Whole Life Decarbonization in Alternative Real Estate Sectors

FINDINGS FOR REAL ESTATE INVESTMENT MANAGERS

MAY 2024

ABOUT THE PROJECT TEAM

ABOUT HARRISON STREET

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Cover Photo: Detail of cross laminated timber at Pacific Center Life Sciences Development, San Diego

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Real estate investment managers worldwide are grappling with the challenge of decarbonization and the translation of net zero commitments into tangible actions.

As constructing and operating buildings currently contributes an estimated 42% of the world's carbon emissions[1], the built environment's role in climate mitigation is increasingly critical.

This report discusses best practices for real estate assets to reduce both operational and embodied carbon – whole life carbon – to hold a market advantage today and into the future.

This report provides an overview of embodied and operational carbon, market trends and regulatory drivers, and sector-based strategies to help architects, building owners, engineers, and others to reduce whole-life carbon. Key points outlined in this paper:

1. DECARBONIZATION IS ALIGNED WITH FIDUCIARY RESPONSIBILITY.

Building owners have a dual responsibility: to enhance value and manage risk. Carbon reduction plays a pivotal role in this endeavor. Initially, focusing on carbon reduction translates to prioritizing energy efficiency. This not only directly lowers energy expenses which can improve Net Operating Income (NOI). Furthermore, the global momentum towards energy efficiency has substantially augmented the availability of rebates and incentives for updating building systems.

However, buildings with high carbon footprints face escalating risks due to exposure to carbon-related regulations, taxes, or fines, which are progressively being implemented across various regions of North America and Europe. In contrast, buildings with superior performance face considerably lower transition risks as disclosure and performance legislation expands.

With the growing public consciousness and market demand for real estate meeting sustainability criteria, addressing decarbonization diminishes the risk of having stranded assets and fortifies an asset's potential to maintain a competitive edge in the future market.

Decisions taken today can yield dual benefits by reducing both immediate and long-term carbon emissions. Decarbonization not only safeguards asset value but also aligns with the increasing tenant preference for eco-friendly buildings. Moreover, it bolsters resilience against climate change and related risks.

2. PROJECTED GROWTH OF DEMOGRAPHIC-DRIVEN AND ENERGY-INTENSIVE REAL ESTATE SECTORS IS EXPECTED TO INCREASE PRESSURE ON CARBON PERFORMANCE.

Global real estate floor area is projected to increase 15% by 2030 and nearly double by 2050.[2] Residential building energy consumption is already twice that of non-residential buildings and is projected to increase by 30% under current policies.[3]

This demand is increasing pressure on designing and operating buildings with efficiency in mind in anticipation of low-carbon infrastructure.

Energy intensive sectors such as life sciences laboratories, healthcare, and data centers are all benefiting from demographic and other secular demand tailwinds. Innovations in healthcare, a shift to outpatient treatment[4], and an aging population[5] all help drive demand for medical office and life sciences real estate, while an exponential increase in data usage and the advent of artificial intelligence continue to fuel demand for data centers[6]. These sectors present challenges of balancing critical operations and building owners' needs to reduce carbon. Sector-aligned strategies are needed to advance development and operational practices.

3. EFFECTIVE DECARBONIZATION STRATEGIES ARE INFORMED BY EACH ASSET'S CONTEXT AND NEEDS.

Decarbonization in real estate requires a nuanced consideration of both embodied and operational carbon. Balancing these factors involves evaluating strategies in light of climate zone, anticipated useful life, context, and building use type. Crucial questions include assessing efficiency improvements' payback in both cost and carbon, resilience to climate and grid changes, and optimal implementation timing.

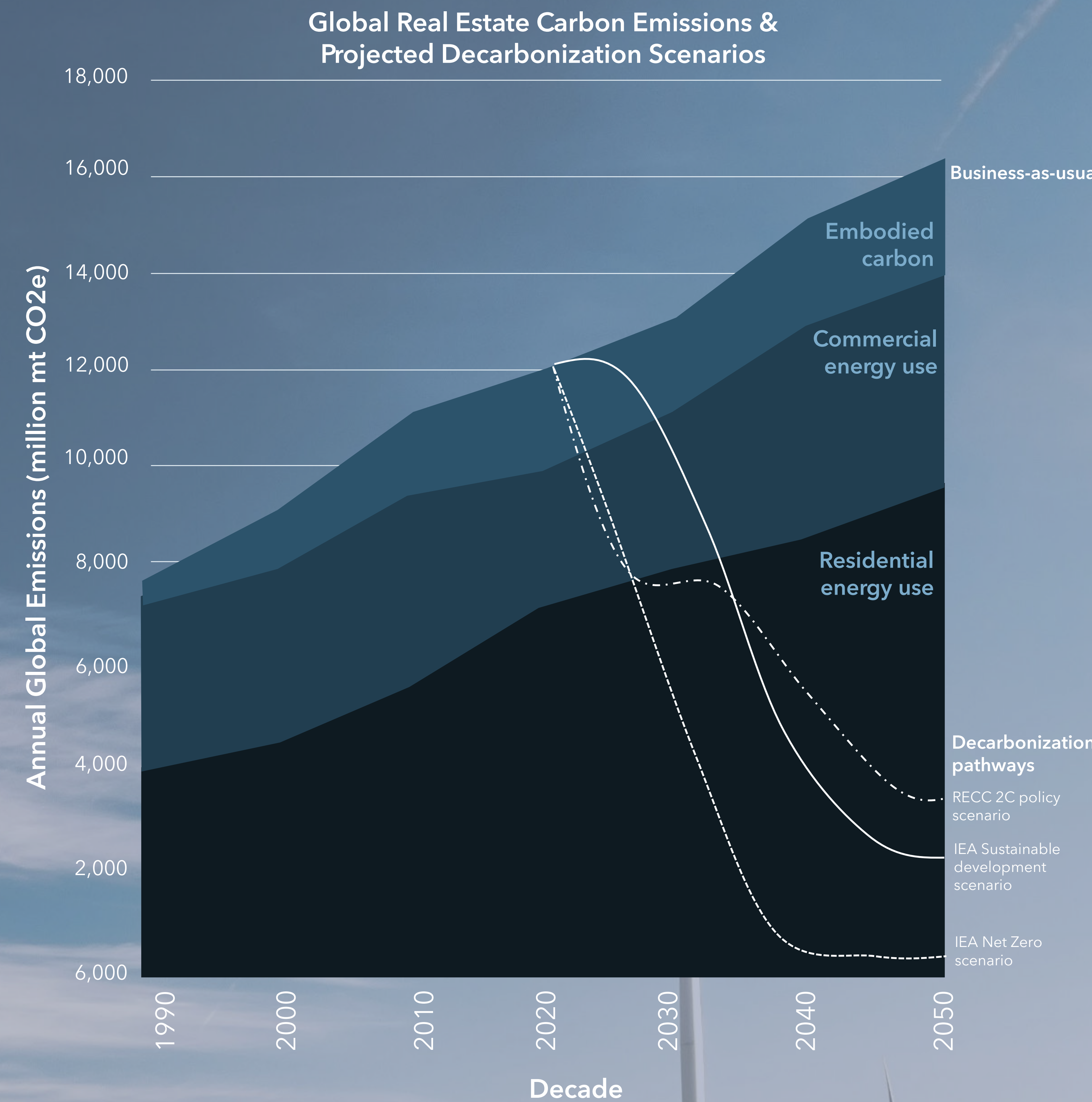
Understanding the unique characteristics of demographic-driven real estate typologies is vital, along with tailoring decarbonization solutions accordingly. Carbon performance can have a direct impact on occupants' experience in the building and can produce outsized operational expense benefits for large energy consumers such as life sciences laboratories, healthcare facilities, and data centers.

Location-specific factors, such as climate conditions and utility grid carbon intensity, significantly influence strategy effectiveness.

In conclusion, the need for real estate investment managers to understand and strategically prioritize decarbonization strategies is clear. By recognizing the impact of both embodied and operational carbon on asset value and market competitiveness, managers can seize opportunities to enhance returns and mitigate risks. Integrating these strategies into investment diligence and management procedures is needed to support asset resilience against future climate-related challenges, ultimately safeguarding long-term value and positioning portfolios for success in a rapidly evolving market landscape.

1. *IEA (2023). Energy Systems – Buildings.*
2. *UN Environment Programme (2022). 2022 Global Status Report for Buildings and Construction.*
3. *Architecture 2030, Why the Built Environment?*
4. *Kaiser Family Foundation (2023). Shift to outpatient treatment.*
5. *Moody's Analytics (2023). Aging population.*
6. *The Economist (2021). Exponential increase in data usage.*

The built environment's role in climate mitigation is increasingly critical.



Adapted from UN Environment Programme (2022). 2022 Global Status Report for Buildings and Construction.

Tooker House, Student Housing, Arizona State University

CHAPTER 1

Why carbon is material

The need for action

Together, constructing and operating buildings currently contributes an estimated 42% of the world's carbon emissions.[1]

Carbon emissions from buildings reached an all-time high in 2022.[2] Without strategies to shift away from business-as-usual practices, this number is only projected to rise, heightening transition risks as disclosure and performance legislation expand.

The transition towards cleaner energy sources is bound to encounter pricing fluctuations. The escalation of carbon emissions will be particularly noticeable as global real estate footprints expand, placing additional strain on grid infrastructure and energy suppliers. These pressures, compounded by geopolitical tensions, contribute to energy pricing volatility, adversely affecting building operating budgets and projected performance.

Tenants are increasingly conscious of these risks which impacts the marketability and attractiveness of buildings to future tenants and buyers. Decarbonization initiatives and sustainable practices can differentiate their properties in the market and attract environmentally-conscious tenants who prioritize sustainability. Several research studies have shown these initiatives can enhance the overall appeal of a building, leading to higher occupancy rates, increased tenant satisfaction, and potentially higher rental or sale prices.[3]

Proactive decisions can be made today can mitigate this risk exposure and support an asset's long-term sustained value and marketability. Energy efficiency strategies, electrification, and low-carbon construction practices are all critical to future-proofing assets.

1. *Architecture 2030, Why the Built Environment?*
2. *IEA (2023). Energy Systems – Buildings.*
3. *Dodge Data & Analytics (2021). World Green Building Trends.*

Regulatory drivers

With increasing regulations, policies, and legislations focused on carbon, higher-performing buildings have much lower risk of operating expense volatility or brown discounts[1].

POLICY: NORTH AMERICA

In the United States, federal support for decarbonization is continuing to grow, and pilot programs within large agencies are likely to accelerate uptake of new technologies and strategies. Key actions are also taking place at the state and regional level. While there is still not yet a consistent policy framework for low carbon design and measurement, ASHRAE is continuing to develop standards for operational carbon, and the Carbon Leadership Forum is advocating for standardization of embodied carbon measurement.

In Canada, Toronto and Vancouver are leading city-level policies. Vancouver requires embodied carbon to be calculated for all rezoning projects and is establishing operational carbon limits beginning in 2026. Toronto currently requires a 20% embodied carbon reduction for all municipally-owned projects and the Toronto Green Standard has stringent operational carbon intensity targets for all projects requiring planning approval.

POLICY: EUROPE

In London, requirements for large projects to undertake an embodied carbon assessment for planning approval has upskilled embodied carbon specialists, and these studies are becoming more available. RIBA has set 2030 targets around both embodied and operational carbon. Organizations such as the Low Energy Transformation Initiative and the UK Green Building Council are advocating for new Part Z regulations addressing whole-life carbon.

Several countries in Europe have policies or legislation regarding embodied carbon or whole life carbon, including France, Denmark, Finland, and the Netherlands. While there are no policies in place yet in Ireland, the Irish Green Building Council is developing a national methodology for embodied carbon accounting. Across the EU, Level(s) is a voluntary framework for embodied carbon assessment focused on measurement and reporting. The EU Energy Performance of Buildings Directive revisions in 2027 are expected to include a mandatory requirement for whole life carbon assessment.

1 The potential decrease in value of a property that is less energy efficient or sustainable.

RECENT AND UPCOMING CARBON POLICIES

USA	Inflation Reduction Act	Includes a grant to support manufacturers measuring and reporting embodied carbon, and pilot programs for procurement of low carbon materials on federal projects.
USA	Statewide Buy Clean policies	Requirements for embodied carbon in procurement. In New York, embodied carbon limits have been set for concrete, and in California, limits on steel, concrete, glass, and insulation.
USA	California CalGreen	New updates to CalGreen require either substantial reuse, low-carbon procurement, or a minimum 10% reduction in embodied carbon.
USA	New York City's Local Law 97	Local Law 97 sets mandatory operational carbon intensity limits, increasing in stringency from 2024 through 2040. Owners will be charged $268 per excess metric ton CO2e.
USA	Boston BERDO	The Building Emissions Reduction and Disclosure Ordinance (BERDO) requires emissions disclosure and decarbonization targets for existing buildings under operation.
CANADA	Vancouver By-Laws	Vancouver has set energy and operational carbon limits for residential and non-residential projects. Non-residential projects will be fined $350 CAD per excess metric ton CO2e.
CANADA	Toronto Green Standard (TGS)	TGS has minimum and voluntary tiers of performance for both operational and embodied carbon intensity. Planning applications must at least meet the minimum requirements, and improved performance is eligible for financial incentives from the city.
UK	Greater London Authority	Large developments are required to target a 35% reduction beyond energy code and conduct a whole life carbon assessment for planning permission.
UK	MEES	The Minimum Energy Efficiency Standard (MEES) regulations prohibit leasing buildings with an EPC rating below E (125 kg CO2e/m2/yr)
EU	Carbon Border Adjustment Mechanism	Importers of carbon and steel into the EU are required to report embodied carbon, which will be integrated into the Emission Trading System (ETS) beginning in 2026.
EU	Energy Performance of Buildings Directive	Proposed revisions to the EPBD are positioned to set more stringent operational emissions targets for new construction projects, phasing out of fossil fuels, and whole-life carbon assessments.

Market trends

Voluntary green building certifications, reporting schemes, and actions by real estate sector organizations all indicate a growing demand for low-carbon buildings.

CERTIFICATIONS

- **LEED:** LEED v4 rating systems include credits for embodied carbon reporting and reduction, and a compliance pathway for demonstrating operational carbon savings as an alternative metric to energy efficiency. The upcoming LEED v5 systems are anticipated to incorporate decarbonization more explicitly throughout the rating system, as one of the core principles.
- **International Living Future Institute Zero Carbon Certification:** Projects must demonstrate minimum improvement in operational and embodied carbon efficiency to achieve this certification.
- **CaGBC Zero Carbon Certification:** Projects must demonstrate minimum improvements in operational and embodied carbon efficiency to achieve this certification.
- **BREEAM:** Currently, BREEAM awards projects for measuring and reporting embodied carbon, with higher level of detail resulting in greater contributions towards certification.

VOLUNTARY REPORTING

- **GRESB:** GRESB reporting includes operational carbon as a key performance metric. Starting in 2023, GRESB also added a new indicator for embodied carbon tracking across new construction and major renovations.
- **Level(s):** The voluntary European sustainability framework for buildings includes guidelines around measuring and reporting embodied carbon and includes complementary strategies for improved circularity and material sustainability.

REAL ESTATE INITIATIVES

- **Carbon Risk Real Estate Monitor (CRREM):** This tool facilitates climate change risk assessment for commercial real estate, in alignment with Paris Agreement commitments. Users assess asset-level and portfolio-level performance in context of stranding risk due to regulation and shifts in retrofit costs.
- **Task Force on Climate-Related Financial Disclosures (TFCD):** This group established by the Financial Stability Board provided a series of recommendations for risk assessment, disclosure, and strategic planning for financial institutions.

