Building the Future, Responsibly

A Roadmap for Reducing Embodied Carbon in Cities

By Brent Boden

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Contents

1 Executive Summary

In cities, a significant yet often overlooked contributor to greenhouse gas emissions is embodied carbon—the emissions linked to material manufacturing, transportation, construction, and end-of-life processes of buildings and infrastructure.

These upfront "embodied" carbon emissions are locked in before a building is even occupied, making up a significant part of a structure's lifetime **environmental footprint** and, importantly, a substantial share of near-term emissions that will affect the world's ability to meet critical climate targets.

This white paper presents a detailed roadmap for cities to reduce their embodied carbon footprint. The necessary transformative change can be achieved through a systemic approach that combines strategic urban planning, innovative policy measures, a decisive move towards sustainable and circular material economies, and pioneering design principles.

Key strategies include prioritising the reuse and retrofitting of existing structures, promoting compact and transit-oriented development, advocating for the use of bio-based materials like sustainably sourced timber, maximising recycled and salvaged content, and designing for deconstruction and material efficiency.

Cities, policymakers, industry stakeholders, and researchers must collaborate to implement robust policies, encourage material and design innovation, and build a shared commitment to a low-carbon environment. The recommendations below provide a pathway for cities to not only reduce their climate impact but also to create more resilient, resource-efficient, and ultimately, more liveable urban environments for future generations.

Confronting Embodied Emissions

The global push towards decarbonisation has, for many years, focused predominantly on **operational carbon**—the emissions generated from heating, cooling, and powering buildings. While critical, this focus has often overshadowed an equally, if not increasingly, important aspect of the urban carbon footprint: **embodied carbon.**

As cities continue to grow and evolve, understanding and reducing these upfront emissions is becoming a priority.

2.1 Defining Embodied Carbon in the Urban Context

Embodied carbon refers to the greenhouse gas emissions released during the manufacturing, transportation, installation, and end-of-life phases of building materials and construction processes. This includes emissions from the extraction of raw materials, their transportation to manufacturing facilities, the manufacturing processes themselves, the transportation of finished products to construction sites, the construction activities, maintenance and repair throughout a building's life, and finally, the emissions associated with deconstruction, demolition, and disposal or recycling of materials at the end of a structure's service life.

This distinction is crucial because, unlike operational carbon, which can be reduced over time through retrofits and renewable energy adoption, upfront embodied carbon is locked in once construction is complete.

Current estimates suggest that embodied carbon accounts for roughly **25%** of a building's lifetime emissions. However, as buildings become more energy-efficient in their operational phase, the proportional share of embodied carbon is set to increase dramatically. Projections indicate that embodied carbon could represent as much as **50%** of the lifetime emissions from new buildings by 2050, underscoring its growing significance in the climate equation.

Building a case for change

The building sector's contribution to global emissions is staggering. It is responsible for approximately **37%** of worldwide energy and process-related CO_2 emissions.[11]

2.2 The Scale of the Challenge: Why Cities Must Act Now

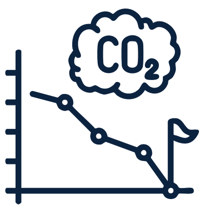
The rapid pace of global urbanisation increases the urgency to tackle embodied carbon. The world is expected to double its existing building stock between 2020 and 2050.[11] This colossal wave of new construction, if pursued using conventional carbon-intensive materials and methods, will result in a massive surge of locked-in embodied carbon, severely jeopardising efforts to limit global warming.

As such, the decisions made at the earliest stages will of urban development and building design have a profound and lasting impact.[11] This means that choices regarding land use, density, infrastructure provision, and material selection made by urban planners, policymakers, and developers at the outset dictate the vast majority of a project's lifetime carbon footprint.

Interventions focused only on later stages, such as optimising construction methods, while helpful, can only reduce a small part of total emissions if the initial design and material choices are inherently carbon-heavy. This highlights the key opportunity that early-stage decisions offer for large-scale carbon reductions.

Consequently, a holistic approach that tackles both operational and embodied carbon simultaneously is essential for achieving truly sustainable urban development. The focus on embodied carbon is no longer a secondary concern but a primary frontier in the fight against climate change.

