A Low-Carbon Future for London

Lessons from Leading Cities on Whole Life Carbon Policy

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Structural Collective

CNCA
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GREATER LONDON AUTHORITY

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Summary of findings and recommendations

Since 2021, the London Plan has required major developments to undertake a whole life carbon assessment (WLCA), a process that measures a project's total greenhouse gas emissions. The Greater London Authority (GLA) is now reviewing its appproach to whole life carbon (WLC) policies – the total emissions from a building's construction, operation and demolition. Establishing robust WLC benchmarks is crucial for reducing embodied carbon emissions – those released during the manufacturing, transport and construction phases.

This report informs London's policy development by analysing the experiences of four pioneer cities – Helsinki, Oslo, Toronto and Vancouver – with additional insights from Stockholm and the Pacific Coast Collaborative (PCC). It draws on insights from a stakeholder workshop organised with the C40 Cities Climate Leadership Group to explore three questions:

- What political, technical and social processes can London learn from other cities when setting WLC targets?
- How can the social impacts of WLC policies be managed?
- How have schemes referable to the Mayor performed against existing benchmarks, and where do stakeholders see opportunities for improvement?

Cities operate in different political and socioeconomic contexts with varying degrees of autonomy in policy-making. Despite these differences, common themes emerge across four stages of WLC policy maturity. We found that a successful strategy for reducing WLC is not about a single policy but an ecosystem of reinforcing actions, and we drew the following key lessons from pioneering cities.

STAGE 0
LAYING THE GROUNDWORK

Pioneering cities begin by embedding WLC limits within a broader policy framework of regenerative design. This acknowledges that WLC is just one component of a building's environmental impact and that policy should push for net-positive outcomes, not merely limit negative ones. Based on the learnings drawn from our case studies, we suggest that pioneering cities should:

Align WLC benchmarks with overall carbon-reduction goals to direct policy efforts effectively. Helsinki, for example, identified its concrete sector as a major source of emissions.[1] In response, it now requires low-emission concrete in infrastructure projects. Its first limit, set in 2023, mandated that the concrete's global warming potential (GWP) could not exceed 85% of the national average for that concrete type. This benchmark, which covers emissions from raw materials, transport and production (life-cycle stages A1–A3), will be tightened over time.

Include infrastructure from the start. The city of Oslo suggested that including infrastructure – one of the highest impact areas – would have contributed greatly to overall reductions.

Ensure policy coherence across different municipal departments. Conflicting policies can undermine progress in London.* For instance, a policy that promotes basement bicycle storage could conflict with embodied carbon limits, as basements are carbon intensive. Furthermore, developers face fragmentation at the borough level, where they must navigate slightly different rules across London.

** Indicated by workshop participants.*

STAGE 1
PILOTING AND BUILDING TRUST

Conflicts between ambitious local policies and less stringent national regulations can complicate implementation, as experienced by Oslo. On the other hand, where cities have significant control, they have been particularly effective in setting thresholds and additional conditions, for example:

Stockholm exercises leverage through its 70% land ownership, creating a financial incentive for developers to comply with environmental requirements.

Helsinki owns 60% of its land and a significant portion of its rental housing, enabling it to set stringent construction conditions.

Oslo has direct influence in about 20% of the local construction market and has used its procurement power to mandate zero-emission machinery and prioritise suppliers with the lowest overall carbon materials. The city also doubled its procurement staff to support this effort.

Multiple cities have started by showcasing what is possible to continue building the case that achieving ambitious emissions targets is feasible. One way is to use high-profile projects to drive innovation and prove that low-carbon construction is not just an abstract idea but an implementable solution. For example:

Work with development competitions. Helsinki used a design competition for a city-owned plot to challenge the market. It organised the Verkkosaaren vähähiilinen viherkortteli (Verkkosaari's low-carbon green block) competition, in which designs were judged on sustainability and carbon footprint in equal measure. This approach proved the feasibility of highly ambitious low-carbon construction, with one design achieving a remarkable carbon footprint of just 5 kg $CO_2/m^2/a$.

Initiate and de-risk pilots. Municipalities can de-risk innovation for the private sector. Oslo's move toward zero-emission construction sites is a good example. As a large client for construction, the city started out by requiring sustainable biofuels in a few municipal projects. During this pilot phase, Oslo directly addressed construction companies' concerns by providing guarantees for the rental of new electric machinery and covering the associated electricity costs, thus lowering the financial burden and risk of transitioning from traditionally used diesel fuels.

To build a credible policy, the data foundation must be consistent and transparent.

Ensure data collection and standards are consistent and transparent. To build a credible and effective WLC policy, the foundation must be a system of consistent, peer-reviewed and transparent data. In the Netherlands, for example, the Nationale Milieudatabase (National Environmental Database) keeps publicly available records of commonly used, generic construction products, enabling construction companies to use similar reference product declarations. Another crucial step for maintaining consistency in reporting could be the creation of a centralised, open-access digital portal where all submitted carbon assessments are publicly available. Such transparency not only holds architects, developers and environmental assessors accountable but also creates trust among stakeholders and allows for independent analysis by researchers and industry experts.

Ensure data is representative of the final 'product'. To manage the uncertainty of initial estimates, an error margin could be applied to values submitted at the planning stage. However, relying on a single assessment only at application stage, when many design choices are not yet final, is insufficient. It is now generally accepted that it is critical to re-evaluate the submitted assessment at later stages, with the detailed design phase being a more reliable point to accurately assess and lock in the project's final carbon impact.

Ensure the reporting process produces consistent results across different assessors. If the thresholds are strictly implemented, the reporting process still needs improvement to ensure consistency. Invest in data and tool development, working with national bodies to standardise methodologies and increase the availability of Environmental Product Declarations (EPDs), while making sure the reporting process remains 'fit for purpose': workshop participants noted in particular that the reporting burden for compliance leaves little room for innovation.

Utilise a flexible, data-driven approach to create the evidence base for setting the threshold. For example:

Helsinki created a central database from its own projects to compare results and develop emission limits. It then lowered the threshold when a district heating system became available after the decommissioning of a coal plant, collectively lowering emissions by 43%.

Toronto built its strategy on research that quantified embodied carbon and set benchmarks based on specific building types.

Vancouver established standardised baselines and phased-in reduction targets for embodied emissions in new construction, requiring whole-building life-cycle assessments (LCAs).

Furthermore, the exact specification of the thresholds merits significant attention and a flexible approach. Most cities have formulated detailed 'base thresholds' based on building types, but also adjustment factors (based on various parameters such as form factor and best-in-class performance of buildings in the categories) and inclusions and exclusions (e.g. types of parking facilities).

STAGE 2
CREATING MARKET MOMENTUM

Once feasibility is established, the focus shifts to creating market momentum, often through broad coalitions. Based on the learnings drawn from our case studies, we suggest pioneering cities should:

Develop coalitions between policy, private sector and educational institutions. Significant progress can be made by creating coalitions of educational institutions and government bodies at all levels to create a network of actors with a shared goal. In Toronto, this approach led to private-sector architects forming their own coalitions to push for change, working directly with manufacturers to increase the availability of Environmental Product Declarations (EPDs), which are essential for measuring embodied carbon. Stockholm's progress has been significantly driven by a national initiative called Fossil-Free Sweden, which unites various sectors to create their own roadmaps for carbon neutrality, fostering a powerful sense of collective action.

Use procurement power to create a market. A market for new materials and technologies will not appear on its own. A city can take the lead by using public procurement power to generate demand, for example through various public-sector housing delivery programmes. Oslo, which controls about 20% of the local construction market, has effectively used its procurement power to mandate zero-emission machinery and prioritise suppliers with the lowest overall carbon materials. To manage this shift effectively, the city nearly doubled its procurement staff, demonstrating the level of investment required to drive such a transformation.

Create financial incentives with e.g. loan conditions. Another step could be for London to use its Homes for Londoners Land Fund to accelerate change. By attaching specific WLC emission targets as conditions for its loans and financing, the GLA can create a financial incentive for developers. Toronto successfully uses a similar model, offering financial incentives like development charge rebates for projects that voluntarily adopt higher, more ambitious tiers of performance in its Green Standard. This rewards developers who reduce pressure on city services and infrastructure through greater resource efficiency.

Lenient threshholds — **Strict threshholds**

1	2	2b	2c	3	4
Substitution of 'low-hanging fruit' construction elements (e.g. insulation)	Electrification of building site and other reductions not related to materials	Substitution of more impactful and expensive elements	Design optimisations (e.g. floor dimensioning, space/façade ratios)	Radical conceptual design changes (e.g. different construction type – biobased construction)	Radical development of modality changes (e.g. retrofitting, vertical extensions preferred over new builds)

Figure 1. *Levels of Setting Whole Life Carbon Tresholds in Construction.*

STAGE 3
THE DEVELOPMENT OF LIMITS AND ROADMAP

If the market is sufficiently mature – as evidenced by project performance and market studies – a city can move towards mandatory limits. There are several options:

A. Blanket carbon limit. One option is a single limit of kg CO_2e/m^2 for a building's full life cycle. Helsinki set a mandatory WLC limit for new multi-storey apartment buildings at 14 kg CO_2e/m^2/a. This target was dynamically adjusted, lowered from an initial 16 kg/m^2/a after the city's district heating network became cleaner due to the decommissioning of a coal plant.

B. Module-specific targets. Alternatively, a city like London could set binding targets for specific life-cycle modules (e.g. A1-A3 or A4-A5). This requires clear data collection to effectively isolate and regulate emissions from each phase, and the ability to see where limits can and should be more stringent.

C. Material-specific limits. A third strategy is to focus on high-impact materials. Vancouver amended its Building By-law to require a whole-building life-cycle assessment (LCA) for nearly all new buildings and set reduction targets against a baseline Embodied Carbon Intensity (ECI). Oslo takes a different approach by making zero-emission machinery mandatory in tenders and using competitive bidding, in which suppliers compete to provide the overall lowest-carbon score for a set of materials rather than setting rigid per-material targets.

A clear, phased roadmap is crucial. Toronto's Green Standard provides a strong model. In predictable four-year cycles, voluntary tiers become the new mandatory baseline, giving the industry the certainty needed for investment and adaptation. Finally, strong enforcement is vital. Workshop participants stressed the need for clear consequences for non-compliance, such as fines. Revenues from these fines could then fund more ambitious low-carbon projects.

The political and social dimensions

The potential social risks and co-benefits of WLC policies are important to consider as they affect the entire built environment. We found the following:

Low-carbon practices can yield significant social benefits. The use of off-site manufacturing and modern technology makes construction sites quieter, cleaner and safer, which not only lessens the negative impact on surrounding communities but also helps attract a new generation to the workforce by creating more appealing work environments. Social value can also be found throughout the supply chain, for instance by using materials that have a positive environmental impact, such as algae bricks that improve ecosystems at their production sites.