DEVELOPMENT INITIATIVES

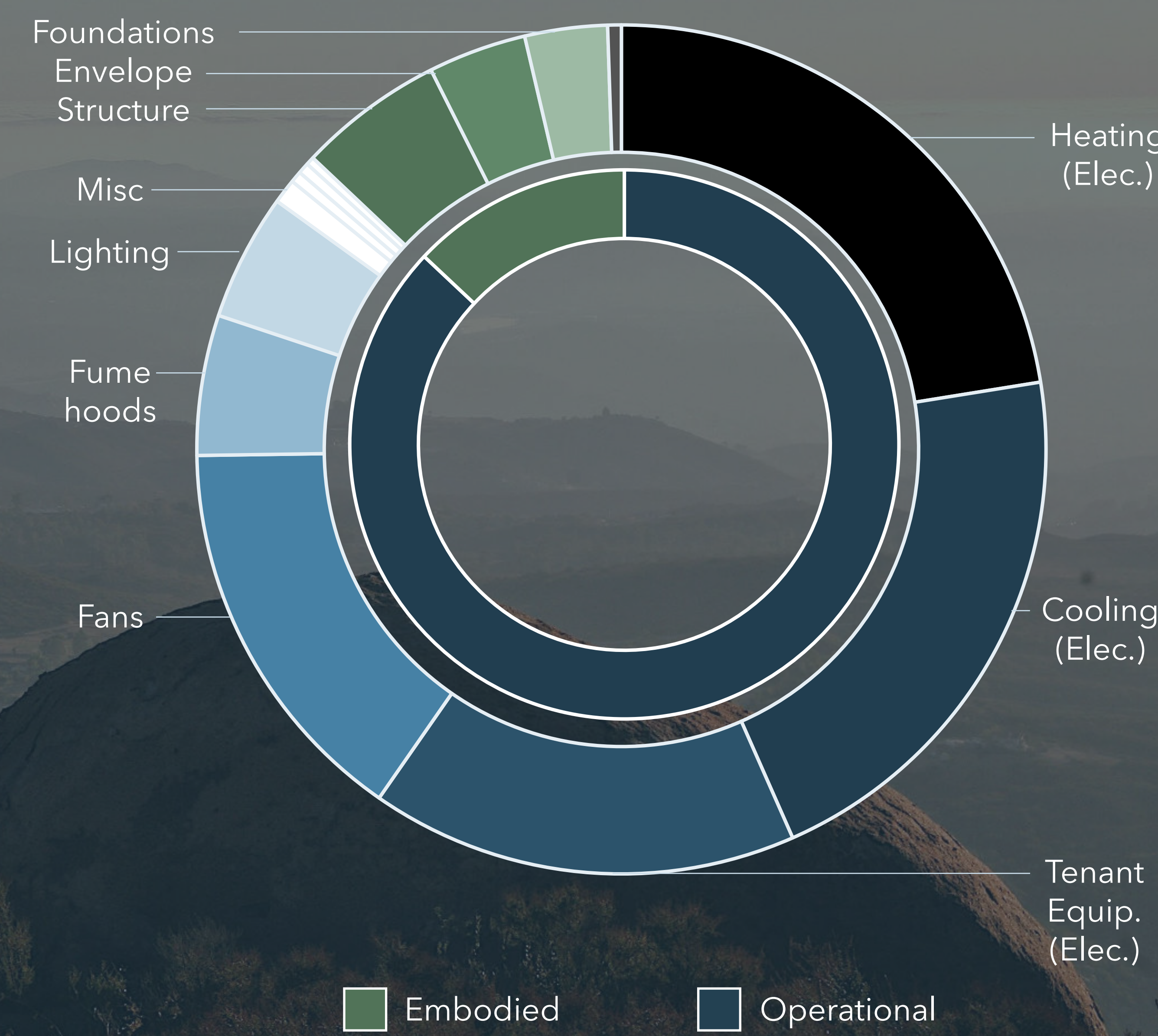
- **Architects Declare and AIA 2030:** Representing coalitions of architecture and interior design professionals, these organizations are targeting as-designed net zero operational carbon.
- **Engineers Declare and MEP 2040:** Representing building services engineering firms, this group is currently focused on refrigerant impact reduction and advocating for embodied carbon data for mechanical equipment.
- **Engineers Declare and SE 2050:** Representing structural engineering firms, this group is benchmarking embodied carbon and setting reduction targets through 2050 within structural systems.
- **ASHRAE 228-2023:** Author of the standards underpinning LEED and many energy and performance codes, ASHRAE released a new standard for evaluating net zero operational energy and carbon performance for new buildings.

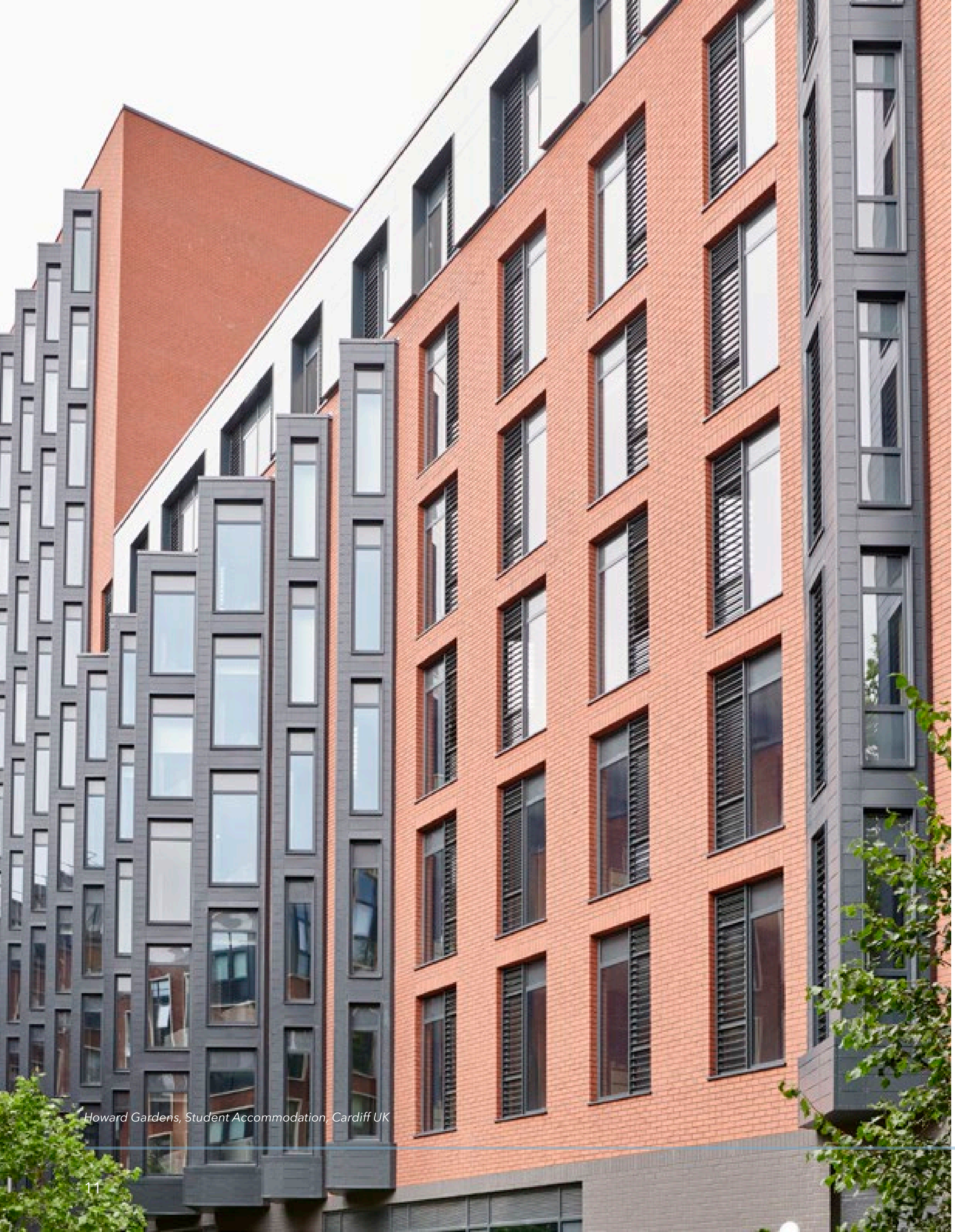
To target areas of highest emissions, a complete understanding of a building's whole-life carbon footprint is required.

Though in aggregate, embodied carbon represents half of the built environment's emissions, this is not always true at an individual project. For example, life sciences' heavy operational energy use can often overshadow the impact of embodied carbon.

Case Study Life Sciences Building in San Diego, Whole Life Carbon

See page 27 for further details on this project.





Howard Gardens, Student Accommodation, Cardiff UK

CHAPTER 2

Understanding carbon

Measuring carbon

Carbon models are powerful tools to support informed decision making on projects.

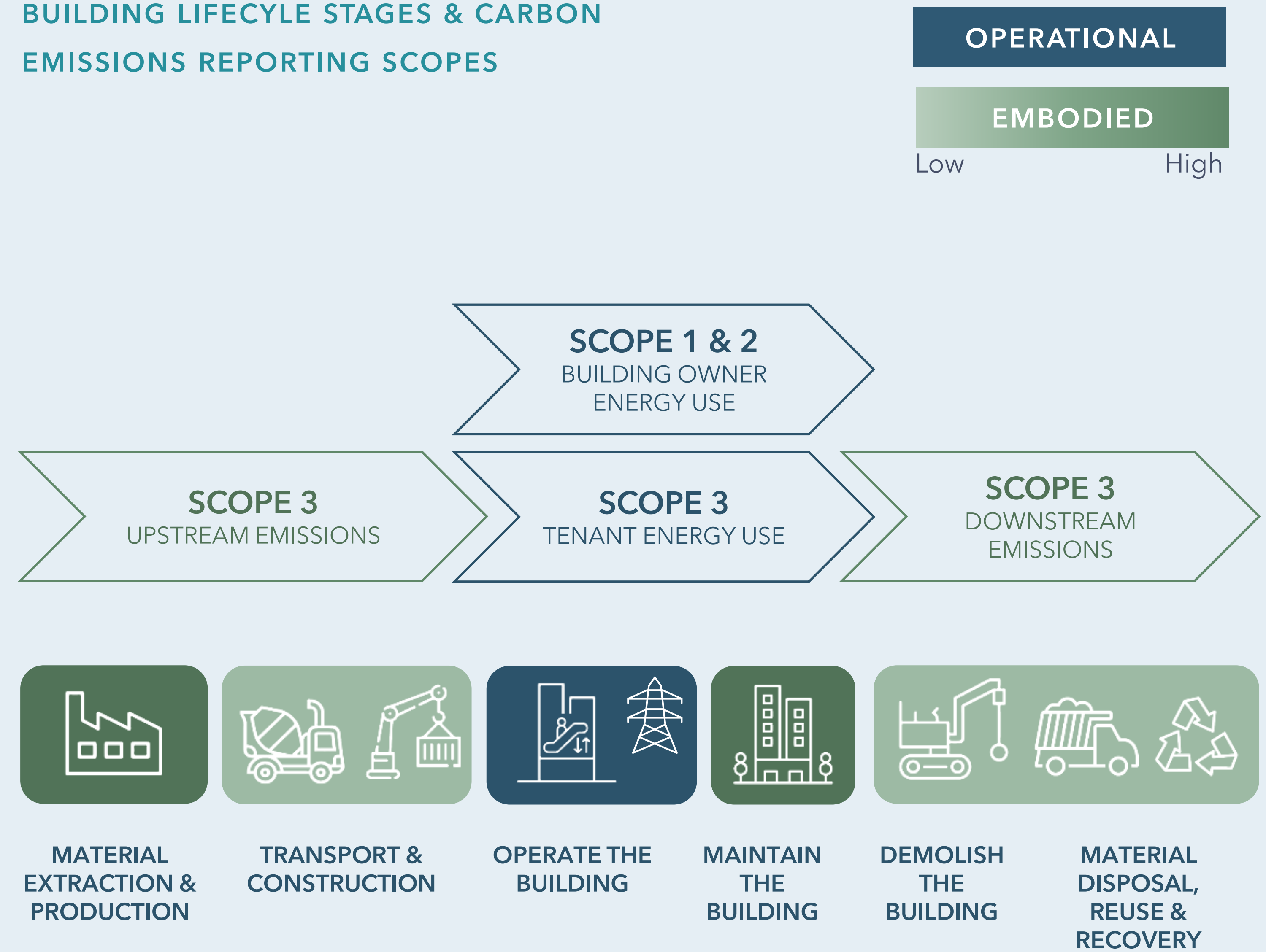
LIFECYCLE ASSESSMENT METHODOLOGY

In the built environment, carbon impacts are typically measured following the methodology established by ISO 14044: Environmental Management. This standard establishes a consistent framework for evaluating impacts within specific stages of a building's useful life, from material extraction through demolition. These calculations are called a lifecycle assessment, or LCA. ISO 14044 expands beyond the Greenhouse Gas Protocol Scope 1 and 2 emissions associated with on-site energy consumption and provides more structure to estimate Scope 3 emissions associated with construction materials and practices.

Carbon impacts are generally estimated by a lifecycle assessor, who uses an inventory of the building materials and estimated energy performance analysis to calculate and analyze the project's carbon footprint. Each building material can be assigned an embodied carbon intensity, measured in carbon dioxide equivalent (CO_2e) per unit, which describes the energy use of material extraction and manufacture, fuel use in transport to the site, maintenance and replacements throughout the building's life, and transport and energy used in eventual demolition. Each fuel source providing building energy can also be assigned an operational carbon intensity, derived from the types of fuels used to create power and (if purchased) the transmission and distribution intensity.

As with all models, a lifecycle assessment should always be interpreted with current limitations in data precision in mind. In particular, product-specific data may not be available, and industry average values may not reflect the exact materials specified. On-site scrap rates may not be tracked precisely. Both embodied and operational carbon intensity factors typically reflect long-term averages which in reality fluctuate in time. Lastly, actual operational energy will vary based on weather and usage patterns. However, LCAs still represent our best ability to understand a building's as-designed carbon footprint and are powerful tools. Having these inventories can guide decision-making by estimating the relative magnitude of each carbon use, allowing for prioritization of the most effective opportunities for reduction.

BUILDING LIFECYLE STAGES & CARBON EMISSIONS REPORTING SCOPES



Upfront carbon: Embodied carbon emitted prior to building opening

Operational carbon: Impacts with energy use in the building

End-of-life carbon: Embodied carbon emitted during and after demolition

Whole-life carbon: The total estimated carbon emissions from construction through use and demolition, including embodied and operational carbon, typically measured over a standard reference lifespan

Upfront carbon

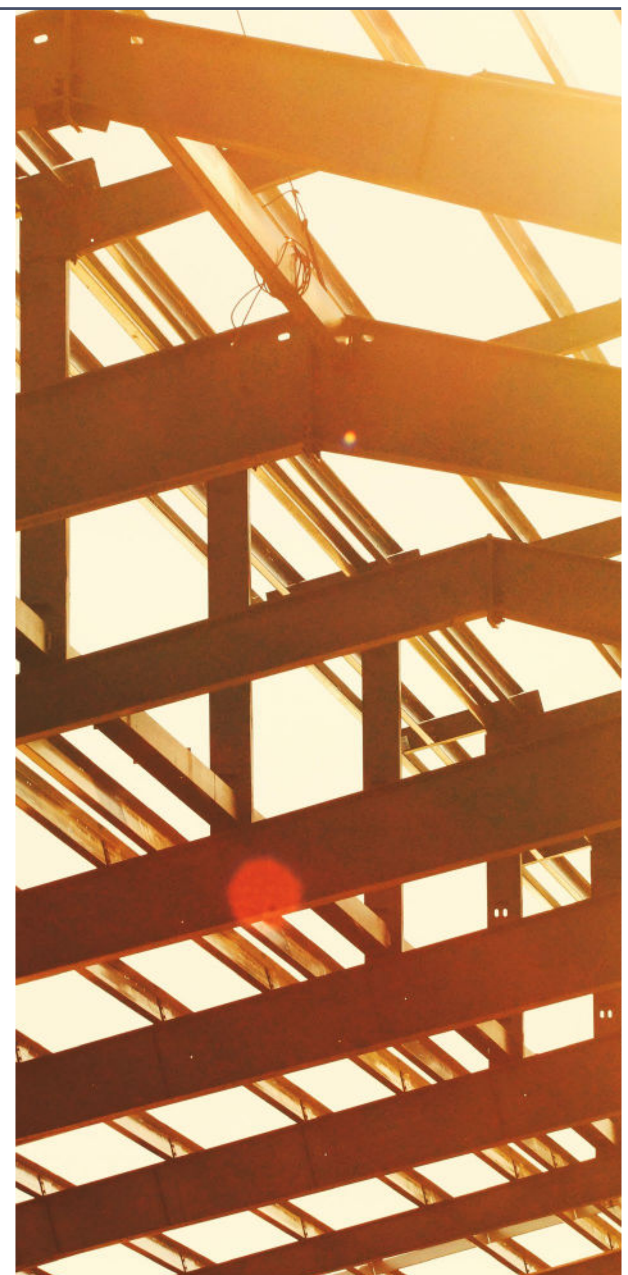
Mitigating the embodied carbon emitted prior to and during construction is critical to unlocking immediate carbon reductions.