3 Pathways to Low-Carbon Cities



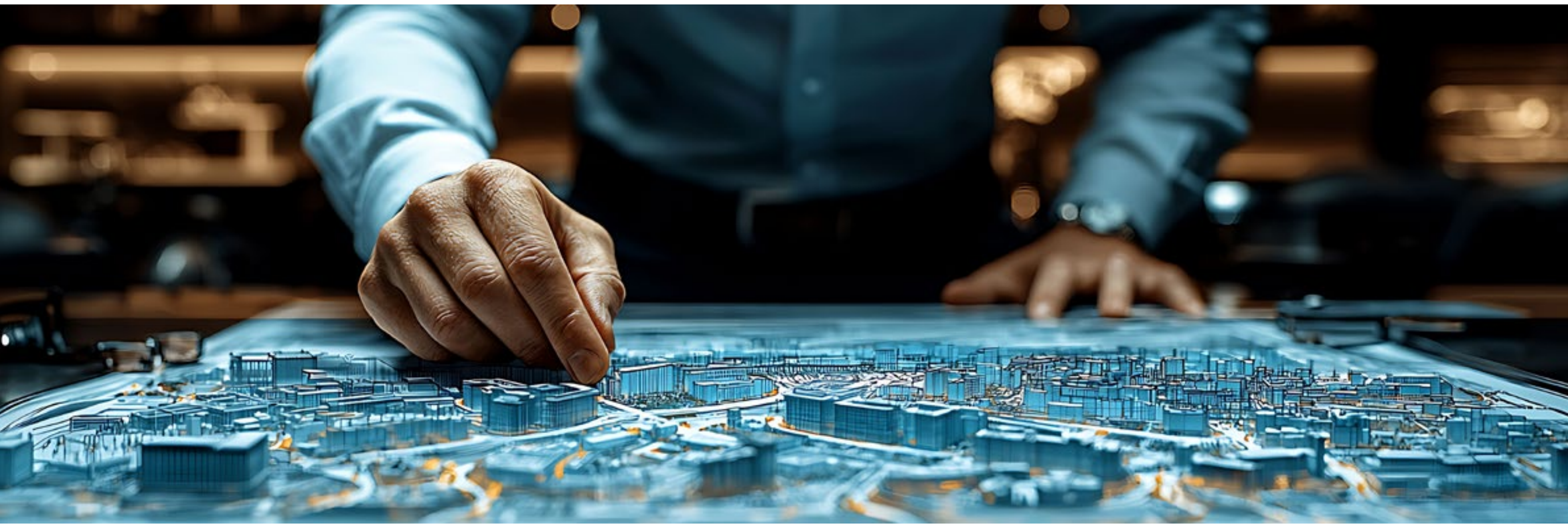
Reducing embodied carbon in cities needs a comprehensive strategy that goes beyond isolated interventions. This means rethinking city planning, how materials are sourced and used, and how buildings and infrastructure are designed and built. A multi-layered approach, involving policy innovation, material science, and creative design, can help create considerably lower-carbon urban environments.

3.1 Strategic Urban Planning and Policy Interventions

The foundation for low-embodied carbon cities can be established through urban planning and policy decisions. These choices can significantly cut the need for new materials and related emissions.

A key strategy is prioritising the reuse and retrofitting of existing buildings and infrastructure. This "Retrofit First" principle, exemplified by the Westminster (London) City Council's soon-to-be adopted Policy 43[12], recognises that the lowest carbon building is often the one that already exists. Reusing structures avoids the significant embodied carbon associated with demolition and new construction. Globally, such an approach could cut building sector emissions by **17%** by 2050.[11]

Effectively managing **urban growth and density** is also crucial. By creating smart growth boundaries, prioritising Transit-Oriented Development (TOD), and planning for complete, higher-density neighbourhoods, cities can minimise the need for new, sprawling infrastructure and reduce per capita land and material consumption. Milan's Air and Climate Plan (PAC), which promotes 15-minute neighbourhoods where daily needs are accessible without a car, is a good example that illustrates this approach.[1]



Protecting natural resources and prioritising brownfield development further reduces embodied carbon. Natural landscapes serve as carbon sinks, and developing on previously used land (brownfield sites) often utilises existing infrastructure, and decreases the need for new, carbon-intensive construction. The Stockholm Royal Seaport project, which is transforming a former industrial area into a sustainable commercial and residential district, serves as a prime example.[5]

Finally, strong regulatory frameworks are vital. This includes policies requiring lifecycle assessments (LCAs) for new projects to measure their total carbon footprint, setting limits on embodied carbon, and providing incentives for low-carbon materials and construction methods. France's RE2020 regulation, which mandates LCAs and sets emission limits for new buildings, and Helsinki's pilot carbon footprint limits for new apartment buildings, showcase the effectiveness of such policies.[3,9]

3.2 Revolutionising Urban Construction: The Shift to Sustainable Materials

The choice of construction materials is a significant determinant of a building's embodied carbon. A transition towards sustainable, low-carbon, and circular material economies is vital.

