Picking up the PACE: How Embodied Carbon and C-PACE are advancing the Decarbonization Roadmap

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ABSTRACT

Through developed research and material resource development, this paper will explore how C-PACE (Commercial Property Assessed Clean Energy) financing can act as a driver to help pull the curve forward on reducing embodied carbon of new buildings, through the provision of cost-efficient capital, an exciting evolution for a policy that has previously been limited to reducing operational carbon by addressing energy efficiency during building operation. This session will explore how C-PACE can be used to reduce the upfront cost of capital for low embodied carbon building materials, such as concrete and steel.

The roadmap provided in this session will help policy makers design C-PACE programs that encourage investments in low embodied carbon materials, while helping members of the commercial real estate industry meet new sustainability mandates and investor ESG targets. The result is a financially viable opportunity to build a more sustainable future.

Executive Summary

Commercial property assessed clean energy (C-PACE) financing is a voluntary finance instrument for private construction projects, enabled by public policy, designed to incentivize commercial property owners and developers to improve the sustainability of the built environment. C-PACE programs offer low-cost, upfront financing, which is subsequently repaid through a special assessment on the property. This financing option supports a wide range of objectives, including increasing energy efficiency, reducing carbon footprint, improving building resiliency, conserving water, protecting occupant health, remediating environmental degradation, installing renewable energy technologies, and similar.

Across the country, 38 states and Washington, D.C. and nearly 2,000 local governments have passed C-PACE enabling legislation, resulting in the creation of over one hundred distinct C-PACE programs and the deployment of $7.25 billion of C-PACE financing nationwide ("C-PACE Originations" 2024, 2) since the programs began to emerge in 2009. While C-PACE programs were originally leveraged by building owners to conduct energy efficiency retrofits targeted to reduce operating cost, the C-PACE market has shifted towards 1) new building construction; and 2) a focus on whole building decarbonization and broader public benefits.

The first trend has been driven predominantly by market demand; C-PACE loans have delivered preferential interest rates, prepayment, and other financial terms that have allowed commercial property developers to achieve a significantly lower weighted average cost of capital for a commercial real estate development, resulting in a dramatically increased return on equity, in some cases between 30-50 percent. Obtaining this large financial incentive has driven commercial developers to design more energy efficient and resilient buildings, since any related cost premium associated with that the building's design and/or construction was more than offset by the reduced financing cost from C-PACE. Half of all C-PACE funding ($3.5B) has been executed in the past 3 years since new construction projects became widespread in the C-PACE market ("PACE Market Data" n.d.); $2.1B was deployed across 247 projects in 2023 alone ("C-PACE Originations" 2024, 2).

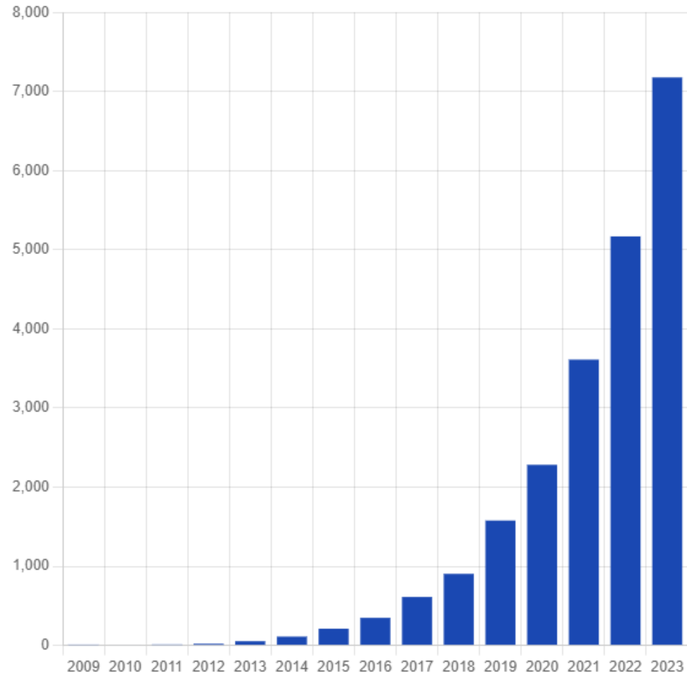

Figure 1. Cumulative C-PACE investment, MM (2009 – Dec 2023). *Source:* PACENation

The second trend has been spurred in part by a narrowing opportunity to deeply slash building energy use in geographies where a high degree of energy efficiency is now already required through stricter building codes. In these areas, C-PACE program administrators expanded the eligibility categories of C-PACE to include investments beyond energy efficiency, such as the capital cost of grid electrification, climate resilience, and indoor health.

Despite recent challenging macroeconomic conditions for commercial real estate, including increased interest rates and the pulling back of available capital from banks and debt funds (Kirk 2024), C-PACE continues to grow market share as a source of financing for new commercial buildings. Therefore, C-PACE is uniquely poised to significantly increase awareness and implementation of lower embodied carbon commercial buildings through tying the financing to the use of low-carbon building materials. In order to do so, C-PACE programs must expand their parameters to include building materials as eligible uses of C-PACE financing. This paper will explore C-PACE as a driver of building sustainability, introduce key concepts and initiatives related to embodied carbon for C-PACE policy and program administrators, and examine the key questions and steps C-PACE programs must undertake to play an impactful role in this next frontier of building sustainability.

