Carbon Footprint of Buildings: Reducing Embodied Carbon

Background

In the urgent battle against climate change, a growing emphasis is being placed on mitigating the environmental impacts of various sectors. One of the key considerations in this endeavor is embodied carbon – a concept that encompasses the greenhouse gas emissions associated with the entire lifecycle of construction and building materials. Understanding and addressing embodied carbon is now critical as we seek to mitigate the impacts of climate change. **Embodied carbon** refers to the sum total of greenhouse gas emissions produced during the extraction, manufacturing, transportation, construction, use, maintenance, and eventual disposal of building materials and infrastructure.[1] It encapsulates carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), and other greenhouse gases emitted throughout a material's life cycle.[2]

In essence, embodied carbon accounts for the carbon footprint of a product or building, not just during its operational phase but through its entire existence. While carbon emissions from the operational phase of buildings (heating, cooling, and electricity use) have traditionally been of primary focus, the significance of embodied carbon cannot be overlooked. Studies have shown that embodied carbon can constitute a substantial portion of a building's total emissions, sometimes exceeding those from its operational lifespan.

According to the World Green Building Council, "currently, buildings account for 39% of energy-related global CO_2 emissions, demonstrating the importance of the building and construction sector in fulfilling these ambitions. Of this sector contribution, 28% comes from operational carbon with 11% arising from the energy used to produce building and construction materials, usually referred to as embodied carbon."[3]

Embodied Carbon Sources

A wide range of materials, manufacturing processes, transportation, and logistics contribute to embodied carbon in the building sector. Understanding these sources is vital for making informed decisions to reduce the carbon footprint of building projects.

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[1] Embodied Carbon, International Code Council. Available at: https://www.iccsafe.org/advocacy/embodied-carbon/#primary.

[2] Embodied Carbon, The Alliance for Sustainable Building Products. Available at: https://asbp.org.uk/workstream/embodied-carbon-2.

[3] Bringing embodied carbon upfront, Coordinated action for the building and construction sector to tackle embodied carbon, World Green Building Council, Published September 2019. Available at: https://worldgbc.s3.eu-west-2.amazonaws.com/wp-content/uploads/2022/09/22123951/WorldGBC_Bringing_Embodied_Carbon_Upfront.pdf.

Building Materials

Common materials like concrete, steel, aluminum, and glass can have high embodied carbon due to the energy-intensive processes involved in their extraction and manufacturing. For instance, steel, a vital component in construction, contributes significantly to embodied carbon due to the CO2 released during iron ore extraction, smelting, and refining.[4] The production of steel is responsible for 6.6 percent of global greenhouse gas emissions.[5] Similarly, while spray foam insulation provides excellent thermal performance, its manufacturing processes and the use of certain blowing agents can result in significant embodied carbon.[6]

Manufacturing Processes

The extraction and production of building materials involves energy-intensive manufacturing processes that contribute to embodied carbon. For example, the production of cement, a primary component of concrete, emits significant amounts of CO2 and is responsible for seven percent of global greenhouse gas emissions.[7] Similarly, aluminum production accounts for two percent of global carbon emissions, which can be attributed to the process of obtaining alumina from bauxite and then smelting it to produce aluminum.[8] Examining the contributions of these materials to global greenhouse gas emissions, it is essential to consider the manufacturing processes and their associated embodied carbon when selecting building materials.

Transportation and Logistics

The transportation of materials from their source site to the factory and construction site involves energy consumption and therefore contributes to increased embodied carbon.[9] The transport of materials and building waste within or across geographic regions can have a major impact on a building's embodied carbon. Based on local material availability and transportation method, embodied carbon may vary between regions of the United States.[10] Although the manufacturing stage normally emits most of the embodied carbon, transportation emissions can be significant, especially when a large amount of material is moved across great distances. This

[4] Carbon Impacts of Steel, Materials Palette. Available at: https://materialspalette.org/steel/.

