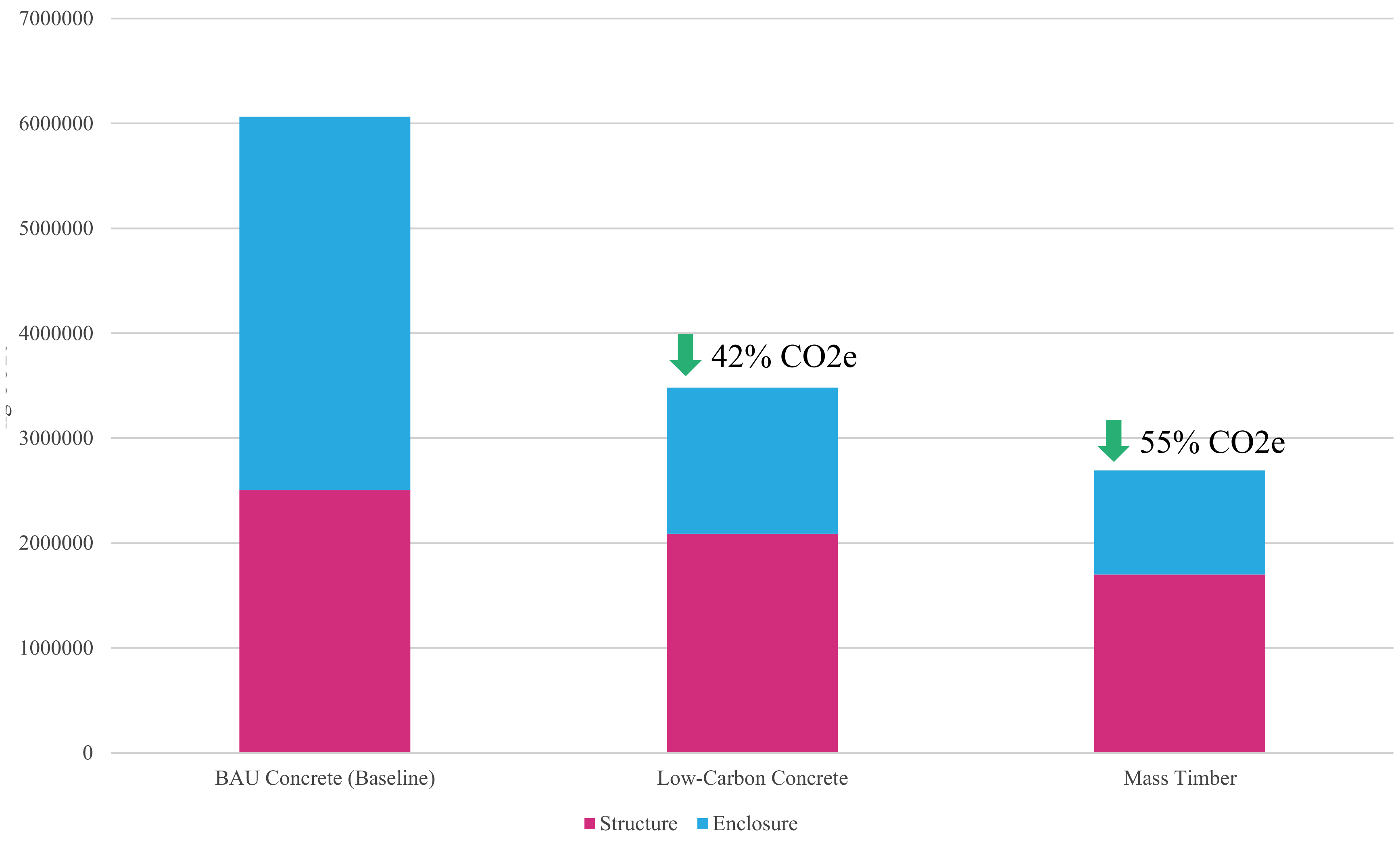


E. **ENVELOPE + STRUCTURE**

COMBINED RESULTS

When compared to the Basis of Design (Design 1), the changes made in Design 2 (curtain wall, window wall, roofing membrane, and low carbon cast in place concrete) represent 42% savings in CO2e.