Prioritising bio-based materials, particularly sustainably sourced wood, offers a significant opportunity. Wood not only has lower embodied energy than conventional materials like concrete and steel but also functions as a carbon sink, storing carbon throughout the building's lifespan. Modern engineered wood products deliver excellent technical performance, including durability, insulation, and a high strength-to-weight ratio, making them suitable for a wide range of applications, including multi-storey buildings. Policies supporting wood include updating building codes, green public procurement, and financial incentives.

Maximising salvaged and recycled content in construction diverts waste from landfills and lowers the demand for virgin raw materials and the energy needed to produce them. This can range from reusing entire building components to incorporating materials with high recycled content, such as recycled aggregates in concrete or recycled steel. Zurich's longtime successful policy (est. 2005) mandating recycled aggregates in public buildings has also encouraged private sector adoption.[7]

The development and specification of low-emission modern materials are also crucial. This includes innovations in concrete, such as using supplementary cementitious materials (SCMs) to lower the clinker content (the most carbon-heavy component). Likewise, advancements in steel manufacturing aim to reduce its carbon footprint. "Buy Clean" policies, adopted by various government agencies, focus on sourcing materials with lower embodied carbon, often verified through Environmental Product Declarations (EPDs).

Underpinning these material choices is the principle of material efficiency and waste reduction. Designing buildings to use materials more efficiently from the outset minimises waste and reduces the overall quantity of materials required, directly lowering embodied carbon.
example that illustrates this approach.[1]

3.3 Designing for Durability, Adaptability, and Circularity

Innovative design principles can further reduce embodied carbon by extending the building's lifespan, decreasing material use, and promoting a circular economy for construction materials.

Design for Deconstruction (DfD) involves planning buildings in a way that allows for easy disassembly of components at the end of their life, facilitating their reuse or recycling. This contrasts with conventional demolition, which often makes materials unusable. Portland, Oregon's deconstruction ordinance, mandating deconstruction for certain older buildings, is a pioneering example of policy supporting DfD.[4]

Structural optimisation and material efficiency in design aim to minimise the amount of materials used without compromising structural integrity or performance. This can involve advanced engineering techniques and choosing materials with optimal strength-to-weight ratios.

Creating **adaptable and multipurpose buildings and infrastructure** extends their useful lifespan, reducing the need for demolition and new construction. Spaces designed for flexibility can evolve with changing user needs or functions.

An often-overlooked aspect of sources of embodied carbon is the impact of below-grade construction. Foundations, basements, and underground parking structures are typically made from concrete and steel, significantly contributing to a project's embodied carbon. Strategies to reduce this include lowering or removing parking minimums and designing more efficient foundation systems. Vancouver's embodied carbon guidelines, for example, penalise underground parking in their calculations.[6]

The most significant reductions in embodied carbon happen when these strategies are combined and integrated. For instance, a project might involve retrofitting an existing building (planning) using bio-based insulation (materials) and incorporating adaptable interior layouts (design).

However, the widespread adoption of many of these technical solutions—such as mass timber construction or designing for deconstruction—often needs supportive policy frameworks and updated building codes to overcome existing barriers.

Additionally, while the primary motivation for these changes is environmental, many strategies, like material efficiency, reuse, and faster assembly times with prefabricated wood components, can also offer economic benefits, including lower material costs and quicker project completion, making them more appealing and encouraging adoption.

See the appendices

Table 1: Core Strategies for Mitigating Urban Embodied Carbon, *for a summary of each of the strategies, including the referenced examples.*

4 Case Study: Copenhagen – Pioneering Embodied Carbon Reduction

Copenhagen, the capital of Denmark, has become a global leader in sustainable urban development, with ambitious targets to cut its carbon footprint significantly. Although its initial goal to reach city-wide carbon neutrality by 2025 faced setbacks, especially regarding carbon capture technologies, its focused efforts to tackle embodied carbon in the construction sector remain highly instructive and influential. The city's approach blends strong regulatory measures with support for innovative projects and practices, offering valuable insights for other cities.