C-PACE as a Driver of Building Sustainability

As a finance instrument established by state and local laws, C-PACE laws establish first and foremost local policy objectives and set out the categories of eligible uses of C-PACE financing, which may include energy efficiency measures (e.g. efficient HVAC systems, building envelopes, lighting, etc.), building resiliency improvements (e.g. seismic hardening, flood-proofing, etc.), water conservation measures, indoor health protections (e.g. air filtering systems), environmental remediation (e.g. lead soil abatement), renewable energy installations, or similar measures.

Once established, C-PACE programs are *voluntary* for commercial property owners and developers, so the use of C-PACE to drive sustainability relies primarily on how attractive the financial incentive is when compared to the additional time, design, and hard costs borne by the project to comply with the sustainability criteria required by the program. The key benefits of C-PACE financing are:

- Attractive interest rates – over the past decade C-PACE rates between 5% and 8% have been competitive with conventional construction debt and other sources of financing used alongside senior mortgages (e.g. mezzanine debt or equity); the lower cost of borrowing directly offsets the additional cost of sustainable building features (see Fig. 2 below).
- Financing terms of up to thirty years – exceeding the term of a conventional commercial construction or mortgage loan by ten years or more reduces the annual payment of a C-PACE assessment, supporting the addition of sustainable capital improvements without exceeding the debt-service coverage limits of commercial properties.
- Repayment through a property assessment – this structure solves the "split incentive" issue wherein tenants pay for energy but not building improvements; in some situations, C-PACE assessments can be passed to tenants who benefit from the reduced energy costs in energy efficiency and clean energy projects.
- The repayment obligation is non-recourse to the property owner corporate and can be transferred to the new owner upon sale of the property – the C-PACE financing is tied to and underwritten against the financial strength of a building's operations, allowing unrated properties to access capital.

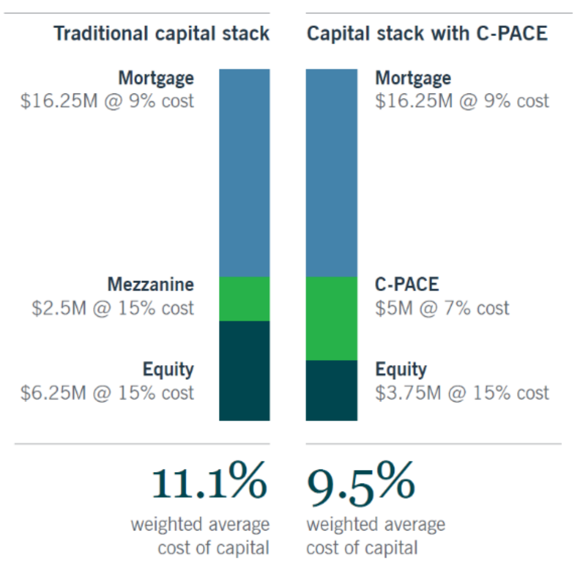

Figure 2. Comparison of traditional capital stack with capital stack incorporating C-PACE financing (for illustrative purposes only). *Source:* Nuveen Green Capital

C-PACE programs, which originated starting in 2009, were originally utilized for retrofit or adaptive reuse of existing buildings to reduce energy demand, improve energy efficiency, or utilize renewable energy onsite. The advent of expanding C-PACE programs to new construction, which began to be authorized via legislation in 2018-2019, drove a major uptick in program utilization ("PACE Market Data" n.d.). This shift, in light of the smaller size of the U.S. market for new commercial construction compared to building retrofits, indicates C-PACE will likely continue to have a disproportionate influence as a sustainability tool in the area of new construction.

Currently, C-PACE financing for new construction is approved based on energy aspects of a building's design meeting or exceeding a specified building energy code or design standard for *operational energy use.* While this approach has allowed for flexibility in C-PACE program design, it means that the energy efficiency benefits of C-PACE are unevenly administered nationwide as commercial building energy code baselines range widely throughout the U.S. While some states continue to have an opportunity to leverage C-PACE to deliver significantly more efficient new buildings compared to their market standard, C-PACE is nearly "maxed out" where the local building code is so advanced that existing technologies are unable to construct a building whose level of onsite sustainable design significantly exceeds code requirements *at reasonable cost.* Some programs (Connecticut, Colorado) have created bonus tiers where larger quantities of C-PACE financing are allowed in certain instances, to offset the cost-premium of, for example, a wholly electric or net-zero building.

As energy efficiency baselines in building codes increase and grids become cleaner, C-PACE's ability to proportionally influence operational energy efficiency through building design is shrinking. This context underscores the vast opportunity for C-PACE programs to expand to embodied carbon: financing of low-emission building materials as an alternate and in some cases a potentially *lower cost option* for commercial building developers to achieve decarbonization.

