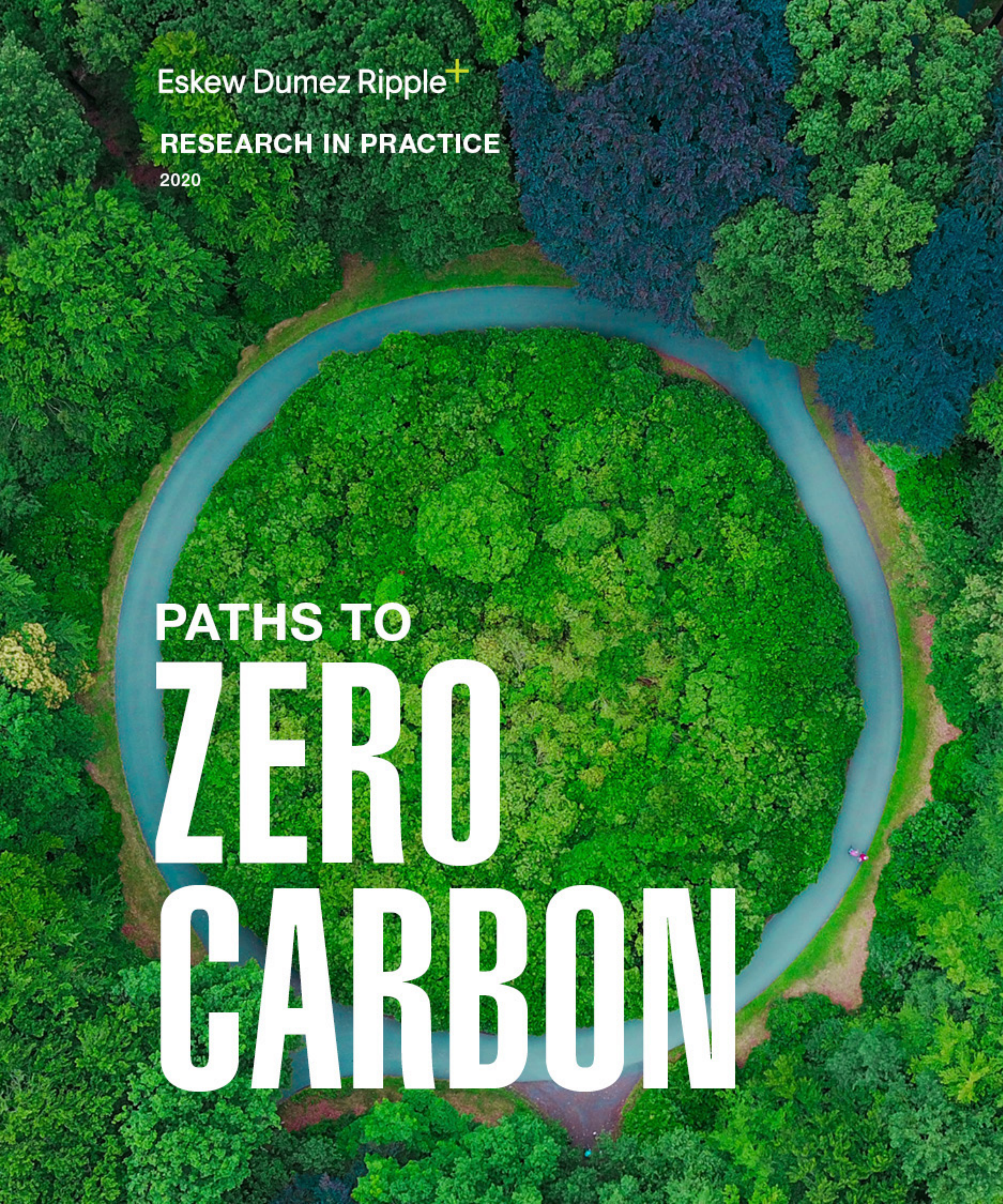


Eskew Dumez Ripple+

RESEARCH IN PRACTICE

2020

PATHS TO ZERO CARBON

ISN'T CARBON IN MY SODA?

INTRODUCTION

"Global warming is, after all, a human invention. And the flip side of our real-time guilt is that we remain in command. No matter how out-of-control the climate system seems... we are all its authors. And still writing."

- David Wallace Wells

Carbon emissions are the invisible building blocks of the architectural indsutry. As architects, we consider ourselves optimists, designing environments for the future, one we can envision to be better than today. The spaces and buildings we inhabit influence our day to day lives, our cities, and our interactions with others. They also have impacts far beyond what we can see, touch, or experience. Those impacts include environmental, and specifically climate change contributions. The way we construct and operate buildings today is a major contributor to climate change, and improved ways to construct and operate buildings can be a major part of the solution. Global data demonstrates building operations and building operations and materials as comprising 40% of annual global carbon emissions.[1] Our industry is responsible for, and capable of, reducing carbon emissions dramatically.

Buildings are responsible for 40% of annual global CO_2 emissions.[1] Carbon associated with buildings can be broken into two types:

OPERATIONAL CARBON

This is the carbon emissions related to building operations.

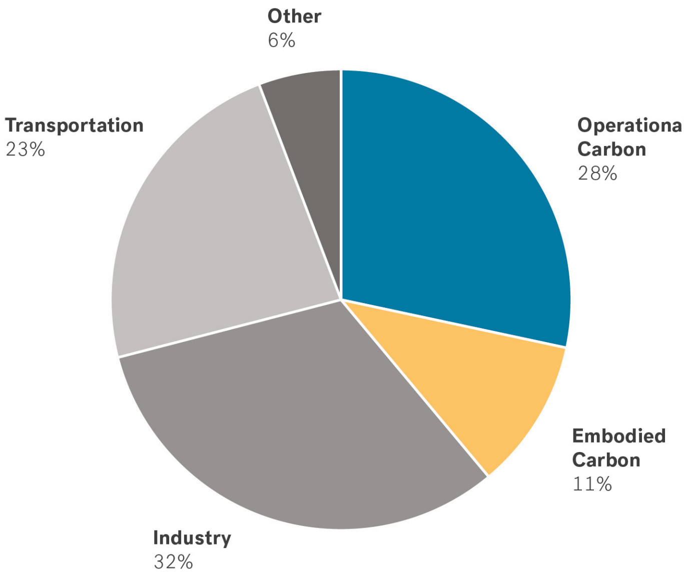
EMBODIED CARBON

Carbon associated with building materials and construction.

Both operational and embodied carbon need to be reduced to remediate climate change impacts associated with architecture. The following case studies set a few of the many paths to carbon reduction. While each study measures both operational and embodied carbon, each project has a major win in reduction of at least one of these two carbon impact.

The AIA 2030 Commitment provides a framework within which architects can target operational carbon through prioritizing energy performance, "more easily work toward carbon neutral buildings," and recently encourages tracking, measuring, and managing embodied carbon.[2] The Architecture 2030 Challenge is as follows:

For buildings constructed in 2020, operational carbon emissions should be reduced by 80% from the national average and the reduction targets get increasingly aggressive - 90% by 2025, and carbon neutral by 2030.[3] The Challenge sets out similar targets for embodied carbon, tiering from a 40% reduction today, 45% in 2025, and 65% by 2030.[4]



Annual CO2 Emissions

HOW TO USE THIS BOOK

The information in this book is meant to be a resource to help designers consider the carbon emissions implications of their decisions throughout the design process. The first component, Case Studies, describes specific lessons of carbon emissions through project-specific examples, with real world costs. The second, Carbon Fluency, supports the case studies and language specific to life cycle analysis. If you don't understand a term in the case studies immediately, look to this section for definitions, standards, and explanations. Carbon Fluency defines common carbon terms, their abbreviations, and why we need to measure and understand impacts of carbon emissions as designers. The Appendix that follows details terminology, case study methodology, inclusions and exclusions, recommended standards, materials, and "lagniappe" resources.

This reference is intended to help architects get started thinking for themselves about carbon. But there are many situations in which the decisions require engaging the entire project team: engineers, mechanical, contractors (including mechanical sub-contractors), material suppliers and manufacturers, and building owners:

Become Carbon Fluent

Share definitions and goals with the entire project team from the start. When carbon becomes a part of the discussion in design, material specifications, or energy efficiency, everyone will understand (or have the resources to understand) the terminology used and why it needs to be a part of the project goals. See and share the Carbon Fluency section of this book.

Set Project Carbon Targets

The architectural community commonly works within design parameters. Buildings must meet energy code targets, budget limits, occupant health standards, and the list continues. Targets and caps guide project decisions throughout design so the entire team works toward a shared goal. Include embodied and operational carbon targets in each project. See Case Studies to better understand setting targets through real world examples of an array of project types in order to establish an appropriate baseline for your next project.

Make Better, Informed Design Decisions

Building materials (steel, concrete, and aluminum) are responsble for 11% of annual global carbon emissions.[1] Commonly used in structure, optimizing material use through structural design early in the project is a lever of biggest impact in reducing embodied carbon. Choose the best fit and lowest impact structure for project type. See Case Studies to weigh structural system impacts. The Case Studies Table of Contents quickly compares building size, cost, embodied and operational carbon to 2030, alongside structural system and in comparison to each other.

COMPONENT ONE:
CASE STUDIES

LESSONS LEARNED AND APPLIED PATHS TO CARBON ZERO

We know we need to reduce our carbon footprint in the building sector. Architecture2030 provides goals for carbon emissions reduction: for buildings constructed in 2020, operational carbon emissions should be reduced by 70% from the national average and aim for a 40% reduction in embodied carbon. Through a portfolio sample of eight projects, a case study approach measures if these targets are met, and how much it would cost to do so. For more details on these goals, benchmarks, and terms used within the case studies, see Component Two: Carbon Fluency.

These studies revealed a few key takeaways. **Operational carbon reductions of 70% are easily achievable and cost effective**, across building types, and in varying climate regions. **Embodied carbon reductions of 40% are much more difficult**, but 1**0% reductions through structural optimization** and **mindful material choice** are achievable at **little to no cost premium**.

Analysis of the embodied carbon of new construction underscores that structure dominates, and that wood structure offers particular promise to lower the carbon impact of construction. More work is being done to verify assumptions being made about building with wood. Look to next year's fellows for more information on this topic.

CASE STUDIES

The ZEROCode framework was applied to each case study. The ZEROCode standard complements Architecture2030 goals in energy reduction, with efficient building design as the first step in the standard. Second is to supply the energy needed through zero emissions infrastructure, in the form of on-site or off-site renewables.[5] Purchase of Renewable Energy Certificates (RECs) to the ZEROCode standard, regardless of region in which the building operates, costs about a 5% premium to the annual energy bill (where operational savings are about 50%). Building on site costs more, but offers benefits such as islanding in a grid shut down.

Structure and envelope are the key building components to focus on for embodied carbon reduction. As designers, our biggest impact is early, in picking structural system. 40% reductions are achievable by trading out an entire structural system. There is interest in lowering the embodied carbon of construction through increasing the use of wood, especially mass timber components such as Cross Laminated Timber (CLT), for building structure. At present, the use of mass timber comes at a cost premium, but one that is shrinking as production scales up and experience is gained. The net environmental impact of wood depends on forestry practices in ways that are a subject of active research.

System optimization and market-ready strategies reduce carbon with little to no additional cost. Envelope design choices are significant, specifically insulation type and blowing agents. These types of choices still allow freedom in design and aesthetic, influencing carbon footprint almost invisibly.

Structure and envelope material choice and optimization together can reduce carbon by about 10%, with little effort and cost. Reductions beyond that amount would take early intervention in design, thorough and iterative optimization, and as noted, likely entire material substitutions.

TABLE OF CONTENTS

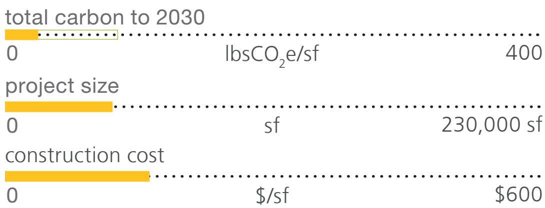
SUMMARY

EMBODIED CARBON AND 10-YEAR OPERATIONAL CARBON

- concrete + steel
- renovation
- wood
- operational

$lbsCO_2e$ = CO_2 equivalent
**includes MEP*

ST. PETER'S RESIDENTIAL

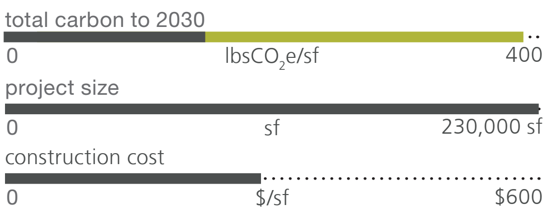


NET ZERO

23 lbsCO2e/sf
pEUI: 17 kBtu/sf/yr
operational: 0 $lbsCO_2e$/sf/yr
45,000 sf
embodied: 23 $lbsCO_2e$/sf

$164/sf
multi family

NEW ORLEANS RESIDENCE HALL

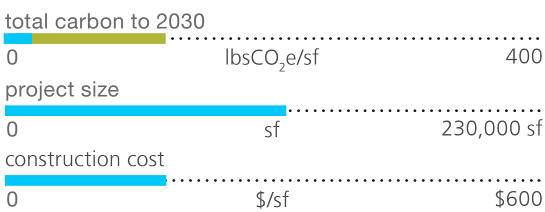


HVAC CHOICE

201 lbsCO2e/sf
pEUI: 43 kBtu/sf/yr
operational: 10 $lbsCO_2e$/sf/yr
230,000 sf
embodied: 101 $lbsCO_2e$/sf*

$295/sf
dormitory

OFFICE RENOVATION

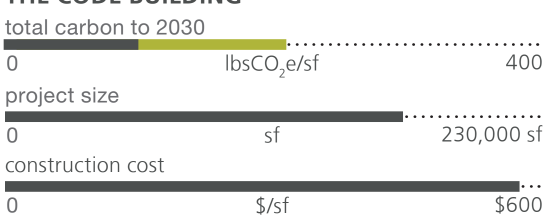


MEP RETROFIT

120 lbsCO2e/sf
pEUI: 32 kBtu/sf/yr
operational: 10 $lbsCO_2e$/sf/yr
130,000 sf
embodied: 20 $lbsCO_2e$/sf*

$185/sf
office renovation

THE CODE BUILDING

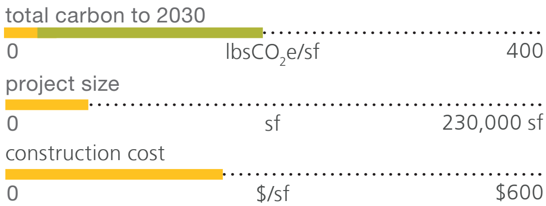


RECS FOR ZERCODE

141 lbsCO2e/sf
pEUI: 27 kBtu/sf/yr
operational: 6 $lbsCO_2e$/sf/yr
170,000 sf
embodied: 81 $lbsCO_2e$/sf*

cost confidential
office

THADEN SCHOOL HOME BUILDING

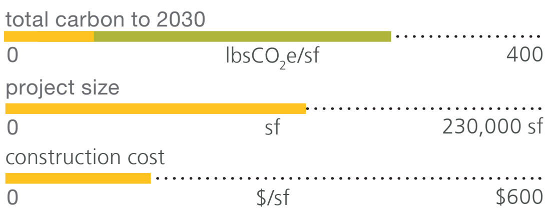


TIMBER RIGID FRAME

130 lbsCO2e/sf
pEUI: 34 kBtu/sf/yr
operational: 10 lbsCO_2e/sf/yr
35,000 sf
embodied: 30 lbsCO_2e/sf