Stakeholders highlighted concerns that stricter reporting standards might disproportionately benefit larger companies, which are better able to absorb the associated overhead costs. This poses risks for smaller, local suppliers, especially if mandates for Environmental Product Declarations (EPDs) become common practice. Smaller manufacturers and suppliers, lacking resources for obtaining EPDs, might be driven out of the market under these stringent requirements.

In the consultation workshop, stakeholders said that social impacts, while real, are very difficult to quantify due to a lack of transparency in supply chains and a tendency to measure only short-term outcomes. To address this, the use of established frameworks like that of Camden Council for setting targets and third-party labels like Declare to verify ethical sourcing were proposed as practical tools. To begin measuring social impact, several proxies were suggested. These include tracking household energy bill savings, monitoring local air quality with a goal of 'pollution-free' construction sites and demonstrating how low-carbon buildings can help address energy poverty through long-term cost savings.

WLC policies have not appeared to have significant political saliency in cities studied. In all cities, interviewees mentioned that the WLC policies have passed largely unnoticed by the general public. If there has been pushback, this has been from industry groups representing the construction sector – but this, too, has been rare. A reason suggested for this lack of interest from the general public is that all cities have opted for very gradual implementation – starting with voluntary and later mandatory requirements – and with thresholds that have been relatively easy to achieve with simple substitutions of a limited number of materials. Consequently, the construction industry has had time to accommodate evolving realities. The progressive political saliency of WLC policy with regard to tightening WLC thresholds is yet to be tested in cities and as yet it is not possible to identify precisely where the pressure points will occur.

Cost concerns are generally overstated. Toronto and Vancouver studies revealed negligible cost effects from carbon reduction measures, and in some cases even cost savings, with material costs comprising a minor share of total development costs:

- The study in Toronto showed that carbon reductions (in Toronto, a 26% reduction) were achievable with negligible effects on cost. Furthermore, green standards have as yet not slowed down housing construction in the city.
- The study in Vancouver found that embodied carbon reduction measures often led to material cost savings. The city also focuses on design efficiency as a first step to reduce embodied carbon, which can lower construction costs.

Furthermore, material costs are neither the sole nor the primary contributor to the final price of a full development from land acquisition to occupancy.* For example, as a share of total cost, a 5% increase in material costs in Europe represents only a 2.5% rise in total development cost, and even where there is a significant increase in design fees, this represents a relatively minor share of overall project costs. Therefore, as thresholds tighten, it becomes increasingly important to ensure that possible cost increases are shared by all stakeholders in the construction process, and are thus not left as a burden on the last stakeholder in the chain. When WLC policies get stricter, they stop being just about the environment and start affecting how housing affordability and how fast they can be built - as has been seen in France.

The co-benefits and risks of implementing WLC policies are understudied, as they depend on the specific interventions chosen.** Excluding the in-use phase, we utilised the LCA phase framework to identify some co-benefits and risks. The example below shows the excerpt of an analysis of the impact of creating demountable high-energy performant biobased construction. It shows that, in this case, most benefits and risks fall towards the community and the wider value chain, while occupiers benefit mostly through reduced energy bills.

These benefits and risks may occur through **strict WLC thresholds** but also through whole-of-city (WOC) policies. Whether a city should prefer realising these co-benefits through WLC thresholds or WOC policies should be considered on a case-by-case basis. For example:

- Co-benefits such as green jobs obtained from shifts in construction may be achieved through additional zoning regulations or procurement guidance that favour certain construction methods.***
- Benefits that occur in the end-of-life and transport phases due to electrification can be obtained by creating WOC policies – such as a city-wide mandate for zero-emission construction sites.****

For a useful impact assessment, each of these interventions should be studied independently, both from the community, occupants and workers' point of view. The report contains an instructive example of applying this assessment framework to biobased construction.

	A1-A3 Production	A4 Transport	A5 Construction	B In-use	C End of life
CO-BENEFITS	Green jobs	Clear air Less noise	Clear air Less noise	Reduced energy bills	Less dust Less noise
POINTS OF ATTENTION	Increased costs Working conditions Impact on nature		Working conditions	Increased rental prices	Working conditions
	Wider value chain	*Community*	*Community*	*Occupier*	*Community*

Figure 2. *Co-benefits and Challenges of Sustainable Building Stages.*

** Embodied carbon reduction strategies led to significant cost savings across residential building types. High-rise designs saw 2–20% savings, mid-rise designs achieved up to 10%, and low-rise designs saved up to 25% compared to a 2018 baseline. Cost-neutral solutions, such as higher SCM concrete mixes and EPS roof insulation, provided notable carbon reductions. Precast concrete panels offered the highest cost savings (19%) for high-rise buildings, while wood-frame construction delivered the greatest impact for mid-rise buildings, with over 15% savings and a 70% reduction in embodied carbon. Ibid.*

*** In the context of the impact of tightening energy performance criteria (so-called phase B or 'in-use'), the benefits and potential harms towards the occupants and the 'split incentives' between owners and occupiers in the decision making towards increasing energy efficiency have been well studied.*

**** Regulations or guidance should be designed such that they do not prejudice material choice.*

**** An unambiguous standard here might be more beneficial for lowering emissions across the board as it removes construction site electrification as an easy alternative for companies that prefer not to make harder choices in design and material substitutions.*

Performance of London's Mayoral Referable Schemes (2021–2024)

Since 2021, the GLA has collected WLC data from major developments referred to the Mayor's office (those with >150 residential units, >30 m in height, or on Green Belt land).[2] The analysis reveals several trends:*

Residential buildings are already partially meeting aspirational benchmarks for 'upfront' carbon (31.7% achieved this benchmark). Office buildings (43%) fare a bit better in terms of meeting Module A aspirational benchmarks, with about half of all educational buildings (50%) meeting the benchmarks already. In terms of the current WLC benchmarks, almost all construction projects of the different building types are meeting the targets for module A (hovering around 90%), whilst performance for modules B-C is a bit more varied. In the latter, 75% of the residential and office buildings are meeting current targets.

We did not find a relationship between the general affordability of an area and the emission intensity of planned projects. Using median borough house prices as a proxy for affordability, we observed no strong correlation between housing prices and lower WLC emissions. Additionally, concerns that strict emissions limits might negatively impact future housing affordability were not a significant issue raised by workshop participants.

The analysis identified little to no correlation between project size and emission intensity. This finding is somewhat counterintuitive, as one might expect larger buildings to require deeper foundations or more structural elements, such as reinforced concrete, which are typically emission-intensive.

The data reveals no clear improvement in carbon performance between 2021 and 2024, indicating that advances in low-emission practices have yet to significantly influence planning applications. An important caveat, highlighted by workshop participants, is the inconsistency in how WLC is measured across different organisations, which may skew results.

The optioneering approach

The City of London's (LPA) approach demonstrates that mandating systematic optioneering at pre-application stage produces tangible outcomes – the City accounted for half of all major retrofit schemes across London in 2023 (17 out of 34 projects). This shows that early-stage policy intervention with standardised assessment tools can shift market behaviour effectively.

However, London's optioneering approach also recognises that retrofit isn't always optimal – demolition proved more carbon-efficient in the case of poorly constructed 1970s buildings. Policy frameworks must be sophisticated enough to support evidence-based decisions rather than blanket mandates.

The Bresca case study shows that material vetting became the most expensive and challenging aspect due to manufacturer opacity. As also highlighted in the context of WLC policy, policy makers should mandate supply-chain transparency and support development of verified sustainable material databases to reduce project costs and risks.

Share Meeting Module A Benchmark (%) and Share Meeting
Modules B-C Benchmark (%)

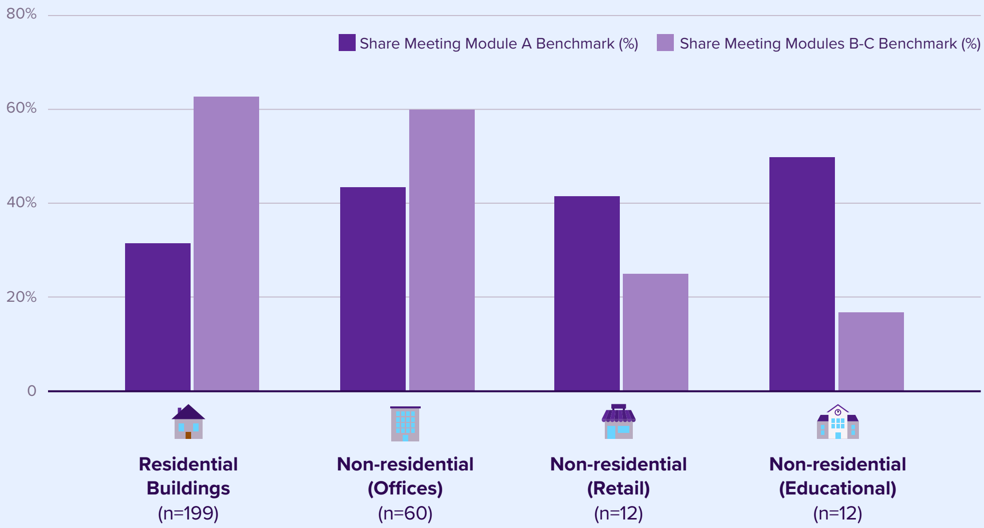

Figure 3. *Analysis of WLC data from major developements referred to the Mayor's office.*

** Note: stakeholders consulted in our workshop highlighted that carbon emission numbers presented in early planning stages of the projects are very unreliable and bound to change significantly during design and even execution. A survey sent out to workshop participants confirms this, as most do not rate their WLC assessment as very accurate – the inaccuracy margin is 20-50%.For LCA phase B this is likely to be less of an issue due to existing policies such as the 'be seen' policy. See also: The 'Be Seen' Energy Monitoring Guidance, 2020. https://www.london.gov.uk/publications/be-seen-energy-monitoring-guidance#:~:text=The%20'be%20seen'%20policy%20will,based%20on%20in%2Duse%20performance.*

Conclusions

The experiences of pioneering cities show that different contexts allow for specialised approaches to WLC policy. Success will depend not on a single, rigid mandate, but on a carefully sequenced approach: building a foundation of transparent data, using public levers such as procurement and land ownership to create market demand, and setting out a predictable, long-term roadmap for the industry. At the same time, navigating the social and economic dimensions, from housing affordability to the viability of small suppliers, will be crucial for securing a just and effective transition. The most effective approaches are not based on a single action but on an ecosystem of reinforcing measures:

Phased and predictable implementation

Successful cities start with voluntary measures, pilot projects, competitions and reporting-only requirements before moving to mandatory limits. Toronto's Green Standard, with its tiered system, in which today's voluntary tiers predictably become tomorrow's new mandatory baseline, provides a clear roadmap for industry.

Using municipal power

Cities that use their unique powers of land ownership and public procurement create initial demand and de-risk innovation for the private sector. Helsinki (60% land ownership) and Stockholm (70%) impose environmental conditions through land leases, while Oslo uses its 20% share of the construction market to mandate zero-emission machinery and low-carbon materials.

