Smart Retrofits: Pathway to a Low-Carbon World

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USGBC LEED Social Equity Working Group
Supporting building design decisions through life cycle assessment

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BuildingEnergy Boston
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What is a green building?
A life cycle perspective should be used to evaluate environmental impacts of building design strategies

Materials & Products
- Use recycled
- Reduce energy
- Improve material performance

Design & Construction
- Use less (i.e., stronger) material
- Create longer-lasting designs
- Reduce construction impacts

Operation
- Reduce building energy consumption
- Reduce maintenance
- Minimize damage due to hazards

End-of-Life
- Enable material recovery
- Enable component recovery

Trade-offs among strategies should be evaluated quantitatively
Life-cycle assessment: Method for quantifying environmental impact

Materials & Production

Design & Construction

Use

End-of-Life

Product

Energy

Raw Materials

Activity

Releases to Land

Air Emissions

Water Effluents
Building LCA Scope from EN 15978
<table>
<thead>
<tr>
<th>Building Product EPD*</th>
<th>Materials &amp; Production</th>
<th>Construction</th>
<th>Usage</th>
<th>Operational</th>
<th>End-of-Life</th>
</tr>
</thead>
<tbody>
<tr>
<td>Whole Building LCA</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Whole Building &amp; Whole Life LCA</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
</tbody>
</table>

*EPD = Environmental Product Declaration
LEED has started to incorporate LCA

EPDs & Whole Building LCA
EPDs and WBLCA Tools are meeting demand for LEED

<table>
<thead>
<tr>
<th>Building Product EPD</th>
<th>Materials &amp; Production</th>
<th>Construction</th>
<th>Usage</th>
<th>Operational</th>
<th>End-of-Life</th>
</tr>
</thead>
<tbody>
<tr>
<td>LEED M&amp;R</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LEED M&amp;R (Embodied Impacts)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Whole Building LCA</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Whole Building &amp; Whole Life LCA</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- Whole Building LCA: ✔ ✔ ✔ ✔ ✔
- Whole Building & Whole Life LCA: ✔ ✔ ✔ ✔ ✔
## Potential objectives for building LCAs beyond LEED

<table>
<thead>
<tr>
<th>Building Product EPD</th>
<th>Vendor Decisions</th>
<th>Design Decisions (Same Operational Performance)</th>
<th>End-of-Life</th>
</tr>
</thead>
<tbody>
<tr>
<td>Whole Building LCA</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Whole Building &amp; Whole Life LCA</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Challenge of supporting building design decisions

Design tension #1: Need for early guidance vs. uncertainty in early design

Design process

Streamlined LCA
- Planning and pre-design
- Conceptual design
- Schematic design
- Design development
- Construction documents

Conventional LCA

- Design process (time)
- Design uncertainty
- Ability to influence performance
- Cost of design change
Challenge of supporting building design decisions

Design tension #2: Guidance vs. maintaining design flexibility

• Early design is about experimenting with potential solutions to variety of design objectives
• Pure optimization is too constraining
• More helpful to identify
  • Near-optimal region of design space
  • Flexible vs. critical aspects of design
**Early-design, probabilistic LCA model**

*Building Attribute to Impact Algorithm*

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**Attributes**

**Building**
Geometry and systems (mechanical, electrical and plumbing systems)

**Assemblies**
Layers defined by material type and thickness

**Materials**
Each material can be specific or underspecified

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**Inputs**

Under-specified design
*(Building, assembly, & material attributes)*

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**Building Attribute to Impact Algorithm**

**Energy model**
Energy use

**Material model**
Material masses

**Cost model**
Impact factors

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**Outputs**

Life-cycle impacts

Life-cycle costs

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Under-specified design

Represented by set of specific designs

Under-specified building

Under-specified roof pitch

Under-specified window area

Set of 1,000 specific, randomly-generated designs

with varying roof pitches and window areas
Sequential specification

Design refinement method #1

Run BAIA
(Monte Carlo LCA)

Input:
Under-specified design information

Refine design
Specify priority attribute(s)

Key outputs:
Life cycle impacts and costs

Probabilistic triage: priority attributes

- Ext. wall insulation
- Heating efficiency
- Bedrooms
- Ext. wall core

- Embodied
- Use-phase
- Total

- Under-specified design information

- Ext. wall insulation
- Heating efficiency
- Bedrooms
- Ext. wall core
Sequential specification example

**Step 1**
- Boston
  - 2400 sq. ft.
  - Any air leakage (0.5 - 7 ACH50)
  - Any win. area (10-40% of wall area)

**Step 2**
- Boston
  - 2400 sq. ft.
  - Low air leakage (≤ 3 ACH50)
  - Any win. area (10-40% of wall area)

**Step 3**
- Boston
  - 2400 sq. ft.
  - Low air leakage (≤ 3 ACH50)
  - Moderate win. area (20-30% of wall area)
Efficient increase in LCA precision through sequential specification

Variability (CV) quickly approaches value from a fully specified design.
Genetic optimization

*Design refinement method #2*

- Optimization method based on natural selection
- Each “generation” uses features from best designs in the previous generation
- Optimization continues until mean impacts and costs change by less than 0.1% over 5 steps
- A quasi-optimum region can be defined and used to determine which parameters are flexible

**Diagram:**
- Black/grey = Intermediate generations
- Orange = Final (optimized) generation
Impact/cost Pareto frontier

Determined by changing $\alpha$, relative weight of impacts and costs

\[
F_i = 1 - [\alpha I_i + (1 - \alpha)C_i]
\]

$F_i$ = Fitness of design $i$
$I_i$ = Impacts* of design $i$
$C_i$ = Cost* of design $i$
$\alpha$ = Weighting factor

*Normalized to $[0,1]$ in each generation
Definition of quasi-optimum regions

Based on % of optimum improvement in impacts and costs

\[ \Delta I_q = \gamma \cdot \Delta I_o \]

\[ \Delta C_q = \gamma \cdot \Delta C_o \]
Increased building attribute flexibility

From exploring quasi-optimum designs ($\gamma = 0.75$)

- **Critical**: $< \frac{1}{2}$ initial range
- **Flexible**: $\geq \frac{1}{2}$ initial range

Larger blue bar indicates more flexibility gained
Case studies

Quasi-optimum designs in different contexts

Four sets of cases, each with three 2,400 square-foot buildings in Chicago (except for climate case):

1. **Climate**
   Chicago (cold), San Francisco (mild), and Phoenix (hot)

2. **Analysis period**
   25 years, 50 years, and 100 years

3. **Energy impact factor variability**
   Double, original, and half coefficient of variation

