LCA Workshop
April 29, 2021

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Martin Torres
Agenda

Background
- LCA overview
- Industry efforts
- System vs. material reductions
- Case studies
- Limitations of LCA and LEED

Demonstration
- Tally
- Athena
- Available resources
LCA Overview

What is LCA?
What does it look like in rating systems?
What are EPDs?
‘Upfront’ Embodied Carbon
Manufacture, transport and installation of construction materials

Operational Carbon
Building energy consumption

Source: SKANSKA
Figure A.9.3 – Graph showing interaction between operation and embodied carbon throughout the lifetime of a building.
Building floor additions from 2020 (billions m²)

<table>
<thead>
<tr>
<th>Region</th>
<th>2030</th>
<th>2040</th>
<th>2060</th>
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<tbody>
<tr>
<td>Africa</td>
<td>10.0</td>
<td>74.7</td>
<td>88.2</td>
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<tr>
<td>China</td>
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<td>10.0</td>
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<tr>
<td>India</td>
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<td>15.8</td>
<td>23.5</td>
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<tr>
<td>North America</td>
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<td>Other Asia</td>
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<td>Middle East</td>
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<tr>
<td>OECD Pacific</td>
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</tr>
<tr>
<td>Caspian Region</td>
<td>6.5</td>
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</tr>
</tbody>
</table>

Source: Architecture 2030: Global ABC, Global Status Report 2017
(areas are approximate)
Environmental Impact Categories

- Global Warming Potential (kg CO₂ eq)
- Non-renewable Energy Demand Potential (MJ)
- Eutrophication Potential (kg N eq)
- Acidification Potential (kg SO₂ eq)
- Smog Formation Potential (kg O₃ eq)
- Ozone Depletion Potential (kg CFC-11 eq)
Embodied impacts for commercial construction

Most emissions are from the structure.

Structure is mostly concrete and/or steel.

Concrete impact is mostly from cement. Cement ≠ Concrete.
Life Cycle Assessment (LCA)
The evaluation of the environmental effects associated with any given activity from the initial gathering of raw material from the earth until the point at which all residuals are returned to the earth.

Source: US EPA
Environmental Product Declarations (EPDs)

LCA is a METHOD

EPD is a REPORT

Building LCA
LCA & EPDs

Product LCA → EPD → Building LCA

Life Cycle Impact Results (per m³)
Declared Unit: 1 m³ of 3,000 psi concrete

**OPERATIONAL IMPACTS**

<table>
<thead>
<tr>
<th>Description</th>
<th>Value</th>
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</thead>
<tbody>
<tr>
<td>Plant Operating Energy (MJ)</td>
<td>14.7</td>
</tr>
<tr>
<td>On-Site Plant Fuel Consumption (MJ)</td>
<td>165.5</td>
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<tr>
<td>Concrete Batch Water (m³)</td>
<td>1.63E-01</td>
</tr>
<tr>
<td>Vehicle and Equipment Wash Water (m³)</td>
<td>5.59E-01</td>
</tr>
<tr>
<td>On-Site Waste Disposal (kg)</td>
<td>0.19</td>
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**ENVIRONMENTAL IMPACTS**

<table>
<thead>
<tr>
<th>Description</th>
<th>Value</th>
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<tbody>
<tr>
<td>Total Primary Energy (MJ)</td>
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<tr>
<td>Climate Change (kg CO₂ eq)</td>
<td>332</td>
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<tr>
<td>Ozone Depletion (kg CFC 11 eq)</td>
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<td>Acidification Air (kg SO₂ eq)</td>
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<td>Eutrophication (kg N eq)</td>
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<td>Photochemical Ozone Creation (kg O₃ eq)</td>
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Environmental Product Declaration (EPD) for Concrete

About Titan Concrete

Our products protect human life and personal property. Improve the quality of life, generate economic prosperity and connect society. Our values guide how we conduct business and our customer efforts, particularly with regard to our customers, our employees, our communities and the environment.

We at Titan Concrete, know that customer satisfaction begins with strict adherence to quality control and that qualified people create quality products. Our ready mixed concrete is manufactured with the most technically advanced equipment available, ensuring that our facilities are among the most efficient and environmentally friendly in the world.