Data-driven benchmarks

Reliable data is crucial for setting effective targets. Cities like Helsinki and Toronto have built central databases and conducted benchmark studies to inform their standards. However, the lack of consistent and available data, for example on the Environmental Product Declarations (EPDs) of construction materials, remains a challenge.

Early and continuous collaboration

Engaging the construction industry from the beginning is critical for market buy-in and success. Helsinki held extensive dialogues with 150 company representatives before setting limits, and Stockholm's progress is built upon a national initiative that unites sectors to create carbon-neutrality roadmaps.

LONDON'S PERFORMANCE REVEALS AN IMPLEMENTATION GAP

Despite having a WLC assessment framework, data from London's planning applications (2021-2024) shows that aspirational goals are not translating into widespread practice, particularly for embodied carbon.

Upfront embodied carbon remains an important challenge

Residential buildings are the worst-performing category, with only 31.7% of projects meeting the aspirational benchmark for upfront embodied carbon (Module A). Office buildings performed moderately better at 43%. The projects are however almost all meeting the current benchmarks.

No visible improvement over time

The data does not show a trend of improving carbon performance between 2021 and 2024. For residential buildings, median emissions for Module A actually increased from 2022 to 2024. It might be the case that current policies are not yet driving significant change at scale, however it could also be that other factors such as more widespread reporting and increased accuracy of measuring WLC emissions are contributing to this trend.

Performance is independent of project size or area affluence

The analysis found no significant correlation between a project's size and its carbon intensity per square metre. Similarly, there was no meaningful link between the median house price of an area and the WLC performance of projects within it.

PERCEIVED COST, NOT ACTUAL COST, IS A BARRIER

The most significant source of industry and political resistance to stricter WLC regulation is the perception of high costs. However, evidence from multiple cities and studies demonstrates that these costs are manageable and often overstated.

Carbon reduction can be achieved with minimal cost impact

A study in Toronto showed that a 26% carbon reduction was achievable with negligible cost effects. In Vancouver, research found that embodied carbon reduction measures frequently led to material cost savings.

Material costs have a limited effect on total development cost: In Europe, materials and labour account for 40-50% of total construction costs. Therefore, a 5% increase in material costs would result in only a ~2.5% rise in the total development cost.

Efficient design is a key cost-saving strategy

A primary strategy to lower both costs and carbon is through efficient design that uses less material overall. Vancouver strategically focuses on design efficiency as the first step to address industry cost concerns.

THE STRATEGIC PATH FOR LONDON: FROM ASPIRATIONAL GOALS TO MANDATED ACTION

London has foundational policies in place but must now transition to the implementation phase, adopting the proven strategies of other leading cities.

Transition to mandatory, phased-in limits

Given that aspirational benchmarks are not driving sufficient improvement, the next step is to establish clear, mandatory WLC limits with a predictable, phased-in roadmap, similar to the Toronto Green Standard.

Adopt a ‘retrofit first’ principle

Prioritising the refurbishment of existing buildings over demolition is the most effective way to minimise embodied carbon. The City of London’s ‘retrofit first’ approach and optioneering framework provide a clear precedent that can be scaled across other boroughs.

Move beyond carbon to a holistic framework

To avoid ‘carbon tunnel vision’, a narrow focus on emissions that overlooks other critical factors, London should integrate a broader, more holistic approach. This involves embedding principles of regenerative design and utilising social impact frameworks to assess the effects of policy on health, biodiversity and community wellbeing.

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Introduction

REPORT OVERVIEW AND INTRODUCTION

This report has been written for the **Greater London Authority (GLA)** under the framework of Carbon Neutral Cities Alliance Project "*Dramatically Reducing Embodied Carbon in the Built Environment*", supported by the Laudes Foundation, in which Greater London Authority participates together with 14 European cities* to empower them to significantly reduce embodied emissions in the built environment, increase the adoption of bio-based materials in construction projects, and prioritize community needs for a just transition.

The report presents information on actions and policies to reduce whole life carbon emissions in the built environment, following the example of cities in Europe and North America (focusing on Helsinki, Oslo, Toronto and Vancouver). The cities discussed all take their own approach to reducing carbon emissions throughout the life cycle of buildings in their municipal boundaries, and the learnings presented can be applied in London's own carbon limit-setting process.Learnings have been collected through extensive literature reviews focusing on the cities mentioned, additional interviews with local government representatives from the selected cities to confirm and expand findings, and an in-person workshop with participants active in London's construction industry. Besides these findings, the report presents a first conceptualisation on measuring the 'shadow' impacts of setting carbon limits in the built environment: which social and environmental factors are at stake in the effort to push sustainability forward?

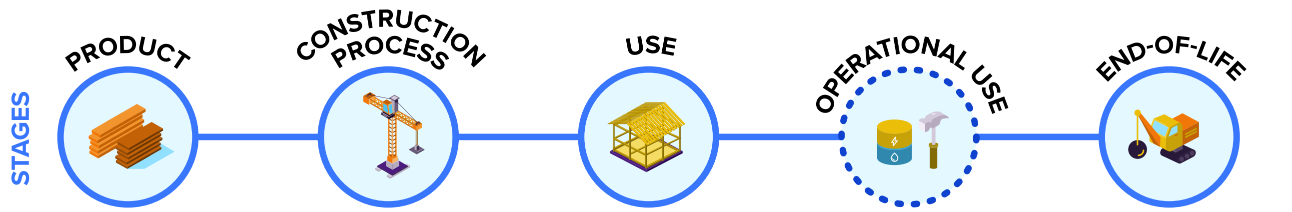
DEFINING WHOLE LIFE CARBON

Whole life carbon (WLC) can be defined as **the combined total of embodied and operational emissions over the whole life cycle of a building.** The whole life cycle of a building covers all stages, from material sourcing, manufacture and construction through use over a given period to demolition and disposal, including transport emissions and waste disposal.[3]

WLC emissions consist of embodied and operational emissions:

Embodied emissions: 'The carbon emissions emitted producing a building's materials, their transport and installation on site as well as their disposal at end of life.'[4]

Operational emissions: The amount of carbon dioxide emissions associated with building operations.[5]



Raw material supply, transport, manufacturing A1 A2 A3	Process Stage: Transport to site, construction A4 A5	User experience of the building fabric B1 B2 B3 B4 B5	Energy, water, maintenance B6 B7	Deconstruction, disposal, recycling C1 C2 C3 C4
A1 Raw material supply	A4 Transport to project site	B1 Use	B6 Operational energy	C1 Deconstruction and demolition
A2 Transport to Manufacturing plant	A5 Construction and installation process	B2 Maintenance	B7 Operational water	C2 Transport to disposal facility
A3 Manufacturing and fabrication		B3 Repair		C3 Waste processing for reuse, recovery or recycling
		B4 Replacement		C4 Disposal
		B5 Refurbishment		
Embodied emissions			Operational emissions	

Figure 4. *Building Life Cycle and Emissions Stages.*

**Participating cities include: Bordeaux métropole, Glasgow, Greater London Authority, Greater Manchester Authority, Helsinki, Lille métropole, London borough of Newham, Lund, Madrid, Nantes métropole, Oslo, Stockholm, Tampere, Turku, Valladolid*

A SHORT OVERVIEW OF WHOLE-LIFE-CARBON FOR BUILDINGS & CONSTRUCTION

- Looking at buildings in the EU, reports suggest that 'WLC emissions of buildings account for 41% of total EU emissions in the baseline year [of 2020]'.[6] 'Across the entire EU building stock, 21% of WLC emissions in the baseline year occur as embodied carbon emissions (related to construction, maintenance, renovation and demolition works) while the remaining ratio of 79% is associated with the operation of the building stock.'[7]
- New construction projects are the major drivers for the embodied emissions (71% of embodied carbon). However, these activities only affect 1.5% of the building stock floor area annually, which makes construction an important carbon hotspot.
- This is supported by the finding that embodied emissions account for up to 74% of WLC emissions in case of advanced energy performance in newly constructed buildings. Therefore, embodied emissions represent an important reduction potential both for individual projects and for the building stock in total.[8]

BUILDING EMISSIONS (LCA)

According to the life cycle assessment (LCA) methodologies, we can distinguish the following phases in the building's life cycle:

Embodied
Operational

A1 Raw material extraction and supply
A2 Transport to manufacturing plant
A3 Manufacturing and fabrication
A4 Transport to project site
A5 Construction and installation process
B1 Use
B2 Maintenance
B3 Repair
B4 Replacement
B5 Refurbishment
B6 Operational energy
B7 Operational water
C1 Deconstruction and demolition
C2 Transport to disposal facility
C3 Waste processing
C4 Disposal
D Reuse, recovery, recycling potential

The different life-cycle stages presented above are affected in different ways in city and national policy efforts to set targets and reduce emissions in the building and construction sectors. We therefore utilise two conceptual approaches to analyse policies and actions taken that are relevant on WLC in cities, a project/development-based approach and a whole-of-city approach.

Project/development based approach

These are approaches that set direct performance thresholds for embedded and operational carbon, often as requirements for construction or development applications. Usually these thresholds are determined by national laws, although in some cases more stringent requirements can be set for certain area developments through by-laws. The investigated cities apply different WLC approaches, covering different stages of the A1-C4 LCA, as illustrated above.

Whole-of-city approach

This pertains to a set of potentially coordinated policies that cover all relevant steps in the production and use of a building, all of which effectively impact the WLC of buildings.

Step 0: Planning and pre-decision (underlying trends and developments)

Step 1: Products (materials)	A1 A2 A3
Step 2: Transport	A4
Step 3: Construction	A5
Step 4: Maintenance and replacement	B1 B2 B3 B4 B5
Step 5: Operation	B6 B7
Step 6: End-of-life	C1 C2 C3 C4

KEY REFLECTIONS

Cost implications of WLC limits

A quickscan of research has found that:

Increased material costs contribute only partially to project costs. Material and labour typically account for 40-50% of total construction costs in Europe. Therefore, a 5% increase in material costs would only lead to a 2.5% rise in the total development cost. However, unexpected additional material costs (e.g. due to supply-chain disruptions) are likely to lead to disruptions.

Early implementation and clear standards are crucial to avoid delays and cost overruns. When sustainability requirements are clear from the beginning of a project, it is possible to avoid negative impacts on housing construction speed and affordability. Offloading these standards late in the process onto contractors, who have slim profit margins, is more likely to cause issues.

Low-carbon material substitutions and efficient design can significantly reduce emissions with minimal cost impact. A study in Toronto showed that significant carbon reductions (26%) were achievable with negligible effects on cost. Furthermore, innovative, efficient designs that use less material can lower both costs and carbon emissions.[9]

The cost impact of stricter regulations varies by region and implementation strategy. In France, new carbon regulations reportedly increased construction costs by 10-20% and slowed demand.[10] Conversely, evidence from the UK and a Toronto case study suggest that with the right approach, such as distributing costs among all stakeholders and focusing on high-impact material changes, the financial burden can be minimal.