4. **Optimization weighting of impacts and costs ($\alpha$)**
   0 (cost only), 0.5 (equal weighting), and 1 (impacts only)
# Summary of cases

*Flexibility of geometrical attributes, $\gamma = 0.75$*

## Attribute Summary

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Summary</th>
<th>Climate</th>
<th>Weight of impacts vs. costs ($\alpha$)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Chicago</td>
<td>Phoenix</td>
</tr>
<tr>
<td><strong>GEOMETRY</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Orientation</td>
<td>✓</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stories</td>
<td>✓</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Roof type</td>
<td>✓</td>
<td></td>
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</tr>
<tr>
<td>Roof pitch</td>
<td>✓</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Window overhang</td>
<td>✓</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Average area of single win.</td>
<td>✓</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Exterior door area</td>
<td>✓</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Interior door area</td>
<td>✓</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Front window-to-wall ratio</td>
<td>✓</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Back window-to-wall ratio</td>
<td>x</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Side window-to-wall ratio</td>
<td>x</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Building aspect ratio</td>
<td>x</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Highlighting indicates sets of cases where flexibility changes*
Summary of cases
Flexibility of occupant- and systems-related attributes, $\gamma = 0.75$

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Summary</th>
<th>Climate</th>
<th>Weight of impacts vs. costs ($\alpha$)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>only (0)</td>
<td>(0.5)</td>
</tr>
</tbody>
</table>

### OCCUPANTS
- Ratio of windows open: ✔
- Heating season shade factor: ✔
- Cooling season shade factor: ✔
- Cooling set point: ✔
- Heating set point: • ✔ ✔ ✔ ✔
- Bedrooms (occupancy): ✗

### SYSTEMS
- Furnace efficiency*: ✔ – – – ✔
- AC efficiency*: ✔ – – – ✔
- MSHP efficiency*: ✗ ✔ ✔ ✔ ✔
- Water heater energy factor: • ✔ ✔ ✗ ✔
- Vent. heat recovery rate: • ✔ ✔ ✔ ✔
- Air leakage: • ✔ ✔ ✔ ✔
- LED ratio: ✗

*Highlighting indicates sets of cases where flexibility changes

*Mini-split heat pump preferred in majority of cases
Benefits of BAIA Approach

- Building design attributes are inputs
- Combined embodied and energy analysis
- Feedback provided on key parameters
- Details specified only when necessary
- Uncertainty quantified for impacts
- Quasi-optimization guides flexible design
The future of BAIA

• Expand to commercial structures
• Integrate with design software
• Evaluate potential to integrate with design process
More information available at:
http://cshub.mit.edu/
jgregory@mit.edu
Pathways to a Low Carbon World
Achieving a Deep Understanding
### Environmental Impacts

#### Your Building Product

<table>
<thead>
<tr>
<th>LCA IMPACT MEASURES</th>
<th>TOTAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Primary Energy (MJ)</td>
<td>12.4</td>
</tr>
<tr>
<td>Global Warming Potential (kg CO² eq)</td>
<td>0.96</td>
</tr>
<tr>
<td>Ozone Depletion (kg CFC-11 eq)</td>
<td>1.80E-08</td>
</tr>
<tr>
<td>Acidification Potential (mol H⁺ eq)</td>
<td>0.93</td>
</tr>
<tr>
<td>Eutrophication Potential (kg N eq)</td>
<td>6.43E-04</td>
</tr>
<tr>
<td>Photo-Oxidant Creation Potential (kg O₃ eq)</td>
<td>0.121</td>
</tr>
</tbody>
</table>
GLOBAL WARMING POTENTIAL (GWP)  Carbon footprint. Quantification of greenhouse gas and other types of emissions which contribute to global warming/climate change.

ACIDIFICATION POTENTIAL  When emissions (especially sulfur dioxide from coal-burning) contribute to acid rain, which leads to the build-up of acidity in soil and bodies of water.

OZONE DEPLETION  The thinning of the earth’s stratospheric ozone layer due to widespread production and release of halogens (notably CFCs, HCFCs, freons and halons), which also contributes to global warming/climate change.

EUTROPHICATION  The potential increase in chemical nutrients, such as nitrogen and phosphorus often found in fertilizers, in aquatic ecosystems. The added nutrients stimulate excessive plant growth and algal blooms, depleting oxygen and light leading to large scale fish kills.

SMOG/PHOTOCHEMICAL OZONE CREATION POTENTIAL  Potential contribution of a substance towards creating “ground level ozone.” POCP is formed by reactions of VOCs and nitrogen oxides in the presence of heat and sunlight.
Global Warming Potential
Photochemical Ozone Creation Potential - Smog
Carbon as a Proxy for Other Environmental Impacts

Environmental Impact per Dollar Spent in Sector
How do we use the tools

Environmental Impacts
Building Product Disclosure & Optimization

ENVIRONMENTAL PRODUCT DECLARATIONS - Disclosure

• Option 1: Use at least 20 different permanent products from at least 5 manufacturer’s that have an EPD (1 point)
  – Product-specific LCA from cradle to gate following ISO 14044 = 1 product
  – Industry-wide EPD = 1 product
  – Product-specific EPD = 1.5 product
Gypsum Board

Environmental Product Declaration

According to ISO 14025 and ISO 21930

An industry average cradle-to-gate EPD for Glass Mat Gypsum Panels produced by Gypsum Association member companies for the USA and Canadian Markets.

Declaration Number: EPD-038
Date of Issue: 09/13/2016
Period of Validity: 5 years

EPD Summary Results - 1 MSF of 1/2” and 5/8” Glass Mat Gypsum Panels

Environmental PRODUCT DECLARATION

JOINT COMPOUND

DRYWALL FINISHING COUNCIL

Typical (5/8” Type X)

North American Gypsum Boards
Metal Stud

Steel Recycling Institute
680 Andersen Drive
Pittsburgh, PA 15220 USA

A complete list of manufacturers represented by this EPD can be found here: www.recycle-steel.org/epd-companies

Product
Industry-wide Cold-Formed Steel Studs and Track manufactured in U.S. and Canada.
**Product Description**

The steel framing & metal lath products covered by this EPD are:

**Structural Stud and Track (ICC-ES ESR 3016)**
- Manufactured for the use in curtain wall, load-bearing, rough-opening & ceiling/floor applications
- Available in typical c-shaped sections ranging in thickness from 33 mls to 110 mls

**ViperStud® Interior Framing (ICC-ES ESR 2620 & ATIES 0154)**
- Proprietary interior framing system using high-strength steel to increase overall performance
- Available in c-shaped sections ranging in thickness from 15 mls to 33 mls

