In collaboration with Accenture

WORLD ECONOMIC FORUM

Reducing Embodied Carbon in Cities: Nine Solutions for Greener Buildings and Communities

WHITE PAPER

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Foreword

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Cities are at the forefront of climate action. More than half of the global population lives in cities, consuming over 78% of the world's core energy and generating 70% of carbon emissions. The built environment, including the operations and construction of building and infrastructure, is the single largest contributor to global CO_2 emissions, generating about 40% of total emissions.[1] As urban populations expand, construction is essential for cities to accommodate this growth, but it also poses a challenge: how to reduce the amount of greenhouse gas (GHG) emissions related to both construction and demolition, known as embodied carbon.

The World Business Council for Sustainable Development reports that, of a building's whole-life carbon footprint, as much as half comes from embodied carbon,[2] which encompasses all of the GHG emissions associated with production and movement of the materials used in construction and demolition (as opposed to the amount of energy used for daily operations). As operational building efficiency continues to improve, embodied carbon is quickly becoming the critical driver of emissions associated with the construction industry. Yet most of us are only beginning to understand the solutions that are central to assessing and reducing the environmental impacts of building products both before, during and after construction.

To help drive progress in this area, this report explores existing challenges to wide-scale adoption and implementation of low or zero embodied carbon practices during all phases of building construction. In addition, the report highlights nine innovative solutions that seek to address the issue of embodied carbon and which provide a range of additional benefits, including workforce development, standardization of policies and regulations, and technological advances in clean construction. The intention is for cross-sector leaders to be able to replicate and implement these solutions according to the local context.

The report is the result of a joint effort by the World Economic Forum and Accenture to support collaboration in the private and public sectors to drive sustainable impact for all stakeholders and develop solutions to reduce carbon emissions – from buildings and transport to energy systems in cities – while embedding social and economic benefits. This work culminated in a series of workshops, known as a City Sprint, that took place in the autumn of 2023 in collaboration with the City of Los Angeles. The findings and action items of the LA City Sprint emerged from the expertise of more than 50 participants from local government, civil society and a wide range of private companies from the construction, design, engineering, finance and material production and supply industries and provide a model for cities seeking achievable solutions to meet sustainable development goals.

Executive summary

Public-private action needs to be accelerated to reduce carbon emissions across construction and development industries.

Despite widespread efforts to curb emissions in the buildings and construction sector, the gap is widening between climate performance and the necessary pathway to decarbonization.[3] In addition to reducing the carbon emissions from day-to-day building operations, limiting a building's embodied carbon, which includes the carbon emissions associated with materials and construction processes throughout the whole life cycle of a building, from material extraction to end of life, plays a significant yet often understated role on the path to net zero.[4] This paper identifies common challenges cities face in the effort to reduce embodied carbon emissions from the built environment and offers innovative solutions and case studies that address those challenges and provide inspiration for both industry and municipalities to advance their embodied carbon reduction goals.

To reduce embodied carbon emissions within the built environment, challenges in the planning, sourcing, construction and end-of-life processes must be addressed. First, a lack of comprehensive regulations and policy frameworks leads to inconsistent outcomes within jurisdictions and among regions. Additionally, the lack of standardized approaches results in fragmentation across construction and real estate, as well as in the energy, transportation and waste sectors, and presents challenges to the widespread adoption and implementation of tried-and-tested low-carbon solutions and innovative approaches.

This report presents nine cross-sector solutions organized into three themes aimed at curbing embodied carbon in cities: (1) adopting enabling policy frameworks, regulations and incentives; (2) strengthening the low embodied carbon ecosystem; and (3) spurring innovation in clean construction.

Adopting enabling policy frameworks, regulations and incentives

Under this theme, solutions occur at varying levels of policy intervention and advocate for standardized regulatory frameworks to signal a market response and position cities as global sustainability leaders.

- **Requirements for low-carbon materials (solution one):** requiring the integration of low-carbon concrete in new construction and encouraging the responsible use of materials. Value-chain transparency and environmental product declarations (EPDs) are key components.
- **Mandates for whole-life carbon assessments (solution two):** enacting requirements to regulate embodied carbon in construction projects, promoting sustainability through standardized methodologies and data compilation, and providing technical tools and support. Included in this solution area is consideration for expedited approvals and permitting to create incentives for low-carbon projects.
- **Executive orders for clean construction (solution three):** demonstrating the pivotal role of city governments in requiring city agencies to adopt clean construction practices and lead by example in driving the adoption of low-carbon practices within the construction sector. This includes environmental preferable purchasing (EPP) or green procurement and may extend to using low-carbon equipment in construction.

Strengthening the low embodied carbon ecosystem

Solutions under this theme bridge the built environment, transport and energy sectors and take a holistic approach to reducing embodied carbon in cities. Solutions could be deployed independently or collectively to create a low embodied carbon ecosystem; they require cross-sector collaboration and present an opportunity to influence broader outcomes for quality of life, including resilience, health and affordability.

- **Large-scale adaptive reuse (solution four):** championing the reuse of existing assets over building new, including material repurposing, contributing to circularity and carbon reduction goals as well as economic and community revitalization.
- **Citywide circular economy strategy (solution five):** creating a framework for resource efficiency, minimizing waste, introducing incentivizes for reuse and promoting sustainable economic development.

– **Programmes to electrify heavy transport and machinery (solution six):** collaborating with governments and industries to create incentives for electrified fleets and electric vehicle (EV) infrastructure to decarbonize the transport of goods to construction sites and electrify construction machinery.

Spurring innovation

Solutions under this theme seek to encourage investments, technological advances and workforce development to accelerate embodied carbon reduction while delivering on broader economic outcomes as well as social value creation.

– **Innovation hub for clean construction (solution seven):** a collaborative space for testing and piloting new and innovative low-carbon construction practices, creating shared tools and promoting sustainable urban development through regional and/or global collaboration, technological advances, community engagement and knowledge dissemination.

– **Programmes for residential deconstruction and workforce development (solution eight):** shifting from demolition to meticulous deconstruction maximizes material recycling, reduces landfill waste and nurtures a skilled, more environmentally conscious workforce. This approach addresses challenges posed by older housing and growing construction demands, paving the way for sustainability.

– **Online marketplace for a circular built environment (solution nine):** a digital materials exchange platform to encourage the rescue and reuse of salvaged and surplus items while diverting built environment materials and products from landfills.

1 Four stages of embodied carbon

From mining or quarrying building materials to a structure's demolition, embodied carbon covers the whole life cycle of a building.

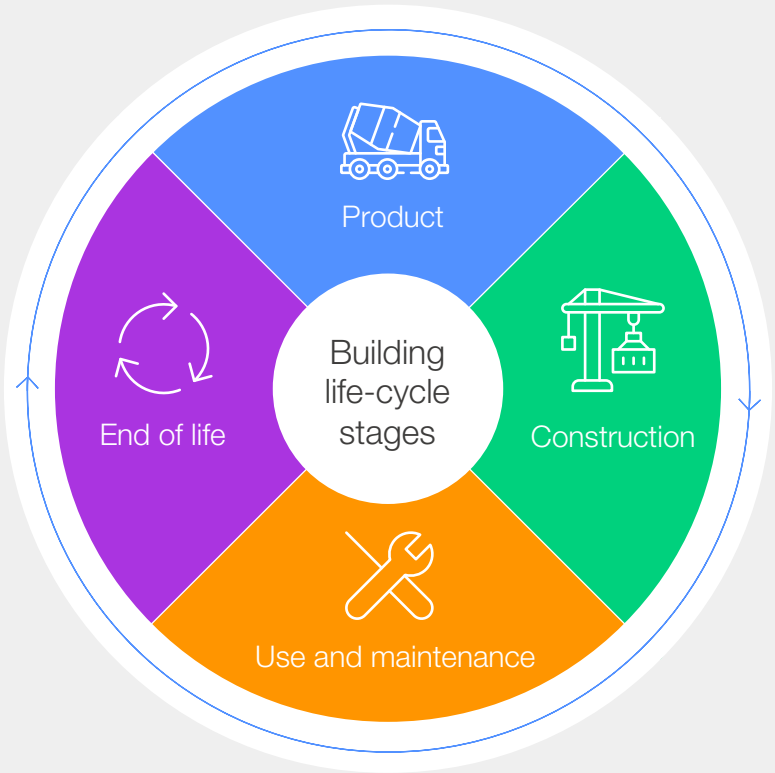
Embodied carbon refers to the sum of greenhouse gas (GHG) emissions released during four stages of a building's life: (1) material extraction and transport and manufacturing of materials; (2) construction processes and off-road construction transport; (3) renovation and maintenance requirements; and (4) end of life, including demolition or reuse. It is called "embodied" because this carbon is locked in once the building is built or retrofitted. Once this carbon is expended, its environmental impacts are established, and it becomes a part of the building throughout the building's lifetime.

The challenges identified in this white paper were compiled through a stakeholder engagement process that included interviews as well as collaborative exercises and discussions engaging a diverse representation of industry and public-sector perspectives. It was through further examination of the phases of embodied carbon that the challenges and solutions emerged, wherein the sampling of solutions offers emissions reduction potential that is cross-cutting and requires collaboration across sectors to implement. Solutions are presented as a menu of options that can be deployed separately or in tandem to address the landscape of embodied carbon in cities. It is important to note that there is no silver bullet solution or hierarchy, and the list of solutions does not represent the full range of actions that may be necessary.