$249/sf
school

THE SHOP SLC AND MYA

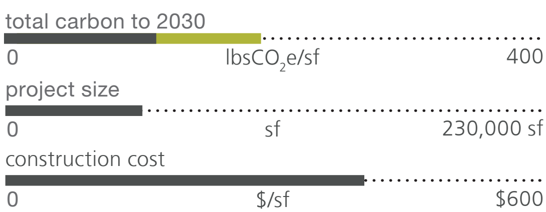


MIXED STRUCTURE

163 lbsCO2e/sf
pEUI: 43 kBtu/sf/yr
operational: 11 lbsCO_2e/sf/yr
130,000 sf
embodied: 53 lbsCO_2e/sf

$165/sf
mixed use

U.S. FEDERAL COURTHOUSE

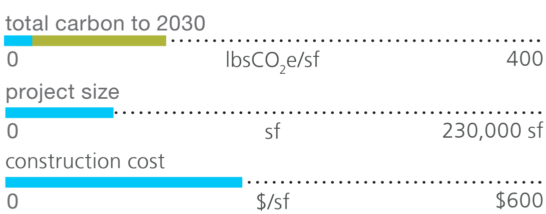


CONCRETE MIX

176 lbsCO2e/sf
pEUI: 27 kBtu/sf/yr
operational: 8 lbsCO_2e/sf/yr
58,000 sf
embodied: 96 lbsCO_2e/sf*

cost undisclosed
courthouse

LYCEE FRANCAIS



RENOVATION

95 lbsCO2e/sf
pEUI: 34 kBtu/sf/yr
operational: 7 lbsCO_2e/sf/yr
45,000 sf
embodied: 25 lbsCO_2e/sf

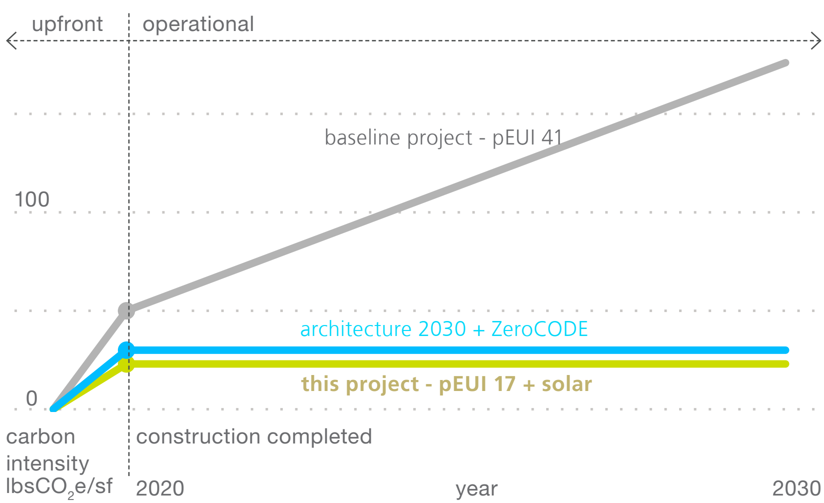
$272/sf
office renovation

NET ZERO ON A BUDGET
ST. PETER'S RESIDENTIAL (SBP)

NET ZERO MULTI FAMILY HOUSING PROJECT WITH ABILITY TO ISLAND IN CRISIS

A client curiosity about **battery power** for buildings when talking about resilience in the face of storm-related power outages sparked conversation about **energy use** in this project. Once **ability to island in the event of power loss** became clear to design teams, steps were taken to design for a **low energy use building**. From there, an **all-electric design** was proposed, and had the ability to be fully powered by **on site solar panels**. Curiosity led to a **net-zero design**, built on a budget.

WHOLE-BUILDING CARBON INTENSITY OVER TEN YEARS



ST. PETER'S RESIDENTIAL

CASE STUDY

PROJECT INFO

Project Type: multi-family residential
New Construction
45,154 sf
Site: 91,021 sf
Stories: 3
Location: New Orleans
Climate Zone: 2A
EnergySTAR and Net Zero

EMBODIED CARBON

Main Structural Material: stick-framed wood
Foundation Material: timber piles and concrete slab
Meets Architecture2030 40% reduction target

OPERATIONAL CARBON

0 lbsCO_2e/sf/yr

**60 lbsCO_2e/sf over 10 years before solar*

0 lbsCO_2e/sf 200

Annual Operational Carbon: 6 lbsCO_2e/yr, *before solar*
pEUI: 23 kBtu/sf/yr, *projected*
Meets ZEROCode Standard with on site solar

BUDGET

$164 per square foot

Construction cost including solar panels and battery back up. Base building construction cost was $153 per square foot - before solar and batteries.

ZEROCODE COST

Adding on site solar has a **one-time upfront cost of $8.00/sf**, but in a net-metering billing framework can eliminate annual energy bills. **This array pays for itself through energy cost savings in under 13 years.**

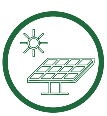
Annual Energy Bill:
$0.58/sf, *estimated, without solar*
$26,100 total, *estimated*

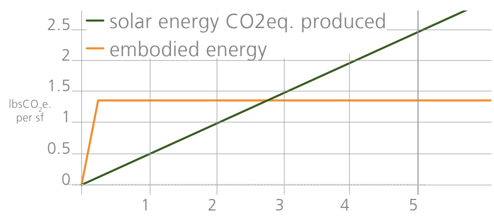
$8.00 on site solar cost per square foot (one time cost)

St. Peter's Residential from the sky. All available roof area is covered in solar panels.

PV PANEL PAYBACK THROUGH SOLAR POWER

Based on the **low pEUI (**Predicted Energy Use Intensity) **of 17**, this project would emit 130 tonsCO_2e. each year (120 tons less than the national average multi-family building) for its power use. With **100% on-site solar power** feasible, **St. Peter's Residential is a net zero project**. The annual production from the solar away is equal to the predicted annual consumption. Installation and construction cost of the solar array **pays itself off in less than 8 years** through **energy bill savings**. PV embodied carbon offsets its upfront carbon emissions with clean energy produced in about three years.





DESIGNING FOR OPTIMIZED ENERGY PERFORMANCE

Tight Envelope:

- continuous insulation
- field-verified airtightness

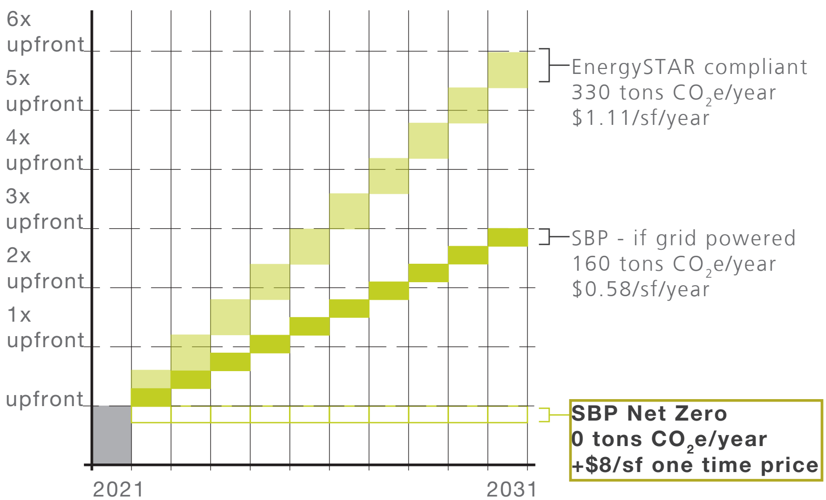
HVAC and Water Heating:

- SEER 17 AC heat pumps
- heat pump water heaters

Efficient Appliances:

- EnergySTAR rated appliances

10-YEAR OPERATIONAL AND EMBODIED CARBON COMPARED

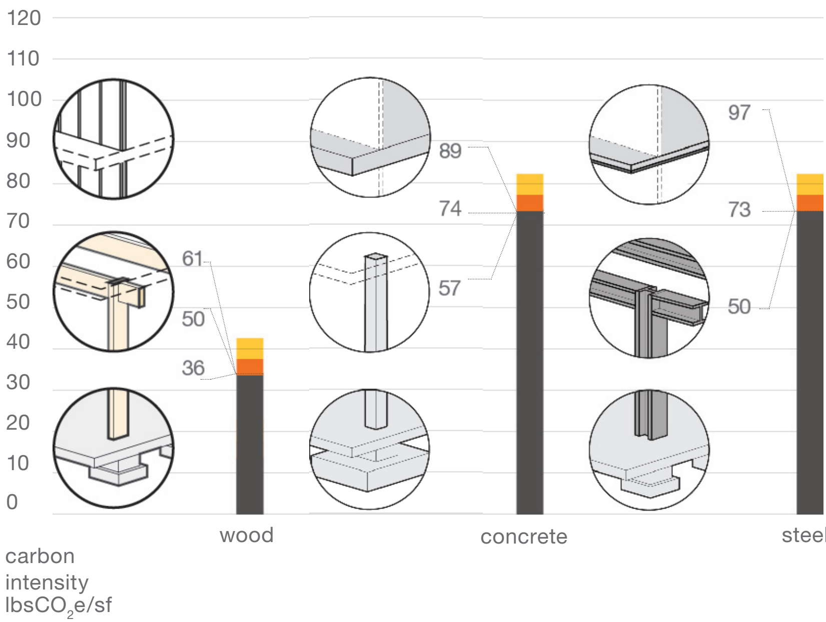


0 tons CO_2e per sf per year

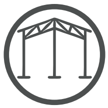
CARBON STORAGE IN WOOD

Trees grow from absorbing CO_2 and some of that CO_2 stays in lumber products (lumber is about 50% carbon). Some carbon accounting takes credit for this stored carbon, called sequestration, in the overall carbon footprint. Even leaving this sequestration out of the equation, **wood has a lower CO_2 footprint** than other common structural elements like concrete or steel. Because of its light weight, wood construction also offers **carbon savings** benefits through foundation (and therefore concrete) reduction. **Emissions avoided** in smaller foundations are an additional benefit to the natural carbon savings inherent in wood. This study includes biogenic carbon.

LOW CARBON DESIGN BY STRUCTURE CHOICE



STRUCTURE 60%



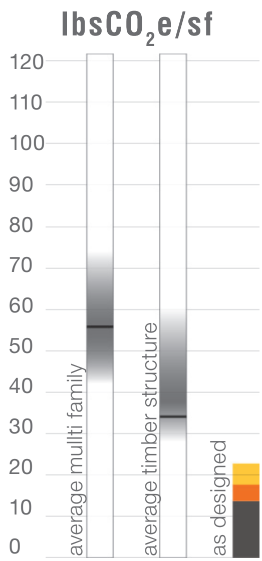
Wood construction
- timber piles
- stick framed
- wood joists
- concrete foundation

ENVELOPE 17%

Exterior wall assembly
- Zipwall sheathing
- glazing and mullions

INTERIOR 21%

Simple finishes
- gypsum wall finishes with paint
- gypsum ceilings
- wooden doors



23 $lbsCO_2e$ per square foot

*averages from Carbon Leadership Forum database

ST. PETER'S RESIDENTIAL

CASE STUDY

Battery storage shed near community area in foreground with apartments beyond.

BONUS - BATTERIES FOR RESILIENCE

The non-profit organization acting as developer of this affordable housing project specializes in helping communities recover after disasters. Since power outages commonly accompany such disasters, this client was interested in adding battery backup to the project. Proposed efficiency upgrades lower peak demand and extend battery life during outages. Adding in on site solar PV generation (178kW) to the battery installation (125kW / 371kWh capacity) allowed the developer to access tax incentives for this combined system. The battery system's capacity is equal to 15 hours of average consumption. A local utility donated $1M to the project budget to cover efficiency upgrades solar, and battery systems and will study how these facilities can act as 'grid citizens.'

SIMPLE, ATTAINABLE STRATEGIES AT A LOW COST

The study illustrates an **affordable**, **simple construction method** with **low embodied carbon** impacts available in the industry for implementation and execution now. Uncertainties in comparison reveal a need for absolute benchmarks to be established in order to further progress Architecture 2030 goals, but reporting this study helps to expand the dataset on embodied carbon of construction.

Funding programs and partnerships helped to make **on site solar power** accessible. Better than code energy requirements by EnergySTAR certification set the project up to be highly energy-efficient, further facilitating implementation of **net zero**. **Operational energy emissions** were drastically **reduced**, then eliminated through clean power generation on site. St. Peter's Residential sets an example of **meeting ZEROCode standards** through on site power generation, and does it at a low cost.

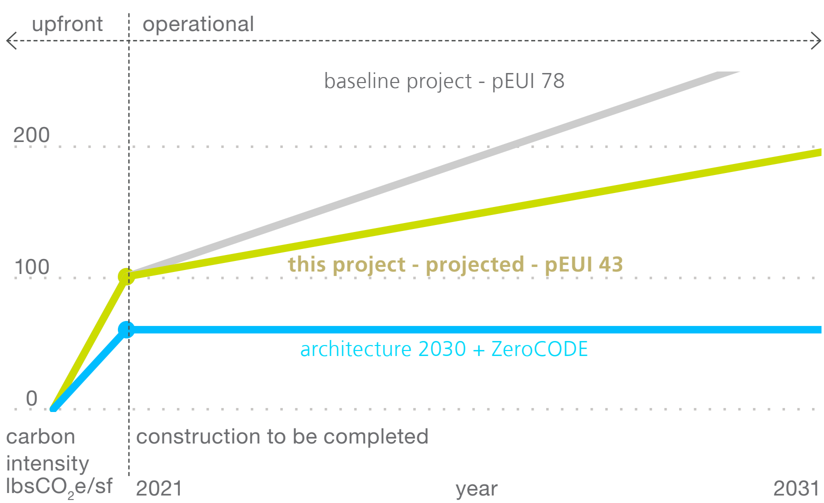
Embodied carbon was also quite low for the construction of St. Peter's Residential. This was accomplished through simple building techniques (wood-framed construction), and careful, minimal use of high upfront carbon materials, like glazing. Timber piles rather than concrete have a lower carbon footprint, too. **Less is more**, from designed elements to energy use.

UPFRONT VS LIFECYCLE COST IN DESIGN
NEW ORLEANS RESIDENCE HALL

THINKING FOR DURABILITY, LIFESPAN, COST, AND CARBON IN DESIGN LCA STUDY

This design-phase LCA of a residence hall balances **upfront costs**, **operations**, **durability**, and **maintenance**. With campus power, HVAC system design should provide a significant cost and **energy savings** for New Orleans Residence Hall Commons. The **less expensive** - initial and operational costs - system was ultimately specified, with energy savings. The system will provide a **better building** for the occupants and the planet, with better fresh air turnover rates and **less CO_2 emissions**.

WHOLE-BUILDING CARBON INTENSITY OVER TEN YEARS



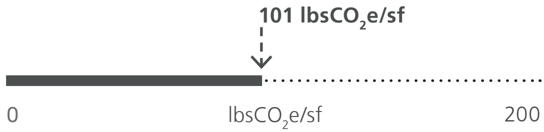
NEW ORLEANS RESIDENCE HALL

CASE STUDY

PROJECT INFO

Project Type: dormitory
New Construction
229,272 sf
Site: 81,000 sf
Stories: 7
Location: New Orleans
Climate Zone: 2A
LEED Silver Targeted

EMBODIED CARBON



Main Structural Material: light gauge steel framing
Foundation Material: concrete piles and grade beams
Does not meet Architecture2030 reduction target

OPERATIONAL CARBON

10 $lbsCO_2e/sf/yr$

**100 $lbsCO_2e/sf$ over 10 years*

0 $lbsCO_2e/sf$ 200

Annual Operational Carbon: 9 $lbsCO_2e/sf/yr$
pEUI: 43 kBtu/sf/yr, *projected*
Could meet ZEROCode Standard with RECs

BUDGET

$295 per square foot

Construction cost, from preliminary, SD level estimate.

