Embodied Carbon Reductions Built Project Case Study Collection

APRIL 2025

CLF Carbon Leadership Forum

About the Carbon Leadership Forum

The Carbon Leadership Forum is a nonprofit dedicated to accelerating the transformation of the building sector to radically reduce the greenhouse gas emissions attributed to materials (also known as embodied carbon) used in buildings and infrastructure. We research, educate, and foster cross-collaboration to bring the embodied carbon of buildings and infrastructure down to zero.

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Cover Images are credited in individual case studies.

If you would like to see more case studies in the future and are interested in supporting this work, visit this link for ways to support CLF.

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Introduction

The momentum behind addressing embodied carbon is rapidly accelerating. The past five years have seen an unprecedented increase in incentives and requirements related to embodied carbon reporting and reductions across codes and policies, certification programs, and voluntary commitment programs. Built environment leaders are also increasing internal efforts to assess and reduce embodied carbon across their projects.

In the fall of 2024, the Carbon Leadership Forum launched a new effort to collect, curate, and publish building project case studies across North America that have achieved embodied carbon reductions. This effort aims to support the growing community of architecture, engineering, and construction teams, as well as owners and developers looking for inspiration and practical strategies to reduce embodied carbon on their projects. Each case study's results are backed by data from a reviewed life cycle assessment (LCA).

The goal of this effort is to create a collection of project case studies that showcase how completed projects have assessed and reduced their embodied carbon, making it easier for building industry professionals to scale low-carbon design and construction practices. Being a 'CLF Embodied Carbon case study' is not part of a verification or certification process. These case studies focus on reduction strategies and are not intended to be used for benchmarking. To learn more about North American whole building life cycle assessment (WBLCA) building benchmarks, see CLF's latest publications from the CLF WBLCA Benchmarking Study v2 or visit the public dataset (Benke et al. 2024, Benke et al 2025a).

This document explores all of the project case studies in detail and includes more about the selection and review process, limitations, and areas for future development.

Background

Life Cycle Assessment

Each case study's results are backed by data from a life cycle assessment (LCA). LCA is the agreed-upon methodology for measuring embodied carbon and involves evaluating the environmental impacts of a building, product, or process over its full life cycle, from raw material extraction through end-of-life and disposal. By providing a standardized and robust approach to estimating the carbon impacts of construction products and projects, LCA can support more informed decision-making from early design through procurement.

LCA provides an estimate of greenhouse gas emissions over all (or a portion of) the building's life cycle, reported as global warming potential (GWP). LCAs also report other environmental and human health impacts – such as acidification, eutrophication, and smog formation – which were not included in this collection of case studies. Life cycle stages (product, construction, use, end-of-life) and modules (A1, A2, etc.) subcategorize the life cycle of a building and help communicate when environmental impacts occur, as described in Figure 1.

The term whole building life cycle assessment (WBLCA) is used to refer to LCA performed at the building scale, commonly including foundations, structure, and enclosure elements. At the product scale, life cycle assessments can be translated into third-party verified product disclosures called Environmental Product Declarations (EPDs).

For more quick, introductory resources to LCA and building LCA, we recommend CLF's Embodied Carbon Video Training Series and CLF's embodied carbon policy factsheet series, including Building LCA 101 (Waldman et al., 2024, Lewis et al., 2024a).

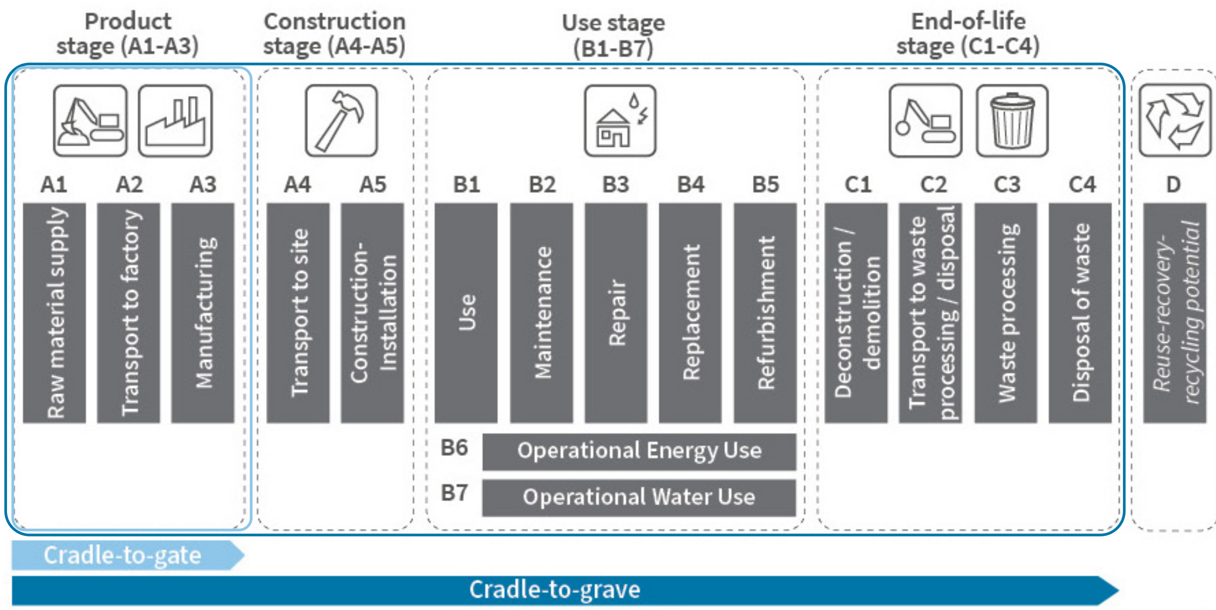

Figure 1. Life cycle stages. Life cycle stages and modules subcategorize the life cycle of a building to communicate when environmental impacts occur and what parts of the life cycle are included in an assessment. Source: Carbon Leadership Forum, 2023.

Life Cycle Assessment Tools

A wide range of tools is available to measure the embodied carbon of the built environment. This collection of case studies includes analyses completed in Tally, One Click LCA, and the BEAM estimator tool. The EC3 tool was also used by some projects to identify and compare product-specific EPDs used on their project as a complement to Tally. The following provides an overview of these key tools:

- Tally is a plug-in tool that uses Revit's building information model for estimating material quantities and enables users to link environmental impact data from its material library (Building Transparency, 2025b). Its primary LCI data source is GaBi. Tally includes life cycle stages A-D and allows users to select whether to exclude or include biogenic carbon flows in their analysis.

- One Click LCA has a range of tools for different project types and regions, and offers both a web-based and a Revit plug-in tool for building analysis (One Click LCA, 2025). It can extract material quantities and properties from Revit, import a spreadsheet of quantities, and create manual entries of material quantities and properties for different design stages of a building. Its primary LCI data sources are ecoinvent and EPDs. One Click LCA for LEED and One Click LCA Life Cycle Carbon tool (the primary tools used in these case studies) include life cycle stages A-C and D, and report biogenic carbon storage (but exclude biogenic carbon flows).

- The Building Emissions Accounting for Materials (BEAM) Tool was designed for users in the low- and mid-rise residential sector and can be used for new construction or renovations (Builders for Climate Action, 2025). BEAM is a "cradle-to-gate" estimator, meaning that it includes all emissions associated with turning raw materials into building products (life cycle stages A1-A3). BEAM accounts for carbon storage in products that contain biogenic materials sourced from agricultural or forestry residues and recycling streams. No carbon storage is attributed to virgin forest products, including framing lumber, plywood, OSB, and wood trusses or I-beams.

- Embodied Carbon in Construction Calculator (EC3) is a free, open-access tool and supporting EPD database that encourages low-carbon specification and procurement (Building Transparency, 2025a). EC3 houses a database of Environmental Product Declarations (EPDs) and enables users to enter material quantities from BIM models, construction estimates or as-builts to assess the impact of their procurement choices. Currently, EC3 supports A1-A5 analyses using data from EPDs (A1-A3) and emissions factors for A4 and A5. EC3's biogenic carbon reporting is consistent with that provided in the EPD: if the EPD includes biogenic carbon flows and/or storage, then this is reported in EC3.

Baselines and Benchmarks

Demonstrating an embodied carbon reduction requires defining what value a project is reducing from. In other words, a reduction from what? Policies and programs typically require one or a combination of the following approaches:

1. **% Reduction Targets:** Projects must reduce the building's embodied carbon by a certain percentage compared to a user-modeled, building-specific baseline. This requires project teams to model a functionally equivalent building with typical systems or materials to compare to their project. Functional equivalence usually means a project with the same area, function and operational performance.

2. **Benchmarks (or Building Carbon Budgets):** Projects must have an embodied carbon intensity (ECI) per floor area (kg CO2e/m2) below a maximum value. This value is defined by the policy, program, or reference benchmark published by a third-party organization.

In each case study in this collection, the project team has provided either a user-modeled baseline (including a description of the main assumptions) or a benchmark value. The source of each of the referenced benchmark values is included in the relevant case study, and includes the Toronto Green Standard v4, the International Living Future Institute (ILFI) Zero Carbon Certification, and the RMI and Builders for Climate Action published benchmarks for residential projects (City of Toronto 2025, ILFI 2024, Magwood et al., 2023) .

Some projects also use the National Ready Mixed Concrete Association (NRMCA) concrete regional baselines. NRMCA publishes the "NRMCA Member National and Regional LCA Benchmark (Industry Average) Report" with industry-average GHG emissions for 72 normal-weight and lightweight concrete mixes at various compressive strengths (NRMCA, 2022). NRMCA began publishing baselines in September 2014 and has subsequently updated the baselines in October 2016 (v2.0), November 2019 (v3.0), February 2020 (v3.1), and December 2021 (v3.2).

To learn more about baselines for other construction materials, see the CLF's latest Material Baselines report (Waldman et al., 2023).

To learn more about different building LCA requirement frameworks, see the Building-Scale Embodied Carbon Performance Requirements in the CLF's Policy Toolkit (Lewis et al., 2024b). To learn more about North American whole building LCA (WBLCA) benchmarks, see CLF's latest publications from the CLF WBLCA Benchmarking Study v2 (Benke et al., 2024).

Selection and Review Process

The initial call for case studies was made in October 2024. CLF requested that teams meet the following minimum requirements to be considered:

- **Built/Completed in the last 5 years**: Must be a built project, completed in 2019 or later.
- **North American:** The project must be located in the US or Canada.
- **Life Cycle Assessment (LCA) Data**: The project must have either (1) completed a cradle-to-grave whole building LCA using one of Tally, One Click LCA, or Athena covering at least structure and enclosure; (2) used environmental product declarations (EPDs) to demonstrate material-specific reductions against a baseline; or (3) used other analysis tools to achieve reductions in interiors, MEP systems, landscape, infrastructure, or single-family residential projects.
- **Demonstrated Reductions:** The LCA must demonstrate an embodied carbon reduction from a baseline model or benchmark. There is no minimum reduction required.
- **Project Team Participation:** The team must be willing to submit the LCA data and raw tool results to CLF for review. Members from the design, construction and/or ownership team must be willing to complete an interview with CLF.

We also had a few priorities we took into account in selecting the case studies:

- **Unique and Replicable:** We aimed to highlight case studies that are unique, push the boundary with embodied carbon reduction as a parameter, and have replicable strategies that can be used by other projects.
- **Variety of Project Types:** We hoped to highlight that a variety of project and building types can reduce embodied carbon.

Review Process

After receiving the LCA tool results and project description from each team, the CLF team reviewed each LCA submission to (1) identify any perceived major errors in modeling or reporting and (2) make minor adjustments to increase comparability between case study results, as possible.

For all projects, we generally confirmed their physical scope and life cycle stages and that the embodied carbon intensities (ECIs) were within an expected order of magnitude for buildings, usually between 200-700 $kgCO_2e/m^2$ for the non-residential use types and <300 $kgCO_2e/m^2$ for single-family residential. Project embodied carbon intensities were based on the raw results files provided, normalized by the gross floor area (GFA) figure provided by the teams.

The review process for projects with a modeled baseline included a comparative review of the raw results submitted by project teams. The CLF team created templates that took the global warming potential (GWP) results organized by material and compared summaries of baseline results to proposed results. This allowed us to observe the key differences between the baseline and proposed models and confirm questions or uncertainties with the project teams. We did not review the material data assumptions or the relationship of the absolute figures to the design documentation. Rather, we looked at the relative differences between the models alongside the strategies implemented by the teams, and focused only on flagging any perceived major errors. In a few cases, we suggested a change to the modeling approach and supported the team in making adjustments.

The review process for projects with a benchmark for comparison involved a review of the raw results and confirming the overall scope of the modeled study to that of the benchmark. As we later note in the individual case studies, we made some minor adjustments to the case study results where necessary to align the study scope with the benchmark scope. For example, we added a placeholder value for construction impacts (A4-A5) to better align with the benchmark used for comparison. These cases are indicated with a half-filled scope designation when present, otherwise, all other results were modeled and represent the raw results.

In all projects, we asked for teams to report biogenic carbon separately. We used the results to summarize the biogenic carbon **storage** for One Click LCA and BEAM results, and biogenic carbon **flows** for Tally results, when available from the team. See the Biogenic Carbon Calculation and Reporting section below for more information.

Overall for this series, CLF made our best effort to select case studies with strong and clear evidence of the reduction claims made. However, we did not exhaustively review these analyses.

Addressing Comparability

Given the current lack of North American WBLCA standards, each case study and LCA is unique, with various scopes, assumptions and best practices. CLF chose not to limit potential submissions with strict requirements that would increase the comparability of each LCA, but include many projects that achieved reductions demonstrated by best practice standards from the last five years.

These case studies focus on reduction strategies and are not intended to be used for benchmarking. However, the case study template aims to clearly communicate the following major areas of difference between the case studies:

- Physical scope
- Life cycle stages
- Biogenic carbon accounting
- LCA tool used

Reference Unit

All results in these case studies are reported in global warming potential (GWP) normalized by gross floor area (GFA), commonly referred to as embodied carbon intensity (ECI). The figures reported reflect varied physical scopes, life cycle stages, and biogenic carbon accounting approaches, which we noted where relevant. Our aim was to keep the results reported as close to the figures reported directly by the tools as possible.

Life Cycle Stages

LCA can capture the impacts of the full life cycle of a building across all life cycle stages (see Figure 1 above), from raw material extraction through end-of-life and disposal. However, different tools and certification programs allow different scopes.

The case studies in this collection have varying life cycle scopes. The life cycle stages included in each are noted in the “Life Cycle Assessment (LCA) Approach” of each case study. Even when available in the modeled results, we excluded Module D from our reported results.

Biogenic Carbon Calculation and Reporting

Biogenic carbon refers to carbon that is derived from or contained in biomass (e.g. plants and trees) (EN 16485:2014). This is in contrast to fossil carbon, which comes from dead matter that has accumulated and been compressed over time into concentrated fuel. Fossil carbon from burning fossil fuels is the primary source of greenhouse gas emissions from human activities. In contrast, incorporating biogenic carbon into the built environment through the use of bio-based building materials can provide the benefit of storing carbon throughout the building’s life cycle.

Biogenic carbon accounting in these case studies follows the methodologies of the LCA tools used by each project team. Currently, the modeling and reporting of biogenic carbon (such as the treatment of CO2 sequestered during plant growth, the carbon stored in ecosystem stocks such as soils, and the carbon stored in building materials) vary widely across tools and between standards, making it difficult to compare biogenic carbon storage and emissions across projects. There are many gaps in the current LCA standards for materials and buildings that exist, including that they do not account for the temporal value of carbon emissions and storage.

For these reasons, CLF required that biogenic carbon storage be reported separately, rather than as a net value combined with fossil emissions, when it was reported by the project team. This ensures transparency across tools and aligns with broader recommendations and policy requirements. In each case study, we have also noted the sources of the biogenic carbon storage or biogenic carbon flow values, which vary by tool. While **biogenic carbon storage** refers to the stored carbon in a unit of material, **biogenic flows** refers to the absorption and release of carbon over the life cycle. These values, sourced from different tools should not be compared directly to one another.

To learn more about how the LCA tools used in these case studies handle biogenic carbon accounting, see the tool documentation from each of the tool providers referenced in the *Life Cycle Assessment Tools* section. To read more about differing biogenic carbon calculation and reporting requirements across different policies and programs, see *Project Life Cycle Assessment Requirements: ECHO Recommendations for Alignment*, Appendix A (Lewis et al., 2024c).

Modeling Building Reuse

Adaptive reuse of a building is defined as the reuse of some substantial proportion of existing materials in-situ. This saves embodied carbon through extending the life of existing assets and avoiding the need for manufacturing of new materials. Generally, adaptive reuse refers to when a project would have otherwise been demolished or an entirely new project would have been created to house the new project's function. In other words, minor renovations that occur across a building's life are not counted as adaptive reuse.

We did not require that teams model reuse according to any specific rules, given this best practice is not well-defined in the industry. From our observations, most teams either excluded upfront impacts (A1-A5) or all impacts (A-C) associated with the reused building components in the proposed models.

Limitations and Areas for Future Development

CLF was impressed by the number and diversity of building projects that we received in the short submission window in October 2024. However, as with any project dependent on individual contributors, the ultimate case study collection categories had to be flexible in reaction to what submissions we received. We also faced challenges in navigating and communicating the modeling differences and lack of comparability between the reported results from the different tools used in this collection of case studies.

The primary limitations of this first volume of case studies were the comparability of tools - particularly related to biogenic carbon – and project scope/covered building elements.

Project Scope/Building Elements: Nearly all the case study submissions we received were building-level assessments that used either a cradle-to-grave WBLCA tool (e.g. Tally, OneClick LCA, Athena) or used BEAM to assess reductions of residential projects. In future collections of case studies, CLF may expand the project scope and building elements highlighted in this collection of case studies. In the meantime, we have included a list of additional embodied carbon case study collections for reference in Additional Resources that include a broader range of project types.

Comparability of Results: CLF chose not to limit potential submissions with strict requirements that would increase the comparability of each LCA. The embodied carbon intensities reported for each case study therefore cannot be compared to each other, as they have different LCA stages, project elements, and accounting methods for biogenic carbon. However, as described above in Addressing Comparability, CLF took steps to increase the comparability of projects as much as possible and created a template that prioritizes transparency about the underlying assessment and tools.

As described in CLF's *Advancing the LCA Ecosystem* (Lewis et al., 2023), ongoing standards development, harmonization initiatives, and collective impact efforts like the ECHO Project may be able to address the comparability of WBLCA results over time (Lewis et al., 2024c). Based on the learnings during this case study process and the findings from the recent CLF WBLCA Benchmarking Study v2, we may also refine the submission process when developing case studies in the future (Benke et al., 2024).

Additional Resources

Throughout the process of developing the framework for this case study collection, CLF collected the following list of embodied carbon case studies from other publications.

North American Case Studies

- **Lower-Carbon Concrete Task Force** (https://lowercarbonconcrete.org/case-studies): A collection of case studies with real-world applications of lower-carbon concrete strategies, providing insights into practical implementation, challenges, and detailed testing and performance data and outcomes.
- **SE2050 Case Studies** (https://se2050.org/resources-overview/case-studies/): A collection of built projects and studies focused on embodied carbon reductions in structural systems. Case studies are sourced from the Structural Engineering Institute Sustainability Committee Circular Economy Work Group, from signatories to the SE2050 Challenge, and from external sources.
- **MEP2040** (https://www.mep2040.org/): To be published in 2025
- **HomebuildersCAN Case Studies** (https://rmi.org/homebuilderscan/resources/): A collection of real-world, residential case studies from homebuilders of all sizes with operations in North America.
- **Climate Positive Design Case Studies** (https://climatepositivedesign.org/education/case-studies/): A collection of landscape architecture project case studies that used the Climate Positive Design (CPD) Pathfinder tool to measure emissions. CPD also includes case studies in their annual reports: 2022 CPD Annual Report and 2023 CPD Annual Report.
- **CARE Tool Case Study:** (https://nextcity.org/urbanist-news/we-cant-build-our-way-to-net-zero)

CLF Hub Case Study Collections

The majority of case studies in this collection are sourced from members of CLF's network of Regional Hubs. Additionally, many of these Regional Hubs have collaborated to publish their own case studies, following their own templates, selection, and review processes.