A CLT structure -in lieu of the low carbon concrete- represents a 55% reduction in CO2e when compared to the Basis of Design.



E. **ENVELOPE + STRUCTURE**

CO2e EQUIVALENCIES

WHAT DOES THIS MEAN?

To have a grasp of how much 2.5 million kilograms of CO_2 really is, we equate it to every day consumption concepts.

The Basis of Design embodied carbon is the equivalent of the use of electricity of 1,086 homes for 1 full year, or of 15 million miles travelled by an average car.

	Homes' electricity use for 1 year	Miles travelled by average car
BAU Concrete	1,086	15 million
Low Carbon Concrete	↓ 459	↓ 6.3 million
Timber	↓ 599	↓ 8.3 million

F. CIP VS CLT

BUDGET COMPARISON

CO2e savings vs. $$$

The alternates analyzed for envelope and structure were priced, to see the construction budget premiums for these same components.

***Design 2** represents a 2.4% premium in cost compared to the Basis of Design.*

***Design 3** represents an 21.2% premium in cost compared to the Basis of Design.*

2.4% $ **2**

INCLUDES LOW CARBON CONCRETE, ENVELOPE & ROOFING

21.2% $$$$ **3**

INCLUDES CLT, LOW CARBON CONCRETE, LOW CARBON ENVELOPE & ROOFING

DOEE Grant
CIP vs Timber Comparison
DPR Construction
9/27/2021

1

CIP Concrete Structure							
Structural Systems							
Wall Footing	54.00	CY	$	550.00	$	29,700	Footings per ARUP Plans
Concrete Beam - 12"x20"	77.00	CY	$	550.00	$	42,350	Footings per ARUP Plans
Concrete Beam - 24"x20"	83.00	CY	$	550.00	$	45,650	Footings per ARUP Plans
Concrete Upturned Beam - 15"x20"	2.00	CY	$	550.00	$	1,100	Footings per ARUP Plans
Concrete Grade Beam - 18"x30"	11.00	CY	$	550.00	$	6,050	Footings per ARUP Plans
Concrete Strap Beam - 48"x36"	17.00	CY	$	550.00	$	9,350	Footings per ARUP Plans
Concrete Beam - 24"x24"	9.00	CY	$	550.00	$	4,950	Footings per ARUP Plans
Interior Square Footing - 21'6"x21'6"x50"	856.00	CY	$	550.00	$	470,800	Footings per ARUP Plans
Irregular Footing	12.00	CY	$	550.00	$	6,600	Footings per ARUP Plans
Perimeter Square Footing - 17'6"x17'6"x44"	707.00	CY	$	550.00	$	388,850	Footings per ARUP Plans
Interior Square Footing - 8'0"x8'0"x22"	138.00	CY	$	550.00	$	75,900	Footings per ARUP Plans
Shear Wall/Core Pad Footing	648.00	CY	$	550.00	$	356,400	Footings per ARUP Plans
Perimeter Square Footing - 10'0"x10'0"x44"	231	CY	$	550.00	$	127,050	Footings per ARUP Plans
Interior Square Footing - 10'0"x10'0"x22"	216	CY	$	550.00	$	118,800	Footings per ARUP Plans
Interior Square Footing - 10'0"x10'0"x50"	185	CY	$	550.00	$	101,750	Footings per ARUP Plans
Garage Walls, Slab On Grade, Plaza Slab						See Below	Not a Variable in Comparison
Ground Level Slab	25,093.00	SF	$	38.00	$	953,534	Ground Level Slab (Supported Above Garage)
CIP Shear Walls	6,900.00	SF	$	50.00	$	345,000	
Plaza Slab	6,702.00	SF	$	38.00	$	254,676	Garage Roof/ Plaza Slab
Typical Floors CIP Concrete Decks	139,438.00	SF	$	39.00	$	5,438,082	CIP Structure Based on 156,586sf of elevated deck 2-PH
Roof Slab	23,995.00	SF	$	39.00	$	935,805	Roof and PH Roof
Exterior Envelope and Roofing							
Kawneer Curtainwall System	51,163.00	SF	$	120.00	$	6,139,560	SF of full CW system including trims, mullions and IGUs
Henry/Hydrotech hot fluid applied roofing	25,093.00	SF	$	20.00	$	501,860	
CIP Scheme Total	164,531.00	GSF	$	99.40	$	16,353,817	
Low Carbon Concrete Mix Premium	164,531.00	GSF	$	0.61	$	100,000	