This paper recommends that cities approach embodied carbon reduction by addressing challenges across the phases of embodied carbon, whereby a diversity of intervention points and owners of change will be needed to make a positive impact. Foundational to this is public-private collaboration and tailoring solutions to the local context, including considerations to advance local equity and resilience.

> Solutions are presented as a menu of options that can be deployed separately or in tandem to address the landscape of embodied carbon in cities.

FIGURE 1 **Embodied carbon throughout a building's life-cycle stages**



2 Existing challenges for cities

In decarbonizing the built environment and creating a cleaner construction industry, cities and private industry face multifaceted challenges that hinder the swift adoption of low embodied carbon practices.

2.1 Regulatory and policy constraints

Policy and regulation can be a powerful tool for dramatically reducing embodied carbon in cities and signalling to the market the need for wide-scale adoption of more sustainable practices. Issues arise during the design and construction phases, including outdated building codes, lengthy permitting processes and a lack of targeted requirements, with processes failing to address the urgency of reducing embodied carbon and measuring progress.

> Policy and regulation can be a powerful tool for dramatically reducing embodied carbon in cities and signalling to the market the need for widescale adoption of more sustainable practices.

Citywide approach

- **Lack of citywide approaches for circularity and building reuse:** There is a need for comprehensive citywide strategies and policies to create incentives and promote circularity and the adaptive reuse of existing buildings, structures and materials.

Codes and permitting requirements

- **Absence of low embodied carbon requirements in building codes:** Current building codes often lack explicit requirements that low-carbon construction methods be used and do not sufficiently discuss the need for low-carbon procurement methods.
- **Lengthy approvals and permitting:** Lengthy and complex approval and permitting procedures for sustainable construction projects delay implementation and increase project costs.
- **Absence of standardized embodied carbon metrics:** The lack of a standardized approach to measuring and reporting embodied carbon across the entire building life cycle leads to inconsistency in the assessment and comparison of sustainable construction practices.
- **Only partial tracking of building components:** There is insufficient tracking and assessment of the entire building and all materials used, focusing on specific components rather than a comprehensive view, which makes it harder to gain an accurate understanding of embodied carbon across the entirety of construction.
- **Frequent renovations without carbon reduction targets:** Buildings undergo a high frequency of interior refits over the course of their lives without specific targets for reducing embodied carbon in the renovations.

2.2 Ecosystem challenges

The challenge lies in creating a comprehensive and interconnected low-carbon ecosystem within cities. Fragmented approaches and insufficient collaboration among stakeholders hinder progress, particularly in addressing emissions impact and developing sustainable value-chain, infrastructure and energy solutions. Siloed initiatives, lack of education and awareness, and gaps in infrastructure impede the seamless integration across the built environment, energy, transportation and waste management sectors as well as the phases of embodied carbon (i.e. manufacturing, construction, maintenance and end of life).

Emissions impact

- **Emissions from primary materials, particularly cement:** Significant emissions arise from the production of key materials such as cement, iron and steel, which are integral to construction. Cement, for example, is responsible for nearly 8% of global GHG emissions and is the most widely used substance on earth after water.[5]
- **Environmental impact of logistics and freight:** Transportation and logistics within the building materials supply chain have a significant carbon footprint.

Infrastructure and energy

- **Lack of electric infrastructure and energy system alignment:** There is a shortage of EV infrastructure and electric and/or zero-emission construction equipment. Charging cycles are incompatible with construction hours and worker shifts.
- **Modernizing the energy supply chain:** Insufficient investment has been made in grid modernization and renewable energy sources for construction.

2.3 Barriers to innovation

> The evolving nature of a cleaner construction industry poses challenges in ensuring that workers are equipped with the necessary skills for sustainable practices and innovative techniques.

Diverse challenges with regard to capabilities, opportunities and resource allocation obstruct the widespread adoption of innovative solutions. These include workforce limitations in adapting to new technologies, limited material awareness and investment affecting innovation uptake, and restricted access to incentives and equipment crucial for innovation. Embracing new approaches to a cleaner construction economy will quicken the pace of technological diffusion.

Workforce challenges

- **Upskilling and reskilling:** The evolving nature of a cleaner construction industry poses challenges in ensuring that workers are equipped with the necessary skills for sustainable practices and innovative techniques. As construction industries embrace digitalization and automation, the need for digital upskilling within the existing construction workforce will continue to grow.
- **Mental health impacts and union involvement:** There is limited recognition of the mental health impact on construction workers arising from the industry's demanding nature. Labour unions play a vital role in advocating for workers' rights and welfare, and their involvement and support of workers involved in the decarbonization process is essential.

Material awareness and availability

- **Transparency in the value chain:** There is insufficient awareness, inadequate incentives and too few resources to encourage the use of environmental product declarations (EPDs) for sourcing lower-carbon materials, which are crucial for making informed and sustainable procurement decisions.
- **Lack of incentives for local production:** Inadequate policies or incentives exist to promote and support local manufacturing of low-carbon materials and otherwise increase their accessibility and affordability.
- **Affordability of low-carbon materials:** Financial burdens associated with the high cost of low-carbon material alternatives and their manufacturing limit their widespread adoption and market absorption.

- **Lack of low-carbon interior materials:** A shortage of low-carbon materials specifically tailored for interior refits makes it challenging to implement sustainable choices in interior design and renovations.

Innovation and access

- **Lack of incentives for sustainable product development:** There are insufficient incentives or policies to encourage innovation in the development of lower-carbon construction products and technologies; for example, carbon-capturing systems or alternative binding materials to replace cement.
- **Limited availability of zero-emission equipment:** Challenges exist in accessing a variety of electric and zero-carbon equipment alternatives due to the fragmented availability and manufacturing difficulties.

3 Nine global solutions

Case studies highlight diverse approaches to embodied carbon reduction and provide invaluable insights into environmentally conscious building solutions in practice.

3.1 Adopting enabling policy frameworks and regulations

The following solutions focus on establishing robust regulatory frameworks and policies that encourage and mandate low-carbon practices. They may include the need to create guidelines and standards to drive the adoption of sustainable technologies and practices within urban environments.

Requirements for low-carbon materials

Solution 1

TOOLBOX OF SOLUTIONS LINK:

Requirements for low-carbon materials

What is the challenge?

The embodied carbon in buildings comes primarily from the energy-intensive production of cement, steel, aluminium, glass and insulation materials. Concrete is one of the most prevalent human-made materials in the world and one of the largest contributors to embodied carbon in the built environment. Concrete carries a substantial carbon load mainly due to its cement component, responsible for about 90% of its emissions. The prevalence of concrete-based structures, crucial for urban development, exacts a steep environmental cost due to cement's carbon-intensive nature.

Inherent to this challenge is the need to balance the use of concrete as a foundational building material with a reimagining of construction processes to minimize the reliance on high-emission constituents while maintaining structural integrity.

What is the solution?

Efforts aimed at decarbonizing buildings and infrastructure must consider the need to reduce embodied carbon emissions in building materials. Local and state governments often possess the power to enforce building codes and code amendments mandating the use of low-carbon materials such as concrete mixes with reduced GHG emissions. By enacting regulations that limit carbon emissions from carbon-intensive materials such as concrete, cities can significantly reduce the upfront carbon of their built environment.

Low-carbon concrete, an environmentally conscious alternative to conventional concrete, achieves a significantly reduced carbon footprint through a strategic substitution: it replaces a portion of cement with supplementary cementitious materials (SCMs), such as fly ash, slag or calcined clays that offer properties akin to or even superior to cement.

> A growing number of local, state and federal procurement policies require EPDs for reporting the embodied carbon of eligible products.

The use of low-carbon concrete not only reduces the embodied carbon but also addresses the issue of waste management, as SCMs repurpose waste materials that would otherwise occupy landfill or add to air pollution. This practice demonstrates a circular approach, simultaneously mitigating environmental strain and conserving natural resources.

The potential impact of SCMs on carbon reduction is significant, potentially slashing the embodied carbon of concrete by up to 70%. However, achieving such reductions depends on several factors, including the specific type and proportion of supplementary materials used, considerations regarding material availability and transportation logistics, and transparency of the value chain in measuring and reporting emissions of materials through environmental product declarations (EPDs).

SPOTLIGHT ON

Environmental product declarations (EPDs) in Portland, Oregon

A growing number of local, state and federal procurement policies require EPDs for reporting the embodied carbon of eligible products. EPDs are appropriate for use in procurement policies because they already exist as agreed-upon resources for calculating and documenting the embodied carbon of products.[6] In the case of Portland, Oregon, the city created a local Low Carbon Concrete Initiative to use EPD data to reduce the carbon footprint of concrete used on city projects and encourage the use of low-carbon concrete products. EPDs are required for concrete mixes used in city projects, establishing a methodology for calculating the mixes' embodied carbon.[7]

Implementation considerations

Key stakeholders involved:

- City government agencies and other regulatory bodies
- Concrete and construction industry, including supply chain and logistics
- Engineers, contractors and architects
- Financial institutions and investors

Relevant policy and funding considerations:

- Implementing clear building codes and standards that require and/or create incentives for the use of low-carbon materials can significantly drive their adoption.
- As major consumers of construction materials, governments can use their purchasing power through procurement policies that prioritize low-carbon materials.
- Incentivizing programmes such as tax credits, grants or subsidies to encourage the use of low-carbon materials can offset the initial higher costs associated with adopting new technologies or materials.
- Allocating funding for research and development (R&D) in the field of low-carbon materials and construction methodologies encourages innovation.
- Implementing carbon-pricing mechanisms or emissions-trading schemes can influence construction practices by assigning a cost to carbon emissions.
- Supporting and endorsing green building certification systems – e.g. Leadership in Energy and Environmental Design (LEED), the Building Research Establishment Environmental Assessment Methodology (BREEAM) – encourages the use of low-carbon materials by recognizing and promoting sustainable construction practices.