**ProX Header® (IAPMO ER-0286)**
- Proprietary header/rough-opening system designed to use less material and increase safety
- Available in sections ranging in thickness from 33 mls to 68 mls

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**Material & Goal**
- Galvanized steel

**SureBoard® for Shear panels (IAPMO ER-0130)**
- Steal sheathing product designed specifically for wall shear applications

**Sure-Span® Floor Joint Framing System (ESR PENDING)**
- Proprietary steel floor joint/roof sheet framing system with extra-large flared punch-outs for greater access of HVAC, MEP, and TECO systems
- Available in proprietary c-shaped sections ranging in thickness from 43 mls to 87 mls

**CST, SLP-100, and FAS Track 1000 Brand Slotted Tracks (ICC-ES ESR 2012)**
- Head of Wall top tracks designed for stone and brick applications
- Available in c-shaped sections in thicknesses ranging from 33 mls to 68 mls

**USG SHAFTWALL Brand CH and H-Stud Studs and Track (AER 0503)**
- USG's CH studs and flanges for shaftwall and stored applications
- USG's H-Stud and C-Runner for area separation wall assemblies

**Expanded Metal Lath Products (ICC-ES ESR 1639)**
- Manufactured for the use in exterior and interior applications for 2-coat stucco assemblies
- Available in various flat, self-tapped, ribbed, and paper-backed versions

**Plastering Accessories (ICC-ES ESR 1620)**
- Various profiles used in conjunction with expanded metal lath products
- Products designed and manufactured for sawing, corners, control joints, expansion joints, screw holes, and weep holes

**Drywall/Interior Accessories (ICC-ES ESR 2016)**
- Product designed for use with interior load-bearing stud framing systems
- Products include angles, drywall finishing tools, fast straps, fitting channels, and resilient channels

**Connectors, Clips, and Channels (ICC-ES ESR 3840)**
- Various connectors and clips used for connecting structural and non-structural steel framing components
- Products included are clip angles, corner angles, ledgers, diagonal tension strapping, gusset plates, side clips, and l-shaped channels
DOES THIS ITEM COUNT AS A PRODUCT?
MR Building Product Disclosure and Optimization Credits

Purchased item is...
- Part of assembly
  - Finished product
    - Product Function?
      - Unique function
        - Unique Product
      - Same as another product
        - Different color?
          - No
            - Different Manufacturer?
              - No
                - Not a unique product
              - Yes
                - Unique manufacturer
                  - Unique Product
            - Yes
              - Different Manufacturer?
                - Yes
                  - Not a unique product
                - No
                  - Unique Product
Insulation
**Table 3: Life-cycle Impact Category Results for the Functional Unit of FOAMULAR® XPS Insulation**

<table>
<thead>
<tr>
<th>Impact category</th>
<th>Unit</th>
<th>Total</th>
<th>Raw materials acquisition</th>
<th>Transportation</th>
<th>Installation, Maintenance &amp; Use</th>
<th>End of life</th>
</tr>
</thead>
<tbody>
<tr>
<td>Global warming</td>
<td>kg CO₂ eq</td>
<td>6.08E+1</td>
<td>5.70E+0</td>
<td>2.50E-2</td>
<td>1.33E-1</td>
<td>1.95E+1</td>
</tr>
<tr>
<td>Acidification</td>
<td>mol H⁺ eq</td>
<td>1.78E+0</td>
<td>1.45E+0</td>
<td>5.05E-3</td>
<td>4.43E-2</td>
<td>2.53E-1</td>
</tr>
<tr>
<td>Eutrophication</td>
<td>kg N eq</td>
<td>9.85E-4</td>
<td>8.42E-4</td>
<td>4.66E-6</td>
<td>4.23E-5</td>
<td>6.83E-5</td>
</tr>
<tr>
<td>Smog</td>
<td>kg O₃ eq</td>
<td>2.08E-1</td>
<td>1.35E-1</td>
<td>1.05E-3</td>
<td>2.17E-2</td>
<td>3.55E-2</td>
</tr>
<tr>
<td>Ozone depletion</td>
<td>kg CFC-11 eq</td>
<td>3.63E-4</td>
<td>3.63E-4</td>
<td>4.12E-10</td>
<td>5.82E-12</td>
<td>2.16E-10</td>
</tr>
<tr>
<td>Waste to Landfill</td>
<td>kg</td>
<td>8.57E-1</td>
<td>8.57E-2</td>
<td>4.91E-4</td>
<td>0.00E+0</td>
<td>1.09E-4</td>
</tr>
<tr>
<td>Metered Water</td>
<td>kg</td>
<td>3.79E+1</td>
<td>3.54E+1</td>
<td>1.76E+0</td>
<td>0.00E+0</td>
<td>7.31E-1</td>
</tr>
</tbody>
</table>

**Environmental Product Declaration**

**STYROFOAM™ INSULATION**

**TUFF-R™ AND THERMAX™ INSULATION**

**Life Cycle Assessment – Product**

<table>
<thead>
<tr>
<th>Impact category</th>
<th>Unit</th>
<th>Total</th>
<th>Raw materials</th>
<th>Manufacturing</th>
<th>Transport</th>
<th>Installation, maintenance</th>
<th>End of life</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ozone depletion</td>
<td>kg CFC-11 eq</td>
<td>6.71E-04</td>
<td>6.71E-04</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Global warming</td>
<td>kg CO₂ eq</td>
<td>9.53E+0</td>
<td>9.03E+0</td>
<td>2.54E+0</td>
<td>1.90E-1</td>
<td>2.72E+0</td>
<td>3.33E+0</td>
</tr>
<tr>
<td>Smog</td>
<td>kg O₃ eq</td>
<td>1.96E-1</td>
<td>3.38E-1</td>
<td>2.30E-2</td>
<td>3.50E-2</td>
<td>0</td>
<td>2.08E-3</td>
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<tr>
<td>Acidification</td>
<td>mol H⁺ eq</td>
<td>9.98E-01</td>
<td>7.48E-01</td>
<td>1.72E-1</td>
<td>6.50E-2</td>
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<td>3.00E+0</td>
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<tr>
<td>Eutrophication</td>
<td>kg N eq</td>
<td>2.72E-03</td>
<td>1.86E-03</td>
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<td>1.10E-04</td>
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<tr>
<td>Water use</td>
<td>kg</td>
<td>5.45E+0</td>
<td>1.45E+0</td>
<td>4.00E+0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Non-hazardous waste</td>
<td>kg</td>
<td>7.99E-01</td>
<td>1.60E-02</td>
<td>6.00E-03</td>
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<td>0</td>
<td>7.77E-01</td>
</tr>
<tr>
<td>Hazardous waste</td>
<td>kg</td>
<td>2.20E-03</td>
<td>2.20E-03</td>
<td>0</td>
<td>0</td>
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<td>0</td>
</tr>
<tr>
<td>Waste to energy</td>
<td>kg</td>
<td>7.80E-05</td>
<td>7.80E-05</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Primary Energy</td>
<td>MJ</td>
<td>8.88E+0</td>
<td>7.48E+0</td>
<td>1.06E+1</td>
<td>3.20E+0</td>
<td>0</td>
<td>2.20E-01</td>
</tr>
</tbody>
</table>