ZEROCODE COST

Designing a better than baseline building saves $0.37/sf/yr in energy costs. Purchasing RECs to the ZEROCode Standard would add only a **2% premium** for the project to effectively be zero carbon operations, and still represents an **energy savings of $0.35/sf/yr.**

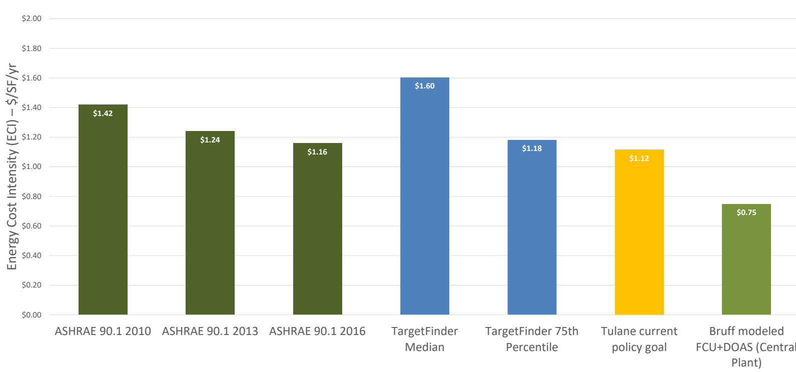
Annual Energy Bill:
$0.75/sf, *estimated,*
$201,945 total, *estimated*

$0.07 ZEROCode RECs per square foot (cost per year)


Dorm double height lounge area.

FIRST COST AND OPERATIONAL COSTS

Project **sustainability** and **efficiency goals** can be met at an **affordable cost**. Good thermal comfort for dormitory occupants and **high air quality** standards are optimally designed through use of DOAS, and the HVAC system with the **best energy performance comes at the lowest upfront cost**. This system also has the **lowest operation** and **maintenance costs**.



DESIGNING FOR OPTIMIZED ENERGY PERFORMANCE

Lighting:

- LED fixtures
- occupancy sensors
- low LPD (.4W/sf)

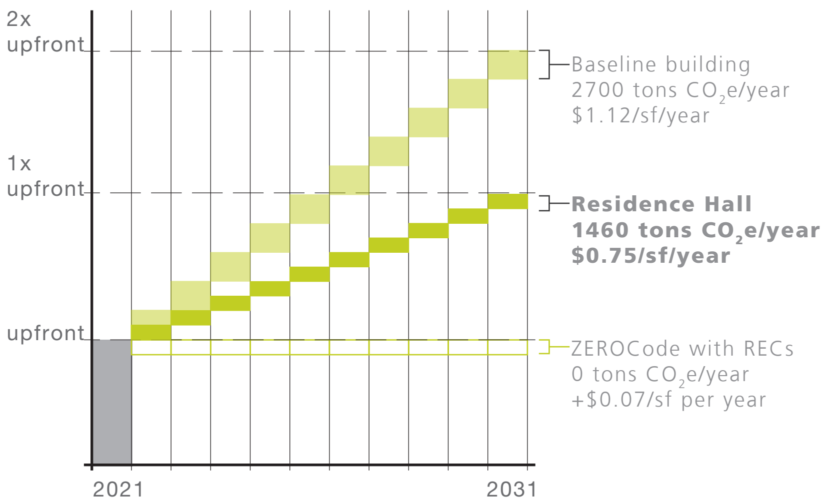
FCU HVAC System:

- FCU (Fan Coil Unit) + DOAS system efficiencies
- DOAS provides better fresh air return rates and better occupant comfort

Power Plant:

- on campus central plant provides energy efficiency savings, and uses a system that's already in place

10-YEAR OPERATIONAL AND EMBODIED CARBON COMPARED



10 lbsCO_2e per sf per year

MEP SYSTEM EMBODIED CARBON CONTRIBUTIONS

16 lbsCO_2e per square foot

Weighing mechanical system options provided **operational energy savings**. The system also comes at an upfront carbon cost. When considering life cycle costs, the embodied carbon of this MEP system is minimal compared to the grid and energy savings it provides.

DURABILITY, MAINTENANCE, AND MATERIAL IMPACTS

Interiors are projected to be only 15% (or 15 lbsCO2 e/ft2) of LCA impacts for New Orleans Residence Hall. As the table below shows, flooring choice has a significant impact, although its maintenance over 60 years will be the the most significant. The table below studies impacts of durability and material replacement on Global Warming Potential (GWP) of this project. Often ignored in LCAs, interiors are thought to have a 'low' material impact. In high-traffic projects such as dormitories, emissions throughout Use or Module B - which includes maintenance and replacement - adds up over time.

	60-Year Total (A1-A3&B2 lbsCO_2e/ft^2)	**Production** (A1-A3, lbsCO_2e/ft^2)	**60-Year Use** (B2, lbsCO_2e/ft^2)
LVT (interface)	7.1	2.2	4.9
LVT (industry)	8.2	3.3	4.9
Linoleum (floro)	4.1	0.1	4.0
Carpet Tile (nylon)	33.5	3.2	22.3

HOW MUCH DOES MY BUILDING WEIGH?

STRUCTURE 65%

- concrete foundations
- concrete grade beams
- steel floor decks
- light gauge steel walls

ENVELOPE 20%

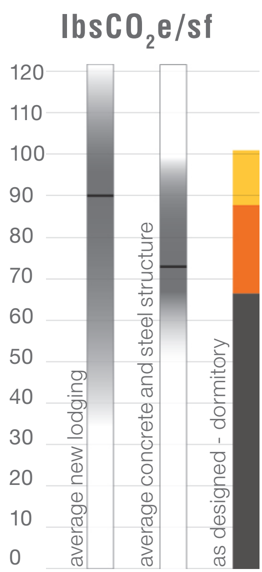
Campus feel

- brick to match campus
- ACM panels
- glazing
- curtain wall system

INTERIOR 15%

Durable finishes

- LVT flooring
- doors
- fiberglass ceiling tiles



101 $lbsCO_2e$ per square foot

*averages from Carbon Leadership Forum database

SHELTER IN PLACE CAPABILITY

Designed with a gas-fueled generator, New Orleans Residence Hall will have a three day shelter in place capability. Driving initial energy use intensity down saves upfront cost on generator size, and allows for shelter in place for students in the event of lost power and disaster.

LIFECYCLE THINKING

During design, the team **balanced multiple concerns**. The **biggest impact** in the study of this project was in the weighing of **upfront costs versus life cycle costs** - both dollars and **carbon footprint**.

Together, the design team and client looked at HVAC system choices - weighing efficiencies and costs in decision making. The designed choice is projected to cost less initially and over its lifespan - and will **save 3500 tons CO_2e per year!** Maintenance and facilities are stakeholder concerns can be met at an effective cost. This case study allowed for the design team to study upfront and lifecycle costs in finishes while decisions could still be influenced by the analysis.

For a dormitory building, durability, maintenance, use, and upkeep costs are important design factors in finishes, especially flooring. This study shows that a low upfront carbon material (marmoleum flooring) can have very similar lifecycle emissions after examining maintenance and replacement as a standard finish (LVT).

The use of lifecycle thinking and analysis as a **tool during design** informs project decisions, and allows teams to make better material choices. Budget is always a factor to balance, and as architects, we are always weighing multiple concerns to make the best choice available. The ongoing study of New Orleans Residence Hall Commons throughout design phases facilitates balancing budget with measurable sustainability. While the first choice may not always be an option - as demonstrated by the flooring study - with thorough analysis, negative environmental impacts can still be minimized.

This design-phase LCA can later be compared to constructed building LCA when the project is complete, allowing project teams to better understand where disparity may occur between studied values and reality of construction material. This LCA is demonstrative of **LCA as a process tool** to inform design, not just a backward benchmark analysis.

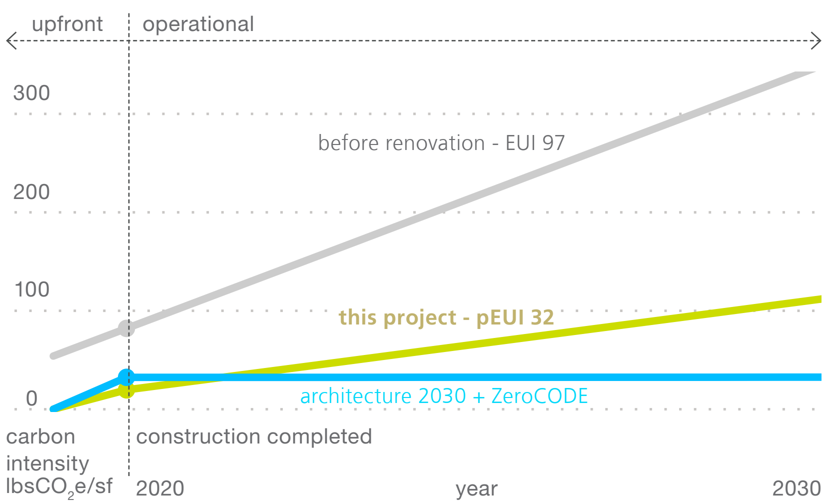

YA GOT DAT RIGHT!

RETROFIT CARBON REDUCTIONS
OFFICE RENOVATION

DESIGN OPPORTUNITIES IN MECHANICAL SYSTEM AND BUILDING RETROFIT

The **interior renovation** presents a design opportunity as a result of necessary **mechanical system upgrades**. Improving building efficiency and **quality of space** are linked goals in the project. **Improving daylighting** within the space resulted in **minimal walls and partitions**, providing carbon savings through material reduction. Air quality and **occupant comfort** improvements are tied to the **new mechanical system** with **better energy performance**.

WHOLE-BUILDING CARBON INTENSITY OVER TEN YEARS



OFFICE RENOVATION

CASE STUDY

PROJECT INFO

Project Type: office
Renovation
130,467 sf
Site: 149,846 sf
Stories: 8
Location: Louisiana
Climate Zone: 2A
LEED Silver Targeted

EMBODIED CARBON

Main Structural Material: existing concrete and steel
Foundation Material: existing concrete
Meets Architecture2030 40% Reduction Target

OPERATIONAL CARBON

7 $lbsCO_2e/sf/yr$

**70 $lbsCO_2e/sf$ over 10 years*

0 — $lbsCO_2e/sf$ — 200

Annual Operational Carbon: 7 $lbsCO_2e/sf/yr$
pEUI: 32 kBtu/sf/yr, *estimated*
Could meet ZEROCode Standard with RECs

BUDGET

$185 per square foot

Construction cost of interior renovation, finishes, and mechanical system upgrades. The mechanical system cost about $70 per square foot.

ZEROCODE COST

Renovating an existing building with mechanical system upgrades saves $0.68/sf/yr in energy costs. Purchasing RECs to the ZEROCode Standard would **effectively make the project zero carbon operational**, and still represents an **energy savings of $0.64/sf/yr** from the existing system.

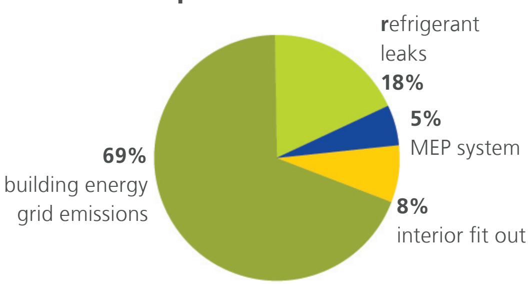
Annual Energy Bill:
$0.27/sf, *estimated,*
$35,100 total, *estimated*

$0.04 ZEROCode RECs per square foot (cost per year)

Office Renovation stair and designed double height spaces aid in daylighting and encourage occupant activity.

MEP RETROFIT UPGRADES AND EMISSIONS TO 2030

Operational efficiency is well worth the embodied carbon of mechanical system upgrades to this office renovation. Providing a **70% annual energy bill savings**, the **deep energy retrofit** demonstrates **carbon savings through building operations**. Even with the benefit and **energy savings** shown in the graph to the right, the pie chart below shows significant grid emissions remain. For **less than a nickel** per square foot per year, the **purchase of RECs** would make **Office Renovation ZEROCode compliant**.



2020-2030 emissions

DESIGNING FOR OPTIMIZED ENERGY PERFORMANCE

Lighting Upgrades:

- LED fixtures
- occupancy sensors ensure minimal waste

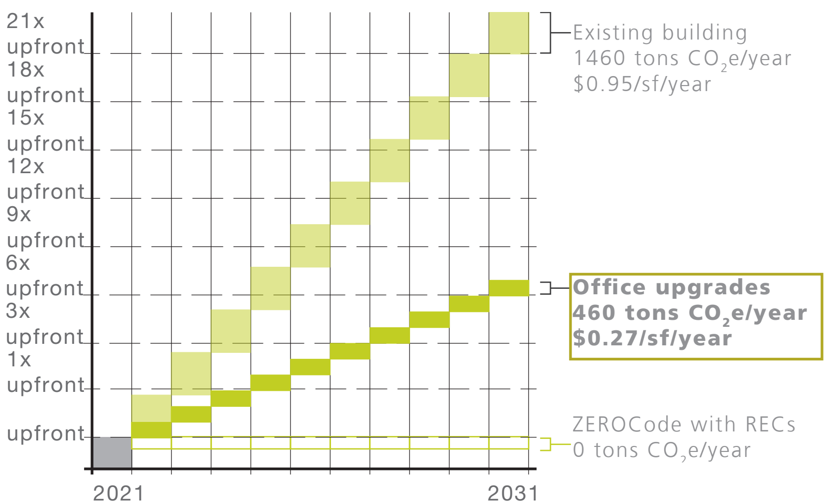
Efficient Lighting:

- low LPD (.56 W/sf)
- floorplan adjusted to optimize daylight with existing building, allowing perimeter light to penetrate the floorplate further

VRF HVAC System:

- switch from VAV to VRF offers system efficiencies
- DOAS provides better fresh air return rates and better occupant comfort

10-YEAR OPERATIONAL AND EMBODIED CARBON COMPARED



7 lbsCO_2e per sf per year

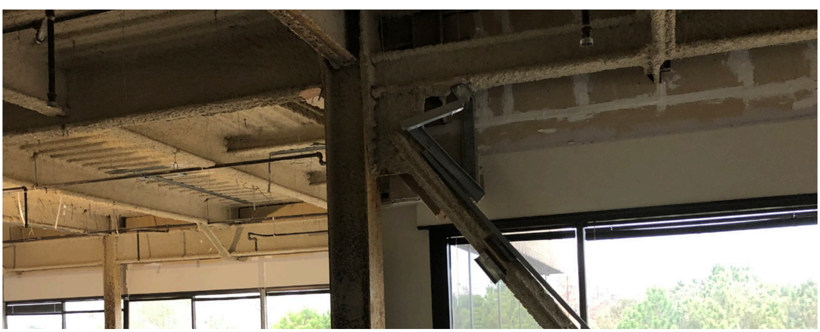
MEP SYSTEM EMBODIED CARBON CONTRIBUTIONS 40%

8 lbsCO_2e per square foot

Mechanical system upgrades provided **operational energy savings**. Mechanical system upgrades are significantly valuable in a building renovation cycle and given the time value of carbon. **For this project, MEP systems contribute ~40% of the total renovation embodied carbon impact.** See next page for details.

EXISTING STRUCTURE FOR LOW CARBON IMPACT

In comparison to a new construction office building, Office Renovation achieves an **85% reduction** in embodied CO_2 emissions. By **retaining existing structure and envelope**, the high-impact upfront carbon items, **emissions are avoided**. Design teams were conscious about **recycling** existing carpet and metals removed from the building, which provides a CO_2 emissions benefit in the demolition process. **Minimal interior finishes** (such as refinishing existing concrete as the flooring material) limited emissions, but that benefit was a result of **designing an open floorplan**, with better circulation, creating a **daylit** office space.



HOW MUCH DOES MY BUILDING WEIGH?

