1300 SYCAMORE

“BUILDING INNOVATION DESIGN ASSISTANCE: EMBODIED CARBON LIFECYCLE ANALYSIS ASSISTANCE”
GRANT TEAM

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HICKOK COLE

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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**
"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."

A. WHAT IS A “GOOD” LCA?

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

1. 6 STORIES
   - 10'-10”, TYP. FLR-FLR HEIGHT
   - 24,892 SF, TYP. FLR
   - 164,531 SF (INCL. PH)
   - BAU CONCRETE
   - BLD CWALL / WWALL
   - BLD 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

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 provide a 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;
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;
      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.

filenames: 40 5294 att. 1 - activities funded_hickok cole ec.docx
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 CO2e. 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

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 invaluable 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 an 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%.

<table>
<thead>
<tr>
<th>Material</th>
<th>BAU Concrete Basis of Design</th>
<th>Low Carbon Concrete</th>
<th>Mass Timber</th>
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<tbody>
<tr>
<td>Concrete, CY</td>
<td>10k</td>
<td>10k</td>
<td>5k</td>
</tr>
<tr>
<td>Steel, lbs</td>
<td>1M</td>
<td>1M</td>
<td>400k</td>
</tr>
<tr>
<td>Timber, CY</td>
<td>--</td>
<td>--</td>
<td>6k</td>
</tr>
</tbody>
</table>

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.

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

ALL MEASURED IN PCY (POUNDS PER CUBIC YARD)
The low carbon concrete decreases the embodied carbon by 17% when compared to BAU.

The CO2 reduction from the CLT is nearly double that.

It is important to note that sequestered carbon is not subtracted 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

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Washington, DC 20007

1023 31   Street, NW
D. ARCHITECTURAL ENVELOPE

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.
GENERAL NOTES:
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D. ARCHITECTURAL ENVELOPE
FACADE - DELINEATION OF ELEMENTS

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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.

SOUTH ELEVATION
D. ARCHITECTURAL ENVELOPE
QUANTIFYING WINDOW WALL + METAL PANEL

ENLARGED, TWO- STORY ELEVATION

8" PT CONCRETE SLAB
12" DEEP ALUMINUM BRAKE METAL SLAB EDGE COVER
1'-3"
10'-1/2"
9'-10"

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 801T 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

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D. ARCHITECTURAL ENVELOPE
PENTHOUSE ARTICATION

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
D. CLT SCHEME
MASSING & PLANS

- **Ground Floor:** 31,705 GSF
- **Typical Floor:** 27,545 GSF
- **Total GSF:** 141,885 GSF
- **Phase:** 15,875 SF
- **Total SF Incl. Phase:** 157,760 SF

- **Architectural - Multi-Tenant Demising**

- **Structural Framing**
  - **40' x 20' Column Grid**
  - **Double 10.5x34.375 GLULAM Beams**
  - **7 PlyC Lt Panel**

- **Aerial, from northeast**
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.

### Metal Panel Areas

<table>
<thead>
<tr>
<th>OA Height</th>
<th>Dimensions in Decimals</th>
<th>Perimeter - LF</th>
<th>Area - SF</th>
<th>Location</th>
<th>OneClick Specification</th>
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<tbody>
<tr>
<td>Ground Floor</td>
<td>16'-4&quot;</td>
<td>1'3&quot;</td>
<td>1.25</td>
<td>483</td>
<td>603.75</td>
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<tr>
<td></td>
<td>15'-2&quot;</td>
<td>1'3&quot;</td>
<td>1.25</td>
<td>40</td>
<td>603.33</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1'3&quot;</td>
<td>1.25</td>
<td>40</td>
<td>50.00</td>
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<tr>
<td>Level 02</td>
<td>10'-10&quot;</td>
<td>9'-7&quot;</td>
<td>9.58</td>
<td>523</td>
<td>483.96</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1'3&quot;</td>
<td>1.25</td>
<td></td>
<td>653.75</td>
</tr>
<tr>
<td></td>
<td>10'-10&quot;</td>
<td>9'-7&quot;</td>
<td>9.58</td>
<td>523</td>
<td>93.5</td>
</tr>
<tr>
<td></td>
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<td>1'3&quot;</td>
<td>1.25</td>
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<td>653.75</td>
</tr>
<tr>
<td></td>
<td>10'-10&quot;</td>
<td>9'-7&quot;</td>
<td>9.58</td>
<td>523</td>
<td>76.3</td>
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<td>1'3&quot;</td>
<td>1.25</td>
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<td></td>
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<td>1'3&quot;</td>
<td>1.25</td>
<td></td>
<td>653.75</td>
</tr>
<tr>
<td></td>
<td>10'-10&quot;</td>
<td>10'-0&quot;</td>
<td>10</td>
<td></td>
<td>71.8</td>
</tr>
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<td></td>
<td></td>
<td>1'3&quot;</td>
<td>1.25</td>
<td></td>
<td>653.75</td>
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### Total Areas

<table>
<thead>
<tr>
<th></th>
<th>Total Metal Panel</th>
<th>Total Slab Edge</th>
<th>Total Vertical Façade Panel</th>
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<tbody>
<tr>
<td>Ground Floor</td>
<td>603.33</td>
<td>653.75</td>
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<tr>
<td>Level 02-06</td>
<td>3268.75</td>
<td>3,787.54</td>
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<td>Penthouse</td>
<td>7,090.00</td>
<td></td>
<td></td>
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<tr>
<td><strong>TOTAL AREAS</strong></td>
<td><strong>603.33</strong></td>
<td><strong>3922.50</strong></td>
<td><strong>10877.54</strong></td>
</tr>
</tbody>
</table>


**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

**1300 SYCAMORE DRIVE SE**

**REDBRICK LMD**

**DOEE LCA GRANT DOCUMENT**

**11.09.2021 REV A 26**
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 in no.2, and replaces the structure with cross laminated timber.
- 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/Hydratech 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.
**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.