Increased design fees for sustainable buildings have a minor effect on total project costs. Even a significant 25% increase in technical design fees would only translate to a 0.6-1.3% increase in total project costs, factoring in land and other expenses.

SHOWCASE: BUILDING AFFORDABLE HOUSING WITH LOW-CARBON MATERIALS

The general affordability of lower-carbon construction approaches such as biobased building is showcased by various projects, for example the Valckensteyn apartment block in Rotterdam, the Netherlands. This building is mainly constructed using cross-laminated timber (CLT) and achieved an MPG (environmental performance score) of under 0.5.* To make building with biobased or 'environmentally friendly' materials more attractive, the Dutch government provides various subsidies. This project made use of a profit tax deductible called the environmental investment deductible (milieuinvesteringsaftrek), which in view of the below-average MPG score gave the developer a €1.3 million deduction on taxable profits.[11]

In the Netherlands, some early indications suggest that building with biobased materials can be cost-competitive: the AEDES network of housing corporations indicates that of the total number of buildings built in 2023, 8% were built with wood.[12] When compared to 'business as usual' concrete-based building, the costs for the wood-based building (timber frames) were €2455 per square metre compared to €2708 per square metre for concrete-based developments. Furthermore, interviews with stakeholders have suggested that if the demand scales, pre-fabricated biobased construction can turn out to be cheaper than 'business as usual'.

THE SHORT-TERM VERSUS LONG-TERM VIEW ON AFFORDABILITY

Interventions on operational emissions: Setting a requirement for landlords to perform expensive energy efficiency upgrades could lead them to raise rents, potentially displacing low-income tenants (a 'retrofit-rent spiral'). Similarly, other instruments like carbon taxes can disproportionately affect lower-income households. To summarise: there is the risk of landlords passing on higher costs resulting from carbon limits and legislation directly to the tenants.

Follow on the next page >

** Valckensteyn, 2024. https://www.waal.nl/projecten/valckensteyn/ The MPG (Milieu-Prestatie Gebouwen) expresses a building's environmental impact in euros per square metre of gross floor area per year, based on the life-cycle of its materials. A lower MPG score means better (more sustainable) environmental performance.*

However, these negative impacts are not inevitable and can be managed by means of counteracting or balancing policy interventions. For example:

- **Tenant protection.** Retrofit subsidy programmes for landlords can be tied to rent stability requirements to protect tenants.
- **Carbon dividends.** Revenue from carbon taxes can be returned to the public, especially low-income households, through rebates, offsetting the financial burden.

Conversely, a more efficient heating and cooling balance for homes implies that there are benefits which may counteract cost increases:

- **Direct savings for tenants.** Energy-efficient upgrades lead to lower monthly utility bills. This can offset a modest rent increase, potentially leaving tenants with more disposable income. Regulations will have to ensure that this balance is achieved.

Finally, the cost of inaction on climate change – through rising insurance premiums and property damage – also poses a significant long-term threat to housing affordability for everyone. To account for the cost of inaction, it is important to shift the view on the cost implications of more stringent carbon regulations towards the whole life of a building as well – in the same way that carbon accounting considers emissions across the entire life cycle. One option might be whole-life costing approaches. Whole-life costing is a method that calculates the total cost of a building over its entire lifespan, not just the initial construction price. This approach looks beyond the upfront expense to include all future lifetime costs, such as energy, maintenance, repairs and eventual demolition. By taking this broader view, it becomes clear that investing more at the beginning in durable materials and energy efficiency can lead to significant long-term savings and a more valuable building.

01
WLC strategies from four leading cities

INTRODUCTION & GENERAL TRENDS

In this section, we present several key lessons and trends based on a comprehensive review of WLC-related policies and experiences in Helsinki, Oslo, Toronto and Vancouver, with additional insights into policies in Stockholm and the Pacific Coast Collaborative (PCC). These are summarised case examples of different approaches to whole life carbon (WLC) limits and policies.

A successful strategy for reducing WLC is not about a single policy but an ecosystem of reinforcing actions. To summarise, these are some of the more important commonalities between the cities:

Table 1. *General trends highlights.*

	Present a way forward that has clear phases and objectives Virtually every successful city has adopted a gradual, phased approach to implementation. This often starts with voluntary standards, pilot projects or reporting-only requirements before moving to mandatory limits.
Toronto	The Toronto Green Standard (TGS) is the key 'standard' to follow here, with its tiered system, where voluntary tiers are incentivised and eventually become the mandatory baseline in predictable four-year cycles. This gives the industry a clear roadmap for future requirements.
Vancouver	Vancouver began with low-stakes, reporting-only mandates for embodied carbon around 2017 before implementing lenient limits in 2023, allowing the industry to build capacity and understanding.
	Use the municipality's unique position and power to drive adaptation and innovation Cities that can exert direct influence through land ownership and procurement have a powerful tool to use. By setting high standards for their own projects, they create initial demand for low-carbon materials and construction practices, de-risking innovation for the private sector.
Helsinki & Stockholm	With 60% and 70% land ownership respectively, Helsinki and Stockholm can impose stringent environmental conditions on developers through, for example, land leases, creating a strong incentive to comply.
Oslo	Controlling 20% of the value in the local construction market, Oslo has used its procurement power to mandate zero-emission machinery and prioritise suppliers with the lowest overall carbon materials. This was supported by a near-doubling of procurement staff to manage the process effectively.
	Communicate affordability and combat false assumptions of cost increase While studies show that significant carbon reductions can be achieved with minimal or no increase in total project costs, the perception of high costs is the most significant source of industry and political resistance.
Vancouver	Despite data showing potential cost savings, strong pushback from the high-rise concrete sector over cost neutrality concerns forced the city to delay its initial 10% reduction target in order to gather more real-world examples. This demonstrates that evidence alone is not always enough to overcome industry opposition.
Oslo	Interviewees noted that opponents can exploit the high percentage cost increase of a single green material (like low-carbon concrete) to argue against a policy, even if its impact on the total project budget is small.

LACK OF INFORMATION ON SOCIAL AND ENVIRONMENTAL EFFECTS OF PROPOSED LIMITS

A significant and recurring theme is that because these policies are relatively new, there is a major gap in understanding their long-term effectiveness and unintended consequences.

Deficit in understanding social and environmental impacts

In our literature review, we have found that limited published literature exists on the social impact of WLC policies. Key questions about equity, affordability for residents, effects on local employment and impacts on biodiversity remain largely unanswered by empirical data. In Section 4 of this report, we present the social impact framework, which is a conceptual tool to begin assessing these factors.

	Establish a single reference point through common data, tools and standards A lack of consistent, reliable data on embodied carbon is a universal challenge. Successful cities invest in creating a supportive ecosystem with standardised tools, clear guidelines and accessible data like Environmental Product Declarations (EPDs).
Vancouver	The city's development of standardised guidelines and reporting templates was described as 'crucial for progress' and proved so effective that they were adopted nationally, simplifying compliance for the industry.
Stockholm	IProgress is built upon a government-backed national research programme that created a common framework for calculations, which the city can then use as a baseline to set more ambitious local targets.
	Collaborate Cities do not act in isolation. They must align with regional and national bodies to make local policy stronger and to reduce market confusion.
PCC	This partnership between states, a province and major cities uses a shared 'menu' of actions on embodied carbon. By acting as an economic bloc, the PCC aims to move the global market, accelerating the transition to low-carbon materials.
Oslo	The city has faced legal hurdles trying to enforce local requirements that are stricter than Norway's national building code.

Table 2. *Lack of real-world results highlights.*

	Lack of real-world results Many policies have been implemented too recently for a substantial number of projects to be completed under the new rules.
Helsinki	In Helsinki, a recession slowed construction, meaning very few buildings have been completed under the new carbon limit, resulting in a shortage of real-world data on the policy's impact.
Vancouver	In Vancouver, the city had to delay its mandatory reduction target specifically to 'gather solid examples from actual projects' to prove to the industry that reductions could be achieved without increasing costs.

AN OVERVIEW OF WLC STRATEGIES PER CITY

Helsinki, Finland

Action on the national level: Finland

Finland's new Building Act came into effect on 1 January 2025. The values in the above table are still labelled as preliminary: the Building Act introduces climate change mitigation into construction law, emphasising carbon reduction throughout a building's life cycle. Implementation will occur through decrees under the act, including regulations on climate declarations, building product reporting and carbon footprint limits, which will be part of Finland's national building code.[13]

The essential technical requirement for low-carbon buildings mandates that new constructions should be designed and built with low-carbon principles suited to their intended use. Developers must provide a climate report detailing the carbon footprint and handprint of the building and site. Finally, certain projects will also require a list of building products used. Additionally, new buildings must stay within carbon footprint limits set for their specific category. [14]

Table 3. *Limit values for Finland.*[15]

Building type	Limit value 2026–2027 (kg $CO_2e/m^2/a$)	Stricter limit value from 2028 (kg $CO_2e/m^2/a$)
Terraced houses and apartment blocks	16	14
Office buildings and health centres	20	18
Commercial, retail, department stores, theatres, concert halls, congress centres, cinemas, libraries, archives, museums, art galleries and exhibition halls	22	20
Accommodation buildings, hotels, hostels, service houses, nursing homes and care institutions	25	24
Educational buildings and childcare centres	20	18
Sports halls	21	20
Hospitals	29	28
Warehouse and transport buildings (heated net area > 1000 m^2), (indoor) swimming pools and indoor ice rinks	24	22

Helsinki, Finland

0. SUMMARY OF POLICY GOALS AND TARGETS

a. General strategy for Helsinki

Helsinki is implementing the following strategy to reduce carbon emissions across a building's entire life cycle:

- The city is facilitating the development of national life-cycle assessment tools and setting stricter energy efficiency and carbon footprint criteria for new construction, while promoting the use of biobased materials such as timber and piloting low-emission concrete.
- For construction and transport, Helsinki is establishing models for emission-free construction sites and strengthening environmental criteria in all its procurement processes.
- Finally, for existing buildings, the focus is on energy-efficient renovations, improving energy monitoring, recovering heat loss and systematically exploring the use of renewable energy.

b. Specific WLC-related targets for Helsinki

Helsinki aims to be carbon-neutral by 2030 by reducing emissions by at least 80% from 1990 levels and compensating for the remainder, with a further goal of becoming carbon-zero by 2040.

- To achieve this, the city has set a mandatory WLC limit for new multi-storey apartment buildings of 14 kg CO_2e/m^2/a, which must be met to obtain planning permission in specific zones.
- This target covers emissions from materials, construction, energy use and end-of-life stages, with minor allowances for buildings with complex shapes or integrated parking garages (A1 - A5, B4, B6, C1-C4).

1. ACTION ON WLC: STEPS TAKEN

Initial research and data collection. Helsinki began by conducting an academic study to identify the biggest sources of emissions in a building's life cycle. For years, the city has performed life-cycle carbon calculations on its own projects, creating a central database to compare results and develop emission limits.

