# EXECUTIVE SUMMARY

The buildings and infrastructure that define our cities are also one of the largest sources of greenhouse gas (GHG) emissions.  Embodied carbon is the GHG emissions arising from the extraction, manufacturing, transportation, installation, maintenance, and disposal of construction materials. Embodied carbon associated with the construction of our built environment accounts for approximately 20-23% of total global energy-related GHG emissions.[1,2]

A growing number of cities recognize their role and commit to action to tackle the urgent challenge of their built environment carbon footprint through their policies and programs. 110 cities took the Cities Race to Zero Clean Construction pledges to reduce embodied emissions in their policies and programmes in 2021, 40 leading cities are participating in the C40 Clean Construction programme and mayors are setting the direction of travel by signing the Clean Construction Declaration, which requires collective action to halve embodied emissions by 2030.[3]

However, embodied carbon is a new policy area for many cities and the lack of city-level data is a significant barrier for policymakers to gain political support and make informed decisions. Not only do more cities need to adopt policies targeting embodied carbon to reach global decarbonization targets, but cities who have already committed to reducing embodied carbon have to overcome several challenges:

- With limited time to act in the crucial window between now and 2030, pursuing the most impactful strategies is key to maximizing the available political and financial resources.
- Currently, there are tools to measure embodied carbon for a building or product, but there is a lack of tools for modeling embodied carbon impacts at the scale of a city. This limits policymakers' ability to assess which policies will be needed to reach their targets.
- Without data on carbon savings potentials, policymakers are also limited in their ability to communicate why policies must be passed.

The goal of developing an embodied carbon policy reduction calculator is to address these challenges by:

- Modeling the potential embodied carbon reduction of a selected number of policies to give cities the values they need to make informed decisions;
- Allowing for comparison of emissions reduction policies for embodied carbon by key target dates (2030 and 2050) to assess the largest opportunities for impact;
- Evaluating which policies may be required to meet embodied carbon reduction targets, such as those set by city or regional climate action plans; and
- Ultimately enabling cities to make the case for and adopt policies to reduce embodied carbon.

1 United Nations Environment Programme. (2021). *2021 Global Status Report for Building and Construction: Toward Zero-emissions, Efficient and Resilient Buildings and Construction Sector*. Nairobi. https://globalabc.org/sites/default/files/2021-10/GABC_Buildings-GSR-2021_BOOK.pdf

2 Lizhen Huang, Guri Krigsvoll, Fred Johansen, Yongping Liu, Xiaoling Zhang. (2018). *Carbon emission of global construction sector, Renewable and Sustainable Energy Reviews*. Volume 81, Part 2, 2018, ISSN 1364-0321. https://doi.org/10.1016/j.rser.2017.06.001

3 C40 Cities. (n.d.). *Clean Construction Declaration*. https://www.c40.org/declarations/clean-construction-declaration/

***Proof-of-Concept Study***

The Carbon Leadership Forum and C40 Clean Construction teams collaborated in 2021 to develop a proof-of-concept for an embodied carbon policy reduction calculator, described in this report. The goal of this study was to:

- Assess the availability of city data and life cycle assessment data required to develop a successful tool;
- Assess tool scope and functionality required to support cities' needs; and
- Demonstrate the tool concept to pilot cities to determine if it would be useful in policymaking.

The team developed four prototype calculators to estimate emissions from four types of embodied carbon policies (summarized in Figure 1):

1. Reducing the embodied carbon footprint of entire buildings
2. Limiting the embodied carbon footprint of concrete
3. Increasing adaptive reuse
4. Evaluating the carbon impact of housing policy

Policymakers using the calculators would need to input data on building use (e.g., multi-family, commercial), building size for that building use (e.g., low-rise, mid-rise), and expected area of growth by 2050. Various percentage (%) reduction targets can then be selected or entered manually. The final output of the calculators provides 1) baseline embodied carbon emissions by 2050, and 2) the various carbon savings potentials of the selected reduction targets.

It is important to note that the calculators described in this report are proof-of-concept: they are still limited in their ability for comparative decision-making at this time due to the gaps in data identified through this initial phase. Appendix B lists the priorities identified by the authors, contributors, and pilot cities necessary for their future development.

***Case Studies***

The team worked with three C40 North American cities to assess the potential of the prototype calculators:

- **New York City, New York,** using values for growth in projected floor area from New York City's 80x50 Technical Working Group report;
- **Portland, Oregon,** using values for growth in projected floor area from the City of Portland's 2007 analysis of baseline building stock and future growth; and
- **Austin, Texas - South Central Waterfront,** using values for growth in projected floor area from their Vision Framework Plan.

For each city, the CLF used building stock and growth projections noted above as inputs for each prototype calculator to assess the total embodied carbon by 2050 for a baseline scenario and 3-6 reduction scenarios that correlated with the evaluated policy type.

Overall, policies requiring reductions in whole building embodied carbon were found to have the largest impact. The second-most impactful policy type based on the findings from the prototype calculators was incentivizing adaptive reuse, followed by low-carbon concrete and housing size policies.  These findings highlight the need for better research and benchmarks on the whole buildings of different building typologies to support more robust estimates of total carbon savings potentials associated with each, but also to enable cities to pass these policies.

The difference in the overall carbon savings potentials of the four different policies highlight the importance of physical scope in determining the impacts of embodied carbon. Whole buildings cover the largest scope in terms of the physical materials and building typologies impacted. They also allow for the largest range of embodied carbon reduction strategies. Other policies, such as the low-carbon concrete policy, impact only a portion of a building (only the concrete), and therefore result in lower overall reductions. Similarly, policies that address only one typology—such as policies targeting housing—resulted in lower overall carbon savings potential, despite multifamily residential being the type with the largest projected growth for some of the cities included in this study.

However, total reductions are not the only relevant policy goals: policymakers must balance political and economic barriers to identify the policy solutions that are feasible in their jurisdictions, and balance social, environmental, and public health co-benefits alongside carbon savings.

### *Conclusion*

The initial results from this proof-of-concept study and feedback from cities indicate that these calculators could be a powerful resource for enabling policymakers to use the carbon savings potential estimates to develop and advocate for the policy solutions that are right for their cities and achieve their cities' goals.

Throughout the study, the authors and contributors sought feedback from the pilot cities on the efficacy and applicability of the selected policy types and calculators. Each city overwhelmingly found that reducing the embodied carbon footprint of entire buildings, limiting the embodied carbon footprint of concrete, and increasing adaptive reuse were the most helpful and useful policy calculators for communicating the importance of embodied carbon and advancing policy development in their city. Additionally, the city feedback reinforced the need for future research development of the calculators. A full list of future priorities is included in Appendix B. High priorities for future work include:

- Developing regionally and typologically specific building embodied carbon intensity values;
- Expanding the physical and temporal scope of the calculators to include infrastructure, parking, and cradle-to-grave impacts;
- Including stepped policy limits to evaluate the impact of incremental phasing over time and the cumulative impact of two or more policies combined;
- Adding additional policy types that could target material reuse, procurement, or other types of planning and zoning strategies.

City policymakers need to have measurable, reliable, and actionable data to support development of their embodied carbon policy strategies. These future research priorities will help refine and expand the calculators in order to provide those metrics and help cities across the globe address the urgent need to decarbonize the built environment.