**Environmental Product Declaration**

**W CHEMICAL COMPANY**

**THERMAX™**

<table>
<thead>
<tr>
<th>Impact category</th>
<th>Unit</th>
<th>Total</th>
<th>Raw materials</th>
<th>Raw Material Transport</th>
<th>Manufacturing</th>
<th>Gate to Grave Transport</th>
<th>End of life</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ozone depletion</td>
<td>kg CFC-11 eq</td>
<td>6.60E-07</td>
<td>6.00E-07</td>
<td>2.05E-08</td>
<td>8.00E-09</td>
<td>2.00E-08</td>
<td>1.80E-09</td>
</tr>
<tr>
<td>Global warming</td>
<td>kg CO₂ eq</td>
<td>6.11E+0</td>
<td>5.02E+0</td>
<td>1.24E+1</td>
<td>2.13E-01</td>
<td>1.47E-01</td>
<td>4.93E-03</td>
</tr>
<tr>
<td>Smog</td>
<td>kg O₃ eq</td>
<td>4.14E-01</td>
<td>2.46E-01</td>
<td>3.22E-02</td>
<td>9.87E-03</td>
<td>2.87E-02</td>
<td>9.76E-02</td>
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<tr>
<td>Acidification</td>
<td>mol H⁺ eq</td>
<td>1.66E+0</td>
<td>1.47E+0</td>
<td>6.30E-02</td>
<td>6.75E-02</td>
<td>2.07E-03</td>
<td></td>
</tr>
<tr>
<td>Eutrophication</td>
<td>kg N eq</td>
<td>1.33E-02</td>
<td>1.23E-02</td>
<td>1.94E-04</td>
<td>6.55E-04</td>
<td>1.98E-04</td>
<td>6.37E-06</td>
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<tr>
<td>Primary Energy</td>
<td>MJ</td>
<td>9.97E+0</td>
<td>9.24E+0</td>
<td>1.89E+0</td>
<td>2.88E+0</td>
<td>2.38E+0</td>
<td>1.31E-01</td>
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<tr>
<td>Water</td>
<td>M³</td>
<td>4.55E-02</td>
<td>4.41E-02</td>
<td>4.35E-04</td>
<td>4.95E-04</td>
<td>5.00E-04</td>
<td>1.16E-04</td>
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<tr>
<td>Waste to Landfill</td>
<td>kg</td>
<td>7.23E+0</td>
<td>0.00E+0</td>
<td>0.00E+0</td>
<td>7.08E+0</td>
<td>0.00E+0</td>
<td>6.52E-01</td>
</tr>
</tbody>
</table>
Option 2: Use products that comply with one of the criteria below for 10%, by cost, of the total value of permanently installed products in the project, or use at least 10 permanently installed products sourced from at least three different manufacturers:

- Any product with a “Life Cycle Impact Reduction Action Plan” is valued at 50% or ½ product
- Any product with third-party verified, published EPD or LCA showing reductions in GWP:
  - Any reduction = 1 product or 100% of cost
  - >10% reduction = 1.5 products or 150% of cost
## Metal Stud

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Unit</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Global warming potential (GWP)</td>
<td>metric ton CO₂ eq</td>
<td>2.25</td>
</tr>
<tr>
<td>Depletion potential of the stratospheric ozone layer (ODP)</td>
<td>metric ton CFC-11 eq</td>
<td>5.04E-08</td>
</tr>
<tr>
<td>Acidification potential of soil and water (AP)</td>
<td>metric ton SO₄ eq</td>
<td>1.21E-02</td>
</tr>
<tr>
<td>Eutrophication potential (EP)</td>
<td>metric ton N eq</td>
<td>5.25E-04</td>
</tr>
<tr>
<td>Formation potential of tropospheric ozone (POCP)</td>
<td>metric ton O₃ eq</td>
<td>0.181</td>
</tr>
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</table>

### Life Cycle Impact Assessment

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Unit</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>GWP</td>
<td>metric ton CO₂ eq</td>
<td></td>
</tr>
<tr>
<td>ODP</td>
<td>metric ton CFC-11 eq</td>
<td></td>
</tr>
<tr>
<td>AP</td>
<td>metric ton SO₄ eq</td>
<td></td>
</tr>
<tr>
<td>EP</td>
<td>metric ton N eq</td>
<td></td>
</tr>
<tr>
<td>POCP</td>
<td>metric ton O₃ eq</td>
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### Life Cycle Impact Assessment

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Unit</th>
<th>LCIA Method</th>
<th>A - A3</th>
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</thead>
<tbody>
<tr>
<td>GWP</td>
<td>metric ton CO₂ eq</td>
<td>TRACI (version 2.1)</td>
<td>2.89</td>
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<tr>
<td>ODP</td>
<td>metric ton CFC-11 eq</td>
<td>TRACI (version 2.1)</td>
<td>5.07E-08</td>
</tr>
<tr>
<td>AP</td>
<td>metric ton SO₄ eq</td>
<td>TRACI (version 2.1)</td>
<td>0.0184</td>
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<tr>
<td>EP</td>
<td>metric ton N eq</td>
<td>TRACI (version 2.1)</td>
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<td>POCP</td>
<td>metric ton O₃ eq</td>
<td>TRACI (version 2.1)</td>
<td>0.185</td>
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### Impact Category

<table>
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<tr>
<th>Parameter</th>
<th>Unit</th>
<th>Value</th>
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<tr>
<td>Global warming [a]</td>
<td>ton CO₂ eq</td>
<td>2.2</td>
</tr>
<tr>
<td>Global Warming Potential (GWP)</td>
<td>ton [d]</td>
<td></td>
</tr>
<tr>
<td>Raw Material Extraction / Processing</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Transport to the Manufacturer</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Manufacturing</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reuse, Recovery, Recycling Potential</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Rating System

LEED BD+C: New Construction, LEED BD+C: Core and Shell, LEED BD+C: Schools, LEED BD+C: Retail, LEED BD+C: Healthcare, LEED BD+C: Data Centers, LEED BD+C: Hospitality, LEED BD+C: Warehouses and Distribution Centers, LEED ID+C: Commercial Interiors, LEED ID+C: Retail, LEED ID+C: Hospitality

Rating System Version

v4 - LEED v4

Inquiry

How can products contribute to earning Option 2 of the LEED v4 MR credit BPDO – Environmental Product Declarations?