---

**60% CO2e**

**71% CO2e**

---

**ONE CLICK LCA RESULTS**

---
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 encompasses 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.
D. CWALL / WWALL EPD
KAWNEER (BASIS OF DESIGN)
D. CWALL / WWALL EPD
KAWNEER (BASIS OF DESIGN)
D. CWALL / WWALL EPD
KAWNEER (BASIS OF DESIGN)

Environmental Product Declaration

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 analysis was performed because primary data from more than one location is averaged for a cell 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 2%, 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

<table>
<thead>
<tr>
<th>Impact Category</th>
<th>CV (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Global warming potential</td>
<td>1%</td>
</tr>
<tr>
<td>Ozone depletion potential</td>
<td>1%</td>
</tr>
<tr>
<td>Acidification potential</td>
<td>1%</td>
</tr>
<tr>
<td>Eutrophication potential</td>
<td>1%</td>
</tr>
<tr>
<td>Smog formation potential</td>
<td>1%</td>
</tr>
</tbody>
</table>

The coefficient of variation for each impact category was calculated by first determining the weighted standard deviation ($\sigma_w$) and the weighted average ($\mu_w$) and then applying

$$CV = \frac{\sigma_w}{\mu_w}$$

The weighted average was calculated as

$$\mu_w = \frac{\sum w_i \cdot \mu_i}{\sum w_i}$$

while the weighted standard deviation is determined by

$$\sigma_w = \sqrt{\frac{\sum w_i \cdot (\mu_i - \mu_w)^2}{\sum w_i}}$$

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

Environment

UL
D. CWALL / WWALL EPD

KAWNEER (BASIS OF DESIGN)

ENVIRONMENTAL PRODUCT DECLARATION

Window Wall
Featuring MasterView™ PG tint Window Wall

According to ISO 14025

Additional Information

Disclosure of Window 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 [REACH 1915].

Recyclable Content

Aluminum is a highly efficient sustainable building material. Aluminum is 100% recyclable and can be recycled repeatedly. Recycled aluminum is identical to excited 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


EN 15804 2012 European Committee for Standardization (CEN). "EN 15804:2012. Sustainability of construction works — Environmental product declarations — Core rules for the product category of construction products"


Environment

The Life Cycle Assessment was conducted by thinkstep (formerly PE INTERNATIONAL) using GaBi data.
D. CWALL / WWALL EPD
YKK (LOW CARBON ALTERNATE)

**ENVIRONMENTAL PRODUCT DECLARATION**

**ALUMINUM WINDOW WALL SYSTEMS**

YKK AP AMERICA

YKK AP America is taking positive steps toward sustainable manufacturing by designing, testing and producing energy-efficient and multi-functional products that minimize environmental impacts.

**PROGRAM OPERATOR**

UL Environment

**DECLARATION HOLDER**

YKK AP America

**DECLARATION NUMBER**

79293322-106.1

**ALUMINUM WINDOW WALL SYSTEMS**

**REFERENCE PDP**


**DATE OF ISSUE**

November 13, 2015

**PERIOD OF VALIDITY**

5 Years

**PRODUCTS**

Aluminum Window Wall Systems

**DESCRIPTION**

Aluminum window systems are available in different window configurations and are used in applications such as shown in 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.

**CONTENT 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 and installation**
- **Information about in-use conditions**
- **Life cycle assessment results**
- **Testing results and verifications**

**The PCR review was conducted by**

- The Independent Expert Committee

**This declaration was independently verified in accordance with ISO 14025 by Underwriters Laboratories**

**This life cycle assessment was independently verified in accordance with ISO 14044 and the reference PCR by**

- Thomas Glaris, Industrial Ecology Consultant
D. CWALL / WWALL EPD

YKK (LOW CARBON ALTERNATE)

ENVIRONMENTAL PRODUCT DECLARATION

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, tested 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 jibes or re-work. YKK AP offers a complete suite of tools and engineering services to assist in proper system selection, specification and installation.

Product Description

The following YKK AP America aluminum window systems are covered by this EPG (copying is excluded from this study):

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

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

YWE 60 T 3-3/8" x 4 1/2" 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.

Materials & Coatings

Aluminum Alloys:

6063 T5, 6060 T5, 6060 T5

Available Finishes:

ARCHITECTURAL ANODIZED FINISHES

PAINTED FINISHES
D. CWALL / WWALL EPD

YKK (LOW CARBON ALTERNATE)

ENVIRONMENTAL PRODUCT DECLARATION

YKK AP America
Aluminum Window Wall Systems

According to ISO 14025

YWW 45 FS 8.3/4” x 6.3/4” 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 also be installed with head and all members running continuously or with the head and all members cut between the vertical members. Stiff flooring is only required when the head and all members are cut in between the verticals; in addition, all members are anchored without penetrating the sill flashing.

YWF 50 T1 RAL 8017 Thermally Brokens Window Wall System with Optional Stab Edge Cover

YWW 50 T1 is a Window Wall glazing system designed for use in multi-story applications. It includes an optional stab 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 T1 is designed to accommodate 1” glazing with seal, and with the use of adaptors, can also accommodate 1/4” glazing. The system has multiple 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-Thermi thermal break technology that also provides the system with dual finish capability. The screw apsine assembly design makes fabrication and installation more efficient.

YWW 45 T1 8.3/4” x 6.3/4” Thermally Broken Window Wall System

YWW 45 T1 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 T1 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.