[5] Embodied Carbon in Construction: High Time to Reduce it, The Constructor. Available at: https://theconstructor.org/building/embodied-carbon-construction/295849/.

[6] Efficiency Vermont, Ask an Expert: How to choose insulation with the lowest carbon impact, Published May 5, 2022. https://www.efficiencyvermont.com/blog/our-insights/ask-an-expert-how-to-choose-insulation-with-the-lowest-carbon-impact.

[7] Anderson, J. and Moncaster, A., 2020. Embodied carbon of concrete in buildings, Part 1: analysis of published EPD. *Buildings and Cities*, 1(1), p.198–217.DOI: https://doi.org/10.5334/bc.59.

[8] Aluminum Climate Impact: An International Benchmarking of Energy and CO2 Intensities, Ali Hasanbeigi, Cecilia Springer, Dinah Shi, Global Efficiency Intelligence, Published May 2022. Available at: https://www.bluegreenalliance.org/wp-content/uploads/2021/04/Aluminumreportdesign-FinalFeb2022.pdf.

[9] Ciaran Malik, Trasport to site embodied carbon A4. https://ciaranmalik.org/portfolio/transport-to-site-embodied-carbon-a4/.

[10] Embodied Carbon in U.S. Industrial Real Estate, 2023 Benchmark Study, Published May 2023. Available at: https://branchpattern.com/wp-content/uploads/2023/05/BranchPattern-Embodied-Carbon-in-U.S.-Industrial-Real-Estate-Report.pdf.

primarily depends on the means of transportation, which currently relies heavily on fossil fuels and contributes significantly to the embodied carbon of a building.[11]

Disposal of Materials

The disposal of construction and building materials at the end of their life cycle, particularly in landfills, results in the emission of greenhouse gases such as CO2 and CH4, making it a significant source of embodied carbon in the building industry.[12]

Balance Point: Addressing Embodied Carbon and Operational Carbon Together

In the context of reducing emissions from buildings, carbon emissions can be broadly categorized into two main types: embodied carbon and operational carbon. **Operational carbon** represents the ongoing carbon emissions arising from the energy required to power a building and ensure its proper functioning throughout its occupied life.[13] Operational carbon currently accounts for 28 percent of global greenhouse gas emissions and embodied carbon accounts for 11 percent. However, with the estimated increase in construction, by the year 2050 embodied and operational carbon emission levels will be the same.[14] To achieve a comprehensive reduction in carbon emissions, it is critical to address both embodied carbon and operational carbon together. This requires a holistic approach that considers the entire life cycle of buildings, from material selection to construction techniques, energy used throughout the occupational period of the building, and waste management.

Strategies for finding a balance between embodied and operational carbon include conducting research to evaluate the carbon footprint of different materials, equipment, and systems. This analysis will enable one to consider both embodied and operational carbon of a building design and make informed decisions and identify opportunities for optimization. For instance, the Whole Building Life Cycle Assessment, shown in Figure 1, allows architects and engineers to explore different design scenarios and analyze their carbon impacts throughout the building life cycle. This makes it easier to fine-tune the design to achieve an optimal balance between embodied and operational carbon, considering that trade-offs may be necessary to effectively reduce the overall carbon footprint. It is important to note that the Whole Building Life Cycle Assessment does not account for costs associated with building materials, equipment, and systems. Furthermore, data availability and accuracy on embodied carbon in building materials create barriers to the widespread use of Life Cycle Assessment. All of these challenges will be addressed below. Additionally, exploring low-global warming potential alternatives, prioritizing energy efficiency measures, and sustainable manufacturing processes can contribute to reducing the carbon footprint of buildings. Promoting efficient transportation and logistics, as well as implementing sustainable waste management practices, are also essential. By integrating these strategies, the building

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[11] 5th Annual Carbon Footprint Report 2012-2016, South Mountain Company. Available at: https://www.southmountain.com/wp-content/uploads/2017/05/SMC-Environmental-Foorprint-Graphic-2017-Hi-Res-compressed-rotated.pdf.