CIP Scheme Building GSF		
Level	GFA	Structural Deck
1	25,093	CIP Concrete
2	24,892	CIP Concrete
3	24,892	CIP Concrete
4	24,892	CIP Concrete
5	24,892	CIP Concrete
6	23,995	CIP Concrete
Office	148,656	
PH	15,875	CIP Concrete
Total	164,531	
Additonal Structure		
Main Roof	8,120	CIP Concrete
PH Roof	15,875	CIP Concrete
Structure Totals		
Timber	-	
CIP	188,526	

CLT Above Grade Structure							
Wall Footing	54.00	CY	$	550.00	$	29,700	Footings per ARUP Plans (Reduced for CLT)
Concrete Beam - 12"x20"	22.00	CY	$	550.00	$	12,100	Footings per ARUP Plans (Reduced for CLT)
Concrete Beam - 24"x20"	83.00	CY	$	550.00	$	45,650	Footings per ARUP Plans (Reduced for CLT)
Concrete Upturned Beam - 15"x20"	2.00	CY	$	550.00	$	1,100	Footings per ARUP Plans (Reduced for CLT)
Concrete Grade Beam - 18"x30"	11.00	CY	$	550.00	$	6,050	Footings per ARUP Plans (Reduced for CLT)
Concrete Strap Beam - 48"x36"	17.00	CY	$	550.00	$	9,350	Footings per ARUP Plans (Reduced for CLT)
Interior Square Footing - 13'0"x13'0"x36"	225.00	CY	$	550.00	$	123,750	Footings per ARUP Plans (Reduced for CLT)
Irregular Footing	12.00	CY	$	550.00	$	6,600	Footings per ARUP Plans (Reduced for CLT)
Perimeter Square Footing - 11'0"x11'0"x24"	152.00	CY	$	550.00	$	83,600	Footings per ARUP Plans (Reduced for CLT)
Interior Square Footing - 8'0"x8'0"x22"	138.00	CY	$	550.00	$	75,900	Footings per ARUP Plans (Reduced for CLT)
Shear Wall/Core Pad Footing	680.00	CY	$	550.00	$	374,000	Footings per ARUP Plans (Reduced for CLT)
Perimeter Square Footing - 10'0"x10'0"x44"	231.00	CY	$	550.00	$	127,050	Footings per ARUP Plans (Reduced for CLT)
Interior Square Footing - 10'0"x10'0"x22"	216.00	CY	$	550.00	$	118,800	Footings per ARUP Plans (Reduced for CLT)
Interior Square Footing - 10'0"x10'0"x50"	185.00	CY	$	550.00	$	101,750	Footings per ARUP Plans (Reduced for CLT)
Garage Walls, Slab On Grade, Plaza Slab						See Below	Not a Variable in Comparison
Ground Level Slab	31,705.00	SF	$	38.00	$	1,204,790	Ground Level Slab (Supported Above Garage)
Plaza Slab		SF				N/A	Garage and Office Have Same Approx Footprint
CIP Shear Walls	6,750.00	SF	$	50.00	$	337,500	Higher Floor to Floor, 1 Less Floor
18"x16" Glulam Column	28.00	EA			In CLT Deck		
7-Ply CLT (Includes Columns and Beams)	142,862.00	SF	$	57.00	$	8,143,134	Nordic Pricing Adjusted for Reduced Qty*
5-Ply CLT (Includes Columns and Beams)	10,738.00	SF	$	51.00	$	547,638	Nordic Pricing Adjusted for Reduced Qty* (PH Roof)
3" NWC + 3/4" Acoustic Mat	153,600.00	SF	$	8.00	$	1,228,800	
18"x19" Glulam Column	28.00	EA			In CLT Deck		
Exterior Envelope and Roofing							
YKK Curtainwall System	53,721.00	SF	$	120.00	$	6,446,520	SF of full CW system including trims, mullions and IGUs
Sarnafil roofing	27,545.00	SF	$	29.00	$	798,805	Roof size larger in CLT scheme
CLT Total	157,760.00	GSF	$	125.65	$	19,822,587	
Variance $/GSF of Office		GSF	$	26.86			
Alternate for 175mm CLT ILO 245mm		GSF	$	(6.50)			Reduced per reduced SF.** Needs Structural Analysis