STRUCTURE 0%

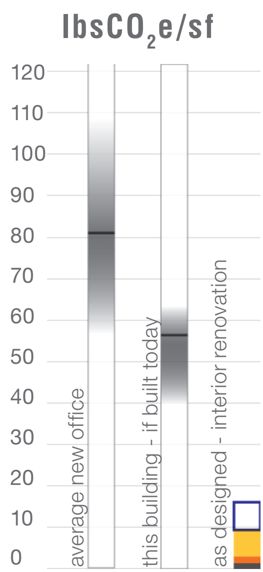
Retained existing
- foundations
- columns
- beams
- floor decks

ENVELOPE 4%

Retained existing
- interior sheathing
- glazing and mullions
- insulation
- cladding

INTERIOR 96%

Minimal finishes
- new wall framing
- new gypsum walls
- new dropped ceiling



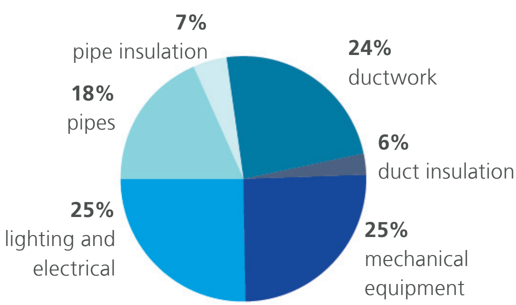
10 lbsCO_2e per square foot

*averages from Carbon Leadership Forum database

MEP RETROFIT IMPACTS

For this project**, renovation was found to have an embodied carbon only 18% of that of new construction.** Mechanical system upgrades were designed with operational energy savings required. The simplest solution to meet code requirements of energy efficiency was a change in HVAC distribution systems, with no changes to the building envelope. Old mechanical equipment, air and water distribution, and plumbing systems were removed. Original 1980's **cooling towers were retained** and utilized in the **new HVAC system**. Old lighting was removed, and **LED fixtures, occupancy sensors, and switches** were installed. In total, the **system embodied carbon** is **8 lbsCO_2e/ft^2**.

For this project, MEP systems contribute ~40% of the total renovation embodied carbon impact. Retrofit and reuse provide carbon savings, but mechanical system efficiency has a longer timeline of carbon impact. Still, systems are a component where optimized material use will reduce impacts. Lifetime efficiency and maintenance must also be considered when upgrading or installing a mechanical system, especially one using refrigerant.



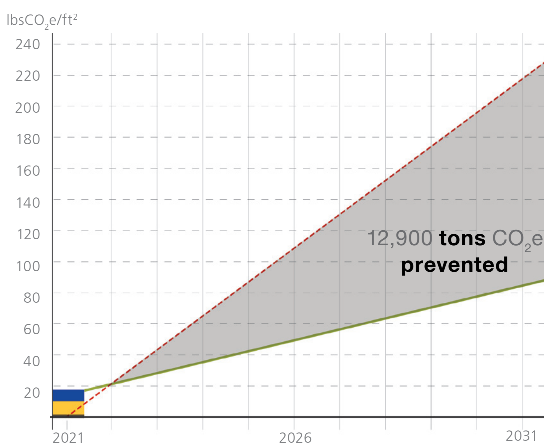
MEP System Impact by Component

CARBON PAYBACK OF MEP RETROFIT

Systems upgrades decreased the building Energy Use Intensity (EUI) from a measured 93 kBtu/sf/yr to projected 32 kBtu/sf/yr. Many of the performance improvements are attributed to efficiencies in variable refrigerant flow (VRF) system, though lighting efficiency made a significant energy reduction impact. Through this renovation, operational carbon cut from 140 to 45 kgCO2e/m2 per year. The renovation emits 85 kgCO2e/m2. In one year, operational efficiency upgrades save 95 kgCO2e/m2. **This means a carbon payback of one year when compared to business as usual operations**!

OPERATIONAL CARBON INTENSITY & SAVINGS**

*Renovation Carbon includes interior renovation and MEP upgrade impacts
**Savings assumes no change to electricity grid mix and represents ten years of operation



carbon payback in MEP upgrades versus operational efficnecy improvements

Existing Operations:
EUI 93
30 lbsCO2e/ft2/yr

Upgraded System:
pEUI 32
10 lbsCO2e/ft2/yr
Office Renovation
Renovation Carbon*
18 lbsCO2e/ft2

1 YEAR

Double height space serves double purpose, creating more daylight and encouraging occupants to use the stairs.

A NOTE ON REFRIGERANTS

This project uses R-410A, with a GWP(20) of 900 lbs CO_2e/m^2. Given an initial charge of 1500 lbs of refrigerant and assuming a 5% annual leakage rate, ~3 lbsCO_2e/ft^2/yr could be emitted via system leaks.

A concern with VRF systems are emissions as a result of refrigerant leaks. In this project, **refrigerant leaks alone could make up ~27% of annual carbon impacts** during building use! Given significant potential emissions, regular monitoring, maintenance, and preventative measures should be prioritized when designing and operating VRF systems.

GLOBAL IMPACTS & HEALTHY ENVIRONMENTS:

The **simplest solution** to meet code requirements of **energy efficiency** was a **change in HVAC distribution systems**, to a Variable Refrigerant Flow (VRF) system, with no changes to the building envelope.

With carbon emissions avoided through **reuse of an existing structure**, **minimal interior finishes**, and smart floorplan use to **optimize daylight** and **floor area**, Office Renovation is an example of **simple design with maximum impact**.

This renovation provided an opportunity to measure the embodied carbon impacts of MEP systems. For this project, **MEP systems contribute ~40% of the total renovation** embodied carbon impact. Mechanical system upgrades are significantly valuable in the time value of carbon to 2030. Through this renovation, mechanical system upgrades demonstrate a **carbon pay back of one year** when compared to business as usual operations.

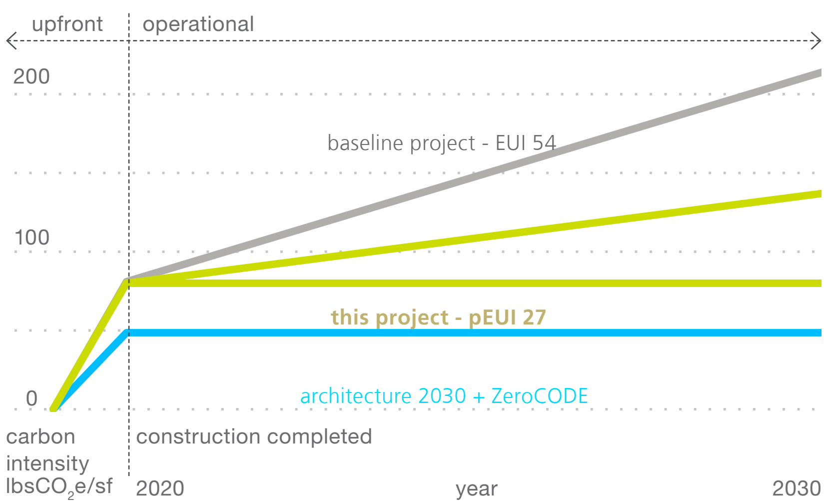
Office Renovation is a good example of a **structure being used for its maximum lifespan**. This renovation occurred after 40 years of operation, while a concrete and steel structure can be expected to last 100 years. This **deep energy retrofit** is exemplary of informed design decisions leading to **minimal intervention** with **high environmental impact** - in the form of global warming potential reduction.

CARBON REDUCTIONS AFTER DESIGN
THE CODE BUILDING

LIFE CYCLE ASSESSMENT GUIDES ZEROCODE IMPLEMENTATION

Creating a state-of-the-art workplace with an emphasis on **occupant comfort**, project teams **integrated sustainable strategies** into each aspect of design. Design of a Direct Outdoor Air System (DOAS) is more efficient and delivers significantly higher fresh air rates than a traditional office HVAC system. Along with the design of **self-shading glazing** elements, **system efficiencies** created a low-energy use building that **performs significantly better** than a standard office building.

WHOLE-BUILDING CARBON INTENSITY OVER TEN YEARS



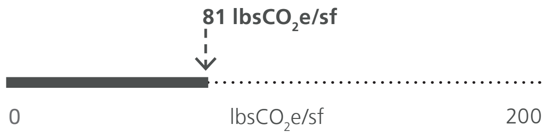
THE CODE BUILDING

CASE STUDY

PROJECT INFO

Project Type: office
New Construction
170,570 sf
Site: 43,023 sf
Stories: 9
Location:
Charlottesville, Virginia
Climate Zone: 4A
LEED Platinum targetted

EMBODIED CARBON



Main Structural Material: cast-in-place concrete
Foundation Material: concrete footings
Does not meet Architecture2030 40% Reduction

OPERATIONAL CARBON

6 lbsCO_2e/sf/yr **60 lbsCO_2e/sf by 2030*

0 lbsCO_2e/sf 200

Annual Operational Carbon: 6 lbsCO_2e/sf/yr
pEUI: 27 kBtu/sf/yr, *projected*
Could meet ZEROCode Standard with RECs

BUDGET

confidential

Construction cost including site work and parking garage.

ZEROCODE COST

Designing a better than baseline building saves $0.74/sf/yr in energy costs. Purchasing RECs to the ZEROCode Standard would add only a **6% premium** for the project to effectively be zero carbon operations, and still represents an **energy savings of $0.70/sf/yr.**

Annual Energy Bill:
$0.66/sf, *estimated,*
$113,000 total, *estimated*

$0.04 ZEROCode RECs per square foot (cost per year)

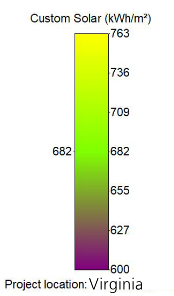
OPERATIONAL CARBON

THE CODE BUILDING: CASE STUDY

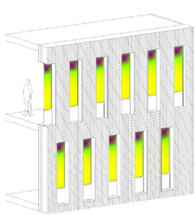
Courtyard as outdoor community space

TARGETTING LEED - OPTIMIZE ENERGY PERFORMANCE

The project will perform 52% better than the national average office building. Envelope design and window shading studies reduce heating loads, a major contributor to energy use. Simple electrical and lighting strategies, like daylighting and automated sensors, also save on operational energy. The LEED rating system recognizes and rewards projects that commit to purchasing Renewable Energy Certificates (RECs) offsetting their utility use for five years. The Architecture2030 'ZEROCode' suggests a 15-year commitment. The purchase of RECs in the national market to meet the ZEROCode requirements for the project are estimated to cost about $6k/year, or 6% of the annual anticipated energy bill.

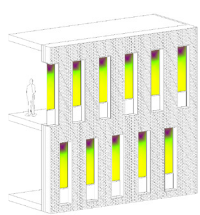


OPTION 1
6" INSET GLAZING



14,058 KWH

OPTION 2
12" INSET GLAZING



11,259 KWH11,259 KWH
20% REDUCTION IN SOLAR GAIN

DESIGNING FOR OPTIMIZED ENERGY PERFORMANCE

Window Shading and Envelope:

- inset windows reduce heat gain and lower cooling loads
- improved envelope performance with continuous insulation

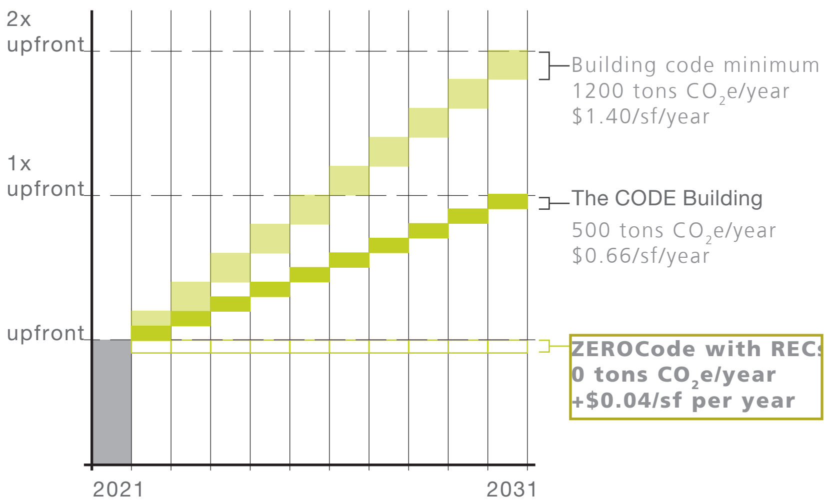
Electrical and Lighting:

- thinner building width optimizes daylighting
- automated sensors ensure sensible use
- LED fixtures

HVAC:

- efficient mechanical equipment
- higher rate of fresh air turnover through use of DOAS

10-YEAR OPERATIONAL AND EMBODIED CARBON COMPARED

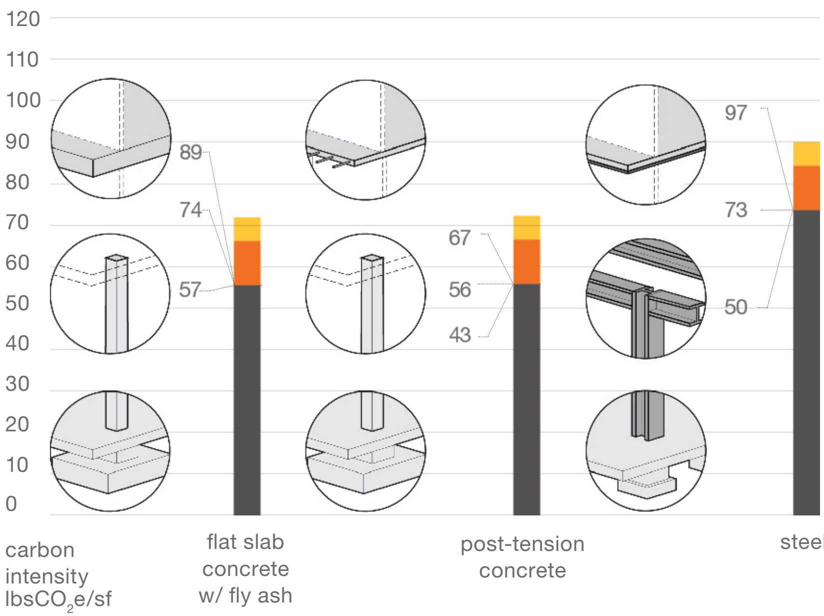


6 lbsCO_2e per sf per year

FOCUS ON STRUCTURAL MATERIAL

In order to achieve a 40% reduction in embodied carbon, **structural system variation** and **concrete mix design** are examined. Global Warming Potential (GWP) **can be reduced by 28%** - the same reduction as choosing a steel structure instead of cast in place concrete - by adjusting the concrete mix design. A typical mix uses 0-19% fly ash as supplementary cementitious material (SCM). A more aggressive cement substitute target is >20% fly ash and >30% slag. It comes at no additional cost, but proved impossible to source regionally during construction for this project. Work with structural engineers and ready-mix suppliers early in design to ensure SCM quantities.

CARBON INTENSITY OF STRUCTURAL SYSTEMS



HOW MUCH DOES MY BUILDING WEIGH?