CASE STUDY: LOW-CARBON CONCRETE COMPLIANCE

Marin County, California, USA

Marin County, California, was the first jurisdiction to pass a low-carbon concrete code. The code included regional stakeholder engagement and passed as an amendment to the existing code in November 2019. The effort was grant funded, and included tools to aid other jurisdictions to adopt similar amendments.

The County of Marin Low Carbon Concrete Code focuses on concrete performance, creating standards for composition that "maintains adequate strength and durability for the intended application" while reducing embodied carbon, according to the county website.[8] The code covers both residential and commercial construction and includes standards for a number of industry practices, including replacing Portland cement with supplementary cementitious materials (such as fly ash, slag and ground glass), minimizing the amount of cement in mixes, selecting low-carbon aggregate and changing the requirements for how quickly concrete has to cure (which affects the amount of cement used).

The code does not cover precast or concrete masonry units, nor other high-carbon materials such as steel, glass or insulation. It code lays the groundwork for research into other avenues for developing low-carbon concrete and has the potential to be adopted by other regional, state or national code bodies and standard developers.[9]

SPOTLIGHT ON

State legislation in California, USA

Although California is not the only jurisdiction seeking to make headway on embodied carbon emissions, California's leadership with respect to embodied carbon presents a good use case of what the future may look like for other regions and cities. California's Assembly Bill (AB) 2446 includes requirements to develop a framework for measuring and reducing the average carbon intensity of building materials, with a target set of 40% reduction by 2035. It builds on landmark bill AB 262, also known as the Buy Clean California Act, which specifies the use of environmental product declarations (EPDs) to comply with global warming potential (GWP) limits for construction materials used in public works projects.

Additionally, recent changes were approved for Calgreen, California's state-wide green building code, requiring embodied carbon provisions for commercial buildings and schools, such as building reuse, whole building life-cycle assessments (WB LCA) and EPDs for concrete.

Mandates for whole-life carbon assessments

TOOLBOX OF SOLUTIONS LINK:

Mandates for whole-life carbon assessments

Solution 2

What is the challenge?

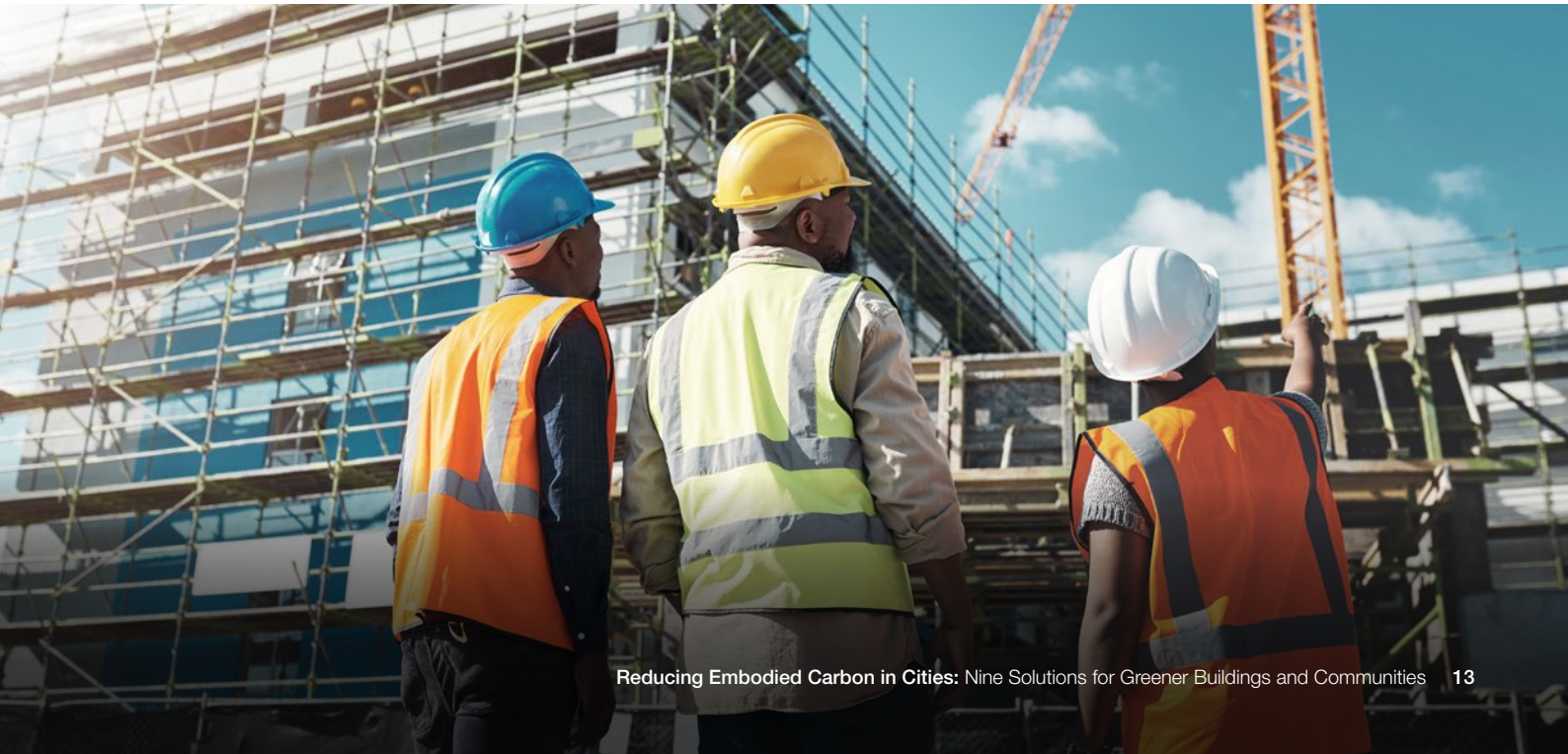
Traditional systems for measuring emissions from the built environment often overlook the entirety of carbon emissions, focusing solely on operational phases and neglecting the significant carbon footprint embedded in materials and construction processes. Embodied carbon emissions account for approximately 50% of an average building's whole-life emissions, where most of these emissions occur before anyone even sets foot in the building.[10] By acknowledging, measuring and reporting this full spectrum of emissions, strategies can be developed to effectively reduce the overall environmental impact of urban structures.

What is the solution?

One of the first steps cities can take is to understand the full carbon footprint of their built environment throughout the life cycle of a constructed asset, from the early stages of development though to the end of life.

Vancouver has developed a robust strategy that can be adapted in other contexts. The city's Whole Building Life-Cycle Assessments (WBLCA) policy is strategically aligned with the city's Embodied Carbon Strategy and Climate Emergency Action Plan. By setting specific targets within these frameworks, governments create a powerful mechanism for driving new legislation that prioritizes sustainability.

Moreover, government specifications of methodologies and frameworks for whole-life carbon assessments (WLCAs), such as the Vancouver model, can provide essential guidance for conducting comprehensive evaluations. These guidelines ensure consistency and standardization, promoting accurate assessment practices across various projects and sectors. Concurrently, the availability and use of dedicated life-cycle assessment software solutions not only aid in meeting reporting criteria but also serve as catalysts for growth and innovation within the sustainable construction space. This combination of clear policies, standardized methodologies and technological support promotes an environment conducive to widespread adoption of low-carbon practices, thereby advancing sustainability efforts in the construction industry.



Benefits of implementing whole-life carbon assessments include:

- Support for industry-wide capacity and knowledge of embodied carbon
- Lower operating costs and increased asset value for building owners and occupants, as zero-carbon buildings are more energy-efficient and resilient
- Improved public health and safety by curbing fossil fuel combustion that worsens air quality, especially for vulnerable groups such as children, elderly people and marginalized communities
- Boost for local economy and job creation by supporting the innovation and adoption of low-carbon materials and technologies, and promoting a circular economy that reduces waste and saves resources

SPOTLIGHT ON

Whole Life Carbon Assessment Mandates Model Policy, a resource created through the World Economic Forum's G20 Global Smart Cities Alliance

The objective of this model policy is to help cities draft legislation requiring WLCAs for major developments in the built environment. The model policy is meant to be used as a template for policy-makers and is accompanied by a playbook for local governments and a playbook for practitioners. It was launched in collaboration with C40 Cities and Infosys during the Smart Cities Expo in Barcelona in 2023.[11]

Download here

Implementation considerations

Key stakeholders involved:

- Commercial real estate stakeholders
- City government agencies and other regulatory bodies
- Technology and early case assessment (ECA) software providers
- Standards organizations and certification bodies

Relevant policy and funding considerations:

- Allocating funding for R&D in WLCA methodologies and tools supports innovation in assessment techniques and technologies.
- Collaboration between the public and private sectors can lead to funding initiatives supporting the implementation of WLCA.
- Public and private funding/investing in education, training and capacity-building programmes familiarize professionals in the construction industry with WBLCA methodologies.