4.1 Copenhagen's Ambitious Vision and Regulatory Landscape

Following the Netherlands and France, Denmark became the third country to introduce embodied carbon limits into its national building regulations, a landmark step that came into force in 2023. This national strategy provides the overarching framework for Copenhagen's efforts. Key elements of the regulatory landscape include:

Mandatory Life Cycle Assessments (LCAs)

All new buildings must undergo an LCA to document their environmental impact over a 50-year lifespan. This requirement has been part of the voluntary DGNB (German Sustainable Building Council) certification since 2010, which by 2023 covered around 50% of large-scale new constructions in Denmark, laying the groundwork for the mandatory approach.

CO_2 Limit Values

For new buildings exceeding 1,000 square meters, a limit value of 12 kg CO_2/m^2 per year was initially set. This comprehensive limit includes all building-related greenhouse gas emissions across the lifecycle.

Influence of DGNB Certification

The DGNB certification system, widely adopted in Copenhagen, plays a significant role in promoting sustainable building practices. DGNB criteria assess environmental quality, including building lifecycle assessment, local environmental impact, and responsible resource extraction, directly aligning with embodied carbon reduction goals. Nordhavn, a central urban development area, achieving DGNB Gold certification is a testament to this influence.

Phased Tightening and Differentiated Standards

The regulations are designed with a clear roadmap for progressively stricter limits. For instance, from July 2025, multi-story apartment buildings must meet a maximum emission level of 7.5 kg of CO_2/m^2 per year, with an additional cap of 1.5 kg of CO_2/m^2 for emissions arising from the construction phase itself. The framework also differentiates standards based on building type, recognising that some typologies, like schools, may have unique requirements leading to slightly higher allowances. In contrast, others, such as single-family homes and offices, fall within lower ranges. Revisions to these limits are planned through political negotiations to reflect technological advancements and feasible targets over time.

See the appendices

Table 2:
Copenhagen's Embodied Carbon Policy and Project Highlights, *for a summary of each of the strategies, including the referenced examples.*

This regulatory approach, characterised by clear mandates combined with flexibility and a forward-looking strategy for ongoing improvement, has been crucial in steering the industry towards lower embodied carbon solutions. It offers the necessary impetus for developers, designers, and material suppliers to innovate and adapt.

Image: Nordhavn District, Copenhagen

Portland Cement silos *(foreground, far-right)* have been converted into a BREEAM-certified Office Building.

4.2 Innovations in Action: Leading Projects and Practices

Copenhagen is not just setting regulations; it is also a living laboratory for low-embodied carbon construction, showcased through numerous **pioneering projects:**

Nordhavn District

This former industrial port is being transformed into a large sustainable urban area, aimed at creating a "5-minute city" where residents can access all essential amenities within a short walk or bike ride. The master plan prioritises mixed-use development, sustainable transport options (focused on cycling and public transport), renewable energy sources (including geothermal and solar), and smart city infrastructure. Nordhavn's integrated planning aims to reduce overall material use and transport-related emissions, with the district designed to operate at carbon-neutral levels. The Århusgade neighbourhood within Nordhavn highlights challenges in balancing new construction emissions with reuse in dense areas, but also demonstrates efforts to refurbish existing structures such as concrete grain silos and brick warehouses.

Ripple Residence (Nordhavn)

This six-storey residential building, currently under construction, is a flagship project for timber construction. Made mainly of timber, including load-bearing structures, walls, and facades, it is expected to emit only 5 kg of CO_2/m^2 per year, which is well below Denmark's upcoming regulatory limit of 7.5 kg for such buildings. The building is also designed for disassembly, and its blueprints will be publicly available to promote wider adoption of timber construction.