Ruling

In addition to the option outlined in the credit language, products that meet any of the following requirements can also contribute towards Option 2:

1. Demonstrate reduced impact with a product-specific EPD against an industry-wide generic EPD, provided the manufacturer was part of the study and the two conform to the same PCR.

2. Demonstrate reduced impact of the same product, over time, with two product-specific EPDs.
Products Catalog

3 results

Clear All Filters

Already Applied Filters
- Certification
- EPD - Optimization

Manufacturer / Brands

Product Type

EcoTouch® Unfaced Insulation
Kohler Co.

Highcliff™

Interface Americas
GlasBac, Type 66 Nylon
4. Interpretation of Optimization Results

The environmental impact reductions were due to improved efficiencies in raw materials, inbound transportation, manufacturing, outbound transportation and end of life transportation. Improved manufacturing capabilities allow for less waste and fewer raw materials needed to manufacture an equivalent product. Numerous energy efficiency programs have also lowered the energy intensity of our products. More details of the company-wide efforts can be found on our website http://sustainability.owenscoming.com.

The additional plant which was included in the optimized EPD makes the EPD more representative of the product being produced. The use of primary calculated emissions for natural gas combustion, rather than the emissions included in a secondary database process, are more representative in the overall model. The type of primary calculated emissions used for the 2016 data set were not available for the 2011 data set.

Using the comparability criteria, the comparison can be termed a robust comparison. Eight of the criteria were identical or equivalent. Four of the criteria required additional interpretation for comparison. For Scope, the validity periods are different since this summary is comparing an earlier version of the same product. For Data Quality, the number of plants was increased and level of primary emission data included in the analysis was more detailed for the optimized version of the EPD. The Cut-off Rules varied only by the inclusion of packaging end of life in the optimized EPD which was shown to be insignificant. The EPDs were originally created under different versions of the reference PCR. The LCA model from the reference EPD was updated and re-analyzed to provide a robust comparison.
Big Moves
Generic EPD’s

ENVIRONMENTAL PRODUCT DECLARATION
NRMCA MEMBER INDUSTRY-WIDE EPD FOR READY MIXED CONCRETE

ENVIRONMENTAL PRODUCT DECLARATION
PRIMARY STRUCTURAL STEEL FRAME COMPONENTS
METAL BUILDING MANUFACTURERS ASSOCIATION INDUSTRY-WIDE EPD

ENVIRONMENTAL PRODUCT DECLARATION
NORTH AMERICAN GLUED LAMINATED TIMBERS
AMERICAN WOOD COUNCIL
CANADIAN WOOD COUNCIL
### Table 8. Summary Results (A1-A3): 3001-4000 psi (20.69-27.59 MPa) RMC product, per cubic meter

<table>
<thead>
<tr>
<th>Indicator/LCI Metric</th>
<th>GWP</th>
<th>ODP</th>
<th>AP</th>
<th>EP</th>
<th>POCP</th>
<th>PEC</th>
<th>NRE</th>
<th>RE</th>
<th>NRM</th>
<th>RM</th>
<th>CBW</th>
<th>CWW</th>
<th>TW</th>
<th>CHW</th>
<th>CNHW</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unit (equivalent)</td>
<td>kg CO2</td>
<td>kg CFC-11</td>
<td>kg SO2</td>
<td>kg N</td>
<td>kg O3</td>
<td>MJ</td>
<td>MJ</td>
<td>MJ</td>
<td>kg</td>
<td>kg</td>
<td>m3</td>
<td>m3</td>
<td>m3</td>
<td>kg</td>
<td></td>
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<tr>
<td>Minimum</td>
<td>251.8</td>
<td>7.3O-6</td>
<td>0.99</td>
<td>0.32</td>
<td>20.63</td>
<td>1918</td>
<td>1880</td>
<td>36</td>
<td>2011</td>
<td>2.01</td>
<td>0.13</td>
<td>0.12</td>
<td>0.29</td>
<td>0.42</td>
<td>4.32</td>
</tr>
<tr>
<td>Maximum</td>
<td>416.9</td>
<td>1.00E-5</td>
<td>1.31</td>
<td>0.50</td>
<td>26.87</td>
<td>2642</td>
<td>2591</td>
<td>51</td>
<td>2327</td>
<td>3.05</td>
<td>0.13</td>
<td>0.12</td>
<td>0.29</td>
<td>0.47</td>
<td>5.95</td>
</tr>
<tr>
<td>4000-00-FA/SL</td>
<td>416.9</td>
<td>1.00E-5</td>
<td>1.31</td>
<td>0.50</td>
<td>26.87</td>
<td>2642</td>
<td>2591</td>
<td>51</td>
<td>2327</td>
<td>3.05</td>
<td>0.13</td>
<td>0.12</td>
<td>0.29</td>
<td>0.47</td>
<td>5.95</td>
</tr>
<tr>
<td>4000-20-FA</td>
<td>356.3</td>
<td>8.90E-6</td>
<td>1.15</td>
<td>0.43</td>
<td>23.91</td>
<td>2304</td>
<td>2260</td>
<td>44</td>
<td>2182</td>
<td>2.61</td>
<td>0.13</td>
<td>0.12</td>
<td>0.29</td>
<td>0.43</td>
<td>5.44</td>
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<tr>
<td>4000-30-FA</td>
<td>323.6</td>
<td>8.10E-6</td>
<td>1.07</td>
<td>0.39</td>
<td>22.31</td>
<td>2212</td>
<td>2181</td>
<td>40</td>
<td>2104</td>
<td>2.37</td>
<td>0.13</td>
<td>0.12</td>
<td>0.29</td>
<td>0.43</td>
<td>5.15</td>
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<tr>
<td>4000-40-FA</td>
<td>289.2</td>
<td>7.3O-6</td>
<td>0.99</td>
<td>0.35</td>
<td>20.63</td>
<td>1930</td>
<td>1894</td>
<td>36</td>
<td>2021</td>
<td>2.11</td>
<td>0.13</td>
<td>0.12</td>
<td>0.29</td>
<td>0.42</td>
<td>4.86</td>
</tr>
<tr>
<td>4000-40-FA/SL</td>
<td>289.2</td>
<td>7.3O-6</td>
<td>0.99</td>
<td>0.35</td>
<td>20.63</td>
<td>1930</td>
<td>1894</td>
<td>36</td>
<td>2021</td>
<td>2.11</td>
<td>0.13</td>
<td>0.12</td>
<td>0.29</td>
<td>0.42</td>
<td>4.86</td>
</tr>
<tr>
<td>4000-50-FA</td>
<td>251.8</td>
<td>8.80E-6</td>
<td>1.20</td>
<td>0.32</td>
<td>22.10</td>
<td>2089</td>
<td>2056</td>
<td>11</td>
<td>2056</td>
<td>2.11</td>
<td>0.13</td>
<td>0.12</td>
<td>0.29</td>
<td>0.47</td>
<td>4.32</td>
</tr>
</tbody>
</table>