- **CLF SF/Bay Area Hub:** (https://www.clf-sfbayarea.org/casestudies)
- **CLF Boston/Northeast Hub:** The Massachusetts Embodied Carbon Reduction Challenge (https://builtenvironmentplus.org/embodied-carbon-reduction-challenge-peoples-choice/) led by the Massachusetts Clean Energy Center (MassCEC) and Built Environment Plus (BE+) resulted in 16 project case studies, all of which performed a WBLCA and achieved embodied carbon reductions.
- **CLF British Columbia Hub:**
    - Project case studies (https://clfbritishcolumbia.com/resources/categories-case-studies-and-guides/)

  - BC Embodied Carbon Awards: https://clfbritishcolumbia.com/press-release-bc-embodied-carbon-awards-recognize-excellence-in-climate-friendly-building-design/
- **CLF Ontario Hub:** Embodied Carbon Awards (https://www.clftoronto.com/awards-2024)
- **CLF Seattle Hub:** Recorded case study webinars on YouTube (https://www.youtube.com/channel/UCZ3cIX3c-lih6K81oV7YVVg)

European Case Studies

- **LETI Embodied Carbon Case Studies** (https://www.leti.uk/case-studies)
- **Aalborg University Housing Construction from 4 to 1 Planet** (https://vbn.aau.dk/ws/portalfiles/portal/648080437/Housing_construction_from_4to1_planet_-_24_best_practice_cases.pdf): Collection of 24 Danish building case studies demonstrating best practices for reducing whole life carbon. The majority of case studies are single-family, terraced, or multi-storey housing.
- **Nordic Innovation's Best Practice Catalogue** (https://pub.norden.org/us2024-461/index.html): A collection of building LCA Cases from the Nordic countries and Estonia.

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Case Studies

KEY

Life Cycle Assessment (LCA) Data Collection

Projects that completed a cradle-to-grave whole building LCA using Tally, OneClick LCA, or Athena and covering at least the structure and enclosure

Projects that used environmental product declarations (EPDs) to demonstrate material-specific reductions against a baseline

Projects that used other analysis tools to achieve reductions in interiors, MEP systems, landscape, infrastructure, or single-family residential projects.

Embodied Carbon Reduction Strategies

Low Carbon Concrete

Material Efficiency (Structural Design)

Mass Timber

Non-structural Biobased Materials

Adaptive Reuse of a Building

Material Reuse/Salvaged Materials

Single Family Residential

Interior Fit-out: Reduction of materials, use of low-carbon finishes

Interior Fit-out: Reuse of interior materials

MEP Systems

1510 Webster

EMBODIED CARBON REDUCTION CATEGORY: MASS TIMBER

Image Credit: WoodWorks and DCI Engineers

Embodied Carbon Highlights

- First building in the world with a point-supported mass plywood panel structure (using mass-ply panel (MPP) floors and mass-ply laminate (MPL) columns)
- Reductions in concrete shear walls and foundations due to the lighter-weight MPP system
- Extensive structural material testing to eliminate beams and reduce column requirements
- The fireproofing requirements of the mass timber design did add significant amounts of gypsum board under the floors and around the columns, which offset some of the GWP savings
- Supplemental cementitious materials (SCMs), including fly ash in the foundation and columns and slag in all concrete elements

PROJECT INFORMATION

Project Name: 1510 Webster

Region: West Coast US

Location: Oakland, CA

Building Type: Residential: Multifamily

IBC Construction type: IV-A over type I-A podium

Gross Floor Area: 175,750 ft^2

Year of completion: 2025

PROJECT TEAM

Architect: oWOW Design

Structural Engineer: DCI Engineers

General Contractor: oWOW Construction

Owner: oWOW

Other Team Members:

Mass Timber Installer: Webcor Timber

Mass Timber Manufacturer: Freres Engineered Wood

Column Contractor: Rothoblaas

Overview and Project Goals

Located in the heart of downtown Oakland, CA, 1510 Webster is a 19-story mixed-use high-rise, 16 stories of which are mass timber. Designed using the tall wood code provisions in the 2021 International Building Code (IBC), the 187-foot-tall project consists of a residential tower with 222 one- & two-bedroom apartments sitting atop a concrete podium that contains retail, commercial spaces, a covered public plaza and one-below grade level for storage. 1510 Webster is the first Type IV-A building in the U.S., and the tallest mass timber building located in a high seismic region in the world.

Project developer oWOW's goal was to provide affordable housing for "the missing middle," defined as households earning between 80 and 120 percent of the area's median income (AMI). As a vertically integrated development, design, and construction firm, oWow's approach is unique. They set out to prove that mass timber is an effective option for budget-conscious developers looking to quickly create cost-effective housing, and they succeeded.

How Does this Project Reduce Embodied Carbon?

1510 Webster achieved reductions through a combination of using mass timber rather than a post-tensioned concrete system, increasing material efficiency through optimizing the structural design, and using lower carbon concrete mixes.

1510 Webster was designed using veneer-based mass timber products, including mass ply panels (MPP) and mass ply laminate (MPL) columns, in an innovative point-supported beam configuration. It is the first building in the world with a point-supported mass plywood panel structure. This contributed the largest embodied carbon reductions on the project. Compared to post-tensioned concrete slabs and concrete columns, the mass ply panels and laminate columns are less emissions-intensive to manufacture than concrete and are lighter weight, reducing the embodied carbon impact of the concrete shear walls and foundation system by allowing them to carry less load. The mass-ply panels were domestically sourced from Oregon, and the team was able to verify the product's A1-A3 emissions with a product-specific EPD provided by the manufacturer.

As the first prescriptive Type IV-A building in the U.S., the requirements for a 3-hour fire rating for this construction type meant they had to cover all the wood with three layers of gypsum wallboard. Unfortunately, this offset some of the embodied carbon savings. However, the team was comfortable with having to cover the wood because of the realized savings in speed of construction and cost from using mass timber. All 16 floors of mass timber were installed in less than three months and the structure topped out more than a full month ahead of schedule.

In addition to choosing a lower-carbon structural system, the design team focused on material efficiency, reducing embodied carbon through optimizing the structural design. The design team did extensive structural testing and was able to (1) eliminate the need for beams due to the panels' two-way spanning capabilities, and (2) eliminate the need for 47 columns on each of the building's 16 mass timber-framed floors by making strategic changes to the grid spacing.

Last, the mix designs provided by Cemex replaced a portion of the ordinary Portland cement with supplemental cementitious materials (SCMs), including fly ash in the foundation and columns and slag in all concrete elements.

What was the baseline and how was it established?

The baseline building was designed as a functionally equivalent concrete system consisting of 2-way post-tensioned concrete slabs and concrete columns. The residential post-tensioned concrete slabs were 7.5" thick with approximately 1.8 psf of mild reinforcement and 0.9 psf of post-tensioning tendons. To maintain the same floor-to-floor height as the building utilizing the mass timber system, the fully concrete podium levels grew 1 1/2" taller to accommodate the thicker floor slabs and the residential tower was 8" shorter due to the thinner floor assembly. The same enclosure system was used for both structural systems to avoid introducing too many variables into the analysis.

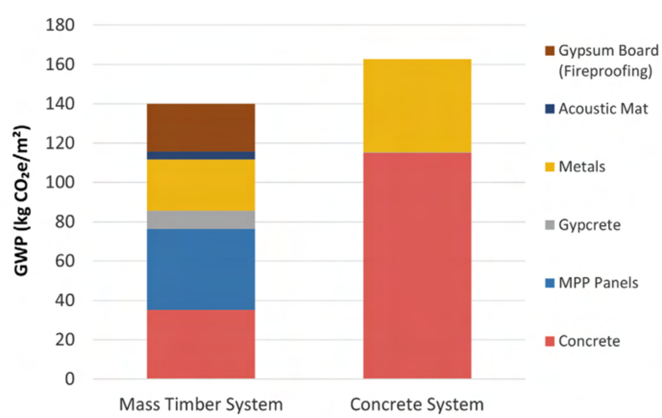

Figure 1. Early design analysis of the structural systems GWP comparison by material, above the podium only.
Source: DCI Engineers

Life Cycle Assessment (LCA) Approach

LCA Tool/Software Used: One Click LCA for LEED, US Tool

Life Cycle Stages Included:

- ■ **A1-A3**
- ■ **A4**
- ☐ A5
- ☐ B1
- ☐ B2-B3
- ■ **B4-B5**
- ☐ B6-B7
- ☐ C1
- ■ **C2-C4**
- ☐ D

LCA Scope:

- ■ **Substructure**
- ■ **Shell - Superstructure***
- ■ **Shell - Exterior Enclosure**
- ☐ Interiors - Construction
- ☐ Interiors - Finishes
- ☐ Sitework
- ☐ Services (MEP)
- ☐ Equipment & Furnishings

LCAs Completed During:

- ☐ Pre-design
- ☐ Schematic Design
- ☐ Design Development
- ☐ Construction Documentation
- ■ **Construction**
- ☐ Completed/Post-Occupancy

*Fire-rated gypsum board used for encapsulation was included in the WBLCA.

Additional LCA Information

In the results of this LCA, life cycle stage A4 transportation distances were approximated by One Click LCA using industry averages for each material type. The team conducted a secondary study on the impact of changing the A4 distances of the highest contributing materials: MPP and ready-mix concrete. Measuring the distances between the known sourcing locations and the project site, they updated the values from 130 miles to 15 miles for concrete and 360 miles to 600 miles for MPP. One Click LCA does not include life cycle stage A5, construction installation, in the LCA for the LEED, US tool. However, the team conducted a separate analysis using the One Click LCA's Life Cycle Carbon Tool. In that tool, the assumed wastage percentages for the highest contributing materials, ready-mix concrete, and MPP, are 4% and 16.7%, respectively. When discussing this internally, our team and Woodworks agreed that based on professional experience, 16.7% wastage for MPP was excessive, and in reality, these elements are coordinated to an extent where material waste is nearly non-existent. The reported values are therefore likely an overestimate, as reduced wastage for MPP would provide material and carbon savings on the project but was not included as part of the reported savings.

The team also reported biogenic carbon stored for the lifetime of the building, as is reported separately below. The team utilized the default end-of-life scenarios assumed by One Click LCA, except for the mass ply panels, which would have been assumed to be incinerated (based on more common practices in Europe). Instead, the team assumed 'reuse as material' for the mass ply panels. See the section on Biogenic Carbon in LCA linked below for more explanation.

Embodied Carbon Reduction from the Baseline

Results are displayed as the global warming potential (GWP) per unit of floor area in kg CO_2e/m^2 (embodied carbon intensity or ECI) based on outputs from **One Click LCA** for LEED, US Tool. The gross floor area was supplied by the project team.

Baseline GWP	Proposed Design GWP	Estimated Embodied Carbon Savings	Biogenic Carbon Storage*
279 kgCO_2e/m^2 (excl. b.c storage)	**265 kgCO_2e/m^2** (excl. b.c. storage)	**5%** (14 kgCO_2e/m^2)	**122 kgCO_2e/m^2**

*This value is the "Biogenic carbon storage" inventory metric calculated by Woodworks, and represents stored carbon in a unit of material rather than biogenic carbon flows.

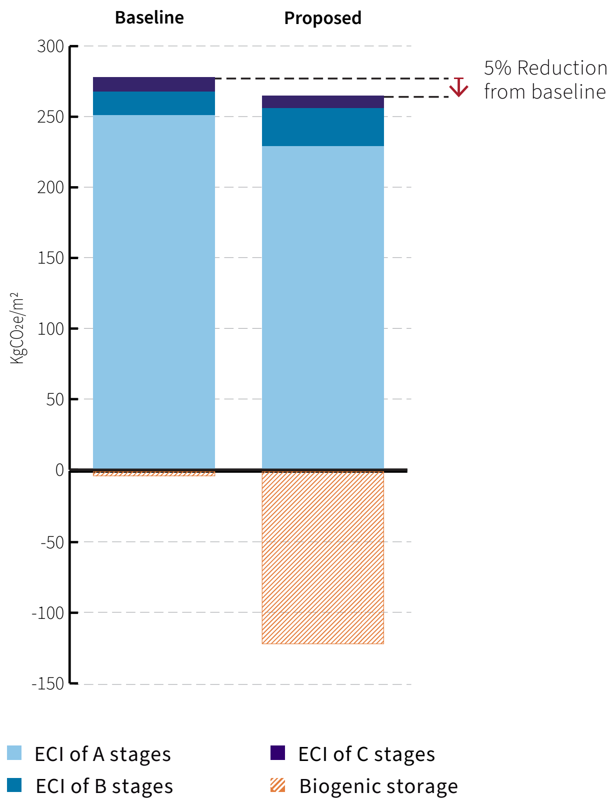

Figure 2. Embodied carbon intensity comparison of baseline and proposed design

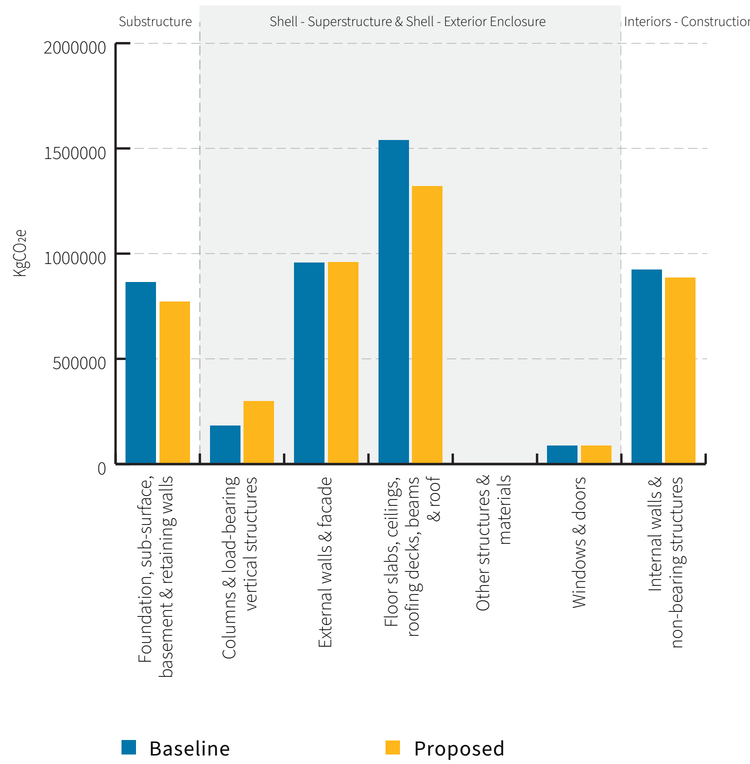

Figure 3. Total embodied carbon comparison of baseline and proposed design, by building element group

Highlights and Lessons Learned

Mass-ply panel (MPP) system: The structural engineering team found the MPP system to be a great equivalent design solution compared to a typical flat plate concrete system. It simplified the design by requiring only one connection type throughout the building, and the mechanical penetrations were much simpler to coordinate.

Speed of Construction: Webcore, the mass timber installer on the project, self-performed both concrete and timber and had the same crews installing both on the project, which resulted in efficiency and large schedule savings. Over a three-month period, Webcor's mass timber installation speed improved substantially. For example, installation of the mass timber system for levels 4 through 8 took four days each; levels 9 through 17 took three days; and the top two levels required just two days to complete. Ultimately, the project finished an extraordinary four weeks ahead of schedule.

Cost Savings: oWow, the integrated owner, designer, and contractor of the project, states in the WoodWorks case study, "Mass Timber: The Optimal Solution for Multi-Family High Rise Construction," that the use of mass timber realized a $30 million savings in net project cost over that of a traditional concrete project of this scale. The excellent strength-to-weight ratio of mass timber helped reduce the weight of the building, reduced foundation requirements, and made the lateral system more efficient to the extent that they were able to eliminate one of the building's concrete cores, saving more than $2 million. The mass timber system costs approximately $20 per square foot less than the structural concrete system in the Oakland, CA region, and including installation, the cost for 1510 Webster was about $400 per square foot.

The sustainability and embodied carbon reduction benefits of mass timber were important to the architect and developer from day one, but the cost savings allowed them to reach the overall project goal of creating affordable housing for households earning 80% of the Area Median Income.

Case Study Contributors

Arizona Dabrusin, DCI Engineers

Additional Project Information

oWow project webpage

DCI Engineers project webpage, including construction video

WoodWorks Case Study

CLF Seattle Hub Case Study Video

Image Credit: WoodWorks and DCI Engineers

Holgate Library for Multnomah County

EMBODIED CARBON REDUCTION CATEGORY: MASS TIMBER AND MATERIAL REUSE/SALVAGED MATERIALS


Image Credit: (c) Lara Swimmer 2024 ALL RIGHTS RESERVED

Overview and Project Goals

Holgate Library for Multnomah County Library in Southeast Portland is one of the largest and most energy-efficient libraries in the county, tripling the size of the original 1971 building to provide services for one of the city's most diverse communities. Boasting a mass timber structure, the library is designed to foster a culture of civic pride, offering healthy and inspiring spaces with ample connections to nature to provide patrons of all ages and backgrounds with an uplifting and welcoming library experience.

Taking inspiration from the fluttering wings of the butterfly—a universal symbol of resilience, hope, beauty and transformation—the building is wrapped in custom chevron-patterned metal cladding, creating a calming yet dynamic rhythmic play of light and shadow. Utilizing a Design Justice lens, Bora Architecture held extensive community engagement sessions to ensure the building would authentically represent its patrons. This resulted in flexible programming and spaces including a large play and learning area for families, a dedicated teen room, and an outdoor plaza for gathering. Holgate Library's interior design, exterior color and patterns were publicly voted on by the community. The designs by local artists enlivening the lobby and exterior were also guided by extensive community input. At every turn, the design reflects its patrons' aspirations to make the new library an inclusive celebration of people and place.

PROJECT INFORMATION

Project Name: Holgate Library for Multnomah County

Region: West Coast US

Location: Portland, OR

Building Type: Other: Library

IBC Construction type: Type V-B

Gross Floor Area: 21,000 ft²

Year of completion: 2024

PROJECT TEAM

Architect: Bora Architecture & Interiors

Structural Engineer: Equilibrium Engineers

General Contractor: Swinerton

Owner: Multnomah County Libraries

Other Team Members:

Mass timber preconstruction, digital construction, fabrication, and installation services: Timberlab

CLT and Glulam Supplier: Kalesnikoff

Embodied Carbon Highlights

- **Mass timber hybrid structure**
- **Existing structural members and the existing MEP system were salvaged for reuse.**
- **Low carbon interior finishes**

How Does this Project Reduce Embodied Carbon?

The Holgate Library structure is a hybrid mass timber structure that balances material efficiency and programmatic needs to optimize for embodied carbon. The ground floor, which is divided into several rooms, utilizes a denser column layout to accommodate the heavy library floor loads from the book stacks. The second floor features a more open design with increased column grid spacing and fewer columns, as the lighter roof loads allow for longer spans. The solution strategically combined mass timber for its gravity load-carrying capacity with steel-braced frames to resist lateral forces.

This innovative structure utilizes the following:

- Cross-Laminated Timber (CLT) decks serve as the primary floor and roof decking, efficiently distributing gravity loads and acting as horizontal diaphragms.
- Glue-Laminated Timber (GLT or glulam) beams and girders provide the primary structural support for the building.
- Buckling-Restrained Braces: These diagonal steel elements provide lateral stability, ensuring the building can withstand seismic forces and wind.

The primary timber species used throughout the project is Douglas-fir, known for its strength, durability, and regional availability in the Pacific Northwest. Embodied carbon was also a consideration when selecting materials beyond the structure. The floor finishes – particularly the carpet tiles – are lower carbon than average. In addition, the project team worked to salvage materials where possible to further reduce embodied carbon by preventing manufacturing of new materials. The existing MEP system was salvaged to be reused at a different site, and existing structural members were salvaged to create casework for the new project.

What was the baseline and how was it established?

The baseline model was a functionally equivalent building using a steel structural system.

Besides structural materials and associated finishes, the proposed design model includes a lower window-to-wall ratio than the baseline (while maintaining good daylighting), and floor finishes with lower embodied carbon, particularly the carpet tiles.

Life Cycle Assessment (LCA) Approach

LCA Tool/Software Used: Tally

Life Cycle Stages Included:

- ■ **A1-A3**
- ■ **A4**
- ☐ A5
- ☐ B1
- ☐ B2-B3
- ■ **B4-B5**
- ☐ B6-B7
- ☐ C1
- ■ **C2-C4**
- ☐ D

LCA Scope:

- ■ **Substructure**
- ■ **Shell - Superstructure**
- ■ **Shell - Exterior Enclosure**
- ■ **Interiors - Construction**
- ■ **Interiors - Finishes**
- ☐ Sitework
- ☐ Services (MEP)
- ☐ Equipment & Furnishings

LCAs Completed During:

- ☐ Pre-design
- ■ **Schematic Design**
- ■ **Design Development**
- ☐ Construction Documentation
- ☐ Construction
- ■ **Completed/Post-Occupancy**

Embodied Carbon Reduction from the Baseline

Results are displayed as the global warming potential (GWP) per unit of floor area in kg CO_2e/m^2 (embodied carbon intensity or ECI) based on outputs from **Tally**. The gross floor area was supplied by the project team.