ENVIRONMENTAL PRODUCT DECLARATION

YKK AP America
Aluminum Window Wall Systems

According to ISO 14025

Technical Performance

<table>
<thead>
<tr>
<th>Property</th>
<th>Notes</th>
<th>Value</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thermal Transmission (U-Value)</td>
<td></td>
<td>1, 2, 4</td>
<td>0.33 - 0.39</td>
</tr>
<tr>
<td>Solar Heat Gain Coefficient (SHGC)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Glazing 30%</td>
<td>1, 4</td>
<td>0.93 - 0.26</td>
<td></td>
</tr>
<tr>
<td>Condensation Resistance Factor (CFR)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>AAMA 1201</td>
<td>2, 3, 4</td>
<td>57 - 70</td>
<td></td>
</tr>
<tr>
<td>Water Infiltration ASTM E 305 and AAMA 401.1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>10 - 15</td>
<td>pcf</td>
<td></td>
</tr>
<tr>
<td>Air Infiltration ASTM E 331 at 0.48 psf</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>0.06</td>
<td>cfm²²</td>
<td></td>
</tr>
</tbody>
</table>

Industry Standards

AAMA 1201, ASTM E1425, ASTM E90, ASTM E411, ASTM E1332, ASTM E2335, ASTM E2303, ASTM E320, AAMA 507, AAMA 1003, NFRC 100, NFRC 103, NFRC 290, NFRC 105, NFRC 103, ASTM E311

YKK AP® does not test or rate the declared products for extraordinary effects. I.e., performance under unforeseeable influences of rain, wind or structural deformation.

Delivery Status

YKK AP® window wall systems vary in size depending on the application. They are currently used in diverse window configurations or panelized openings. The framing system spans from double-deck and can be installed from the building’s interior to improve logistics and reduce installation costs. Window wall systems can also employ floor soul edge covers that enable the system to mimic the look of a curtain wall system at a significantly reduced cost.
D. CWALL / WWALL EPD
YKK (LOW CARBON ALTERNATE)

Environmental Product Declaration

YKK AP America
Aluminum Window Wall Systems

Basis and Auxiliary Materials

<table>
<thead>
<tr>
<th>Material</th>
<th>Painted</th>
<th>Unpainted</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aluminum 6060</td>
<td>5.38-8.59</td>
<td>8.8-16.01</td>
</tr>
<tr>
<td>Anodizing coat, optional</td>
<td>0 - 0.25</td>
<td>&lt;1</td>
</tr>
<tr>
<td>PVD coat, optional</td>
<td>0 - 1.49</td>
<td>&lt;1</td>
</tr>
<tr>
<td>MegaTherm (Rynite 6 Klass fiber)</td>
<td>3.96</td>
<td>&lt;1</td>
</tr>
<tr>
<td>Thermakool (Polyurethane)</td>
<td>1.90</td>
<td>&lt;1</td>
</tr>
<tr>
<td>EPDM</td>
<td>3.99</td>
<td>&lt;1</td>
</tr>
<tr>
<td>EVA</td>
<td>2.00</td>
<td>&lt;1</td>
</tr>
<tr>
<td>Teflon</td>
<td>5.87</td>
<td>&lt;1</td>
</tr>
<tr>
<td>Polycarbonate</td>
<td>1.54</td>
<td>&lt;1</td>
</tr>
<tr>
<td>PVC</td>
<td>2.04</td>
<td>&lt;1</td>
</tr>
<tr>
<td>Steel</td>
<td>2.75</td>
<td>&lt;1</td>
</tr>
</tbody>
</table>

Note: Cladding 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:

1. Extrusion of aluminum profile
2. Surface treatment (optional), i.e., anodizing or painting
3. Extrusion of aluminum profile
4. Surface treatment (optional), i.e., anodizing or painting
5. Fabrication and assembly
6. Packaging
7. Thermal treatment (optional), i.e., MegaTherm

Environmental

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

Packaging

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

Process Description

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

End of Life

Recycling

<table>
<thead>
<tr>
<th>Category</th>
<th>Material</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Recycled Aluminium</td>
<td>3,240</td>
<td>97.00% / 99.00%</td>
</tr>
<tr>
<td>Other Recyclables</td>
<td>0</td>
<td>0.00% / 0.00%</td>
</tr>
</tbody>
</table>

Aluminum extrusions are highly efficient sustainable building materials. Aluminum is 100% recyclable and can be recycled repeatedly. Recycled aluminum is identical to unmilled aluminum but requires only 1/3 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.


Environment and Health

Product manufacturing: Paint emissions to atmosphere are monitored (if applicable) and comply with local laws.

Product use: YKK AP products are not expected to exceed 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.
**D. CWALL / WWALL EPD**

**YKK (LOW CARBON ALTERNATE)**

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### ENVIRONMENTAL PRODUCT DECLARATION

**YKK**

ALUMINIUM WINDOW WALL SYSTEMS

According to ISO 14025

---

#### Life Cycle Assessment – Product System and Modelling

A “cradle-to-gate with options” analysis using life cycle assessment (LCA) techniques was conducted for this EPD. The methodology was done according to the product category rule (PCR) for Curtain Walling and related LCA principles.

The system boundaries are such that the resulting LCA model will 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 sq. meter) of window wall product.

<table>
<thead>
<tr>
<th>Declared Unit</th>
<th>Unit</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 sq. meter</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Conversion factor to 1 kg: 15 kg

#### System Boundaries

For 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 the “options” Disclosure and Credibility, i.e., modules C4 and D:

#### DESCRIPTION OF THE SYSTEM BOUNDARY (as included in LCA; WIND = MODULE NOT DECLARED)

<table>
<thead>
<tr>
<th>PRODUCT SPACE</th>
<th>CONSTRUCTION PHASE</th>
<th>LCA PHASE</th>
<th>DOE OF LIFE PHASE</th>
<th>BENEFITS AND IMPACTS</th>
<th>ENVIRONMENTAL IMPACTS</th>
<th>SYSTEM BOUNDARIES</th>
</tr>
</thead>
<tbody>
<tr>
<td>A1</td>
<td>A2</td>
<td>A3</td>
<td>A4</td>
<td>A5</td>
<td>A6</td>
<td>A7</td>
</tr>
<tr>
<td>D1</td>
<td>D2</td>
<td>D3</td>
<td>D4</td>
<td>D5</td>
<td>D6</td>
<td>D7</td>
</tr>
<tr>
<td>C1</td>
<td>C2</td>
<td>C3</td>
<td>C4</td>
<td>D</td>
<td></td>
<td></td>
</tr>
<tr>
<td>X1</td>
<td>X</td>
<td>X9</td>
<td>X7</td>
<td>X8</td>
<td>X2</td>
<td></td>
</tr>
</tbody>
</table>

#### Time coverage:

Primary data were collected from within calendar year 2014. Background data for upstream and downstream processes (i.e., raw materials, energy sources, 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’s manufacturing facility in the United States.