CASE STUDY: GREEN BUILDING BY-LAW UPDATE FOR EMBODIED CARBON LIMIT

Vancouver, British Columbia, Canada

In 2019 the City of Vancouver created its Climate Emergency Action Plan (CEAP), with the goal of halving its emissions by 2030 and becoming carbon neutral by 2050. The plan addresses several sectors, including zoning, transportation and construction. To reduce emissions in the construction and land-use planning sectors, Vancouver also updated its building by-laws to establish embodied carbon limits for all new buildings with more than three floors or a footprint of more than 600 square metres (about 6,460 square feet). By adding reduction requirements, Vancouver estimates it can prevent up to 100,000 tonnes of CO_2 emissions annually.

In addition, Vancouver created embodied carbon guidelines that provide technical guidance on how to calculate a project's embodied carbon benchmark and embodied carbon limit, which must be submitted to the city. Technical guidance includes suggested software programs that can be used to comply with the Vancouver Building By-Laws' Life-Cycle Assessment (LCA) requirement.[12]

SPOTLIGHT ON

Expedited approvals and permitting in Seattle, Washington, USA

Expedited approvals and permitting specifically tailored for low-carbon projects can significantly enhance the effectiveness of such policies. Streamlining the approval process for projects that demonstrate low embodied carbon or meet predefined sustainability criteria not only accelerates the implementation of eco-friendly initiatives but also serves as a strong incentive for developers and builders to prioritize carbon-conscious strategies. Seattle, Washington, is a city that successfully implemented facilitated approvals through its Priority Green Expedited (PGE) programme, led by the Seattle Department of Construction and Inspections (SDCI). This programme is part of Seattle's green building initiatives, aiming to expedite and streamline the permitting process for projects that meet specific sustainable and environmental criteria. In essence, the PGE programme expedites permit reviews for projects that meet sustainability standards. It offers faster processing, requiring adherence to green criteria covering energy efficiency and eco-friendly materials. This benefits applicants by hastening construction while promoting Seattle's environmental commitment. The programme also provides technical support and aligns with the city's broader ecological goals.[13]

Executive orders for clean construction

Solution 3

TOOLBOX OF SOLUTIONS LINK:

Executive orders for clean construction

What is the challenge?

Tackling embodied carbon in urban development requires addressing the issue comprehensively across both public- and private-sector projects. While creating new policy frameworks can be a slow process, the public sector is one of the largest developers, owners and operators of real estate and infrastructure projects in many cities around the world, and a key driver of construction.

And therein lies the leadership opportunity for the public sector to reduce embodied carbon emissions from city operations as well as to signal future policy or regulation, while incentivizing the market adoption of sustainable practices throughout the construction industry.

What is the solution?

Crafting an executive order focused on clean construction presents a pivotal strategy for municipalities to significantly reduce the embodied carbon inherent in construction practices within their operational framework. This initiative not only underscores the critical importance of minimizing embodied carbon emissions but also serves as a blueprint showcasing the efficacy of clean construction methods, encouraging voluntary adoption by businesses and other entities.

Moreover, by integrating directives for clean construction practices into public procurement policies outlined within this executive order, municipalities hold immense leverage through the power of the purse. These directives can emphasize and provide guidelines and recommendations on the procurement of electric construction equipment, incentivizing manufacturers to innovate and produce more sustainable machinery. Such integration within public procurement channels amplifies the influence of the order, driving market demand towards eco-friendly solutions.

SPOTLIGHT ON

Green procurement in Oslo, Norway

The city of Oslo, Norway, has used public procurement to take the lead in the zero-emission construction vehicles and machinery market. The city's procurement strategy shows a reinforced commitment to sustainable procurement. The strategy's main objective is that Oslo Municipality is to conduct appropriate and cost-effective procurement processes – providing sound and socially responsible solutions in both the short and long term. It includes strategic provisions to ensure a common course and commitment through agency procurement. The provisions largely concern building up expertise, strategic planning, risk management and inspiring a culture of common action. The strategy is also aligned with Oslo's climate budget.[14]

> As the appetite for sustainable technology grows, manufacturers are driven to increase the production and accessibility of electric and zero-carbon equipment.

Executive orders often give indications of forthcoming requirements and regulations that will affect the private sector, particularly in the real estate and construction sectors. By taking this initial step, cities effectively stimulate related actions within the private sector. These policy mandates act as catalysts for a transformative shift in the market landscape, compelling manufacturers to pivot towards more sustainable practices and encourage the spread of eco-friendly machinery.

The imposition of policies mandating the use of low-carbon equipment in construction projects acts as a lynchpin to drive heightened demand for electric and zero-carbon machinery. This proactive approach compels manufacturers to invest in and produce environmentally conscious machinery, to meet the burgeoning demand created by these regulations. As the appetite for sustainable technology grows, manufacturers are driven to increase the production and accessibility of electric and zero-carbon equipment.

Implementation considerations

Key stakeholders involved:

- Government agencies
- Environmental agencies and advocacy groups
- Residents and community groups
- Manufacturers and suppliers
- Construction industry consortiums and professionals

Relevant policy and funding considerations:

- Implementing financial incentives or tax credits for construction companies adopting low-carbon practices is an effective approach.
- Allocating funds or creating grant programmes supports research, development and implementation of sustainable construction methods.
- Collaborating with private entities through public-private partnerships can attract additional resources, expertise and technology to implement sustainable practices.
- Investing in training programmes and educational campaigns for construction professionals helps disseminate the knowledge and skills required for the more widespread adoption of clean construction practices.
- Integrating life-cycle assessment methodologies into construction policies ensures a comprehensive approach that considers the environmental impact of materials and construction processes from production to demolition.

CASE STUDY: CLEAN CONSTRUCTION EXECUTIVE ORDER 23

New City, New York, USA

New York City Mayor Eric Adams signed Clean Construction Executive Order 23 (EO23), which requires the city's capital project agencies to commit to actions that will lower embodied carbon from municipal construction projects. The actions taken by EO23 will reduce GHG emissions, air pollution and noise pollution citywide. They will also ensure that any construction funded by new federal infrastructure and climate bill funding will use sustainable materials, equipment and practices.

Important directives include a focus on low-carbon concrete specifications for construction projects, requirements for EPDs to the Building Transparency database, and the incorporation of low-emission vehicles and equipment in construction contracts. Additionally, it mandates life-cycle assessments for projects complying with green building standards and action plans aimed at reducing embodied carbon in capital projects.[15]

3.2 Strengthening the low embodied carbon ecosystem

Solutions within this theme emphasize building a supportive infrastructure and ecosystem that generates, promotes and rewards the implementation of low-carbon solutions.

These involve promoting collaboration among stakeholders, investing in green infrastructure and developing sustainable models for energy, transportation and waste management.

Large-scale adaptive reuse

Solution 4

TOOLBOX OF SOLUTIONS LINK:

Large-scale adaptive reuse

What is the challenge?

One key historical dilemma in urban development lies in the sustainable use of existing infrastructure amid burgeoning construction demands. Rapid urbanization often favours the creation of new buildings despite the environmental impact of discarding or neglecting existing structures. This trend perpetuates the cycle of resource-intensive new construction, contributing significantly to carbon emissions, waste generation and the depletion of natural resources. This situation, widely seen in cities globally, underscores the urgent need to reimagine urban development practices, steering away from a disposable culture towards maximizing the potential of the current built environment. This challenge calls for innovative approaches that transform existing buildings into integral components of a sustainable solution rather than viewing them merely as obsolete structures.

What is the solution?

Large-scale adaptive reuse includes reducing carbon emissions by making existing buildings and infrastructure a larger part of the climate solution. Through the repurposing of buildings, materials and other spaces, developers can decrease CO_2 emissions associated with new materials and reduce waste and debris that would otherwise go to landfills. The United Nations Environment Programme claims that the average lifetime of buildings ranges from around 30 years in China and India to 80 years in the United States.[16] Reuse, repair and recycling enable the value of the building components and materials to be retained. Research indicates that selective deconstruction can offer large carbon savings. A study in Belgium showed that deconstruction measures led to a 59% decrease in GHG emissions per capita compared to landfill, whereas implementing recycling and downcycling practices alone led to a 36% decrease in emissions.[17]

Given that nearly two-thirds of the buildings that exist today will still exist in 2050, the path to resilience should include an adaptive reuse strategy and deep retrofits.[18] These reuse strategies can take place at various scales to help reach net-zero embodied carbon goals:

- Reuse, reduce, recycle products
- Use locally sourced products
- Design for disassembly
- Select low-carbon materials
- Reposition and retrofit buildings
- Consider repurposing the core and shell of buildings

This solution can be applied at a policy level through adaptive reuse strategies and ordinances that require and/or create incentives for adaptive reuse by relaxing current regulations and zoning to make adaptive reuse feasible. An important barrier to adaptive reuse projects is the compounding costs of development due to zoning restrictions, regulatory hurdles and environmental constraints. The solution can also be considered at the project

level, where lessons learned and best practices on a project-by-project basis can be more widely shared and replicated across global development projects.