STRUCTURE 75%

Cast in place concrete

- foundations
- columns & beams
- floor decks

ENVELOPE 19%

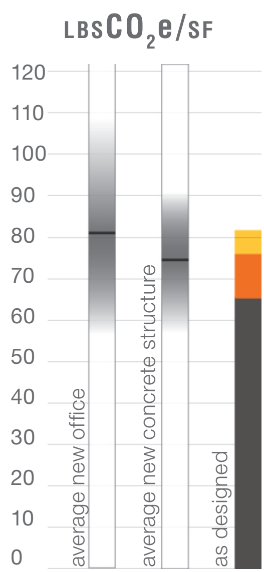
Exterior wall assembly

- continuous insulation
- glazing

INTERIOR 6%

Core and shell

- minimal finishes
- to be completed by tenants

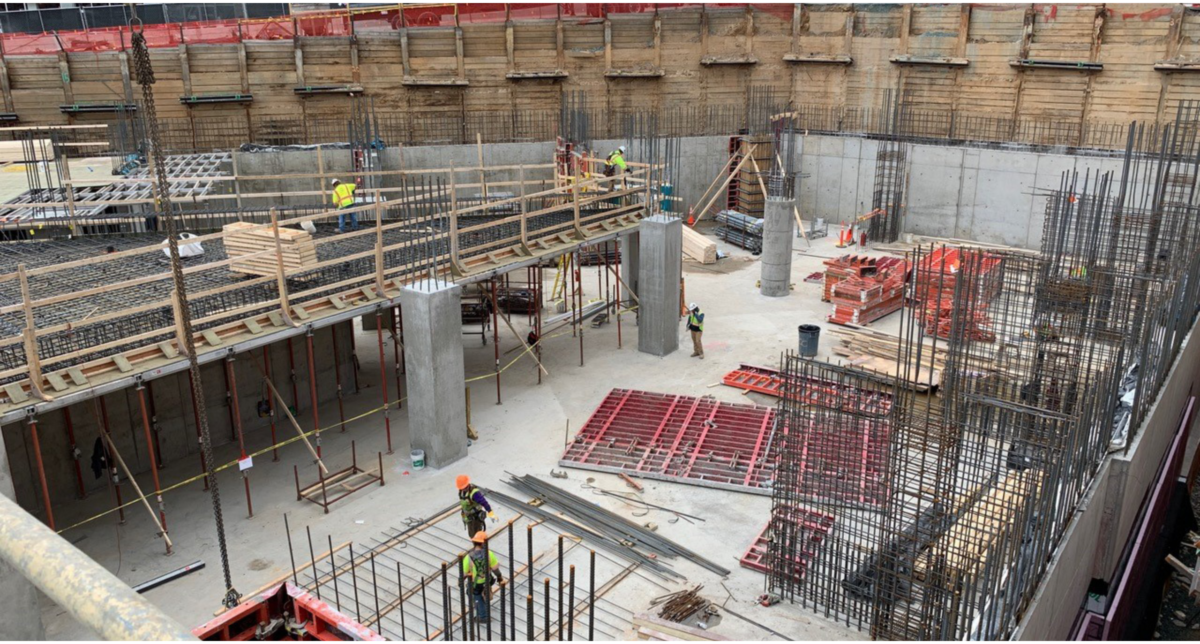


80 $lbsCO_2e$ per square foot

*averages from Carbon Leadership Forum database

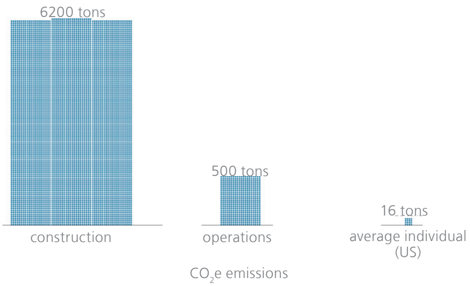
THE CODE BUILDING

CASE STUDY



Under construction shows concrete structural elements - the buildings main contributor to embodied carbon.

CARBON IN CONTEXT



Opportunities to explore pathways to zero embodied carbon were presented when the client became curious about carbon footprints. Building scale impact are huge when considering personal transportation versus carbon of construction.

RETROSPECTIVE CARBON INTERVENTIONS

One of **many paths to carbon zero** were explored in this analysis. The ZEROcode lays out an approach to achieving net zero carbon emissions during building operation: Design an efficient building, then offset annual energy use with a combination of onsite and offsite renewable power. For this project, we explored the use of offsite renewable power and **offsite carbon sequestration to offset the carbon emissions associated with construction**. We discovered options for a project already designed and under construction. As influencers of the built environment, we still have opportunity to **reduce emissions**, to zero carbon, through design and education.

Renewable Energy Certificates (**RECs**) and **carbon offsets** provide outlets of opportunity for this project, where carbon design was not a forefront of discussion early enough in design to intervene. The **market** has signalled importance of **carbon reduction** outside of architecture, and those strategies were analyzed for this project. **Operational carbon can be reduced through RECs**, and **embodied carbon can be offset through carbon offsets**.

Carbon mitigation strategies are attainable with today's technology. Some of those, like agriculture and forestry practices, or wind power and solar power, are able to be funded from afar. Carbon offset and REC brokers sell sponsorships to these efforts, with which companies can **claim carbon neutrality.**

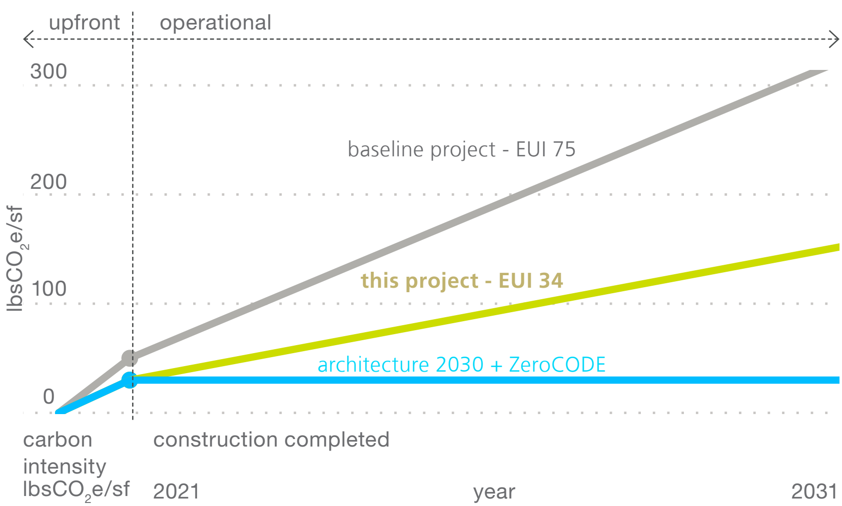
What's shocking about this is the **low cost**. **RECs add about a 5% premium** to annual operational energy bill, while **offsets can be bought** at a price averaging to about **$15 per ton of carbon**.

CREATIVE STRENGTH IN COMMON MATERIALS
THADEN SCHOOL 'HOME' BUILDING

BEAUTY AND INNOVATION IN WOOD STUD CONSTRUCTION KEEPS LCA IMPACTS LOW

Thaden promotes **natural materials** to be celebrated in their buildings. Given the strong history of timber in the region, a **wood building** was fitting, and the Home building became the natural fit as the "hearth" of the campus. In order to find a way to use that material to create a room so large, the team **designed rigid frames** for the dining hall. A combination of **common material**, **existing technology**, and some **innovation** proved a creative way to provide a grand dining hall with the material in a building that is otherwise fairly conventional

WHOLE-BUILDING CARBON EMISSIONS INTENSITY BY 2030



THADEN SCHOOL 'HOME' BUILDING

CASE STUDY

PROJECT INFO

Project Type: K-12 educational facility
New Construction
34,686 sf
Site: 660,593 sf
Stories: 1
Location: Bentonville, AR
Climate Zone: 4A

EMBODIED CARBON

Main Structural Material: wood stud and rigid frame
Foundation Material: timber piles and concrete slab
Meets Architecture2030 40% Reduction

OPERATIONAL CARBON

10 $lbsCO_2e$/sf/yr

**100 $lbsCO_2e$/sf by 2030*

0 $lbsCO_2e$/sf 200

Annual Operational Carbon: 10 $lbsCO_2e$/sf/yr
pEUI: 34 kBtu/sf/yr, *projected*
Could meet ZEROCode Standard with RECs

BUDGET

$241 per square foot

Construction cost of project. The mechanical system cost about $106 per square foot. This projects share of the campus-wide geoethermal system is about $8 per square foot.

ZEROCODE COST

Design of an efficient building and campus was a goal from the start for HOME. Choosing a campus wide geothermal system results in heating savings for all of Thaden School, reflected in the energy efficiency in the HOME building. **Purchasing RECs to meet ZEROCode would be about a 5% premium to the energy bill.**

Annual Energy Bill:
$1.04/sf, *estimated*
$36,810 total, *estimated*

$0.05 ZEROCode RECs per square foot (cost per year)

Home entry with permeable pavers and planted site work.

CAMPUS-WIDE GEOTHERMAL EXCHANGE SYSTEM

Arkansas' neutral soil temperatures and climate are ideal for geothermal systems. Considering a campus-wide energy use perspective allowed for study and implementation of a shared wellfield to serve four buildings. At a daily scale, various building use and needs facilitate a connected system sharing or 'stealing' waste loads from another building. On an annual timeframe, the system acts as a large-scale thermal mass, slowly heating the ground temperature by dispersing excess or waste heat throughout the summer, where the heat can be 'held' 'til winter, when it is used to heat the buildings in the winter.

DESIGNING FOR OPTIMIZED ENERGY PERFORMANCE

Appliances:

- induction cooktops reduce waste heat
- low CFM exhaust hoods

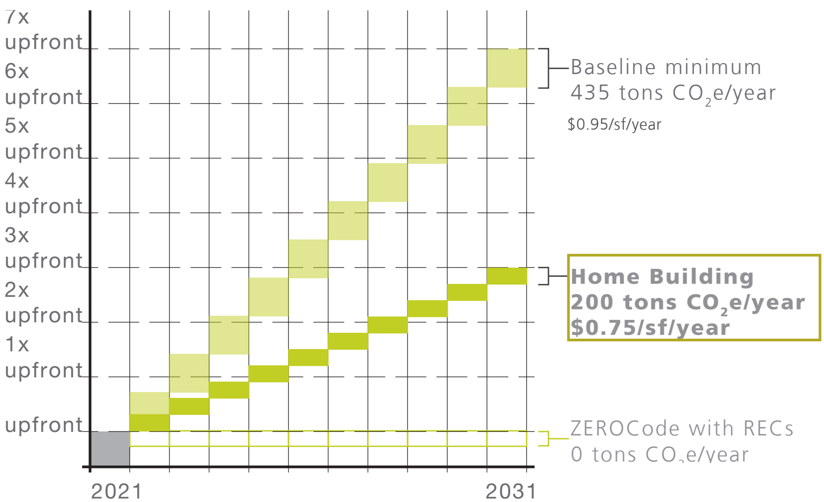
HVAC and Geothermal:

- demand control ventilation
- high-efficiency geothermal heat pumps.

Lighting:

- daylighting for low LPD
- LED fixtures
- occupancy sensors

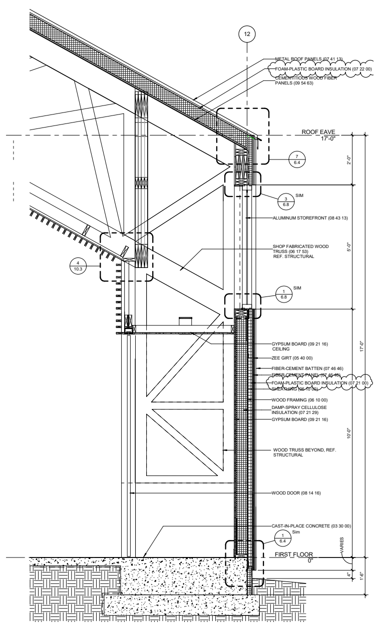
10-YEAR OPERATIONAL AND EMBODIED CARBON COMPARED



10 tons CO_2e per sf per year

RIGID FRAME TIMBER DESIGN

In order to acheive a **70-foot open span**, the design, structural, and fabrication teams took cues from warehouse construction. Standard **rigid frame** building technique was applied with **dimensional lumber**, keeping in mind flat-pack shipping on a flat-bed 18-wheeler. Combining a simple, common steel structural technique and working with a wood truss manufacturer kept costs low. The use of **timber keeps carbon footprint down**. A beautiful structural finish exposes wood to the user, teaching occupants about structure and materials.



STRUCTURE 59%

Load bearing wood stud construction

- Concrete Foundations
- Rigid Frame Construction using Dimensional Lumber

ENVELOPE 31%

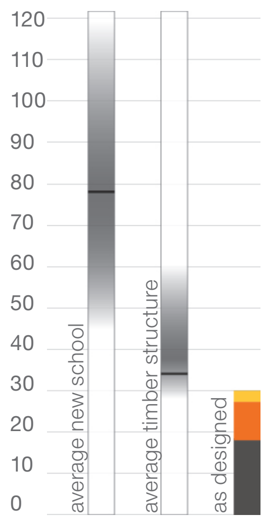
- Continuous XPS insulation
- Plywood Sheathing
- Cellulose Cavity Insulation

INTERIOR 10%

Minimal finishes

- load-bearing walls
- concrete as finish floor
- wood finishes direct-applied to structure

lbsCO_2e/sf



30 lbsCO_2e per square foot

*averages from Carbon Leadership Forum database

Double-height space allows daylighting, wood finishes compliment and expose the wood structure of the Home building.

HEARTH OF THE CAMPUS

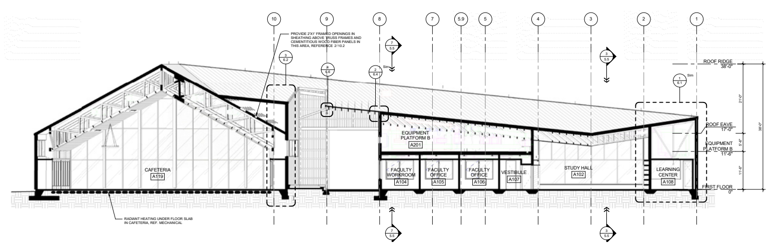
The entire campus and approach of Thaden schools was developed and designed with an integrative approach. It should come as no surprise that the buildings on campus are designed with a holistic mindest as well. The campus shares a geothermal heating loop system, reducing electric-grid supplied heating and cooling loads. Each building serves multiple purposes, and encourages occupants to engage their environment. The Home building is the hearth of the campus, with a large gathering space, and with views to the outdoors and a natural material choice, it reflects the values of Thaden.

INTEGRATED CAMPUS, INTEGRATED DESIGN

Low carbon construction does not have to mean high **budget**. Low carbon buildings don't have to be high tech. With intention & creativity, our team developed and delivered a beautiful, **energy efficient** building, with both low upfront carbon and operational energy use.

Efficiencies in the banal and seemingly obvious became beautiful architectural solutions. Taking a **standard structural solution**, like the warehouse steel rigid frames, and tweaking it slightly made for a unique, innovative structure. Converting that construction technique to be used with dimensional lumber, a common building material, kept **natural efficiencies of truss design** and manufacture in place, but used a more **carbon-friendly** material than steel. Collaboration facilitated innovation, efficiency and intentionality of materials. Further **material optimization** developed by using structure as finish, or as a base for finish to be directly applied.

The study of Home illustrates low carbon impacts through energy efficiency planning, campus-wide synergies, and innovative, though simple, wood construction techniques. Operational needs were reduced through geothermal systems, daylighting, and careful appliance specification. As with the overall campus plan, efficiencies and optimizations of material use reduce overall materials in the building, naturally **lowering its impact**.