SHORT-TERM SAVINGS

New development requires new materials, which results in upfront carbon.

The embodied carbon associated with raw material extraction, manufacturing, transportation, and construction is increasingly important as operational efficiency becomes more achievable and grids begin to decarbonize.

For typical energy performing buildings, upfront carbon is equal to 7-8 years' of operational carbon emissions; for high-performance buildings, upfront carbon can be equal to more than 30 year's worth of operational carbon emissions.



BUILDING LIFECYLE STAGES

EXTRACT RAW MATERIALS

Associated with: Raw materials used to create construction products
Generated by: Manufacturers' upstream suppliers
Can be reduced through: Use of recycled and sustainably-sourced ingredients

TRANSPORT TO FACTORY

Associated with: Movement of raw materials to manufacturers' factories
Generated by: Manufacturers' upstream suppliers
Can be reduced through: Selection by manufacturers of more regional , advocacy for lower-carbon transportation (i.e. ship instead of air, rail instead of truck, more compact shipments) lighter-weight packaging

MANUFACTURE PRODUCTS

Associated with: Energy and additional resources used to create products
Generated by: Manufacturers
Can be reduced through: More efficient processes, simpler process with fewer additives, location of manufacturing facilities in lower-intensity electricity grid regions, sourcing of renewable energy resources

TRANSPORT TO SITE

Associated with: Movement of construction projects to site
Generated by: Contractors' suppliers
Can be reduced through: Preference of local manufacturers during design, bidding, and procurement

CONSTRUCT THE BUILDING

Associated with: Energy and additional resources used during the construction of a building
Generated by: Contractors
Can be reduced through: Efficient installation practices such as modularity, design for disassembly, smart scheduling and coordination, and the use of efficient equipment during construction

Advancements in low-carbon materials

The construction industry is quickly innovating low carbon materials. Early conversations with construction teams can help identify low-carbon options for the "heavy hitters" with little to no cost premium.

EMBODIED CARBON CALCULATION & LIFECYCLE ASSESSMENT TOOLS

Athena Impact Estimator for Buildings (calculatelca.com) – A software tool designed to evaluate whole buildings and assemblies based on internationally recognized life cycle assessment (LCA) methodology.

One Click LCA (oneclicklca.com) – a streamlined and automated life-cycle assessment tool with a global database of environmental product declarations.

Tally (choosetally.com) – An LCA database application that enables calculating the environmental impacts of building material selections directly in an Autodesk Revit model.

	CONCRETE	STEEL	LAMINTATED TIMBER	INSULATION	GYPSUM BOARD	FAÇADE DESIGN
MATERIAL	Traditional concrete's high embodied carbon results from cement manufacturing. Low carbon alternatives, like Portland Limestone Cement (PLC), replace up to 15% of cement with unfired limestone. Blended cements may utilize natural pozzolans or calcined clays, achieving reductions of 50–70%. Admixtures like Carbon Cure inject CO_2 into fresh concrete for carbon sequestration.	Steel production often generates high emissions due to reliance on coal in traditional methods like blast furnaces for iron ore reduction. Low carbon steel manufacturers reduce emissions by using scrap steel and electric arc furnace that runs on renewable electricity as opposed to traditional fuel-based furnaces. Innovative approaches like hydrogen-based steelmaking replace coal with hydrogen, further reducing carbon.	Cross laminated timber (CLT) is a low-carbon alternative to concrete or steel due to its significantly lower embodied carbon emissions. It's made by layering wood panels at right angles and gluing them together under pressure, resulting in a strong and versatile building material. This manufacturing process effectively sequesters carbon dioxide within the timber.	Typical commercial insulation, like fiberglass and foam board, require high energy inputs during production. Mineral wool batt and fiberglass batt have lower embodied carbon compared to rigid and spray foams like polystyrene and polyiso for wall assembly. Natural alternatives like sheep's wool, dense-pack cellulose, cork, and straw bale are carbon-sequestering.	Gypsum board is the most common material used for interior ceilings and partitions and is made from both natural mined gypsum and synthetic sources. These materials require high energy input to manufacture. Lightweight gypsum board uses less water and requires lower drying energy. To reduce the embodied carbon, use lightweight gypsum board at the thinnest thickness necessary.	The embodied carbon of Façade panels vary greatly, impacted by the proportion of glass, aluminum, ceramic, steel, or precast stone in the assembly. In most cases, the largest carbon contributor is aluminum, the main material used in curtain walls due its strength and light weight. Low carbon aluminum can be achieved through sourcing renewable power for the smelting process.
DESIGN	Low carbon cements can meet the same PSI, water ratios, slump and strength performance standards and should have no impact on design or integrity.	Low-carbon steel may have slightly different structural performance compared to traditional steel, and availability can vary based on factors like market demand and production capabilities. Collaboration with suppliers is crucial to ensure suitable options for projects.	CLT can be used as an alternative to concrete to form roofs, floors, walls, and ceilings. CLT can be used to provide offsite pre insulated wall and roof sections and can be used in virtually any building type.	Low-carbon insulation options require integrative design into wall assemblies to achieve similar thermal performance, and moisture management.	Require an Environmental Product Declaration when sourcing gypsum board to enable team to choose the lowest-embodied carbon option. Design partition sizing align with panel standard sizing to reduce off-cutting waste.	Perform a schematic study of façade design options, comparing the embodied carbon of the materials making up each assembly option. Consider fire requirements, thermal goals, and supply availability when determining a chosen low-carbon façade.

In-use carbon

Energy efficiency, sourcing, maintenance, and renovations will comprise the largest portion of carbon over a building's entire service life.

LONG-TERM EFFICIENCIES

Operational carbon includes Scope 1 emissions (on-site fuel combustion), Scope 2 emissions (grid electricity use), and Scope 3 emissions (associated with tenant resource use, and refurbishments and replacement).

Operational carbon fluctuates over time and is affected by external factors including weather, building occupancy and use patterns, and energy sources. **Strategies which can reduce these long-term recurring emissions reduce risk of stranding assets** and often have the greatest impact towards emissions reductions.

Fuel type is as important as efficiency when considering operational carbon. Fossil fuel-based equipment locks in emissions that could potentially be avoided as electricity grids decarbonize. However, electric heat can result in higher operating expenses than fuel powered heating in some markets. **Performing a cost benefit analysis for electrification** when capital planning will be critical to avoid future carbon and expense risk.

In-use carbon also includes material replacement. **Preferring durable materials** and **reducing the total quantity of materials**, particularly those that aren't reusable, reduces impacts and maintenance costs.

BUILDING LIFECYLE STAGES

MAINTAIN THE BUILDING

Associated with: Additional materials used for replacement of building components, upgrades, and energy use required for maintenance
Generated by: Building operators and tenants
Can be reduced through: Selection of durable and low-impact materials, programs to encourage reuse for tenants

OPERATE THE BUILDING

ONSITE COMBUSTION

Associated with: On-site fossil fuel combustion
Generated by: Building operators or tenants
Can be reduced through: Efficient equipment, effective controls, tenant engagement and incentives, electrification of equipment, and conversion to low-carbon fuel alternatives.

GRID ELECTRICITY

Associated with: Grid electricity use
Generated by: Building operators or tenants
Can be reduced through: Efficient equipment, effective controls, tenant engagement and incentives, on-site solar, and procurement of renewable electricity.

REFRIGERANTS

Associated with: Refrigerants use & leakage
Generated by: Building operators or tenants
Can be reduced through: Selecting low-GWP refrigerants, phasing out high-emissions refrigerants, like R22, and controlling leakage of refrigerants on existing appliances.

Whole life carbon

Tradeoffs between embodied and operational carbon must be considered when evaluating efficiency improvements.

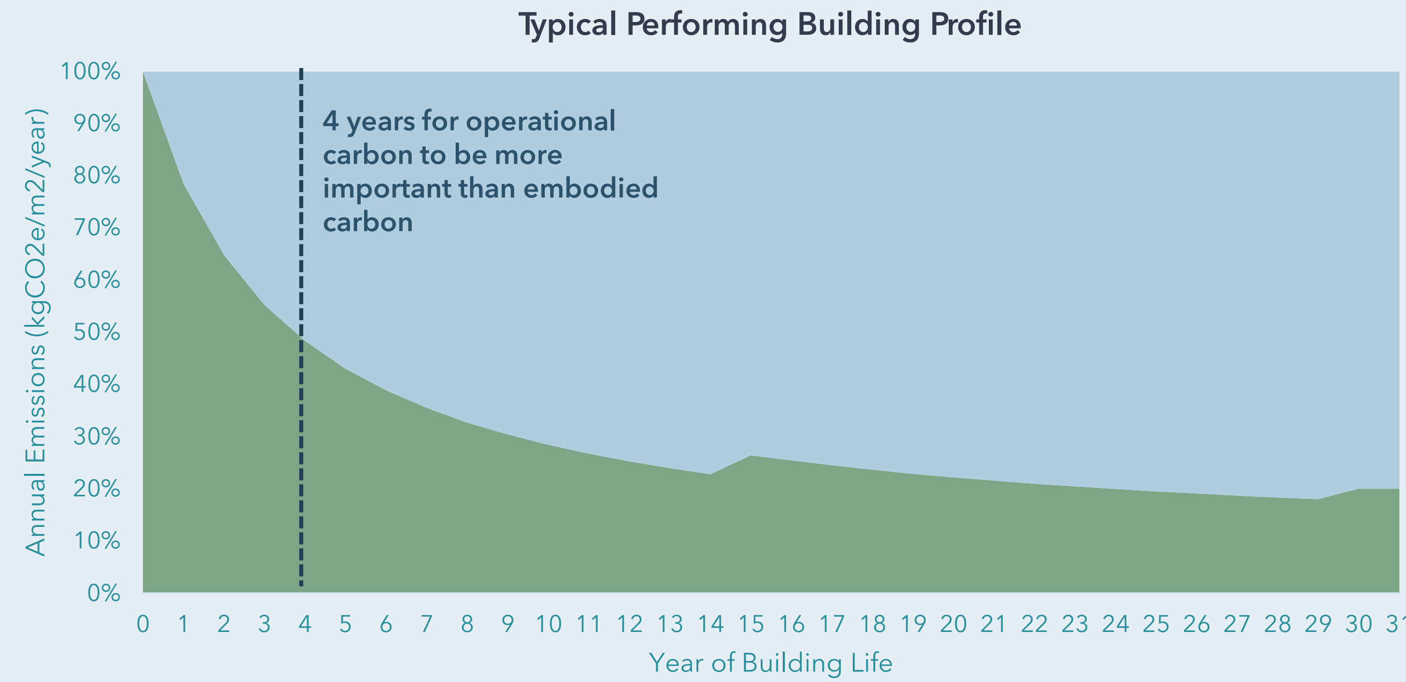
FINDING THE RIGHT BALANCE

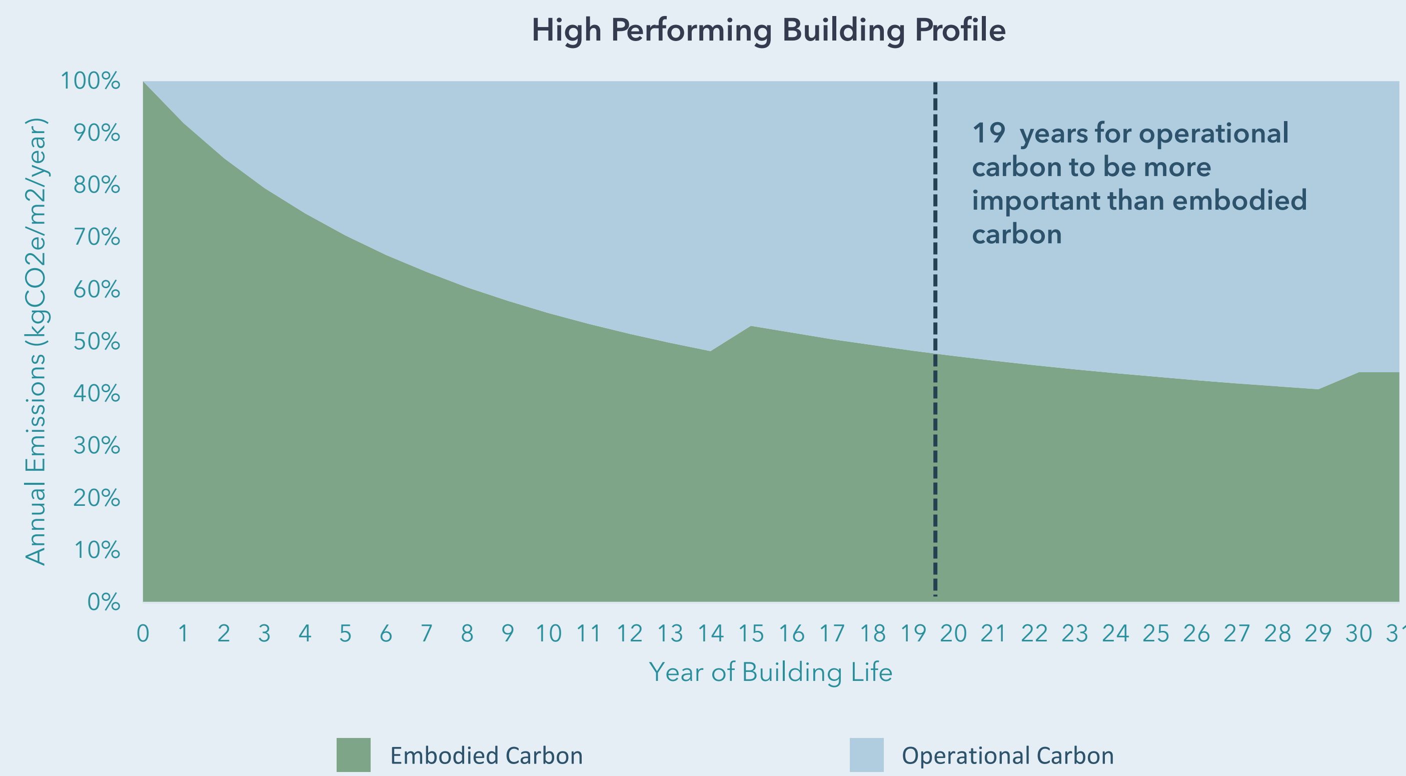
Whether strategies to reduce operational carbon intensity result in net whole life carbon depends on climate zone, anticipated useful life, context, and use type. Each intervention should be evaluated within the full context to understand the true degree of potential benefits.

