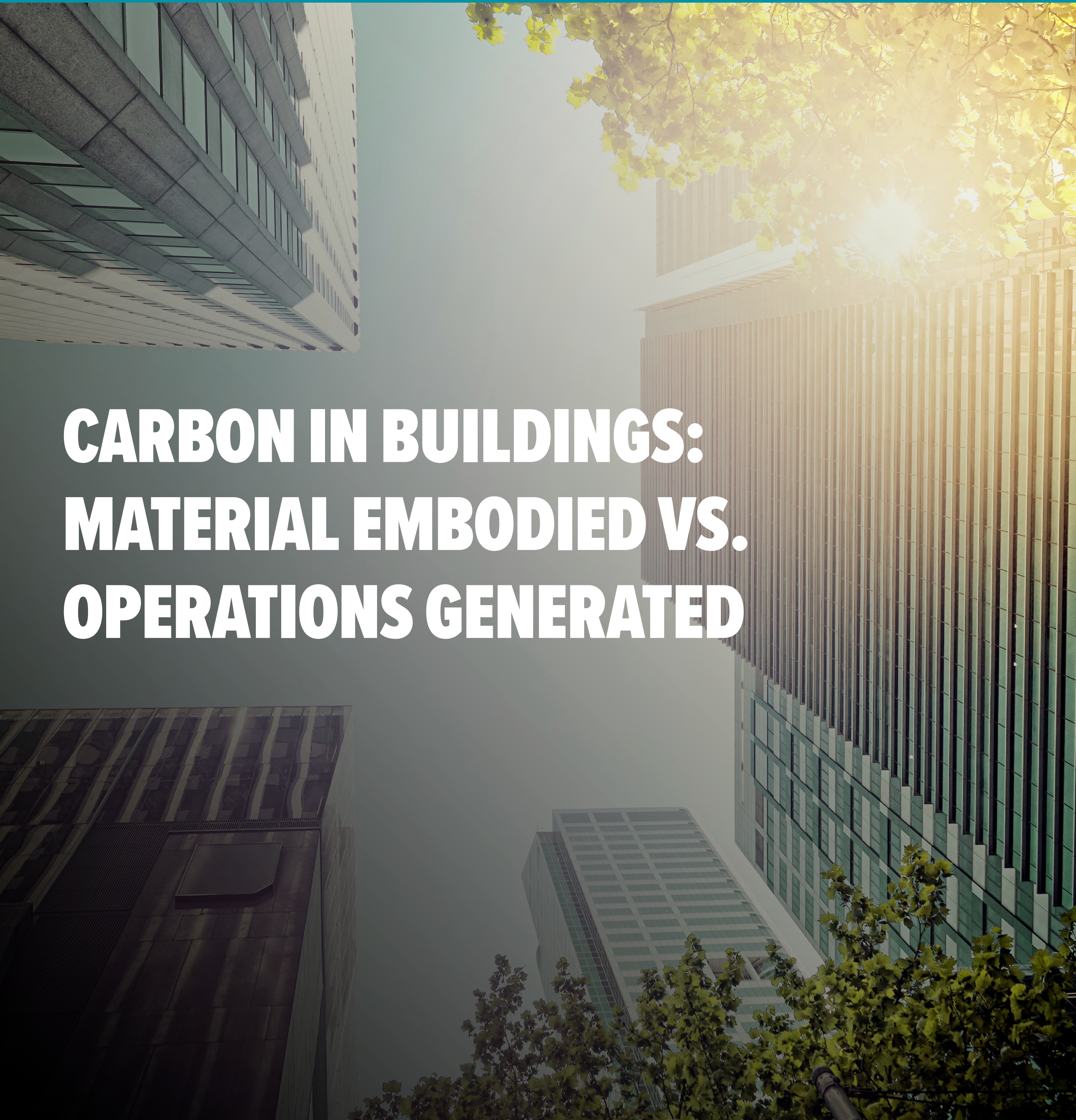
CARBON IN BUILDINGS: MATERIAL EMBODIED VS. OPERATIONS GENERATED



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INTRODUCTION

When it comes to reaching ambitious goals for building sustainability and resilience, our industry's focus often centers on improvements related to embodied carbon – how we minimize emissions in the manufacturing, production, and transport of the materials used in a building. However, over the long service life of a building, there are also significant opportunities to reduce operational carbon by increasing energy efficiency in ways that are commonly overlooked during the initial building phase.

It is, thus, becoming a critical responsibility of designers, specifiers, and building operators to take a more holistic approach to building energy efficiency. As building emissions continue to increase, carbon reduction becomes a significant preliminary planning tool for collective building environmental benefits.

RESILIENCE DOESN'T END WITH INITIAL CONSTRUCTION

A design's resilience is an urgent issue due to the rising effects of climate change; consequently, the building industry is increasingly striving to design, operate, and maintain spaces that can sustain longer life cycles. However, as our population increases and building density continues to grow, greenhouse gas emissions continue to rise steadily.