Titan Concrete
455 Fairway Drive
Deerfield Beach, FL 33441
800-588-3559
www.titanconcrete.com
LCA Overview

1. Initiate Assessment
   What is the goal and scope?

2. Define the Building
   Size, scale, construction, use, and end-of-life scenarios

3. Determine Environmental Impacts
   Which LCA tool do you use?

4. Interpret Results
   Is the analysis sufficient to meet project goals?

5. Prepare Reports
   Document analysis and findings
Life Cycle Impact Results (per m³)
Declared Unit: 1 m³ of 10,000 psi concrete at 28 days

<table>
<thead>
<tr>
<th>OPERATIONAL IMPACTS</th>
<th>Performance™ PERCTOR</th>
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<td>On-Site Plant Fuel Consumption (MJ)</td>
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<td>Concrete Batch Water (m³)</td>
<td>1.68E-01</td>
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<tr>
<td>Concrete Wash Water (m³)</td>
<td>1.91E-02</td>
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<td>On-Site Waste Disposal (kg)</td>
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<table>
<thead>
<tr>
<th>ENVIRONMENTAL IMPACTS</th>
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<tbody>
<tr>
<td>Total Primary Energy (MJ)</td>
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<td>Climate Change (kg CO₂ eq)</td>
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<td>Human Depletion (kg CFC 11 eq)</td>
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<td>Acidification Air (kg SO₂ eq)</td>
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<tr>
<td>Eutrophication (kg N eq)</td>
</tr>
<tr>
<td>Photochemical Ozone Creation (kg O₃ eq)</td>
</tr>
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</table>

MATERIAL QUANTITY ESTIMATE × IMPACT PER MATERIAL EPDS = BUILDING IMPACT ESTIMATE
<table>
<thead>
<tr>
<th>Description</th>
<th>Desktop</th>
<th>Revit Plugin</th>
<th>Web-based with BIM integration</th>
</tr>
</thead>
</table>
| Cost        | Free    | $695/year + Revit | Starter: $790/year  
|             |         |               | Business: $1690/year  
|             |         |               | Expert: $3000/year |
| Data source | [Image] | Large LCA database with manufacturer-specific and | |
|             | [Image] | [Image] | [Image] |
| Report      | Basic excel reports  
|             | without disaggregation | Detailed PDF report and Excel output | Dynamic graph previews, EPD comparisons, detailed LCA results in Excel and Word |
Industry Efforts

Architecture 2030
SE 2050
Embodied Carbon in Construction Calculator
Embodied Carbon in Construction Calculator (EC3) tool

- Compare materials via EPDs
- Ballpark comparisons of whole buildings
- Verify EPDs if a program operator
- Overall: a work in progress as more EPDs are added to the tool
EC3 Uses “burden of the doubt” approach

1. Manufacturer specific
2. Facility specific
3. Product specific
4. Time specific
5. Supply-chain specific

Interpreting data visualization in the EC3 tool
A. Highest results for this category in the database
B. CLF Beta Baseline – high estimate per category
C. GWP of 80% of EPDs in category is below this
D. EPD result plus uncertainty estimate – EC3 value
E. EPD embodied carbon result
F. GWP of 20% of EPDs in category is below this
G. Lowest results for this category in the database

Figure 4. Visualizing the burden of the doubt approach.

A primary goal of the EC3 tool is to help users interpret EPDs via two primary functions:

1. Grouping EPDs based on performance, and
2. Estimating the variability (range of reasonably expected results) and uncertainty (precision of LCA data) within EPDs when this data is not provided within the EPD.
AN IMMEDIATELY APPLICABLE, HIGH-IMPACT PATHWAY TO EMBODIED CARBON REDUCTIONS IN THE BUILT ENVIRONMENT
SE 2050 Commitment Program

Asks structural engineers and structural engineering firms to accelerate the embodied carbon reduction in structural systems and materials through three main activities.
LEED v4.1: Life Cycle Impact Reduction Credit