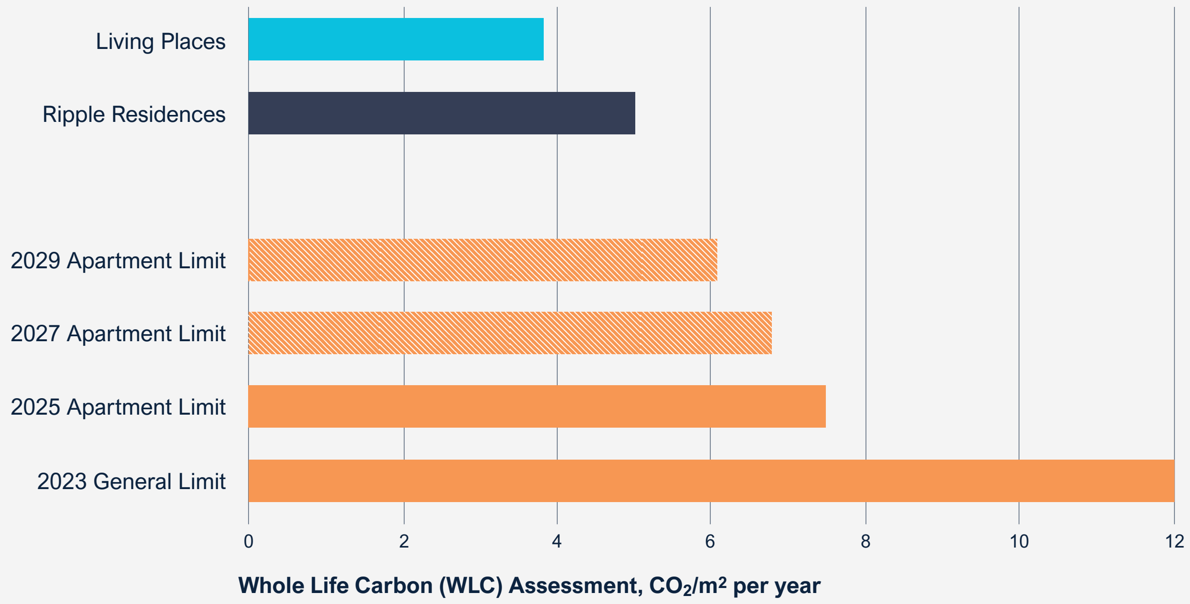
Living Places Copenhagen

Developed by VELUX Group and partners, this project showcases seven prototypes, including two full-scale homes, demonstrating that buildings with a record-low carbon footprint (3.8 kg CO_2/m^2 per year – three times lower than the 2023 Danish legislation) and excellent indoor climates can be built using existing technologies and at market-comparable prices. The project highlights healthy, affordable, simple, shared, and scalable design principles.

Resource Rows (Ørestad)

This residential development exemplifies circular economy principles in action, making extensive use of upcycled materials. Facades are built from brick modules repurposed from demolished buildings, including the historic Carlsberg Brewery and old schools. Surplus timber from Copenhagen Metro construction and offcuts from flooring manufacturing have been utilised for facades, rooftop terraces, and pavilions. This innovative approach led to a **12%** reduction in CO_2 from materials and a **29%** CO_2 saving over a 50-year lifespan when including both embodied and operational emissions.

Project Performance vs Regulation



Urban Loop Project / CIRCuIT

Copenhagen is a key partner in the CIRCuIT (Circular Construction in Regenerative Cities) project, which aims to expand circular construction practices across European cities. The broader "Urban Loop" initiative in Copenhagen incorporates advanced circular economy principles, including smart infrastructure for resource management, automated waste sorting, achieving **80%** resource recovery, and building designs that enable material recovery through standardised components and mechanical connections instead of permanent adhesives. This has resulted in a **40%** reduction in construction waste compared to traditional methods and the development of digital material tracking systems integrated with Building Information Modelling (BIM).

These projects not only demonstrate technical feasibility but also serve as powerful "show, don't just tell" examples. By making successes visible and sharing knowledge, as with the Ripple Residence blueprints, Copenhagen helps de-risk innovation for the broader industry, which also helps to build market confidence, accelerating the transition to low-carbon construction.

4.3 Navigating the Journey: Key Learnings, Challenges, and Future Directions

Copenhagen's journey towards reducing embodied carbon, while progressive, has not been without its challenges, offering valuable lessons for other cities.