Using competitions to drive innovation. The city held competitions, such as the Verkkosaaren vähähiilinen viherkortteli (Verkkosaari's low-carbon green block), in which designs were weighted 50% for architectural merit and 50% for sustainability and carbon footprint. This proved that low-carbon construction was feasible, with one winning design achieving a footprint of just 5 kg CO_2/m^2/a.

Engaging the private sector. Following the competitions, Helsinki held dialogue sessions with the Finnish Ministry of the Environment, academic experts and 150 business representatives to discuss feasibility and costs before setting mandatory limits.

Evolving carbon targets. Initially, a limit of 16 kg/m^2 was set. This was later reduced to 14 kg/m^2, after the city's district heating became cleaner due to the decommissioning of a coal plant.

Influencing national policy. Helsinki's policies have not posed major problems so far, leading the Finnish national government to adopt a similar carbon emissions limit, a move that construction companies have praised for its flexibility.

Helsinki, Finland

2. KEY ENABLERS (factors or context with positive influence)

Significant control over land. Helsinki has a substantial influence on development because it owns 60% of its land and a large portion of its rental housing, allowing it to set conditions for construction through long-term leases.

Support from national regulations. The city's efforts are reinforced by national government regulations that already aim for a 50% reduction in concrete usage for infrastructure projects.

Cleaner energy and lower emissions. The city's operational emissions are decreasing as its district heating becomes cleaner, driven by EU carbon pricing. This is complemented by initiatives that help citizens improve energy efficiency. Strong internal leadership: The carbon reduction strategy was driven by key internal figures, specifically the climate director working in partnership with the planning department.

High levels of public trust and citizen investment. A culture of trust makes it easier for the city to implement new initiatives. Citizens, who own 60% of the residential building stock through housing companies, are actively investing in renovations such as heat pumps and solar panels, creating a market worth €300 million.

Strategic approach. Helsinki's success came from setting clear objectives based on research and dialogue, rather than forcing specific materials or methods. This empowered the industry to find its own innovative ways to meet the city's climate goals.

3. KEY DISABLERS OR CHALLENGES (factors or context with negative influence)

High costs and general economic status. High material costs and a recession have slowed down construction, so very few buildings have been completed under the new carbon limit. This means there is little real-world data on how the policy is working.

Low material availability. When the city first required low-emission concrete, local suppliers were not available, and the materials had to be imported.

Relatively lenient target level. The current carbon target is not very demanding and can be met with normal construction methods. The main goal for now is to ensure companies become familiar with the process of calculating emissions.

Renovation and efficiency improvements for current stock. It is difficult to apply strict carbon regulations to existing buildings because this affects homeowners' personal finances and property rights.

Low awareness of current limit. The carbon limit policy is not well known among the public or even some city employees, and there has been little public discussion about it.

Focus on other issues around development. The public is often more focused on other development issues, such as protecting nature and biodiversity, than on the carbon footprint of new buildings.

4. FUTURE DEVELOPMENT OF ACTIONS

Emissions in non-material manufacturing stages. While emission-free sites are targeted, their contribution to overall reductions within a 50-year timeframe is relatively small. Reporting and further consideration are necessary, but Helsinki is prioritising the use of low-carbon concrete and focusing on building components with higher reduction potential that could be more impactful.

Oslo, Norway

Action on the national level: Norway

Even though Oslo has incredibly ambitious emission reduction targets, setting national limits for WLC emissions has been delayed in Norway due to the relatively slow implementation of regulations within the Norwegian building code (TEK17). Mandatory reporting of embodied carbon emissions was only introduced in 2023, covering life-cycle modules A1-A5 (production and construction stages), B2 (maintenance), and B4 (replacement). The Norwegian building and construction industry has been advocating for stricter regulations on embodied carbon emissions within the national building code.[16]

0. SUMMARY OF POLICY GOALS AND TARGETS

a. General strategy for Oslo

The City of Oslo is tackling carbon emissions in the construction sector through a life-cycle-based strategy integrated into its governance model with a dedicated 'climate budget':

- Oslo mandates the use of low-emission and reused materials while progressively requiring construction sites to become first fossil-free and ultimately zero-emission.
- To drive this transition, the city offers financial incentives to businesses for electric machinery and to citizens for energy-efficiency upgrades such as solar panels.
- This entire effort is supported by strong collaboration with industry, for example opting to work with manufacturers to develop electric machinery, using demo or customised machines first.

b. Specific WLC-related targets for Oslo

The city aims for all buildings, both new and old, to meet net-zero carbon standards by 2050. For new buildings and major retrofits, Oslo will strive to reduce embodied emissions by at least 30% by 2025, increasing this to a 50% reduction by 2030.

- The city aims for all buildings, both new and old, to meet net-zero carbon standards by 2050. For new buildings and major retrofits, Oslo will strive to reduce embodied emissions by at least 30% by 2025, increasing to a 50% reduction by 2030.
- The city also aims to reduce embodied emissions from all infrastructure projects by at least 50% by 2030 and will procure only zero-emission construction machinery starting in 2025.

Oslo, Norway

1. ACTION ON WLC: STEPS TAKEN

Just get started. A key takeaway is the importance of taking action even without perfect data. Implementing impactful measures immediately is considered more effective than waiting for complete, quantified impact data before beginning.

Set an ambitious overall goal. The strategy began by establishing a clear, high-level target of reducing the city's total emissions by 95% by 2030.

Pilot solutions on a small scale. Oslo initiated its efforts by requiring sustainable biofuels in a small number of municipal projects. This allowed the city to test new methods and technologies without causing major market disruption while paving the way to emission-free construction sites.

Address market concerns through collaboration. In the pilot phase, the city directly addressed construction businesses' primary concerns. It mitigated investment risks by offering guaranteed rentals of new electric machinery and covering the electricity costs to lower the financial burden of transitioning from diesel.

Scale up from pilot to standard practice. After the successful pilot programmes, the use of biofuels became the norm for all municipal construction projects. Oslo then adjusted its procurement strategy to require zero-emission electric technology, signalling a clear direction to the market.

Focus on high-impact materials. Moving on from emission-free construction sites, Oslo's strategy is starting to prioritise reducing embodied carbon by concentrating on a few key material groups (such as concrete and steel) that account for the majority of a project's emissions, making reductions easier to measure and achieve.

Use procurement as a powerful tool. Procurement became the key mechanism for change. Oslo made zero-emission machinery mandatory in tenders and now uses competitive bidding where suppliers compete to provide the lowest overall carbon score for a set of materials, rather than setting rigid per-material targets.

Establish baselines and clear requirements. To avoid risks associated with purely carbon-based bidding (like excessively high costs per ton of reduced CO_2), Oslo is moving toward setting standard baseline requirements that all bidders must meet, ensuring a level playing field and predictable outcomes.

2. KEY ENABLERS (factors or context with positive impact)

Using procurement and market share. Oslo uses its significant market influence, controlling about 20% of the local construction market, to push the industry forward. The city has nearly doubled its procurement staff and works with businesses to create policies. In its contracts, Oslo prioritises environmental performance over the lowest price and financially supports contractors in their transition to zero-emission machinery.

Internal collaboration and political will. A strong coalition within the city's government, unified by the 'climate budget' integration, is the driving force behind the city's ambitious agenda. This approach ensures that well-developed proposals are presented to political leaders who have shown consistent agreement on positioning Oslo as a climate leader.

Ambitious and specific emission targets. The city has set climate goals that are stricter than national standards. This includes a specific target to reduce the emission intensity of building materials used in its own projects by 30% annually. Furthermore, Oslo set a goal of achieving 50% zero-emission energy use in all developments by 2025, with a target of 100% by 2030.

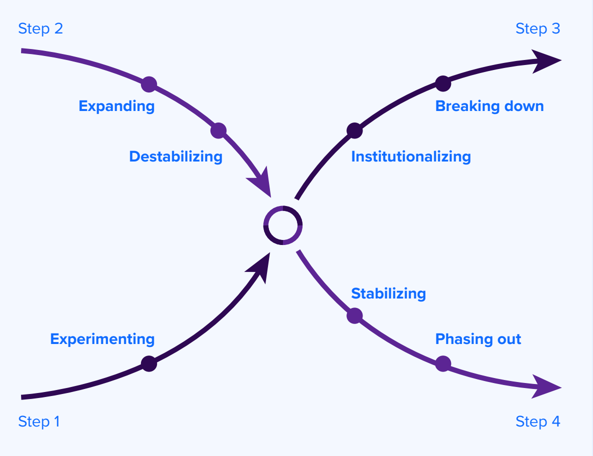
Cost-effectiveness of zero-emission construction. Contrary to initial concerns, the transition to electric equipment has not led to significant price increases. The total cost of ownership for electric machinery is competitive with traditional fossil-fuel equipment, and these costs are expected to decrease as production volumes grow.

Oslo, Norway

Framing policy progress in the case of Oslo's zero-emission sites

Framing the systemic transformation of the building and construction sector to become carbon-neutral through the X-Curve.[17]

This example of how the X-Curve by DRIFT can be used to explain and understand how to make a lasting impact with your policy efforts, is based upon the approach taken by Oslo to transform its construction sites to become zero-emission or emission free. Taking the life-cycle view of a project, this effort has a direct impact on the emissions from step A5: Construction and Installation Process.



Step 1
EXPERIMENTATION ((building the new system)

Start with a smaller-scale pilot and involve market actors early on to understand concerns and build critical mass. Start the pilot where conditions are beneficial – for example somewhere where the power grid is ready to power electric machinery.

Step 2
ACCELERATION AND EMERGENCE (building the new system) + **DESTABILISATION** (removing the old system)

Clearly signal intent and provide indicators of the path forward: commit to a goal and outline the path towards that goal and the role construction plays in it. Build public support by showing the advantages of the new approach over the old one. Start building the infrastructure around the new approach: e.g. zero-emission construction sites will need sufficient power or renewable energy to truly achieve their goal. Start pushing for regulatory changes on the national and international level

Step 3
INSTITUTIONALISATION (building the new system) + **BREAKDOWN** (removing the old system)

Use the power of public procurement to establish the practices you want to see, and first expand the pilot or practice through projects under public control, slowly but steadily allowing the market to adapt. Require national legislation to be adapted to the needs of zero-emission construction.

Step 4:
Stabilisation (building the new system) + **PHASE OUT** (removing the old system)

After market adaptation has been achieved and the existence and benefits of clean construction sites have become public knowledge, scale the requirements to all private projects as well, consolidating the practice for the whole city.

Oslo, Norway

3. KEY DISABLERS OR CHALLENGES (factors or context with negative influence)

Challenges related to national legislation. A significant hurdle for Oslo is the uncertainty within national laws, which can make it difficult to enforce the city's strict climate requirements on private construction projects. This is because the city's requirements are often stricter than Norway's national building code (TEK17), creating legal challenges. Clearer national mandates are needed to boost confidence in future developments in the market.