#### Geographical coverage:

All YKK™ products are manufactured in Duluth, Georgia, USA. As such, the geographical coverage for this study is based on United States system boundaries for all processes and products. Wherever US background data were not readily available, European data or global data were used as proxy.

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### Environmental Product Declaration

**YKK**

ALUMINIUM WINDOW WALL SYSTEMS

According to ISO 14025

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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 roll of materials (Roll) specifies the profile which comprise an individual product, the underlying model was created to describe YKK AP™ aluminum extrusions as generic industrial products (IPs) which were assumed to be the same extrusion profile split for surface treatments—i.e., 20% anodized, 18% powder coated, 18% satin finish, 18% standard finish—against to extrusions going into window wall control products as well as extrusions going into other products, e.g., railings, etc. (see approved 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 partly, used to the realities on the factory floor, packaging materials were scaled with the aluminum content as identified in the Roll.

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 materials 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 [https://www.gabi-software.com/support/pdf/gabi-4-l1-doc/documentation/](https://www.gabi-software.com/support/pdf/gabi-4-l1-doc/documentation/).

#### Cut-off Criteria

As required by EN 14804, 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 averages 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 aluminum extrusions were taken from the GaBi 2014 database.

#### LCA Practitioner

This EPD and the underlying LCA model were developed by thinkstep, Inc.
D. CWALL / WWALL EPD
YKK (LOW CARBON ALTERNATE)

ENVIRONMENTAL PRODUCT DECLARATION

YKK AP Americas
Aluminum Window Wall Systems

According to ISO 14025

Life Cycle Assessment – Results and Analysis

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

<table>
<thead>
<tr>
<th>Component</th>
<th>Manufacturing</th>
<th>Transportation</th>
<th>Commissioning</th>
<th>Salvage and Disposal</th>
</tr>
</thead>
<tbody>
<tr>
<td>W</td>
<td>4,598.39</td>
<td>4,097.63</td>
<td>3,736.78</td>
<td>3,542.24</td>
</tr>
<tr>
<td>C</td>
<td>4,598.39</td>
<td>4,097.63</td>
<td>3,736.78</td>
<td>3,542.24</td>
</tr>
<tr>
<td>R</td>
<td>4,598.39</td>
<td>4,097.63</td>
<td>3,736.78</td>
<td>3,542.24</td>
</tr>
</tbody>
</table>

Glacis

Environmental impacts

GHG: Global warming potential
EP: Eutrophication potential
AP: Acidification potential
POCP: Primary energy consumption (primary aluminium)
ADP: Air emissions potential
PE: Primary energy potential
RF: Resource consumption

Resource use

FEW: Use of renewable primary energy excluding renewable energy from biomass
PFEW: Use of non-renewable primary energy resources
PEEE: Use of secondary energy resources
PEEM: Use of non-renewable primary energy resources
PEEB: Use of secondary energy resources

ENVIRONMENTAL PRODUCT DECLARATION

CML Impact Categories

<table>
<thead>
<tr>
<th>Category</th>
<th>CML Impact</th>
</tr>
</thead>
<tbody>
<tr>
<td>D</td>
<td>20%</td>
</tr>
<tr>
<td>E</td>
<td>10%</td>
</tr>
<tr>
<td>F</td>
<td>5%</td>
</tr>
</tbody>
</table>

ENVIRONMENTAL PRODUCT DECLARATION

CML Impact Categories

<table>
<thead>
<tr>
<th>Category</th>
<th>CML Impact</th>
</tr>
</thead>
<tbody>
<tr>
<td>D</td>
<td>20%</td>
</tr>
<tr>
<td>E</td>
<td>10%</td>
</tr>
<tr>
<td>F</td>
<td>5%</td>
</tr>
</tbody>
</table>

Environmental

References


ENVIRONMENTAL PRODUCT DECLARATION

CML Impact Categories

<table>
<thead>
<tr>
<th>Category</th>
<th>CML Impact</th>
</tr>
</thead>
<tbody>
<tr>
<td>D</td>
<td>20%</td>
</tr>
<tr>
<td>E</td>
<td>10%</td>
</tr>
<tr>
<td>F</td>
<td>5%</td>
</tr>
</tbody>
</table>
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.
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.

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

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

Select threshold : Cut off 5%

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

Your material: Window wall curtain wall system = 457.61 m² - CO2 TRACI

United States

<table>
<thead>
<tr>
<th>Factor</th>
<th>Unit</th>
<th>District of Columbia</th>
<th>United States</th>
<th>Neighbouring countries</th>
<th>All</th>
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<tr>
<td>Products in area</td>
<td>product</td>
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<td>21</td>
<td>1</td>
<td>31</td>
</tr>
<tr>
<td>00th percentile</td>
<td>kg CO2eqm²</td>
<td>0</td>
<td>157.00 - Use as benchmark</td>
<td>138.0</td>
<td>303.500 - Use as benchmark</td>
</tr>
<tr>
<td>Average</td>
<td>kg CO2eqm²</td>
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<td>158.027 - Use as benchmark</td>
<td>138.0</td>
<td>227.455 - Use as benchmark</td>
</tr>
<tr>
<td>Median</td>
<td>kg CO2eqm²</td>
<td>0</td>
<td>150.0 - Use as benchmark</td>
<td>138.0</td>
<td>180.0 - Use as benchmark</td>
</tr>
</tbody>
</table>
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