Success Factors

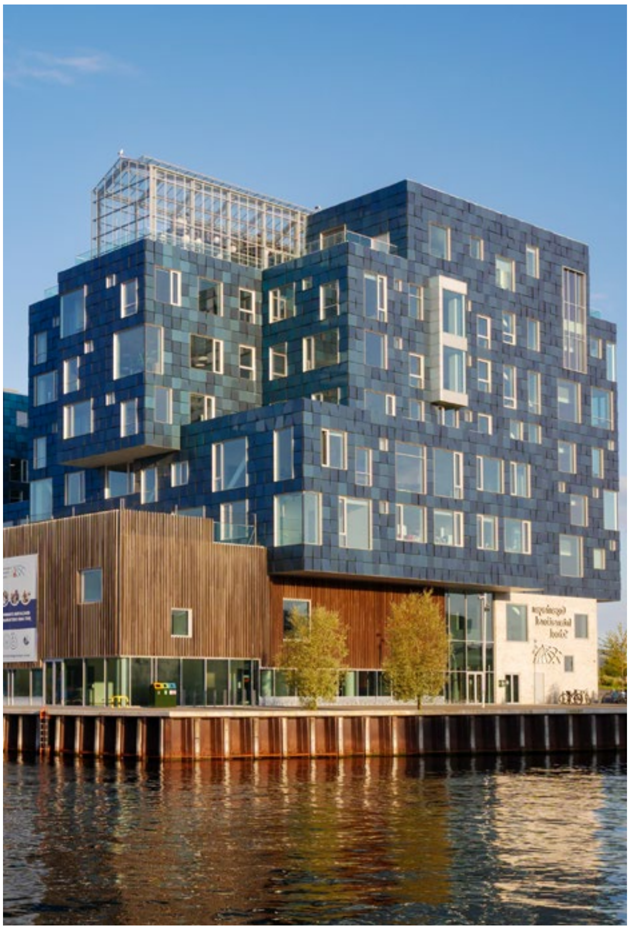
A key driver of progress has been active involvement and voluntary commitments from the private sector. More than 630 Danish companies, including major construction and materials firms, have pledged to cut their embodied carbon emissions, building significant industry momentum. Additionally, Copenhagen's success is rooted in long-term strategic planning, such as the historic "Finger Plan" that directed development along transit corridors, and sustained investment in quality of life and infrastructure, which in turn adds value and encourages further sustainable initiatives.

Challenges Encountered

The city has navigated several hurdles:

- **Balancing Ambition with Feasibility:** Setting appropriate carbon limits needs careful consideration of what is technologically and economically possible for the industry at any given time. The planned revisions to Denmark's limits mirror this ongoing balancing act.
- **Expanding LCA Scope:** Efforts are underway to expand the scope of LCAs to more fully cover all lifecycle stages, including emissions from transporting materials to the site and from end-of-life demolition and processing. This involves developing robust methods and data for these currently less-quantified phases.
- **Revising Outdated Building Codes:** Traditional building codes, often focused on safety standards from different eras, can inadvertently hinder the adoption of innovative low-carbon materials and construction methods. Updating these codes to align with current sustainability targets is a vital but challenging task.
- **Dominance of New Construction Emissions:** Even with substantial efforts in material innovation and reuse, the large volume of new construction in urban development areas can hinder achieving significant overall embodied carbon reductions. The Århusgade neighbourhood study in Nordhavn found that while refurbished buildings had a positive impact, their effect on the total embodied emissions of the dense new development was relatively minor. This emphasises the need to also consider strategies that decrease the overall amount of new buildings.

- **City-Wide Carbon Neutrality Target Setbacks:** Copenhagen's ambitious goal to be a carbon-neutral city by 2025 was ultimately not achieved, mainly due to underperformance and insufficient funding for Carbon Capture and Storage (CCS) technology at a key waste-to-energy plant. This highlights an important lesson about the risks of relying too heavily on immature technologies to reach broad climate goals and emphasises the need for diversified strategies and strong accountability measures.
- **Retrofitting Existing Buildings:** A practical challenge in reducing emissions from the existing building stock is the "landlord-tenant conundrum," where neither party may have the incentive or resources to invest in energy efficiency retrofits, especially in a city with a large rental population.



Carbon Emissions Down Under

Compared to the standards being adopted in Denmark, a new 200m^2 house in Melbourne, built to meet the National Construction Code (NCC, 2022), isn't required to carry out a WLC assessment and, based on estimated comparative calculations, would have operational emissions of roughly 35-45 CO_2 / m^2 per year.

While the NCC establishes a minimum standard, other schemes like the National Australian Built Environment Rating Scheme (NABERS) and the Green Star rating system are also helping to drive improvement across the building industry.

Future Directions

Copenhagen continues to push boundaries. The city is committed to the continued tightening of CO_2 limits for construction. There is a growing focus on circular construction principles, aiming to shift the sector from a linear "take-make-dispose" model to one where materials are kept in use for as long as possible. This involves an ongoing evolution of building practices to fully integrate sustainability and low-carbon thinking into every stage of a building's lifecycle. Even when city-wide targets are adjusted, the focus on reducing embodied carbon in the built environment remains a strong policy driver. This adaptive management approach, which learns from both successes and setbacks, is essential for long-term progress.