The real vs perceived cost of green materials. Using low-carbon materials adds only a small amount – a few percentage points – to a total project's budget. However, some pushback arises from focusing on the price increase of individual items, such as low-carbon concrete, which appears much more expensive than its standard alternative. This is then used to argue against green investments, even though the overall financial impact is minimal.

4. FUTURE DEVELOPMENT OF ACTIONS

Including infrastructure projects. In retrospect, a key lesson for Oslo was that not including infrastructure projects in initial emission targets was a missed opportunity. The city now recognises that managing the entire portfolio, including infrastructure, is the logical next step.

Toronto, Canada

Action on the national level: Canada

At national level, Canada is looking to include concrete targets for operational GHG emissions in its 2025 revision of the national model building codes.[18] At the time of writing, more ambitious carbon targets can often be found at provincial or city level.

The Government of Canada's Standard on Embodied Carbon in Construction requires federal organisations to disclose and significantly reduce the carbon footprint of major building projects. The policy mandates that final project designs achieve a 30% reduction in embodied carbon, verified through whole-building life-cycle assessments (it is however unclear to which baseline this is compared). For key materials such as concrete and steel, contractors must provide Environmental Product Declarations (EPDs) and meet specific emission reduction targets. Exemptions are possible for performance or availability issues.

0. SUMMARY OF POLICY GOALS AND TARGETS

a. General strategy for Toronto

Toronto's strategy to achieve net-zero emissions in buildings starts with mandating near-zero emissions for all new construction by 2030 through the Toronto Green Standard:

- The city is tackling embodied carbon by studying and setting building level embodied carbon limits and promoting low-carbon alternatives.
- Toronto is first introducing new standards and requirements for its own municipal buildings, making sure that new constructions meet rigorous green standards while also retrofitting existing buildings.
- To address emissions from current buildings, the city will transition from voluntary programmes to mandatory performance reporting and support financing for energy-efficient upgrades.
- The plan also includes phasing out natural gas and expanding renewable energy systems to achieve its climate targets.

b. Specific WLC-related targets for Toronto

Toronto has set city-wide goals to cut greenhouse gas emissions, aiming for a 65% reduction by 2030 and achieving net zero by 2040.

- The primary tool for new construction is the Toronto Green Standard (TGS), which sets sustainable design requirements using a tiered system. While Tier 1 is currently mandatory, tiers 2 and 3 are voluntary but encouraged with financial incentives.
- The TGS is regularly updated, which is when, over time, the previously voluntary tiers become the new mandatory Tier 1. This creates a clear roadmap for the construction industry to adapt to progressively stricter standards. This approach applies to both operational carbon (energy use) and, increasingly, embodied carbon (emissions from materials, now linked to phases A1-A3 or A5).

Toronto, Canada

1. ACTION ON WLC: STEPS TAKEN

Collaborative start. The process began by creating a voluntary standard and involving the construction industry from the beginning. Major developers and associations were consulted and supported the adoption of the Green Standard: there was market buy-in.

Phased-in mandatory requirements. Toronto gradually made basic green standards mandatory while offering financial incentives, such as development charge rebates, for projects that voluntarily adopted higher, more ambitious tiers of performance.

Clear long-term goals. The city created a clear roadmap with long-term goals, such as reaching net-zero emissions by 2040. This gave the market confidence to invest in green technologies and materials, knowing there would be future demand.

'Stepped pathway' evolution. The standard is designed to become stricter over time. In four-year cycles, the requirements of the formerly voluntary tiers become part of the new mandatory baseline, progressively raising the minimum standard for all new construction.

Research and benchmarking. The strategy is built on a foundation of research, including quantifying embodied carbon and setting benchmarks based on specific building types. This data-driven approach ensures the standards are effective and practical.

Leading with public projects. Toronto first implemented stricter standards, including life-cycle assessments (LCAs) and embodied carbon caps, on its own publicly-owned buildings. This helped to create a local ecosystem for low-carbon construction before the requirements were extended to the private sector.

National collaboration. Toronto's efforts are aligned with and supported by national organisations such as the Canada Green Building Council (CGBC), which helps to standardise tools, processes and the availability of Environmental Product Declarations (EPDs) across the country.

2. KEY ENABLERS (factors or context with positive influence)

Strong political support. The Toronto Green Standard benefits from strong, consistent support within the city council and the Mayor's Office, with the main focus being on how and when to best implement stricter standards, not whether to have them.

Strategic use of city land. The city's ownership of key plots of land, such as in the Waterfront Toronto project, provides a direct way to pilot and implement advanced green building policies.

Collaboration with companies. The private sector is an active partner in the transition. Architects have formed their own coalitions to push for change, working directly with manufacturers to increase the availability of EPDs, which are essential for measuring embodied carbon.

Minimal cost impact. While energy-efficient homes can cost slightly more upfront (an estimated 2-4%), this increase is small compared to that caused by factors such as inflation and interest rate fluctuations. The costs are expected to decrease over time and are offset by long-term utility savings for residents, improving affordability.

Early results

Green standards have not resulted in a housing slow-down. In 2023, Toronto exceeded its housing targets by 51%, with nearly 96% of housing starts being subject to the Toronto Green Standard. Overall, Toronto's housing starts have grown or stayed consistent nearly every year since the TGS was implemented.[19]

Toronto, Canada

3. KEY DISABLERS OR CHALLENGES (factors or context with negative influence)

Prioritising building more homes over green standard implementation. Even when new green standards were found to add minimal cost and were already being met by many developers, the city council chose to delay implementation. The priority was to streamline procedures and accelerate the speed of housing construction, viewing new regulations as potential administrative burdens.

Pushback from industry. Construction industry groups such as RESCON have actively resisted the trend of municipalities adopting stricter sustainability standards. They argue that these regulations make construction more difficult and conflict with the goal of building homes quickly and at a lower cost.

4. FUTURE DEVELOPMENT OF ACTIONS

Need for standards adapted to diverse typologies. The current system using a single, absolute cap for embodied carbon doesn't work well for non-standard or industrial buildings (e.g. water treatment plants). The proposed solution for Toronto would be to create a more flexible system that requires a certain percentage of improvement over a 'reference' or baseline building, a method already used in Vancouver. This would allow a wider variety of building types to comply and still achieve meaningful carbon reductions.

Lack of reliable emissions data. A Transitioning to a single target: The city plans to move from the current system of individual carbon goals for each of its housing companies to a single, unified target.

Vancouver, Canada

Action on the national level: Canada

At national level, Canada is looking to include targets for operational GHG emissions in its 2025 revision of the national model building codes. At the time of writing, more ambitious carbon targets can often be found at provincial or city level.

The Government of Canada's Standard on Embodied Carbon in Construction requires federal organisations to disclose and significantly reduce the carbon footprint of major building projects. The policy mandates that final project designs achieve a 30% reduction in embodied carbon, verified through whole-building life-cycle assessments (it is however unclear to which baseline this is compared). For key materials such as concrete and steel, contractors must provide Environmental Product Declarations (EPDs) and meet specific emission reduction targets. Exemptions are possible for performance or availability issues.

0. SUMMARY OF POLICY GOALS AND TARGETS

a. General strategy for Vancouver

Vancouver is implementing its strategy to reduce carbon emissions from building materials through new policies and building code updates.

- The city is establishing standardised baselines and phased-in reduction targets for embodied emissions in new construction, aiming for a 40% reduction by 2026 and even deeper cuts by 2030.
- Key actions include requiring whole-building life-cycle assessments (LCAs), promoting the use of low-carbon materials such as mass timber and incentivising developers who adopt sustainable practices.
- Furthermore, Vancouver's plan addresses the entire building life cycle by encouraging sustainable sourcing, supporting zero-emission construction sites and promoting deconstruction and material reuse.

b. Specific WLC-related targets for Vancouver

Vancouver has established a number of greenhouse gas reduction goals, aiming for all new construction to be zero-emission by 2030 and specifically targeting a 40% reduction in embodied carbon from a 2018 baseline.

- To enforce this, the city has amended its building by-law to require an LCA for nearly all new buildings, from large commercial and residential towers to small homes and public facilities (A1-C4).
- The regulation sets a baseline embodied carbon intensity (ECI) of 400 kg CO_2e/m^2, which is then multiplied by a reduction factor to determine the specific target for each project, ensuring measurable and enforceable emission cuts.

Vancouver, Canada

1. ACTION ON WLC: STEPS TAKEN

Phased and predictable policy. Vancouver's Zero Emissions Building Plan (ZEBP) uses a gradual approach, updating its building by-law every five years to predictably tighten emission limits (GHGI and TEDI) for new buildings, providing regulatory certainty on the path to its 2030 zero-emissions target.

Strong local leadership. The city's local policy innovations, including the ZEBP, have directly influenced and helped shape higher-level regulations, such as the province-wide BC Energy Step Code, by demonstrating feasibility and aligning standards.

Economic benefits. Focusing on a green economy, particularly in the building sector, has driven major economic growth, creating a 53% increase in green building jobs between 2010 and 2016 and generating significant annual savings for residents.

Gradual implementation. The city introduced embodied carbon requirements strategically, starting with low-stakes reporting-only mandates around 2017 before implementing lenient limits in 2023 to ease the industry into the new regulations.

Tools and national alignment. Developing standardised guidelines and reporting templates was a key enabler, reducing the burden on both the industry and the city. These tools proved so effective that they were adopted nationally by Canada's National Research Council.

2. KEY ENABLERS (factors or context with positive influence)

Unique regulatory authority. Vancouver has significant control over its land use, zoning and building standards through its own unique building by-laws within British Columbia.

Outcome-focused policy. The city's strategy emphasises setting clear, medium-term targets (such as a 40% emissions reduction by 2030) and collaborating with stakeholders, allowing the industry flexibility on how to achieve these goals.

Industry collaboration and capacity building. Vancouver works closely with the construction industry through consultations, capacity building and incentive programmes for early adopters to ensure targets are achievable and to identify and remove regulatory barriers.

Leading by example. The city uses its own building projects and procurement processes to pilot new standards, identify challenges and demonstrate the viability of zero-emission construction.

Effective engagement. Key enablers of success include providing standardised guidelines and templates and using real-world project examples from incentive programmes to build industry confidence and buy-in.

Strategic management of costs. To address cost concerns, the city's approach prioritises design efficiency as a first step in reducing embodied carbon (reducing material intensity overall).