Implementation considerations

Key stakeholders involved:

- Urban planners and city government authorities
- Commercial real estate stakeholders and property owners
- Architects and design professionals
- Community and public engagement groups

Relevant policy and funding considerations:

- Incentives include zoning reform, tax incentives and expedited approvals.
- Flexible zoning can allow for changes in land use and building codes that support the conversion of existing structures into new functionalities.
- Resources/toolkits can be issued to increase awareness and education.
- Policies can be established to promote the preservation of historic or culturally significant buildings through adaptive reuse.

CASE STUDY: ONE WESTSIDE

Los Angeles, California, USA

Facing new challenges related to housing shortages and affordability, and to the COVID-19 pandemic recovery, Los Angeles City Planning proposed a significant update: the Citywide Adaptive Reuse Ordinance.

The City of Los Angeles has been a pioneer in revitalizing its urban landscape through the 1999 Adaptive Reuse Ordinance (ARO), a groundbreaking initiative that set out to rejuvenate Downtown LA and historic neighbourhoods. This ordinance facilitated more than 12,000 housing units in Downtown alone, fuelling economic growth, offering housing solutions and preserving the city's architectural heritage.

Facing new challenges related to housing shortages and affordability, and COVID-19 pandemic recovery, Los Angeles City Planning proposed a significant update: the Citywide Adaptive Reuse Ordinance. This evolution aimed to streamline the conversion of pandemic-affected commercial spaces into much-needed housing, a pivotal strategy within the broader Citywide Housing Incentive Program. The draft of the ordinance marked a shift towards inclusivity by expanding eligibility beyond buildings constructed before 1 July 1974.

This proposed expansion aligns with the city's goal of addressing housing shortages and fulfils its state Housing Element obligations.[19]

In this context, One Westside emerged as a first-of-its-kind adaptive reuse and conversion project, transforming a struggling West Los Angeles shopping mall into Class A office space. In January 2019, Google signed a lease as the sole tenant of One Westside; today, the property is owned and occupied by the University of California Los Angeles (UCLA).[20]

Of the 14,000 square metres (150,000 square feet), more than 75% of construction and demolition debris was diverted from landfills. For example, the project repurposes high ceilings and a multilevel atrium and skylight. By reusing as much of the existing material as possible, the project achieved a 33% reduction in embodied carbon compared to a ground-up scenario. The largest embodied carbon savings came from reusing the structural steel from the original mall. Adaptive reuse in this case was more environmentally friendly and faster than ground-up construction.

Residents in nearby neighbourhoods and tenants of One Westside experience quality-of-life improvements related to the increased walkability of the environs and greater access to green spaces and nature through enhanced outdoor spaces. Typically, with an adaptive reuse project or new development, the City of Los Angeles Department of Cultural Affairs (DCA) requires owners to allocate a percentage of costs to fund public art. In the case of One Westside, the project channelled funds into a grant programme to employ local artists and celebrate the cultural heritage and diversity of the neighbourhood.

Citywide circular economy strategy

TOOLBOX OF SOLUTIONS LINK:

Citywide circular economy strategy

Solution 5

A citywide circular economy strategy involves a comprehensive approach implemented by a city or municipality to minimize waste generation, maximize resource efficiency and promote sustainable economic development.

What is the challenge?

Cities face a web of complex challenges rooted in the linear consumption and production patterns prevalent today. The predominant "take-make-dispose" model generates staggering amounts of waste, strains finite resources and exacerbates environmental degradation. Inefficient use of materials and inadequate waste-management systems contribute to overflowing landfill sites, escalating resource depletion and heightened carbon emissions. Furthermore, urban areas grapple with the social and economic implications of this linear model, including disparities in resource access, economic volatility stemming from resource scarcity, and the absence of resilient, circular systems. Embracing a circular economy strategy becomes necessary to address these multifaceted challenges, requiring a fundamental shift towards optimizing resources, minimizing waste and creating sustainable, regenerative urban ecosystems.

What is the solution?

A citywide circular economy strategy involves a comprehensive approach implemented by a city or municipality to minimize waste generation, maximize resource efficiency and promote sustainable economic development. The circular economy can provide community-wide benefits by designing waste and pollution out of the economic system and keeping products and materials in use for as long as possible through reuse and repair. It also aims to protect and regenerate natural systems, while creating local wealth and economic opportunities.

In a circular economy, activity builds and rebuilds overall system health. It is based on three principles: eliminate waste and pollution; circulate products and materials; regenerate nature.

Designing a citywide circular economy strategy is useful for cities wishing to develop a shared vision for an inclusive circular economy and to identify and act on essential areas for mutual collaboration and coordination. A successful citywide circular economy strategy requires strong collaboration among various stakeholders, strong leadership, investment in infrastructure, technological innovation and a commitment to long-term sustainability goals.

Implementation considerations

Key stakeholders involved:

- Government agencies
- Residents and community groups
- Local businesses and industries
- Waste management and recycling companies
- International organizations

Relevant policy and funding considerations:

- Develop a circular strategy as an extension of current climate action plans.
- Implement policies that hold manufacturers responsible for the end-of-life disposal of their products, encouraging design for recyclability and reuse.
- Encourage investment in circular economy projects by issuing green bonds or financial instruments directed specifically at funding sustainable and circular initiatives.
- Develop green procurement policies.
- Promote collaboration between the public and private sectors to fund and implement circular economy projects, using resources and expertise from both spheres.
- Implement incentives for circular business models.
- Initiate grant funding/philanthropic support.
- Look at resourcing and develop partnerships with non-profit entities.

FIGURE 2 | **Roadmap for developing a city-wide circular economy strategy as identified during the Los Angeles City Sprint**

01	Identify a champion	Identify a champion from local government (e.g. city council, Mayor's office, Chief Sustainability Officer).
02	Secure funding	Identify and secure funding streams from grant-making bodies, city departments or district, regional or federal entities, tax allocation, etc.
03	Undertake assessment	Undertake an assessment of current waste streams to increase transparency into waste and market data.
04	Review leading practices	Review existing initiatives and precedents as well as global leading practices to identify implementable solutions.
05	Collaborate with a diverse set of stakeholders	Foster collaboration with a diverse set of stakeholders from the community, local and regional government and the private sector.
06	Identify the co-benefits and intended outcomes	Identify a range of co-benefits and intended outcomes such as job creation, improved health and biodiversity, economic and environmental impact.

CASE STUDY: CIRCULAR CLEVELAND INITIATIVE

Cleveland, Ohio, USA

The City of Cleveland is becoming North America's leader in designing and implementing an inclusive circular economy. As part of the Circular Cleveland initiative, the city, in collaboration with Cleveland Neighborhood Progress (CNP), is working with local champions to develop a blueprint to enable an inclusive circular economy in the Great Lakes region. The Circular Cleveland initiative is funded by a $476,000 grant from the Robert Wood Johnson Foundation as part of a $3 million programme to address the intertwined issues of health, equity and climate change.[21]

The Circular Cleveland strategy functions as an extension of the Climate Action Plan, aiming to create an economy that keeps materials in circulation at their highest value for the longest time possible. The reduced dependency on raw materials and waste generation for economic growth shifts away from the "take-make-waste" linear economic model while limiting consumption, toxicity and waste, to the benefit of society.

The circular economy touches on many topics that have a significant impact on the residents of Cleveland. To ensure the city's roadmap represents the needs of the local community, and the perspectives of those most affected, Cleveland undertook robust public engagements. Four priority topics were selected based on their potential to address social and economic issues along with environmental concerns. These include:

1. Circular manufacturing: a concerted reduction effort among local stakeholders.
2. Remediating pollution: in areas where pollution still affect the health of citizens and biodiversity in the region.
3. Circular built environment: one of the main leverage points to reduce the city's CO_2 emissions.
4. Getting more value from resources: preserving and extending the value of products and materials.

Programmes to electrify heavy transport and machinery

TOOLBOX OF SOLUTIONS LINK:

Programmes to electrify heavy transport and machinery

Solution 6

What is the challenge?

The movement of heavy vehicles that rely on fossil fuels imposes a significant carbon footprint in cities and is a contributing factor in the embodied carbon impact on the built environment. This includes the transport of raw materials, transport of materials to construction sites and the operation of heavy equipment and machinery during construction.

Moreover, the transportation sector's traditional reliance on conventional fuels compounds pollution, affecting air quality and public health, while the rapid urbanization and expansion of cities amplifies the strain on transport systems and use of off-road vehicles. The growing demand for logistics and freight services, coupled with ageing transport infrastructure, further complicates the challenge of reducing embodied carbon within cities.

What is the solution?

The solution is to accelerate the adoption of electric fleets and decarbonize heavy transport and construction machinery. This solution includes programmes that may be anchored by utility providers in collaboration with government bodies and private industry to create a suite of financial incentives and subsidies designed to ease the transition and encourage the adoption of zero-emission construction practices.

This calls for a transformative shift towards electrified fleets and robust EV infrastructure to mitigate carbon-intensive transport practices. Focus should be placed on high-traffic areas, important transport corridors and logistics hubs, alleviating concerns about range limitations and facilitating electric transport's seamless integration into existing transport ecosystems.