5 Recommendations for Urban Decarbonisation

The need to reduce embodied carbon in cities is clear, and as the example of Copenhagen demonstrates, significant progress can be made through collective effort and innovation. To speed up this transition worldwide, policymakers, industry leaders, and collaborative groups should consider a range of actionable recommendations. These aim to foster a supportive environment for low-embodied carbon development, drawing on best practices and overcoming key barriers.

5.1 Policy and Governance Recommendations

Effective policy and governance are the bedrock upon which widespread embodied carbon reduction can be built. Cities and national governments should:

1. **Adopt and Enforce Mandatory Whole Life Carbon (WLC) Assessments and Benchmarks:** Implement regulations requiring WLC assessments for all new construction and major renovation projects. Establish clear, ambitious yet achievable embodied carbon benchmarks or limits (e.g., kg CO_2/m^2), which are progressively tightened over time, similar to the approaches in Denmark and France’s RE2020. This creates a level playing field and encourages market demand for low-carbon solutions.

2. **Implement “Retrofit First” Policies:** Prioritise the reuse, refurbishment, and retrofitting of existing buildings over demolition and new construction whenever possible. Simplified permitting processes for retrofits and disincentives for unnecessary demolition can help achieve this.

3. **Revise Building Codes for Performance and Innovation:** Shift building codes from prescriptive to performance-based standards that are material-agnostic. This allows greater flexibility in using innovative, low-carbon materials like mass timber and earth-based products, as long as they meet safety and durability requirements. Codes should be regularly updated to reflect advances in material science and construction techniques.

4. **Integrate Embodied Carbon into Planning and Procurement:** Incorporate embodied carbon considerations into zoning laws, land-use planning decisions, and public procurement processes. “Buy Clean” policies, which require government projects to use materials with verified low embodied carbon (often through EPDs), can utilise public spending to foster market change.

5. **Support Regional Material Reuse Networks:** Support the growth of markets for salvaged and recycled construction materials. This involves establishing platforms for material exchange, deconstruction hubs, and standards for quality assurance of reused components, inspired by Copenhagen’s circular economy initiatives.

5.2 Industry and Innovation Recommendations

The construction industry and its allied sectors have a pivotal role in developing and deploying low-carbon solutions. Key actions include:

1. **Invest in Research & Development (R&D):** Increase investment in R&D for low-carbon cement alternatives, bio-based materials, advanced timber products, modular construction systems, and design for deconstruction techniques. Public-private partnerships can accelerate this innovation.
2. **Develop Tools for Transparency and Data Sharing:** Develop and promote easy-to-use tools for conducting LCAs, digital material passports to track components through their lifecycle, and open databases for Environmental Product Declarations (EPDs). Data transparency is essential for informed decision-making and accountability.
3. **Upskill the Workforce:** Invest in comprehensive training and education programs for architects, engineers, contractors, and tradespeople on low-carbon design principles, sustainable material use, LCA methodologies, and circular construction practices.3 This increases the industry's capacity to adopt new policies and technologies.
4. **Foster Cross-Sector Collaboration:** Encourage collaboration across the entire building value chain—from material suppliers and designers to contractors and developers—to identify systemic challenges and co-create scalable solutions. Industry associations can play a vital role in facilitating this.

5.3 Collaboration and Knowledge Sharing

Addressing embodied carbon is a global challenge that benefits from shared learning and collective action. Efforts should focus on:

1. **Establish City Networks and Knowledge Platforms:** Support and strengthen networks like C40 Cities where local councils can share best practices, policy innovations, successful project case studies, and lessons learned in tackling embodied carbon.
2. **Develop Standardised Methodologies:** Strive for international harmonisation of methods for embodied carbon accounting, reporting, and verification. This promotes data comparability, supports global benchmarking, and builds trust in carbon reduction claims.
3. **Engage Financial Institutions:** Collaborate with banks, investors, and insurers to develop green financing mechanisms, such as preferential loan terms or reduced insurance premiums, that recognise and reward projects with low embodied carbon.[3] This can create powerful market incentives.

A key foundation for many of these recommendations is the need for standardisation and data transparency. Without consistent LCA methodologies, reliable EPDs, and accessible material data, it becomes difficult to establish meaningful benchmarks, accurately track progress, or make informed comparisons between different design and material options. Furthermore, the success of new policies and technologies also depends on building knowledge and capabilities across the industry. If the workforce lacks the necessary skills and knowledge, even the most well-intentioned regulations will fall short.

Finally, inspired by Copenhagen's pragmatic approach, policies should be introduced gradually and remain adaptable, setting ambitious long-term goals while enabling manageable implementation steps and regular reviews to incorporate new insights and technological developments. This approach ensures that the transition remains both ambitious and achievable.