Timber Scheme GSF		
Level	GFA	Structural Deck
1	31,705	CIP Concrete (Garage Below)
1	27,545	Mass Timber
1	27,545	Mass Timber
1	27,545	Mass Timber
1	27,545	Mass Timber
Office	141,885	
PH	15,875	Mass Timber
Total	157,760	
Additonal Structure		
Main Roof	11,670	Mass Timber
PH Roof	15,875	Mass Timber
Structure Totals		
Timber	153,600	
CIP	31,705	

*Nordic had 192,167sf of CLT deck at $9,850,000. Average $51.25/sf
**Nordic Option Saved $1,150,000 on 176,379sf of 7ply deck $6.52/sf

F. **AREA TAKEOFFS**

FOR BUDGET COMPARISON

These are the area takeoffs for the basis-of-design CIP concrete and envelope (Design 1).

Sr No.	Type	Condition	As per Narrative				As per Plan		Comments
			QTY1	UOM1	QTY2	UOM2	QTY	UOM	
1	A1010.11 CONTINUOUS FOOTINGS & GRADE BEAMS	Wall Footing	54	CY			54	CY	
2	A1010.11 CONTINUOUS FOOTINGS & GRADE BEAMS	Concrete Beam - 12''x20''	77	CY	1246	LF			Size of beam is as per narrative
3	A1010.11 CONTINUOUS FOOTINGS & GRADE BEAMS	Concrete Beam - 24''x20''	83	CY	675	LF			Width of Beam assumed as per representation in plan and Height as per typical beam
4	A1010.11 CONTINUOUS FOOTINGS & GRADE BEAMS	Concrete Upturned Beam - 15''x20''	2	CY	20	LF			Width of Beam assumed as per representation in plan and Height as per typical beam
5	A1010.11 CONTINUOUS FOOTINGS & GRADE BEAMS	Concrete Grade Beam - 18''x30''	11	CY	77	LF			
6	A1010.11 CONTINUOUS FOOTINGS & GRADE BEAMS	Concrete Strap Beam - 48''x36''	17	CY	39	LF			
7	A1010.11 CONTINUOUS FOOTINGS & GRADE BEAMS	Concrete Beam - 24''x24''	9	CY	72	LF			
8	A1010.31 SPREAD FOOTINGS	Interior Square Footing - 21'6''x21'6''x50''	856	CY					
9	A1010.31 SPREAD FOOTINGS	Irregular Footing	12	CY			12	CY	
10	A1010.31 SPREAD FOOTINGS	Perimeter Square Footing - 17'6''x17'6''x44''	707	CY					
11	A1010.31 SPREAD FOOTINGS	Interior Square Footing - 8'0''x8'0''x22''	138	CY					
12	A1020.60 MAT FOUNDATIONS	Shear Wall/Core Pad Footing	648	CY			145	CY	For Plan Footing is taken without any offset
13	A1010.31 SPREAD FOOTINGS	Perimeter Square Footing - 10'0''x10'0''x44''					231	CY	