Embodied Carbon in Today's Built Environment

According to the Global Alliance for Buildings and Construction's "2022 Global Status Report for Buildings and Construction," buildings contribute to 39 percent of annual greenhouse gas emissions worldwide, with 28 percent originating from the ongoing operation of buildings and 11 percent arising from the production of building materials and construction processes, commonly referred to as "embodied carbon." As buildings become more energy efficient in their operations and local energy grids progressively decarbonize, the significance of embodied carbon emissions is expected to grow within the real estate sector's total annual greenhouse gas emissions. To facilitate a focus on reductions in *embodied* carbon, C-PACE program administrators will want to familiarize themselves with key concepts and methodologies used in embodied carbon policy; an overview of these key concepts, including Environmental Product Declarations (EPDs), Product Categories, Life Cycle Analysis (LCA) and Whole Building Life Cycle Analysis (WBLCA),are included in summary in Appendix I. Additionally, C-PACE program administrators will benefit from understanding the current local or regional policy context in which any C-PACE program expansion would occur, so as to most effectively consider how C-PACE can be an effective policy incentive tool in their region.

Federal and State Action on Embodied Carbon

The federal government and several states are implementing or considering policies targeting embodied carbon emissions in the built environment. Major federal initiatives extend from the Inflation Reduction Act (IRA), which allocates $5 billion in spending for low-carbon procurement projects, including the development and standardization of EPDs, the adoption of low-embodied carbon materials in federal projects, and the provision of financial assistance through the Federal Emergency Management Agency (FEMA) Building Materials Program to encourage low-carbon and net-zero energy projects. The Environmental Protection Agency (EPA) has been tasked with creating a carbon labeling program aimed at specified construction materials displaying significantly lower levels of GHG emissions. This program will serve as a crucial step in fostering sustainability within the construction industry by providing clear and standardized information about GHG emissions associated with the extraction, manufacturing, transportation, and procurement of various materials. By labeling materials with their associated carbon impact, the EPA's program will empower manufacturers and consumers to make informed choices that can contribute to reduced environmental impact.

This initiative will support the federal “Buy Clean” policy, the prevailing approach for regulating and procuring individual construction materials. This policy framework entails the inclusion of requirements for low-carbon material procurement in any project receiving funding from a governing jurisdiction, typically through EPDs. The General Services Administration (GSA) initiated a six-month pilot program in May 2023 (“GSA Pilots Buy Clean Inflation Reduction Act Requirements for Low Embodied Carbon Construction Materials” 2023) to use IRA Buy Clean specifications for purchasing approximately $2.15 billion worth of construction materials with significantly lower carbon emissions for federal projects. This pilot involved applying GSA's “Interim IRA Low Embodied Carbon Material Requirements” to eleven construction and renovation projects managed by the GSA and establish limits on the GWP for IRA-funded materials like asphalt, concrete, glass, and steel.

State level Buy Clean policies have similarly been adopted for state funded projects, including in states with C-PACE programs like California and Colorado. In March 2023, the Biden-Harris Administration introduced the Federal-State Buy Clean Partnership, which includes 13 leading states: California, Colorado, Hawaii, Illinois, Maine, Maryland, Massachusetts, Michigan, New Jersey, New York, Oregon, and Washington at the outset, with Minnesota later joining. These states all have C-PACE programs and will also work with the federal government and each other to create a unified demand for greener materials. As discussed further below, such Buy Clean standards could act as an initial framework for a prescriptive materials-based approach in C-PACE programs; additionally, aggregating demand for low-carbon building materials from commercial projects with public ones could bolster the availability of compliant materials locally and drive down their costs.

Low Embodied Carbon in Building Codes, Stretch Codes, and Whole-Building LCAs

The latest International Panel on Climate Change (IPCC) report emphasized that building energy codes are the most effective regulatory instruments for reducing emissions in both new and existing buildings. Various code frameworks exist for embodied carbon in buildings.

IECC and ASHRAE form the backbone for current C-PACE eligibility standards in new construction. The “ASHRAE 189.1 Standard for the Design of High-Performance, Green Buildings Except Low-Rise Residential”, which has been adopted as the International Green Construction Code, introduced specific prescriptive embodied carbon amendments in 2021. One of these changes stipulates that a certain proportion of material products, determined by their total cost within the project, must obtain EPDs. The EPD reporting amendments do not explicitly outline specific products or product categories that must comply, such as steel or mineral wool insulation. Instead, they establish criteria that *trigger* a requirement for any particular product to comply. For example, any product category whose cost exceeds 5 percent of the total cost of all permanently installed products in the project must adhere to these stipulations. This approach grants project teams some flexibility in choosing which products will meet the kgCO2e limits. Apart from the higher-cost products, project teams must possess a minimum of 30 EPDs, representing at least 20 distinct products from 10 distinct manufacturers. Collectively, these EPDs must account for no less than 25 percent of the total estimated costs of all building products permanently installed in the building project. The requirement to simply collect EPDs is a common emerging best practice that encourages broader availability of embodied carbon data across materials and provides experience to building design teams in accessing and evaluating them while in a building design process. This is valuable even without specifying a minimum standard for such EPDs to meet, and while certain regional markets may be in a position to set minimum standards at this time, not all will be. At this relatively early stage in low embodied carbon policy development, both approaches are valid (Aurora Jensen, Embodied Carbon Lead, Brightworks Sustainability, in discussion with the author, online June 2024). An amendment is under consideration that suggests that a certain percentage of products adhere to specific GWP limits but is not yet adopted.