Baseline GWP	Proposed Design GWP	Estimated Embodied Carbon Savings
562 kgCO₂e/m² (excl. b.c. flows) 524 kgCO₂e/m² (incl. b.c. flows)*	**299 kgCO₂e/m²** (excl. b.c. flows) 195 kgCO₂e/m² (incl. b.c. flows)*	**47%** (excl. b.c. flows) 63% (incl. b.c. flows)*

*These values are based on including "biogenic carbon (b.c.)" in Tally, which triggers the tool to include the flows of biogenic carbon, or the "carbon absorbed and generated by biological sources (e.g. trees, algae) rather than from fossil resources."

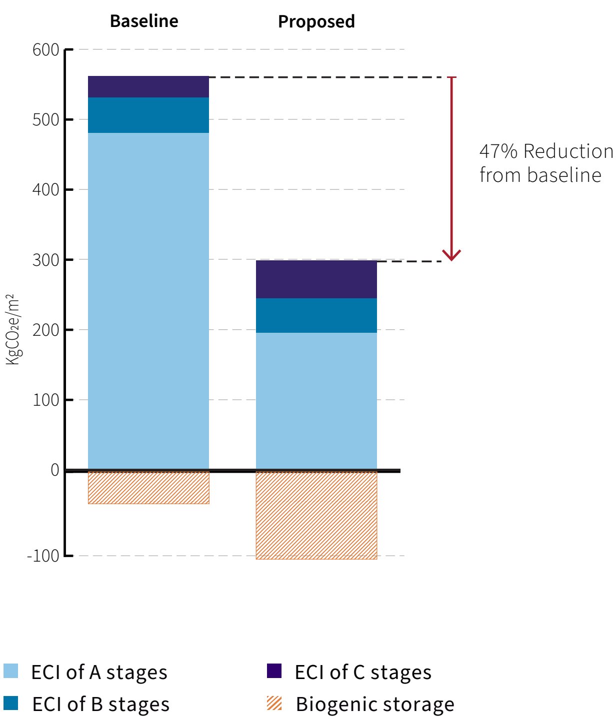

Figure 1. Embodied carbon intensity comparison of baseline and proposed design

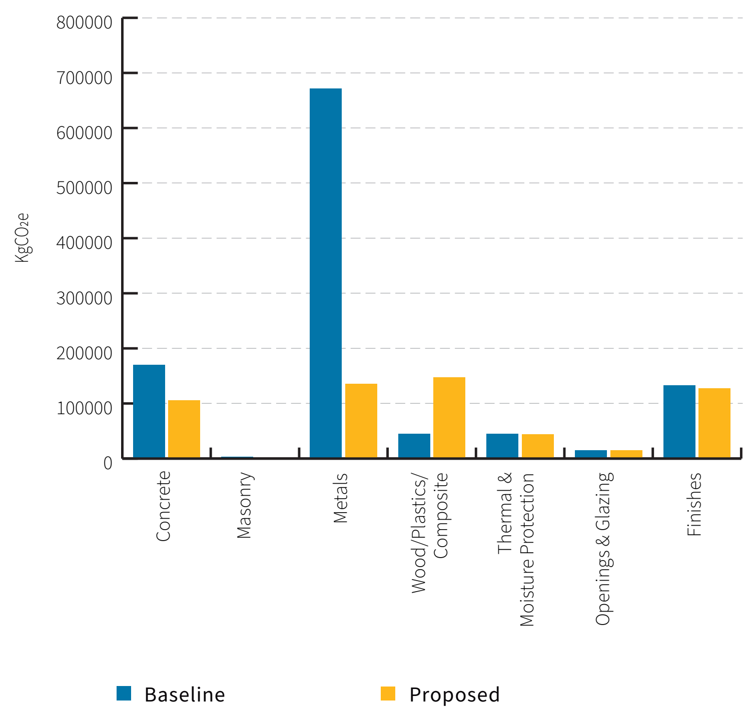

Figure 2. Total embodied carbon comparison of baseline and proposed design, by CSI Division (Tally material categories)

Project Outcomes & Lessons Learned

The embodied carbon analysis of Holgate Library highlights the importance of selecting low-carbon materials for big ticket items – like structural systems – but also for products and systems that appear many times over in the projects (e.g. window systems and floor finishes).

LCA is starting to become an integral part of Bora Architecture and Interiors' practice, from early on in design to inform each project's big moves and overall form, but also for validating projects against benchmarks later on in the project. The firm has explored different tools for increasing the efficiency of LCA, especially during early design phases when aspects of the project change quickly and there is less time for in-depth analysis.

Bora has found that when using LCA to assess design decisions, it is important to consider the cascading effects of any particular decision holistically across the building. For example, when choosing structural systems, evaluation of the building as a whole – rather than just the structural materials themselves – allows for evaluating related impacts, such as any increased interior finishes required to cover up structural members that are not aesthetically pleasing.

The project is also a success story in how early design decisions allowed the project team to 'bake' sustainability into the design, preventing the benefits from being lost to value engineering later on in design and construction. For example, the massing and orientation, with opaque programs laid out towards the east and west of the building, contributed to daylighting and operational energy performance. All of these were achieved in conjunction with robust community engagement processes that supported aligned project goals with the community.

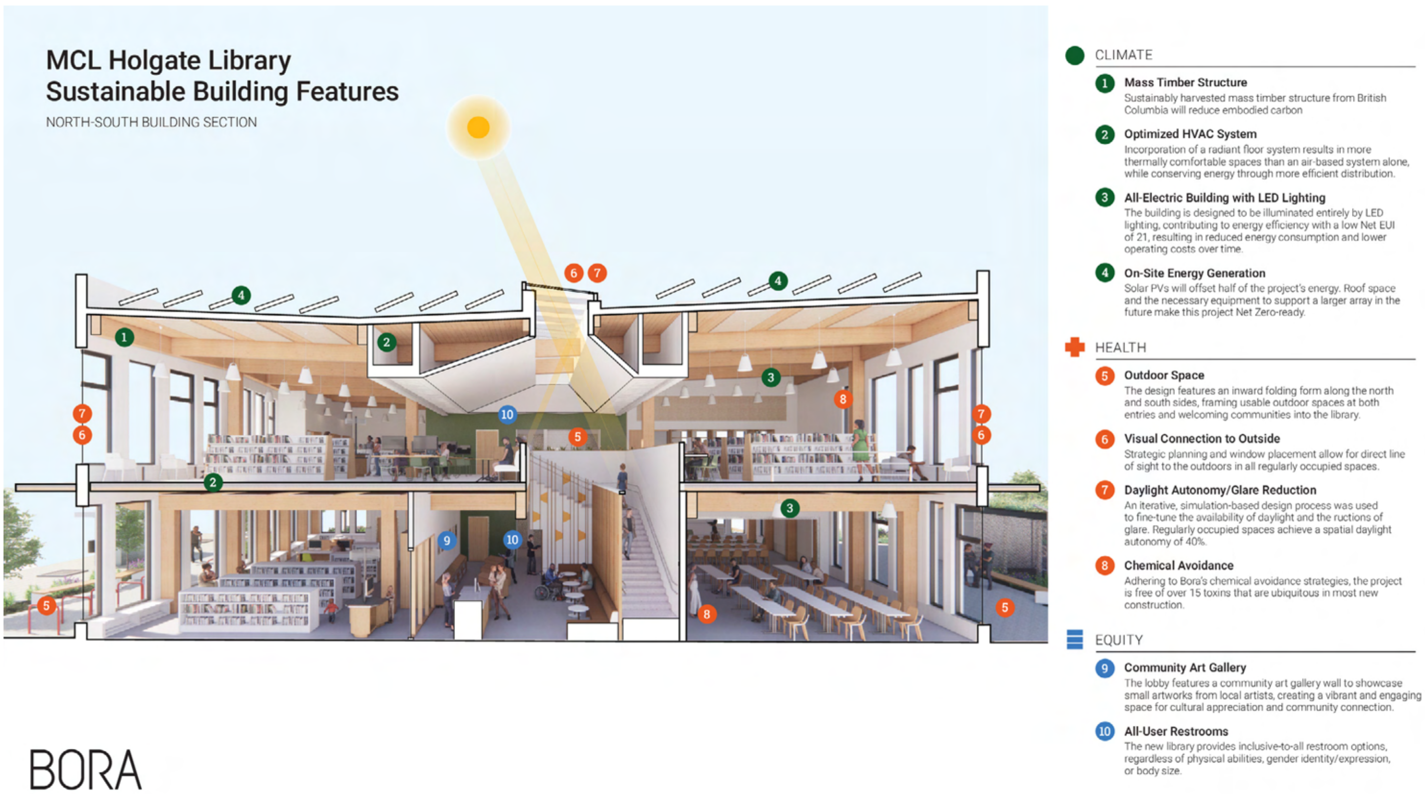

Image Credit: (c) Bora Architecture and Interiors 2022 ALL RIGHTS RESERVED

Certifications & Achievements

IIDA Oregon Design Excellence Awards, 2024, Best in Category (Public & Civic)

Case Study Contributors:

Thuy Le, Bora Architecture & Interiors

Niusha Manavi, Bora Architecture & Interiors

Additional Resources for More Information on this Project

Bora Architecture & Interiors project webpage - [Holgate Library]

Mass Timber LinkedIn Group - [Exploring A Community-Driven Mass Timber Design with Sustainability and Innovation: The Holgate Library]

The Ontario Secondary School Teachers' Federation Headquarters (OSSTF HQ)

EMBODIED CARBON REDUCTION CATEGORY: MASS TIMBER

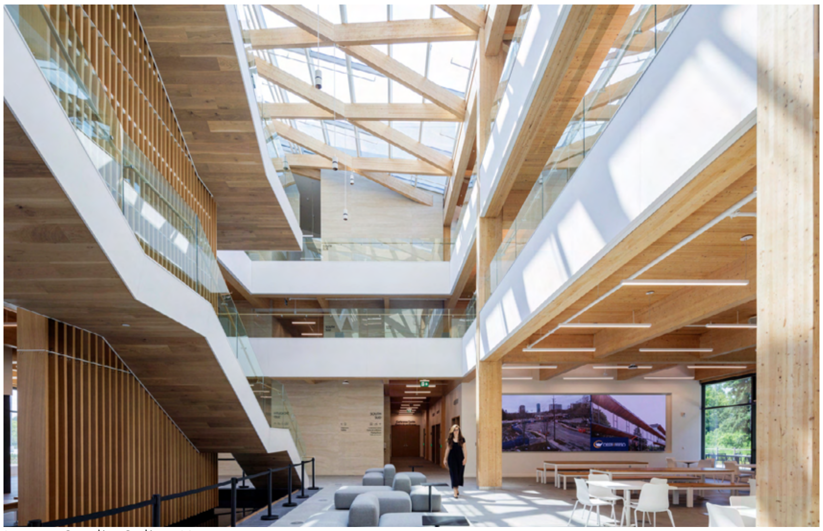
Image Credit: Salina Kassam


Image Credit: Tom Arban

Embodied Carbon Highlights

- The mass timber structural system was chosen by the client from the outset.
- Many structural design iterations ultimately informed the most material-efficient option.
- Early selection and procurement of the mass timber allowed for a more material and cost efficient system through integrating design assist feedback from the supplier on key connection details.

PROJECT INFORMATION

Project Name: The Ontario Secondary School Teachers' Federation (OSSTF) Headquarters

Region: Southern Ontario, Canada

Location: Toronto, Ontario

Building Type: Office

OBC Ontario Building Code: Allowable combustible construction

Gross Floor Area: 127,000 ft²

Year of completion: 2024

PROJECT TEAM

Architect: Moriyama Teshima Architects

Interior Design: Kasian Architecture (office), Moriyama Teshima Architects (non-office, lobby)

Structural Engineer: Fast + Epp

Construction Manager: Eastern Construction Company (BTY Group)

Owner: Ontario Secondary School Teachers' Federation (OSSTF)

Client Representative: BTY Project Managers

Other Team Members:

Mechanical Engineer, Electrical, LEED, IT, AV, Security, Comms, Lighting: Introba

Building Science Consultant: Morrison Hershfield

Environmental Consultant: Transsolar KlimaEngineering

Civil Engineer: Matrix Solutions

Fire: CHM Fire Consultants

Wayfinding: Strange Colour

Landscape Architect: FORREC

Mass Timber Supplier: Nordic Structures

Overview and Project Goals

The Ontario Secondary School Teachers' Federation Headquarters (OSSTF HQ) is a progressive 124,000 square-foot, three-story office building and new home of the Ontario Teachers' Union. The building has a below-grade level for parking, office space and mechanical equipment. From the outset, the project decided on a mass timber structural system with the goal of reducing the project's embodied carbon.

In addition to reducing embodied carbon through an optimized, material efficient mass timber structural system, the project significantly reduced its operational energy through a geothermal heat pump and a passive natural ventilation system used together with a decoupled active mechanical system, a raised floor system with a fully integrated underfloor air distribution (UFAD) displacement ventilation system, and energy generation from the rooftop photovoltaic array.

The client's goals included both environmental and financial sustainability, so the operational budget savings were critical and all project decisions were evaluated for their fiscal and sustainability impact. Ultimately, a successful balance was achieved, with a project focus on user comfort and operational simplicity as well as low embodied carbon.

How Does this Project Reduce Embodied Carbon?

The major embodied carbon reductions were from the mass timber structural system, which was designed to be as efficient as possible to reduce material use and ensure capital costs were controlled. The primary structural system consisted of cross-laminated timber (CLT) floor plates, with 2-inch topping slabs and glulam posts-and-beams and cross-bracing. In the below-grade parking garage, the nine structural bays of the timber system meet the piers of the building's concrete foundation, and steel is used for the building core and stairwells.

The project's structural engineer developed 15 different structural options for the bay, with the goal of reducing material volume and cost. The final iteration resulted in a thinner three-ply CLT for the floor plates, saving on cost and material compared to the standard five-ply CLT. The mass timber structure of the building uses a 9m x 9m grid of glulam columns, beams, and purlins with a cross-laminated timber (CLT) infill panel for the general floor system. This 9m x 9m grid was chosen by the team to optimize the volume of timber used while also providing optimal spacing for office layouts. In combination with the raised floor system, the design aims to provide flexibility for tenants and future changes without requiring additional embodied carbon for renovations.

The contractor was engaged with the team early, allowing the timber to be procured early. This created an opportunity for the final detailing to incorporate design assist services feedback from the supplier, Nordic Structures in Quebec, which ultimately resulted in a more material-efficient and cost-effective design.

Using the CLT exterior wall panels in place of steel created a continuous surface for the construction team to work with, which simplified installation and drove down costs. The contractor spent more time upfront coordinating the mass timber penetration locations, but then spent less time in the field during construction.

The use of mass timber also allowed for a reduction in the interior finishes and drywall, as the client wanted to expose as much of the wood as possible and enhance the building occupants' experiences by creating a biophilic space.

What was the benchmark and how was it established?

This project did not create a modeled baseline building but instead compared the results of their LCA to the [Toronto Green Standard (TGS)] V4 building benchmark, GHG 2.1 Low Embodied Emissions Materials. Embodied carbon was added as one of the performance measures within the TGS Version 4 update that took effect in 2022. The city established embodied carbon caps based on the results of two benchmarking studies that looked at the embodied carbon associated with the construction of Part 3 (> 600 m²) and Part 9 (< 600 m²) buildings across the Greater Toronto and Hamilton Area.

The TGS v4 benchmarks are based on a "cradle-to-substantial completion" LCA (life cycle stages A1-A5) that includes "permanently installed envelope and structural elements, including footings and foundations, complete structural wall assemblies (from cladding to interior finishes, including basement), structural floors and ceilings (not including finishes), roof assemblies, stairs, and parking structures" (City of Toronto Planning & Development).

As of 2025, only city-funded projects are required to meet the TGS V4 embodied carbon caps. However, residential and commercial projects applying for the voluntary Tiers 2 and 3 requirements must meet the following targets:

- **Tier 2- Low Embodied Emissions Materials:** Residential and commercial projects must demonstrate an embodied emissions intensity of less than 350kg CO_2e/m^2 for the lifecycle stages (A1-A5)

- **Tier 3- Extra Low Embodied Emissions Materials:** Residential and commercial projects must demonstrate an embodied emissions intensity of less than 250kg CO_2/m^2 for the lifecycle stages (A1-A5)

Life Cycle Assessment (LCA) Approach

LCA Tool/Software Used: One Click LCA

Life Cycle Stages Included:

- ■ **A1-A3**
- ■ **A4**
- ■ **A5**
- □ B1
- □ B2-B3
- □ B4-B5
- □ B6-B7
- □ C1
- □ C2-C4
- □ D

LCA Scope:

- ■ **Substructure**
- ■ **Shell - Superstructure**
- ■ **Shell - Exterior Enclosure**
- ◩ **Interiors - Construction**
- ◩ **Interiors - Finishes**
- □ Sitework
- □ Services (MEP)
- □ Equipment & Furnishings

LCAs Completed During:

- □ Pre-design
- □ Schematic Design
- □ Design Development
- □ Construction Documentation
- □ Construction
- ■ **Completed/Post-Occupancy**

Note: The half-shaded boxes indicate matching the scope of the project's benchmark reference which includes partial scope for interiors.

Additional LCA Information

The scope of the LCA aligns with the life cycle stages and scope of materials required in the Toronto Green Standard building benchmark (see description above).

The project includes a unique raised floor underfloor air distribution displacement ventilation system, which is part of the MEP system (as well as the flooring system) and not included in the LCA scope.

Embodied Carbon Reduction from the Baseline

Results are displayed as the global warming potential (GWP) per unit of floor area in kg CO_2e/m^2 (embodied carbon intensity or ECI) based on outputs from **OneClick LCA** (Life Cycle Carbon) tool. The gross floor area was supplied by the project team.

Benchmark GWP (A1-A5) (Toronto Green Standard Mandatory Limit)**	Proposed Design GWP (A1-A5)	Estimated Embodied Carbon Savings	Biogenic Carbon Storage*
350 $kgCO_2e/m^2$ (excl. b.c storage)	**205 $kgCO_2e/m^2$** (excl. b.c. storage)	**41%** (excl. b.c.storage)	**139 $kgCO_2e/m^2$**

*This value is the "Biogenic carbon storage kg CO_2e bio" inventory metric calculated by OneClick LCA (Life Cycle Carbon) tool, and represents stored carbon in a unit of material rather than biogenic carbon flows.
**This limit reflects the requirement of the Toronto Green Standard's mandatory GWP limit on the A1-A5 embodied carbon impacts of residential and commercial buildings.

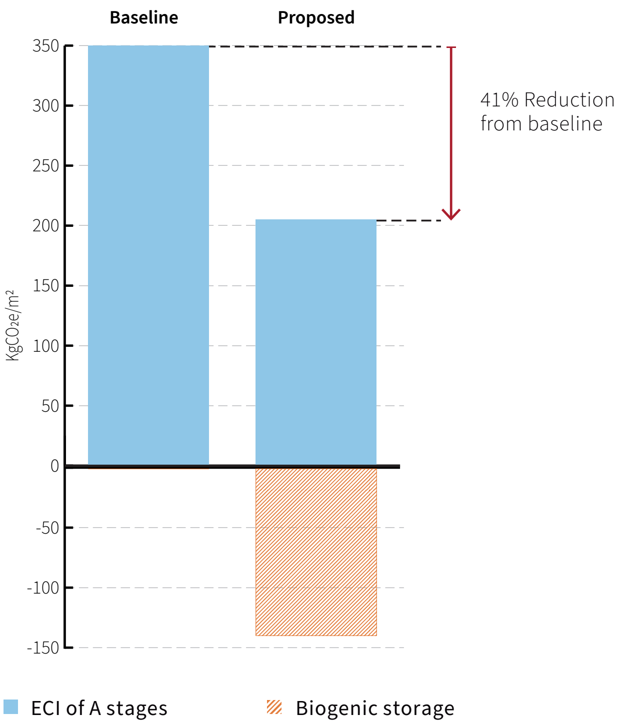

Figure 1. Embodied carbon intensity comparison of baseline and proposed design

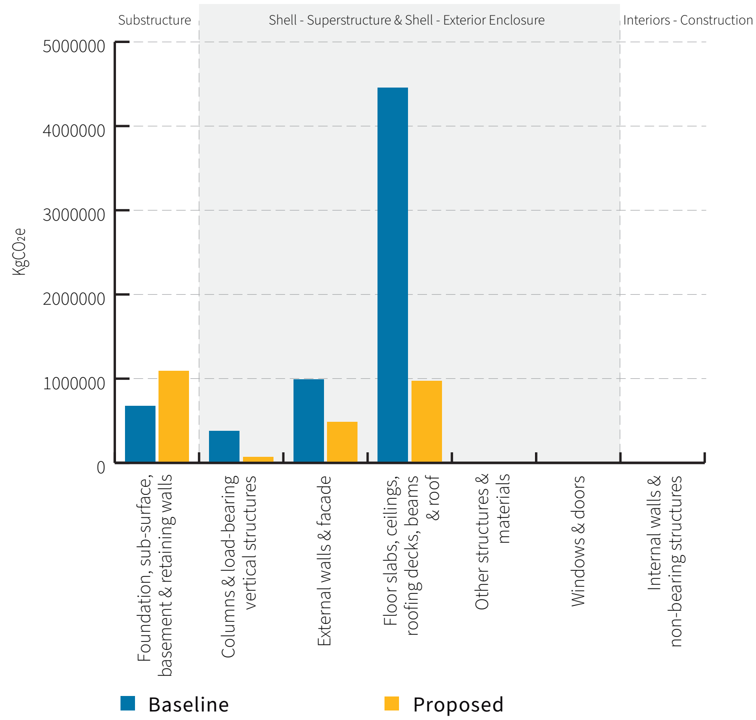

Figure 2. Total embodied carbon comparison of baseline and proposed design, by building element group

Highlights and Lessons Learned

The design team LCA was completed after construction was complete and they used the shop drawings to confirm that the material quantities and selection data were accurate. The findings demonstrated that the concrete and steel rebar were the major embodied carbon contributors to the final project.