<table>
<thead>
<tr>
<th>Category</th>
<th>A1-A3 Materials</th>
<th>A4 Transportation</th>
<th>A5 Construction</th>
<th>A6 Repair</th>
<th>A7-85 Replacement</th>
<th>B4-86 Energy</th>
<th>B5 Water</th>
<th>B6 C3-C4 Waste processing</th>
<th>B7 Use Phase</th>
<th>Total kg CO2</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 - Concrete Option (BAU)</td>
<td>2448730</td>
<td>42231</td>
<td>13996</td>
<td>2544417</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>804694</td>
</tr>
<tr>
<td>2 - Timber Option</td>
<td>1329005</td>
<td>55169</td>
<td>316497</td>
<td>3700324</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>417783</td>
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<tr>
<td>2 - Concrete Option (Low Carbon)</td>
<td>2039474</td>
<td>42231</td>
<td>13996</td>
<td>2086634</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Enclosure</th>
<th>A1-A3 Materials</th>
<th>A4 Transportation</th>
<th>A5 Construction</th>
<th>A6 Repair</th>
<th>B4-85 Replacement</th>
<th>B6 Energy</th>
<th>B5 Water</th>
<th>B6 C3-C4 Waste processing</th>
<th>B7 Use Phase</th>
<th>Total kg CO2</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 - SE P-17 B-2 (base)</td>
<td>3415485</td>
<td>9108</td>
<td>30091</td>
<td>0</td>
<td>54750</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>51490</td>
<td>3559524</td>
</tr>
<tr>
<td>2 - v1_base w/ rev CW-1 / WW-1</td>
<td>1351055</td>
<td>5203</td>
<td>26468</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>4783</td>
<td>0</td>
<td>1395467</td>
</tr>
<tr>
<td>2 - v2_CLT rev CW/WW rev rf memir</td>
<td>973477</td>
<td>3801</td>
<td>10413</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>4783</td>
<td>992475</td>
</tr>
</tbody>
</table>

### Combined

| BAU Concrete (Baseline)       | 5864215          | 51399             | 64886           | 3590500   | 0                 | 0       | 0       | 0                           | 0            |              |
| Low-Carbon Concrete           | 3388033          | 47434             | 20137           | 3455633   | 2524867          | 42%     |         |                             |              |              |
| Mass Timber                   | 2302482          | 58971             | 329033          | 2682386   | 3298114          | 55%     |         |                             |              |              |

| BAU Concrete (Baseline)       | 5864215          | 51399             | 64886           | 3590500   | 0                 | 0       | 0       | 0                           | 0            |              |
| Low-Carbon Concrete           | 3388033          | 47434             | 20137           | 3455633   | 2524867          | 42%     |         |                             |              |              |
| Mass Timber                   | 2302482          | 58971             | 329033          | 2682386   | 3298114          | 55%     |         |                             |              |              |
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 CO2 really is, we equate it to everyday 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.

<table>
<thead>
<tr>
<th></th>
<th>Homes’ electricity use for 1 year</th>
<th>Miles travelled by average car</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>BAU Concrete</strong></td>
<td>1,086</td>
<td>15 million</td>
</tr>
<tr>
<td><strong>Low Carbon Concrete</strong></td>
<td>↓ 459</td>
<td>↓ 6.3 million</td>
</tr>
<tr>
<td><strong>Timber</strong></td>
<td>↓ 599</td>
<td>↓ 8.3 million</td>
</tr>
</tbody>
</table>
## 1. CIP Scheme Building GSF

<table>
<thead>
<tr>
<th>Description</th>
<th>SF</th>
<th>CY</th>
<th>GSF</th>
<th>Minor</th>
<th>Major</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ground Level Slab</td>
<td>32,565</td>
<td>550.00</td>
<td>18,013</td>
<td>46.66</td>
<td>6,150</td>
</tr>
<tr>
<td>Garage Walls, Slab On Grade</td>
<td>11,098</td>
<td>550.00</td>
<td>6,066</td>
<td>11.11</td>
<td>2,438</td>
</tr>
<tr>
<td>Interior Square Footing - 10'0''x10'0''x22''</td>
<td>118,800</td>
<td>550.00</td>
<td>216.00</td>
<td>3.90</td>
<td>6,050</td>
</tr>
<tr>
<td>Concrete Grade Beam - 18''x30''</td>
<td>6,050</td>
<td>550.00</td>
<td>11.00</td>
<td>0.20</td>
<td>1,100</td>
</tr>
<tr>
<td>Perimeter Shear Wall/Core Pad Footing</td>
<td>11,098</td>
<td>550.00</td>
<td>6,066</td>
<td>11.11</td>
<td>2,438</td>
</tr>
<tr>
<td>CIP Concrete Structure</td>
<td>216,000</td>
<td>550.00</td>
<td>123,750</td>
<td>225.00</td>
<td>45,650</td>
</tr>
<tr>
<td>CIP Shear Walls</td>
<td>6,750</td>
<td>50.00</td>
<td>337,500</td>
<td>2.00</td>
<td>1,100</td>
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<tr>
<td>Plaza Slab</td>
<td>25,095</td>
<td>550.00</td>
<td>13,835</td>
<td>25.00</td>
<td>125,860</td>
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<tr>
<td>Concrete Beam - 24''x20''</td>
<td>45,650</td>
<td>550.00</td>
<td>83.60</td>
<td>1.50</td>
<td>1,960</td>
</tr>
<tr>
<td>3'' NWC + 3/4'' Acoustic Mat</td>
<td>101,750</td>
<td>550.00</td>
<td>188,526</td>
<td>38.00</td>
<td>77.00</td>
</tr>
<tr>
<td>Shear Wall/Core Pad Footing</td>
<td>6,066</td>
<td>550.00</td>
<td>337,500</td>
<td>2.00</td>
<td>1,100</td>
</tr>
<tr>
<td>Structure Totals</td>
<td>53,721</td>
<td>550.00</td>
<td>15,875</td>
<td>24.892</td>
<td>550.00</td>
</tr>
</tbody>
</table>