In fact, the global building inventory, which currently generates nearly 40% of annual global greenhouse gas emissions, is expected to double in floor area by 2060, according to Architecture 2030. Since buildings are designed for longevity, we can expect that the compounding environmental impact of such growth over several decades will be massive. Thus, building industry professionals, lawmakers, policy regulators, and other key stakeholders are increasingly interested in accommodating this growth and aligning buildings with future carbon net-zero or net-negative targets.

The U.S. has recently rejoined the Paris Climate Agreement and, along with other nations around the world, committed the country to aggressive emissions reduction goals. In order to incrementally reduce environmental impact over the various phases of a building's life cycle, designers, contractors, and building owners alike must take immediate action.

ADDRESSING THE TWO-PRONGED CARBON CHALLENGE

Efficient and effective operation, as well as ongoing maintenance, are key to optimizing building sustainability. But to accomplish this from an emissions standpoint, we must first gain a fundamental understanding of the carbon impact a building will have throughout its full lifecycle, with an eye to both its embodied materials and operational states.

In new construction, embodied carbon often takes center stage, as it is set by decisions made at the beginning of the building's life cycle and cannot later be altered. Embodied carbon represents emissions from building materials and construction and typically represents 28% of global building sector emissions.

However, building owners and tenants must also recognize the operational carbon that's inherent in buildings. This carbon, emitted through the functional use, management, and maintenance of the building, will escalate over the building's life cycle. It is this emissions source that continues to dominate CO2 emissions (representing the remaining 72% of building sector emissions).

Projections looking ahead to 2050 with business-as-usual practices indicate that the impacts of embodied carbon and operational carbon will be nearly equivalent. However, those estimates are dependent upon the expected implementation of functional energy efficiency improvements over time. Thus, it is increasingly critical for designers, specifiers, and building operators to first proactively consider both active and passive energy efficiency techniques to satisfy the immediate challenge of ongoing operational carbon emissions.

THE BENEFITS OF PASSIVE BUILDING DESIGN

Advancing progress on our building footprints begins with an investment in sustainable building design and construction – one that reduces the carbon load in both the building lifecycle and the emissions generated through its long-term operation. The initial embodied carbon of the building product and any replacement embodied carbon associated with repair and replacements are outweighed by the operational carbon savings of the installed products that improve energy efficiency.

Over the lifespan of a building, the energy used to heat and power our buildings will result in cumulative operational carbon loads. Therefore, it's critical that designers exercise caution when specifying products that may present initially low embodied carbon rather than prioritizing products that offer long-term operational carbon savings.

Fortunately, the initial embodied carbon of the building product, combined with any replacement embodied carbon associated with repair and replacements can largely be offset by implementing passive building design techniques.

Passive building design is an impactful design methodology that limits emissions by reducing the energy loads of a building through intentional, non-mechanical design strategies. Passive design features – including building orientation, exterior radiative or insulative properties, daylighting, natural ventilation, massing, and the specification of enclosure systems – can have a significant impact on a building's lifespan. These are permanently rooted features in the building design that remain functional for a long period of time, unlike non-passive elements such as HVAC systems and aesthetic finishes.

When we hone in on designing for an energy efficient building envelope – a primary building component that is in the first line of defense to limit energy gain and loss – we can see that there is huge potential for operational carbon and energy savings. Furthermore, when we examine building energy consumption, space conditioning continues to be a major portion of this energy consumption of commercial buildings, according to the *Annual Energy Outlook 2021* report, which provides energy market projections through 2050 via the U.S. Energy Information Administration (EIA).

According to EIA, heating and cooling also represent the largest building utility expenses. As such, it is imperative to contain these loads by focusing on the design and use of the building envelope in order to reduce the building's carbon footprint and mitigate long-term operational carbon.

INVESTING IN THE BUILDING ENCLOSURE

Investing in the building enclosure will provide energy, carbon, and cost savings over the building's useful life. The installation of new roof insulation or the upgrade of existing insulation is one such passive strategy that can minimize energy loads in the building, while also offsetting any embodied carbon increases that may result from other aspects of building design.

For example, roofs are particularly vulnerable to energy loss, due to their large surface area and the physics of the stack effect through which heat rises. Using higher-efficiency roof insulation materials will not only prevent conditioned air from escaping, it can also deliver additional benefits, such as protection of the building from harsh weather conditions including varying differences in temperature. In such cases, roofing insulation also results in greater interior comfort for building occupants.

Proper specification and installation of roof insulation can also prevent unforeseen risks caused by weather conditions and fluctuations in temperature by preventing the formation of ice dams, mold, and other maintenance issues stemming from condensation.

As building professionals, we should understand these risks and apply these solutions to both new and existing construction markets. In fact, the majority of commercial roof projects are installed on existing buildings.

While new construction projects can apply roofing insulation best practices at preliminary design phases, the larger portfolio of existing buildings in the U.S. will benefit from roof retrofits through replacement of previous, less efficient building envelope components and the addition of insulation onto aging roofs.

Existing building roof projects should look to pair roof replacements or upgrades with the addition of efficient roof deck insulation. Specifying the proper insulation to meet current and future energy codes is key to cutting building emissions.