- **Option 1:** Historic Building Reuse (5 Points)
- **Option 2:** Renovation of abandoned or blighted building (5pts)
- **Option 3:** Building and material reuse (2-4 points)
- **Option 4:** Whole-Building LCA (1,2,3 or 4 points)
  - **NEW** Conduct a *life-cycle assessment* of the project’s *structure and enclosure* – 1 Point
  - **NEW** Demonstrate a minimum of *5% reduction*, compared with a *baseline building*, in at least *three* of the six impact categories listed. One of which must be GWP. No measure may increase by more than 5%. – **2 Points**
  - (3) 10% reductions – **3 Points**
  - **NEW - 4 Points**
    - 20% reduction in GWP
    - (2) 10% reductions in other impacts
    - Include salvaged materials
# ZGF Concrete LCA Tool, lca-tool@zgf.com

## Proposed Mix Designs

<table>
<thead>
<tr>
<th>Application</th>
<th>Mix Design Name</th>
<th>Weight (lbs)</th>
<th>Aggregate (by Volume)</th>
<th>Aggregate (by Weight)</th>
<th>Water</th>
<th>Admixtures</th>
<th>cement</th>
<th>Fly Ash</th>
<th>Slag</th>
<th>Course Aggregate</th>
<th>Fine Aggregate (Sand)</th>
<th>Per CY of Mix</th>
<th>Total Mix (by Volume)</th>
<th>Total Mix (by Weight)</th>
<th>Total Impact</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>1,080</td>
<td>312</td>
<td>0.00</td>
<td>312</td>
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<td>418.18</td>
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## NRMCA Baseline

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<th>Mix Design Name</th>
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<th>Admixtures</th>
<th>cement</th>
<th>Fly Ash</th>
<th>Slag</th>
<th>Course Aggregate</th>
<th>Fine Aggregate (Sand)</th>
<th>Per CY of Mix</th>
<th>Total Mix (by Volume)</th>
<th>Total Mix (by Weight)</th>
<th>Total Impact</th>
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<tr>
<td></td>
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<td>418.18</td>
<td>418.18</td>
<td>418.18</td>
<td>2470</td>
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## Comparison

<table>
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<th>Environmental Impact Comparison</th>
<th>Weight (lbs)</th>
<th>Aggregate (by Volume)</th>
<th>Aggregate (by Weight)</th>
<th>Water</th>
<th>Admixtures</th>
<th>cement</th>
<th>Fly Ash</th>
<th>Slag</th>
<th>Course Aggregate</th>
<th>Fine Aggregate (Sand)</th>
<th>Per CY of Mix</th>
<th>Total Mix (by Volume)</th>
<th>Total Mix (by Weight)</th>
<th>Total Impact</th>
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<td>Better or Worse?</td>
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<td></td>
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</table>
System vs. material reductions
REDEFINE the solution
REFURBISH existing assets
REDUCE & REPLACE materials and structure
REUSE products and materials
REQUIRE low carbon products

Figure 4: Opportunities to reduce embodied carbon from stage of design process.
Primary high impact materials

**Concrete** - It’s about total cement content, not (just) fly ash replacement

**Steel** - Electric arc furnace (wide flange, recycled) over basic oxygen furnace (HSS, virgin ore)

**Wood** - Is it coming from a sustainably managed forest?
Secondary high impact materials

**Insulation** - Stay away from high intensity HFC blowing agents

**Gypsum** - Specify lightweight gypsum and eliminate waste material

**Envelope** - Lower WWRs, lower aluminum use, prioritize recycled aluminum

**Carpet** - Specify carbon neutral carpet tile products
Case studies

Austin FC Stadium
5-story office building
Case study (system reduction)
Austin FC Stadium
# Impact on Design Documents