In a separate earlier effort, during design, the project was the subject of a University of Toronto graduate studio research project called Half Studio, under the direction of principal researcher and educator Kelly Doran. Using design drawings, the students examined the embodied carbon of a number of mass timber buildings across Canada and Europe. Their analysis of one bay of the OSSTF revealed that while the overall carbon reductions of this building were significant, the construction of the shading device with a steel substructure was a large contributor to the project's total embodied carbon. Steel and aluminum louvers and shading devices are often excluded from embodied carbon analyses: their finding demonstrates that the inclusion of these elements is key to understanding the total (operational + embodied) carbon of the project.

Exterior shading devices like the awnings used on this project are a key passive design strategy for reducing mechanical equipment cooling loads and sizing. Though the team and the client were heavily invested in achieving a balance between reducing operational energy and embodied carbon, because mechanical systems are not typically included in LCA yet, it's difficult to quantify the whole carbon impact of these strategies. Ultimately, we need to better understand the relationship between operational and embodied carbon. Analysis like this project can help us understand where tradeoffs do occur to inform future projects where embodied carbon reductions could help balance the addition of high-carbon project elements required for optimizing operational carbon.

Image Credit: Tom Arban

Certifications and Achievements

Designed to achieve LEED BD+C Platinum certification

Case Study Contributors:

Cathy McMahon, Moriyama Teshima Architects

Laura Wang, Moriyama Teshima Architects

Katie Weber, Moriyama Teshima Architects

Additional Project Information

Architectural Record article, 2024

Moriyama Teshima Architects Sustainability Case Study, 2024

Better Builder Magazine: https://www.slideshare.net/slideshow/better-builder-magazine-issue-25-spring-2023/257397507 (2023)

Toronto Life Magazine: https://torontolife.com/city/sustainable-architecture-building-our-future-city/ (2022)

Transsolar Project: Ontario Secondary School Teachers' Federation

Pepper Construction Cincinnati Office

EMBODIED CARBON REDUCTION CATEGORY: ADAPTIVE REUSE

Image Credit: James Winters

Embodied Carbon Highlights

- **Adaptive reuse and historic preservation of the original building (after 20 years of vacancy)**
- **Restoration of over 25% of the flat brick and 100% of the detailed brickwork**
- **Restoration of 50% of the original windows by a local business**
- **Two historic vault doors were maintained**

PROJECT INFORMATION

Project Name: Pepper Construction Cincinnati Office

Region: Midwest US

Location: Cincinnati, OH

Building Type: Office

IBC Construction type: 5-B

Gross Floor Area: 23,313 ft²

Year of completion: 2023

PROJECT TEAM

Architect: emersion DESIGN

Structural Engineer: JCA Engineering

General Contractor: Pepper Construction

Owner: Pepper Construction

Other Team Members:

MEP Engineers: CMTA

Civil Engineers: The Kleingers Group

Historic Consultant: Beth Sullebarger, Sullebarger Associates

Commissioning: ZHCx

Solar: Pepper Energy

Overview and Project Goals

In 2021, Pepper Construction purchased the former Stearns & Foster building in Lockland, Ohio, just outside of Cincinnati. Built in 1912, the team approached the adaptive reuse of the building with a vision of turning it into a contemporary workspace for their company. The project included a full exterior restoration with the addition of a vestibule to create a 23,000-square-foot interior buildout. Historical elements were restored throughout the space, including exposed brick, wood floors, original windows and plaster finishes.

Their goal was to create a space that fosters collaboration, represents their values and brand, and positions them to become a contributing member to the revitalization of the Lockland community. The 110-year-old historical building sat vacant for 20 years, so their first challenge was restoring the building while following the historic restoration guidelines. This included rebuilding the rotted wood structure, restoring the interior and exterior brick, installing new wood floors to match the original construction, refurbishing the original windows, and completing extensive plaster work on the walls and soffited ceilings.

Pepper Construction is committed to building healthier, cleaner and smarter, and being their own client allowed them to fulfill that commitment. In addition to the embodied carbon reduction strategies, the project utilized several strategies to reduce operational energy, including the installation of 16 geothermal wells that feed a radiant floor heating system, an all-electric high-efficiency mechanical system, and a solar array on the rooftop and parking lot canopies that generates the entire energy demand of the building.

The project achieved LEED Net Zero Energy Certification, making it one of the oldest buildings in the country to do so. The building is also LEED Gold certified and is currently pursuing WELL Silver certification.

How Does this Project Reduce Embodied Carbon?

Pepper Construction's choice to revitalize the former 110-year-old Stearns and Foster office building rather than building new significantly reduced the embodied carbon of their new office. Transforming a historic landmark into a high-performing work environment for a growing team reflects Pepper's company culture. Little additional material was added to the building envelope: among the restored historical elements are 100% of the detailed brickwork, over 25% of the flat brick, and 50% of the original windows. Two historic vault doors were also restored.

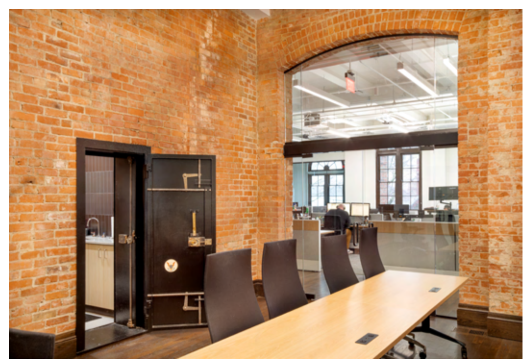

Image Credit: John Evans

Pepper, emersion DESIGN and CMTA collaborated on approximately nine exterior envelope repair strategies. Through this life cycle and risk analysis the project optimized the envelope repairs and upgrades to minimize the building's EUI footprint, meet long term quality performance requirements, and align with the historic preservation requirements. Through this rigorous process, the exterior wall plaster was repaired and enhanced to act as the building's air barrier - without adding additional insulation to the existing exterior wall assemblies. The existing roof had deteriorated and was in need of replacement, providing them an opportunity to maximize the roof insulation to improve the building's energy performance and decrease its energy use intensity.

Emersion collaborated with Pepper to provide a database for materials selection, allowing for easily identifying Red List Free finish materials as well as products with EPDs. This approach allowed for competitive pricing for multiple manufacturers per product selection while striving to push the industry limits on material tracking. The result was 35 products with EPDs and 21 with LEED's 'Material Ingredient Reporting' included in the project.

What was the baseline and how was it established?

The baseline for this project modeled the structure and enclosure as if it were new construction. The team was interested in understanding the comparison to the resources needed to build a similar building with all new materials.

Life Cycle Assessment (LCA) Approach

LCA Tool/Software Used: One Click LCA

Life Cycle Stages Included:	LCA Scope:	LCAs Completed During:
■ **A1-A3**	☐ Substructure	☐ Pre-design
■ **A4**	■ **Shell - Superstructure**	☐ Schematic Design
☐ A5	■ **Shell - Exterior Enclosure**	☐ Design Development
☐ B1	☐ Interiors - Construction	☐ Construction Documentation
☐ B2-B3	☐ Interiors - Finishes	■ **Construction**
■ **B4-B5**	☐ Sitework	■ **Completed/Post-Occupancy**
☐ B6-B7	☐ Services (MEP)	
☐ C1	☐ Equipment & Furnishings	
■ **C2-C4**		
☐ D		

Embodied Carbon Reduction from the Baseline

Results are displayed as the global warming potential (GWP) per unit of floor area in kg CO_2e/m^2 (embodied carbon intensity or ECI) based on outputs from **One Click LCA**. The gross floor area was supplied by the project team.

Benchmark GWP	Proposed Design GWP	Estimated Embodied Carbon Savings	Biogenic Carbon Storage*
270 kgCO_2e/m^2 (excl. b.c storage)	**98 kgCO_2e/m^2** (excl. b.c. storage)	**64%** (excl. b.c.storage)	*Not reported*

*We chose not to report "Biogenic carbon storage kg CO2e bio" inventory metric calculated by OneClick LCA (Life Cycle Carbon) tool, due to methodological uncertainties about how to report biogenic carbon of reused wood.

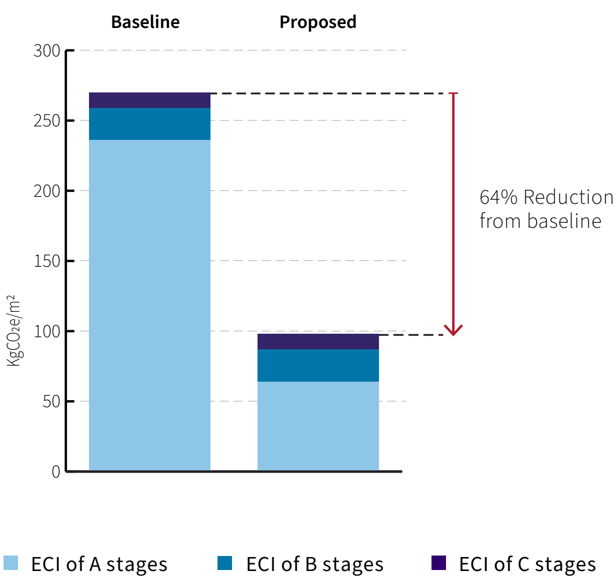

Figure 1. Embodied carbon intensity comparison of baseline and proposed design

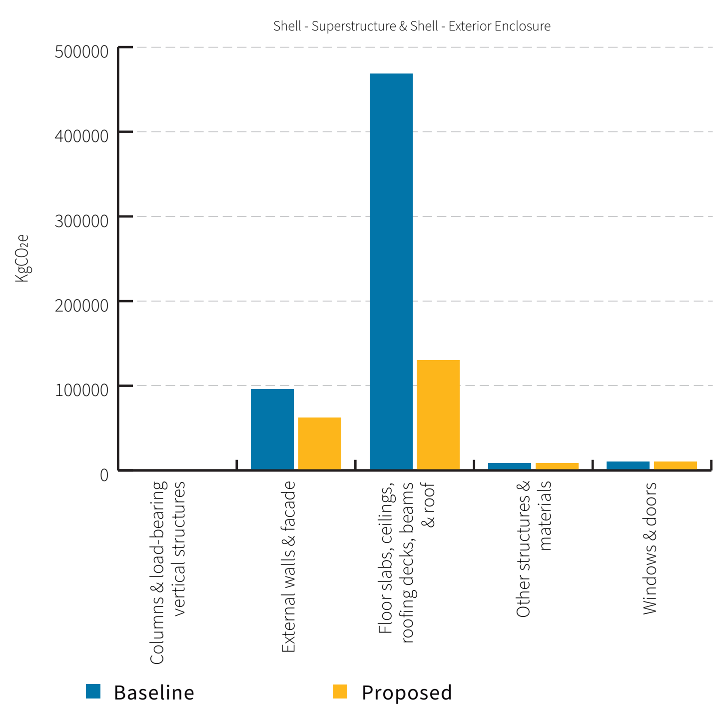

Figure 2. Total embodied carbon comparison of baseline and proposed design, by building element group

Highlights and Lessons Learned

The team found that the project was an incredible opportunity to use available LCA modeling software to compare adaptive reuse and new construction scenarios. This allowed the team to create real-time data to help vet and evaluate the LCA tool, as well as the overall impact of capitalizing on reuse of as much of the existing building as feasible.

In addition to supporting analysis of this project, the experience helped the team identify current gaps within the industry. They found many building materials where there is an opportunity to continue to grow our knowledge of tracking impact opportunities within A1 to A3 life-cycle stages. Through this analysis, they saw a huge opportunity for MEP products and manufacturers to catch up with the more traditional building materials, in terms of tracking and reporting embodied carbon. This project also helped put a spotlight on the massive benefits of adaptive reuse by reusing materials and diverting from landfills.

Pepper Construction has been incorporating LCA into projects that are pursuing building certifications to develop a database of projects across markets and structure types. As their project database continues to grow, they are excited to see trends emerge.

Certifications & Achievements

One of the oldest buildings in the country to achieve LEED Net Zero Energy Certification- https://www.pepperconstruction.com/blog/pepper-constructions-cincinnati-office-achieves-leed-zero-energy-certification

LEED BD+C v4 Gold Certification

2024 USGBC Iconic Building Award

ENR Midwest Best Projects 2023, Excellence in Sustainability Award

Case Study Contributors:

Natalia Alvarez, Pepper Construction

Juanita Garcia, Pepper Construction

Wyatt Ross, CMTA

Kyle Waymeyer, CMTA

Brett Macht, emersion DESIGN

Additional Project Information

Pepper's New Cincinnati Office

Pepper's New Cincinnati Office Construction Journey - Blog

Prologis Nexus

EMBODIED CARBON REDUCTION CATEGORY: MATERIAL REUSE/SALVAGED MATERIALS

Image Credit: N-Render

Overview and Project Goals

Prologis Nexus is an innovative, future-forward 266,640 square foot industrial space. The Nexus project is unique for Prologis and the Bay Area overall in that it retrofitted an existing site and used components from the existing industrial buildings rather than demolishing the entire site and constructing a new building. The site originally had three buildings built at different times around the late 1960s, covering 55% of the site area.

The project team set out three goals for the project from the beginning to: (1) create a Class A industrial facility, (2) embrace sustainability innovations and lower the carbon footprint in every possible aspect, including the pursuit of a LEED Platinum rating, and (3) create a people-centric design.

The project reuses the foundation, walls and other features of the existing 1960s building, helping the project to achieve a significant reduction in embodied carbon compared with a newly constructed building. The team achieved the remainder of embodied carbon reductions through other material reuse, the use of low-carbon concrete, an optimized slab design, cross-laminated timber, and insulated metal panels.

PROJECT INFORMATION

Project Name: Prologis Nexus

Region: West Coast US

Location: San Leandro, CA

Building Type: Industrial

IBC Construction type: Type V-B

Gross Floor Area: 266,640 ft²

Year of completion: 2024

PROJECT TEAM

Architect: Lowney Architecture

Structural Engineer: HSA & Associates

General Contractor: Whiting-Turner

Owner: Prologis

Other Team Members:

Civil Engineer: Kimley Horn

MEP Engineer: WB Engineers & Consultants

Sustainability and LCA Consultant:
BranchPattern

Embodied Carbon Highlights

- Reuse of an existing building's structure and enclosure
- Engaging the structural engineer early in design to study slab depth reduction and the use of insulated metal panels
- Engaging early with the concrete manufacturer to procure low-carbon concrete
- Identifying strategies and materials to reduce embodied carbon in the site work

How Does this Project Reduce Embodied Carbon?

The project achieves reductions through a combination of building and material reuse, material efficiency (through an optimized slab design), low-carbon concrete mixes, and material substitution, using cross-laminated timber and insulated metal panels as an alternative to concrete in several building elements.

The Prologis Nexus project reused approximately 60% of the existing 1960s warehouse structure and enclosure, including walls, foundation, perimeter columns, perimeter girders and w-flange columns/beams, contributing the largest embodied carbon savings of the project. The City of San Leandro was supportive of the reuse and rehabilitation of the existing facility, which streamlined the entitlement process and created an additional incentive for reuse. The existing building footprint and the column spacing were surprisingly advantageous for the requirements of this modern industrial facility type, which was key for enabling the adaptive reuse of the existing structure.

The architects engaged the structural engineering team early in design to study the use of insulated metal panels (IMPs) in place of the concrete needed to extend the height of the east, west, and south facades. The existing facades of the building consisted of 7” thick concrete walls and 12” x 12” pilasters every 25’, extending approximately 27 feet in height. To reach the desired height of 47.5 feet, an additional 38,750 square feet of wall was constructed using 6-inch insulated metal panels (IMPs). The choice to reuse the existing walls and extend them with IMPs reduced the concrete volume required, avoiding an additional 2,297 cubic yards of concrete that would have been required to extend the height of the three facades and construct the new north facade. The design team’s choice to use 6” wide IMPs instead of a typical 3” width also eliminated the need for intermediate metal supports, further reducing the need for additional structural materials. Last, IMP is relatively lightweight, allowing for extending the height of the existing wall without additional framing and foundation support that would have been required if heavier materials (like concrete) were used to extend the building’s height.

The mezzanine of the new building used cross-laminated timber (CLT), deck and glulam beams from wood sourced from FSC-certified forests. Based on studies by the design team, the CLT deck assembly alone – as compared to a steel deck assembly – achieves a 72% reduction without including the biogenic carbon storage benefits.

The project also pursued several lower-carbon concrete strategies. The architect and engineering teams collaborated to use fiber-reinforced Type 1 concrete, reducing the volume of concrete required on the project by allowing for the reduction of the concrete slab from 9" to 6". Because this product is new to the U.S. market and more common in Europe, Prologis had to conduct their own extensive testing and mock-ups of the material. In addition, low-carbon concrete with 30% slag content was used in the project’s concrete walls, foundations, and slab on grade for further embodied carbon reductions.

The team also worked to reduce the embodied carbon of the site work through utilizing recycled crushed concrete as aggregate and reducing the total embodied carbon from asphalt. 30% of the existing asphalt paving was reused, and recycled asphalt pavement (RAP) was used for new paved areas.

What was the baseline and how was it established?

The baseline building for the project is the same as the proposed design, but assumed to be 100% new tilt-up concrete construction without any reuse. The baseline building is a 1-story warehouse, with the same area and height as the final design. The structural frame for the baseline is a hybrid concrete and steel structure: 11” tilt-up concrete walls at the perimeter, HSS and W-flange columns, steel joists and girders, and a metal deck roof. The foundations are concrete direct-bearing with slab-on-grade and rebar reinforcement. Exterior walls are concrete panels with rebar reinforcement.

The baseline and the proposed design LCA models for the project included slab on grade, foundations, exterior walls, structural frame, roof assembly, exterior walls, tenant improvement, MEP systems, and site work.

Image Credit: N-Render

Life Cycle Assessment (LCA) Approach

LCA Tool/Software Used: One Click LCA (Life Cycle Carbon) tool

Life Cycle Stages Included:

- ■ **A1-A3**
- ■ **A4**
- ■ **A5**
- ☐ B1
- ■ **B2-B3**
- ■ **B4-B5**
- ☐ B6-B7
- ■ **C1**
- ■ **C2-C4**
- ☐ D

LCA Scope:

- ■ **Substructure**
- ■ **Shell - Superstructure**
- ■ **Shell - Exterior Enclosure**
- ■ **Interiors - Construction**
- ■ **Interiors - Finishes**
- ■ **Sitework**
- ■ **Services (MEP)**
- ☐ Equipment & Furnishings

LCAs Completed During:

- ☐ Pre-design
- ☐ Schematic Design
- ■ **Design Development**
- ■ **Construction Documentation**
- ☐ Construction
- ☐ Completed/Post-Occupancy

Additional LCA Information

In 2024, BranchPattern released *Embodied Carbon in U.S. Industrial Real Estate Benchmark Study- Version 2*, an expanded analysis of the average embodied carbon footprint of new development projects within the U.S. industrial real estate industry. The study originally assessed 26 WBLCA projects completed in 2022, accounting only for the building core and shell (structure and enclosure). The Benchmark Study Version 2 builds upon the previous study by offering new insights based on a more robust dataset consisting of 94 additional projects completed in 2023 and expanding the scope of results to include site hardscapes.

The study initially established an industry average benchmark of 23.0 $kgCO_2e/ft^2$ (248 $kgCO_2e/m^2$) for core and shell 2022 projects. It was then found that the industry has reduced its embodied carbon emissions by 4% compared to the 2023 projects, based on a 60-year Reference Study Period (RSP). When the site is included, the new benchmark rises to 32.1 $kgCO_2e/ft^2$ (346 $kgCO_2e/m^2$), with 10.1 $kgCO_2e/ft^2$ (109 $kgCO_2e/m^2$) attributed solely to the site. (This case study includes interiors and MEP in addition to structure, enclosure, and sitework, so these intensity values are not comparable to the values described in Table 1).