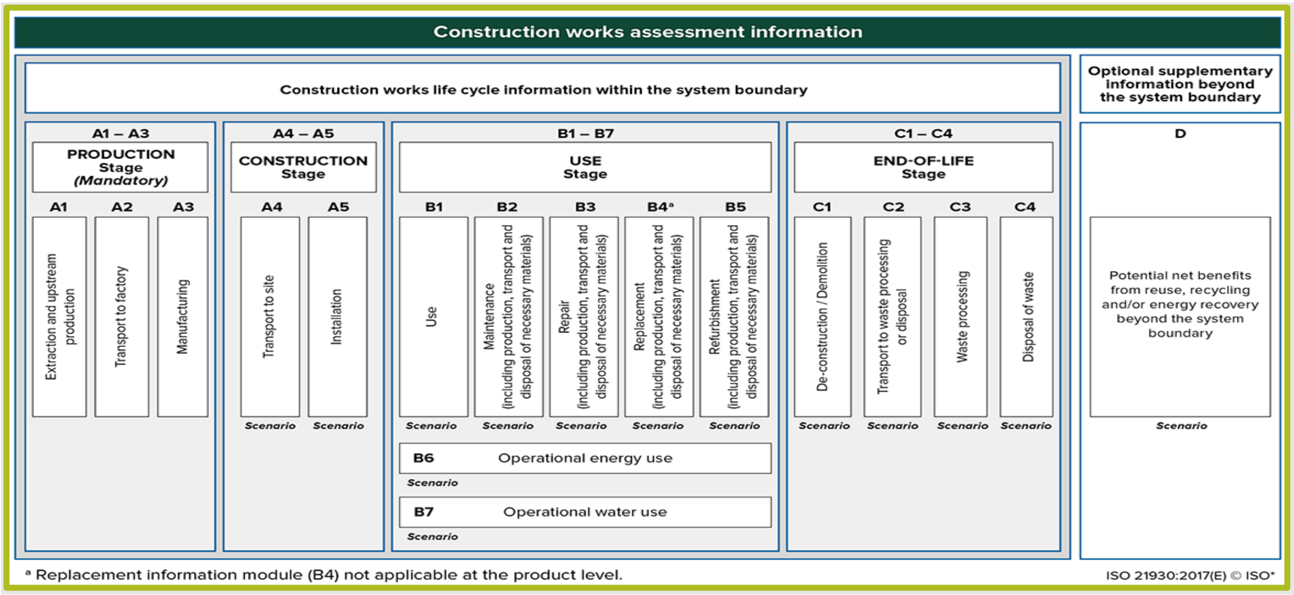
[12] Aquicore, Understanding Embodied Carbon in Buildings. https://www.aquicore.com/blog/embodied-carbon-buildings#:~:text=And%20the%20deconstruction%20and%20disposal,the%20final%20waste%20disposal%20itself.

[13] Operational Carbon in Building Energy Codes, Northeast Energy Efficiency Partnerships. Available at: https://neep.org/operational-carbon-building-energy-codes.

[14] Embodied vs Operational Carbon, Spot UL, August 16, 2020. Available at: https://spot.ul.com/blog/embodied-vs-operational-carbon/.

industry can find the balance point between reducing embodied carbon and improving operational carbon efficiency, leading to a more sustainable and resilient built environment.

Figure 1: Whole Building Life Cycle Assessment, courtesy of [WoodWorks](#)



Different Approaches in Measuring Embodied Carbon of Building Materials and Products

Measuring embodied carbon is key to evaluating the highest-impact and the most cost-effective solutions to reducing embodied carbon. Different approaches exist for determining and measuring embodied carbon in construction materials and processes. Here are some common methodologies and technologies used today:

Life Cycle Assessment (LCA)

LCA is a comprehensive methodology to assess the environmental impacts of a product or system throughout its entire life cycle. It considers various stages, including material extraction, manufacturing, transportation, construction, use, and end-of-life disposal.[15] LCA is done through data gathering and computer modeling, and often contains proprietary product formulation or manufacturing information. As a result, they are rarely released publicly.