Other code standards could be a more immediate jumping off point for C-PACE programs. The International Building Code (IBC) presently regulates the utilization and performance of diverse building materials, from concrete and steel to gypsum board, across its multiple chapters. The Embodied Carbon Building Code overlay works as a comprehensive solution for policymakers dealing with greenhouse gas emissions in new commercial construction or major renovations (Bowles et al. 2023). This overlay suggests changes to the IBC setting limits for the GWP for around 40 commonly used and high carbon materials and requiring verification through EPDs. Policymakers can customize these changes by selecting specific material products, adjusting reporting requirements, or modifying GWP limits. This provides a flexible and practical way to include sustainability measures in building practices regulated by the IBC and represents the trends in embodied carbon on an international level.

Finally, the California Building Standards Commission (CBSC) enacted a comprehensive embodied carbon policy within the California Building Standard Code, CALGreen, which takes effect July 1, 2024. This pioneering policy is the first to mandate reduced embodied carbon in commercial buildings (as opposed to public projects as in Buy Clean policy) irrespective of whether it involves adaptive reuse or new construction. The CALGreen code includes both a prescriptive and whole building approach. This groundbreaking policy was designed with input from the private sector to align with the expected supply chain production for lower emission materials and serves as a flexible model for other local and state jurisdictions to adopt.

Industry Trends Using Prescriptive and Performance Specs to Reduce Embodied Carbon

In addition to regulatory frameworks, C-PACE administrators will want to be familiar with other embodied carbon frameworks and initiatives being employed on a voluntary basis by commercial building owners and developers.

Voluntary green building certification programs are promoting the widespread understanding and application of embodied carbon principles across private sector practitioners in building design and construction. One notable example is the International Living Future Institute's (ILFI) Net Zero Carbon Certification. This certification program sets forth explicit requirements for the reduction of embodied carbon in building materials and processes. It establishes a clear pathway for buildings to achieve a net-zero carbon footprint, addressing operational emissions as well as the emissions associated with the entire life cycle of materials and construction. The ILFI Living Building Challenge's Energy + Carbon Reduction Petal is another existing program that places a strong emphasis on minimizing the carbon footprint of building projects. Finally, the Leadership in Energy and Environmental Design (LEED®) Building Design and Construction (BD+C) version 4.1 allows projects to earn credits by conducting WBLCAs and taking concrete steps to curtail embodied carbon.

In the context of corporate sustainability reporting and environmental transparency, embodied carbon accounting is indispensable for measuring and reporting "Scope 3" emissions. These emissions, as defined by the Greenhouse Gas Protocol (World Business Council for Sustainable Development (WBCSD) and World Resources Institute (WRI) n.d.), encompass the indirect emissions associated with a company's value chain, including those linked to the production and transportation of building materials. Forward looking companies in the building construction industry, such as Lendlease, are measuring and disclosing the carbon impact of their Scope 3 emissions using LCAs and EPDs, as required by the European standard BS EN 15978:2011 (Lendlease n.d.). Industry groups and non-profit leaders, such as the Holcim Foundation for Sustainable Construction, are pushing the building industry to innovate on EPD and LCA data collection and standard setting through the Holcim Foundation Impact Summit and working groups comprised of industry, finance[1], and policy representatives. In support of such streamlined approaches, The Carbon Leadership Forum, whose mission is to eliminate embodied carbon in buildings, materials, and infrastructure, published a second version of the "North American Materials Baseline" in August 2023, which is an estimate of industry-average GHG emissions for construction materials manufactured in North America, primarily based on industry-wide EPDs, for use by the private sector (Waldman 2023).

Ongoing Challenges in Implementing Low Embodied Carbon Policies & Practices

Despite the existing and emerging frameworks for embodied carbon in buildings, C-PACE program administrators should be aware of the known challenges that have been identified by public and private practitioners in implementing these policies:

- Regional Material Availability: There is wide variation in the availability of EPDs for low-carbon material, such as concrete, across the country. This makes uniform procurement of materials for a single developer or policy difficult.
- Industry Education: The real estate industry is not yet widely educated on the proven performance of lower-carbon material or what actionable resources are available to begin addressing embodied carbon in the build environment. Similarly, some architects, engineers, contractors, and manufacturers lack technical expertise in such products.
- Performance Standards: There is no clear performance standard to spark competition within the building industry, although there are voluntary standards such as the *Carbon Leadership Forum's 2023 Material Baselines* (Waldman 2023).
- Incentive to Act: The significant cost-savings from energy efficiency and clean energy have accelerated their adoption in real estate. The impact of similar incentives through procurement policies for low-carbon, high-performance materials is not yet known.