## Classes of Concrete Matrix

<table>
<thead>
<tr>
<th>Concrete Usage</th>
<th>Minimum Compressive Strength (ksi)</th>
<th>Concrete Type</th>
<th>Exposure Class</th>
<th>Maximum W/C Ratio</th>
<th>Maximum Air Content</th>
<th>Required Cement Replacement</th>
<th>Maximum Aggregate Size</th>
<th>Maximum Aggregate Content (Lb/CY)</th>
<th>Environmental Impact Indicators</th>
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<tbody>
<tr>
<td>Deep Foundations</td>
<td>4,000 PSI AT 28 DAYS</td>
<td>IPF</td>
<td>C1</td>
<td>N/A</td>
<td>N/A</td>
<td>40-70%</td>
<td>1&quot;</td>
<td>500</td>
<td>422</td>
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<tr>
<td>Shallow Foundations</td>
<td>4,000 PSI AT 28 DAYS</td>
<td>IPF</td>
<td>C1</td>
<td>N/A</td>
<td>N/A</td>
<td>40-70%</td>
<td>1&quot;</td>
<td>500</td>
<td>422</td>
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<tr>
<td>Grade Beams - Exterior</td>
<td>4,500 PSI AT 56 DAYS</td>
<td>PMF</td>
<td>B2</td>
<td>0.45</td>
<td>0</td>
<td>25-50%</td>
<td>1&quot;</td>
<td>500</td>
<td>422</td>
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<tr>
<td>Exterior Beam Caps</td>
<td>4,500 PSI AT 56 DAYS</td>
<td>PMF</td>
<td>C1</td>
<td>0.45</td>
<td>6</td>
<td>25-50%</td>
<td>1&quot;</td>
<td>500</td>
<td>422</td>
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<td>Interior Beam Caps</td>
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<td>PMF</td>
<td>C1</td>
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<td>N/A</td>
<td>40-70%</td>
<td>1&quot;</td>
<td>500</td>
<td>422</td>
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<tr>
<td>Columns, Supporting Steel Columns</td>
<td>4,500 PSI AT 56 DAYS</td>
<td>PMF</td>
<td>C1</td>
<td>N/A</td>
<td>N/A</td>
<td>40-70%</td>
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<td>Spread Footings</td>
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<td>C1</td>
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<td>40-70%</td>
<td>1&quot;</td>
<td>500</td>
<td>422</td>
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<tr>
<td>Foundation Walls</td>
<td>4,500 PSI AT 56 DAYS</td>
<td>PMF</td>
<td>C1</td>
<td>N/A</td>
<td>N/A</td>
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<td>1&quot;</td>
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<td>422</td>
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<tr>
<td>Exterior Retaining Walls</td>
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<td>PMF</td>
<td>C1</td>
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<td>N/A</td>
<td>40-70%</td>
<td>1&quot;</td>
<td>500</td>
<td>422</td>
</tr>
<tr>
<td>Slabs - Grade</td>
<td>4,000 PSI AT 28 DAYS</td>
<td>PMF</td>
<td>C1</td>
<td>N/A</td>
<td>N/A</td>
<td>40-70%</td>
<td>1&quot;</td>
<td>500</td>
<td>422</td>
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<tr>
<td>Slabs - Slab-on-Grade</td>
<td>4,000 PSI AT 28 DAYS</td>
<td>PMF</td>
<td>C1</td>
<td>N/A</td>
<td>N/A</td>
<td>40-70%</td>
<td>1&quot;</td>
<td>500</td>
<td>422</td>
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<tr>
<td>Slab-on-Grade (All Other)</td>
<td>4,000 PSI AT 28 DAYS</td>
<td>PMF</td>
<td>C1</td>
<td>N/A</td>
<td>N/A</td>
<td>40-70%</td>
<td>1&quot;</td>
<td>500</td>
<td>422</td>
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<tr>
<td>Floor/Deck Slabs - Slab on Grade</td>
<td>3,600 PSI AT 28 DAYS</td>
<td>PMF</td>
<td>C1</td>
<td>N/A</td>
<td>N/A</td>
<td>40-70%</td>
<td>1&quot;</td>
<td>500</td>
<td>422</td>
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<tr>
<td>Deck Slabs - Slab on Grade (All Other)</td>
<td>3,600 PSI AT 28 DAYS</td>
<td>PMF</td>
<td>C1</td>
<td>N/A</td>
<td>N/A</td>
<td>40-70%</td>
<td>1&quot;</td>
<td>500</td>
<td>422</td>
</tr>
<tr>
<td>Deck Slabs at Roof, Balconies and Terraces</td>
<td>3,600 PSI AT 28 DAYS</td>
<td>PMF</td>
<td>C1</td>
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<td>N/A</td>
<td>40-70%</td>
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<td>500</td>
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<tr>
<td>Exterior Topping Slabs - Moisture Sensitive Floor Coverings</td>
<td>5,000 PSI AT 28 DAYS</td>
<td>PMF</td>
<td>C1</td>
<td>N/A</td>
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<td>1&quot;</td>
<td>500</td>
<td>422</td>
</tr>
<tr>
<td>Exterior Topping Slabs (All Other)</td>
<td>5,000 PSI AT 28 DAYS</td>
<td>PMF</td>
<td>C1</td>
<td>N/A</td>
<td>N/A</td>
<td>40-70%</td>
<td>1&quot;</td>
<td>500</td>
<td>422</td>
</tr>
<tr>
<td>Exterior Toppings Slabs and Curves</td>
<td>5,000 PSI AT 28 DAYS</td>
<td>PMF</td>
<td>C1</td>
<td>N/A</td>
<td>N/A</td>
<td>40-70%</td>
<td>1&quot;</td>
<td>500</td>
<td>422</td>
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<td>LEED</td>
<td>GWP</td>
<td>AP</td>
<td>EP</td>
<td>ODP</td>
<td>SFP</td>
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<td>1</td>
<td>Baseline</td>
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<td>100%</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
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<td>96%</td>
<td>98%</td>
<td>100%</td>
<td>98%</td>
<td>97%</td>
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<tr>
<td>3</td>
<td>First concrete submittals</td>
<td>3 pts</td>
<td>88%</td>
<td>91%</td>
<td>89%</td>
<td>100%</td>
<td>89%</td>
<td>93%</td>
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<tr>
<td>4</td>
<td>Updated column mix</td>
<td>3 pts</td>
<td>88%</td>
<td>91%</td>
<td>89%</td>
<td>100%</td>
<td>90%</td>
<td>93%</td>
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<tr>
<td>5</td>
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<td>92%</td>
<td>91%</td>
<td>100%</td>
<td>91%</td>
<td>93%</td>
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</tr>
<tr>
<td>6</td>
<td>Updated slab mix (hypothetical)</td>
<td>3 pts</td>
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<td>90%</td>
<td>99%</td>
<td>89%</td>
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<table>
<thead>
<tr>
<th></th>
<th>GWP</th>
<th>AP</th>
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<tr>
<td>1</td>
<td>12%</td>
<td>38%</td>
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- GWP: Gas Wattage Product
- AP: Air Permeability
- EP: Energy Performance
- ODP: Odour and Pollutant Emission
- SFP: Sustainable Flows
- NRED: Non-Recycling Energy Demand