Environmental Product Declarations (EPDs)

EPDs are standardized documents that provide information about the environmental impact of a product or material based on LCA data. They include data on embodied carbon, energy use, water consumption, and other

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[15] What is life cycle assessment (LCA)?, Rochester Institute of Technology, Published July 2, 2022. Available at: https://www.rit.edu/sustainabilityinstitute/blog/what-life-cycle-assessment-lca.

environmental indicators. EPDs offer a transparent and consistent way to compare the embodied carbon of different materials.

Global Warning Potential ([GWP](#))

GWP is a metric that quantifies the potential of a greenhouse gas to contribute to global warming over a specific time horizon, usually 100 years. It allows for the comparison of the global warming potential of different greenhouse gases related to CO2. When assessing embodied carbon, GWP is often used to convert emissions of other greenhouse gases such as CH4 or N2O into CO2 equivalent. This helps provide a standardized measure of the overall climate impacts of embodied carbon emissions.

Carbon Emission Intensity

The carbon footprint intensity is the carbon footprint contributed per unit of material or activity. It is often expressed as kilograms of CO2 per unit, such as kilograms of CO2 per kilogram of material or per square meter of construction.[16] Carbon emission intensity is used to measure embodied carbon by quantifying the amount of CO2 emissions associated with the production, transportation, and installation of construction materials. It provides a way to compare the climate impacts of different materials and processes and helps identify options with lower-carbon footprints.

Embodied carbon footprint calculators are user-friendly tools that enable the public to estimate the environmental impact of construction materials and processes, facilitating informed decisions towards more sustainable building practices. Many of these calculators are readily available online or can be accessed through different subscription plans, offering accessibility to individuals, architects, engineers, and policymakers. Some examples include:

- Embodied Carbon in Construction Calculator (EC3)
- eTool
- One Click LCA
- Mesh Embodied Carbon Calculator V6.0
- Kaleidoscope: Embodied Carbon Design Tool
- ECOM – Embodied Carbon Estimator
- Tally
- BEAM Estimator

The Role of Building Codes in Addressing Embodied Carbon

Building codes are the critical regulatory framework that shapes the building industry, ensuring safety, energy efficiency, and sustainability. Stretch codes, in particular, offer an opportunity to incorporate more ambitious

[16] Carbon Emission Intensity Explained, Nicole Sullivan, Carbon Better, February 7, 2023. Available at: https://carbonbetter.com/story/carbon-emissions-intensity/.

sustainability measures beyond baseline requirements of traditional building codes. To effectively address the environmental impacts of buildings throughout their life cycle, it is important to incorporate embodied carbon considerations into these codes. By doing so, building codes, including stretch codes, can achieve:

- **A holistic approach to carbon reduction** through the entire life cycle of a building. This will ensure that environmental impacts of construction materials and processes are considered, leading to a lower carbon impact of new buildings.
- **Adherence to a consistent set of standards** by establishing a baseline for the industry to follow, leading to more low-impact design and construction practices across the industry.
- **Transparency and informed decision-making** by industry professionals who would be aware of environmental impacts of construction materials and practices, enabling them to make environmentally conscious choices.
- **Market transformation** by stimulating the supply chain to innovate and produce sustainable alternatives, accelerating the transition towards a low carbon-built environment.

Navigating Challenges in Addressing Embodied Carbon

Addressing embodied carbon presents several challenges that must be overcome to effectively reduce environmental impact of buildings.