[1] Study author Nuveen Green Capital is a member of the Holcim Foundation finance working group.

How Can C-PACE Support Reductions in Embodied Carbon?

C-PACE can help to address the current aforementioned challenges in implementing low embodied carbon practices in commercial buildings.

First, C-PACE programs that expand to include low-carbon building materials and publish updated technical standards would bring the concept of embodied carbon to thousands of commercial building design and development professionals, increasing market awareness of low-carbon products and design methodologies like EPDs and WBLCAs. With C-PACE programs authorized by nearly 2,000 local governments nationwide, the potential impact is extensive. C-PACE financing applications are prepared by financiers, architects, and professional engineers, all of whom are channels for property developers to understand how much C-PACE financing they can access on a given project. Given the strong financial incentive provided by C-PACE, property developers may also be more willing to engage in a WBLCA, or to require a general contractor to obtain an EPD, if it meaningfully unlocks their ability to access C-PACE financing.

Second, expanding C-PACE to low-embodied carbon new construction would provide a critical financial incentive to act. The lower interest rates associated with C-PACE financing in new construction could balance potential cost premiums in accessing lower emission building materials and as a source of construction financing because the provision of C-PACE dollars can be tied to material and measurable reductions in embodied carbon. While the exact financial benefit of C-PACE would be highly dependent on the material and its cost and availability for the project at hand, developers can calibrate the cost of a material and any increase to a project's capital budget against the cost of borrowing and determine whether the reduced cost of borrowing justifies the inclusion of that material. Furthermore, provisions of additional C-PACE dollars over and above current program limits could be used as an incentive to allow developers to address whole building carbon. The documented trend of C-PACE program administrators offering larger quantities of C-PACE financing for developers who incorporate "bonus" categories of building features (i.e. electrification, EV charging, seismic hardening) underscores the logic of this approach for building materials not currently covered by C-PACE programs.

Finally, C-PACE is a public-policy tool that states and localities can use to leverage both more activity in the private sector and more data on low-carbon policy design. While the implementation of new commercial building standards and codes that address embodied carbon could span a decade or longer, C-PACE policies are flexible and iterative, with C-PACE program administrators updating their program guidelines regularly to account for shifting market conditions and maturing policies. Even a few commercial pilot projects in different geographic areas through C-PACE programs could help build the data set informing performance standards and incentivize more robust regional markets for low embodied carbon materials.

Key Considerations When Designing Low Embodied Carbon C-PACE Policy

Expanding C-PACE programs requires considering what categories of building materials are eligible, what technical methodologies and supporting documentation may be utilized to determine eligibility, and how best to calibrate the financial incentive to spark participation.

Policy Considerations

C-PACE programs are established through state and local law and administered via program guidelines. Implementing a low embodied carbon C-PACE policy may require expanding program parameters via legislative amendment and/or updating program guidelines. Some legislation may already be flexible enough to allow C-PACE to fund low embodied carbon materials. As a first step, C-PACE program should review the existing, state-enabling policy – specifically the definitions for eligible improvements – to determine whether one or more categories of low-emission building materials are currently eligible for funding. Existing language that is more amenable to implementing low embodied carbon policies would include explicit allowance for financing measures that directly reduce carbon, GHG emissions, or that adhere to nationally accepted or best practice commercial building code standards. Broad authorizations of "decarbonization" or language that allows the financing measures that "reduce energy use" may also allow for certain low embodied carbon materials whose lower-carbon profile stems from a reduction in the energy used to product the material. Similarly, language that authorizes the financing of measures that "improve air quality" could be deemed to authorize certain low embodied carbon materials due to the cleaner manufacturing processes used to produce them (Mills 2023). Finally, certain low embodied carbon materials might also be classified as a form of "climate adaptation." For programs considering legislative expansions, language such as "carbon" and "GHG reduction" may engender pushback. C-PACE administrators may choose to focus more on adherence to building codes (which may include building material methodologies) given the wide range of building codes and standards described in this paper that encompass embodied carbon. As lower-emission materials are often produced locally (due to the reduction in energy used for transport), the economic and social benefits connected to the local production and supply chain of building materials to C-PACE funded projects should be noted.

Beyond C-PACE enabling policy, policymakers should consider the current real estate and construction markets to determine whether low embodied carbon is a reasonable fit for C-PACE locally. Are there other low embodied carbon policies (e.g. Buy Clean or potentially building energy performance standards) in the jurisdiction already? Is there a (regional) market for low embodied carbon materials? Can they reasonably be sourced? Who are local partners that can help identify supply chains, manufacturers, and prospective construction projects? Policymakers should identify the key resources necessary to scale the market.

Technical Considerations

Beyond the C-PACE policy framework, there are programmatic considerations that must also be evaluated, chiefly the technical review process and which building materials are to be eligible under the program. There are two main approaches for C-PACE to set an embodied carbon evaluation standard: a material/product specific approach (also called a "prescriptive" approach) or a whole building (also called a "performance") approach. Both approaches seek to expand real estate's awareness of embodied carbon solutions, accelerate development of lower-carbon materials, and reduce embodied carbon from new construction.