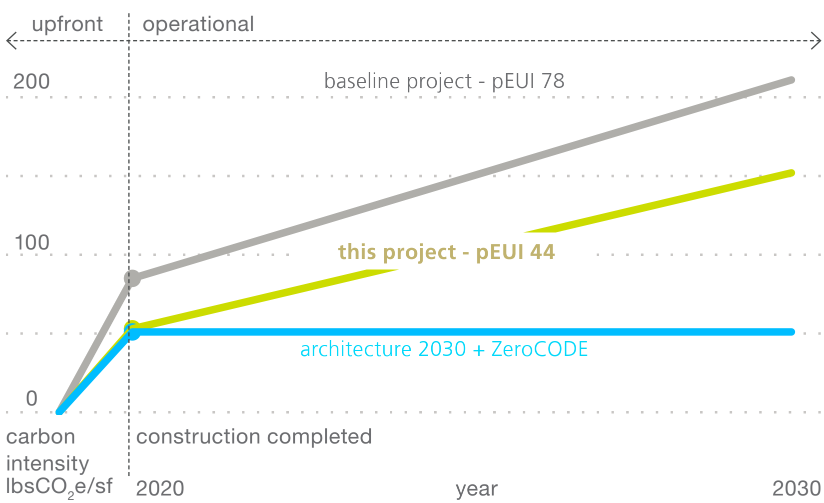


MIXED STRUCTURAL SYSTEMS
THE SHOP SLC AND MYA

IMPACTS OF MIXED STRUCTURE ON LIFE CYCLE ANALYSIS

Branching out of the southeast presents a learning opportunity to **design in other climates**. Early design proposed CLT structure, but more **cost-effective standard construction** was used in the final design. A direct comparison of **structural assemblies** reveal how much better **wood is for embodied carbon** than other structural assemblies. **EnergySTAR** rated project requirements supported project goals in designing an **energy efficient building.**

WHOLE-BUILDING CARBON INTENSITY OVER TEN YEARS



THE SHOP SLC AND MYA

CASE STUDY

PROJECT INFO

Project Type: mixed- use residential and retail

New Construction

129,101 sf

Site: 38,098

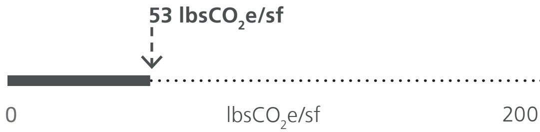
Stories: 4

Location: Salt Lake City

Climate Zone: 5B

EnergySTAR

EMBODIED CARBON

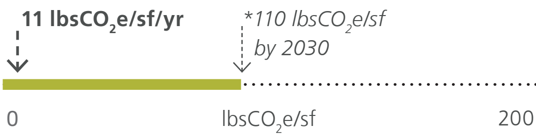


Main Structural Material: mixed stick and steel framed

Foundation Material: concrete

Achieves 28% reduction compared to **new mixed use**

OPERATIONAL CARBON



Annual Operational Carbon: 11 $lbsCO_2e/sf/yr$
pEUI: 43 kBtu/sf/yr, *estimated*
Could meet ZEROCode Standard with RECs

BUDGET

$165 per square foot

Construction cost of entire project.

ZEROCODE COST

Designing to EnergySTAR standards results in 20% energy savings from a baseline model. Baseline bulding design energy would cost $1.22/sf/yr, while EnergySTAR design is predicted at $0.96/sf/yr. **Purchasing RECs to meet ZEROCode would be about a 5% premium to the energy bill, and still an 18% savings** from the baseline.

Annual Energy Bill:
$0.96/sf, *estimated,*
$124,325 total, *estimated*

$0.05 ZEROCode RECs per square foot (cost per year)

Mixed construction types based on building use are shown here. EnergySTAR envelope requirements had to be met for both.

ENVELOPE PERFORMANCE

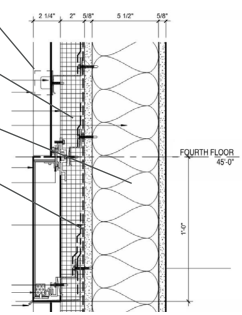
Salt Lake City is in ASHRAE Climate Zone 5B, characterized as cold and dry. **Heating loads** are therefore prominent, and **insulation** is of utmost importance in designing an energy efficient building. In a heating climate with a lot of annual snowfall, the importance of building enclosure was emphasized in design. **Air tightness**, **continuous insulation**, and **weather barriers** provide most of the thermal and **energy performance** in the assembly. ACM panels serve as finish cladding. Enterprise green communities sets a higher standard for envelope than code, improving heating and cooling energy performance.

acm panel

2” rigid mineral wool board continuous insulation: R-4

cavity batt insulation: R-19

fluid-applied weather barrier: air-infiltration 0.04cfm/ft^2



Residential (stick-framed): U=0.051

Commercial (light-gauge steel-framed): U=0.079

DESIGNING FOR OPTIMIZED ENERGY PERFORMANCE

Tight Envelope:

- continuous insulation
- low WWR

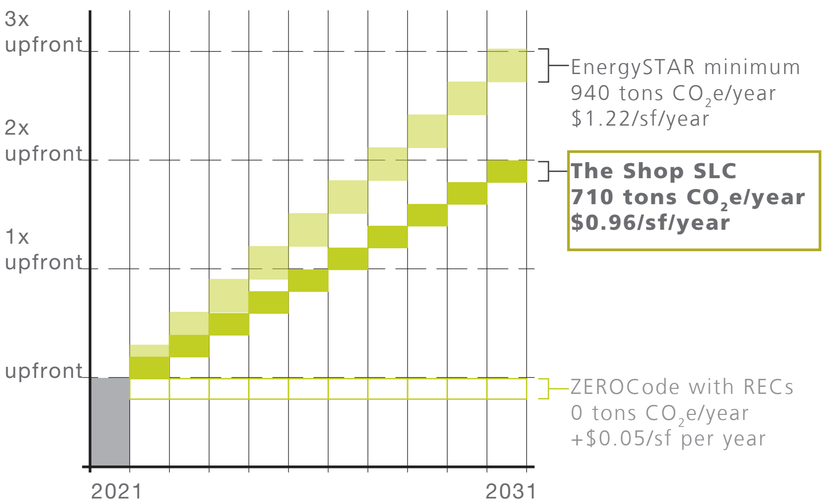
HVAC:

- efficient system design
- heat pump water heaters

Lighting:

- LED fixtures
- occupancy sensors

10-YEAR OPERATIONAL AND EMBODIED CARBON COMPARED



11 lbsCO_2e per sf per year

MIXED STRUCTURE IMPACTS ON EMBODIED CARBON

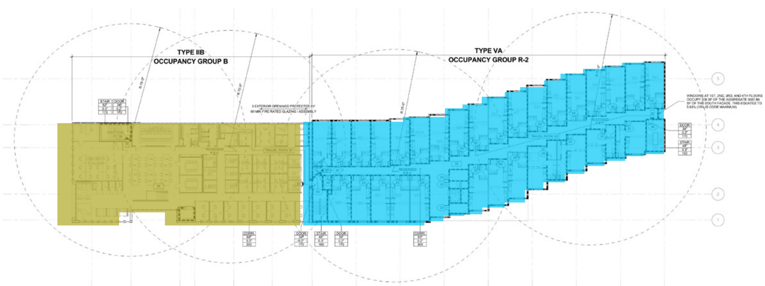
Mixed use project meant mixed construction types. Light gauge steel-framed bearing walls on the commercial part of the building, and stick-framed with OSB sheathing for residential. The use of wood framing in this project is where we see embodied carbon "savings" when compared to other mixed-use construction, which is typically all steel-framed.

Change in structure and construction types presented design/detail/and construction challenges, but also offer an embodied carbon prevention of about 1040 tons CO_2e!

Residential
26 lbs CO_2e/sf
100,000 sf

Commercial
76 lbs CO_2e/sf
30,000 sf

Total Project
53 lbs CO_2e/sf
130,000 sf



RESIDENTIAL VS COMMERCIAL CARBON INTENSITY		
	residential (wood stick-framed)	**commercial** (light gauge steel)
area footprint (of total square feet)	**77%**	**23%**
carbon footprint (of interior framed walls)	**21%**	**79%**

STRUCTURE 80%

Mixed construction

- stick framed
- steel framing
- concrete foundation

ENVELOPE 13%

Exterior wall assembly

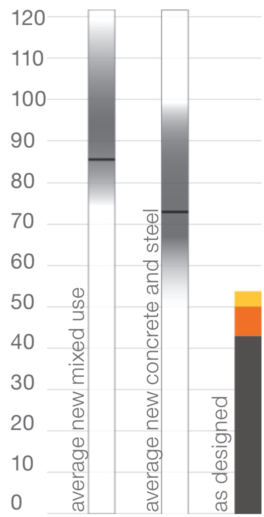
- ACM Panels
- glazing and mullions

INTERIOR 7%

Simple finishes

- gypsum wall finishes with paint
- ceilings
- doors

lbsCO_2e/sf



53 lbsCO_2e per square foot

*averages from Carbon Leadership Forum database

Retail level glazing.

ENERGYSTAR STANDARD IN DESIGN

Project certifications like EnergySTAR, Enterprise Green Communities, and LEED provide incentives for building owners and facilities managers to ask for a more efficient building. For architects, these certifications help to normalize and make common best practices. The Shop SLC and Mya implemented many best practice strategies in design, from minimizing glazing, to continuous insulation. As a Life Cycle Assessment, a mixed-use project with mixed construction types revealed interesting information about building area and carbon impacts.

MIXED USE, MIXED STRUCTURE

Most **mixed use construction** today is made with concrete and light gauge steel mixed. This project **mixed construction types**, from **light gauge steel framing** at commercial use to **traditional stick framing** for residential area. It comes as no surprise that the **residential portion** of the project has a **significantly lower carbon footprint** than the more carbon-intensive materials used in the commercial zones. While details and construction had to be managed, this mix of structure reveals a significant carbon savings compared to if the project had just been light gauge steel.

While this project succeeded in lowering carbon footprint, this project revealed that the **reduction of 50 CO_2e/sf** through stick frame construction compared to the commercial light gauge, **actually costs less**. Commercial framing and walls cost about $100 per square foot, while the lower carbon residential stick frame cost about $50. Using proven, common building techniques, can also lower carbon footprint. This strategy for carbon reduction is market-ready.

The **market also signals lower carbon and energy use** through building **certifications** and **incentives**. Pursuing EnergySTAR both pushes this project to have better energy performance and a **lower carbon footprint** as a result. For relatively standard construction, The Shop SLC and Mya is exemplary of **cost-effective strategies** to be better than baseline, **preventing about 1600 tons CO_2e by 2030.**

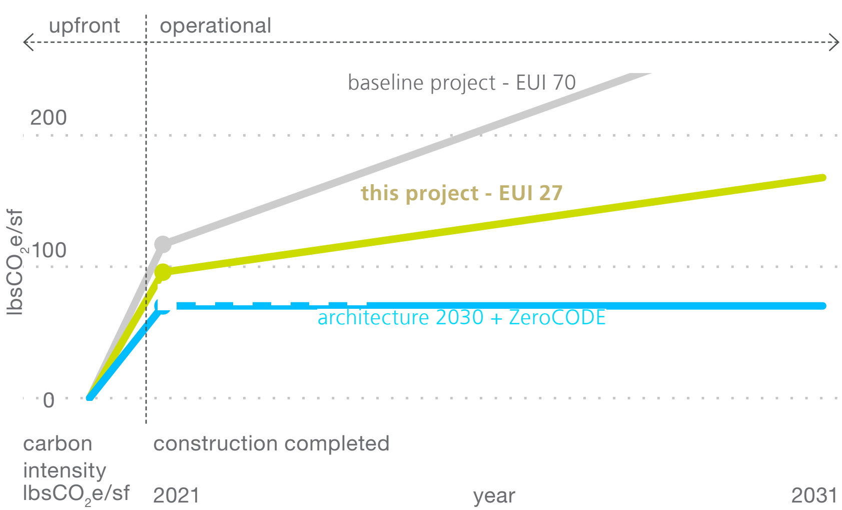

UNITED STATES COURTHOUSE

INTERVENTION FOR LOWERED IMPACTS
NEW U.S. FEDERAL COURTHOUSE

LIFE CYCLE ASSESSMENT AS DESIGN TOOL TO LOWER IMPACTS OF STRUCTURE

There are many points to **influence sustainability** efforts on a project. The sooner the intervention, the bigger the impact. Through collaboration, this project team found opportunity for **embodied carbon reduction** during design development. **Structural optimization** and insulation **material specification reduce the buildings embodied carbon impact by 5%**, without compromising architectural elements. This in-progress project demonstrates life-cycle analysis as a working tool.

WHOLE-BUILDING CARBON EMISSIONS INTENSITY BY 2030



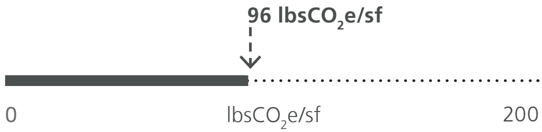
U.S. FEDERAL COURTHOUSE

CASE STUDY

PROJECT INFO

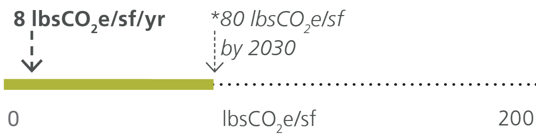
Project Type: courthouse
New Construction
55,568 sf
Site: 106,286 sf
Stories: 3
Location: undisclosed
Climate Zone: 3A
LEED Gold Target

EMBODIED CARBON



Main Structural Material: concrete and steel
Foundation Material: concrete piers and grade beams
Does not meet Architecture2030 40% Reduction

OPERATIONAL CARBON



Annual Operational Carbon: 8 $lbsCO_2e/sf/yr$
pEUI: 27 kBtu/sf/yr, *projected*
Could meet ZEROCode Standard with RECs

BUDGET

construction budget undisclosed.

ZEROCODE COST

This project required energy efficient design for LEED certification and project goals. Purchasing RECs to the ZEROCode Standard would add only a **7% premium** for the project to effectively be zero carbon operations.

Annual Energy Bill:
$0.67/sf, *estimated*

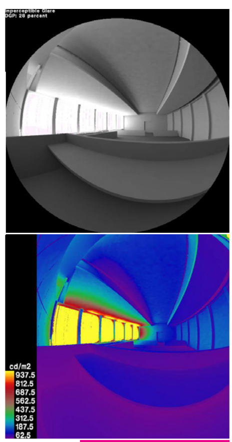
$0.05 ZEROCode RECs per square foot (cost per year)

Courtroom design with daylighting through interior louvers odesigned to allow lighting in and prevent glare.

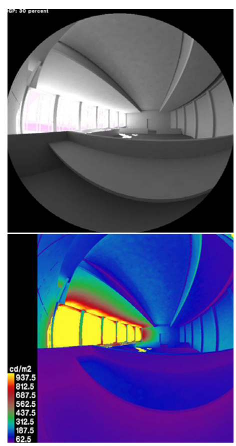
DAYLIGHTING AND GLARE

Daylighting is highlighted as a **strategy to lower energy use** and make occupants more comfortable. It has to be balanced with designing to **minimize glare** while allowing natural light in. The design team did extensive studies to ensure the louvers function appropriately and daylight delivers the foot candles required.

Daylight Glare Probability (**DGP**) is the metric used to evaluate comfort, considering overall brightness of view, position of 'glare' sources, and visual contrast. To the right, window with no louvers versus window with louvers show a 2% DGP improvement.