BranchPattern then assessed (5) Prologis North American projects completed by Prologis in 2022, again accounting for only the building core and shell, and the resulting average was 20.6 $kgCO_2e/ft^2$ (222 $kgCO_2e/m^2$) for a 60-year RSP. For the Prologis Nexus project, the embodied carbon intensity for just the structure and enclosure was 18.9 $kgCO_2e/ft^2$ (203 $kgCO_2e/m^2$), 9% lower than the average.

Embodied Carbon Reduction from the Baseline

Results are displayed as the global warming potential (GWP) per unit of floor area in kg CO_2e/m^2 (embodied carbon intensity or ECI) based on outputs from **One Click LCA**. The gross floor area was supplied by the project team.

Baseline GWP	Proposed Design GWP	Estimated Embodied Carbon Savings	Biogenic Carbon Storage*
502 $kgCO_2e/m^2$ (excl. b.c storage)	**296 $kgCO_2e/m^2$** (excl. b.c. storage)	**41%** (excl. b.c.storage)	**3 $kgCO_2e/m^2$**

*This value is the "Biogenic carbon storage kg CO2e bio" inventory metric calculated by OneClick LCA (Life Cycle Carbon) tool, and represents stored carbon in a unit of material rather than biogenic carbon flows.

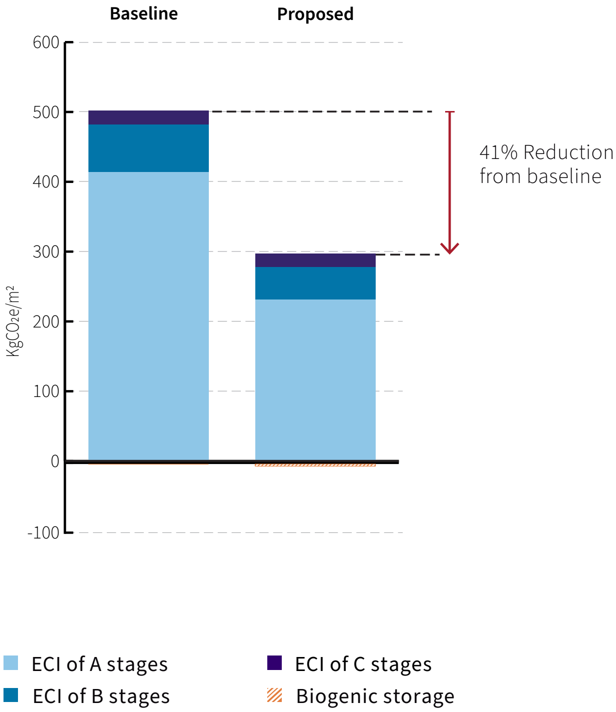

Figure 1. Embodied carbon intensity comparison of baseline and proposed design

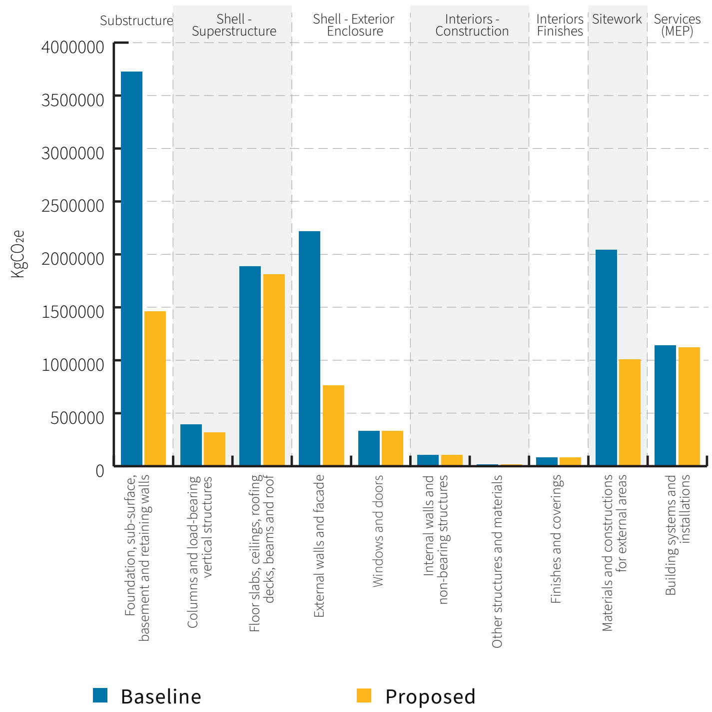

Figure 2. Total embodied carbon comparison of baseline and proposed design, by building element group

Highlights and Lessons Learned

Global, Replicable Strategies: Prologis benefits from its development of many industrial facilities globally and can take lessons learned from facilities in Europe and implement those strategies and materials in the U.S. The in-house Prologis Innovations team plays a significant role in research, bringing lessons learned from global projects to local teams and helping to bring new products and materials to the U.S. market. On this project, the use of IMPs, Type 1 fiber-reinforced concrete, and the mass timber were strategies imported from other projects, such as their facilities in France and Italy.

Innovative Materials: Because there was no existing comparable Type 1 fiber-reinforced concrete data in the U.S., the Prologis team found a lab in Atlanta to test different types and mixes of the fiber-reinforced concrete, and using this data, the team designed and tested mockups to inform the final specifications.

Certifications and Achievements

Designed to achieve a LEEDv4 C&S Platinum rating

NRMCA Concrete Innovations Award 2024

NAIOP Development of the Year, 2024

Case Study Contributors:

Jenny Emrick, Prologis

Claudia Tarpin, Prologis

Eliana Peralta-Sapienza, BranchPattern

Additional Project Information

Prologis Nexus

Lowney Architecture project webpage

Stanley Center for Peace and Security

EMBODIED CARBON REDUCTION CATEGORY: ADAPTIVE REUSE

Image Credit: Cameron Campbell, Integrated Studio

Overview and Project Goals

With its proximity to the Mississippi River, Muscatine, Iowa has been an industrial hub since the early 1900s. In 1956, Muscatine natives Max and Elizabeth Stanley established the Stanley Center for Peace and Security—a global policy influencer focused on promoting nuclear disarmament, preventing mass atrocities, and mitigating climate change.

In late 2019, Stanley Center staff and governance members began a collaborative process of describing their ideal workplace. They knew we wanted a home that offered the chance to live and share their core values and demonstrate their commitments to mitigating climate change and building just and equitable communities within society. The Stanley Center and Neumann Monson explored many sites before choosing to renovate the 1970s-era former Musser Public Library, which had been abandoned years earlier and stood empty. The building provided 19,260 square feet of occupiable space and a prime downtown location for strengthening community connections.

The Stanley Center's new headquarters is tracking to be the second renovation to achieve a full Living Building Certification (LBC) from Living Future and will be the first LBC building in Iowa. Embodying the Stanley Center's mission, the building produces over 100% of its energy on-site, collects all potable and non-potable water through rainfall, uses Red List-compliant materials, and 48% of all new materials were sourced within 500km of the site. A portion of the existing building was removed to create an urban agriculture space that provides fresh produce for both building occupants and the Muscatine Center for Social Action, a neighboring food bank. This removal also helped provide daylighting and views in 95% of occupied spaces.

PROJECT INFORMATION

Project Name: Stanley Center for Peace and Security

Region: Midwest US

Location: Muscatine, Iowa

Building Type: Office

IBC Construction type: V-B

Gross Floor Area: 19,823 ft^2

Year of completion: 2023

PROJECT TEAM

Architect: Neumann Monson Architects

Structural Engineer: Raker Rhodes Engineering

General Contractor: Graham Construction

Owner: Stanley Center for Peace and Security

Other Team Members:

Materials Consultant: Materially Better (formerly Integrated Eco Strategy)

MEP Engineer: Design Engineers

Civil Engineer: Environmental Consulting & Technology Inc.

Landscape Architect: Environmental Consulting & Technology Inc.

Water Systems Engineer: Biohabitats

Embodied Carbon Highlights

- **Reuse of over 90% of an existing 1970s public library building**
- **Selection of lower carbon finish options for gypsum board, ceiling tile, carpet, and flooring through comparing EPDs in EC3 Tool**

How Does this Project Reduce Embodied Carbon?

Nearly 94% of the existing building mass was reused, significantly reducing the amount of embodied carbon that would have been required for a new construction building. The project team carefully tracked all existing building components and materials in a matrix, and prioritized their ability to be reused on-site. Reuse strategies included:

- Reuse of the existing structure allowed for the reduction of new reinforced concrete at the foundation level. 91% of the final foundation consists of re-used material by weight.
- Reuse of the existing concrete columns and beams allowed for the reduction of new structural steel members in the structure and superstructure.
- 99% of the final roof construction consists of reused material by weight.
- Reuse of the existing brick & CMU cavity wall assembly as a primary structural assembly, allowing the reduction of new metal-framed structure. The exception was the new courtyard walls, which were built with new materials.
- Reuse of the existing slab at ground level and second-level deck allowed reduction of new reinforced concrete and concrete topping.
- Reuse of 4" of existing roof insulation which was added to the required R-30 roof assembly, reducing the new rigid insulation on the roof.
- Reuse of plaster ceiling in some areas, reducing the need for installing a new gypsum ceiling.
- Chose a low embodied carbon siding material - charred Accoya wood

Analyses supported design and material selection throughout the project when new materials had to be selected. During design development, the design team used LCA to compare different new cladding options and create a visual matrix for the client to make an informed decision, leading to the selection of Accoya wood cladding which is lower carbon than metal panels or glass. The design team also weighed different options for interior finish materials – including gypsum board, ceiling tile, carpet, and flooring – by obtaining product-specific EPDs and comparing their embodied carbon impacts to select the lowest options available.

What was the baseline and how was it established?

The baseline for this project modeled the structure and enclosure as if it were new construction. Additional interior reductions were modeled in EC3, seen in the results tables below.

Life Cycle Assessment (LCA) Approach

LCA Tool/Software Used: Tally

Life Cycle Stages Included:

- ■ **A1-A3**
- ■ **A4**
- ☐ A5
- ☐ B1
- ■ **B2-B3**
- ■ **B4-B5**
- ☐ B6-B7
- ☐ C1
- ■ **C2-C4**
- ☐ D

LCA Scope:

- ■ **Substructure**
- ■ **Shell - Superstructure**
- ■ **Shell - Exterior Enclosure**
- ☐ Interiors - Construction
- ☐ Interiors - Finishes
- ☐ Sitework
- ☐ Services (MEP)
- ☐ Equipment & Furnishings

LCAs Completed During:

- ☐ Pre-design
- ☐ Schematic Design
- ■ **Design Development**
- ☐ Construction Documentation
- ■ **Construction**
- ☐ Completed/Post-Occupancy

Additional LCA Information

LCAs were completed during design development and during the construction phase. During DD, the design team used LCA to compare different new cladding options and create a visual matrix for the client to make an informed decision.

Embodied Carbon Reduction from the Benchmark

Results are displayed as the global warming potential (GWP) per unit of floor area in kg CO_2e/m^2 (embodied carbon intensity or ECI) based on outputs from **Tally**, and **Tally+EC3**. The gross floor area was supplied by the project team.

Tally

Benchmark GWP	Proposed Design GWP	Estimated Embodied Carbon Savings
507 kgCO₂e/m² (excl· b·c· flows)*	**194 kgCO₂e/m²** (excl· b·c· flows)*	**62%** (excl. b.c. flows)*

*These values are based on excluding "biogenic carbon (b.c.)" in Tally.

Tally + EC3

Benchmark GWP (A1-A5)	Proposed Design GWP w/product substitutions	Estimated Embodied Carbon Savings w/product substitutions
507 kgCO₂e/m²	**187 kgCO2e/m²**	**63%**

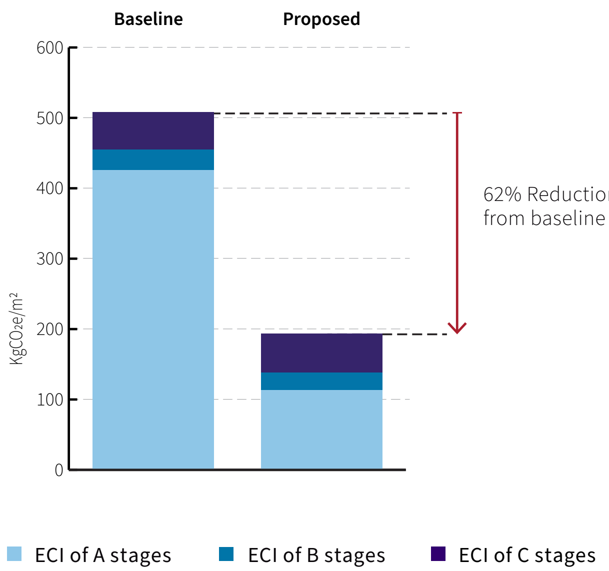

Figure 1. Embodied carbon intensity comparison of baseline and proposed design

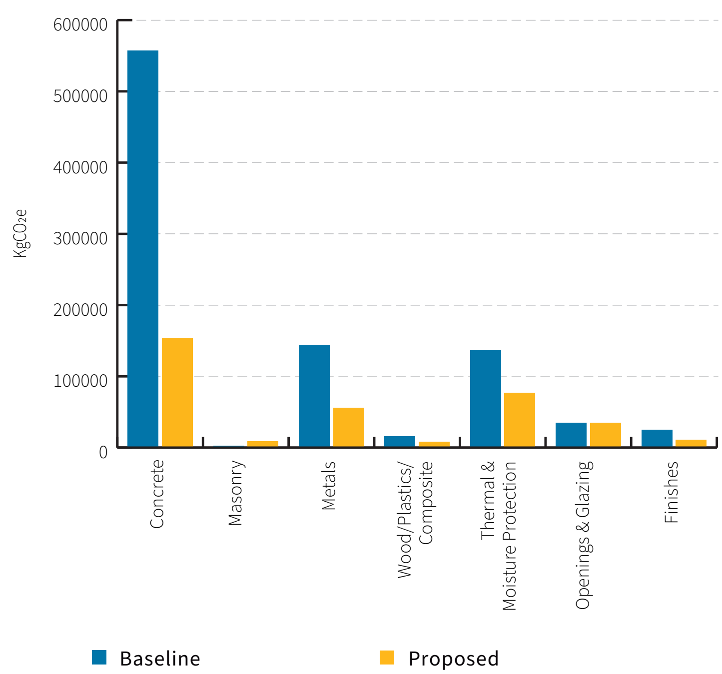

Figure 2. Total embodied carbon comparison of baseline and proposed design, by CSI Division (Tally material categories)

Highlights and Lessons Learned

Reuse! Starting with the assumption that the project would keep everything it possibly could, the team started to think about the project approach differently and come up with novel solutions. For example, just because the roof membrane could not be saved, it didn't mean the insulation underneath could not be reused. This project required the team to challenge industry norms and expectations with simple questions that led to transformative and effective solutions.

LCA incorporated into practice: Neumann Monson is working to include LCA during their project design process. In early phases, using hot-spot LCA analysis helps the team and clients make informed decisions about major materials and systems. This early design analysis also helps establish a baseline from which they can compare later in design.

Image Credit: Cameron Campbell, Integrated Studio

Certifications & Achievements

Metropolis 2024 Planet Positive Award (Workplace Category)

American Architecture Awards 2024, Honorable Mention

Iowa American Society of Landscape Architects 2024 Honor Award

American Institute of Architects, Central States Merit Award, 2024

American Institute of Architects, Iowa Impact Honor Award, 2024

American Institute of Architects, Iowa Merit Award, 2023

1000 Friends of Iowa Best Development Award: Innovative Leadership, 2023

The Chicago Athenaeum Green Good Design Global Sustainability Award, 2022

Case Study Contributors:

Lyndley Kent, Neumann Monson Architects

Additional Project Information

Neumann Monson Architects project webpage- The Stanley Center for Peace and Security with video case study

Living Building Video Stories - Episode 1 – A Living Building

Book - Healing Ground, Living Values: Stanley Center for Peace and Security

America By Design, Architecture Season 2, Episode 7

America By Design- Stanley Center for Peace and Security

The Aliki Perroti and Seth Frank Lyceum

EMBODIED CARBON REDUCTION CATEGORY: ADAPTIVE REUSE

Image Credit: Robert Benson Photography and Bruner/Cott Architects

Overview and Project Goals

The 20,000 square foot Aliki Perroti & Seth Frank Lyceum at Amherst College in Amherst, Massachusetts, brings together the school's Center for Humanistic Inquiry and the Department of History to drive discourse and critical thinking. Inspired by the Lyceum of Ancient Athens—a place for philosophical discussions and debate—the building's spaces are arranged to encourage interaction, collaboration, and conversation among faculty, students, and the greater Amherst College community and act as an incubator for a new campus district.

The Lyceum project incorporates an existing historic Greek Revival house on the site with a newly constructed addition. The house's interior was modified to provide a program of offices, classrooms, and support spaces. A new two-story addition is situated next to the house, separated by a transparent exterior wall. These two elements contain the project's large public spaces, an event space, and a flexible classroom. A new three-story office wing wraps behind the existing house to create a linear band of offices looking west into the building's natural setting. An open, central commons created by the adjacencies of the Lyceum's offices, classrooms, and ground floor event space along with outdoor terraces provide a vibrant place for the community to share thoughts, ideas, and work.

In addition to a commitment to studying and reducing embodied carbon, the project aligns with Amherst College's goal to be carbon neutral by 2030. The building envelope is highly insulated and airtight, coupled with all-electric mechanical systems and a roof-mounted solar array.

PROJECT INFORMATION

Project Name: The Aliki Perroti & Seth Frank Lyceum

Region: Northeast US

Location: Amherst, MA

Building Type: Education

IBC Construction type: VB

Gross Floor Area: 20,000 ft²

Year of completion: 2023

PROJECT TEAM

Architect: Bruner/Cott Architects

Structural Engineer: Foley Buhl Roberts & Associates

General Contractor: Daniel O'Connell's Sons, Inc.

Owner: Amherst College

Other Team Members:

Carbon Consultant: New Frameworks Natural Design/Build

Specifications: Kalin Associates

MEP, FP, AV, Energy Modeling: BuroHappold

Landscape Architect: Stimson

Embodied Carbon Highlights

- Reuse and restoration of a masonry building
- Low carbon specifications for the envelope including wall framing, insulation (cellulose), wood and local stone cladding
- FSC Certified CLT, timber, exterior cladding, millwork and flooring

How Does this Project Reduce Embodied Carbon?

Reusing the site's existing house preserves a piece of the region's history and plays an important part in the project's carbon reduction strategy. Reuse and material selection were key in helping the project attain the operational and embodied carbon targets set in alignment with the International Living Future Institute (ILFI)'s Zero-Carbon standard.

In addition to preserving existing materials, the team selected lower-carbon structural materials such as CLT deck, a timber superstructure, light wood framing, and domestically produced steel. The envelope uses cellulose insulation and locally sourced granite and wood cladding, and the interior materials include American hardwood millwork and lower carbon carpet tiles and gypsum wallboard.

The design team initially assessed the cellulose acoustic batt insulation, cellulose blown thermal insulation, carpet, and gypsum wallboard materials using Tally, later obtaining EPDs for the selected products to include more project-specific GWP numbers.

Image Credit: Robert Benson Photography and Bruner/Cott Architects

The design team completed a comparative analysis of three different wall assemblies ranging from "business as usual" steel framing with mineral wool to the double-stud framed wall insulated with cellulose. The analysis included embodied carbon impacts (using BEAM and Tally), durability, and moisture control (using WUFI software analysis) to allow the client to consider embodied carbon without sacrificing key performance criteria. The client ultimately decided to increase the budget to use cellulose acoustic batts over mineral wool after seeing its carbon storage potential.

What was the benchmark and how was it established?

In the conceptual phase of the project, the design team studied a number of third-party certifications that aligned with the client's project goals to expand their current rigorous focus on energy performance to include a new concentration on embodied carbon. Ultimately, the college chose not to pursue certification, but the design team continued to use performance metrics identified during this phase of the project.

For the purpose of assessing embodied carbon, the project team chose to adopt the ILFI Zero Carbon Certification standard embodied carbon intensity cap and operational energy requirements rather than modeling a comparative baseline building. Under Zero Carbon version 1.0, the maximum embodied carbon intensity for life cycle stages A1-A5 was 500 kg CO_2e/m^2 (covering structure, enclosure, and interiors scope).

Life Cycle Assessment (LCA) Approach

LCA Tool/Software Used: Tally Commercial Version 2020.06.09.01, and EC3 to customize results for specific products. The BEAM Tool was used starting with the conceptual and schematic design phases and for the wall assembly study.