A prescriptive approach targets improved GWP performance in specific building products. C-PACE programs could set a standard level of performance for each listed material in order for C-PACE to finance those costs, with performance based on product EPDs. Another feature of a prescriptive pathway could be to simply require collection of EPDs across a certain number of building products (to promote data collection and EPD uptake in early years of the program) in addition to performing at or below the established industry GWP baseline. Material-specific GWP maximums are often established for solely materials with the highest embodied carbon, which may be appropriate for C-PACE programs that are allowing C-PACE to finance

100% of the cost of such qualifying material or product. Two of the most extensively utilized substances in the construction of modern edifices are concrete and steel. These materials are responsible for around eleven percent (IEA 2022), of global GHG emissions linked to product manufacturing and construction. Internal portfolio analysis from Nuveen Green Capital (see Fig. 3) found that concrete and steel are 22 percent of new construction costs on average. Notably, aluminum, glass, and insulation building products are other major contributors to this carbon footprint. Whichever materials are allowed, for a prescriptive approach, the choice of eligible building materials may be driven by policy constraints (i.e., certain programs may only be able to enable solely materials that create reductions in energy, or that support certain allowable resiliency benefits), market constraints (i.e., availability of materials), or economic viability.

A whole building approach prioritizes low embodied carbon throughout the building lifecycle and allows projects to demonstrate lower impact through reduced material usage as well material performance. C-PACE programs could set a standard level of embodied carbon performance for a whole building project, such as GWP or allowable emissions per area (kgCO2/m2). Performance can be based on WBLCAs, and thresholds may include reducing carbon intensity compared to project or industry building type baselines. The whole building approach can encompass the entire building or a specific set of systems, and it encourages holistic strategies such as material and building reuse, material substitution, and material efficiency. Since it involves comparing materials across product categories, this approach requires considering the entire life cycle of a product when assessing the impact of design choices on embodied carbon. With this approach, C-PACE programs should also consider allowance of "swapping" embodied for operational approaches to decarbonization. Often, design decisions that enable significant reductions in operational energy (such as passive orientation or building morphologies that create shade and reduce the size of HVAC systems) could increase or decrease building footprints and need for materials that change embodied carbon.

Since C-PACE financing applications and the decision to utilize C-PACE financing is often made "at point of sale" (i.e. a developer has already completed building design drawings and/or the project is permitted), a change in material procurement can still make a meaningful impact on embodied carbon. For this reason, as well as the relative simplicity and time efficacy of requesting and using EPDs (when compared to WBLCA) C-PACE programs expanding into embodied carbon should, at minimum 1) require the collection of EPDs and 2) include a prescriptive pathway. Further, if such prescriptive path includes a maximum GWP threshold, C-PACE programs can encourage developers to request a range of EPDs based on their particular building's specifications so as to achieve a more robust set of data and material options, some of which may achieve decarbonization well over the threshold; this is in line with current private industry best practice. We recommend whole building approaches also be considered and possibly developed by C-PACE administrators and practitioners as a national methodology so as to streamline this approach nationally for C-PACE. Key resources for prescriptive EDP and WBLCA methodologies are included in Appendix I.

Regardless of which approach described above is implemented, policymakers will need to determine how and by whom projects are approved. C-PACE programs with a positive savings-to-investment ratio (SIR) requirement, which requires estimated operating savings resulting from the measures financed to exceed the cost of those building measures, will not be able to apply such a requirement to low embodied carbon policies, which do not imply any "savings" as in a classical energy efficiency program.

Financial Considerations

C-PACE programs must also consider how to calibrate the C-PACE financing incentive against technical standards that govern eligibility. Since C-PACE program administrators do not set interest rates (these are negotiated among the developer and their financier), C-PACE program administrators should consider the following factors: quantity of allowable C-PACE financing, maximum term of C-PACE financing, C-PACE administrative fees.

Increasing the *quantity* of allowable C-PACE financing will provide the largest incentive, as many developers prefer C-PACE financing over other sources of capital. Accessing more C-PACE dollars directly reduces a project's overall weighted cost of capital. Figure 3, below, shows an internal sample of thirty-seven Nuveen Green Capital new construction projects from across the U.S. demonstrates the proportion of the construction budget allocated to key materials driving embodied carbon. Concrete and steel emerge here as the largest categories by dollar. Insulation, drywall, glazing and finishing materials are also emerging opportunities for embodied carbon reduction, and may be targeted by developers. As C-PACE can currently fund between 10 – 30% of a building construction budget related to eligible energy or water components, the addition of an additional 10-15% would be significant for a developer.