KEY EVALUATION QUESTIONS

- Will this strategy result in enough of an efficiency improvement to pay back embodied carbon within the equipment's useful life?
- Will this strategy pay back in both cost and carbon? If not, how significant are these trade-offs?
- Are the projected savings resilient to changes in climate, use, or grid intensity?
- Is there an optimal time to implement this strategy based on projected context changes?
- Will new materials last as long as needed by occupants? If not, could a more durable option be a better solution?

CARBON EMISSIONS BALANCE OVER TIME





Adapted from US Commercial Building Energy Consumption Survey (US EIA, 2018) and the Embodied Carbon Benchmark Study (Carbon Leadership Forum, 2017). Assumes gradual grid decarbonization to zero by 2050.

Evaluating context

Although universal best practices provide a good foundation, carbon action is not a one-size-fits all solution.

CHARACTERISTICS

Demographic-driven real estate typologies have unique needs, and the right decarbonization solution for one use may not be right for another. Highest priority should be given to strategies which address the largest carbon sources. Impacts may vary with differences in occupancy, use schedule, degrees of occupant awareness and engagement with low-carbon practices, and environmentally-beneficial lease breaks.

Understanding the lifespan of both the building and equipment is fundamental to making decisions around whole-life carbon. For example, durable materials are a more effective strategy if used in assemblies that will last, but not if in assemblies that are generally replaced upon tenant turn.

Lastly, decisions made to support carbon reduction should always be considered within the broader context of occupant and community health. Many carbon mitigation strategies have co-benefits for wellbeing goals. For example, electric stovetops reduces indoor air pollutants and associated health risks.

LOCATION

Location is also a key determinant of which decarbonization strategies will be effective. Climate conditions, including heating and cooling loads, humidity, and solar intensity, determine the effectiveness of many energy efficiency strategies and what works well in one region may not translate to another.

However, making decisions to reduce carbon also requires understanding the carbon intensity of energy sources. The differences in carbon intensity of utility grids can mean that less energy-efficient assets in areas with cleaner grids can still have lower operational carbon intensity.

Availability of and familiarity with low-carbon construction materials, key to embodied carbon reductions, also varies by region.

While this report provides general findings and recommendations based on project type and location, the most important first step for implementing carbon action on any project is to understand the following points of context which affect decisions:

CONTEXT CHECKLIST

CHARACTERISTICS
Project use and tenancy
Anticipated lifespan of building and equipment
Health and wellbeing goals
LOCATION
Climate conditions: Heating and cooling loads, humidity, and solar patterns
Market availability of low-carbon materials
Current grid carbon intensity
Regionally applicable codes, standards, and legislation
Available incentives
FUTURE SHIFTS
Future utility grid decarbonization plans
Future changes in use patterns
CLIMATE RISK AND RESILIENCY
Intersections between risk reduction and climate change mitigation strategies

Evaluating context

Establishing a whole-life carbon reduction strategy requires understanding future as well as current conditions.

FUTURE SHIFTS

Lifecycle assessments may be based on today's conditions, but in reality, these conditions are already changing quickly. Many utility providers have either voluntary commitments or legislative mandates to decarbonize their grids. When these commitments are taken into consideration, strategies which provide near-term emissions reductions are more impactful than those which may have incremental, long-term benefits after utility grids have already begun to decarbonize.

For critical carbon reduction strategies, stress-testing by developing multiple utility grid carbon intensity scenarios can improve understanding of which factors may impact projected reductions. This approach can also be applied to factors such as usage, tenant equipment, and turnover rates as applicable.

CLIMATE RISK AND RESILIENCY

While understanding today's climate is fundamental to making informed decisions around operational carbon intensity, the climate is also changing, leading to increases and decreases in heating or cooling days. Therefore, the energy profile of a particular building may not look the same in ten- or twenty-years' time. Energy efficiency strategies must consider climate change adaptation as well. Developing multiple scenarios for future climate conditions can also provide direction on the strategies which will be most resilient to these changes.

Climate change also brings risk of operational challenges. Before exploring any carbon reduction strategies in detail, conduct a climate risk assessment to understand what will need to be addressed and how it may affect opportunities for carbon reduction. There are many strategies with co-benefits between climate change mitigation, adaptation, and occupant wellbeing. For example, in areas where electricity grid outages due to excess demand may be possible, on-site renewable energy to support critical power loads is an effective strategy which can also lower everyday operational carbon.

THE CARBON INTENSITY OF ELECTRICITY GRIDS WILL CONTINUE TO VARY

US locations: NREL, Cambium; Ontario: IESO Annual Planning Outlook 2022; UK: National Grid Future Energy Scenarios

Maximizing impact

For those who have set zero carbon targets, an integrative and strategic approach in operational and embodied carbon design is required.

THE NET-ZERO PATHWAY

Although the details will vary based on all the conditions previously described, there are still best practices that provide a solid foundation for carbon action in the built environment. These best practices have been developed and tested over many decades of green building.

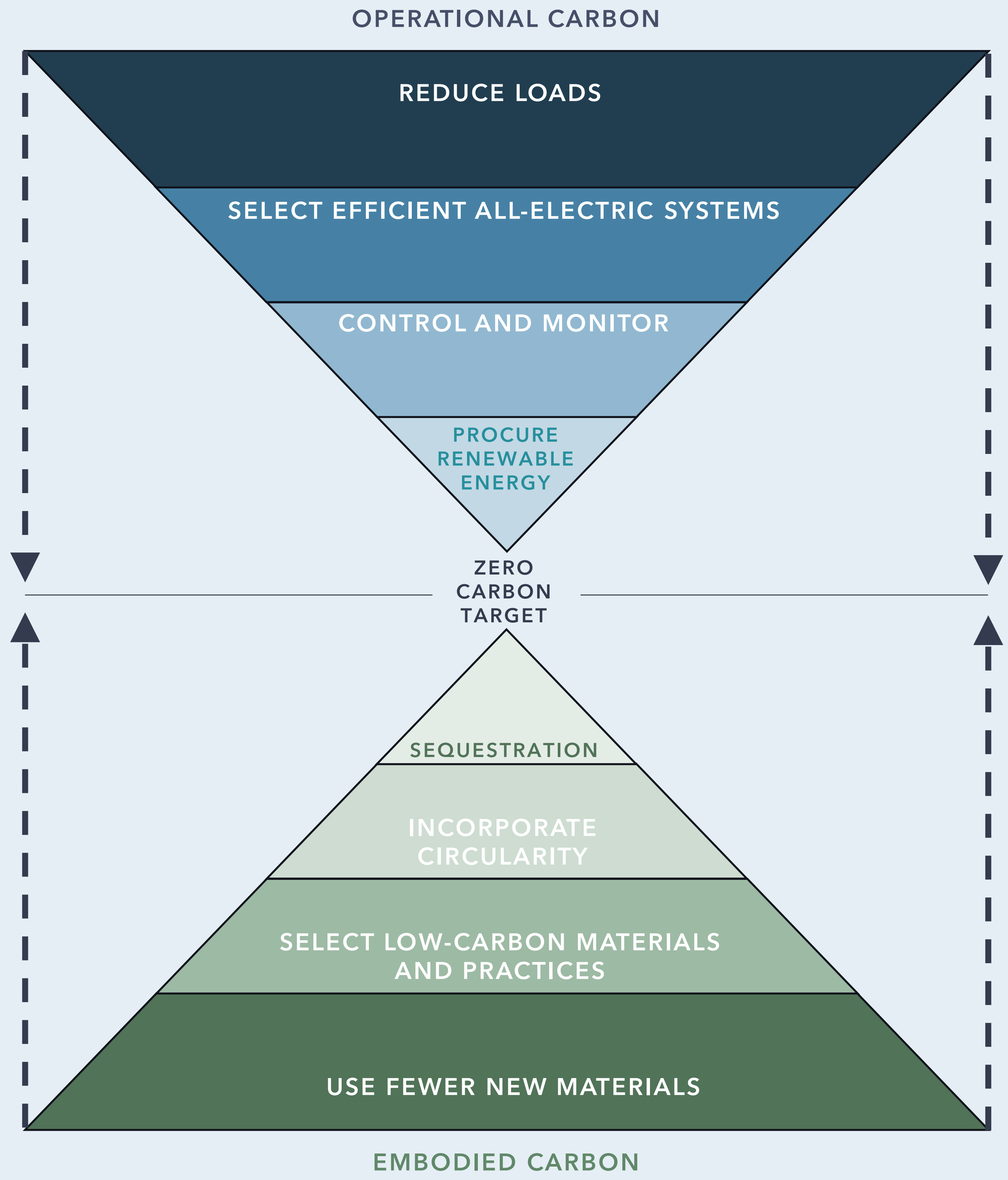
OPERATIONAL CARBON

Reducing operational carbon includes **minimizing energy loads** to lower energy consumption and carbon emissions. **Transitioning to efficient all-electric systems** further shifts reliance away from carbon-heavy fossil fuels. **Control and monitoring systems** ensure energy efficiency and minimize waste. Lastly, **adopting renewable energy sources,** like solar or wind, replaces traditional, carbon-intensive energy sources. Combined, these measures form an integrated approach to significantly cut operational carbon, contributing to a sustainable, low-carbon future.

EMBODIED CARBON

Reducing embodied carbon by **minimizing the use of new materials**, thereby reducing emissions from material extraction, manufacturing, and transportation, is the first step towards a zero-carbon target. **Opting for materials with lower carbon footprints and embracing sustainable practices** also contributes to emission reduction. **Circularity principles**, involving reusing and recycling materials, extend resource lifecycles and lessen the need for new, carbon-intensive materials. Furthermore, strategies like **investing in carbon-sequestering materials and landscaping** offset unavoidable emissions. These combined efforts create an effective strategy to substantially lower the embodied carbon in construction and building activities.

THE IDEAL HIGH-PERFORMANCE DESIGN PATHWAY



Pacific Center

LIFE SCIENCES CAMPUS, SAN DIEGO CA

Development Rendering

KEY TAKEAWAYS

- **Upfront embodied carbon reduction of 11% compared to baseline**
- **In use operational carbon reduction of 22% compared to code**
- **Understanding local material suppliers and supply chain limitations early in design can facilitate more holistic decision-making.**

Pacific Center, a joint venture between Harrison Street and Sterling Bay, is a new life sciences campus being developed in phases over four years in San Diego's desirable Sorrento Mesa submarket. Starting with a May 2023 groundbreaking, the first phase will include 500,000 rentable square feet of brand-new, state-of-the-art scientific research space, a 28,000-square-foot amenity center, and a 1,700-space parking facility.

The buildings are on track to achieve LEED Gold certification and a Fitwel 1 Star rating. To meet the project's LEED certification targets, energy modeling and lifecycle analysis was conducted to identify opportunities for carbon reduction within the parameters of highly-intensive future uses.

The project is almost fully electric, with on-site fossil fuel reserved for cooking equipment and emergency generators only. The California grid is currently decarbonizing with a goal of achieving net zero, so electrification is a forward-thinking strategy in this region which may result in further operational carbon savings over time.

An on-site solar array housed on the parking garage provides 3% of the campus' energy needs with supplemental clean energy.

CLIMATE ZONE: 5 (WARM)

ELECTRICITY GRID: CALIFORNIA (CAMX)

WHOLE-LIFE CARBON FOOTPRINT: 1.4-6.7 mt CO_2e/m^2 OVER 60 YEARS [1]

1 Range based on current grid decarbonization scenarios

Pacific Mesa

EMBODIED CARBON

SUCCESSES

Within the requirements for a conventional structure to accommodate mechanical equipment, the two lab buildings still reduced embodied carbon by 11% over business-as-usual practices.

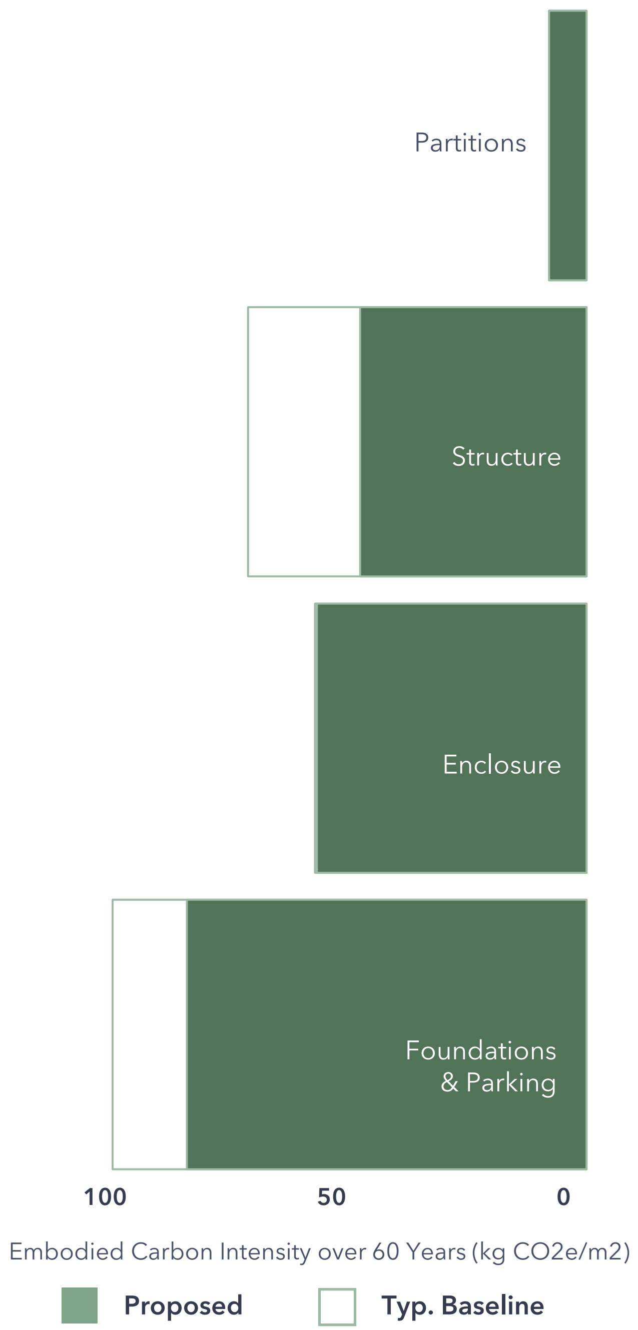
Structural steel selections include up to 97% recycled content, which reduces energy used during processing. While challenging in the local market, the project team was able to source concrete mixes with 6-11% embodied carbon intensity reductions, as reported by supplier Environmental Product Declarations (EPDs).

Although the program and site could not fully accommodate extensive mass timber, amenities were able to be separated from lab and office space into a smaller pavilion constructed using mass timber. This strategy reduced the campus' embodied carbon by 607 metric tons of CO2e.