Point in time Glare Study - 28% dgp
June 21, 9am



Point in time Glare Study - 30% dgp
une 21, 9am

DESIGNING FOR OPTIMIZED ENERGY PERFORMANCE

Lighting:

- LED fixtures
- occupancy sensors
- 60% energy savings from baseline

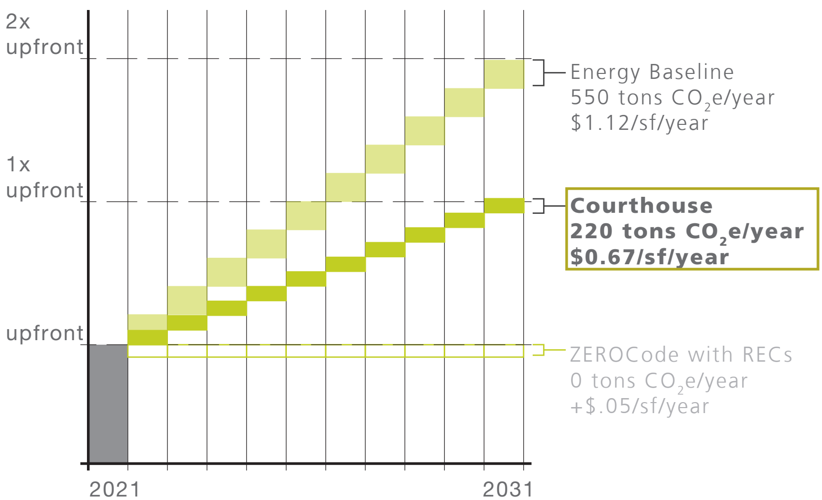
HVAC:

- 45% energy savings over baseline model
- air-cooled chillers
- louvered glazing to reduce heating loads
- high efficiency fans

Envelope:

- R-25+ roof assembly
- continuous insulation
- glazing designed for daylighting
- louvers designed to minimize glare

10-YEAR OPERATIONAL AND EMBODIED CARBON COMPARED



8 lbs CO_2e per sf per year

MATERIAL SPECIFICATION FOR CARBON REDUCTION

Given soil conditions at this project site, significant foundations are required. The design team was able to **target the large volume of concrete** in the foundational piers and **optimize the concrete mix design** in those elements, **reducing the carbon impact** of concrete used.

Portland cement is a proxy for **CO_2 emissions in concrete.** In order to reduce portland cement, **Supplementary Cementitious Materials** (**SCMs**) were integrated into the mix. Fly ash is the most common SCM on the market for no extra cost. Typical concrete mix for the region and concrete mix design are shown in the table below

Insulation blowing agents are another building component that **have a significant carbon impact**. Hydrofluoro-olefin (HFO) versus hydrofluorocarbon (HFC) GWP values vary, as shown in the table below. We eliminated cavity insulation as the continuous insulation does most of the work thermally. Less material = less carbon.

Working together with suppliers and structural engineers to **minimize portland cement** in the foundation piers, **specify HFO blowing agents** in insulation, and **switch from a PVC to TPO membrane** combined provide **5% GWP reduction** over the original design.

Envelope Insulation	GWP-100	GWP ($lbsCO_2e/sf$)
HFC (average)	1,230	13
HFO (solstice)	1	10

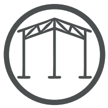
Insulation. Next-generation blowing agents have low GWP. Solstice, a selected HFO blowing agent, is one.

Concrete Mix	cement (lbs/cy)	fly ash (lbs/cy)	GWP ($lbsCO_2e/sf$)
average (regional)	465	111	48
design (reduced)	410	274	46

Concrete Mix. Regional average concrete mix design versus optimized design. Regional values taken from NRMCA data.

HOW MUCH DOES MY BUILDING WEIGH?

STRUCTURE 51%



Steel and concrete

- cast pile foundations
- concrete grade beams
- steel framing
- concrete floor decks

ENVELOPE 30%

Glazing for daylighting

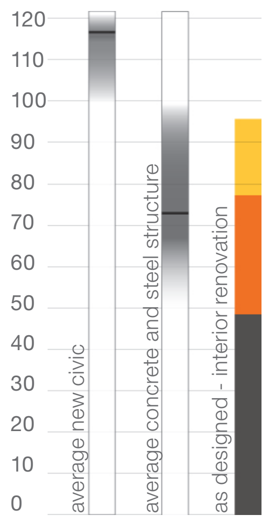
- continuous insulation
- curtain wall with EPD
- TPO roofing membrane
- precast panel cladding

INTERIOR 20%

Simple finishes

- wood louvers at courtrooms
- ballistic glass
- acoustic dropped ceilings

lbsCO_2e/sf



96 lbsCO_2e per square foot

*averages from Carbon Leadership Forum database

U.S. FEDERAL COURTHOUSE

CASE STUDY

Early concept rendering illustrating the courthouse as a civic building creating public square and community ammenity space.

A CIVIC SPACE

A civic space for a community rich in history, this project will be a landmark and a town center that will last for decades. While this case study focuses on the critical timeline to 2030, and project-related emissions ‘til that time, the building will last for decades. This is true both because of the intended use of the courthouse, and the materials chosen for construction. Concrete, while extremely high in embodied carbon emissions, is a resilient material. The decision to build with such high impact materials should not be taken lightly, and should be considered with time, use, and community benefits weighed and balanced.

PROJECT GOALS AND POINTS OF INFLUENCE

Mindful design, aesthetics, and function were balanced with project sustainability goals and requirements. Some were implemented early, aiding in their execution, while other opportunities became a focus later in design. Timing limited the potential impact, but proved that **no matter the product stage**, **better options are available** to make more **sustainable design choices.**

Setting project goals early with design teams brings stakeholders and design teams together to accomplish sustainability goals. LEED-Gold as a target, the teams designing the courthouse were open to strategies big and small **influencing energy use and material impacts**. **Design for daylight** and **energy efficient systems** were consistent conversations throughout early phases of design. Later, nearing 100% Design Development, the architecture team's influence presented **opportunity in material specificity and optimization**.

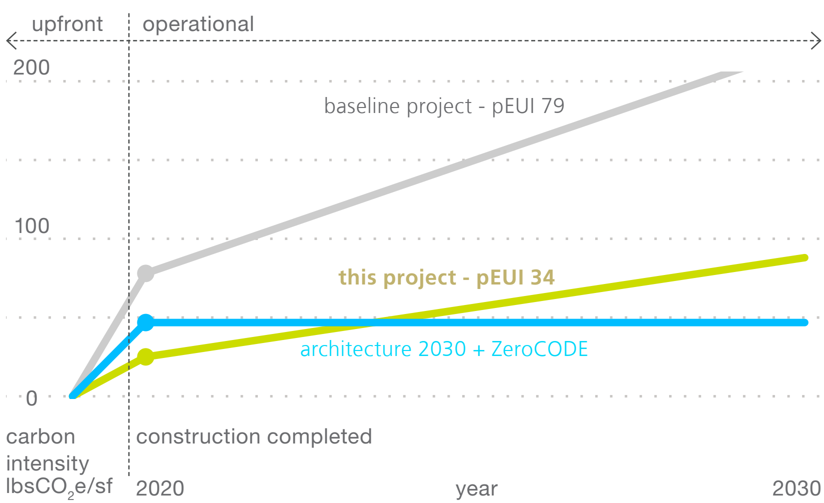
Earlier in the project, reductions of 10% may have been possible. A few simple decisions prove to make a 5% Global Warming Potential (GWP) **impact reduction** - without changing aesthetics and architecture within the design. **Concrete mix design**, **insulation specification**, and **roof membrane** material together did not change the architecture, but provide **GWP impact reductions at no additional cost**.

VACANT BUILDING RENOVATION
LYCEE FRANCAIS

LIFE CYCLE ANALYSIS OF MIXED RENOVATION AND NEW CONSTRUCTION

Located in Pigeon Town and formerly a neighborhood school, Lycee Francais schools bought this building, vacant for 20 years, to become an anchor in the community. Historic tax credits set guidance for the **renovation**, which influenced the **new classroom addition**. This project is mixed new construction and renovation, and follows proven **best practices** for **operational efficiency**. **Building reuse** is one of the most **high impact strategies** to **reduce both operational and embodied carbon**.

WHOLE-BUILDING CARBON INTENSITY OVER TEN YEARS



LYCEE FRANCAIS

CASE STUDY

PROJECT INFO

Project Type: K-12 school
Renovation and New Construction
32,168 sf *existing*
8,695 sf *new*
Site: 90,691 sf
Stories: 3
Location: New Orleans
Climate Zone: 2A

EMBODIED CARBON

Main Structural Material: concrete and steel
Foundation Material: concrete piers and grade beams
Does not meet Architecture2030 40% Reduction

OPERATIONAL CARBON

7 lbsCO_2e/sf/yr **70 lbsCO_2e/sf by 2030*

0 lbsCO_2e/sf 200

Annual Operational Carbon: 7 lbsCO_2e/sf/yr
pEUI: 34 kBtu/sf/yr, *projected*
Could meet ZEROCode Standard with RECs

BUDGET

$272 per square foot

Construction cost of interior renovation, new construction addition, and face brick masonry as needed to existing building.

ZEROCODE COST

This project used TargetFinder and ZEROTool to estimate its energy use. Basic Energy Models can predict energy efficiency as well, giving us an estimate to understand kWh loads, and therefore price RECs to meet ZEROcode.

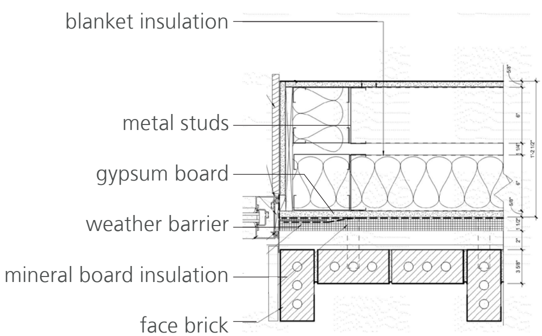
Annual Energy Bill:
$0.88/sf, *estimated*
$41,781 total *estimated*

$0.05 ZEROCode RECs per square foot (cost per year)

Interior of the new addition to Lycee Francais provides natural light.

BENCHMARKS AND BASELINES AS DESIGN GUIDE

This project does not have an energy model, but like all new construction, must be built to meet the energy code. The project team **set energy targets** (20% better than ASHRAE 90.1-2016) beyond Louisiana's accepted energy code (ASHRAE 90.1-2007). Exemplary of implementing proven strategies in the New Orleans climate, both the addition and existing building will get a VRF HVAC system with DOAS, providing **system efficiencies** and occupant health benefits. One of the **simplest strategies** to design into any project for energy efficiency savings is **continuous insulation** - although it is not required by code in Louisiana.



Code Minimum:
U-0.094

Designed:
U-0.028

BEST PRACTICES FOR ENERGY PERFORMANCE

Envelope:

- air barrier
- mineral board rigid thermal insulation

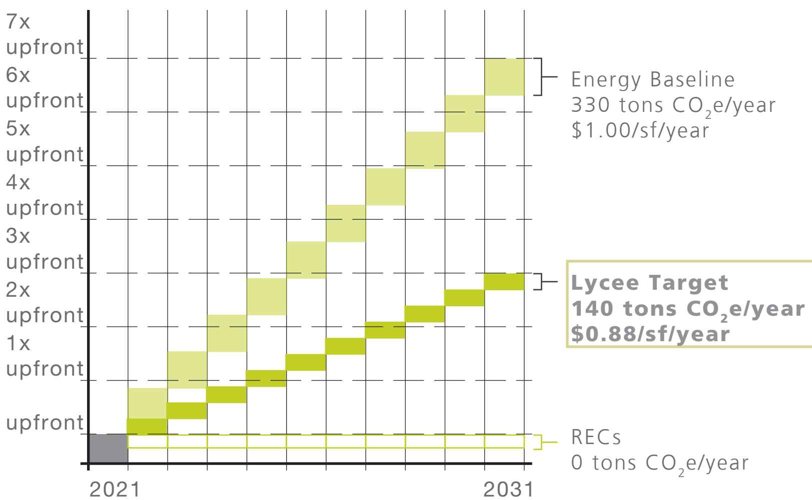
Lighting and Automation:

- use LED fixtures
- occupancy sensors

HVAC System:

- VRF offers system efficiencies
- DOAS provides better fresh air return rates and better occupant comfort

10-YEAR OPERATIONAL AND EMBODIED CARBON COMPARED

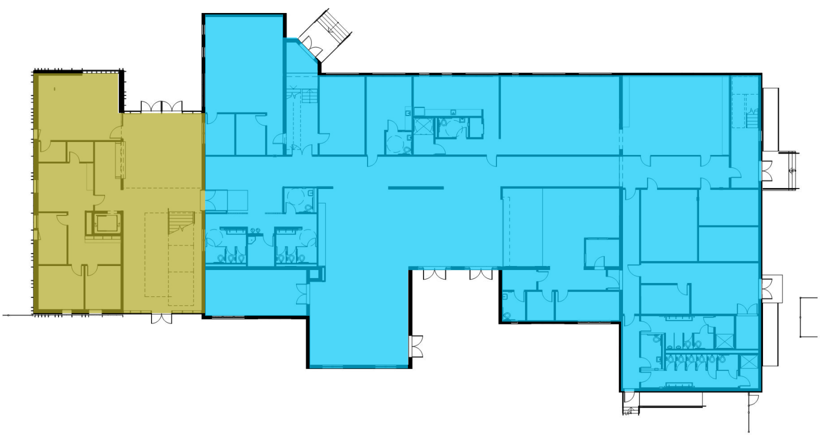


7 lbsCO_2e per sf per year

EXISTING STRUCTURE FOR LOW CARBON IMPACT

In comparison to a new construction school building, the entire project area and scope - including renovation and new construction - for Lycee Francais achieves a **65% reduction** in embodied CO_2. By **retaining existing structure**, new construction **emissions are avoided**. The addition is built **on par with new construction** projects (100 lbsC_02e/sf). Across entire project floor area, this retrofit represents an **overall reduction in embodied carbon**. The **new addition** comprises **20% of floor area,** but **70% of project emissions.** Existing building interior renovation and window replacement makes up the rest, with end of life impacts associated with demolition minimal.

New Construction	Renovated Existing	Total Project
100 lbs CO_2e /sf	9 lbs CO_2e /sf	25 lbs CO_2e /sf
9,000 sf	32,000 sf	41,000 sf



HOW MUCH DOES MY BUILDING WEIGH?

STRUCTURE 42%

New construction

- concrete foundation
- steel columns and beams
- light gauge steel framing

ENVELOPE 35%

New and demolition

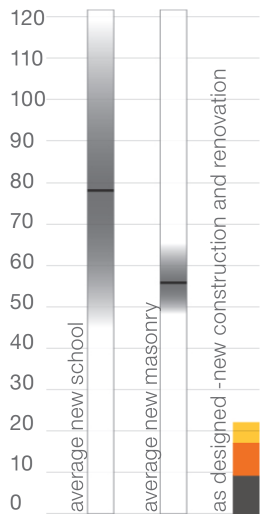
- interior sheathing
- glazing and mullions
- mineral wool board insulation
- brick cladding

INTERIOR 23%

New and demolition

- new wall framing
- new gypsum walls
- new ceilings
- concrete floor finish

$lbsCO_2e/sf$



25 $lbsCO_2e$ per square foot

*averages from Carbon Leadership Forum database

New construction compliments the existing building.

HISTORIC TAX CREDITS AND FAÇADE DESIGN

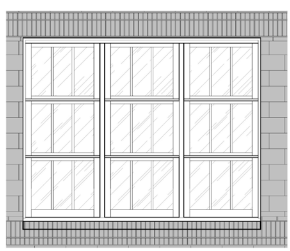
Originally built in the 1930s, Lycee Francais is a historical building in New Orleans. As such, historic tax credits were available to help fund the project. These credits influence facade design and building interventions. Aspects influenced and guided by historical tax credits are cladding material and window design. Existing windows and replacements were designed to fit the historical nature of the building. Use of brick in new construction fits the context appropriately. A simple but meaningful design gesture connects the new building to the vernacular.

COMMUNITY LANDMARK AND ANCHOR

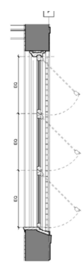
Building reuse has huge impacts in **reducing carbon emissions**, largely through **emissions avoided**. If this project were built entirely new, in just the short time it would take to construct the building, about 2600 tons of CO_2 would have been emitted associated with the construction of the new building. Instead, **reusing an existing, vacant, under utilized structure**, and building a **small addition**, **450 tons CO_2** will be associated with this project's upfront carbon. That difference represents an **80% reduction in embodied carbon** - on a short timeline. When time is critical to reductions, **building reuse proves to be a significantly successful path** to embodied carbon management.