### Table 2: Cradle-to-Gate Impact Assessment Results - 1m³ North American Glulam

<table>
<thead>
<tr>
<th>Impact category indicator</th>
<th>Unit</th>
<th>Total</th>
<th>Forestry operations</th>
<th>Glulam production</th>
</tr>
</thead>
<tbody>
<tr>
<td>Global warming potential</td>
<td>kg CO₂ eq</td>
<td>197.97</td>
<td>11.37</td>
<td>186.59</td>
</tr>
<tr>
<td>Acidification potential</td>
<td>H⁺ moles eq</td>
<td>102.67</td>
<td>8.33</td>
<td>67.55</td>
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<tr>
<td>Eutrophication potential</td>
<td>kg N eq</td>
<td>0.1198</td>
<td>0.0226</td>
<td>0.0970</td>
</tr>
<tr>
<td>Ozone depletion potential</td>
<td>kg CFC-11 eq</td>
<td>0.0000</td>
<td>0.0000</td>
<td>0.0000</td>
</tr>
<tr>
<td>Smog potential</td>
<td>kg O₃</td>
<td>26.12</td>
<td>4.27</td>
<td>21.86</td>
</tr>
<tr>
<td>Total primary energy consumption</td>
<td>Unit</td>
<td>Total</td>
<td>Forestry operations</td>
<td>Glulam production</td>
</tr>
<tr>
<td>Non-renewable fossil</td>
<td>MJ</td>
<td>3211.72</td>
<td>173.32</td>
<td>3038.40</td>
</tr>
<tr>
<td>Non-renewable nuclear</td>
<td>MJ</td>
<td>338.86</td>
<td>1.71</td>
<td>337.15</td>
</tr>
<tr>
<td>Renewable, biomass</td>
<td>MJ</td>
<td>2201.18</td>
<td>0.00</td>
<td>2201.18</td>
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<tr>
<td>Renewable, other</td>
<td>MJ</td>
<td>82.40</td>
<td>0.22</td>
<td>83.16</td>
</tr>
<tr>
<td>Material resources consumption</td>
<td>Unit</td>
<td>Total</td>
<td>Forestry operations</td>
<td>Glulam production</td>
</tr>
<tr>
<td>Non-renewable materials</td>
<td>kg</td>
<td>4.10</td>
<td>0.00</td>
<td>4.10</td>
</tr>
<tr>
<td>Renewable materials</td>
<td>kg</td>
<td>553.80</td>
<td>30.44</td>
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<td>Fresh water</td>
<td>l</td>
<td>963.21</td>
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### Parameters Describing Environmental Impacts

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<tr>
<th>Abbreviation</th>
<th>Product Stage</th>
<th>Per Metric Tonne</th>
<th>Per Short Ton</th>
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<tbody>
<tr>
<td>GWP</td>
<td>Global warming potential</td>
<td>1489 kg CO₂ eq</td>
<td>1350.8 kg CO₂ eq</td>
</tr>
<tr>
<td>ODP</td>
<td>Depletion potential of the stratospheric ozone layer</td>
<td>5E-06 kg CFC-11 eq</td>
<td>4.5E-06 kg CFC-11 eq</td>
</tr>
<tr>
<td>AP</td>
<td>Acidification potential</td>
<td>5.8 kg SO₂ eq</td>
<td>5.2 kg SO₂ eq</td>
</tr>
<tr>
<td>EP</td>
<td>Eutrophication potential</td>
<td>0.259 kg N eq</td>
<td>0.235 kg N eq</td>
</tr>
<tr>
<td>POCP</td>
<td>Photochemical ozone creation potential</td>
<td>81.8 kg O₃ eq</td>
<td>74.2 kg O₃ eq</td>
</tr>
<tr>
<td>ADP-elements</td>
<td>Abiotic depletion potential for non-fossil resources</td>
<td>1.96E-04 kg Sb eq</td>
<td>1.78E-04 kg Sb eq</td>
</tr>
<tr>
<td>ADP- fossil fuels</td>
<td>Abiotic depletion potential for fossil resources</td>
<td>19,769 MJ, LHV</td>
<td>1.7E+07 BTU, LHV</td>
</tr>
</tbody>
</table>
Structural Systems - Concrete

• Reduce Cement Content:
  – Lower quantity of Portland Cement with SCM’s
    • Fly Ash
    • Granulated Blast Slag
    • Metakaolin
  – Specify Higher quality Aggregate
  – Reduce water content

• High Strength Concrete = Less Cement
Consult your Structural Engineer

Ove Arup
Structural Systems - Steel

• Clean up the steel
  – North American steel is cleaner, higher recycled content.
• Use Less Steel
• Efficient Design
Consult your Structural Engineer

Ove Arup

Gustave Eiffel
Structural Systems - Wood

• Complicated Topic
• Use only FSC and salvaged wood
• Use only what you need - efficiency
Consult your Structural Engineer

Ove Arup  
Gustave Eiffel  
Stephanie Kwolek
Focus on the materials you use the most of, and the energy and carbon intensive materials.
Where to focus:

**SCOPE**

**INCLUDES:**
- Foundations
- Columns + Beams
- Floors
- Roof
- Exterior Walls
- Windows + Doors
- Interior Partitions
- Wall + Floor Finishes
- Ceilings
- Stairs + Railings

**DOES NOT INCLUDE (YET):**
- Furniture
- Casework
- MEP Systems
- Planting
- Excavation

**1 / STRUCTURE**
- Beams + Columns
- Floors + Roofs

**3 / FINISHES**
- Ceiling Tile
- Gypsum Wall Board
- Carpet

**2 / BUILDING ENVELOPE**
- Rigid Insulation
- Metal Panels (especially insulated)
- Glass
- Precast Panels (Or Other Rain Screen)
- Aluminum Mullions

Image: Mithun (Meghan Lewis)
1. If you are buying more than a ton of it, know its carbon footprint.
Understand the formula

\[
\frac{\text{Kg CO}_2 \text{ eq}}{\text{metric tonne}}
\]