Early results

In a study on possible reductions in embodied carbon for Vancouver, material costs for different building design options were assessed to evaluate the financial impact of various strategies for reducing embodied carbon. These costs were compared to a baseline design reflecting typical construction practices. In most cases, the adoption of embodied carbon reduction measures led to material cost savings rather than increased expenses.[20]

Embodied carbon reduction strategies led to significant cost savings across residential building types. High-rise designs saw 2-20% savings, mid-rise designs achieved up to 10% and low-rise designs saved up to 25% compared to a 2018 baseline. Cost-neutral solutions, such as higher SCM concrete mixes and EPS roof insulation, provided notable carbon reductions. Precast concrete panels offered the highest cost savings (19%) for high-rise buildings, while timber-frame construction delivered the greatest impact for mid-rise buildings, with over 15% savings and a 70% reduction in embodied carbon.[21]

Vancouver, Canada

3. KEY DISABLERS OR CHALLENGES (factors or context with negative influence)

- Initial reporting-only requirements for embodied carbon were met with minimal resistance as the industry grew accustomed to the concept. However, significant pushback emerged when mandatory reductions were proposed, led primarily by the high-rise concrete sector, representatives of which were concerned that a 10% reduction would not be cost-neutral.
- To address these cost concerns, the city's strategy focused first on design efficiencies – the 'low-hanging fruit' – which can lower construction costs, rather than immediately forcing material swaps, which are often perceived as more expensive.
- Recognising that developers find real-world projects more convincing than theoretical models, the city delayed the mandatory 10% reduction. The goal is to first gather solid examples from actual projects to prove that significant carbon reductions, potentially of up to 20-30%, can be achieved without increasing costs.

4. FUTURE DEVELOPMENT OF ACTIONS

- Active collaboration with industry is ongoing to find case studies and build consensus.
- Delays in initial reduction steps risk compressing the timeline to meet the 2030 target.

Additional insights:

Stockholm, Sweden

Action on the national level: Sweden

Since January 2022, Sweden has required a **climate declaration** for all new buildings, which reports the embodied greenhouse gas emissions from the construction phase (specifically, modules A1-A5 of the life cycle).

The government plans to introduce mandatory limit values for this embodied carbon. However, this process has been delayed due to upcoming EU regulations and is now not expected to be introduced before 2030.

1. ACTION ON WLC: STEPS TAKEN

Focus on materials and construction. Due to Stockholm's largely low-emission energy and heating systems, the majority of the built environment's climate impact comes from the production of materials and the construction phase itself.

National collaboration and industry leadership. A national initiative called Fossil-Free Sweden unites various sectors, including construction, to create roadmaps for carbon neutrality. This has fostered a collaborative environment where construction companies are now often leading the charge in developing low-emission solutions.

Leverage through land ownership. Because the city owns 70% of the land, it can impose specific environmental and construction requirements on developers who want to build in attractive, economically viable locations, creating a strong financial incentive for compliance.

Strong social and corporate pressure. A widespread understanding of the climate crisis in Sweden has created a culture where companies are expected by owners and customers to have strong sustainability plans and deliver results, making greenwashing practices socially unacceptable.

Anticipation of EU legislation. Upcoming EU directives act as an external driver for progress. By adopting more stringent policies now, Stockholm gains a competitive advantage and a smoother learning curve, which prepares the city well for future regulations.

Development of tools. The city is actively exploring new planning tools, such as Spacescape, to better visualise and measure the climate impact of urban development projects during their initial stages.

Consistent political and societal will. There is broad political consensus and strong societal support for maintaining ambitious environmental goals, which have become integral to the city's identity. This has allowed for a consistent focus on sustainability, including embodied carbon, regardless of shifts in political leadership.

Stockholm, Sweden

2. KEY ENABLERS (factors or context with positive influence)

Pioneering with pilots. Stockholm utilised the high-profile Royal Seaport project to test the limits of low-carbon construction. It implemented transparent, mandatory energy targets for new buildings, using public reporting on results as a dynamic to drive developer performance.

Building a national knowledge base. Progress is built on a government-backed national research programme, which collaborated with housing companies to develop shared knowledge and calculations. This informed the creation of a common national framework, which the city can then use as a baseline to set even more ambitious local targets.

Integrating goals into local strategies. The city's public housing companies are actively adopting the national findings to create their own step-by-step strategies for becoming fossil-free. This effort is supported by regional climate networks that bring together municipalities and businesses to share knowledge specifically on reducing construction emissions.

The city prioritises implementing changes within its own residential housing companies first, ensuring a cost-effective approach. The focus has evolved from simply advocating for specific materials (like timber) to more impactful strategies, such as prioritising building renovation and material reuse over demolition and new construction.

Maintaining industry contact. To ensure regulations are feasible, Stockholm maintains constant communication with industry players, giving them opportunities to provide feedback on upcoming requirements. This ongoing discussion aims to balance ambitious political climate goals with the economic realities of the sector, particularly the need to maintain housing affordability.

3. KEY DISABLERS OR CHALLENGES (factors or context with negative influence)

Cost and affordability concerns. There is a significant and ongoing concern that mandating low-carbon construction will increase housing costs. Arguments brought forward in this debate include the higher price of sustainable materials such as zero-emission steel, and potential trade-offs, such as timber construction leading to thicker walls and therefore less usable floor area.

City-wide movement of the targets might be challenging. The delay of introducing Sweden's national carbon requirements from 2027 to 2030 has created uncertainty for Stockholm. This postponement makes it challenging for the city to set its own firm targets, as there is a real concern that moving too quickly could place an excessive financial burden on developers and negatively impact housing affordability.

4. FUTURE DEVELOPMENT OF ACTIONS

Transitioning to a single target. The city plans to move from the current system of individual carbon goals for each of its housing companies to a single, unified target.

Phased implementation. This common goal will be rolled out in phases, starting with the city's own building stock and later expanding to include private developers who are building on city-owned land.

Target-setting across different typologies. The process is taking time because establishing appropriate and fair carbon reduction goals requires careful consideration of different building typologies, as the carbon footprint of a school, for example, is different from that of a residential building.

Additional insights:

Pacific Coast cities, USA

1. ACTION ON WLC: STEPS TAKEN

San Francisco is in a stage of implementation and advancement. The city has a policy requiring whole-building life-cycle assessments (LCAs) for its municipal projects. The introduction of the state-wide California Green Building Standards Code, also known as CALGreen, enforced since July 2024, has been politically beneficial, providing a baseline that San Francisco is now working to align with and exceed.[22]

Portland and Oregon (state) represent different stages of progress.

- **Portland** is currently in an exploratory phase. Although its Climate Emergency Workplan (2022-2025) included goals to reduce embodied carbon, according to interviewed representatives there has been 'zero implementation' on that front. Advocacy efforts are underway to begin implementation, possibly starting with new permits or city-led projects.
- **Oregon** (state) is in a phase between study and preparation. It possesses a 20-year consumption-based emissions inventory, which helps in understanding imported embodied carbon. However, there is not yet an explicit state greenhouse gas reduction goal tied to this data, though recommendations have been made to Oregon's legislature to formally include these emissions.

Colorado is also in a phase between study and preparation. The state has completed research in partnership with the National Buildings Institute (NBI) to develop carbon limits and a recommended goal. This goal is not yet public or finalised, as it is awaiting internal approval before the state proceeds with a broader industry consultation in Colorado.

2. KEY ENABLERS (factors or context with positive influence)

San Francisco: The city began its efforts by focusing on its own municipal projects. A key element of its strategy was leveraging California's state-wide CALGreen standards, which provided a foundational baseline. This allowed the city to shift its role from being a direct enforcer to a supporter, helping projects meet established state requirements. The city chose to implement its regulations through building standards rather than through zoning laws.

San Francisco:
Working with industry. San Francisco finds that many local construction companies are already ahead of the curve, so major industry pushback is not their most serious concern. To build support, the city holds meetings that bring industry leaders, community groups and officials together. A key goal is to make rules consistent across the region so it's less confusing for businesses.

Oregon (state): The state's strategy focuses on reducing the compliance burden for architects, developers and industry. This includes exploring policy concepts to require Environmental Product Declarations (EPDs) for materials sold in Oregon and using partnerships, education and incentives to encourage industry adoption. A successful three-year incentive programme resulted in the creation of 1,500 concrete EPDs. The state also utilises federal funds to incentivise low-carbon housing.

Portland: Portland's experience highlights the power of citizen-led action. Its original deconstruction law was successfully championed by citizens who framed it as a public-health issue focused on reducing hazardous waste. This suggests a potent political strategy: linking materials with low embodied carbon (which are often biobased with fewer VOCs) to the creation of healthier communities.

Colorado: Colorado's strategy centres on careful internal and external engagement. To convince internal leadership, the central argument was that initial standards could be met without adding cost to a project. Learning from past pushback, the state plans to consult with a large industry group for feedback on proposed standards before they are formally adopted. Colorado also emphasises the need for consistency with national codes and standards set by others (such as CALGreen), recognising that collaboration helps industry professionals who find it difficult to keep up with varying requirements.

The Pacific Coast Collaborative: PCC is a collaboration platform that includes the states of California, Oregon, Washington, the province of British Columbia and major cities. It facilitates a shared action plan on embodied carbon that functions like a 'menu'. Members are not required to adopt identical policies but can choose which actions to implement, allowing for flexibility across different jurisdictions.

Pacific Coast cities, USA

3. KEY DISABLERS OR CHALLENGES (factors or context with negative influence)

San Francisco

Winning political support. Getting politicians fully on board is a major challenge. The city argues that these policies create new, skilled jobs, but they admit that as yet they have little data to back this up, which makes it harder to secure funding for training workers.

Portland

State law obstacle and internal resistance. Portland faces a unique roadblock: a state law stops it from making its building codes stricter than Oregon's. This means the city has to find creative workarounds to push for change. Internally, there is resistance from city teams who have long focused on a building's energy use (from factors such as heating) and are concerned that adding complex rules about materials will distract from their original goals.

Oregon (state)

Lack of clear state-wide goals. The state is taking a data-driven approach, using reports to show that reducing carbon from materials is one of the most cost-effective ways to fight climate change. While useful data is available, clear state-wide goals to drive progress still need to be set.

Colorado

Internal hurdles. In Colorado, the biggest challenges are internal. Progress is often slowed by government red tape and trying to figure out how this new focus on materials fits with existing environmental policies.

Getting buy-in. To get government leaders and the construction industry on board with new policies, the main argument is that changes can be made without making projects more expensive. Learnings from past experience have led to plans to work closely with the construction industry from the start to get input and support before making any rules final.

4. FUTURE DEVELOPMENT OF ACTIONS

San Francisco's main goal is to go 'above and beyond' the CALGREEN baseline set by the State of California. They plan to do this by applying carbon-reduction rules to smaller buildings not covered by state regulations. This would increase the policy's impact from 40% of the city's construction projects to about 60%. However, making this happen will require more conversation and agreement with local community and industry groups.

Colorado is focused on a collaborative and smooth rollout. Having learned from past experience, their top priority is to work closely with the construction industry from the very beginning to avoid pushback. They are also considering pilot programmes and financial incentives to encourage companies to start adopting low-carbon practices voluntarily, even before new rules are officially in place. This approach emphasises that having consistent rules across different cities and states is crucial for the industry.