Simultaneously, technological advances targeting battery-powered heavy-duty transport require collaborative R&D initiatives, led by public-private partnerships focused on enhancing battery technology for trucks, buses and other heavy vehicles.

Implementation considerations

Key stakeholders involved:

- Utility providers
- Government agencies and transport departments
- Fleet operators
- Vehicle manufacturers and charging infrastructure companies
- Universities, research institutions and technology companies
- Logistics and transport associations and labour unions
- Consumer advocacy groups and environmental organizations
- Financial institutions
- Testing and pilot programme participants

Key funding and policy considerations:

- Government grants and subsidies: Allocate funds to create incentives for the purchase of EVs, build charging infrastructure and support R&D in battery technology.
- Private investment: Encourage private-sector involvement through tax incentives, grants or partnerships to fund infrastructure development and technological innovation.
- Public-private partnerships (PPP): Establish models in which both the public and private sectors contribute funds, resources and expertise to support electrification programmes and infrastructure expansion.
- Regulatory frameworks: Implement policies mandating a certain percentage of new vehicle sales to be electric, phasing out internal combustion engine vehicles over time.

- Charging infrastructure standards: Establish standards for the deployment of charging infrastructure, ensuring interoperability and accessibility across different charging networks.
- Zoning and land-use policies: Encourage the installation of charging stations in residential, commercial and public areas through zoning regulations and building codes.
- Carbon-pricing and emissions-reduction targets: Set targets for reducing carbon emissions and introduce carbon-pricing mechanisms to create incentives for the adoption of low-carbon technologies.
- Incentives for grid integration: Introduce policies supporting smart grid technologies and time-of-use pricing to manage electricity demand when charging EVs, ensuring grid stability.

CASE STUDY: POWER YOUR DRIVE FOR FLEETS

San Diego, California, USA

Power Your Drive for Fleets is a utility-provided programme to help fleet owners and operators reduce operating costs, eliminate emissions and simplify vehicle maintenance by transitioning to EVs. The programme connects fleets with resources, fleet-friendly charging rates and financial incentives to design and install the charging infrastructure needed to power medium- and heavy-duty electric fleets easily and cost-effectively.

The local utility helps install make-ready charging infrastructure for medium- and heavy-duty EVs, working with fleets from the initial infrastructure planning stage through to design, construction and ongoing site maintenance.

All utility customers operating medium- and heavy-duty vehicles are eligible for assistance through the programme. Additional resources and financial incentives are also available for fleets operating in disadvantaged communities and for small business fleets. The goal of the programme is to serve a minimum of 3,000 medium- and heavy-duty on-road and off-road class 2–8 vehicles at 300 customer sites throughout the utility company's service area.[22]

3.3 Spurring innovation

This theme centres on driving technological advances and innovation in various sectors to mitigate embodied carbon. Solutions in this grouping include practices aimed at creating incentives for research, development and implementation of cutting-edge technologies, encouraging intelligent, creative and low-cost solutions to reduce carbon footprints across industries and urban landscapes.

Innovation hub for clean construction

Solution 7

TOOLBOX OF SOLUTIONS LINK:

Innovation hub for clean construction

What is the challenge?

The embodied carbon problem is difficult to measure and complex to solve. It requires the engagement of stakeholders from across the value chain and in both the public and private sectors to collaboratively identify and pilot solutions to overcome traditional methods, a lack of resources and common regulatory barriers. There is a pressing need for new approaches and cohesive strategies to bring scalable solutions to market.

What is the solution?

Innovation hubs bring together researchers, creators and innovators to develop ideas into industry-changing products and services. These collaborative innovation centres can be tailored to advance low-carbon construction practices, accelerate technology and market solutions, create knowledge products and disseminate lessons learned. They are adaptable to a specific physical or virtual space and embody the principles of collaboration, innovation and sustainability. Innovation hubs focused on clean construction may incorporate:

- Tailored R&D to pioneer materials and construction methods
- Regional collaboration and knowledge exchange to facilitate partnerships and collaborations with academic institutions as well as municipal authorities to ensure that solutions are not only developed but also effectively implemented and integrated into city planning and construction regulations
- Championing of sustainable urban practices, extending influence beyond individual construction projects to affect urban planning, zoning regulations and building codes
- Technological advances and investment in technology
- Engaging with local communities to raise awareness about the importance of reducing embodied carbon in construction, promoting support and participation in sustainable urban development initiatives
- Capacity-building and knowledge dissemination through educational programmes and workshops to develop skills among industry professionals, policy-makers and communities
- Implementing robust monitoring and evaluation mechanisms to assess the impact and effectiveness of initiatives within these centres; successful practices and innovations can then be scaled up and replicated in other cities

Implementation consideration

Key stakeholders involved:

- Private-sector companies
- Government and policy-makers

- Construction material suppliers and manufacturers
- Building design and construction firms
- Industry associations and advocacy groups

Relevant policy and funding considerations:

- Secure government funding or grants dedicated to establishing and sustaining these hubs to facilitate research, innovation and collaboration within the construction sector.
- Align government policies with the objectives of these hubs to encourage the adoption of sustainable construction practices and streamline regulatory frameworks.
- Align national, regional and local policies to support the goals and initiatives of the innovation hubs, ensuring regulatory frameworks are conducive to supporting innovation in clean construction practices.
- Implement incentives or tax credits for companies investing in R&D specifically aimed at low-carbon construction innovation within these hubs.
- Create consortia or collaborative funding models involving multiple stakeholders, including municipalities, industry players and research institutions, to share costs and resources for sustained development of the hubs.
- Develop sustainable financial models for the hubs to ensure their long-term viability, considering revenue streams, cost-recovery mechanisms and the potential for economic self-sufficiency.

CASE STUDY: HOLCIM INNOVATION HUB

Lyon, France

Holcim's innovation hub at the company's global R&D centre in Lyon, France, functions as an interactive space to showcase sustainable building solutions and to accelerate low-carbon, circular and energy-efficient construction on a global scale. The three-floor facility hosts start-ups, think tanks and partners, supporting collaborative innovation and urban dialogues on sustainable cities and construction practices.

Holcim is committed to promoting sustainable construction globally through innovative solutions – in sites extending from Zurich to New York, Mexico and Manila. The company's ECOPact concrete makes a significant contribution to reducing CO_2 emissions without compromising performance, and its aim is to make low-carbon concrete the primary building material for a net-zero future, focusing on lower-carbon, circular solutions to minimize buildings' carbon footprint and have a positive impact on the environment.[23]

SPOTLIGHT ON

YES SF, a place-based innovation challenge through the World Economic Forum's UpLink innovation programme

The city of San Francisco in California has a long history of environmental leadership. Between 1990 and 2020, the city's carbon footprint was reduced by 48%, while the population grew by 21% and GDP increased by 194%. Meanwhile, almost half of San Francisco's citywide emissions come from buildings and, in the current decade, the city is expected to grow its households by 82,000 units. By driving urban sustainability efforts to modify existing spaces and reduce embodied carbon and operational emissions, San Francisco hopes to become a role model for green cities.[24]

In recognition of this, in June 2023 the World Economic Forum's UpLink innovation programme launched its first place-based challenge aimed at creating sustainable buildings, targeting green and blue[25] infrastructure technology innovators who would commit to being located in and deploying their solutions in San Francisco. Top innovators will benefit from access to a suite of resources to help deploy their solutions; introductions to key stakeholders, potential funders, experts and advisory services; and a $1 million grant to be distributed among the top innovators to help them build and scale their solutions.[26]

Programmes for residential deconstruction and workforce development

Solution 8

TOOLBOX OF SOLUTIONS LINK:

Programmes for residential deconstruction and workforce development

What is the challenge?

The rapid pace of new construction alongside an ageing building stock poses a profound conundrum and an opportunity for more sustainable development to reduce the escalating carbon footprint from conventional demolition practices. Indiscriminate demolition not only contributes substantially to landfill waste but also squanders valuable resources embedded within structures slated for destruction.

The need to upskill the existing workforce is paramount. The demand for circularity in construction and sustainable practices necessitates a workforce adept at finding innovative solutions – yet traditional training often falls short of these imperatives. As cities strive for sustainability, the challenge lies in reconciling the demand for new construction with responsible disposal of older structures while developing a workforce equipped to navigate the transition to a green economy.

What is the solution?