14	A1010.31 SPREAD FOOTINGS	Interior Square Footing - 10'0''x10'0''x22''					216	CY	
15	A1010.31 SPREAD FOOTINGS	Interior Square Footing - 10'0''x10'0''x50''					185	CY	
16	(no type)	Core	6316	SF					
17	A2010.10 SUBGRADE FRAME	12'' Thick Foundation Walls - B1, 5000psi	9441	SF					
18	A4010.10 SLAB ON GRADE	5'' Slab on Grade	31795	SF					
19	B1010.11 CONCRETE FRAME	12'' One-Way Vault Slab, 7.5PSF Mild Reinf.	5724	SF					
20	B1010.11 CONCRETE FRAME	12'' Slab + 8'' Drop Panels	1722	SF					
21	B1010.11 CONCRETE FRAME	8'' Slab + 8'' Drop Panels, 5.0PSF Mild. Rein.	69809	SF					
22	B1010.11 CONCRETE FRAME	10'' PT Slab + 8'' Drop Panels	4214	SF					
23	B1010.11 CONCRETE FRAME	9'' Thick Concrete Slab	1194	SF					
24	B1010.11 CONCRETE FRAME	10'' PT Slab + 10'' Drop Panels	12673	SF					
25	B1010.11 CONCRETE FRAME	8'' PT Slab + 8'' Drop Panels	73162	SF					
26	B1010.11 CONCRETE FRAME	Concrete Column - 16'' Dia, Ht - 26'1''	14	CY	8	EA			
27	B1010.11 CONCRETE FRAME	Concrete Rectangular Columns - 12''x24'', Ht - 9	71	CY	10	EA			
28	B1010.11 CONCRETE FRAME	Concrete Parking Columns - 24''x24'', Ht - 10'5''	32	CY	21	EA			
29	B1010.11 CONCRETE FRAME	Concrete Post Up Column - 24''x24'', Ht - 10'7''	6	CY	4	EA			
30	B1010.11 CONCRETE FRAME	Concrete Post Up Column - 16'' Dia, Ht - 18'8''	10	CY	10	EA			
31	B1010.11 CONCRETE FRAME	Concrete Column - 24''x24'', Ht. -26'1''	4	CY	1	EA			
32	B1010.11 CONCRETE FRAME	Concrete Column - 24''x24'', Ht - 77'4''	229	CY	20	EA			
33	B1010.11 CONCRETE FRAME	Concrete Column - 24''x24'', Ht - 10'5''	3	CY	2	EA			
34	B1010.11 CONCRETE FRAME	Concrete Column - 24''x24'', Ht - 66'9''	40	CY	4	EA			
35	B1010.11 CONCRETE FRAME	Concrete Column - 24''x24'', Ht - 96'0''	114	CY	8	EA			
36	B1010.11 CONCRETE FRAME	Concrete Post Up Column - 24''x24'', Ht - 18'8''	14	CY	5	EA			
37	B20 Exterior	Glass	40494	SF					
38	B20 Exterior	Metal	16966	SF					
39	B20 Exterior	Total Exterior Skin	60178	SF					
40	B20 Exterior	% OF Glass	67.29%						
41	B20 Exterior	% of Metal	28.19%						

F. AREA TAKEOFFS
FOR BUDGET COMPARISON

These are the area takeoffs for the CLT alternate (Design 3).