- **Data availability and accuracy:** One significant challenge is the lack of comprehensive data on the embodied carbon of different materials and processes. Obtaining accurate data for a wide range of construction materials can be time-consuming and resource intensive. While many embodied carbon estimator tools have been developed, a standardized database of reliable and public data specifically focused on embodied carbon could better address this challenge.
- **Limited cost data and potential higher initial cost:** Cost data for low-carbon materials and construction practices are not readily available, and builders and developers have pointed out that embodied carbon reduction measures can cause higher upfront costs. Conducting a comprehensive Life Cycle Cost Analysis to showcase long-term financial benefits of embodied carbon reduction, such as energy savings, operational cost reductions, and increased market value, is the first step in addressing this challenge. Additionally, introducing financial incentives, grants, and tax credits specifically targeting embodied carbon reduction can offset initial cost and incentivize environmentally conscious decisions.
- **Lack of awareness and understanding:** Many stakeholders in the construction industry including designers, builders, and code officials, may have limited awareness or understanding of embodied carbon and its importance. This lack of awareness can lead to lower demand for low-carbon materials resulting in a limited supply of sustainable alternatives and higher costs for those available. It is necessary to conduct educational campaigns, foster knowledge-sharing platforms, and facilitate training programs to increase the knowledge and understanding of embodied carbon among industry professionals. Embodied carbon education can be incorporated into professional development courses, certification programs, and university curricula.

Legal Approaches in Addressing Embodied Carbon

So far, addressing embodied carbon has not been done uniformly. Different jurisdictions have taken different legal approaches to address embodied carbon in the building industry, encompassing a range of policies, legislation, regulations, and initiatives at various levels of government. Here are some examples:

Legislation

The Buy Clean California Act, enacted in 2017, is state-level legislation that requires contractors bidding on publicly-funded projects to disclose and meet embodied carbon emissions limits for the materials they intend to use. Focused on public infrastructure projects, the Act sets the maximum acceptable GWP limit for key material categories associated with the production of structural steel (hot-rolled sections, hollow structural sections, and plate), concrete reinforcing steel, flat glass, and mineral wool board insulation. Each contractor looking to work on a public project must demonstrate compliance by presenting an EPD.

In a similar manner, the New York Low-Embodied-Carbon Concrete Leadership Act required the Office of General Services to create guidelines and minimum standards for the use of low-carbon concrete in public projects. In recent years, other states (including Washington, Oregon, Colorado, Minnesota, and New Jersey) have advanced statewide Buy Clean or Buy Clean-related policies. By incorporating embodied carbon considerations into public procurement, these laws incentivize the use of low-carbon materials, set a precedent, and promote accountability and transparency in the construction industry. While the Acts do not apply to privately-funded buildings and development, they can serve as a model for sustainable construction practices and influence the broader building industry to consider embodied carbon reduction voluntarily.

Massachusetts initially tried to incorporate embodied carbon considerations into its stretch code, however, it was ultimately not included in the final draft. Nevertheless, the state is currently engaging in legislative efforts to address embodied carbon in statewide policy through the introduction of several bills in the 2023-2024 legislative session:

- An Act Incorporating Embodied Carbon into State Climate Policy
- An Act Requiring State Procurement of Low-Carbon Building Materials
- An Act Requiring State Procurement of Low-Carbon Building Materials

Zoning Initiatives

Boston has created the Zero Net Carbon Building Zoning Initiative and proposes zoning policies that will help steer Boston towards a carbon-neutral future. Some of the recommendations include setting embodied carbon reduction goals and strategies and implementing a zero net embodied carbon standard in the next climate action plan update, a zoning update that will require achievement of specific LEED (Leadership in Energy and Environmental Design) credits and associated points related to embodied carbon (examples include construction and demolition waste management, building life-cycle impact reduction, building product disclosure and optimization, low embodied carbon structural designs, materials, and systems), and integrating whole building life cycle assessment into permitting review.

Action Plan

Cambridge is addressing embodied carbon through its Net Zero Action Plan and will incorporate embodied carbon reduction in the Cambridge Green Building Requirements. The Net Zero Action Plan outlines actions such as: adopting embodied carbon narrative for new construction, assessing LEED alternative pathways and zero carbon certification, designing and developing policy to prioritize re-use, designing carbon intensity targets, developing toolkit/templates, performing a technical assessment of carbon impacts, participate in peer learning sessions with other cities, adopt life cycle analysis/carbon reduction requirements, and implement and monitor performance. Using action plans to address embodied carbon can provide a comprehensive and strategic roadmap for governments, organizations, and communities to take coordinated actions toward reducing the full life cycle carbon emissions of buildings.