The Pacific Coast Collaborative (PCC)'s strategy is all about collaboration and market power. Their main goal is to send a strong, unified message to the region's entire construction industry. They are thinking about creating a shared carbon reduction target that all members – including California, Oregon, Washington and British Columbia – would agree to. By acting together as a significant economic bloc (which would be the world's fifth largest economy), they believe they can pressure the global market to move faster toward low-carbon building materials and methods.

02
Social impact framework

Measuring social impact when attempting to reduce carbon emissions in the built environment

A wide range of measures can reduce carbon emissions in the built environment, including:

- Prioritising reuse, retrofitting, and vertical extensions of existing buildings.
- Using biobased materials, recycled resources, and low-carbon concrete.
- Implementing design for disassembly to ensure future adaptability.
- Utilising prefabrication and modular construction for efficiency.
- Generating on-site renewable energy and installing water conservation systems.

These interventions have varied social impacts that are complex to measure. To provide a systemic overview, we at Structural Collective have developed a social-impact framework. This model combines insights from social life-cycle assessments (sLCA's), the World Green Building Council (WorldGBC)[23] framework, and Metabolic's seven pillars of the circular economy.[24]

Our framework uses a whole-systems approach, viewing the building process as a complex web of environmental, social, and economic interdependencies. This perspective covers the entire lifecycle, from material extraction to a building's operational impact.

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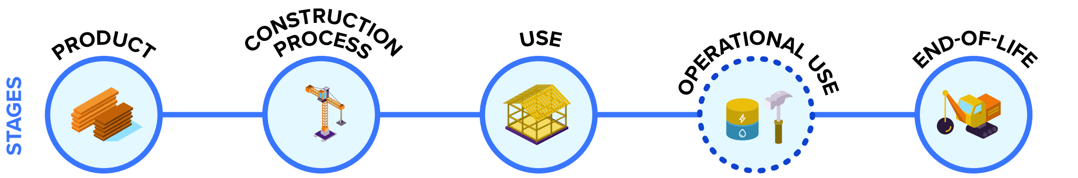
Circular impact framework



Intervention: **Building with wood versus Business As Usual**	Raw material supply, transport, manufacturing A1 A2 A3	Process stage: transport to site, construction A4 A5	User experience of the building fabric B1 B2 B3 B4 B5	Energy, water, maintenance B6 B7	Deconstruction, disposal, recycling C1 C2 C3 C4
SCOPE 0 **Entity and internal practices**	Development of new procurement policies for certified, sustainable materials.	Need for upskilling the workforce and developing new safety protocols for biobased construction.	Enhanced brand reputation and property value due to "green" and "healthy building" credentials.	Lower operational carbon emissions, helping to meet corporate ESG (Environmental, Social, Governance) targets.	Potential for revenue from salvaged high-value materials. Need for new deconstruction business models.
SCOPE 1 **Building and site users** (Occupants, workers)	*No direct impact on users at this stage*	Safer and healthier on-site conditions; less silica dust compared to concrete work. Lighter materials may reduce accidents.	Significant indoor air, humidity, and acoustic improvement. Low VOCs. Biophilia has proven psychological benefits.	Lower utility bills for occupants due to the natural insulating properties of biobased materials.	*Minimal direct impact, as users have likely vacated. Indirectly benefits society through resource availability.*
SCOPE 2 **Community and surroundings** (The local neighbourhood)	Potential for local/regional processing facilities, creating jobs near the source.	Reduced noise, dust, and disruption during construction, especially with prefabricated timber panels leading to faster assembly.	Creation of aesthetically pleasing buildings that can better integrate with natural surroundings or create unique local character	Reduced strain on local energy infrastructure due to the building's higher energy efficiency.	Reduced landfill burden on the local community. Potential for local reuse of salvaged materials in other projects.
SCOPE 3 **Supply and value chains** (From source to site)	Supports rural economies through sustainable forestry and agriculture. Promotes fair labour practices if certified (e.g., FSC).	Lighter materials can mean fewer transport journeys, reducing emissions and road congestion affecting other communities.	Increased demand for specialised, skilled trades for the maintenance of biobased materials over the long term.	*Minimal direct impact, linked more to operational systems than the biobased fabric itself.*	Creation of a circular economy. Development of new industries for reclaiming, reprocessing, and selling used biobased materials.

PILLARS

Materials · Energy · Water · Biodiversity · Society & Culture · Health & Wellbeing · Economy & Value

Figure 6. *A first draft for an LCA-bound social-impact framework, integrating the seven-pillars assessment.*

Example: building with timber to reduce carbon emissions

PART 1 - LIFE CYCLE ANALYSIS

First, we analyse how using timber changes various processes and creates different impacts at each stage of a building's life cycle.

Production (A1-A3)

Raw material extraction

A1 **Dependency.** The project's dependency shifts from quarried aggregates and minerals for cement to timber from forests.

Resources. It significantly increases the use of a (theoretically regenerative) resource (wood). The social impact hinges on whether this wood is from a certified sustainable source (e.g. FSC, PEFC); certifications include criteria for labour rights and community relations.

Upstream impacts. Land use changes from mining/quarrying to forestry. This has major implications for biodiversity, water cycles and carbon sequestration in the forest ecosystem itself.

Transport to manufacturer

A2 **Logistics.** The location of raw material sourcing changes from quarries, often near urban centres, to forests, which can be remote. This may increase transport distances for raw logs to sawmills or manufacturing plants.

Manufacturing

A3 **Energy.** Manufacturing mass timber products like cross-laminated timber (CLT) is generally less energy-intensive than producing cement, which requires firing a kiln at over 1,400°C. The energy source for sawmills and pressing plants (e.g. grid electricity vs. biomass cogeneration) is a key factor.

Emissions and waste. This process avoids the direct chemical process emissions of calcination in cement production. The primary co-product is sawdust and wood chips, which are often reused for energy generation or other products such as particleboard, minimising waste.

Construction (A4-A5)

Transport to site

A4 **Logistics.** Prefabricated timber components (like CLT panels) are significantly lighter than concrete equivalents. This reduces the number of truck deliveries to the site, leading to lower fuel consumption, less traffic congestion and fewer emissions in the local community.

Construction and installation

A5 **On-site impact.** Construction is often faster due to the use of prefabricated elements. This leads to less on-site energy consumption and a shorter period of disruption (noise, dust) for the surrounding neighbourhood.

Labour and safety. Timber construction requires a different skill set for on-site workers, shifting from wet trades (pouring concrete) to carpentry and crane operation. This introduces new safety protocols related to lifting large panels and fire safety during construction.

Use phase (B1-B7)

Use

B1 **Occupant experience:** The presence of exposed wood has a documented positive psychological effect on occupants (biophilia). It can also improve indoor air quality (if low-VOC adhesives are used) and acoustics.

Carbon sequestration. The building structure itself becomes a form of carbon storage for its entire lifespan.

Maintenance, repair, replacement, refurbishment

B2 B3 B4 B5 **Durability.** Wood might require different maintenance methods than concrete to protect it from moisture and pests.

Adaptability. Repairing or modifying a timber structure can be simpler than repairing or modifying a reinforced concrete structure. For example, creating a new opening in a CLT wall might be more straightforward, making the building more adaptable for future refurbishment.

Operational energy

B6 **Mechanism.** Wood has natural thermal insulating properties that are superior to concrete, which reduces the energy needed for heating and cooling the building, thus lowering operational energy costs for occupants.

Operational water

B7 **Impact.** This intervention has a minimal direct impact on operational water use within the building.

End-of-life (C1-C4)

Deconstruction

C1 **Disassembly.** Timber structures, especially those using bolts and screws, are highly suited for design for disassembly. This makes it easier to salvage entire components for direct reuse.

Transport and waste processing

C2 C3 **Logistics and value.** Lighter components reduce transport energy. The end-of-life pathways for wood are high-value: direct reuse of beams and panels, recycling into wood-based products or use as a carbon-neutral fuel source for energy recovery (biomass).

Disposal

C4 **Final destination.** Far less material is sent to landfill compared to demolished concrete and rubble. The final fate of the sequestered carbon depends on the end-of-life pathway (it is returned to the atmosphere if burned or decomposing).

Follow on the next page >

PART 2 - LOCATING AND ANALYSING SOCIAL IMPACT

We now map the effects noted above to the LCA framework's social scopes, then analyse them through the lens of the seven-pillars framework. This is a non-exhaustive example focusing on a few key impact factors.

Example 1
Shift from quarrying to sustainable forestry (production stage)

Located in: Scope 3 (supply chain)

This impact primarily affects workers and communities in the regions where timber is harvested, who are not on the construction site. It can also touch Scope 0 (entity) if the developer/builder adopts a formal sustainable procurement policy.

Seven-pillar analysis

Pillar 1 (materials). The core of the change: ensuring the material source is renewable, responsibly managed and its origin is traceable.

Pillar 4 (biodiversity). The direct impact on forest ecosystems is the most significant consequence. Sustainably managed forests can support biodiversity, while poorly managed ones lead to habitat destruction.

Pillar 5 (society & culture). Can positively impact communities if forestry is community-managed, but can negatively impact them by restricting access to traditionally public lands or competing with other land uses.

Pillar 6 (health & wellbeing). Shifts worker health risks from silica dust in quarries to the physical and chemical (e.g. chainsaw fumes) risks of logging and timber processing.

Pillar 7 (economy & value). Changes job types from mining to forestry and sawmilling. Creates economic value for rural communities and for certification bodies.

Example 2
Faster, quieter construction using prefabricated wood panels (construction stage)

Located in: Scope 2 (community & surroundings) and Scope 1 (building users)

The primary social impact is felt by the community living and working near the construction site. It also affects the future occupants who may be able to move in sooner.

Seven-pillar analysis

Pillar 5 (society & culture). Less disruption can lead to greater community acceptance of the project and of urban development in general.

Pillar 6 (health & wellbeing). Reduced noise and dust pollution leads to better physical and mental health for neighbours. A shorter construction period means less prolonged stress and disruption for the community.

Pillar 7 (economy & value). A shorter construction timeline reduces financing costs for the developer and provides a faster return on investment. For future residents or businesses (Scope 1), it means they can occupy and use the building sooner.

Example 3
Exposed timber and biophilic design in the finished building (use phase)

Located in: Scope 1 (building users)

This directly impacts the daily experience of the people living or working inside the building.

Seven-pillar analysis:

Pillar 1 (materials). The physical substance of the building is made visible and becomes a key part of the user experience, connecting occupants to the material's natural origins.

Pillar 5 (society & culture). The aesthetic can create a unique cultural identity for the building and its users, fostering a sense of pride and connection to nature.

Pillar 6 (health & wellbeing). This is the core impact. Biophilia is linked to reduced stress, improved cognitive function and higher satisfaction for occupants. Better indoor air quality (if natural materials are used) also contributes to physical health.

Pillar 7 (economy & value). Buildings that promote health and wellbeing can command higher rents or sale prices and may lead to increased productivity for commercial tenants. There is clear economic value in creating a desirable place in which to live or work.

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