### Additional Structure

- **Office**: 180,608
- **Main Roof**: 9,320
- **Timber**: 31,705
- **Structure Totals**: 185,936

### Timber Scheme GSF

- **Office**: 180,608
- **Main Roof**: 9,320
- **Timber**: 31,705
- **Structure Totals**: 193,233

### CIP Scheme Building GSF

- **Office**: 180,608
- **Main Roof**: 9,320
- **CIP**: 110,536

### DOEE LCA GRANT DOCUMENT

- **11.09.2021 REV A**
- **ENVELOPE & ROOFING**
  - CIP Concrete Structure
  - Mass Timber

### Timber Envelope

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

**CIP Scheme Building GSF**

<table>
<thead>
<tr>
<th>Level</th>
<th>GSF</th>
<th>Structuralリスク</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>83,000</td>
<td>CIP Concrete</td>
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<tr>
<td>2</td>
<td>21,600</td>
<td>CIP Concrete</td>
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<tr>
<td>3</td>
<td>21,600</td>
<td>CIP Concrete</td>
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<tr>
<td>4</td>
<td>21,600</td>
<td>CIP Concrete</td>
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<tr>
<td>5</td>
<td>21,600</td>
<td>CIP Concrete</td>
</tr>
<tr>
<td>Total</td>
<td>185,936</td>
<td>CIP Concrete</td>
</tr>
</tbody>
</table>

### Timber Scheme GSF

- **Office**: 180,608
- **Main Roof**: 9,320
- **Timber**: 31,705
- **Structure Totals**: 193,233

### 2.4% $ 2 INCREASES LOW CARBON CONCRETE, ENVELOPE & ROOFING

### 21.2% $$$ 3 INCLUDES CIP, MASS TIMBER, LOW CARBON ENVELOPE & ROOFING

### Additional Structure

- **Main Roof**: 9,320
- **Timber**: 31,705
- **Structure Totals**: 193,233

### Design

- **Design 1**: 2.4% premium in cost compared to the Basis of Design
- **Design 2**: 21.2% premium in cost compared to the Basis of Design