**Legend:**
- Finishes
- Openings and Glazing
- Thermal and Moisture Protection
- Wood/Plastics/Composites
- Metals
- Masonry
- Concrete
Case study (component reduction)
Cladding examples
McLennan Design Example

![Graph showing embodied carbon comparison between baseline and proposed designs.](Image)

**Baseline WALL-1**
- TYPICAL PLASTER OVER MTL STUD RAINSCREEN

**Proposed WALL-2**
- OPTIMIZED PLASTER OVER MTL STUD RAINSCREEN

*Courtesy McLennan Design*
A Tale of Five Bricks

GWP

- Precast w/ Thin Brick
- Brick over Insul Metal Panel
- Brick on MTL Studs
- Brick on MTL Studs
- Thin Brick on MTL Studs

Baseline 2.5% Thin Brick
Spray Foam
Brick
Brick Mod 1
Brick Mod 2
Min Wool
Bett Insul
Min Wool
Metal Lath
Cement Board
Thin Brick

LMN example
Limitations and next steps

What can we do?
Limitations of LCA and LEED

- Absolute vs. relative differences
- Benchmarks for whole-building LCA are not solid
- Difference in scope with EPDs and impact data
- Easy to get away with bad practice
- Does not currently capture uncertainty
What do we need to do locally?

- Reuse existing buildings
- Conduct LCAs
- Request EPDs (especially concrete)
- Circular economy
- Policies + incentives
Demonstrations

Tally & Athena
Resources

- **EC3 tool** (EPD database)
- **OneClick LCA** – another whole building LCA tool
- **Tally tutorials**
- **Athena IEB tutorials**
- **LETI embodied carbon primer**
- **World GBC 2020 global status report for buildings and construction**
- **US Federal Government takes the lead on low embodied carbon buildings**
- **Not zero: how net zero targets disguise climate inaction**
- **Carbon smart materials palette**
- **Architecture 2030**
- **SE 2050**
- **Biogenic carbon accounting of wood products in WBLCA**