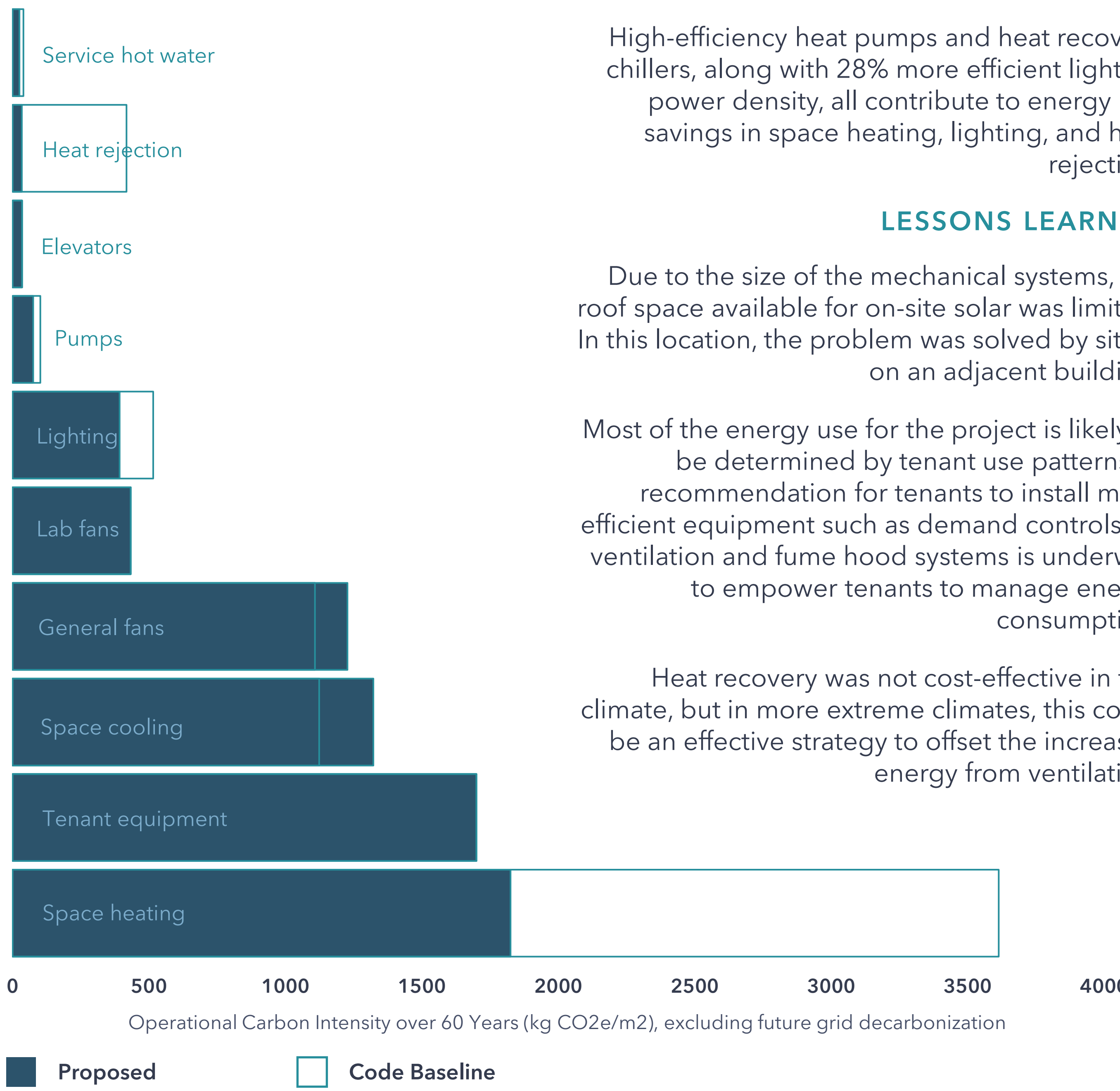
LESSONS LEARNED

In this market, it was challenging to find a low-carbon lightweight concrete mix, as the use of supplemental cementitious material is limited for lightweight applications. Researching availability of local suppliers and understanding limitations upfront on projects can facilitate more holistic decision-making during design.

Alternative concrete mix designs can often have longer cure times, and schedule adjustments should be planned for in advance to avoid future challenges.



OPERATIONAL CARBON



SUCCESSES

High-efficiency heat pumps and heat recovery chillers, along with 28% more efficient lighting power density, all contribute to energy use savings in space heating, lighting, and heat rejection.

LESSONS LEARNED

Due to the size of the mechanical systems, the roof space available for on-site solar was limited. In this location, the problem was solved by siting on an adjacent building.

Most of the energy use for the project is likely to be determined by tenant use patterns. A recommendation for tenants to install more efficient equipment such as demand controls on ventilation and fume hood systems is underway to empower tenants to manage energy consumption.

Heat recovery was not cost-effective in this climate, but in more extreme climates, this could be an effective strategy to offset the increased energy from ventilation.

Redgate Traffic Street

STUDENT ACCOMODATION, NOTTINGHAM UK

Development Rendering

KEY TAKEAWAYS

- **Early engagement was found to be crucial to align the design and suppliers**
- **Electrification of final design was key to achieving the whole-life carbon goals**
- **Concrete dominated the embodied carbon intensity of the project**

Redgate Traffic Street, a joint venture of Harrison Street and Torsion Developments, is a new 300-bedroom student housing development located in Nottingham, adjacent to the new city center campus and offering increased exposure to fast-growing and undersupplied university city.

The site is targeting BREEAM Very Good certification and Fitwel 3-star rating. The building is steel framed and will be clad with brick slips and glazing. The development will take advantage of bathroom pods manufactured offsite to maximize efficiency, safety and minimize embodied carbon.

The scheme aims to exemplify an environmentally and socially conscious construction culture with regular education activities around carbon reduction and wellbeing, as well as the positive promotion of construction through local apprenticeships and work experience.

CLIMATE ZONE: 3 (COOL)

ELECTRICITY GRID: UK NATIONAL GRID

WHOLE-LIFE CARBON FOOTPRINT: 1.3-2.6 mt CO_2e/m^2 OVER 60 YEARS[1]

1 Range based on current grid decarbonization scenarios

Redgate Traffic Street

EMBODIED CARBON

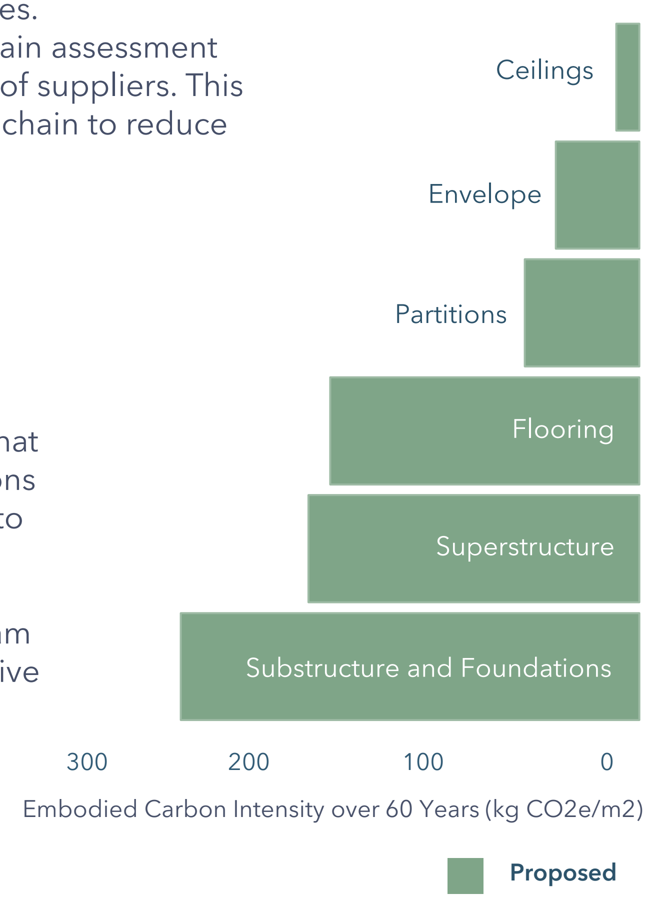
SUCCESSES

Several strategies greatly contributed to the project's success and low-embodied carbon, including:

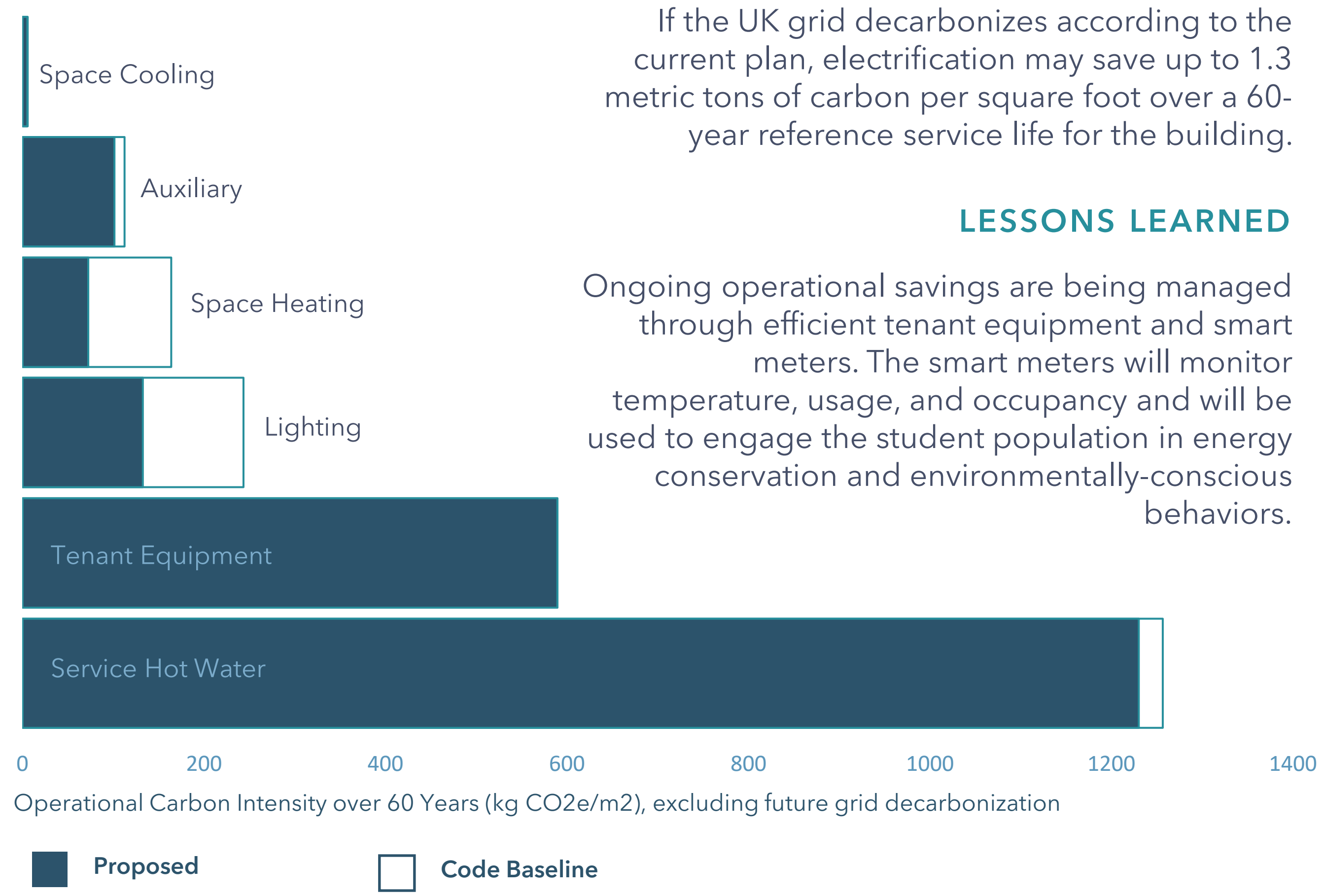
- The construction team used low emissions/electric vehicles on site to transport materials and staff.
- The buildings in-unit bathrooms were built offsite on a production line which uses prepared cut lists of all sheet materials to ensure the optimum number of materials, cut in the most efficient manner to maximize efficiency and minimize waste.
- Training is provided for the construction team to up-skill the workforce on carbon reduction practices in construction and methods for conserving energy and resources.
- The construction team conducted supply chain assessment including reviews of environmental policies of suppliers. This supported the in engaging across the value chain to reduce emissions.

LESSONS LEARNED

The embodied carbon assessment identified that the concrete within the substructure, foundations and superstructure as the biggest contributor to carbon intensity. Timing and supply chain limitations did not allow for a low-carbon concrete to be used for the project, but the team gained insight from this experience that will drive earlier material specification and supplier identification on future projects.



OPERATIONAL CARBON



SUCCESSES

Sustainability initiatives implemented in the building include water efficient fixtures, thermal envelope improvements of 30-50% over Part L reference minimums, improved airtightness, efficient lighting, and energy efficient space and hot water heating equipment. Electric panel heaters have been installed with automatic temperature cut off points to reduce operational heating waste or misuse.

If the UK grid decarbonizes according to the current plan, electrification may save up to 1.3 metric tons of carbon per square foot over a 60-year reference service life for the building.

LESSONS LEARNED

Ongoing operational savings are being managed through efficient tenant equipment and smart meters. The smart meters will monitor temperature, usage, and occupancy and will be used to engage the student population in energy conservation and environmentally-conscious behaviors.