### Cost Savings vs. $$$

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

**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

<table>
<thead>
<tr>
<th>Sr No</th>
<th>Type Condition</th>
<th>As per Narrative</th>
<th>As per Plan</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>A1010.11 CONTINUOUS FOOTINGS &amp; GRADE BEAMS Wall Footing</td>
<td>54 CY</td>
<td>54 CY</td>
</tr>
<tr>
<td>2</td>
<td>A1010.11 CONTINUOUS FOOTINGS &amp; GRADE BEAMS Concrete Beam - 12''x20''</td>
<td>77 CY</td>
<td>1246 LF</td>
</tr>
<tr>
<td>3</td>
<td>A1010.11 CONTINUOUS FOOTINGS &amp; GRADE BEAMS Concrete Beam - 24''x20''</td>
<td>81 CY</td>
<td>675 LF</td>
</tr>
<tr>
<td>4</td>
<td>A1010.11 CONTINUOUS FOOTINGS &amp; GRADE BEAMS Concrete Upturned Beam - 15''x20''</td>
<td>2 CY</td>
<td>20 LF</td>
</tr>
<tr>
<td>5</td>
<td>A1010.11 CONTINUOUS FOOTINGS &amp; GRADE BEAMS Concrete Grade Beam - 18''x30''</td>
<td>13 CY</td>
<td>77 LF</td>
</tr>
<tr>
<td>6</td>
<td>A1010.11 CONTINUOUS FOOTINGS &amp; GRADE BEAMS Concrete Drop Beam - 48''x30''</td>
<td>17 CY</td>
<td>99 LF</td>
</tr>
<tr>
<td>7</td>
<td>A1010.11 CONTINUOUS FOOTINGS &amp; GRADE BEAMS Concrete Beam - 24''x24''</td>
<td>9 CY</td>
<td>72 LF</td>
</tr>
<tr>
<td>8</td>
<td>A1010.31 SPREAD FOOTINGS Interior Square Footing - 21'6''x21'6''x50''</td>
<td>856 CY</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>A1010.31 SPREAD FOOTINGS Irregular Footing</td>
<td>12 CY</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>A1010.31 SPREAD FOOTINGS Perimeter Square Footing - 17'6''x17'6''x44''</td>
<td>707 CY</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>A1010.31 SPREAD FOOTINGS Interior Square Footing - 8'0''x8'0''x22''</td>
<td>136 CY</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>A1010.60 MAT FOUNDATIONS Shear Wall/Core Pad Footing</td>
<td>648 CY</td>
<td>145 CY</td>
</tr>
<tr>
<td>13</td>
<td>A1010.31 SPREAD FOOTINGS Perimeter Square Footing - 10'0''x10'0''x44''</td>
<td>231 CY</td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>A1010.31 SPREAD FOOTINGS Interior Square Footing - 10'0''x10'0''x22''</td>
<td>9 CY</td>
<td>72 LF</td>
</tr>
<tr>
<td>15</td>
<td>A1010.31 SPREAD FOOTINGS Interior Square Footing - 10'0''x10'0''x22''</td>
<td>185 CY</td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>(No type) Core</td>
<td>6316 SF</td>
<td></td>
</tr>
<tr>
<td>17</td>
<td>A1010.10 SUBGRADE FRAME 12'' Thick Foundation Walls - 81, 5000 psi</td>
<td>9441 SF</td>
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<tr>
<td>18</td>
<td>4010.10 SLAB ON GRADE 5'' Slab on Grade</td>
<td>31795 SF</td>
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<tr>
<td>19</td>
<td>4010.11 CONCRETE FRAME 12'' One-Way Vault Slab, 7.5PSF Mild Rein.</td>
<td>5174 SF</td>
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<tr>
<td>20</td>
<td>4010.11 CONCRETE FRAME 12'' Slab + 8'' Drop Panels</td>
<td>1723 SF</td>
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</tr>
<tr>
<td>21</td>
<td>4010.11 CONCRETE FRAME 8'' Slab + 8'' Drop Panels, 5.0PSF Mild Rein.</td>
<td>6980 SF</td>
<td></td>
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<tr>
<td>22</td>
<td>4010.11 CONCRETE FRAME 10'' FT Slab + 8'' Drop Panels</td>
<td>4214 SF</td>
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<tr>
<td>23</td>
<td>4010.11 CONCRETE FRAME 9'' Thck Concrete Slab</td>
<td>1194 SF</td>
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<tr>
<td>24</td>
<td>4010.11 CONCRETE FRAME 10'' FT Slab + 10'' Drop Panels</td>
<td>1267 SF</td>
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</tr>
<tr>
<td>25</td>
<td>4010.11 CONCRETE FRAME 8'' FT Slab + 8'' Drop Panels</td>
<td>7512 SF</td>
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<tr>
<td>26</td>
<td>4010.11 CONCRETE FRAME Concrete Column - 16'' Dia., Ht. - 28''</td>
<td>14 CY</td>
<td>8 EA</td>
</tr>
<tr>
<td>27</td>
<td>4010.11 CONCRETE FRAME Concrete Rectangular Columns - 12''x24'', Ht. - 48</td>
<td>72 CY</td>
<td>10 EA</td>
</tr>
<tr>
<td>28</td>
<td>4010.11 CONCRETE FRAME Concrete Parking Columns - 24''x24'', Ht. - 100''</td>
<td>32 CY</td>
<td>21 EA</td>
</tr>
<tr>
<td>29</td>
<td>4010.11 CONCRETE FRAME Concrete Post Up Column - 24''x24'', Ht. - 107''</td>
<td>6 CY</td>
<td>4 EA</td>
</tr>
<tr>
<td>30</td>
<td>4010.11 CONCRETE FRAME Concrete Post Up Column - 24'' Dia., Ht. - 184''</td>
<td>10 CY</td>
<td>10 EA</td>
</tr>
<tr>
<td>31</td>
<td>4010.11 CONCRETE FRAME Concrete Column - 24''x24'' Ht. - 201''</td>
<td>4 CY</td>
<td>1 EA</td>
</tr>
<tr>
<td>32</td>
<td>4010.11 CONCRETE FRAME Concrete Column - 24''x24'' Ht. - 73''</td>
<td>22 CY</td>
<td>20 EA</td>
</tr>
<tr>
<td>33</td>
<td>4010.11 CONCRETE FRAME Concrete Column - 24''x24'' Ht. - 109''</td>
<td>3 CY</td>
<td>7 EA</td>
</tr>
<tr>
<td>34</td>
<td>4010.11 CONCRETE FRAME Concrete Column - 24''x24'' Ht. - 60''</td>
<td>40 CY</td>
<td>4 EA</td>
</tr>
<tr>
<td>35</td>
<td>4010.11 CONCRETE FRAME Concrete Column - 24''x24'' Ht. - 90''</td>
<td>114 CY</td>
<td>8 EA</td>
</tr>
<tr>
<td>36</td>
<td>4010.11 CONCRETE FRAME Concrete Post Up Column - 24''x24'', Ht. - 184''</td>
<td>14 CY</td>
<td>5 EA</td>
</tr>
<tr>
<td>37</td>
<td>620 Exterior</td>
<td>Glass</td>
<td>4094 SF</td>
</tr>
<tr>
<td>38</td>
<td>620 Exterior</td>
<td>Metal</td>
<td>1096 SF</td>
</tr>
<tr>
<td>39</td>
<td>620 Exterior</td>
<td>Total Exterior Skin</td>
<td>60178 SF</td>
</tr>
</tbody>
</table>
| 40 | 620 Exterior | % of Glass | 67.29%
| 41 | 620 Exterior | % of Metal | 28.19%

These are the area takeoffs for the basis-of-design CIP concrete and envelope (Design B).
### F. AREA TAKEOFFS
#### FOR BUDGET COMPARISON