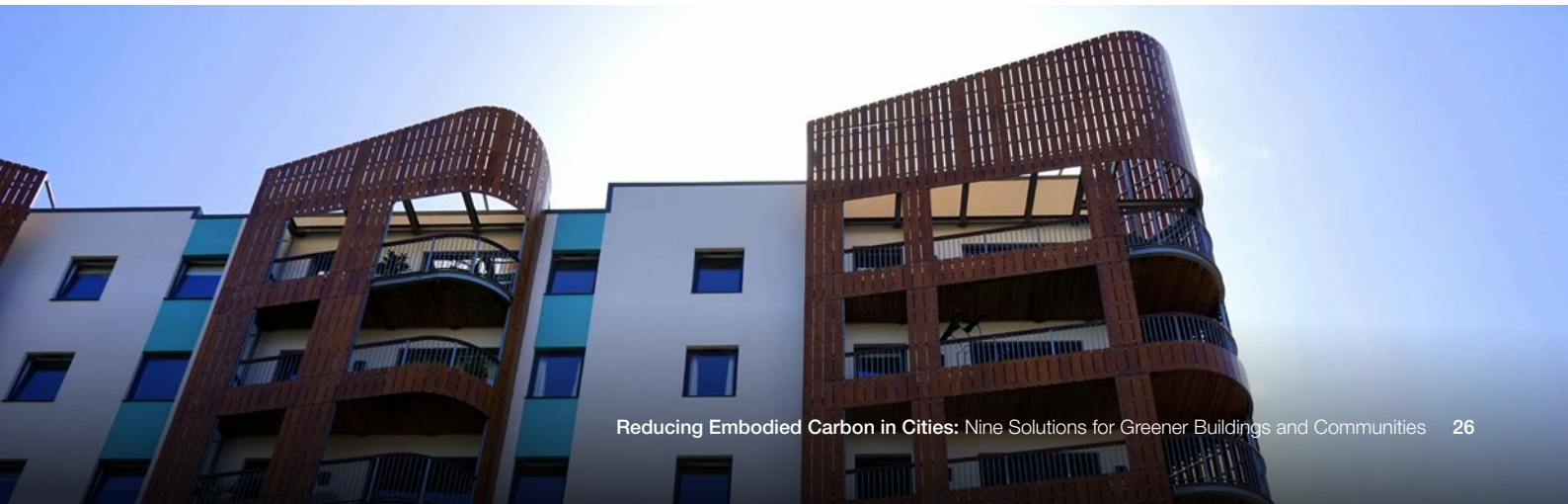
Governments possess a potent lever in their quest for carbon neutrality: making it mandatory to shift from demolition to deconstruction – a process entailing the systematic dismantling of buildings and embodying a crucial ethos – and to reclaim and repurpose building materials. This strategic pivot ensures maximal recycling of materials and a substantial reduction in landfill waste.

Collaborating with non-profit or private-sector entities, governments can spearhead initiatives to upskill the construction workforce and equip them with skills to salvage materials expertly. Reuse, for example, creates more than 200 times as many jobs as relying on landfills and incinerators.[27]

Reskilling and upskilling the current workforce should include deconstruction techniques, stringent safety protocols and an engrained environmental consciousness, advocating waste reduction and championing sustainability.

The practice of deconstruction and workforce development is ideal for cities facing the dual challenge of significant stocks of older buildings, including housing, alongside a burgeoning demand for new construction, providing a lifeline for cities seeking to revitalize their workforce, nurturing a cadre of skilled professionals adept at embracing circularity solutions.

Construction and demolition waste accounts for upwards of 40% of the US waste stream.[28] Despite the amount of raw materials consumed every year, only one-third of all construction and demolition (C&D) waste is recovered and reused.



Implementation considerations

Key stakeholders involved:

- Developers and real estate firms
- Government agencies
- Certified deconstruction contractors
- Workforce development partners
- Recycling system operators
- Non-profits and community organizations

Relevant policy and funding considerations:

- Governments can enact regulations mandating the deconstruction rather than demolition of buildings, emphasizing material recycling and waste reduction.
- Tax credits, grants or subsidies create incentives for contractors and developers to adopt deconstruction practices and invest in workforce training.
- Integrating sustainable construction practices into building codes promotes deconstruction-friendly designs and materials, developing a culture of reuse.
- Investment is needed in vocational training and education programmes that focus on deconstruction techniques, safety protocols and environmental awareness.
- Governments can fund research initiatives aimed at advancing deconstruction technologies, materials recycling and sustainable construction methods.
- Assessments should consider the long-term economic and environmental benefits of deconstruction compared to traditional demolition in project planning and decision-making.

CASE STUDY: DECONSTRUCTION PROGRAM

Portland, Oregon, USA

Since 2016, Portland's Deconstruction Program[29] requires that qualifying residential buildings be deconstructed instead of demolished. This increases the amount of salvageable material from a given project and diverts it from landfill. To ensure that materials are salvaged safely and effectively, deconstruction must be done by a certified contractor. The certification process includes:

1. Non-profit organization Build Reuse's project management training course, taught by a trainer registered in the National Registry of Deconstruction Trainers
2. A hands-on skills assessment conducted at a construction site
3. A written exam administered by Build Reuse
4. Credentials for safe disposal of lead paint and asbestos

Build Reuse created the National Registry of Deconstruction Trainers and the deconstruction training course required to become a certified deconstruction contractor in Portland. The Oregon Department of Environmental Quality (DEQ) completed an evaluation of the carbon and energy impacts from deconstructed homes in the City of Portland. This study analysed the first 36 homes to pass through the city's required deconstruction programme and compared the impacts of deconstruction against the alternative scenario of mechanically demolishing the homes. It found that the average deconstructed home showed a carbon benefit of 13.8 $MtCO_2e$ (megatonnes of carbon dioxide equivalent) while demolition showed a carbon benefit of 6.2 $MtCO_2e$. Deconstruction yields a net carbon benefit of approximately 7.6 $MtCO_2e$ compared to demolition. The carbon benefits are mainly attributed to the avoided production of new materials and the continued sequestration of biogenic carbon in the wood.[30]

The full range of benefits from this programme include:

- Environmental benefits: Using salvaged materials can decrease the embodied carbon of both the project from which they are sourced and the project using them.
- Economic benefits: By requiring certified demolition contractors, the programme creates jobs and demand for businesses that can process salvaged materials.
- Health benefits: Compared to demolition, deconstruction releases fewer air pollutants. In addition, certified contractors are trained to safely dispose of lead paint and asbestos if these are found during the deconstruction process.

Online marketplace for a circular built environment

TOOLBOX OF SOLUTIONS LINK:

Online marketplace for circular built environment

Solution 9

What is the challenge?

The built environment uses half of global raw materials extracted, produces one-third of the world's waste and accounts for approximately 39% of global energy-related CO_2 emissions,[31] one-quarter of which come from embodied carbon or the emissions associated with the entire life cycle of building materials and construction. Interior fit-outs, in particular, present waste-generation challenges and contribute to nearly one-third of emissions over the life of a building. Despite the environmental imperative to reduce reliance on new or virgin resources, there is little access to recycled materials or awareness about material reuse.

Producing a ton of newly manufactured bricks releases 258kg of CO_2 emissions, whereas for a ton of recycled bricks the emissions are only 2.7kg. Newly manufactured bricks therefore emit 95 times more CO_2 in their production than recycled bricks.[32]

What is the solution?

A centralized-platform model ecommerce business known as a reuse online marketplace aggregates material listings into a unified platform to streamline procurement of reused materials, providing a centralized hub for accessing a wide range of circular products for construction, renovations and interior fit-outs.

A unified-marketplace platform promotes the availability of comprehensive data, offering insights into the supply-and-demand dynamics of reused materials as well as consumer behaviour. By aggregating information on material listings, transactions and user interactions, such a marketplace has the potential to generate valuable analytics that shed light on broader trends. This data-driven approach not only enhances transparency within the marketplace but also supports stakeholders by providing achievable insights to help them optimize their material procurement strategies. Additionally, the possibility of conducting analysis of consumer behaviour provides valuable feedback for improving the user experience, tailoring services to better meet the needs of users, and enabling informed decision-making, driving efficiency and innovation in the reuse ecosystem while further advancing the goals of sustainability and circularity in construction practices.

Implementation considerations

Key stakeholders involved:

- Government and regulatory bodies
- Construction industry associations
- Technology providers and developers
- Materials suppliers and construction firms
- Environmental NGOs and advocacy groups

Relevant policy and funding considerations:

- Regulatory frameworks: Governments can establish regulations and standards to promote the use of reused materials in construction projects. This may include mandates for incorporating reused materials in public infrastructure projects, setting minimum recycled content requirements or offering tax incentives for businesses that prioritize material reuse.
- Procurement policies: Public procurement policies can be revised to prioritize the procurement of reused materials for government-funded projects.

- Waste-management policies: Policies aimed at reducing waste generation and promoting the circular economy can support the development of a reused materials marketplace.

- Public funding: Governments can allocate funding for R&D initiatives, pilot projects and incentives to promote the adoption of reused materials. This may include grants, subsidies or low-interest loans for businesses and organizations involved in the reuse sector.

- Carbon pricing and revenue streams: Carbon-pricing mechanisms, such as carbon taxes or cap-and-trade systems, can generate revenue that can be reinvested in initiatives to reduce carbon emissions, including the promotion of reused materials. Revenue from carbon pricing can be used to fund research, development and incentives for the reuse sector.

CASE STUDY: MATERIAL REUSE PORTAL

London, UK

The Material Reuse Portal is a pioneering platform that uses an aggregator model to streamline material procurement for projects. It facilitates the listing of surplus materials post-deconstruction and provides access to best practices and service providers supporting the reuse journey. The portal's adaptable architecture allows for seamless integration of new material data sources and customization for different locations. It collects data on material demand and supply, derived from user searches and listings, respectively. Free to use, the portal offers a user-friendly interface for stakeholders across the construction industry to engage in sustainable material reuse practices.