Life Cycle Stages Included:

- ■ **A1-A3**
- ■ **A4**
- ◩ **A5**
- □ B1
- □ B2-B3
- □ B4-B5
- □ B6-B7
- □ C1
- □ C2-C4
- □ D

LCA Scope:

- ■ **Substructure**
- ■ **Shell - Superstructure**
- ■ **Shell - Exterior Enclosure**
- ■ **Interiors - Construction**
- ■ **Interiors - Finishes**
- □ Sitework
- □ Services (MEP)
- □ Equipment & Furnishings

LCAs Completed During:

- ■ **Pre-design**
- ■ **Schematic Design**
- ■ **Design Development**
- ■ **Construction Documentation**
- □ Construction
- □ Completed/Post-Occupancy

Note: The half-shaded box indicates that stage A5 was added manually to the model to align with the ILFI Zero Carbon benchmark

Additional LCA Information

The project team ran multiple LCA iterations in Tally to study the material choices more closely. They ran specific analyses on new envelope options, maintaining the same cladding, interior finishes and R-value, but using different framing and insulation strategies. They also studied the differences between Tally's default insulation, carpet and gypsum board inputs compared with actual EPDs from EC3 for the materials ultimately selected, including cellulose exterior insulation, cellulose EcoBatt Sound Attenuating Batts, Interface Embodied Beauty Line carpet, and EcoSmart gypsum wallboard.

Embodied Carbon Reduction from the Benchmark

Results are displayed as the global warming potential (GWP) per unit of floor area in kg CO_2e/m^2 (embodied carbon intensity or ECI) based on outputs from **Tally, EC3**, and manual inputs for the cellulose insulation. The gross floor area was supplied by the project team.

Tally

Benchmark GWP (A1-A5)* ILFI Zero Carbon Standard Limit	Proposed Design GWP (A1-A5)**	Estimated Embodied Carbon Savings**
500 $kgCO_2e/m^2$	**244 $kgCO_2e/m^2$** (excl· b·c· flows)	**51%** (excl. b.c. flows)

Tally + EC3

Benchmark GWP (A1-A5)* ILFI Zero Carbon Standard Limit	Proposed Design GWP (A1-A5) w/product substitutions	Estimated Embodied Carbon Savings w/product substitutions
500 $kgCO_2e/m^2$	**232 $kgCO_2e/m^2$** (excl. b.c.) or **218 $kgCO_2e/m^2$** (with b.c. storage)***	**54%** or **56%** (with b.c. storage)***

*This reflects the ILFI Zero Carbon Standard GWP limit of the A1-A5 embodied carbon impacts.
**These values are based on excluding "biogenic carbon (b.c.)" in Tally.
***This value includes a "Carbon Storage" inventory metric calculated manually by the team only for cellulose insulation.

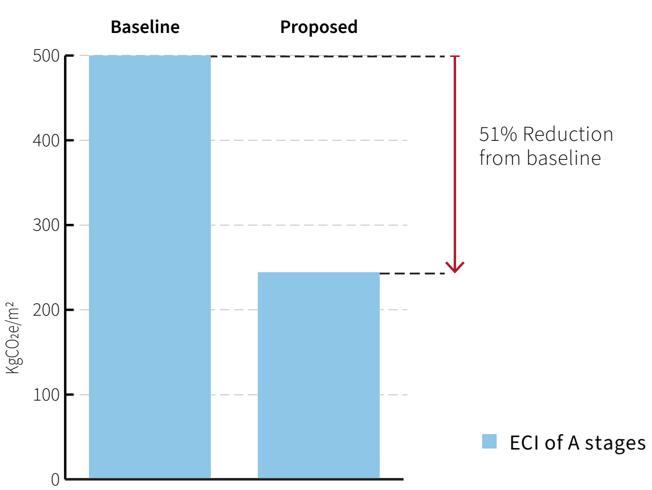

Figure 1. Embodied carbon intensity comparison of Tally baseline and proposed design

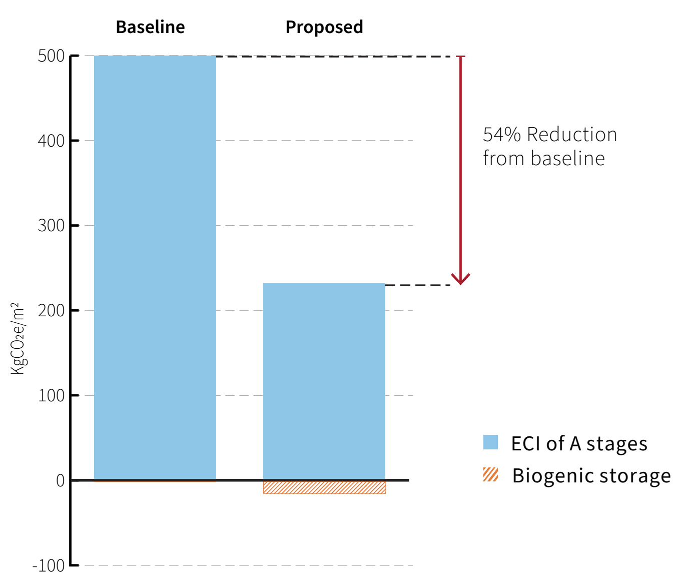

Figure 2. Embodied carbon intensity comparison of Tally+EC3 baseline and proposed design

Highlights and Lessons Learned

The Lyceum project is part of a longer trajectory of growing embodied carbon literacy and analysis at Bruner/Cott Architects. The firm first began modeling embodied carbon about 10 years ago using the Athena EcoCalculator, later integrating Tally into their design workflow. More recently, they have included more LCA modeling at each design phase in their most recent sustainability plan, and have added more in-house training on early design tools and EPD databases like EC3 to help their designers specify lower-carbon materials. They have also updated their specifications to require EPDs for multiple divisions and highlight lower embodied carbon options for common materials that have little to no cost or durability drawbacks.

Image Credit: Robert Benson Photography and Bruner/Cott Architects

The team reflected that while they still feel more confident in the accuracy of energy modeling, their increasing carbon literacy, in combination with growing availability of lower-carbon materials and data on their embodied carbon performance, has increased their confidence in making key choices about the materials that can make the biggest differences. Much like setting any project goal, they have found that aligning with the client's goals and setting measurable targets early is key to success. When the entire team understands the importance that products can have in achieving project goals, procuring specific lower-carbon items becomes more feasible.

Certifications and Achievements

2025 BSA Honor Award for Design Excellence, Adaptive Reuse, Renovation & Historic Preservation

2024 Retrofit Metamorphosis Awards, 1st Place - Additions

Case Study Contributors

Christopher Nielson, Bruner/Cott Architects

Additional Project Information

Project E-book

Bruner Cott project website

The Architect's Newspaper, article

The Amherst Student, article

Thurston Hall Renovation

EMBODIED CARBON REDUCTION CATEGORY: ADAPTIVE REUSE

Image Credit: Alan Karchmer

Overview and Project Goals

As the largest first-year residence hall at The George Washington University (GW), Thurston Hall is the first impression that many students receive at GW.

The 1929 brick building started out as an apartment block before being converted into student residences in the late ’60s. This 2022 ambitious renovation of the historic building removed the south central portion of 5 stories of Thurston Hall, enhancing the building’s courtyard and access to natural light and providing more flexible, safe, and healthy places for learning and gathering. 80% of the existing floors, roof, and exterior walls were retained and reused. This project is another success story of the shifting trends towards the benefits of revitalizing the nation’s existing building stock.

In addition to addressing embodied carbon, the project had aggressive overall sustainability goals, and ultimately achieved a LEED v4 BD+C Platinum Certification. The student residences are conditioned with heat pumps to reduce operational energy in line with the goals of the DC Building Energy Performance Standards (BEPS). The measured Energy Use Intensity (EUI) for this project is 60.3 kBtu/ft^2/yr, compared to the benchmark EUI of 99.7 kBtu/ft^2/yr.

PROJECT INFORMATION

Project Name: Thurston Hall Renovation, The George Washington University

Region: South Atlantic US

Location: Washington DC

Building Type: Residential: Multifamily (Residence Hall)

IBC Construction type: IB

Gross Floor Area: 207,820 ft^2

Year of completion: 2022

PROJECT TEAM

Architect: VMDO Architects

Structural Engineer: Springpoint (formerly Fox & Associates)

General Contractor: Clark Construction Company

Owner: George Washington University

Other Team Members:

Interior Designer: SMBW

MEP Engineer: CMTA

LEED Consultant: SDC

Embodied Carbon Highlights

- Adaptive reuse of an existing building
- Low-carbon concrete mix using SCMs (40% slag) for the structure

How Does this Project Reduce Embodied Carbon?

The renovation of Thurston Hall reduces embodied carbon primarily through (1) the preservation and reuse of the existing historic structure and (2) utilizing low carbon concrete in the new components of the building. The main design considerations were revitalizing the historic building, modernizing the infrastructure, and creating a dynamic new courtyard to support the students. Reusing as much of the existing structure and envelope as possible while accommodating the design and program changes allowed the project team to achieve carbon savings without sacrificing design ambition or needing specialized materials or techniques.

The additions to the existing building required concrete for structural reinforcement and to accommodate the changes to the courtyard. Even though it was a relatively small quantity, the team knew from previous experience that newly poured concrete would be the major driver of embodied carbon on this project. In the DC market, a 40% supplementary cementitious material (SCM) mix is relatively common practice, so the project was able to use several lower carbon concrete mixes with a range of 40-60% slag replacement for Portland cement. The original project design also included CarbonCure technology which injects CO2 into the concrete mix, but this product was ultimately eliminated during construction. Whenever additional materials were needed as part of the renovation, care was taken to choose materials that were lower carbon, such as selecting mineral wool insulation instead of foamed plastic at the interior side of all exterior walls.

What was the baseline and how was it established?

The baseline condition for this project was created by performing an LCA on the existing structural materials to remain on the project and then adding the embodied carbon from the proposed new building components. This approach provided the full embodied carbon impact of constructing the project as if it were new. The reductions from baseline to proposed therefore represent the embodied carbon of constructing the existing structural materials as if they were new. See the section, '*Modeling Building Reuse*' in the Introduction for more information.

Life Cycle Assessment (LCA) Approach

LCA Tool/Software Used: Tally version 2023.09.13.01

Life Cycle Stages Included:

- ■ **A1-A3**
- ■ **A4**
- □ A5
- □ B1
- ■ **B2-B3**
- ■ **B4-B5**
- □ B6-B7
- □ C1
- ■ **C2-C4**
- □ D

LCA Scope:

- ■ **Substructure**
- ■ **Shell - Superstructure**
- ■ **Shell - Exterior Enclosure**
- ■ **Interiors - Construction**
- ■ **Interiors - Finishes**
- □ Sitework
- □ Services (MEP)
- □ Equipment & Furnishings

LCAs Completed During:

- □ Pre-design
- □ Schematic Design
- □ Design Development
- □ Construction Documentation
- □ Construction
- ■ **Completed/Post-Occupancy**

Embodied Carbon Reduction from the Baseline

Results are displayed as the global warming potential (GWP) per unit of floor area in kg CO_2e/m^2 (embodied carbon intensity or ECI) based on outputs from **Tally**. The gross floor area was supplied by the project team.

Baseline GWP	Proposed Design GWP	Estimated Embodied Carbon Savings
380 $kgCO_2e/m^2$	272 $kgCO_2e/m^2$	29%

*These values exclude biogenic carbon flows, using the "exclude biogenic carbon" option in Tally.

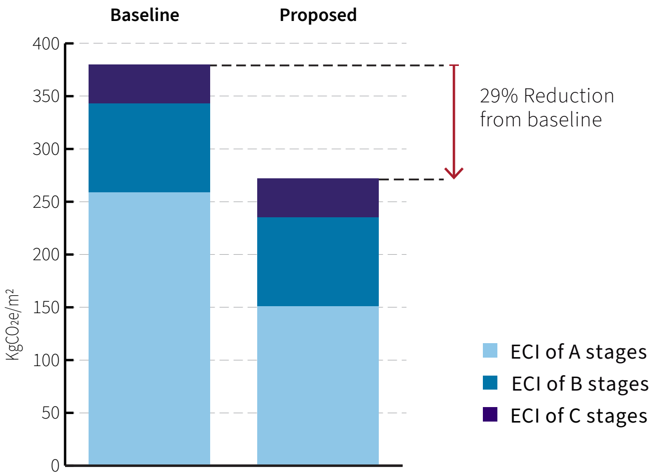

Figure 1. Embodied carbon intensity comparison of baseline and proposed design

Highlights and Lessons Learned

VMDO Architects believes that caring for and celebrating our existing buildings is the key to sustainable design and prioritizes reusing existing buildings whenever possible. This project is a great example of marrying design goals with the reuse of a building. Thurston Hall's three AIA Awards for design demonstrate that adaptive reuse is a viable strategy to reduce embodied carbon without sacrificing design.

Despite embodied carbon reductions not being a major priority during design, Thurston Hall was still able to achieve reductions due to the high impact of reuse and the increasing prevalence of low carbon concrete mixes using supplementary cementitious materials (SCMs).

VMDO has been working to conduct LCA's on all recent projects to create a firmwide database and benchmarks for embodied carbon across their portfolio. The team did an additional analysis comparing this baseline and proposed case to a group of 5 new construction residence halls designed and built by VMDO Architects in the last 5 years. The Tally models from those 5 buildings showed an average embodied carbon intensity (ECI) over 600 $kgCO_2e/m^2$, significantly higher than this adaptive reuse project. This reinforces the value of reusing even a portion of a building's structure and enclosure.

Certifications and Achievements

Leed Platinum Certified (LEED v4 BD+C)

AIA National Architecture Award 2024

AIA National Housing Award 2024

AIA COTE Top 10 Award 2024

Case Study Contributors:

Tyler Pitt, VMDO Architects

JP Mays, VMDO Architects

Jenna Pye, VMDO Architects

Additional Project Information

VMDO Architects project webpage

GW Documentary: History of Thurston Hall

Image Credit: Alan Karchmer

The Wendy

EMBODIED CARBON REDUCTION CATEGORY: LOW CARBON CONCRETE

Image Credit: Aaron Taule, Sustainable Building Partners

Overview and Project Goals

Located in Arlington, VA, The Wendy is a 16-story, mixed-use, multi-family tower. The tight, triangular-shaped site is created by the intersection of the county's two most prominent thoroughfares, providing dramatic distant views. The shape of the tower follows the form of the site and creates a symbolic "flatiron" architectural gateway at the seat of the county government. Each glass panel in the building's chamfered curtainwall façade reflects light differently throughout the day, making the prow of the façade extremely dynamic.

In addition to the 231 residential units, the building has two below-grade parking levels and rooftop amenities, including a pool. The base of the building features 3,500 square feet of ground floor retail, along with a public plaza that celebrates the building's connection to the community with a lush landscape.

The project achieves a number of sustainability strategies across many categories and is LEED v4 BD+C Multifamily Midrise Platinum Certified. This case study focuses specifically on the strategies used by the project team to reduce the carbon footprint of the concrete, using product-specific EPDs to compare against industry-average values from the National Ready Mixed Concrete Association (NRMCA).

PROJECT INFORMATION

Project Name: The Wendy

Region: South Atlantic US

Location: 2025 Clarendon Boulevard, Arlington, Virginia

Building Type: Residential: Multifamily

IBC Construction type: 1A (Modified)

Gross Floor Area: 318,610 ft^2

Year of completion: 2024

PROJECT TEAM

Architect: Cooper Carry

Structural Engineer: SK&A Structural Engineers

General Contractor: John Moriarty & Associates

Owner: Greystar

Other Team Members:

Concrete Supplier: Vulcan Materials Company

Trade Partner: Schuster Concrete Construction

LEED Consultant, Life Cycle Assessment:
Sustainable Building Partners

Embodied Carbon Highlights

- **Use of low-carbon concrete mix with 30% slag as a supplementary cementitious material (SCM) substitute throughout, except for the above-grade floor slabs**
- **Use of Type 1L Portland Limestone Cement**
- **Early strategizing and ongoing assessments were crucial to design decisions that reduced material, thereby reducing embodied carbon**

How Does this Project Reduce Embodied Carbon?

Early discussions of low carbon concrete strategies with the design team, general contractor, and concrete supplier were pivotal in establishing the project's use of concrete with a higher percentage of SCMs as well as the use of Type 1L cement. The project was required to meet at least a 5% reduction in embodied carbon as part of Arlington County's Green Building Incentive Policy in order to pursue a density bonus of additional floor area ratio (FAR).

The team pursued savings in the concrete package in four complementary ways: 1) reducing the volume of the concrete through design optimization, 2) replacing cement with SCMs, 3) selecting a lower carbon cement, and 4) sourcing concrete from a ready mix plant a very short distance to the site.

First, during design, the team reduced the volume of concrete required through reducing one of the heaviest concrete elements in the foundations - the mat slab - from a typical 48" slab to a 40” slab.

All concrete mixes used on the project contain Type 1L (Portland Limestone Cement or PLC) instead of typical Portland Cement. Type 1L is a type of blended cement that contains between 5 and 15% limestone. The product performs the same as standard cement but has a lower global warming potential. With the exception of the mixes used for the above-grade floor slabs, all concrete mixes also utilized 30% slag as a supplementary cementitious material, reducing the cement quantity on the project.

The concrete mixes were procured from a local concrete supplier, Vulcan Materials Company (VMC), located only 4 miles from the project site - saving emissions in transportation. VMC has an internal sustainability goal to reduce their scope 1 and 2 GHG emissions intensity per ton of product produced by 10% by 2030, and to report their scope 3 emissions. In the fall of 2022, all VMC concrete plants in the DMV Region – the Washington metropolitan area, which includes the District of Columbia (DC), Maryland, and Virginia – fully switched over to using Type 1L cement, and producing EPDs for all of their concrete mixes. The use of Type 1L cement on this project in place of ordinary Portland cement in all concrete mixes was cost neutral.

What was the baseline and how was it established?

The project team used OneClick LCA to create both a baseline and design WBLCA for the project. The quantities between the baseline and the proposed model were the same, except for the mat slab, which was reduced in depth from 48” in the baseline to 40” in the design condition.

This case study focuses on a subset of the team’s WBLCA analysis in which they compared the final concrete design mixes to the 2022 NRMCA Eastern Region Benchmark global warming potential values for all of the concrete mixes used on the project (NRMCA,2022). The NRMCA eastern region baseline values and baseline quantities were multiplied by the quantities of each concrete mix used on the project and compared against the values sourced from product-specific EPDs using the same calculation process.

Life Cycle Assessment (LCA) Approach

LCA Tool/Software Used: One Click LCA with NRMCA baseline values

Life Cycle Stages Included:

- ■ **A1-A3**
- ☐ A4
- ☐ A5
- ☐ B1
- ☐ B2-B3
- ☐ B4-B5
- ☐ B6-B7
- ☐ C1
- ☐ C2-C4
- ☐ D

LCA Scope: *Concrete elements only*

- ■ **Substructure**
- ■ **Shell - Superstructure**
- ☐ Shell - Exterior Enclosure
- ☐ Interiors - Construction
- ☐ Interiors - Finishes
- ☐ Sitework
- ☐ Services (MEP)
- ☐ Equipment & Furnishings

LCAs Completed During:

- ☐ Pre-design
- ☐ Schematic Design
- ■ **Design Development**
- ■ **Construction Documentation**
- ■ **Construction**
- ☐ Completed/Post-Occupancy

Embodied Carbon Reduction from the Baseline - Concrete Only

Results are displayed as the global warming potential (GWP) per unit of floor area in kg CO_2e/m^2 (embodied carbon intensity). The gross floor area was supplied by the project team.

Concrete Baseline GWP (A1-A3)*	Concrete Proposed Design GWP (A1-A3)	Estimated Embodied Carbon Savings
197 $kgCO_2e/m^2$	154 $kgCO_2e/m^2$	22%

*Based on multiplying the NRMCA Eastern baselines for the appropriate compressive strength for the baseline quantities for this project. NRMCA. (2022). National and regional LCA benchmark (industry average) report - v3.2.

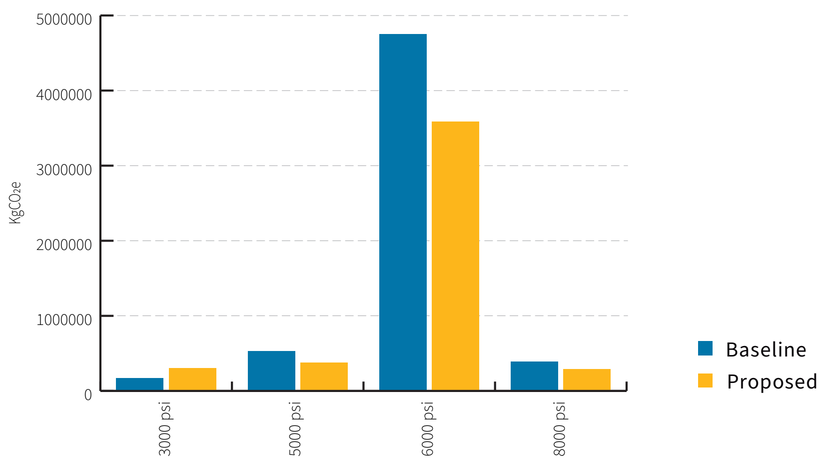

Figure 1. Comparison of total embodied carbon of concrete for baseline and proposed design by concrete strength

Highlights and Lessons Learned

The contractor was supportive of the project goals and onboard to better understand the concrete mix specifications and the Type 1L cement. They did not see any impacts to the schedule from the use of the new materials.