Codes

In 2019, Marin County, California adopted the first code in the nation that addressed embodied carbon by setting limits on carbon emissions from concrete. Recently, Vermont has taken a significant step towards addressing embodied carbon by incorporating it into the Residential Building Energy Standard[17] and Commercial Building Energy Standard[18] (also known as Energy Code). It is important to note that the current focus is primarily on the embodied carbon of insulation. Codes are an effective means of addressing embodied carbon since they regulate new construction, and construction materials are one of the main contributors to embodied carbon emissions.

The New Building Institute (NBI) released an Embodied Carbon Building Code overlay. This overlay introduces code solutions for commercial new construction or major renovation that incorporate prescriptive embodied carbon amendments for nearly 40 products, including widely used and high carbon-emitting building materials. The model code language is designed for adoption by states or local jurisdictions, allowing them to incorporate these provisions into their building codes.

Green Building Certification Programs

Certification standards and programs can play a critical role in addressing embodied carbon, offering a framework to assess and communicate the environmental impacts of building materials and practices. Notably, LEED has started to incorporate embodied carbon considerations through credits programs, rewarding projects for conducting building reuse, life-cycle analysis in the form of whole-building LCA and EPDs. Additional credits can be awarded for material ingredient reporting and optimization, responsible sourcing of raw materials, including recommendations on transportation distances, and waste reduction and management.

[17] Residential Building Energy Standards (RBES) Amendments, R408 (2023).

[18] Commercial Building Energy Standards (CBES) Amendments, C406.3.9 (2023).

Passive House primarily focuses on operational carbon reduction, but there is room for it to explicitly address embodied carbon in the future. While the [Department of Energy Zero Energy Ready Home] program does not emphasize embodied carbon, some builders following this standard have [voluntarily] explored low-carbon options. The International Living Future Institute's [Zero Carbon Certification] requires that new construction projects must demonstrate a reduction in the embodied carbon of primary materials compared to an equivalent baseline. As the industry increasingly recognizes the importance of reducing embodied carbon, certification systems are evolving to encourage and support the process.

These examples demonstrate the diverse range of legal approaches that governments, municipalities, and organizations have employed to promote sustainable construction and reduce embodied carbon emissions. By enacting legislation, implementing zoning initiatives, formulating action plans, updating building or energy codes, and refining green building certification programs, governments are recognizing the significance of embodied carbon in the construction industry and its role in achieving reductions in greenhouse gas emissions. To enhance the impact of these legal approaches, continued collaboration between policymakers, industry stakeholders, and experts is essential. This collaboration can lead to the development of more effective and targeted policies and standards. By fostering transparency through the requirement of EPDs and promoting research into lower-carbon alternatives, jurisdictions can further incentivize the use of materials that have smaller impact on the environment.

Education and awareness campaigns play a pivotal role in influencing decision-makers in the building industry. Raising awareness about the environmental impacts of different materials and construction techniques can inspire better choices and foster a culture of sustainability.

Moreover, fostering private-public partnerships can accelerate progress in addressing embodied carbon challenges. By offering incentives, such as tax breaks or grants, for private development that meets embodied carbon reduction targets, governments can further encourage participation and expedite the adoption of low-carbon material and construction practices.