\(\text{CO}_2 \text{ eq is Carbon Dioxide Equivalent}\)
Ready Mixed Concrete (Straight Mix) (NWC 3000-4000psi)

Declared unit: 1 kg

24.2 Carbon Dioxide Equivalent

1 yard of concrete = 4000 lbs
1 yard of concrete = 48.4 CO$_2$ eq

Type X Drywall

Declared unit: 1 kg

36 x metric tons

1 gypsum board sheet = 51 lbs
1 gypsum board sheet = 0.918 CO$_2$ eq

Carpet Tile

Declared unit: 1 kg

8.78 x metric tons

1 yard of carpet = 5-20 lbs
1 yard of carpet = 0.066 CO$_2$ eq
ALWAYS REMEMBER

And Never forget
You need a Tracking Tool
<table>
<thead>
<tr>
<th>Manufacturer/Brands</th>
<th>97 Results</th>
<th>New Search</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aquafil Econyl Solution Dyed Nylon 6 with Milliken ES Undercore Backing</td>
<td>Milliken</td>
<td>This tufted carpet tile family is constructed using Aquafil Econyl Solution Dyed Nylon 6 fiber, laminated with a hotmelt coating, with a polyurethane cushion and a releasable felt bottom.</td>
</tr>
<tr>
<td>Continuous Dyed Nylon 6,6 with Milliken ES ComfortPlus® Backing</td>
<td>Milliken</td>
<td>Continuous Dyed Nylon 6,6 with Milliken ES ComfortPlus® Backing</td>
</tr>
<tr>
<td>Coral Brush</td>
<td>Forbo Flooring Systems B.V.</td>
<td>Coral Brush</td>
</tr>
<tr>
<td>Corporate - Commercial Broadloom Carpet with Nylon 6,6 Face Fiber</td>
<td>Shaw Industries, Inc.</td>
<td>Commercial Broadloom Carpet</td>
</tr>
<tr>
<td>Corporate - Commercial Broadloom Carpet with Solution Q, or Solution Q Extreme® Face Fiber</td>
<td>Shaw Industries, Inc.</td>
<td>Commercial Broadloom Carpet</td>
</tr>
</tbody>
</table>
Program Operator Consortium EPD / Transparency Report Catalog

<table>
<thead>
<tr>
<th>CSI MasterFormat® division / # EPDs</th>
<th>Manufacturer</th>
<th>Product name</th>
<th>Ind. avg</th>
<th>LCA scope</th>
<th>Program operator</th>
<th>Expiration date</th>
</tr>
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<tbody>
<tr>
<td>09 00 00 Finishes</td>
<td>Gypsum Association members</td>
<td>Industry Average for Glass Mat Gypsum Panels</td>
<td>C2Gave</td>
<td>ASTM</td>
<td>Aug 17, 2021</td>
<td></td>
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<tr>
<td>09 05 00 Plaster and Gypsum Board</td>
<td>DINOFLEX</td>
<td>Evolution Tile</td>
<td>C2Grave</td>
<td>SCS</td>
<td>Dec 7, 2020</td>
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<td>09 05 00 Resilient Flooring</td>
<td>DINOFLEX</td>
<td>Next Step</td>
<td>C2Grave</td>
<td>SCS</td>
<td>Dec 7, 2020</td>
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<td>09 05 00 Resilient Flooring</td>
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<td>ECOuterfaces</td>
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<td>09 05 00 Resilient Flooring</td>
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<td>Heterogeneous Vinyl Sheet</td>
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<td>C2Grave</td>
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<td></td>
</tr>
</tbody>
</table>
Giga ORIGIN

www.origin.build
Don’t forget about Health
If you don’t spec it, you won’t get it
B. **Sustainable Design Submittals:** For building products sourced from manufacturers documenting efforts to minimize environmental and health impacts, provide the following information to the extent available:

1. **Product Data:** For recycled content, indicating postconsumer and preconsumer recycled content and cost.
2. **Product Certificates:** For regional materials, indicating location of material manufacturer and point of extraction, harvest, or recovery for each raw material. Include distance to Project and cost for each regional material.
3. **Building Product Disclosure Requirements:** [To encourage the use of building products that are working to minimize their environmental and health impacts, provide the following information when available]:
   a. Environmental Product Declarations:
   b. Material Ingredients Documentation demonstrating the chemical inventory of the product to at least 0.1% (1000ppm).
PART 2 - PRODUCTS

2.1 PERFORMANCE REQUIREMENTS

A. Building Product Disclosure Requirements: Provide Building Product Disclosure documentation for products used in this section when available.
   1. Environmental product Declarations:
   2. Material Ingredients — Documentation demonstrating the chemical inventory of the product to at least 0.1% (1000 ppm).
1.4 Application Preparation: Complete every entry on form. Notarize and execute by a person authorized to sign legal documents on behalf of Contractor. Architect will return incomplete applications without action.

A. Entries shall match data on the schedule of values and Contractor's construction schedule. Use updated schedules if revisions were made.

B. Include amounts for work completed following previous Application for Payment, whether or not payment has been received.

C. Include only amounts for work completed at time of Application for Payment.

D. Provide updated Environmental product data submittal form to assure proper accounting of environmental metrics with each application for payment.
<table>
<thead>
<tr>
<th>Project Product Data</th>
<th>MRB CID</th>
<th>Leadership Credits</th>
<th>Materials and Resources LEED Credits</th>
<th>Production Ingredient</th>
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<tr>
<td>9</td>
<td></td>
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</table>
Reuse: measure what we value

15 March 2019
Brad Guy, Assoc AIA
ISO/TC 59/SC 17/WG1 Design for A/D
AIA Materials Knowledge Working Group
USGBC LEED Social Equity Working Group
Building stock available for reuse

- 60% older than 25 years
- 22% older than 50 years
- 2.2% vacant as of 2012 (NGO)
- = 2 billion SF (NGO)
Retrofit trend

• Adaptive reuse (AdRu) ~ 1-2% of all commercial space annually.
• Estimated to be 4% by 2023 – due to mall and store closings and rise of e-commerce and A.I.
• “AdRu now competes effectively against new construction. It can be 15-20 percent cheaper and faster for projects without environmental issues in cities that have sufficiently evolved their zoning and building codes to accommodate it. The wild card is the permitting, engineering, and approval costs for AdRu.”