The project is pursuing LEED v4 BD+C for Multifamily Midrise, which has a verification process that is unique to this LEED rating system. It results in a more rigorous review of the project to verify the sustainability strategies and technologies. Based on the embodied carbon reductions achieved, the project is pursuing a LEED Innovation credit.

Certifications and Achievements

LEED v4 BD+C Multifamily Midrise Platinum Certified

Case Study Contributors:

Haley Hiller, Sustainable Building Partners

Jen Wolf, Sustainable Building Partners

Additional Project Information

2025 Clarendon Boulevard - Cooper Carry

The Wendy

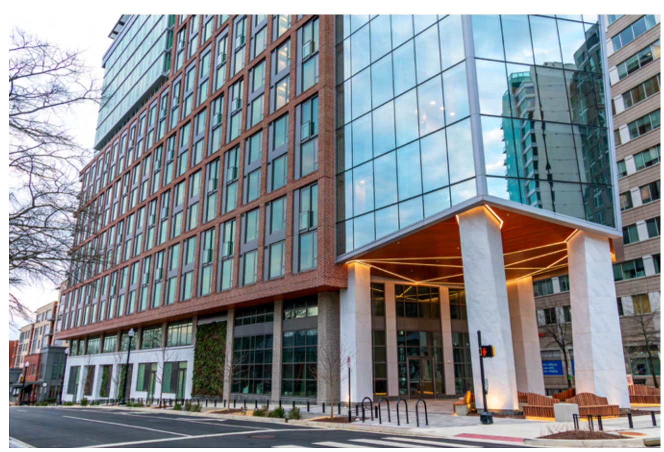

Image Credit: Aaron Taule, Sustainable Building Partners

Justis Residence

EMBODIED CARBON REDUCTION CATEGORY: SINGLE-FAMILY RESIDENTIAL

Image Credit: Arkin Tilt

PROJECT INFORMATION

Project Name: Justis Residence

Region: Mountain West US

Location: Crested Butte, Colorado

Building Type: Residential - Single Family

IBC Construction type: IV

Gross Floor Area: 2,612 ft²

Year of completion: 2023

PROJECT TEAM

Architect: Arkin Tilt

Structural, Mechanical, Energy + Envelope, Electrical Engineer: REG Consulting Engineers

General Contractor: Straw and Timber Craftsmen

Owner: Gary Justis

Overview and Project Goals

Located at over 9,000 ft. of elevation in the Rocky Mountains of Colorado, the goal of this residence and of the client was to design for limited climate impact. To build extremely insulated structures such as this one in the Rockies, builders and designers generally use high embodied carbon, petroleum-based insulation materials. This project turns instead to wheat straw – a waste product of nearby grain farms – to achieve the same high-performance enclosure. In addition to its extensive use of salvaged materials and nods to local mining history, this house has become a showcase for the application of natural building materials for cold climates.

The building is relatively compact in footprint, but tall to limit envelope heat loss. The windows focus on a range of views of its spectacular mountain surroundings, while optimizing for daylight and passive solar gain from the south where feasible. The project is all-electric, and much of the building's energy use is offset by a large solar array on a nearby south-facing barn, as well as a small micro-hydro system fed by an on-site stream.

Embodied Carbon Highlights

- **Use of wheat straw-cel exterior wall construction**
- **Use of cork instead of rigid foam insulation**
- **Reuse of railroad track for stair stringers**
- **Site-milled timber from trees cleared on site**
- **Site-cut whole tree column used in greenhouse**
- **Locally sourced beetle-kill spruce decking**
- **Adobe (clay and straw) floor finishes**

How Does this Project Reduce Embodied Carbon?

Image Credit: Edward Caldwell Photography

The intensive insulation required in this cold climate creates an opportunity to use large amounts of biobased materials that are excellent insulators, and also store carbon. In this case, there are two exterior wall systems: (1) a 2x4 stud wall cavity filled with blown-in cellulose insulation, with straw bales stacked inside it to the interior and (2) thermally-broken double stud walls densely packed with blown-in cellulose insulation. The roof system also uses blown-in cellulose insulation in the joist cavities. Above the joist cavity, there is a continuous layer of rigid cork insulation (as an alternative to higher carbon rigid or spray foam, or mineral wool).

Gypsum board is another typically high impact material, so this project opts for lower impact lime plaster on the interior face of the straw-cel walls. Similarly, the flooring materials are either wood or adobe (straw and clay, hard-troweled and waxed).

The design team used the Building Emissions Accounting for Materials (BEAM) tool for both the house and the solar barn during the design process to show the client the impacts of these choices, relative to the overall impact and cost, and help them make informed decisions. Using straw bales in a hybrid wall system opens up the opportunity to use salvaged or lower impact exterior finish materials instead of the traditional lime plaster. In this case, cedar siding and salvaged corrugated metal were both used to provide fire resilience with less carbon impact than fiber cement or stucco, which is also made with cement.

The local contractor chosen for the project had extensive previous experience with straw bale, clay plaster and adobe floors and was instrumental to the success of the project.

What was the baseline and how was it established?

The design team modeled a baseline home using conventional materials. The baseline model includes typical residential materials, including foam board sub-slab insulation, closed cell spray foam insulation, fiberglass batt, and fiber cement siding. These traditional materials are significantly higher carbon than the alternatives used on the project, as demonstrated by the 49% savings in embodied carbon without even including biogenic carbon storage.

Life Cycle Assessment (LCA) Approach

LCA Tool/Software Used: BEAM beta version, with biogenic methods adapted to align with BEAM v1

Life Cycle Stages Included:

- ■ **A1-A3**
- □ A4
- □ A5
- □ B1
- □ B2-B3
- □ B4-B5
- □ B6-B7
- □ C1
- □ C2-C4
- □ D

LCA Scope:

- ■ **Substructure**
- ■ **Shell - Superstructure**
- ■ **Shell - Exterior Enclosure**
- ■ **Interiors - Construction**
- ■ **Interiors - Finishes**
- □ Sitework
- □ Services (MEP)
- □ Equipment & Furnishings

LCAs Completed During:

- □ Pre-design
- □ Schematic Design
- □ Design Development
- ■ **Construction Documentation**
- ■ **Construction**
- □ Completed/Post-Occupancy

Additional LCA Information

See the '*Life Cycle Assessment Tools*' section in the Introduction for more information on the Building Emissions Accounting for Materials (BEAM) Tool used for this project.

Embodied Carbon Reduction from the Baseline

Results are displayed as the global warming potential (GWP) per unit of floor area in kg CO_2e/m^2 (embodied carbon intensity or ECI) based on outputs from the **BEAM** Tool. The gross floor area was supplied by the project team.

BaselineGWP (A1-A3)	Proposed Design GWP (A1-A3)	Estimated Embodied Carbon Savings (A1-A3)
310 $kgCO_2e/m^2$	**158 $kgCO_2e/m^2$** 83 $kgCO_2e/m^2$ (with b.c. storage)*	**49%** 73% (with b.c. storage)*

*This value is the "Carbon Storage" inventory metric calculated by the BEAM tool and represents stored carbon in a unit of material. This is different from biogenic carbon flows. This analysis includes storage for biogenic materials sourced from agricultural or forestry residues and recycling streams. No carbon storage is attributed to virgin forest products, including framing lumber, plywood, OSB and wood trusses or I-beams.

See '*Biogenic Carbon Calculation and Reporting*' section of the Introduction for more information.

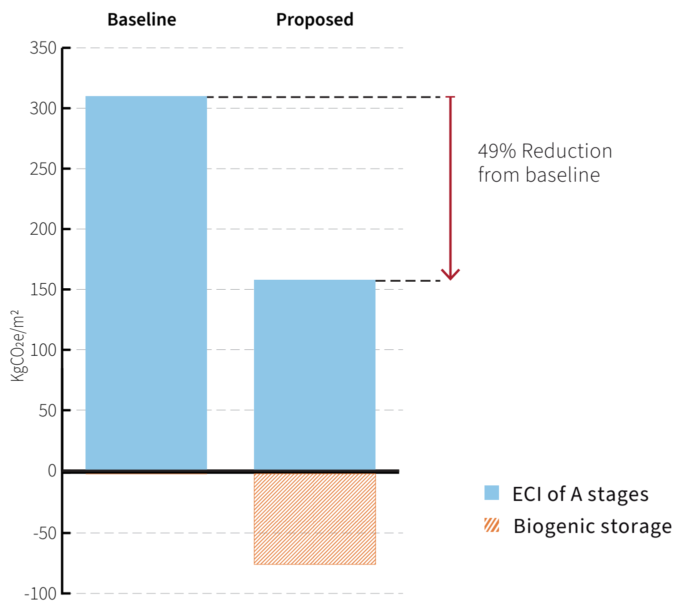

Figure 1. Embodied carbon intensity comparison of baseline and proposed design

Case Study Contributors:

David Arkin, AIA, Arkin Tilt

Tavi Hillesland, Arkin Tilt

Additional Project Information

Magwood, C., Bowden, E., Trottier, M. Emissions of Materials Benchmark Assessment for Residential Construction Report (2022). Passive Buildings Canada and Builders for Climate Action.

Crimmel, Sukita Reay, Thomson, James. "Earthen Floors, A Modern Approach to an Ancient Practice". New Society Publishers. 2016.

Kaplan Williams Residence

EMBODIED CARBON REDUCTION CATEGORY: SINGLE-FAMILY RESIDENTIAL


Image Credit: Daniel J Cardon

Embodied Carbon Highlights

- Compact home prioritizing sufficiency in programming
- Helical pier foundation (steel shafts and plates)
- Prefabricated modular floor, exterior wall, partition wall, and roof panels reduce material waste associated with site-based construction
- Locally sourced sustainable wood products for framing and finishing
- Locally sourced straw for carbon-storing insulation
    - Investment in regional sustainable agriculture supporting conservation in a development-intensive region
    - Investment in local land-based rural economies bolsters regional climate resiliency and incentivizes carbon-smart land use practices
- Compact MEP systems distribution reduces the consumption of piping, ducting, and wiring; compact design reduces the size of mechanical equipment and refrigerant charge

PROJECT INFORMATION

Project Name: Kaplan Williams Residence

Region: Northeast US

Location: Burlington, VT

Building Type: Residential: Single-family

IBC Construction type: VB

Gross Floor Area: 770 ft²

Year of completion: 2024

PROJECT TEAM

Architect: New Frameworks

Structural Engineer: Engineering Ventures

General Contractor: New Frameworks

Owner: Dana Kaplan and Laura Williams

Other Team Members:

Panel Fabricator: New Frameworks

Plumbing and Heating: Moorby Plumbing and Heating

Electrical: Village Voltage


Image Credit: Daniel J Cardon

Overview and Project Goals

The Kaplan Williams residence is a New Frameworks pre-designed, prefabricated home. New Frameworks homes are designed to have lower operational and embodied carbon footprints and feature carbon-storing, regionally-sourced materials, while providing a high-performance, non-toxic residence at an affordable price (~$400/ft²). This home is the 'Terra 600' model from the Casitas Line, built with locally sourced Vermont wood and straw and integrating advanced heating, cooling, ventilation, water, and power systems that are fossil-fuel free and all-electric. It was developed as a detached accessory dwelling unit (ADU) on an existing urban lot, which was facilitated by recent municipal zoning changes designed to encourage housing density and alternative forms of housing development in Burlington, VT.

Residential infill development (like this ADU) supports a "missing middle" housing solution approach, in which greater housing density is realized on existing developed lots with the associated benefits of leveraging existing transportation and building service infrastructure, avoiding sprawl, and creating more financially accessible methods of housing development. This case study therefore highlights the value of this new development pattern in addition to the carbon reduction strategies used by the house itself.

How Does this Project Reduce Embodied Carbon?

The Kaplan Williams Residence achieves embodied carbon reductions through optimizing the overall design, foundation, and mechanical systems to reduce material use, through substituting lower-carbon alternatives for traditional materials, and through reducing material waste with prefabrication. The largest embodied carbon reductions on this home come from the programming and massing simplicity and sufficiency: well-designed, compact, infill development projects reduce the operational and embodied carbon required per occupant before material and system design and selection has even begun. This is supported by broader research findings, such as the Oregon's Department of Environmental Quality research on small housing.

New Frameworks, producers of straw structural insulated panels (SIPs), was committed to creating a building that was net-carbon storing (exclusive of virgin timber) on day one of occupancy. There were two key strategies they employed to reach this goal: 1) use of local organic straw as an insulation material locally pre-fabricated for the wall assemblies to achieve high levels of biogenic carbon storage; and 2) use of a steel helical pier foundation system to avoid the use of concrete and reduce the emissions of the foundation system. Both of these approaches also reduced stage A4/A5 emissions compared to typical alternatives. The project also sourced cellulose and wood fiber insulation rather than petrochemical alternatives, and sourced regional wood framing and interior/exterior finishes treated with a mineral-based (non-petrochemical) wood treatment product.

These strategies nest within a holistic approach to design, fabrication, and construction in which building energy performance was optimized using carbon-storing, regionally-sourced insulation materials and designed for durability and longevity, using best practices of applied building science. When combined with an efficient and sufficient program and compact architectural design, this reduces total consumption of materials, avoiding additional concrete, steel, and glass for foundations, framing, roofing, and glazing.

Compact mechanical systems reduce the consumption of piping, ducting, and wiring for distribution while also reducing the size of mechanical equipment and refrigerant charge, reducing risks for fugitive emissions from refrigerant leakage throughout the building life cycle. Though refrigerants and MEP systems are often excluded from LCAs, these systems are manufactured with energy-intensive materials and components and must be replaced over the building's life, contributing a high percentage to the building's footprint when included.

What was the benchmark and how was it established?

This project did not model a baseline case, but instead used the RMI published report, "*The Hidden Climate Impact of Residential Construction: Zeroing In on Embodied Carbon Emissions for Low-Rise Residential Buildings in the United States,*" which determined an average 184 kg CO2e/m2 (conditioned floor area) for A1-A3 (cradle-to-gate emissions) as a benchmark for new low-rise residential homes. This average was based on 921 homes across the United States, Canada, and Europe.

Life Cycle Assessment (LCA) Approach

LCA Tool/Software Used: BEAM v1.0

Life Cycle Stages Included:

- ■ **A1-A3**
- □ A4
- □ A5
- □ B1
- □ B2-B3
- □ B4-B5
- □ B6-B7
- □ C1
- □ C2-C4
- □ D

LCA Scope:

- ■ **Substructure**
- ■ **Shell - Superstructure**
- ■ **Shell - Exterior Enclosure**
- ■ **Interiors - Construction**
- ■ **Interiors - Finishes**
- □ Sitework
- □ Services (MEP)
- □ Equipment & Furnishings

LCAs Completed During:

- □ Pre-design
- ■ **Schematic Design**
- ■ **Design Development**
- ■ **Construction Documentation**
- ■ **Construction**
- □ Completed/Post-Occupancy

Additional LCA Information

See the '*Life Cycle Assessment Tools*' section in the Introduction for more information on the Building Emissions Accounting for Materials (BEAM) Tool used for this project.

Embodied Carbon Reduction from the Baseline

Results are displayed as the global warming potential (GWP) per unit of floor area in kg CO_2e/m^2 (embodied carbon intensity or ECI) based on outputs from the **BEAM** Tool. The gross floor area was supplied by the project team.

Benchmark GWP (A1-A3) RMI Single Family Average	Proposed Design GWP (A1-A3)	Estimated Embodied Carbon Savings (A1-A3)
184 $kgCO_2e/m^2$	**86 $kgCO_2e/m^2$** (excl· b·c·) -37 $kgCO_2e/m^2$ (with b.c. storage)*	**53%** 120% (with b.c. storage)*

*This value is the "Carbon Storage" inventory metric calculated by the BEAMv1 tool and represents stored carbon in a unit of material. This is different from biogenic carbon flows. This analysis includes storage for biogenic materials sourced from agricultural or forestry residues and recycling streams. No carbon storage is attributed to virgin forest products, including framing lumber, plywood, OSB and wood trusses or I-beams.

See '*Biogenic Carbon Calculation and Reporting*' section of the Introduction for more information.

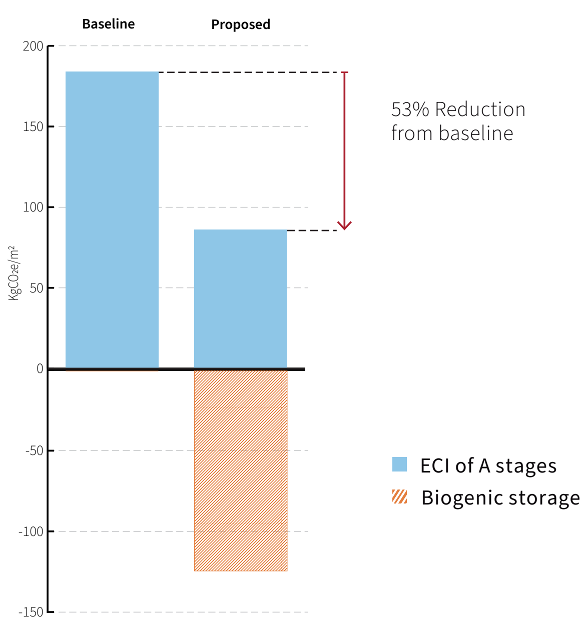

Figure 1. Embodied carbon intensity comparison of baseline and proposed design

Highlights and Lessons Learned


Image Credit: New Frameworks

New Frameworks designs and builds both panelized projects and custom-designed and built projects and has realized many benefits of panelized construction including:

- Enabling the use of straw in more projects by reducing barriers to an atypical insulation product
- Allowing a broader diversity of construction experience; the installation crew requires less technical expertise to install panelized systems
- A decrease in construction time by closing up the projects faster, which also reduces the risk of moisture exposure
- Better quality control - Shop fabrication allows for more consistency and a higher quality of panels than field-built conditions

There are notable differences in embodied carbon accounting between low-rise residential projects and other building types, including:

- Product diversity is significant, with many additional materials available for low-rise residential construction, particularly those made from bio-based materials.
- The supply chains for residential construction are typically more convoluted, with additional retail warehousing and logistics, which make estimations and assumptions for A4 emissions more challenging than for larger buildings.
- Architectural service expectations are different for low-rise construction, and BIM-driven LCA workflows are frequently not possible. Accordingly, take-offs for residential project assemblies and materials are frequently not assisted by BIM design software, nor organized into CSI divisions by construction management software, and require different workflows for material quantification in LCA analysis.

New Frameworks supported Builders for Climate Action in the development of the BEAM Tool to fill this gap in LCA tools for low-rise residential projects. The system-level differences in design and construction processes informed differences in the LCA tools used, boundaries defined for assessment, and overall assessment workflow that are apparent when comparing low-rise residential case studies to those of larger buildings.

Certifications and Achievements

Efficiency Vermont's Best of the Best Award 2025 - Category: ADUs

Case Study Contributors:

Jacob Deva Racusin, New Frameworks

Additional Project Information

New Frameworks Casitas: https://www.newframeworks.com/casitas

Chris Magwood and Tracy Huynh, [*The Hidden Climate Impact of Residential Construction*](), RMI, 2023

Image Credit: New Frameworks

Oceanspray Townhomes

EMBODIED CARBON REDUCTION CATEGORY: NON-STRUCTURAL BIO-BASED MATERIALS

Image Credit: Jovick Construction, Arkin Tilt Architects

Embodied Carbon Highlights

- Rice straw bales for thermal insulation in exterior walls and acoustic insulation in party walls
- Dense-pack cellulose for thermal insulation in the roof and the floor
- Raised wood framed floor and structural design minimizes the size of concrete stem walls and footings
- Efficient building massing and unit layout minimized the exterior envelope
- Concrete with supplementary cementitious materials (SCMs) used for foundation (slag replaced 59% of Portland cement)
- Lime cement stucco and salvaged redwood for a durable and eco-friendly exterior finish
- Locally sourced clay plaster interior wall finish

PROJECT INFORMATION

Project Name: Oceanspray Townhomes

Region: West Coast US

Location: Ashland, Oregon

Building Type: Residential - Multi-Family

IBC Construction type: VB

Gross Floor Area: 5,100 ft^2

Year of completion: 2024

PROJECT TEAM

Architect: Arkin Tilt Architects

Structural Engineer: Verdant Structural Engineers

General Contractor: Jovick Construction

Owner: Radhika and Chandu Thekkath

Other Team Members:

Mechanical Systems, Energy, and Envelope Consulting: Beyond Efficiency

Civil Engineering: Powell Engineering & Consulting

California Straw Building Association (CASBA): Sponsored the straw bale raising work party. CASBA members Jim Reiland and Lydia Doleman, along with Arkin Tilt Architects, led the work.