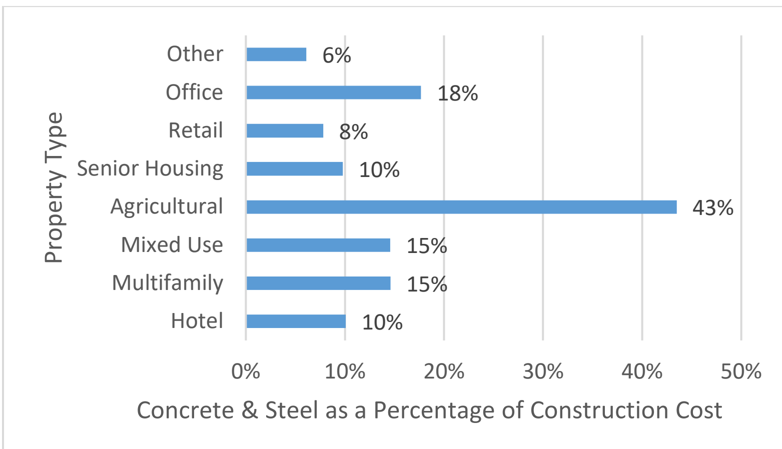

Figure 3. Concrete and steel as a percentage of construction cost in funded projects. *Source:* Nuveen Green Capital

Low embodied carbon concrete is already under development by companies such as CarbonCure, Brimstone, Sublime Systems, and Partanna to name a few. Concrete and steel are well positioned to generate material carbon reduction, in some cases with little or no cost premium (Esau et al. 2021). Analysis from RMI (Rocky Mountain Institute) and Skanska found that new construction today can reduce its embodied carbon 19-46 percent with less than 1 percent cost premium, depending on the low carbon strategy ("Case Studies Show How to Significantly Reduce Carbon Emissions in the Construction of New Buildings at Little to No Cost," n.d.). However, generating low emissions concrete *at scale* will likely require a cost premium for some time from suppliers (Feric 2023). Even if there is hypothetically no absolute cost for a developer or general contractor in switching from one material to a lower embodied carbon equivalent, there remains a cost in time and resources. Such materials may be difficult to source or require a developer or contractor to change their existing procurement policies. It may lengthen the time spent procuring materials and therefore the time (and cost) of construction.

Given the unknowns about the highly localized cost of these materials in any given location, we recommend C-PACE programs allow for the financing of 100% of the cost of eligible (as determined by the program) low-emission building materials capped solely at existing financing maximums (i.e. set by mortgage bank consent requirements or law). For programs that have already set C-PACE funding tiers based upon operational energy efficiency building design, program administrators should consider crafting embodied carbon tiers that may be accessed both after meeting minimum operational thresholds and in addition to or in lieu of higher operational ones. C-PACE programs with no statutory limitations on maximum term of C-PACE financing should apply their existing effective useful life methodology for energy or resiliency measures to building materials; this will, in the case of concrete and steel support more affordable C-PACE assessment payments through longer terms and financially support the consent of the underlying mortgage holder. Finally, C-PACE programs may wish to consider reduced administrative fees for early adopters of a low-emission building materials to encourage pilot projects that can be used for educational and marketing purposes.

Market Considerations

Finally, in considering expanding C-PACE to include low-emissions building materials, policy makers and program administrators should recall the market constraints that exist in this arena and remain flexible toward program improvement over time. For example, regional differences and data inconsistencies will exist and may limit the extent to which C-PACE programs can uniformly adopt technical standards for prescriptive materials in the immediate term. C-PACE programs should collaborate with key stakeholders, including CLF, the U.S. Green Building Council, ILFI, Rocky Mountain International, the New Buildings Institute, and the Holcim Foundation, and considering also sharing project performance data where available.

Conclusion

The growing awareness of embodied carbon's impact on the environment and its crucial role in achieving carbon-neutral structures has prompted significant attention in the real estate industry. Globally, buildings contribute to a substantial portion of GHG emissions, with a growing emphasis on addressing the 11 percent of emissions attributed to embodied carbon. As more states and jurisdictions commit to environmental goals, it is expected that restrictions on embodied carbon emissions in buildings will emerge. Proactively adopting low-embodied carbon design practices not only prepares companies for future regulatory challenges but also displays a commitment to reducing carbon footprints. Access to C-PACE funding enables building owners to comply with evolving regulations and participate in sustainability initiatives. Perhaps more importantly, in the early stages of a national low embodied carbon building framework, C-PACE can encourage the use and education of low embodied carbon tools, such as LCAs, EPDs, and the development of effective regional standards through data collection. With C-PACE lending at a record high (Kirk 2024), foregoing the opportunity for C-PACE to accelerate investments in reducing embodied carbon in the built environment would be shortsighted. The real estate industry is at a pivotal moment in addressing embodied carbon, and C-PACE stands as a crucial tool to support this transformation.

Appendix I: Key Terms Related to Embodied Carbon

Embodied carbon encompasses the carbon dioxide equivalent (CO2e) greenhouse gas emissions linked to both building materials and construction procedures throughout a building's entire lifespan.

In the building industry, embodied carbon refers to the total impact of all human induced greenhouse gases emitted from material extraction through the end of its useful life. Embodied carbon is calculated by summing all carbon emitted from sourcing raw materials, manufacturing, transporting, construction and installation activities, ongoing material use, maintenance, repair, and finally, disposal.