Proactive Steps in Reducing Embodied Carbon

In the face of the increasing climate crisis, the construction industry is taking a transformative step towards mitigating its environmental impacts, and reducing embodied carbon is a critical component. Sustainable and low-carbon solutions have become a central point, urging architects, builders, and stakeholders to reevaluate their practices and shift towards more environmentally responsible choices. The development of new technologies and materials that reduce embodied carbon is emerging as a promising avenue to mitigate the environmental impact of buildings throughout their life cycle. To achieve more low-carbon buildings, here are some strategies for consideration:

Material Selection

Concrete is a common building material but is notorious for its high embodied carbon. Utilizing low-carbon concrete mixes, which incorporate industrial byproducts such as fly ash or slag, can substantially decrease the carbon footprint of concrete while maintaining its structural integrity.[19] Some materials have inherently high embodied carbon due to energy-intensive manufacturing processes. Limiting the use of such materials in favor of low-carbon alternatives can significantly contribute to embodied carbon reduction. For instance, using sustainably sourced timber[20] or recycled steel[21] can be viable alternatives to carbon-intense materials like aluminum and virgin steel. In addition, certain materials, like sustainably harvested wood,[22] have the ability to sequester carbon during their growth cycle. Using these materials can contribute to carbon storage and help offset emissions in construction.

Construction and Project Management Practices

Preserving existing structures and repurposing them for new uses can significantly reduce the environmental impact associated with new construction. Through adaptive reuse, the embodied carbon already invested in the existing building is retained, and the need for energy-intensive production of new construction materials is minimized. Emphasizing the use of salvaged and recycled materials in construction projects can substantially reduce the demand for new production, which often comes with a significant embodied carbon footprint. Designing structures that optimize material use and structural efficiency can reduce the overall volume of materials required for construction, consequently lowering embodied carbon. Implementing efficient waste management practices such as setting up on-site waste segregation stations to separate different types of waste such as wood, concrete, metals, and plastics for recycling and proper disposal, and diverting building waste from landfills, can reduce the environmental impact and embodied carbon of a project. The use of modular or prefabricated construction techniques can optimize the use of materials, resulting in minimal waste material that would otherwise end up in landfills.

Retrofitting and Renovation Strategies

As previously mentioned, repurposing existing buildings through retrofitting and renovation projects can significantly reduce embodied carbon compared to building from scratch. Recently, due to the effects of COVID on the workplace, there has been a growing movement to explore the conversion of underutilized or idle office buildings into housing solutions. New York City's Office Adaptive Reuse Task Force has started an initiative to repurpose these vacant office spaces and has identified a new opportunity to address the pressing challenges of

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[19] Low-Carbon Concrete in the Northeastern United States, Rebecca Esau, Audrey Rempher, Rocky Mountain Institute, Published on June 27, 2022. Available at: https://rmi.org/low-carbon-concrete-in-the-northeastern-united-states/.

[20] 5 reasons why sustainable timber must become a core global building material, Stephanie Burrell, World Economic Forum, Published on January 24, 2023. Available at: https://www.weforum.org/agenda/2023/01/sustainable-timber-core-building-material/.

[21] Recycled Steel in Construction, U.S. Bridge, Published: January 28, 2022. Available at: https://usbridge.com/recycled-steel-in-construction/.

[22] What is Sustainably Harvest Wood?, Marks Lumber, January 12, 2022. Available at: https://markslumber.us/blog/what-is-sustainably-harvested-wood.

affordable housing shortages while concurrently lowering embodied emissions in the built environment.[23] As part of this innovative vision, the Task Force is considering the implementation of tax incentives to support the production of affordable and mixed-income housing through office conversion. Such incentives could act as powerful catalysts, encouraging property owners and developers to participate in this transformational endeavor, thereby facilitating the conversion process and accelerating the delivery of housing solutions. Moreover, this strategy holds particular promise for underserved communities facing housing affordability challenges. By repurposing these office spaces into residential units, there is an opportunity to alleviate the affordable housing crisis, providing accessible and equitable housing options for those in need. California recently introduced legislation that will allow for office-to-affordable housing conversions and would modernize state building codes to make it easier to convert office and retail buildings into housing. At the same time, Denver is future-proofing parking lots by adopting a flexible design structure that allows for easy retrofitting into residential apartments. With increasing demand for occupancy changes, building codes and zoning ordinances must adapt and become more flexible by incorporating provisions that facilitate such changes, promoting sustainable development with ultimately reducing the carbon footprint.