Belmont Village Hunters Creek, Senior Living, Houston TX

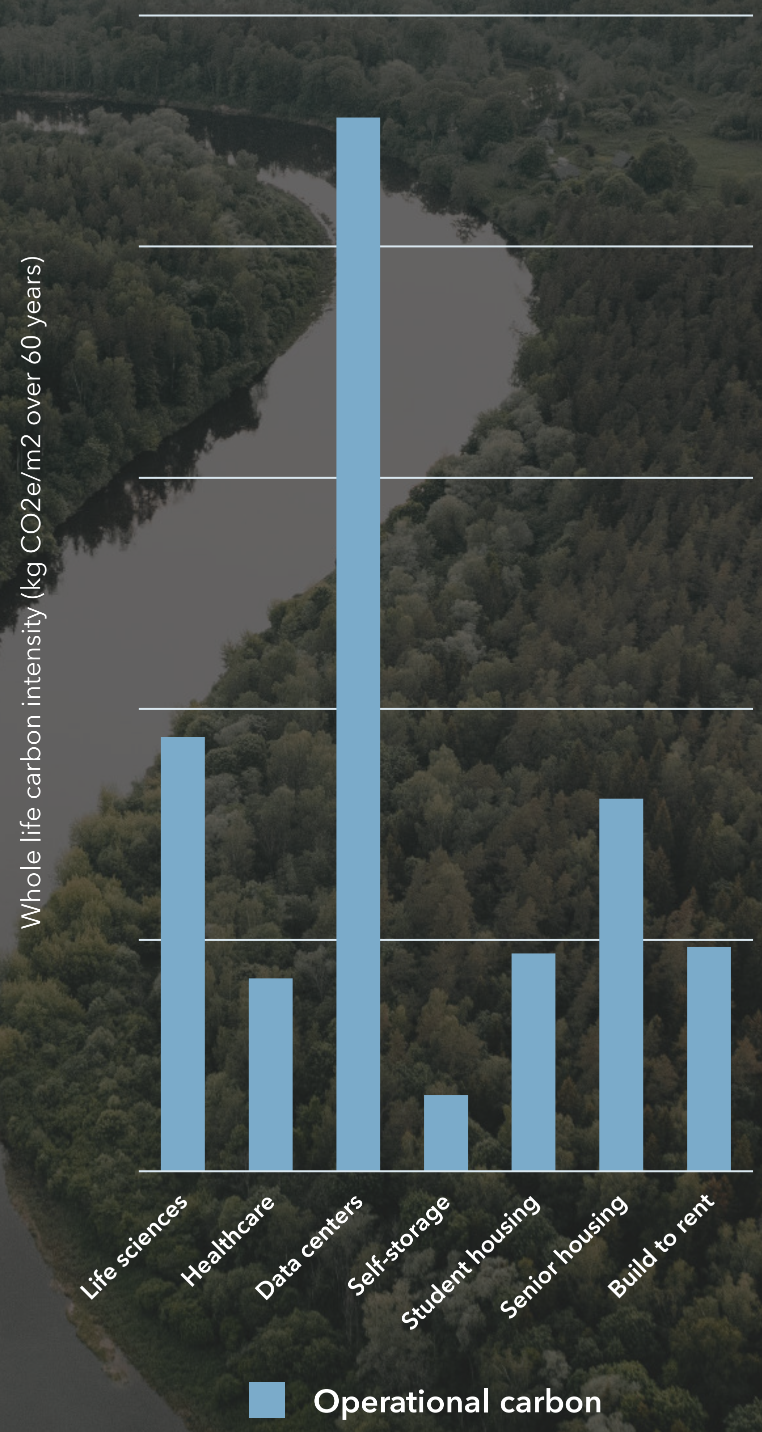
CHAPTER 3

Low-carbon strategies for alternative real estate sectors

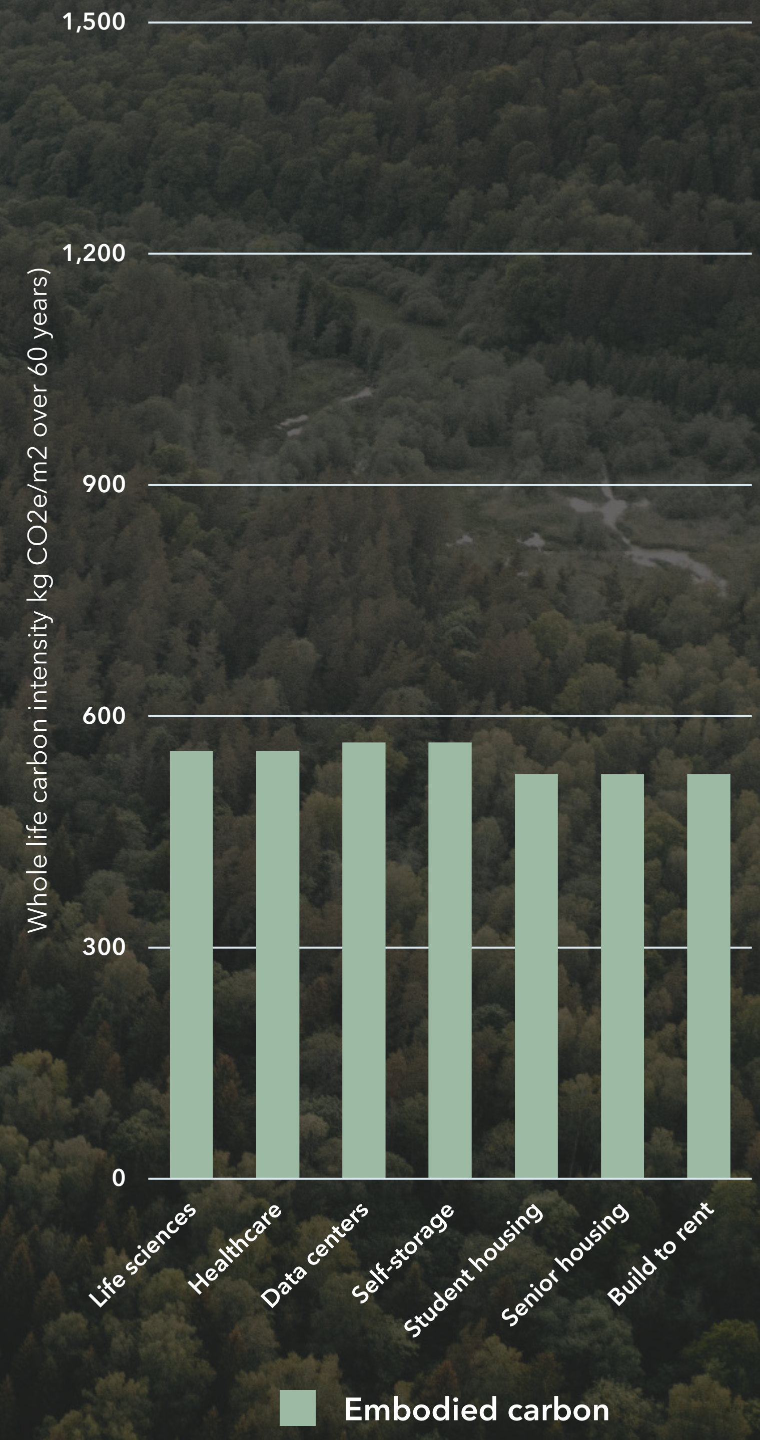
To support real estate investors and operators in aligning low-carbon strategies to sector-specific nuances, the following tables detail design and operational considerations for reducing embodied and in use carbon.

Each asset type has its own challenges and opportunities for successful decarbonization.

US Median Carbon Intensity (over 60-year reference lifespan)



US Median Carbon Intensity (over 60-year reference lifespan)



Adapted from Energy Star Portfolio Manager and Carbon Leadership Forum 2017 Benchmark Study. Operational carbon reflects all-electric energy sourcing.[2]

Life Sciences

Demand for life sciences real estate has been growing due to an increased incidence of chronic disease, an aging population needing healthcare, and funding from pharmaceutical companies, the National Institute of Health, and venture capital firms. Laboratories are **highly specialized spaces** with unique equipment and use patterns.

These translate into **higher operational carbon** through process equipment and ventilation demand, and higher embodied carbon through the need to support all the large equipment.

With such high demands, we believe strategies to improve both operational and embodied carbon efficiency can have a significant positive impact on the footprint of critical research. **Strategies which are adaptable and flexible to researchers' changing needs** will improve the practical longevity of these facilities.

Representative photo of research laboratory

Life Sciences

OPERATIONAL CARBON OVERVIEW

Laboratories typically consume **5 to 10 times more** energy than office buildings[1], and some specialty labs can consume up to 100 times more.

The basic energy challenge confronting laboratory designers is the high cost of conditioning the large volume of **ventilation air** needed to meet safety requirements. The energy requirements of clean rooms and labs with large process loads can be much higher than any other supporting energy use.

1. NREL (nd). Laboratories for the 21st Century: An Introduction to Low-Energy Design.

EMBODIED CARBON OVERVIEW

Laboratories' complex mechanical systems and larger equipment also increase the building's embodied carbon footprint.

The envelopes of life science buildings often feature large curtain wall surfaces, which can be carbon intensive. Additionally, the need for easily cleanable surfaces, such as vinyl-based flooring, a fossil fuel derived material, contributes significantly to embodied carbon impacts.

Life Sciences

EMBODIED CARBON BEST PRACTICES

Planning

Consider timber construction early in the process.

It is best to discuss this during conceptual design and collaborate with a structural engineer as early as possible.

Separating out program types in the project massing can make it easier to integrate a hybrid timber structure for office uses if the weight of lab equipment still requires a standard structure.

When considering a mass timber structure, be sure to assess the regional structural capabilities, and the seismic and fire protection legislations.

If not possible, research the availability of low-carbon concrete mixes, steel with high recycled content, or steel manufactured in electric arc furnaces.

Design

Collaborate with the mechanical team to right-size air distribution.

Due to required high air exchanges, efficient mechanical systems and ducting layout optimization can help to reduce the total amount of sheet metal and associated embodied carbon.

Choose exposed or sealed concrete as the floor finish when a concrete floor slab is used.

This is still a cleanable surface and reduces the need for additional materials.

Construction

Consider a prefab building facade system to reduce construction waste.

Life sciences modules tend to be regular and require high thermal performance, characteristics well-suited to prefabrication. This strategy reduces embodied carbon associated with material waste and can save carbon during construction by streamlining the construction schedule and processes.

Operations

Provide guidance for tenant move-in, move-out, fit-out, and maintenance.

The cleanable materials required for life sciences applications are often more durable. Planning for move-in and move-out of tenants with similar use needs could potentially help to preserve embodied carbon, especially if the need to reconfigure mechanical distribution can be avoided.

Life Sciences

OPERATIONAL CARBON BEST PRACTICES

Planning

Isolate office and support spaces from lab modules.

This reduces the volume of space that needs to be served by 100% outside air and decreases the energy required for conditioning and distribution.

Plan adjacencies considering mechanical system selections.

Zone lab modules based on classification-driven ventilation requirements.

Design

Invest in highly efficient MEP (Mechanical, Electrical, Plumbing) systems first, then focusing on insulation and orientation for significant energy efficiency.

Lab modules normally require 100% outside air – often at exchange rates between 6 and 10 ACH – to meet the aggressive exhaust requirements of fume hoods and in some laboratory designs. These impacts vary by climate type, with higher benefits from high-efficiency conditioning systems in more extreme climates.

Construction

Require Whole Building Commissioning.

With large complex equipment, commissioning is especially valuable for life sciences buildings to reduce operational issues. Commissioning should include adequate training on building management systems before hand-off.

Operations

Provide guidance for tenant equipment.

High-performance fume hoods with occupancy-based face velocity setback, automatic fume hood sash closers, and high-efficiency freezers (Energy Star or equivalent) can help to bring down heating, cooling, and receptacle loads.

Benchmark, monitor, and report annually on energy performance.

Consider occupancy engagement through dashboard displays, or participation in green labs program such as Labs2 Zero, LBL Labs21, or My Green Lab Certification.

SECTOR CONSIDERATIONS

Healthcare

Healthcare real estate demand has grown due to an increase in outpatient treatment and an aging population driving demand for healthcare.

The healthcare sector in the United States contributes to almost **10% of the nation's total greenhouse gas emissions.**[1]

On average, hospitals in the United States consume approximately **5 times more** energy annually compared to non-healthcare commercial buildings[2].

Healthcare facilities typically **function 24/7**, requiring continuous energy supply for lighting, heating, cooling and medical equipment.

1. Commonwealth Fund (2022). How the US Health Care System Contributes to Climate Change.
2. Guttmann (2023). Turning the health care sector toward decarbonization: USGBC.

Representative photo of medical office

SECTOR CONSIDERATIONS

Healthcare

OPERATIONAL CARBON OVERVIEW

Among all commercial building, inpatient healthcare buildings has the highest **space heating and ventilation intensities.**[1]

Healthcare buildings, especially inpatient facilities, typically have high energy consumption due to the continuous need for various **medical equipment, lighting, ventilation**, and other critical services.

Many small healthcare facilities opt for **constant-volume reheat** systems to address space conditioning needs, as they offer independent control over temperature, humidity, and space pressurization requirements.

1. US EIA (2018). Commercial Buildings Energy Consumption Survey.

EMBODIED CARBON OVERVIEW

Similar to laboratories, equipment demand in healthcare results in high embodied carbon for mechanical systems, along with structural requirements to support them.

Like-for-like substitutions for high impact materials such as glass, steel, and concrete can be an appropriate strategy for reducing embodied carbon.

Matching selections with program needs and incorporating natural, biobased, and durable materials as much as possible can further improve savings.


Representative photo of medical office

Healthcare

EMBODIED CARBON BEST PRACTICES

Planning

Plan adjacencies considering mechanical system selections.

Zone modules based on classification-driven ventilation requirements to reduce mechanical distribution infrastructure.

Design for future adaptability.

With changing requirements for healthcare facilities, an adaptable building will have more longevity over time, reducing the need for partial or full demolitions and reconstruction and significantly saving embodied carbon. Designing attached multi-level parking garages to be adapted to accommodate future expansions or use changes over time is another effective futureproofing strategy.

Design

Look for durable and biobased materials.

Non-vinyl alternatives to resilient flooring typically have equal or lower embodied carbon footprints than their synthetic counterparts.

Durable materials in high-traffic areas will reduce the need for maintenance and replacement during operations. For hospitals, materials which have higher upfront carbon may still be less carbon over the building's useful life if they do not need to be replaced frequently.

Construction

Maximize recycled content in concrete and steel.

As early as possible in the project, research available concrete mixes from regional suppliers to understand potential opportunities for maximizing the amount of SCMs or the use of PLC. Source steel from domestic electric-arc furnace facilities that operate on clean grids and boast a recycled content of over 95%. Procure concrete and steel from suppliers with region-specific EPDs to validate its embodied carbon impacts.

Operations

Collaborate across the supply chain.

The long-term demand for material replacements and larger facilities are an opportunity to build long-term relationships with manufacturers and suppliers to implement strategies for embodied carbon reduction throughout the supply chain.

Healthcare

OPERATIONAL CARBON BEST PRACTICES

Planning

Consider orientation and form-to-width relation to daylight and solar gain.
Properly orienting a healthcare facility is vital for optimizing natural lighting, reducing the need for artificial lighting, and improving HVAC system efficiency.

Optimize space allocation for natural ventilation.
Designing spaces with depth-to-height ratios ranging from 2 to 2.5 facilitates the implementation of single-sided natural ventilation.

Design

Invest in highly efficient MEP (Mechanical, Electrical, Plumbing) systems.
With high energy demands, switching to energy-efficient HVAC systems like geothermal heat pumps or high-efficiency central plants can decrease energy consumption while ensuring optimal indoor climate conditions type, with higher benefits from high-efficiency conditioning systems in more extreme climates.

To accommodate fluctuations in energy demand over time, consider modular systems which can better match efficiency to demand compared to oversized equipment.

Construction

Require Whole Building Commissioning.
Healthcare facilities are ideal candidates for commissioning due to their high energy consumption, extended operating hours, substantial ventilation needs, and potential use of outdated equipment.

Many healthcare facilities have expanded without undergoing a commissioning study or recalibrating their Building Automation Systems (BASs). Participating in a utility-offered commissioning program can yield cost savings, and resources from Lawrence Berkeley National Laboratory's Building Commissioning web page provide insights into cost-benefit considerations and inspection processes.

Operations

Benchmark, monitor, and report annually on energy performance.
Building Automation Systems (BASs) are particularly beneficial in healthcare facilities due to their substantial energy consumption and the diverse requirements of various rooms.

The 2020 NREL report on Innovations in Sensors and Controls for Building Energy Management outlines the latest technologies employed for effective building energy use management

Implement sensors or timers in spaces with intermittent use, such as offices, break rooms, storage areas, and restrooms, to conserve energy.

Data Centers

Worldwide, data centers account for **1 to 2% of global electricity demand[1],** and their design has continuously evolved to enhance efficiency and reduce energy consumption. Due to trends such as growth in AI and the distribution of compute to the edge, commissioned power in North America is expected to increase by 85% by 2026.[2]

Data centers operate **full-time every day of the year**, and they usually contain one or more data halls requires the constant provision of power supply.

As more leisure, education and work systems move online, contrasted by a reduction in commercial real estate, **the carbon footprint of data centers is forecast to continue growing**.

1. IEA (2023). Data Centres and Data Transmission Networks.
2. Data Center Hawk (2022). North American Data Center Industry Growth.

Representative photo of data center

SECTOR CONSIDERATIONS

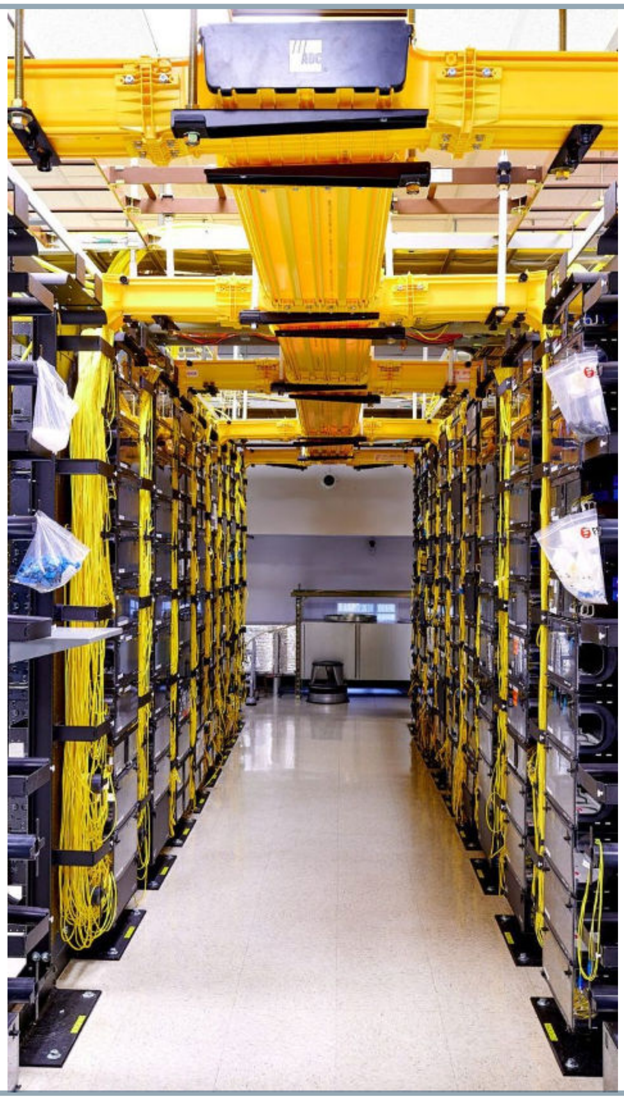
Data Centers

OPERATIONAL CARBON OVERVIEW

Data center's energy use intensity by floor space can be **10 to 50 times higher** than a typical commercial office building.[1]

Cooling systems in data centers are essential for **removing the heat** generated by IT equipment. In areas with suitable climate conditions, the use of an **air-side economizer,** which employs outside air for cooling, can be an effective option. It is crucial to maintain an optimal temperature range, as recommended by ASHRAE[2], **between 65-80F,** to ensure the reliable operation of hardware in these facilities.