Scale-jumping

1. Salvage materials from renovation and demolition.
2. Substitute reclaimed materials for new in renovation and construction.
3. Retrofit existing buildings, reuse in situ.
4. Reuse buildings on Brownfields and within urban fabric.
Four studies of reuse (different scales)

- GWP of demolition versus deconstruction.
- GWP footprint (Scope III) of reuse system for materials.
- Whole building GWP impact reduction for net-zero retrofit.
- Building reuse vs non-reuse via LEED site, energy and IEQ metrics.
LCA of deconstruction vs demolition

• Impacts of process via time, mass, environmental effects?
• Trade-offs between deconstruction and demolition?
• Greenhouse gas (GHG) impacts of deconstruction vs demolition?
• Environmental “break-even” for deconstruction?
Time

**Labor Days**
- Deconstruction: 13.6
- Demolition: 1.5

**Machine Days**
- Deconstruction: 10
- Demolition: 3

Ft. McClellan LCA
CO2-e g/per SF

- Deconstruction
- Demolition

<table>
<thead>
<tr>
<th>Category</th>
<th>Equipment</th>
<th>Transport</th>
<th>Deconstruction</th>
<th>Salvage</th>
<th>Recycling</th>
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<tr>
<td>Ft. McClellan LCA</td>
<td>386</td>
<td>179</td>
<td>111</td>
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<td>-272</td>
<td>335</td>
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<td>1570</td>
<td>1990</td>
<td>179</td>
<td>-1460</td>
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</table>
CO2-e g/sf (what if 55% REUSE)

- Deconstruction
- Demolition

Ft. McClellan LCA
Carbon footprint (scope III) of reuse operation

• Environmental (GHG) benefit to reuse facilities?
• GHG consumer marketing message?
• Internal knowledge of environmental impacts?
• Regional building materials reuse facility, ~55,000 SF, Washington, DC.
Annual MT CO2-e

CF Carbon Footprint
Annual MT CO2-e

- RECYCLING TRANSPORT: 1.1
- CF EMPLOYEE COMMUTE: -18.3
- ELECTRICITY: 51.3
- DONOR TRANSPORT: 60.4
- HEATING (GAS): 68
- WASTE LANDFILL: 127
- DONATION PICKUP: 162
- RECYCLING BENEFIT: -180
- REUSE BENEFIT: -619
- TOTAL ANNUAL CO2-E: -309.3

CF Carbon Footprint
LEED v2 & 3 building reuse vs new

- Energy performance of building reuse vs new construction?
- Is building reuse “sustainable design”?
- Holistic comparison between building reuse and new construction?
Core & Shell EA Energy-use Reduction

V2 EA1 OPTIMIZE ENERGY PERFORMANCE

- Adaptive Reuse: 24%
- New Construction: 18%

V3 EA1 OPTIMIZE ENERGY PERFORMANCE

- Adaptive Reuse: 25%
- New Construction: 25%
Core & Shell SS and IEQ Credits

- SS2 DENSITY AND CONNECTIVITY: 87% Adaptive Reuse, 64% New Construction
- SS4.1 PUBLIC TRANSIT ACCESS: 90% Adaptive Reuse, 71% New Construction
- EQ8.1 DAYLIGHT: 33% Adaptive Reuse, 19% New Construction

LEED Building Reuse
NC & MR EA Energy-use Reduction

LEED Building Reuse
NC & MR SS and IEQ Credits

- SS2 DENSITY AND CONNECTIVITY: 76%
- SS4.1 PUBLIC TRANSIT ACCESS: 60%
- EQ8.1 DAYLIGHT: 19%

Legend:
- Adaptive Reuse
- New Construction

LEED Building Reuse
Whole building net-zero retrofit

- GWP “benefits” between replacement and retrofit?
- Impacts of PV panels for net-zero?
- Hotspots for embodied impacts?
- Building lifecycle (60-year) effects?
Existing Embodied (EM) GWP (kgCO2eq)

- 03 - Concrete: 1,552,648
- 05 - Metals: 518,100
- 04 - Masonry: 203,607
- 09 - Finishes: 73,311
- 08 - Openings and Glazing: 23,790
- 07 - Thermal and Moisture Protection: 7,921

AGU Net-Zero
Existing EM + OP GWP (kgCO2eq)

- 03 - Concrete: 1,552,648 kgCO2eq
- 05 - Metals: 518,100 kgCO2eq
- 04 - Masonry: 203,607 kgCO2eq
- 09 - Finishes: 73,311 kgCO2eq
- 08 - Openings and Glazing: 23,790 kgCO2eq
- 07 - Thermal and Moisture Protection: 7,921 kgCO2eq

Total Operational Energy (2015): 28,419,218 kgCO2eq

AGU Net-Zero
<table>
<thead>
<tr>
<th>Category</th>
<th>Renovation w/ PV GWP (kgCO2eq)</th>
<th>Renovation w/out PV GWP (kgCO2eq)</th>
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<tr>
<td>26 - PV PANELS</td>
<td>715,392</td>
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<tr>
<td>09 - FINISHES</td>
<td>468,550</td>
<td>468,550</td>
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<tr>
<td>05 - METALS</td>
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<td>03 - CONCRETE</td>
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<td>08 - OPENINGS</td>
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<td>07 - THERMAL</td>
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<tr>
<td>06 - WOOD/PLASTIC</td>
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<td>04 - MASONRY</td>
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<td>TOTAL</td>
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AGU Net-Zero
Existing vs Renovation w/ PV

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</table>

AGU Net-Zero
Renovation w/ vs w/out PV

AGU Net-Zero
Building Lifecycle Impact Reduction (GWP)

• **Embodied energy** reduction from existing (i.e. build new) to retrofit.
• Without PV = 33% reduction in GWP
• *Expenditure of high GWP materials – finishes, metals, electrochromic glazing, etc.*
• With PV = 1% reduction GWP
• *Additional expenditure of high GWP metals for PV frame and PV panels.*
• Net-zero retrofit “PV payback” of EM of renovation, i.e. **building is net-positive both EM and OP over 60-year lifespan.**
Themes and findings

• Salvaging reduces GWP impacts of renovation and demolition.
• Reuse substitutes for new materials – **CARBON SINK**.
• Location-related values and GWP are major benefits of reuse.
• More to reuse than just the building (context).

• Building reuse energy-performance comparable or better than new construction (some limitations).
• Renewable-energy buildings’ additional impacts can be offset by starting with existing and vice-versa.
Future

• Carbon offsets for reuse of materials and buildings.
• Scope of reuse in US – more information.
• PCRs and EPDs for reclaimed materials.

• Buildings as invested materials banks for the future (return).
• DESIGN FOR ADAPTABILITY AND DISASSEMBLY (ISO 20887).

• Only two choices for buildings: existing or net production of – materials, energy, ecosystem services, etc.
Thank you!

Brad Guy
materialreuse@gmail.com