The perspective and participation of underserved communities is paramount in this endeavor. Office building conversion represents a visionary approach that bridges both environmental protection and social equity. By maximizing the potential of unused office spaces, cities can take meaningful steps towards sustainable urban development, reducing the demand for new construction materials and lowering embodied carbon emissions. Simultaneously, this endeavor can directly benefit underserved communities by offering affordable and accessible housing options, fostering an inclusive and resilient urban fabric.

Government Regulations and Policies

Encouraging the integration of embodied carbon assessments into building codes and standards can create a level playing field for all construction projects and stimulate the adoption of low-carbon practices across the industry. Moreover, governments and industry organizations can play a crucial role in promoting low-carbon construction practices by offering incentives and support for using low-carbon materials and processes.

By considering these strategies and embracing innovative materials and approaches, architects, builders, and other stakeholders in the construction industry can collectively contribute to a greener and low-carbon future. The pursuit of low-carbon solutions is key to ensuring a resilient and climate-friendly built environment, aligning with global efforts to combat climate change and protect the planet for generations to come.

Conclusion

In the urgent battle against climate change, addressing embodied carbon is a crucial component. To achieve a lower carbon-built environment, architects, builders, and stakeholders in the construction industry can integrate various strategies across different aspects of their practices. By prioritizing material selection considerations,

[23] Mayor Adams Unveils Recommendations to Convert Underused Offices into Homes, New York City Hall, January 9, 2023. Available at: https://www.nyc.gov/office-of-the-mayor/news/022-23/mayor-adams-recommendations-convert-underused-offices-homes.

they can opt for low-carbon and carbon-sequestering materials, while reducing the use of carbon-intensive options. Reusing existing buildings and materials in construction projects can significantly minimize the environmental impact associated with new construction and prevent unnecessary waste. Retrofitting and renovating existing buildings can be an environmentally friendly alternative to constructing new ones. Government regulations and policies also play a critical role in promoting sustainable construction practices. By incentivizing the use of low-carbon materials and processes and integrating embodied carbon considerations into building codes and standards, governments can encourage industry-wide adoption of low-carbon practices.

Despite the importance of addressing embodied carbon, challenges persist. The lack of comprehensive data, limited cost information, and insufficient awareness and understanding are hurdles that must be overcome. Governments, organizations, and communities must collaborate to create a standardized database and foster educational campaigns to promote knowledge-sharing.

Addressing embodied carbon also calls for legal approaches that incentivize and enforce sustainable construction practices. Legislation, zoning initiatives, building codes, and green building certification programs have all played a role in promoting low-carbon construction. By adopting policies like the Buy Clean California Act and incorporating embodied carbon considerations into building codes, governments can set a precedent and accelerate the transition to a low-carbon-built environment.

Moreover, a holistic approach that combines both embodied and operational carbon reduction strategies is essential. Conducting lifecycle assessments, promoting energy efficiency measures, and prioritizing sustainable manufacturing processes can contribute to achieving a balance between embodied and operational carbon.

Reducing embodied carbon in the construction industry is a multifaceted endeavor that requires collaboration, innovation, and commitment from architects, builders, governments, and stakeholders. By integrating the identified strategies and embracing new materials and approaches, the industry can take significant strides towards lowering the carbon footprint of buildings. Recognizing the significance of embodied carbon and collectively working towards its reduction will play a crucial role in combating climate change and ensuring a healthier planet for current and future generations.

Additional Resources

- Embodied Carbon, Codes and Policy. New Buildings Institute. https://newbuildings.org/code_policy/embodied-carbon/.
- Embodied Carbon 101: Building Materials. Madeline Weir, Audrey Rempher, Rebecca Esau. Rocky Mountain Institute. Published March 27, 2023. https://rmi.org/embodied-carbon-101/.
- Embodied Carbon 101. Carbon Leadership Forum. https://carbonleadershipforum.org/embodied-carbon-101/.