For decades, experts specializing in sustainable materials have conducted in-depth studies on embodied carbon and the ecological ramifications associated with building materials and products. Embodied carbon has garnered renewed and heightened attention, particularly within the context of exploring carbon-neutral structures and comprehensively assessing the enduring carbon impacts throughout a building's lifecycle.

As the operational carbon of buildings continues to improve, the significance of embodied carbon as a source of emissions is escalating. Unlike operational carbon emissions, which can be mitigated over a building's lifespan through energy efficient renovations and the transition to a decarbonized power grid, the majority of embodied carbon emissions manifest before a building is even occupied, making their reduction over time unfeasible. Consequently, the imperative to address embodied carbon through building construction material has acquired critical urgency, representing a pivotal stride towards the decarbonization of structures and a substantial reduction in global emissions.

Existing policies to reduce embodied carbon generally require a whole building approach or a materials-based, or prescriptive, approach. The whole building approach considers the life cycle impact of a whole building via a **life cycle assessment (LCA)**; in this instance, the LCA may be called a **whole building LCA (WBLCA)**. The whole building approach is often a combination of choices related to building design, material choice, and construction timelines. Combining these factors in a LCA can help practitioners determine the overall carbon content of an entire building over the course of its useful life. A building-scale approach considers the overall embodied carbon impact of an entire project, including its various components and systems. This method considers a wider range of materials, not just the most impactful ones, and allows for additional strategies to reduce embodied carbon. These strategies can involve reusing materials and buildings, comparing different systems and materials (like comparing mass timber and steel or spray foam and batt insulation), and improving material efficiency. Since materials are compared across various categories, it's essential to include the entire lifespan of a product when using WBLCAs to assess the impact of design choices on embodied carbon. Interest in policies centered around WBLCAs is growing with the support and accessibility of tools like Tally and One Click LCA, which simplify the comparison of design analyses. This capability allows projects to receive recognition for their efforts in reusing building materials or enhancing material efficiency.

The materials-based approach requires a *product* LCA; these LCAs are independently verified following ISO 14040 and ISO 14044 standards. Manufacturers, once armed with an LCA for their product, can create an **environmental product declaration (EPD)** that utilizes LCA information to convey a product's environmental performance throughout its life cycle. EPDs remain valid for five years and encompass data such as ozone depletion potential, acidification, eutrophication, ozone depletion, smog creation, and more. These declarations may also encompass details like ingredients, manufacturing processes, locations, energy sources, water usage, third-party certifications, and other pertinent information. Most importantly for embodied carbon reduction policies, EPDs provide a measurement of the carbon embedded in individual building materials through a measure of **global warming potential (GWP)**. A material's carbon dioxide equivalent (CO2e) is represented as GWP and is the most common metric for measuring and evaluating materials' greenhouse gas emissions over a product or building's lifecycle. GWP calculations for a single product are represented via an EPD, whereas GWP is calculated for an entire building through a WBLCA. Several types of EPDs are in use today:

Product-specific (Type III) EPDs are the most precise EPDs available as they include quantified product information about a sole product from a manufacturer. Type III indicates a referenced **product category rule (PCR)**, in accordance with the ISO 14040 and ISO 14025 series of standards. Product category rules define the product category and are necessary for Type III EPDs. The PCR lays out which environmental impacts the manufacturer must include in the EPD and how to measure each of the impacts. Several tools exist for sourcing and generating EPDs, such as Building Transparency's Embodied Carbon in Construction Calculator (EC3) and One-Click LCA.

In the case where a PCR doesn't exist for the product or a small manufacturer cannot afford their own EPD, an industry average EPD can be a suitable stand-in.

Industry-wide (Generic) EPDs provide an industry snapshot of the carbon impacts of a range of products for a group of manufacturers. These are often created by manufacturing associations to represent the average characteristics of an industry product with a specific PCR. Industry-wide EPDs cannot be used to compare specific products.

Project-specific EPDs are not always verified by a third-party and rely on self-declaration based solely on ISO14021 guidelines.

Supply chain-specific EPDs are product-specific EPDs that use supply chain-specific data in the LCA to model the impacts of key processes upstream in a product's supply chain.

Facility-specific EPDs are product-specific EPDs in which the environmental impacts can be attributed to a single manufacturer and manufacturing facility.

EPDs are appropriate for use in procurement policies because a third-party verified process already exists with agreed-upon resources for calculating and documenting the embodied carbon of individual products. That said, several shortcomings currently limit the use of EPDs. Since manufacturing processes can change, EPDs are valid for 5 years and must be updated to be included in online databases. The creation of EPDs is voluntary; as a result, EPDs do not exist for every product, making it difficult to set targets or compare all known products. Additionally, PCRs implement a different methodology for different product types; therefore, while you can compare the embodied carbon measured via the EPD of one type of steel to that measured via the EPD of another type of steel, you cannot use an EPD to compare embodied carbon across different materials (e.g. steel to cement). This means that while practitioners can use an EPD to compare the same parts (building material A.1 to building material A.2), and practitioners can use whole building LCAs to compare the sum of the parts (total embodied carbon in building X to total embodied carbon in building Y), practitioners cannot compare across the different building material categories (building material A.1 to building material B.1).

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