Sr No.	Type	Condition	As per Narrative		As per Plan		Comments
			QTY	UOM	QTY	UOM	
1	A1010.11 CONTINUOUS FOOTINGS & GRADE BEAMS	Wall Footing	54	CY	54	CY	
2	A1010.11 CONTINUOUS FOOTINGS & GRADE BEAMS	Concrete Beam - 12"x20"	22	CY	360	LF	Width of Beam assumed as per representation in plan and Height as per typical beam
3	A1010.11 CONTINUOUS FOOTINGS & GRADE BEAMS	Concrete Beam - 24"x20"	83	CY	676	LF	Width of Beam assumed as per representation in plan and Height as per typical beam
4	A1010.11 CONTINUOUS FOOTINGS & GRADE BEAMS	Concrete Upturned Beam - 15"x20"	2	CY	20	LF	
5	A1010.11 CONTINUOUS FOOTINGS & GRADE BEAMS	Concrete Grade Beam - 18"x30"	11	CY	77	LF	
6	A1010.11 CONTINUOUS FOOTINGS & GRADE BEAMS	Concrete Strap Beam - 48"x36"	17	CY	39	LF	
7	A1010.31 SPREAD FOOTINGS	Interior Square Footing - 13'0"x13'0"x36"	225	CY			
8	A1010.31 SPREAD FOOTINGS	Irregular Footing	12	CY	12	CY	
9	A1010.31 SPREAD FOOTINGS	Perimeter Square Footing - 11'0"x11'0"x24"	152	CY			
10	A1010.31 SPREAD FOOTINGS	Interior Square Footing - 8'0"x8'0"x22"	138	CY			
11	A1020.60 MAT FOUNDATIONS	Shear Wall/Core Pad Footing	680	CY	145	CY	For Plan Footing is taken without any offset
12	A1010.31 SPREAD FOOTINGS	Perimeter Square Footing - 10'0"x10'0"x44"			231	CY	
13	A1010.31 SPREAD FOOTINGS	Interior Square Footing - 10'0"x10'0"x22"			216	CY	
14	A1010.31 SPREAD FOOTINGS	Interior Square Footing - 10'0"x10'0"x50"			185	CY	
15	(no type)	Core	5863	SF			
16	A2010.10 SUBGRADE FRAME	12" Thick Foundation Walls - B1, 5000psi	9441	SF			
17	A4010.10 SLAB ON GRADE	5" Slab on Grade	31795	SF			
18	B1010.11 CONCRETE FRAME	12" One-Way Vault Slab, 7.5PSF Mild Reinf.	5724	SF			
19	B1010.11 CONCRETE FRAME	12" Slab + 8" Drop Panels	1740	SF			
20	B1010.11 CONCRETE FRAME	8" Slab + 8" Drop Panels, 5.0PSF Mild. Rein.	23663	SF			
21	B1010.11 CONCRETE FRAME	Concrete Column - 24"x24", Ht - 10'5"	51	CY	33	EA	
22	B1010.11 CONCRETE FRAME	Concrete Column - 16" Dia, Ht - 26'1"	14	CY	8	EA	
23	B1010.11 CONCRETE FRAME	Concrete Rectangular Columns - 12"x24", Ht	71	CY	10	EA	
24	B1010.11 CONCRETE FRAME	Concrete Parking Columns - 24"X24", Ht - 10'	35	CY	23	EA	
25	B1010.17 Wood Frame	18"x16" Glulam Column	28	EA			
26	B1010.17 Wood Frame	3" NWC + 3/4" Acoustic Mat + 7-Ply CLT	157457	SF			
27	B1010.17 Wood Frame	18"x19" Glulam Column	28	EA			
28	B20 Exterior	Glass	40494	SF			
29	B20 Exterior	Metal	16966	SF			
30	B20 Exterior	Total Exterior Skin	60178	SF			
31	B20 Exterior	% OF Glass	67.29%				
32	B20 Exterior	% of Metal	28.19%				

CONCLUSIONS

1 REGULATION

The local DC government and the Federal Government should regulate against the use of regular CIP concrete and require the use of low carbon concrete. The carbon saving benefits outweigh the cost premium.

2 VALUE CREATION WITH CLT

On a site only constrained by density, not by surface area, the CLT option option has the most value creation potential.

3 COST VS. RENT

A rent increase of **$1.50/sf** offsets a cost increase of **$26/sf** .

4 DEMAND TRANSPARENCY & UNIFORMITY

Architects and Engineers should demand from manufacturers transparency and uniformity in the reporting of embodied carbon and Environmental Product Data.