The Material Reuse Portal was designed to bring together data on available materials from multiple sources. It is integrated with existing marketplaces to provide a simple way for other vendors/suppliers to be listed on the site. There are plans in place to increase the number of marketplaces and increase choice for those who want to reuse materials and components in their projects.[33]

In London, the built environment consumes 400 million tonnes of materials every year, producing 54% of all waste in the UK's capital city. Reusing materials not only reduces the waste created in the city but also has benefits in terms of carbon emissions. It is estimated that the construction sector is responsible for about 10% of London's consumption-based carbon emissions.[34]

Conclusion

Effective progress in reducing embodied carbon emissions demands swift collective action and collaboration. Public-private partnerships are pivotal, using the strengths of each sector to propel solutions.

There is an urgent need for cities to bring embodied carbon emissions reduction to the forefront of urban agendas, intertwining public health needs, long-term sustainability and the vitality of urban environments, urging concerted efforts for a more environmentally conscious and healthier future. The challenge of funding looms large, however, necessitating diverse resources and collaborative funding models to implement crucial initiatives.

Moreover, the approach must transcend mere carbon reduction, embracing a holistic, whole-systems perspective. Solutions should aspire not only to cut carbon emissions but also to generate broader social and economic benefits. They ought to integrate considerations for workforce development and bolstering the economy, making carbon reduction a co-benefit of these larger, interconnected objectives. This comprehensive approach must underscore any implemented solution, recognizing the intrinsic link between social, economic and environmental prosperity.

Importantly, solutions will not fit a uniform mould. They may be required at various scales and intervention points. Tailoring solutions to suit individual cities and prioritizing immediate actions is imperative. The “right-sizing” of solutions aligns with the unique needs and capacities of each local government and authority, ensuring that pragmatic steps can be taken towards meaningful change.

Moving forward, cities, businesses and communities must unite, encouraging innovation, allocating resources wisely and prioritizing tangible action. Embodied carbon reduction is not just a technical challenge; it is a collective responsibility and opportunity to shape a more sustainable future for generations to come.

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1. IEA50, "Global CO_2 Emissions from Buildings, Including Embodied Emissions from New Construction, 2022", 15 June 2023: https://www.iea.org/data-and-statistics/charts/global-co2-emissions-from-buildings-including-embodied-emissions-from-new-construction-2022.
2. World Business Council for Sustainable Development, ARUP, *Net-Zero Buildings: Where Do We Stand?,* 2021: https://www.wbcsd.org/Programs/Cities-and-Mobility/Sustainable-Cities/Transforming-the-Built-Environment/Decarbonization/Resources/Net-zero-buildings-Where-do-we-stand.
3. UN Environment Programme, Global Alliance for Buildings and Construction, *2022 Global Status Report for Buildings and Construction,* 2022: https://globalabc.org/our-work/tracking-progress-global-status-report.
4. World Green Building Council, *Bringing Embodied Carbon Upfront: Coordinated Action for the Building and Construction Sector to Tackle Embodied Carbon,* 2019: https://worldgbc.s3.eu-west-2.amazonaws.com/wp-content/uploads/2022/09/22123951/WorldGBC_Bringing_Embodied_Carbon_Upfront.pdf.
5. Ben Tracy and Analisa Novak, "Cement Industry Accounts for About 8% of CO_2 Emissions. One Startup Seeks to Change That", CBS News, 16 January 2023: https://www.cbsnews.com/news/cement-industry-co2-emissions-climate-change-brimstone/.
6. Carbon Leadership Forum, "EPD Requirements in Procurement Policies": https://carbonleadershipforum.org/epd-requirements-in-procurement-policies/.
7. City of Portland Office of Management and Finance, "Notice of New Requirements for Concrete", 15 May 2019: https://www.portland.gov/sites/default/files/2020/concrete-epd-requirements-final-20190515.pdf.
8. Candace Pearson, "ISO Simplifies Specifying for Circular Design", Building Green: https://www.buildinggreen.com/taxonomy/term/432/Downloads/www2.buildinggreen.com/article/architecture-heart-five-ways-green-design-promotes-joy-healing-and-relationships-last?page=26.
9. Marin County, California, "Low-Carbon Concrete Compliance: Section II: Marin County Code Chapter 19.07 Added to Marin County Code Title 19": https://www.marincounty.org/-/media/files/departments/cd/planning/sustainability/low-carbon-concrete/12172019-update/low-carbon-concrete-code.pdf?la=en
10. Maria-Cristina Florian, "What COP27 Meant for Architecture and the Construction Industry", ArchDaily, 24 January 2023: https://www.archdaily.com/992583/what-cop27-means-for-architecture-and-the-construction-industry#:~:text=A%20report%20by%20Arup%20and%20the%20World%20Business,of%20building%20materials%20and%20the%20construction%20process%20itself.
11. World Economic Forum G20 Global Smart Cities Alliance, *Whole Life Carbon Assessment Mandates, 2023:* https://www3.weforum.org/docs/WEF_Whole_Life_Carbon_Assessment_Mandates_2023.pdf.
12. City of Vancouver, *Embodied Carbon Guidelines: Version 1.0,* 18 October 2023: https://vancouver.ca/files/cov/embodied-carbon-guidelines.pdf.
13. Seattle Department of Construction & Inspections, "Priority Green Expedited – Overview": https://www.seattle.gov/sdci/permits/green-building/priority-green-expedited-overview.
14. Oslo Municipality Procurement Strategy: https://glcn-on-sp.org/fileadmin/user_upload/Publications/SP_Profiles/City_of Oslo_GLCN_on_SP_Profile.pdf.
15. City of New York, "Executive Order 23: Clean Construction", 22 September 2022: https://www.nyc.gov/office-of-the-mayor/news/023-002/executive-order-23/index.page.
16. United Nations Environment Programme, *Building Materials and the Climate: Constructing a New Future,* September 2023: https://wedocs.unep.org/handle/20.500.11822/43293.
17. Andrea Di Maria, Johan Eyckmans and Karel Van Acker, "Downcycling Versus Recycling of Construction and Demolition Waste: Combining LCA and LCC to Support Sustainable Policy Making", *Waste Management,* Volume 75, 2018: https://pubmed.ncbi.nlm.nih.gov/29398268/.
18. Gail Napell and Anna Bretaña, "The Adaptive Reuse Revolution", Gensler: https://www.gensler.com/climate-action-2021-the-adaptive-reuse-revolution.
19. Los Angeles City Planning Department, "Citywide Adaptive Reuse Ordinance": https://planning.lacity.gov/odocument/6725f347-7fdb-42fa-aa6e-44c37f8fa999/Fact_Sheet_-_Adaptive_Reuse_Ordinance.pdf.
20. Michele Lerner, "One Westside Office Campus Showcases the Potential of Adaptive Reuse", Lerner, 7 March 2023: https://www.reit.com/news/articles/one-westside-office-campus-showcases-the-potential-of-adaptive-reuse.
21. Circular Cleveland: https://circularcleveland.org/.
22. SDG&E, "Power Your Drive for Fleets": https://www.sdge.com/business/electric-vehicles/power-your-drive-for-fleets.
23. Holcim, "Holcim Launches Global Innovation Hub to Accelerate Sustainable Building", 6 September 2023: https://www.holcim.com/media/media-releases/launch-innovation-hub.
24. Sharon Lai, "These Startups Are Making the World's Cities More Sustainable", World Economic Forum Agenda, 10 November 2023: https://www.weforum.org/agenda/2023/11/cities-sustainable-innovation-entrepreneurs-solutions/.

25. Green and blue infrastructure refers to the interweaving of natural systems to create climate-resilient cities and mitigate climate impacts such as flooding and extreme heat.
26. World Economic Forum Uplink, "Yes San Francisco, Urban Sustainability … Supporting the Implementation of World-Leading Innovations in Urban Sustainability", 6 September 2023: https://uplink.weforum.org/uplink/s/uplink-issue/a002o0000174PQwAAM/yes-san-francisco-urban-sustainability-challenge.
27. Recycling Magazine, "Study: Zero Waste Systems Could Create Thousands of Jobs", 16 February 2021: https://www.recycling-magazine.com/2021/02/16/study-zero-waste-systems-could-create-thousands-of-jobs.
28. Beth Cochran, "Demolition vs. Deconstruction: How Shifting to Reuse Impacts the Environment and Economy", Sustainable Earth, 12 July 2022: https://sustainable-earth.org/demolition-vs-deconstruction/.
29. Portland.gov, "Deconstruction: Documents": https://www.portland.gov/bps/climate-action/decon/documents.
30. State of Oregon Department of Environmental Quality, *Materials Management Program 2019–20 Report to the Legislature,* February 2020: https://www.oregon.gov/deq/FilterDocs/MMReport-Leg2019-20.pdf.
31. McKinsey, "Circularity in the Built Environment": https://www.mckinsey.com/featured-insights/world-economic-forum/knowledge-collaborations/circularity-in-the-built-environment.
32. Martha Lewis, "Substantial Reduction of CO_2 Emissions with Recycled Brick Facades", Henning Larsen, LinkedIn, 2 October 2017: https://www.linkedin.com/pulse/substantial-reduction-co$_2$-emissions-recycled-brick-facades-lewis/.
33. Material Reuse Portal: https://www.materialreuseportal.com/About.
34. Ibid.

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