Conclusion

Building a Resilient and Low-Carbon Legacy

The challenge of embodied carbon in our cities is unquestionably serious, but it also presents a great opportunity: to fundamentally transform urban environments into more sustainable and resilient places. The emissions embedded in our buildings and infrastructure from the start form a key lever in the global fight against climate change.

As outlined in this white paper, addressing these upfront emissions requires a shift in thinking—moving beyond a narrow focus on operational efficiency to adopt a comprehensive, lifecycle approach to the built environment.

Strategies that integrate urban planning, transformative policy, a decisive move towards sustainable and circular material economies, and innovative design principles are not just aspirational; they are vital. Prioritising the reuse of existing structures, fostering compact and connected communities, championing materials that store carbon or are sourced from waste streams, and designing for longevity and disassembly are all crucial elements of this new approach paradigm.

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Table 1: Core Strategies for Mitigating Urban Embodied Carbon

Category	Strategy	Description	Example(s)
Urban Planning & Policy	Prioritize Reuse & Retrofit	Maximize use of existing buildings/infrastructure to avoid new construction emissions.	London Retrofit First
	Smart Growth & TOD	Dense, mixed-use, transit-accessible development to reduce sprawl and infrastructure demand.	Milan 15-min neighbourhoods; Oregon density
	Brownfield Redevelopment	Utilize previously developed land to preserve natural areas and existing infrastructure.	Stockholm Royal Seaport
	Implement LCA & Carbon Limits	Mandate assessment of lifecycle emissions and set maximum embodied carbon thresholds for new projects.	France RE2020; Helsinki pilots
Sustainable Materials	Promote Sustainably Sourced Wood	Use timber from sustainable sources for its carbon storage and lower embodied energy.	Ripple Residence
	Maximize Salvaged & Recycled Content	Incorporate reused materials and products with high recycled content to reduce virgin material demand.	LA Metro policy; Zurich recycled concrete
	Specify Low-Emission Modern Materials	Choose alternatives like low-carbon concrete, recycled steel, and bio-based insulation.	Marin County Concrete Code; Green cement
Design & Construction	Design for Deconstruction & Reuse	Plan for future disassembly and material recovery to enable circularity.	Portland Deconstruction Ordinance
	Optimize Structural Systems & Material Use	Efficient design to minimize material volume while ensuring performance and safety.	Nordhavn District
	Design for Adaptability & Longevity	Create flexible spaces that can adapt to changing needs, extending building lifespan.	Detroit QLine
	Minimize Below-Grade Construction	Reduce carbon-intensive foundations and underground parking.	Vancouver guidelines; Toronto parking

Table 2: Copenhagen's Embodied Carbon Policy and Project Highlights

Feature	Detail	Example Project / Initiative	Specific Achievement / Snippet(s)
Regulatory Driver	Mandatory CO_2 Limit for New Buildings (>1000m²)	N/A (Policy)	12 kg CO_2 e/m² per year initially; roadmap for tightening (e.g., 7.5 kg for apartments by 2025)
	Mandatory Life Cycle Assessments (LCA)	N/A (Policy)	Required for new buildings to document environmental impact over 50-year lifespan
	DGNB Certification Influence	Nordhavn District	Nordhavn achieved DGNB Gold; DGNB considers LCA, resource extraction
Material Innovation (Timber)	Prioritizing Mass Timber Construction	Ripple Residence	Primarily timber, achieving 5 kg CO_2 e/m²/year (well below 7.5 kg limit), designed for disassembly
Material Innovation (Upcycling)	Extensive Use of Upcycled Materials	Resource Rows	Facades from upcycled bricks (Carlsberg Brewery), wood from Metro; 12% material CO_2 reduction, 29% lifetime CO_2 reduction
Low-Carbon New Build	Demonstrating Ultra-Low Carbon Homes	Living Places Copenhagen	CO_2 footprint of 3.8 kg/CO_2/m² per year (vs. 12 kg Danish legislation), market-comparable price, uses existing tech
Circular Economy Systems	Systemic Approach to Resource Recovery & Design for Disassembly	Urban Loop Project / CIRCuIT	80% resource recovery, smart waste sorting, standardized components for material recovery, digital material tracking
Sustainable Urban District	Holistic, District-Scale Sustainability Planning	Nordhavn District	"5-minute city," mixed-use, sustainable transport, renewable energy, smart infrastructure, carbon-neutral development plan

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