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

<table>
<thead>
<tr>
<th>Sr No.</th>
<th>Type</th>
<th>Condition</th>
<th>As per Narrative</th>
<th>As per Plan</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1010.11 CONTINUOUS FOOTINGS &amp; GRADE BEAMS</td>
<td>Wall Footing</td>
<td>54 CY</td>
<td>54 CY</td>
<td>As per Narrative</td>
</tr>
<tr>
<td>2</td>
<td>1010.11 CONTINUOUS FOOTINGS &amp; GRADE BEAMS</td>
<td>Concrete Beam - 12”x20”</td>
<td>22 CY</td>
<td>366 LF</td>
<td>As per Plan</td>
</tr>
<tr>
<td>3</td>
<td>1010.11 CONTINUOUS FOOTINGS &amp; GRADE BEAMS</td>
<td>Concrete Beam - 24”x20”</td>
<td>83 CY</td>
<td>676 LF</td>
<td>As per Plan</td>
</tr>
<tr>
<td>4</td>
<td>1010.11 CONTINUOUS FOOTINGS &amp; GRADE BEAMS</td>
<td>Concrete Upturned Beam - 15”x20”</td>
<td>2 CY</td>
<td>20 LF</td>
<td>As per Narrative</td>
</tr>
<tr>
<td>5</td>
<td>1010.11 CONTINUOUS FOOTINGS &amp; GRADE BEAMS</td>
<td>Concrete Grade Beam - 18”x30”</td>
<td>11 CY</td>
<td>77 LF</td>
<td>As per Narrative</td>
</tr>
<tr>
<td>6</td>
<td>1010.11 CONTINUOUS FOOTINGS &amp; GRADE BEAMS</td>
<td>Concrete Strap Beam - 48”x36”</td>
<td>17 CY</td>
<td>39 LF</td>
<td>As per Narrative</td>
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<tr>
<td>7</td>
<td>1010.31 SPREAD FOOTINGS</td>
<td>Interior Square Footing - 13’0”x13’0”x36”</td>
<td>225 CY</td>
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<td>As per Narrative</td>
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<tr>
<td>8</td>
<td>1010.31 SPREAD FOOTINGS</td>
<td>Irregular Footing</td>
<td>12 CY</td>
<td>12 CY</td>
<td>As per Plan</td>
</tr>
<tr>
<td>9</td>
<td>1010.31 SPREAD FOOTINGS</td>
<td>Perimeter Square Footing - 13’0”x11’0”x24”</td>
<td>152 CY</td>
<td></td>
<td>As per Plan</td>
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<tr>
<td>10</td>
<td>1010.31 SPREAD FOOTINGS</td>
<td>Interior Square Footing - 8’0”x8’0”x22”</td>
<td>138 CY</td>
<td></td>
<td>As per Plan</td>
</tr>
<tr>
<td>11</td>
<td>1010.31 SPREAD FOOTINGS</td>
<td>Sheet Wall/Core Pad Footing</td>
<td>680 CY</td>
<td>145 CY</td>
<td>For Plan Footing is taken without any offset</td>
</tr>
<tr>
<td>12</td>
<td>1010.31 SPREAD FOOTINGS</td>
<td>Perimeter Square Footing - 10’0”x10’0”x44”</td>
<td>232 CY</td>
<td></td>
<td>As per Plan</td>
</tr>
<tr>
<td>13</td>
<td>1010.31 SPREAD FOOTINGS</td>
<td>Interior Square Footing - 10’0”x10’0”x22”</td>
<td>216 CY</td>
<td></td>
<td>As per Plan</td>
</tr>
<tr>
<td>14</td>
<td>1010.31 SPREAD FOOTINGS</td>
<td>Interior Square Footing - 10’0”x10’0”x50”</td>
<td>181 CY</td>
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<td>As per Plan</td>
</tr>
<tr>
<td>15</td>
<td>(no type)</td>
<td>Core</td>
<td></td>
<td>586 SF</td>
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</tr>
<tr>
<td>16</td>
<td>1010.10 SUBGRADE FRAME</td>
<td>12” Thick Foundation Walls - B1, 5000psi</td>
<td>944 SF</td>
<td></td>
<td>As per Plan</td>
</tr>
<tr>
<td>17</td>
<td>4010.10 SLAB ON GRADE</td>
<td>5” Slab on Grade</td>
<td>3179 SF</td>
<td></td>
<td>As per Plan</td>
</tr>
<tr>
<td>18</td>
<td>1010.11 CONCRETE FRAME</td>
<td>12” One-Way Vault Slab, 7.5PSF Mild Reinf.</td>
<td>5724 SF</td>
<td></td>
<td>As per Plan</td>
</tr>
<tr>
<td>19</td>
<td>1010.11 CONCRETE FRAME</td>
<td>12” Slab + 8” Drop Panels</td>
<td>1740 SF</td>
<td></td>
<td>As per Plan</td>
</tr>
<tr>
<td>20</td>
<td>1010.11 CONCRETE FRAME</td>
<td>8” Slab + 8” Drop Panels, 5.0PSF Mild Rein.</td>
<td>2366 SF</td>
<td></td>
<td>As per Plan</td>
</tr>
<tr>
<td>21</td>
<td>1010.11 CONCRETE FRAME</td>
<td>Concrete Column - 24”x24”, HT - 10’5”</td>
<td>51 CY</td>
<td>33 EA</td>
<td>As per Plan</td>
</tr>
<tr>
<td>22</td>
<td>1010.11 CONCRETE FRAME</td>
<td>Concrete Column - 16” Dia, HT - 26’1”</td>
<td>14 CY</td>
<td>8 EA</td>
<td>As per Plan</td>
</tr>
<tr>
<td>23</td>
<td>1010.11 CONCRETE FRAME</td>
<td>Concrete Rectangular Columns - 12”x24”, HT - 71’</td>
<td>71 CY</td>
<td>10 EA</td>
<td>As per Plan</td>
</tr>
<tr>
<td>24</td>
<td>1010.11 CONCRETE FRAME</td>
<td>Concrete Parking Columns - 24”x24”, HT - 10’</td>
<td>35 CY</td>
<td>23 EA</td>
<td>As per Plan</td>
</tr>
<tr>
<td>25</td>
<td>1010.17 Wood Frame</td>
<td>18”x16” Glulam Column</td>
<td>28 EA</td>
<td></td>
<td>As per Plan</td>
</tr>
<tr>
<td>26</td>
<td>1010.17 Wood Frame</td>
<td>18”x16” Glulam Column</td>
<td>28 EA</td>
<td></td>
<td>As per Plan</td>
</tr>
<tr>
<td>27</td>
<td>1010.17 Wood Frame</td>
<td>18”x16” Glulam Column</td>
<td>28 EA</td>
<td></td>
<td>As per Plan</td>
</tr>
<tr>
<td>28</td>
<td>20 Exterior</td>
<td>Glass</td>
<td>40494 SF</td>
<td></td>
<td>As per Plan</td>
</tr>
<tr>
<td>29</td>
<td>20 Exterior</td>
<td>Metal</td>
<td>1066 SF</td>
<td></td>
<td>As per Plan</td>
</tr>
<tr>
<td>30</td>
<td>20 Exterior</td>
<td>Total Exterior Skin</td>
<td>60176 SF</td>
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<td>As per Plan</td>
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<tr>
<td>31</td>
<td>20 Exterior</td>
<td>% Of Glass</td>
<td>67.29%</td>
<td></td>
<td>As per Plan</td>
</tr>
<tr>
<td>32</td>
<td>20 Exterior</td>
<td>% of Metal</td>
<td>28.19%</td>
<td></td>
<td>As per Plan</td>
</tr>
</tbody>
</table>
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.