The building was closed and vacant since before Katrina, and had been written off as unusable for years. With a strong vision for the building's potential, the design team was able to take a blighted building, honor historical nature of the existing structure, and build a vision for a community anchor. Historic tax credits help to fund and promote use of existing buildings. Benefits of using existing infrastructure and approach through various lenses, be it preserving history and heritage, minimizing environmental impacts, or incentives like tax credits. Using all of these influences to tell a complete story and transform an eyesore into beautiful, functional design is an example of holistic, sustainable architecture.

07 EXISTING WINDOW PHOTO
3" = 1'-0"



04 EXISTING AWNING WINDOW ELEVATION
1" = 1'-0"



02 EXISTING AWNING WINDOW SECTION
1" = 1'-0"

COMPONENT TWO

CARBON FLUENCY

CARBON TERMS, DEFINITIONS AND ABBREVIATIONS

The study of embodied carbon gets scientific and is filled with abbreviations and letters that can be confusing. Use this to understand GWP, EPD, LCA, CO2E, XYZ, and ABCs of carbon.

It is an environmental imperative that designers make informed, low-carbon material and design decisions. We are the pioneers of the future in environmental impacts of the built environment. We need to better understand where we get every single product that goes into construction so we know the impact we have on the environment not only today but tomorrow. We could live in a sustainable world where our buildings work for us to turn back the tables of global warming. We literally could be a quintessential part in fighting climate change with the tools & knowledge of understanding the life cycle of a building and the products that go into it.

This component of the book defines common carbon terms and abbreviations that have been introduced and will be used throughout. It will help to gain a better understanding of the tools and processes of measurement that quantify product (or building) impacts. Understanding, use, comparison, and reporting impacts through use of these tools is how we push the industry and reduce our impact.

Carbon - defined by Merriam-Webster as, "a nonmetallic chemical element with atomic number 6 that readily forms **compounds** with many other elements and is a constituent of organic compounds in all known living tissues."

For the purposes of this booklet, 'carbon' will be used referring to a particular compound that carbon forms, **carbon dioxide**. **Carbon dioxide emissions** are the standard measure of **greenhouse gases** and are a major marker of **climate change**.

These **many names of carbon** will be used interchangably throughout this booklet:

Carbon

Carbon footprint

Carbon dioxide (**CO_2**)

Carbon dioxide equivalent (**CO_2e** or **CO_2eq**) - refers to gases that are not **carbon dioxide**, but have warming effects. Those gases' emissions are converted to equivalents in CO_2e, keeping the reporting unit consistent. Methane is a common example of this.

"These terms do not share the exact same meaning. Even though the term "carbon" is commonly associated with climate change, it is technically not elemental carbon that contributes to climate change, but carbon dioxide gas along with many other substances such as nitrous oxide and methane. Nevertheless, "carbon" is often used as an abbreviation to refer to **global warming potential**."[6]

Global warming potential (**GWP**) - the impact on global warming of a given substance, measured in **lbsCO_2** or **kgCO_2**. Different timelines for their measurement are used. **GWP100** uses a 100-year timeline, **GWP20**, 20 years. GWP100 is the most common, or default, used and reported. These exist as different gases have a different lifespan, methane, for example, only 'lives' in the atmosphere for about 20 years, so, to represent its GWP in a timescale of 100 years, makes it seem less potent, and therefore less impactful, than it is. For example, methane has a GWP100 of 20, while GWP20 is 84.

KEY DEFINITIONS

Greenhouse gas (**GHG**) **emissions** - gas or chemical that stays in the atmosphere for a certain amount of time, "insulating" the earth, and trapping heat within the atmosphere, therefore contributing to the warming, or "greenhouse effect," of the earth.

Embodied carbon and **operational carbon** are both measured and reported in **CO_2**, but deal with different phases of life of the building.

Embodied carbon might better be called **upfront carbon**. It is the emissions associated with the extraction, production, transport, manufacture, and construction of a given material.

Operational carbon is the emissions associated with the use of a building. It is correlated with energy use, grid power source, and **fossil fuel emissions** .

Both embodied and operational carbon are reported as **GWP** and are commonly measured through **life cycle analysis** (**LCA**).

Life cycle analysis (**LCA**) measures impacts of a product, building, or material over its usable life. Various environmental impact categories are included, but for most architectural study LCA are focused on measuring GWP of a whole building.

Environmental product declarations (**EPDs**) use **LCA** to report impacts of a product or material. They can be industry-wide, product specific, manufacturer, or even plant-specific. You can think of a **whole-building LCA** being made up of multiple **EPDs** for all its components. However, more EPDs are needed throughout the industry, so LCA often uses material average GWPs, which are not as accurate as product-specific EPDs.[7]

Measuring and reporting carbon emissions has opened up a new vocabulary of **Net Zero**, **Carbon Neutral**, **Carbon Positive**, **Carbon Sink**, **Carbon Negative**, and the terms often get confusing and used incorrectly, and are not yet used in a standardized way throughout the industry. For this booklet, those terms are defined on the next page.

CARBON FLUENCY

Before discussing each of the following terms, we need to understand that they are used within a framework of carbon emissions over time. This is commonly **whole life carbon emissions**, but could be reported for a certain time period. For example, measured until 2030, 2050, or over 100 years. **Whole life carbon emissions** will most accurately reflect life cycle impacts of carbon in relation to a product or building.

Whole life carbon emissions - Includes *all* stages of life-cycle analysis in quantifying a building's GWP. This is an important distinction to understand because many studies only focus on Cradle to Gate scope.

Net Zero - Refers to emissions due to **energy use** of a building being balanced by clean energy production. **Net Zero Energy** is an efficient building that produces as much energy as it requires for operations on site, commonly done through use of photovoltaic (PV) arrays.

Net Zero Carbon is the same concept, but focuses on emissions as the reporting measure rather than energy use. **Net Zero Carbon** then can include **off-site energy production**, through a form of Renewable Energy Certficates (RECs). In sum, while the building still requires energy (or carbon emissions as a result of the electric grid), its use is met with renewable, non-emitting sources.

A common interchange within these terms is "zero net" for "net zero."

Carbon Neutral - net zero carbon emissions. This term could refer to a single product or material, or be expanded for a whole building, in which case the building operations would have to be Net Zero Carbon.

Carbon Negative - a product, material, or building that stores more carbon than it emits. Simply put, 10 CO2 emitted - 20 CO2 ***stored*** = -10 CO2 stored, or negative carbon. Despite the literal negative connotation, carbon negative represents a climate and emissions *benefit*. Higher negative numbers are better when referring to GWP.

Carbon Sink - see carbon negative.

Carbon Positive - understably a point of confusion. Especially when we take into consideration the discussion, and the CarbonPositive Conferences. These refer to a "good," "positive," or "beneficial" carbon future, and the term is aspirational. Mathematically, though, a positive carbon number in a GWP represents a carbon emission, or burden. In the case of impact by numbers, the smaller the positive, the better.

Carbon sequestration - a natural part of the **carbon cycle** where carbon is stored, rather than emitted into the atmosphere. Forests, soils, and oceans are the world's largest natural carbon sequestering masses.

Carbon storage - used interchangeably with carbon sequestration.

Life cycle analysis (**LCA**) is a way to measure the impacts of the built environment, from the scale of a whole building to an individual product. LCAs are broken up into **modules** and **stages** along the lifespan of a product or building. Those stages are described in **Figure 1**.

LCAs are used in a variety of ways to inform design decisions. An LCA for a product, or an **environmental product declaration** (**EPD**), can help guide architects to pick the best product among competitors on the market. EPDs can be collected in **life cycle inventory** (**LCI**) databases, where they can be applied for use in whole-building LCA tools.

"**How is LCA used in the building industry?**

- Help building owners make informed choices regarding sustainability and/or resilience.
- Evaluate design options by providing insight into materials choices and their environmental impacts
- Achieve green building certification (e.g. in LEED v4 or Living Building Challenge)
- Assist in assessing the environmental benefits of new products and/or policy
- State that a system or product is environmentally preferable to another (to make a comparative assertion)
- Compare to benchmarks to evaluate a building's performance

The results of an LCA can illuminate which parts of a building have particularly high environmental impacts. This type of **hot-spot analysis** can help the design team achieve a more environmentally conscious design."[6]

Stages of Life Cycle Analysis

Module	Stage	Inclusions
Production (A1-A3)	Raw Materials Extraction Transport to Factory Manufacturing	New: Partitions & Framing, Ceilings, Flooring, Doors, Finishes, MEP System
Construction (A4-A5)	Transport to Site Construction & Install	Included for New
Use (B1-B7)	~~Use~~	Operational Energy
	~~Maintenance~~	~~Operational Water~~
	~~Repair~~ ~~Replacement~~ ~~Refurbishment~~	Projected Operational Energy of new MEP system
End Of Life (C1-C4)	Demolition Transport to Waste Waste Processing Disposal	Old: Partitions & Framing, Ceilings, Flooring, Doors, and Finishes
Benefits (D1-D4)	Reuse Recovery Recycling Exported Energy	Old: Partitions & Framing, Ceilings, Flooring, Doors, and Finishes

Figure 1

APPENDIX

APPENDIX

All LCA projects utilized REVIT models and Tally.

All Tally analysis included Modules A-D. Each project REVIT model did vary in phase, so this is important to note in comparison – as a DD model and CD model might have different results from the building constructed.

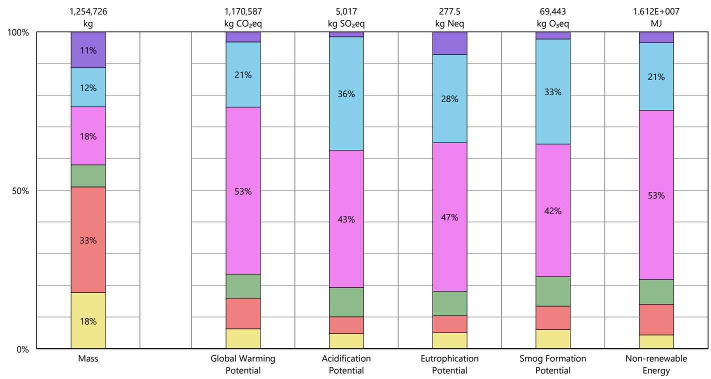
PROJECT NAME	REVIT MODEL PHASE	MODULES INCLUDED	NEW CONS/RENO	BIOGENIC CARBON	BUILDING ELEMENTS	NOTES
SBP	100% CD	A-D	NEW	INCLUDE	F, S, E, I	This one was cross checked / calculated with material take offs and ICE values **18 actual tally value, 23 reported*
BRUFF	90% CD	A-D	NEW	INCLUDE	F, S, E, I	
LWCC	100% CD	D (EXISTING), A1-A3 (RENO)	RENO	INCLUDE	I* + MEP	DEMO AND RENOVATION
CODE	100% CD	A-D	NEW	INCLUDE	F, S, E, I*	CORE AND SHELL, INTERIORS MINIMAL
THADEN	100% CD	A1-A4	NEW	VERIFY	F, S, E, I	
EXCHANGE	100% CD	A-D	NEW	INCLUDE	F, S, E, I	
GREENVILLE	50% DD	A-D	NEW	INCLUDE	F, S, E, I	
LYCEE	100% CD	D (EXISTING) + A-D	RENO*	INCLUDE	F, S, E, I*	PARTIAL RENO, PARTIAL NEW CONSTR

CODE

10/04/2019

Full building summary

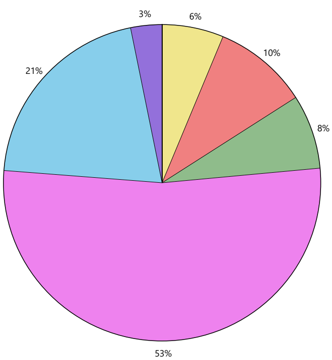
Results per Division



Legend

Divisions

- 03 - Concrete
- 04 - Masonry
- 05 - Metals
- 07 - Thermal and Moisture Protection
- 08 - Openings and Glazing
- 09 - Finishes



Global Warming Potential

What impacts do LCAs measure?

LCAs quantify a variety of measures called **environmental impact categories**. While the focus of this book and most LCAs is on embodied and operational carbon, the impact categories measured by LCA are all important to understand and reduce.

ENVIRONMENTAL IMPACT CATEGORIES		
Category	**Unit**	**Description**
Global Warming Potential (GWP)	CO_2 CO_2e	"Describes potential changes in local, regional, or global surface temperatures caused by an increased concentration of GHGs in the atmosphere, which traps heat from solar radiation through the "greenhouse effect." This impact category is strongly correlated with two others – acidification and smog formation – because global warming is largely driven by the burning of fossil fuels, which also directly contributes to these two impact categories."
Acidification Potential (AP)	--	"Describes the acidifying effect of substances in water and soil. Acidification can occur when substances such as carbon dioxide dissolve in water and lower the pH levels, increasing the acidity of the water. In LCA, this terms refers to the local effects of acidification. However, on a global level, ocean acidification threatens the survival of certain species and jeopardizes marine food supplies for humans [1]. Additional potential effects of acidification include the destruction of forests and erosion of building materials [5]."

Smog formation potential (SFP) *also known as "formation of tropospheric zone"*	--	"Describes the presence of substances such as carbon monoxide and volatile organic compounds (VOCs) in the atmosphere, forming photochemical smog. Smog is harmful to human health (e.g. causing respiratory issues) and ecosystems (e.g. causing deterioration of crops)."
Eutrophication Potential (EP)	--	Rivers, water, fish! "Describes the effect of adding nutrients to soil or water, causing certain species to dominate an ecosystem and compromise the survival of other species. An example of this is when an overgrowth of algae depletes water oxygen levels and kills off fish. Fertilizers are a dominant of eutrophication."
Ozone Depletion Potential (ODP)	--	That big ole hole in the ozone layer. "Describes the degrading effect of substances in the stratosphere on the ozone layer, weakening the ozone layer's ability to prevent excessive ultraviolet radiation from reaching Earth's surface. The Montreal Protocol has effectively mobilized global engagement to address this issue [6], [7]. Ozone impacts from building materials are rarely significant, but refrigerants used in mechanical systems are an area of concern"
Non-Renewable Energy use	--	Fossil fuels

From a practical standpoint, one reason to pay attention to all impact categories is for LEED credits. LEED LCA credits require you to consider all of these-never increasing any-and reduce impact in at least three of these in order to receive material impact reduction credits. LEED prescribes that one of these categories be Global Warming Potential.

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ST. PETER'S RESIDENTIAL

CLIENT: SBP
SOLAR CONSULTANT: SOLAR ALTERNATIVES

NEW ORLEANS RESIDENCE HALL

CLIENT: UNDISCLOSED

OFFICE RENOVATION

CLIENT: UNDISCLOSED
JACOB ALTER, PE/BERNHARD (CARBON EVALUATION OF MEP COMPONENTS)

THE CODE BUILDING

CLIENT: CSH DEVELOPMENT, INC
ARCHITECT OF RECORD: WOLF ACKERMAN
REC & CARBON OFFSET BROKERS:
- CARBON SOLUTIONS GROUP
- NATIVE ENERGY
- 3DEGREES

THADEN SCHOOL HOME BUILDING

CLIENT: THADEN SCHOOL

THE SHOP SLC AND MYA

CLIENT: THE DOMAIN COMPANIES

U.S. FEDERAL COURTHOUSE

CLIENT: GENERAL SERVICES ADMINISTRATION
ARCHITECT OF RECORD: DUVALL DECKER
STRUCTURAL ENGINEER: WALTER P. MOORE

LYCEE FRANCAIS SCHOOL

CLIENT: LYCEE FRANCAIS SCHOOL

ALL STUDIES

ARCHITECTURE 2030
KIERANTIMBERLAKE | TALLY
ZEROCODE