Another important question is, what insulation can we specify for our building roofs that can also be applicable to other building surface areas? For example, Polyisocyanurate insulation (polyiso) is a rigid foam insulation that delivers both versatility and sustainability in its project implementation. It continues to be the most widely used above-deck insulating roof material in commercial buildings because of its reliability.

Polyiso insulation has a high thermal performance of approximately R-6 per inch. It maintains its thermal performance due to its low thermal conductivity, high moisture resistance, and dimensional stability. Due to this efficiency, less insulation thickness is

required, making polyiso a valuable selection for retrofit projects on roofs where space is limited. Additionally, this insulation is a low-density/lightweight product that's easier to handle and install.

With an estimated building service life of 75 years – as calculated through EPD Product Category Rules (PCR) criteria – polyiso insulation is a reliable building application for tackling ongoing operational carbon and can contribute greatly towards the savings required for a minimal building footprint. It is clear that these traits would consistently benefit a building's ongoing carbon footprint and, thus, it is important to specify measures like these that can serve the building throughout its continued use.

THE IMPACT OF BUILDING CODES

As designers and building owners continue to look towards holistic and integrated design approaches to account for all energy generating uses, progress on building operations will also undoubtedly amplify because of government regulations.

Federal and state mandates, including the building energy code, are shifting towards increasing building envelope insulation. These codes provide a prescriptive, baseline requirement and continue to trend towards an increase in roof thermal performance with each code cycle update.

The building energy code, as defined by the International Energy Conservation Code (IECC), is largely recognized as a minimum standard for compliance. Yet, the rise of beyond code standards and third-party green building certifications attest to the need for passive design strategies that further elevate the stringency of building performance.

In addition, carbon-aware building best practices and policies all push for aggressively sustainable design. In fact, LEED for Operations and Maintenance even offers ways for project teams to analyze building operations from the post-construction phase through documentation and tracking. This performance standard identifies the building's current best practices and provides pathways to drive further sustainability improvements.

LEED's Recertification Program is another tool that encourages project teams to track building performance data and verify that the building's performance is optimal and functioning according to design. Supporting LEED's goals for performance monitoring is Arc, a tool developed to measure and score the ongoing performance of a building at any one time.

By pushing for products that exceed regulatory efficiency requirements, manufacturers assert their recognition for the need of energy efficiency improvements. It is clear that the market will continue to create space for best practices that increase building performance.

COST SAVINGS AND INCENTIVES FOR HIGH PERFORMANCE BUILDINGS

The potential to produce cost savings also strengthens the basis for sustainability designers, industry manufacturers, consumers, and contractors to implement emissions-cutting practices into building design, construction, and operation throughout the longevity of buildings.

For example, local utility companies in various jurisdictions around the U.S. offer economic incentives to increase building performance. These incentives include rebates to cover the upfront costs of energy efficient envelope measures, such as upgrades in insulation.

Additionally, federal incentives – including the U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy – provide resources for federal tax deductions for envelope energy savings. The Section 179D tax deduction by the IRS recently became permanent and allows existing building owners and tenants to take tax deductions for qualifying measures, including energy-efficient envelopes.

Energy Star offers a web-based tool, Energy Star Rebate Finder, which pairs building owners with rebates and additional savings for energy-efficiency installations and upgrades based on their location. Additionally, the U.S. Department of Agriculture, the U.S. Department of Energy's Weatherization Assistance Program, and the U.S. Department of the Interior Indian Affairs' Housing Improvement Program all provide assistance for low-income tenants to participate in energy saving measures. All of these programs recognize the importance of envelope efficiency upgrades. Designers and contractors can access these tools to incentivize building managers to take advantage of concurrent energy, carbon, and cost savings.

When analyzing cost savings, it is important to acknowledge the annual savings and returns-on-investment that more efficient and effective roof insulation can provide. The payback of this passive design strategy over the lifespan of the building will offset the initial upfront cost. From an energy and carbon perspective, there is an initial investment for building construction or repair. However, there is also an associated annual return, through which energy savings are compounded.

The aggregate of energy savings lends itself to gaining a surplus economic benefit beyond the initial return on investment. Because passive design strategies like building enclosure improvements have longer service lives than mechanical equipment or finishes, sustained returns provide consistent savings over time.

CONCLUSION

Improvements in building energy efficiency will aid designers and project teams in mitigating emissions. Because building envelopes are permanent fixtures within our building stock, we should continue to target this area as a key project for building performance improvement. Passive design strategies that insulate key areas on the envelope, such as the roof area, will contribute towards the building's sustainability goals, while continuing to drive down greenhouse gas emissions.

Insulating the envelope is a critical step towards enhancing its efficiency, and roof applications are successful candidates for lowering a building's carbon footprint. As regulatory requirements continue to increase thermal performance for the building envelope and prescribed roof insulation values continue to rise, products such as polyiso insulation will continue to be a leading selection for building envelope insulation. Moreover, building owners and property managers will find that there are plenty of economic incentives for implementing envelope insulation for both energy efficiency and carbon reduction.

Ultimately, the goal is to design our buildings for resilience. As environmental stewards, we can embrace the challenges, opportunities, and strategies of building sustainability that will be provided as emissions continue to increase, regulatory requirements become increasingly stringent, and economic incentives continue to diversify.