1. US DOE (nd). Data Centers and Servers.
2. ASHRAE (2021). 2021 Equipment Thermal Guidelines for Data Processing Environments.



EMBODIED CARBON OVERVIEW

Over 90% of a data center's embodied carbon emissions can be associated with mechanical and electrical equipment.[3]

Over the building's lifetime, the widening gap between MEP equipment and other components can be attributed to the **higher replacement rates of all MEP equipment** over the useful life.

Structural steel and concrete, sandwich panels, and reinforcement are top architectural contributors. The footprint of these systems can be **reduced by up to 30% with low-carbon material selections.**[4]

3. Sharma (2023). Hidden Emissions of the Cloud (Impact Fund/Introba).
4. Gensler Research Institute (2023). Designing for Lower Carbon Concrete in Data Center Constructions.

Pittock Block, Data Cetner, Portland OR

Data Centers

EMBODIED CARBON BEST PRACTICES

Planning

Increase equipment density to reduce embodied carbon.

Supporting an increase in power density in data halls means performing the same amount of "work" in a smaller area. The reduction in equipment and floor area reduces need for material resources.

Look for opportunities for adaptive reuse.

Large industrial structures and warehouses are well-suited for adaptive reuse, a strategy which is significantly lower in carbon compared to constructing a new facility in an undeveloped area. Designing data centers that may be used for other purposes in future supports passing along these savings.

Design

Optimize structural efficiency.

Avoid structural over-design by eliminating suspended or rooftop-mounted equipment to lessen the demand on structural steel.

Plan for future expansion to reduce equipment embodied carbon.

Explore opportunities to implement a modular approach for MEP equipment. Instead of oversizing from the outset, design systems to be scalable and expandable as the data center grows.

Don't forget refrigerants.

Prioritize low-impact refrigerants (such as R-513-XP10 and R1234yf).

Construction

Prioritize concrete, steel, and wall panel selections.

As early as possible in the project, research available concrete mixes from regional suppliers to understand potential opportunities for maximizing the amount of SCMs or the use of PLC. Source steel from domestic electric-arc furnace facilities that operate on clean grids and boast a recycled content of over 95%. Procure concrete and steel from suppliers with region-specific EPDs to validate its embodied carbon impacts.

Operations

Monitor refrigerant leakage.

Keep detailed records of refrigerant installation dates and quantities to allow for better monitoring and to facilitate timely maintenance. Install leak detection systems to identify failures and refrigerant leaks promptly.

Adopt a circular mindset.

Establish partnerships with equipment manufacturers to explore and implement environmentally responsible end-of-life strategies. Plan for proper disposal or recycling of equipment at the end of its useful life. Circular and adaptive design of facilities also enables continued usability of facilities as technology rapidly evolves.

Data Centers

OPERATIONAL CARBON BEST PRACTICES

Planning

Consider air-side economizer installation for free cooling.

Economizers are most effective in regions where the outside air is cool and dry for significant portions of the year. Even in climates that may have warm days, if the nights are consistently cool, air-side economizers can be used effectively during these cooler periods.

Check the list of Energy Star Certified IT Equipment.

Opting for IT equipment with the Energy Star label, especially for large network equipment, ensures higher energy efficiency compared to standard products.

Design

Manage airflow using Hot aisle/Cold aisle layout.

This involves arranging server racks in alternating rows with cold air intakes all facing one aisle (cold aisle) and hot air exhausts facing the opposite aisle (hot aisle). This setup improves cooling efficiency by managing air flow more effectively, ensuring that cold air is directed exactly where it is needed, and hot air is efficiently removed.

Consider other applications for free heating.

Data centers in campuses or dense urban areas can allow large scale transfer of waste heat from equipment through thermal exchange loops. The heat can then be used in other buildings that need it, like residential or office spaces.

Construction

Build airtight assemblies.

Airtight assemblies have several benefits for data centers. Reducing infiltration also avoids unfiltered air, particles, and uncontrolled humidity. An additional benefit is the reduction of energy and operational carbon. Coordination between envelope mockups, visual inspections, and spot air leakage testing of the façade enables target airtightness levels to be realized.

Operations

Adjust temperature range to optimize energy use.

By widening the temperature range, cooling systems can run less frequently or at lower capacities, leading to substantial energy savings.

Incorporate humidity sensors in economizers.

When using outside air for cooling, humidity sensors ensure that the air brought in maintains the appropriate humidity levels within the facilities. The ideal humidity level in data centers is typically between 40% and 60% relative humidity, but this can vary based on specific equipment and operational conditions.

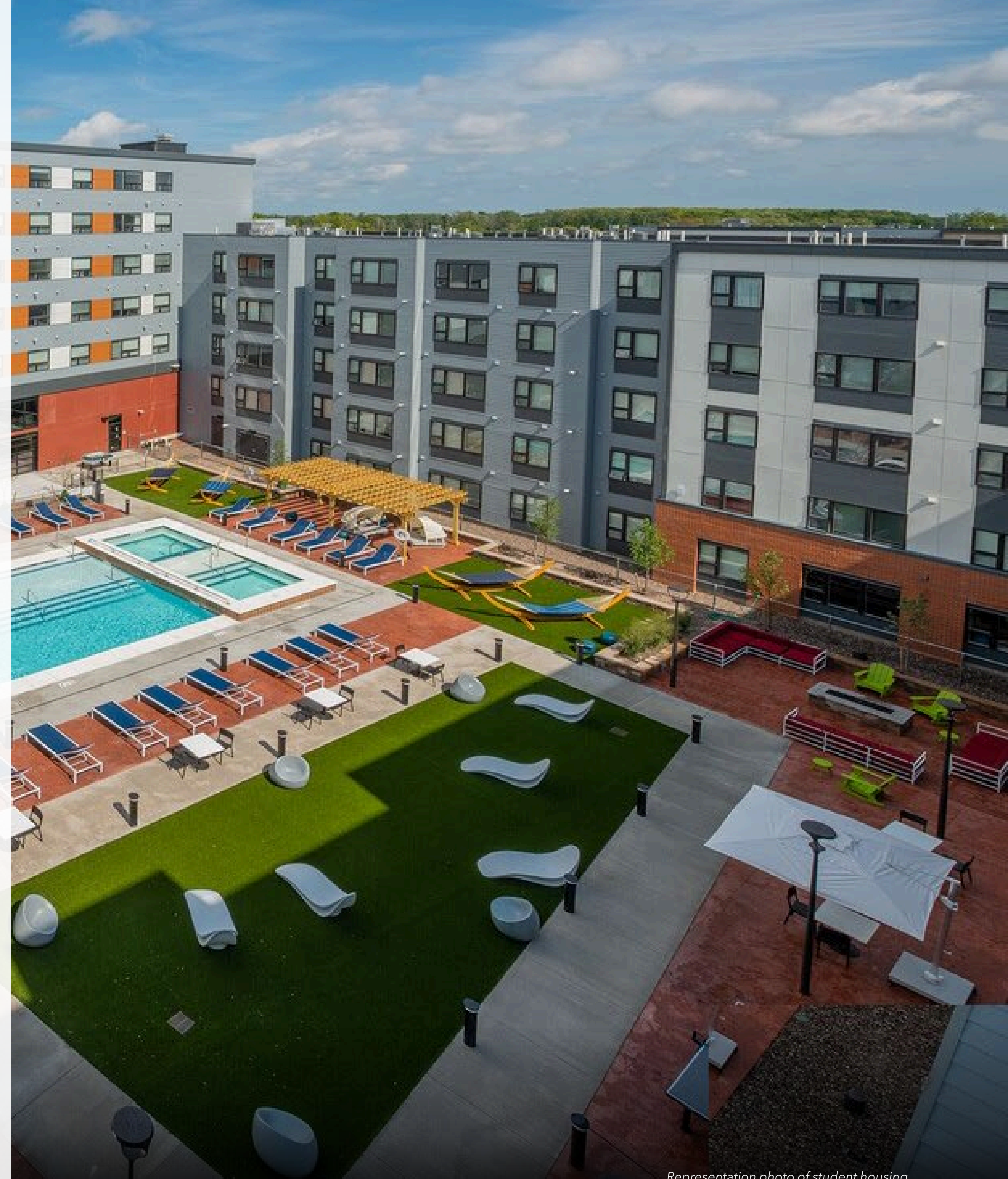
Student Housing

Student housing is often the first unit an individual will live in once leaving home, offering both independence and structured programing to support students in succeeding in their academic pursuits.

Many selective universities have reported **record enrollment** in the last few years, leading for increased housing demand in those markets.[1]

The carbon performance of these facilities is directly tied to resident behavior. Therefore, engaging students' enthusiasm by giving them resources to practice sustainable living is a future-facing decarbonization strategy, can make student housing **a platform for innovation and community**.

1. University websites and common datasets.



Representation photo of student housing

SECTOR CONSIDERATIONS

Student Housing

OPERATIONAL CARBON OVERVIEW

Water and space heating are both significant energy demands in student housing, constituting half of a building's energy use in many climate zones.[1]

Residence halls accommodate large number of students, leading to **increased energy usage due to occupant density**. This can be offset by technologies as smart lighting and HVAC systems.

Residence halls typically have common areas, such as **lounges** and **communal kitchens**, which can contribute to higher energy consumption for shared facilities.

Hub Atlanta Student Housing, Atalanta GA

1. US EIA (2009). Residential Energy Consumption Survey.

EMBODIED CARBON OVERVIEW

With compact spaces, the embodied carbon footprint of student housing typically includes large contributions from wall board, studs, and interior insulation.

Frequent move-ins and move-outs also increase material replacements and subsequent embodied carbon. Durable materials can mitigate the need for frequent replacements and reduce both costs and carbon over time.

Student Housing

EMBODIED CARBON BEST PRACTICES

Planning

Optimize layouts for human experience and materiality.

When designing student housing the balance between communal and private spaces need to be carefully considered to create the optimal user experience. Centralizing common areas provides a platform for students to socialize with each other and reduces the amount of rooms, and therefore material needed to create living areas.

Design

Design for modularity.

Student housing presents an opportunity to find efficiencies in room layouts. An efficient and repeatable layout in construction plays a pivotal role in reducing embodied carbon by optimizing material usage and structural efficiency. A well-planned structural layout optimizes the use of materials and can minimize waste during construction.

Construction

Look for low-carbon alternatives to conventional products.

In many markets, lower-carbon insulation and interior partition materials are available with no increase to cost or technical performance.

For insulation, consider avoiding XPS wherever possible due to the carbon-intensive blowing agents. Where XPS must be used, some manufacturers have developed products with alternative blowing agents that drastically reduce embodied carbon.

For studs, consider lightweight alternatives or even timber wherever feasible.

Operations

Encourage reuse and upcycling.

Engage with the local community to facilitate material reuse after deconstruction, such as community-driven salvage and reuse centers. Explore whether any student groups or classes may be interested in upcycling materials to reduce waste.

Collaborate across the supply chain.

With long-term demand for material replacements, student housing needs are an opportunity to build long-term relationships with manufacturers and suppliers to implement strategies for embodied carbon reduction throughout the supply chain.

Student Housing

OPERATIONAL CARBON BEST PRACTICES

Planning

Optimize façade design.

Window-to-wall ratio affects heat loss, solar gain, and artificial lighting needs. In warm climates, the use of solar shading structures such as brise soleil or internal blinds can mitigate excessive summer solar gain. However, this approach requires a careful balance with beneficial winter solar gain.

Harness natural light in hallways.

Most residence halls maintain hallway lighting throughout the day and night, offering a significant opportunity for energy conservation. If the hallways are equipped with skylights or other sources of natural light, and the lighting system includes dimming features, light intensity can be reduced by 30% during daytime hours.

Design

Invest in strategies addressing hot water systems.

Hot water is a significant energy demand in student housing, constituting one-third or more a facility's energy usage. Commercial heat-pump water heaters (HPWHs) offer a highly efficient alternative, being two to four times more energy-efficient than conventional water heaters. Low-flow water fixtures can also help to reduce demand. Prioritize showers and restroom faucets for maximum savings.

Construction

Construct an air-tight envelope.

An air-tight envelope results in reduced energy consumption and lower carbon emissions associated with heating and cooling in all climates and improves thermal comfort for occupants. Pay further attention to construction details and implement quality control to reduce leakage in the envelope.

Operations

Provide guidance for student behaviors.

The performance and energy consumption of a residence hall is directly tied to student behaviors. Educational and occupant engagement strategies can give students a sense of ownership and empowerment. For example, over the holidays when rooms are vacated, "turn off the heating" campaigns are a simple but effective engagement strategy.

Utilize smart technologies.

Student housing is an ideal project type to implement smart technology to provide active feedback and enhance efficiencies, due to the tech-savvy and dynamic nature of the student demographic.

Senior Housing

In response to the rapidly **increasing population over the age of 65,** there is a pressing need to reduce energy consumption in senior care facilities. The 75+ population in the United States is projected to grow by 10.8 million people by 2032.[1]

The greater energy consumption of this type of building is partly due to the **need for higher comfort levels**, encompassing aspects such as thermal, visual, and indoor air quality, and **additional cooking and other auxiliary equipment uses**.[2]

Given that occupants are more **susceptible to temperature extremes,** controlling the indoor environment quality is a critical design consideration for these facilities.[3]

1. *Moody's Analytics (2023). Aging population.*
2. Sanalife (2023). Prioritizing Energy Cost Reduction And Indoor Air Quality In Senior Care Facilities.
3. Budderfly (2023). Assisted Living Facilities and HVAC Systems: More Than Just Comfort.

Oakmont of The Lakes, Senior Living, Las Vegas NV

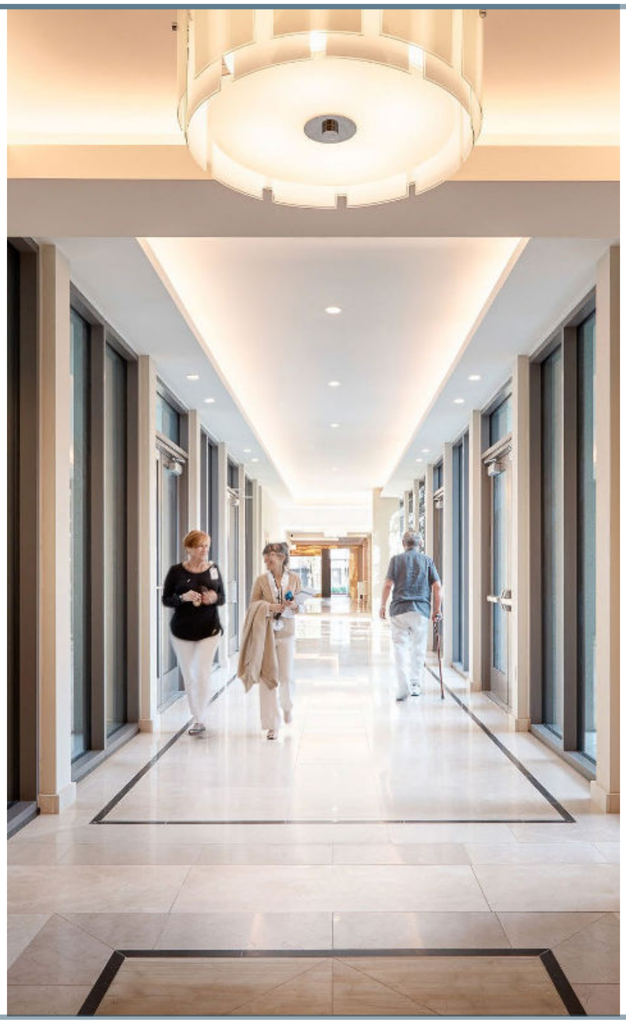
Senior Housing

OPERATIONAL CARBON OVERVIEW

The energy intensity of senior care facilities depends on the specific housing typologies, facility needs, and resident density.