Image Credit: Arkin Tilt Architects

Overview and Project Goals

Oceanspray arose out of a vision of providing sustainable and climate resilient rental units with four 1,275 square foot side-by-side units, each with 2 bedrooms, 2 bathrooms and an attic loft. The development models the use of low carbon and carbon-storing materials, passive solar design, and high-performance construction to yield comfortable, low-impact housing at a competitive market rate. Designed to meet the LEED for Homes certification standard, the project's 7.2 kilowatt photovoltaic system and all-electric appliances and equipment (heat pumps for space and water heating) will help it be close to zero net energy, making it a model of climate smart development.

Given this project's location in a drought and fire-prone region, the project also prioritized water efficiency in addition to carbon. The building stores rainwater for use to flush toilets and irrigate landscapes, and graywater diversion irrigates the landscape in the dry season, reducing the ability for fire to spread to the building.

How Does this Project Reduce Embodied Carbon?

Oceanspray Townhomes uses low carbon design strategies such as efficient building massing and reduced concrete structural design as well as using lower carbon and carbon-storing materials in place of conventional, higher carbon materials to reduce embodied carbon.

The building massing and unit layout is efficient, minimizing the exterior envelope. The design team also reduced embodied carbon through designing the structure to require as little concrete as necessary by minimizing concrete stem walls and footings through a lightweight raised wood framed floor (although these reductions are not captured in the baseline vs. design case quantified below). For the concrete that was required on the project, the team procured a lower carbon concrete mix that uses 59% less Portland cement than a typical mix of the same strength through using slag as a supplementary cementitious material (SCM). This project was the first time the local batch plant and subcontractor had used low carbon concrete.

Using carbon-storing materials was a big priority for the project team. The largest source of carbon storage on the project was from the rice straw bales used for thermal insulation in the exterior walls and acoustic insulation in the party walls. Straw is the stalk of grain crops, and is an agricultural by-product. When baled, it's a good insulator and doesn't burn easily. Kept dry in a well-designed wall system, it does not decay (California Straw Building Association). For this project, straw bales were stacked between traditional wood framing, using a 'Bales On End Between Studs' system, to create well-insulated walls finished with clay plaster on the interior. The project also used dense-pack cellulose for thermal insulation in the roof and the floor. When accounting for the carbon storage of the straw and cellulose insulation used on the project, the project achieves drastic reductions (~76% from baseline).

Permitting the project went smoothly because strawbale construction is allowed in the residential building code in Oregon (among other states), and the City of Ashland building department was responsive and helpful. This multi-family residential project is permitted under the Oregon Building Code (OSSC), rather than the residential code that already allows straw bale. However, the City of Ashland building department reviewed the straw bale fire and acoustic test documents that the team provided and approved the use of bales as both perimeter walls and party walls between units in an R-2 multi-family project.

The project was also able to salvage wood from the demolition on site and use this for the interior stairs, guard rails and trim. Additional materials used included bamboo flooring, wool carpet and lime cement stucco on the exterior.

Image Credit: Jovick Construction, Arkin Tilt Architects

What was the baseline and how was it established?

The project baseline was modeled as an identical building design using conventional materials, including fiberglass batts and exterior foam for thermal insulation, mineral wool batts for party wall acoustic insulation, a conventional concrete mix, and synthetic stucco (acrylic) and fiber cement for the exterior siding. The baseline did already incorporate some lower carbon design strategies, including a foundation design with a low volume of concrete, efficient building massing and unit layout, and a raised floor.

Another comparison point used by the team was the benchmark for new townhome construction published in *Emissions of Materials Benchmark Assessment for Residential Construction* by Builders for Climate Action, Passive Buildings Canada, and The Atmospheric Fund (TAF) in 2022. This benchmark was generated from a data set representing 503 as-built homes of three typologies: single detached, semi-detached and townhouses. For townhouses, the average material carbon intensity was 193 $kgCO_2e/m^2$ (including life cycle stages A1-A3). This provides a useful data point for benchmarking residential construction, and is shown alongside the results reported using the baseline modeled by the design team below.

Life Cycle Assessment (LCA) Approach

LCA Tool/Software Used: BEAM v1.0

Life Cycle Stages Included:	LCA Scope:	LCAs Completed During:
■ **A1-A3**	■ **Substructure**	☐ Pre-design
☐ A4	■ **Shell - Superstructure**	☐ Schematic Design
☐ A5	■ **Shell - Exterior Enclosure**	☐ Design Development
☐ B1	■ **Interiors - Construction**	■ **Construction Documentation**
☐ B2-B3	■ **Interiors - Finishes**	■ **Construction**
☐ B4-B5	☐ Sitework	☐ Completed/Post-Occupancy
☐ B6-B7	☐ Services (MEP)	
☐ C1	☐ Equipment & Furnishings	
☐ C2-C4		
☐ D		

Additional LCA Information

See the '*Life Cycle Assessment Tools*' section in the Introduction for more information on the Building Emissions Accounting for Materials (BEAM) Tool used for this project.

Embodied Carbon Reduction from the Baseline

Results are displayed as the global warming potential (GWP) per unit of floor area in kg CO_2e/m^2 (embodied carbon intensity or ECI) based on outputs from the **BEAM** Tool. The gross floor area was supplied by the project team.

Baseline GWP (A1-A3)*	Proposed Design GWP (A1-A3)	Estimated Embodied Carbon Savings (A1-A3)
105 $kgCO_2e/m^2$	**86 $kgCO_2e/m^2$** 25 $kgCO_2e/m^2$ (with b.c. storage)**	**18%** 76% (with b.c. storage)**

* This baseline was modeled using building materials typical for this type of project in this location.

Baseline GWP (A1-A3)* BfCA Townhome Average	Proposed Design GWP (A1-A3)	Estimated Embodied Carbon Savings (A1-A3)
193 $kgCO_2e/m^2$	**86 $kgCO_2e/m^2$** 25 $kgCO_2e/m^2$ (with b.c. storage)**	**55%** 87% (with b.c. storage)**

*The difference between the modeled baseline and this average ECI for a townhome determined in *Emissions of Materials Benchmark Assessment for Residential Construction* illustrates the impact design decisions and efficiency can have on embodied carbon.

**This value is the "Carbon Storage" inventory metric calculated by the BEAMv1 tool and represents stored carbon in a unit of material. This is different from biogenic carbon flows. This analysis includes storage for biogenic materials sourced from agricultural or forestry residues and recycling streams. No carbon storage is attributed to virgin forest products, including framing lumber, plywood, OSB and wood trusses or I-beams.

See '*Biogenic Carbon Calculation and Reporting*' section of the Introduction for more information.

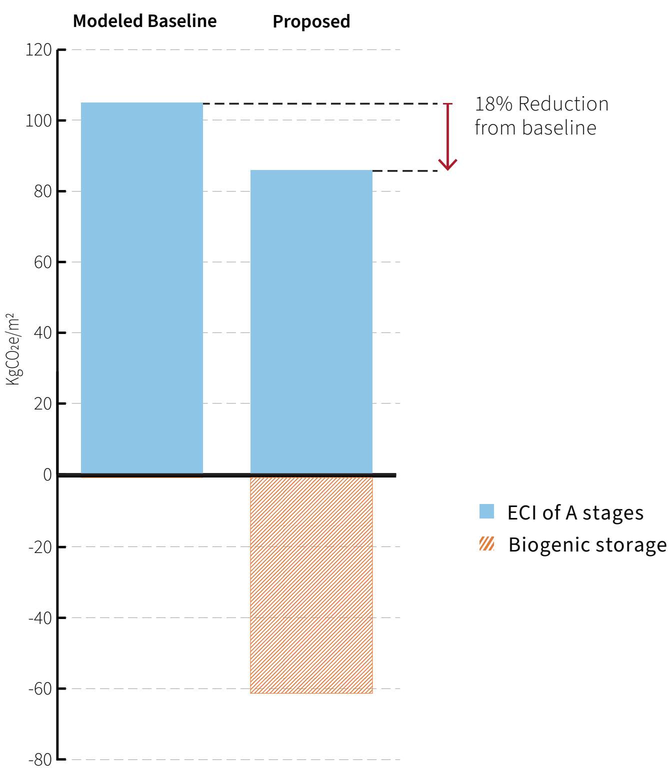

Figure 1. Embodied carbon intensity comparison of baseline and proposed design

Highlights and Lessons Learned

Arkin Tilt Architects has been designing strawbale buildings for over 25 years, using a variety of wall systems on dozens of projects. This project brings strawbale construction into a new context: multi-family residential rental housing. It does so at a competitive price point and low carbon footprint, and provides a chance for many occupants to experience the thermal, acoustic, and aesthetic benefits of strawbale. This was made possible by the whole project team's shared commitment to the goal of making this an example of low-carbon, climate resilient housing, from concept through construction.

The contractor for the Oceanspray project did not have previous experience with strawbale construction, but brought an open mind and enthusiasm to the process. The wall system selected proved well-suited for a contractor who had never built with bales before and a building owner who wanted to limit construction costs. The team looks forward to working with others who share the vision for a decarbonized, healthy built environment, and would certainly use the techniques in this project again to help achieve those goals.

Certifications and Achievements

Designed to meet LEED for Homes Platinum certification

Case Study Contributors:

David Arkin, AIA, Arkin Tilt Architects, who believes that "buildings can become the world's 6th carbon sink."

Tom DeVore, Arkin Tilt Architects

Additional Project Information

Now Under Construction: Oceanspray Townhomes in Ashland, Oregon | Arkin Tilt Architects

Magwood, C., Bowden, E., Trottier, M. Emissions of Materials Benchmark Assessment for Residential Construction Report (2022). Passive Buildings Canada and Builders for Climate Action.

Build Party Blog Post from Luke Lombardi, participant at the Oceanspray Bale Raising

RMI Homebuilders Carbon Action Network Case Studies

Trent University Forensics Crime Scene Facility

EMBODIED CARBON REDUCTION CATEGORY: NON-STRUCTURAL BIO-BASED MATERIALS

Image Credit: Chris Magwood, RMI and Builders for Climate Action

Embodied Carbon Highlights

- Concrete with supplementary cementitious materials (SCMs) used for footings, foundation walls, and floor slab (slag replaced 35-45% of Portland cement)
- Use of foam glass aggregate sub-slab insulation, sourced from Northern Vermont, instead of foam
- Use of two hemp-based materials: Precast hempcrete blocks from a company in Alberta, Canada, instead of CMU, and hemp fiber batt insulation made in Quebec, instead of a spray foam wall system
- Wood-chip Insulated Concrete Form (ICF) foundation
- Replacement of foam exterior continuous insulation with wood fiberboard
- Replacement of mineral fiber roof insulation with cellulose insulation made in Ontario
- Charred wood siding from locally harvested wood and use of bio-based linoleum flooring in classroom areas

PROJECT INFORMATION

Project Name: Trent University Forensics Crime Scene Facility

Region: Eastern Canada

Location: Peterborough, Ontario, Canada

Building Type: Education - College/University

IBC Construction type: Type 5 (although not the formal designation in Canada)

Gross Floor Area: 4,500 ft²

Year of completion: 2021

PROJECT TEAM

Architect: Christopher Z. Tworkowski Architect

Structural Engineer: Building Alternatives

General Contractor: Gerr Construction

Owner: Trent University

Other Team Members:

Zero carbon design and construction consultant: Endeavour Centre/Builders for Climate Action

MEP Engineers & PV Design: ZON Engineering

Overview and Project Goals

Trent University's Forensics Crime Scene Facility is the first-of-its-kind professional forensics training building constructed on a Canadian university campus. The 4,100 square-foot building is home to unique spaces and equipment that pioneer approaches to teach and explore forensic science methodology. This project was the University's first endeavor to design and build a zero-energy building on campus, and the project team embraced the slogan "Emit less, Store more." All products and materials were selected and procured to be the lowest possible embodied carbon, and as many carbon-storing products as feasible were included. In addition to the material choices, the design team pursued a high degree of energy efficiency, with insulation levels upgraded (R-100 attic, R-42 walls, R-28 foundation and slab) and a highly air-tight enclosure (meeting the Passive House minimum requirement of 0.6 ACH50). Heated and cooled with an air source heat pump and with a 43 kWh solar array on the roof, the building has very low energy consumption requirements and is able to meet these on an annual basis with on-site generation.

Trent University set out to build a project that exemplified the institution's commitment to meeting aggressive climate goals on campus. The university wished to be able to quantify its goals, and decided to use the International Living Future Institute (ILFI) Zero Carbon certification as it requires exemplary operational emission reductions while also requiring embodied carbon reductions. A decision was made to attempt to reach the same kind of "net zero" levels of embodied carbon as operational carbon, using novel biogenic carbon stored in products to balance emissions from manufacturing products.

This project is the first building in Canada to receive the ILFI Zero Carbon Certification, a third-party verified, industry-recognized standard verifying that the operational and embodied carbon emissions of a built project have been neutralized. Zero Carbon certified buildings undergo a 12-month performance period and verification by a third party to ensure they are energy-efficient, combustion-free (or actively phasing out combustion), and powered by renewable sources. Under the Zero Carbon version 1.0, active at the time of completion, the project had to comply with a cap on its total embodied carbon of 500 kg CO_2e/m^2 and a reduction of embodied carbon by at least 10% from a base case scenario.

Based partly on the successful example of this project, in 2023 Trent University adopted a Sustainability and Energy Plan, setting goals to achieve net zero operational GHG emissions by 2050 and to complete a scope 3 GHG inventory.

How Does this Project Reduce Embodied Carbon?

The project team sought novel bio-based products to achieve the project's carbon storage goals rather than relying on large volumes of timber products, as they felt that the case for the valuation of carbon storage in short-cycle crops and waste-stream feedstocks was stronger than for virgin timber products. The bio-based products used on the project include two different hemp-based materials, wood-chip insulated concrete form foundations, cellulose insulation, linoleum, and wood siding.

The team also sought to use very low embodied carbon versions of products that could not be replaced with bio-based options, such as expanded glass aggregate insulation for the foundation. Foam glass gravel is a lightweight, thermally insulating aggregate made from recycled post-consumer glass. This lightweight material provides thermal value of R 1.8 per inch and a high structural capacity that allows this one product to replace both sub-slab foam insulation and sub-slab aggregate.

The insulated concrete forms (ICFs) used on the project use waste wood chips bound in cement instead of the typical foam insulation. For the ready-mixed concrete products used in the foundation, footings, walls, and floor slab, the team procured concrete with slag, a waste by-product of steel manufacturing used as an SCM, as a replacement for 35-45% of the Portland cement in the mix.

Precast hemp blocks from a company in Alberta were used as the load-bearing walls instead of CMU, and hemp fiber batt insulation was used to insulate the stud wall cavities instead of spray foam. Hemp fibers are lightweight and make very effective thermal insulators. Hempcrete products like blocks are made from hemp hurd, lime and water.

Image Credit: Chris Magwood, RMI & Builders for Climate Action

What was the baseline and how was it established?

Trent University has established uniform design and construction guidelines for new development on the campus. The design team for this project was able to build a baseline model using these guidelines as a strong indication of the design and product specifications that would have been deployed in a business-as-usual scenario.

The team used the BEAM tool to examine a baseline model for the building to identify the embodied carbon hotspots, and employed the comparison functionality of the tool to identify low-carbon and/or bio-based replacement options. These options were then researched to determine the cost, code, performance, and embodied carbon attributes of each, with the final selection being based on the options that provided all the legal and performance requirements with minimal cost impacts.

Life Cycle Assessment (LCA) Approach

LCA Tool/Software Used: BEAM beta version, with biogenic methods adapted to align with BEAM v1

Life Cycle Stages Included:	LCA Scope:	LCAs Completed During:
■ **A1-A3**	■ **Substructure**	□ Pre-design
□ A4	■ **Shell - Superstructure**	■ **Schematic Design**
□ A5	■ **Shell - Exterior Enclosure**	■ **Design Development**
□ B1	■ **Interiors - Construction**	■ **Construction Documentation**
□ B2-B3	■ **Interiors - Finishes**	■ **Construction**
□ B4-B5	□ Sitework	■ **Completed/Post-Occupancy**
□ B6-B7	□ Services (MEP)	
□ C1	□ Equipment & Furnishings	
□ C2-C4		
□ D		

Additional LCA Information

See the '*Life Cycle Assessment Tools*' section in the Introduction for more information on the Building Emissions Accounting for Materials (BEAM) Tool used for this project.

Embodied Carbon Reduction from the Baseline

Results are displayed as the global warming potential (GWP) per unit of floor area in kg CO_2e/m^2 (embodied carbon intensity or ECI) based on outputs from the **BEAM** Tool. The gross floor area was supplied by the project team.

BaselineGWP (A1-A3)	Proposed Design GWP (A1-A3)	Estimated Embodied Carbon Savings (A1-A3)
518 $kgCO_2e/m^2$	**224 $kgCO_2e/m^2$** 77 $kgCO_2e/m^2$ (with b.c. storage)*	**57%** 85% (with b.c. storage)*

*This value is the "Carbon Storage" inventory metric calculated by the BEAM beta tool and represents stored carbon in a unit of material. This is different from biogenic carbon flows. This analysis includes storage for biogenic materials sourced from agricultural or forestry residues and recycling streams. No carbon storage is attributed to virgin forest products, including framing lumber, plywood, OSB and wood trusses or I-beams.

See '*Biogenic Carbon Calculation and Reporting*' section of the Introduction for more information.

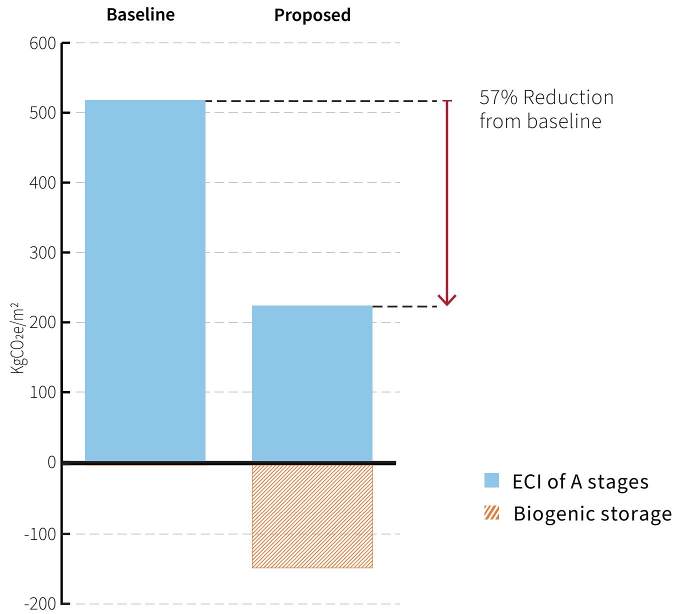

Figure 1. Embodied carbon intensity comparison of baseline and proposed design

Highlights and Lessons Learned

Hitting the embodied carbon target was ultimately easier than achieving the net zero operational energy goals on this project. For example, for the contractor, learning how to do advanced passive design level air sealing was more unique to their typical practice and challenging to implement than learning to install a different type of batt insulation or pour lower carbon concrete.

This was the first time many of the construction team members had worked with any of these innovative materials and realized some benefits during construction. They found that installing the hemp batt insulation did not cause the itchiness and coughing they sometimes experienced installing typical fiberglass batt. The wood-chip Insulated Concrete Form (ICF) foundation was another well-liked material on-site. The material can be cut with regular wood-working tools which makes it quick and easy to install.

The Endeavour Center team handled the hemp block installation, as it was a new product for the whole team, and required that the foundation was leveled to accommodate only an 1/8-inch tolerance for the 'snap fit' hemp blocks, which was a time-consuming process.

Installing the foam glass sub-slab insulation was a labor-saving realization for the contractor because it is a single-step process, and replaced the two-step process of first pouring and leveling gravel and then cutting and trimming typical foam sheets around the pipes, openings and corners.

Excluding the photovoltaics, the cost per square foot of this project ended up approximately the same as typical projects on the Trent University campus.

Certifications and Achievements

The First Building in Canada to Receive the International Living Future Institute (ILFI) Zero Carbon Certification - Trent Forensics Facility Becomes First Building in Canada to Receive ILFI's Zero Carbon Certification - News

Case Study Contributors:

Chris Magwood, RMI and Builders for Climate Action

Additional Project Information

Forensic Science - Trent University

Endeavour Center Sustainable Building School - series of construction blog posts