To provide continuous care, these facilities operate full-time every day of the year. **HVAC efficiency** can reduce energy use by up to 25%.[2] **Improved lighting systems** also enhance energy efficiency and security, providing well-lit, safe spaces for seniors. Additionally, **Energy Star certified equipment** in kitchens, laundry rooms, and bathrooms can save even more energy.

1. EFA (2019). Aiming For Net Zero Senior Living.



EMBODIED CARBON OVERVIEW

Program, typology, and the unique needs of senior housing should be carefully considered with any embodied carbon reduction strategies.

The embodied carbon footprint of senior housing shares characteristics of single- and multi-family housing, along with healthcare. Structural materials for larger buildings are important, while envelope insulation and glazing for smaller-scale portions of communities should be considered to balance thermal comfort, operational carbon, embodied carbon, and occupant experience.

Senior Housing

EMBODIED CARBON BEST PRACTICES

Planning

Consider embodied carbon opportunities when planning adjacencies.

While structural options for facilities with healthcare equipment or large commercial kitchens may be more limited, residential, circulation, and amenity spaces may be more flexible.

For independent living, planning for townhomes in lieu of detached homes can reduce material demand. Co-living programs can also save carbon by improving material efficiency, in some cases by up to 36% per resident.[1]

Design

Prioritize durable materials where needed.

For program components which require high degrees of maintenance and cleaning, durable finishes will reduce the need for replacement and energy for maintenance over time.

Construction

Look for low-carbon alternatives to conventional products.

In many markets, lower-carbon insulation and interior partition materials are available with no increase to cost or technical performance.

For insulation, consider avoiding XPS wherever possible due to the carbon-intensive blowing agents. Where XPS must be used, some manufacturers have developed products with alternative blowing agents that drastically reduce embodied carbon.

For studs, consider lightweight alternatives or even timber wherever feasible.

Operations

Collaborate across the supply chain.

With long-term demand for material replacements, senior housing needs are an opportunity to build long-term relationships with manufacturers and suppliers to implement strategies for embodied carbon reduction throughout the supply chain.

1. *Malmqvist and Brismark (2023). Embodied carbon savings of co-living and implications for metrics: Buildings & Cities.*

Senior Housing

OPERATIONAL CARBON BEST PRACTICES

Planning

Prioritize resilience to accommodate potentially unexpected operations.

Given that seniors are often more vulnerable to emergencies like natural disasters, power outages, and health crises, more resilient housing is essential. The location of facilities should remain safe and functional during such events, offering continued security and comfort to occupants.

Consider Energy Star Certified Equipment.

A focus on acquiring energy-efficient appliances is evident, with many care-related appliances being optimized for better energy efficiency.

Design

Utilize high-performing exterior envelope.

Investing in high-tech insulation and glazing for the exterior envelope minimizes heat loss and prevents interior temperature fluctuations, reducing energy demand.

Incorporate renewable energy resources for electricity use.

Integrating renewable energy sources such as solar panels and wind turbines on-site is a strategic move. For typical senior living communities, the payback period for solar panels is estimated to be between 5-10 years, depending on incentives and tax write-offs. (EFA, 2019)

Construction

Minimize heat loss with air-tight construction.

Preventing the loss of heated or cooled air is crucial, and this can be achieved by sealing all joints, seams, and penetrations in the building envelope. Not only does this enhance the efficiency of HVAC systems, but it also helps maintain indoor air quality by reducing the infiltration of outdoor pollutants and allergens, crucial for protecting the health of senior occupants with potentially weakened immune systems.

Operations

Install motion sensors for automatic lighting control.

Sensors mounted on the wall or ceiling that turn off lights in unoccupied rooms, especially in common areas such as hallways, lobbies, and dining rooms, enhance energy efficiency.

Install smart thermostats with centralized control in units.

Global temperature setpoints and schedules for occupied and vacant units can reduce energy consumption by up to 10%. These temperature boundaries can be customized by the operations team and by residents, respecting the typical preferences of older adults for warmer temperatures.

Build-to-Rent

Hurdles to homeownership in the current for-sale housing market are driving demand for single-family rental units. As this sector grows, strategies to manage and reduce energy use in single-family rentals are critically needed.

The electrical load profile in this type of residential building shows **two distinct peaks,** the first occurring in the early morning around 9 am, and the second extending until about 8 pm.[1]

Prioritizing the implementation of **passive house strategies** can reduce energy use and enhances the comfort level of occupants.

1. ACEEE (2020). Understanding Multifamily Home Energy Efficiency Potential.

SECTOR CONSIDERATIONS

Build-to-Rent

OPERATIONAL CARBON OVERVIEW

Nationally, multifamily homes facing high energy costs can adopt energy efficiency improvements to lower their energy usage **by 17%.** [1]

In the context of residential buildings, **space heating** offers significant opportunities for energy savings. **Centralized systems** for both space and water heating can be more efficient than individual systems in single-family units. Additionally, in multi-family units, there is unique potential for energy efficiency in **lighting and appliances** due to the possibility of uniformity across all units.

1. EPA (nd). Multifamily Housing.

EMBODIED CARBON OVERVIEW

Embodied carbon drivers in residential development tend to be driven by market conventions and regional lifestyle preferences.

In the United States, timber construction and cladding is common, but embodied carbon associated with central heating and cooling systems can be high. In the UK and Europe, MEP equipment infrastructure is greatly reduced with preference for piping and limited use of air conditioning, but carbon-intensive masonry walls and concrete and steel structure are much more typical.

Build-to-Rent

EMBODIED CARBON BEST PRACTICES

Planning

Prefer denser development.

Switching to more efficient multifamily typologies with smaller footprints per occupant can be a very simple and effective way to reduce materials and embodied carbon. This includes medium- and high-rise residential buildings and mid-terrace houses or townhomes.

Look for opportunities for adaptive reuse.

Commercial-to-residential conversions or reuse of existing structures can drastically reduce carbon, while creating value for local communities.

Design

Prioritize natural materials.

Specify sustainably sourced timber for beams, framing, flooring and stairs, and timber cladding as much as possible. For interior insulation, glass wool insulation is lower in carbon, and alternatives such as recycled denim, hemp, or mycelium are opportunities for innovation.

Natural finishes and materials tend to be lower in embodied carbon and often healthier for indoor environments. Avoid vinyl- and plastic-based products as much as possible, and where necessary, look for low-carbon products as verified by manufacturer Environmental Product Declarations.

Construction

Implement blower door testing.

Airtight envelopes improve thermal comfort for residents as well as save energy. Blower door testing during construction can help catch any issues in time to be remediated and verify that intended envelope performance is effectively implemented.

Operations

Consider longer standard lease terms.

Longer leases encourage tenant maintenance and extend the useful life of materials.

Encourage reuse and recycling.

In communities, organizing buy-nothing networks or reuse days can keep useful furniture and other materials out of the landfill, and reduce embodied carbon by avoiding creation of new products.

Provide adequate recycling infrastructure so that unwanted products can contribute to reducing energy demand for processing raw materials in the future.

Build-to-Rent

OPERATIONAL CARBON BEST PRACTICES

Planning

Consider all-electric building to reduce fossil fuel dependence.

All-electric buildings eliminate the need for natural gas or other fossil fuels for heating, cooking, and hot water. These efforts should be accompanied by grid decarbonization or renewable energy strategies.

Improve energy efficiency through centralized systems.

This centralized approach ensures consistent energy management across all units, leading to potential overall energy savings. When coupled with a modern BAS, it also allows for automated and optimized control to reduce energy use. In some cases, geoexchange or similar high-efficiency plant systems can be more cost-effective in centralized applications.

Design

Incorporate renewable energy resources for electricity use.

Adopting renewable energy sources, such as on-site rooftop solar panels or off-site Renewable Energy Certificates (RECs), is a sustainable step for residential buildings, helping to reduce reliance on non-renewable energy sources.

Integrate heat recovery system once applicable.

In cold climates, HRVs are preferred due to their efficiency in recovering heat from exhaust air to warm incoming air. For hot and humid climates, ERVs are more suitable as they handle both heat and moisture exchange, aiding in humidity control.

Construction

Enhance insulation and air sealing.

Improving insulation in walls, roofs, and floors, and reducing heat loss from leakage, are crucial steps in enhancing the energy efficiency of residential units. These measures help maintain a consistent indoor temperature, reducing energy demands for heating and cooling.

Operations

Install programmable or smart thermostats.

This automated system control allows for automated temperature control, which can enhance energy efficiency and provide convenience to homeowners.

Find financial benefits from the nationwide weatherization assistances.

Weatherization efforts, which help reduce initial costs for energy savings, can be a financially beneficial strategy for residential units. These benefits improve the overall energy efficiency and reduce long-term energy costs.

Self Storage

Self Storage demand has benefitted from recurring life events such as household formations, separations, downsizing, and transitory living situations.

Self storage facilities typically have a large spatial footprint but are not used as intensively as other commercial buildings. [1]

As a result, **embodied carbon tends to be a much higher portion** of a self storage's whole life carbon footprint compared to warehouses or similar industrial buildings.

With sustained consumer demand for self storage, there is a need for sustainable practice during design, construction, and operations.

1. US EIA (2018). Commercial Buildings Energy Consumption Survey.

Self Storage

OPERATIONAL CARBON OVERVIEW

Lighting is often the primary energy user in self storage facilities, for security and accessibility in windowless areas.

Self storage buildings usually experience higher occupancy during the daytime, with customers accessing their units and a few employees on-site. Lighting power density is likely to be higher during these peak hours due to both interior and exterior lighting needs for customer safety and ease of access.

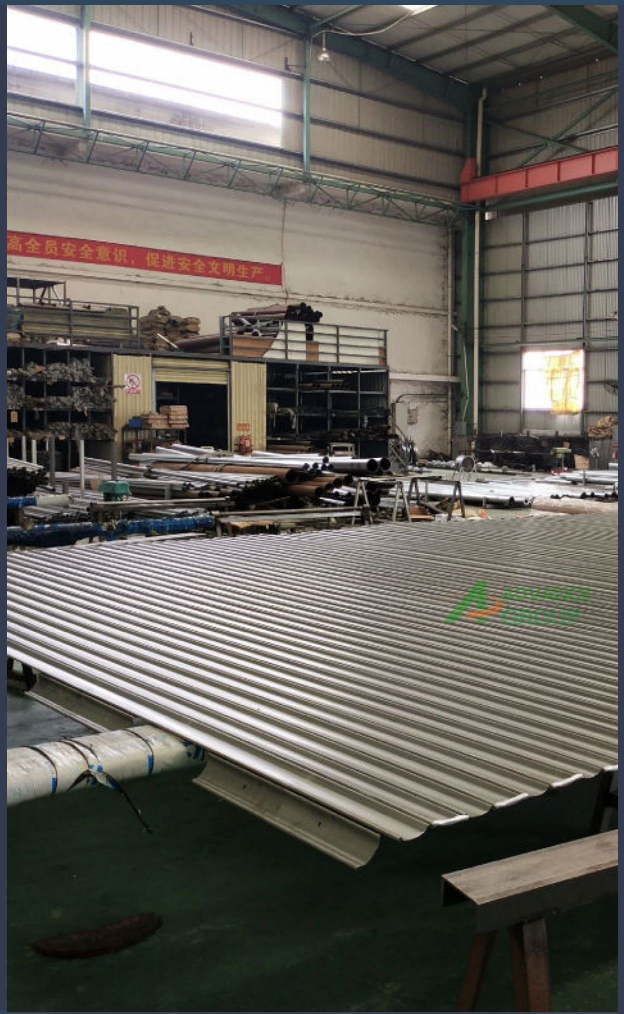
1. Brown and Wilbern (2021). The Path to Sustainability: Designing Self-Storage to be Eco-Friendly and Achieve Green Certification (Inside Self Storage).
2. Anna Shengelia & Aaron Farney (2021). Better Energy Management In Self Storage" By Unwired Logic.
3. EIA (2023). 2018 CBECS: Principal Building Activities Warehouse and Storage.

EMBODIED CARBON OVERVIEW

When looking for embodied carbon reductions in self storage, start with structural concrete and steel.

With limited finishes, the primary drivers of embodied carbon in self-storage are the concrete for slabs and foundations, along with steel decking, cladding, and roofing.

While these are carbon-intensive materials, they represent opportunities for integrating recycled content, alternative production processes, and dematerialization to improve performance.



Self Storage

EMBODIED CARBON BEST PRACTICES

Planning

Consider modularity during planning.

With regularly-sized units, self-storage is an opportunity to explore modular design. This approach can minimize material waste and streamline the construction process.

Plan adjacencies to reduce MEP distribution lengths.

Placing spaces with conditioning needs closer to equipment reduces piping and duct sizing, which in turn saves on embodied carbon.

Design

Prioritize durability in materials.

Materials are likely to have high demands, so durable materials that can withstand frequent user changes and require less replacement will result in carbon savings over time.

Construction

Look for low-carbon concrete.

Explore low-carbon concrete with as high Secondary Cementous materials (SCMs) content as possible, such as ground granulated blast furnace slag (GGBS), Limestone or Fly ash (if available). Possible options will largely depend on local availability.

Research regional EAF steel producers.

Encourage the shift of steel production to Electric Arc Furnace (EAF) technology and avoid specifying steel made from coal-based blast furnace-basic oxygen furnaces (BF-BOF). This allows for increased intake of scrap steel and an overall more efficient production process.

Operations

Think towards future uses.

Plan for adaptive reuse by designing flexible storage spaces that can accommodate changing needs, reducing the need for new construction. Consider engaging with local community groups to upcycle storage unit boxes.

Self Storage

OPERATIONAL CARBON BEST PRACTICES

Planning

Evaluate the need for climate-controlled units.

Many self storage facilities offer climate-controlled units to protect sensitive items from extreme temperatures and humidity. This feature, while attractive to customers, can increase both construction costs and operational energy use.

Consider zoning based on energy needs.

For example, grouping climate-controlled units together will reduce conditioning losses through surfaces and thermal improvements can be applied where they're most needed. Bringing circulation and support spaces to the exterior can facilitate integration of daylight for passive lighting without compromising security.

Design

Design controllable lighting systems with LED fixtures.

Transitioning from incandescent to fluorescent or LED lighting significantly reduces energy consumption. LEDs offer long life spans and substantial energy savings. The integration of occupancy sensors can further enhance energy efficiency, ensuring lights are on only when areas are in use.

Construction

Evaluate rooftop solar.

The typically flat and expansive roofs of self-storage facilities present an ideal opportunity for solar panel installations. Solar panels can significantly offset the building's energy consumption, leading to cost savings and a reduced carbon footprint. The feasibility and efficiency of solar panel installations are influenced by geographic location and the number of sunlight hours.

Operations

Monitor and maintain equipment.

Any controls that are installed should be regularly inspected and maintained in order to realize full potential energy savings.