3 CASE STUDIES

The research team collected projected floor area growth and building typology data from three pilot cities (New York City, Portland, and the Austin South Central Waterfront) to test the potential for use of the Embodied Carbon Policy Reduction Calculator to evaluate embodied carbon policy scenarios. The research team then assessed one baseline scenario and three to six reduction scenarios for each city.

Table 1 summarizes the baseline and reduction scenarios assessed for each city, including the theoretical reduction requirement and which building typologies the reductions were applied to for that scenario.

These scenarios were selected to model a range of reduction scenarios that vary in their ambition and scope (in terms of building typologies targeted). In some cases, reduction scenarios were chosen to reference specific published targets:

- Scenario A1 aligns with the 10% reduction criteria for the building life cycle impact reduction credit in LEEDv4 for New Construction.[24] Similar scenarios could be modeled to understand the potential impact of requiring the Living Building Challenge (requires a 20% reduction) or other certifications.
- Scenarios A2 and A4 align with the 40% reduction target set by Austin's Climate Equity Action Plan.[25]
- Scenarios A5 and B3 align with the 50% reduction targets put forth by the Clean Construction Declaration.[26]
- Research indicates that approximately 30% reductions in the embodied carbon of concrete are possible without additional cost.[27] For this reason, the research team chose 30%, rather than 10% as a conservative percentage reduction requirement for Scenarios B1 and B2.

24 United States Green Building Council. (n.d.). *Building product disclosure and optimization - environmental product declarations.* https://www.usgbc.org/credits/new-construction-schools-new-construction-retail-new-construction-data-centers-new-3?return=/credits/new-construction/v4.

25 City of Austin. (2020). *Austin Climate Equity Action Plan.* https://www.austintexas.gov/page/austin-climate-equity-plan

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

27 Esau, R., Jungclaus, M., Olgyay, V., and Rempher, A. (2021). *Reducing Embodied Carbon in Construction: Low Cost-High Value Opportunities*. https://rmi.org/insight/reducing-embodied-carbon-in-buildings/.

Table 1. Baseline and reduction scenarios assessed for each city.

Scenario	Reductions Required	Building typologies included in scope		
		New York City	*Portland*	*Austin*
BECI Reduction Policy Calculator				
A0 Baseline	**0%** reduction (no policy introduced)	1-4 Family, Commercial, Multifamily, Institutional	Single Family, Commercial, Multifamily	Office, Retail, Multifamily, Hotel
A1	**10%** reduction requirement	Commercial	Commercial	Office, Retail, Hotel
A2	**40%** reduction requirement	Multifamily	Multifamily	Multifamily
A3	**30%** reduction requirement	1-4 Family, Commercial, Multifamily, Institutional	Single Family, Commercial, Multifamily	Office, Retail, Multifamily, Hotel
A4	**40%** reduction requirement	1-4 Family, Commercial, Multifamily, Institutional	Single Family, Commercial, Multifamily	Office, Retail, Multifamily, Hotel
A5	**50%** reduction requirement	1-4 Family, Commercial, Multifamily, Institutional	Single Family, Commercial, Multifamily	Office, Retail, Multifamily, Hotel
Low-Carbon Concrete Policy Calculator				
B0 Baseline	**0%** reduction (no policy introduced)	1-4 Family, Commercial, Multifamily, Institutional	Single Family, Commercial, Multifamily	Office, Retail, Multifamily, Hotel
B1	**30%** reduction requirement	Commercial	Commercial	Office, Retail, Hotel
B2	**30%** reduction requirement	Multifamily	Multifamily	Multifamily
B3	**50%** reduction requirement	1-4 Family, Commercial, Multifamily, Institutional	Single Family, Commercial, Multifamily	Office, Multifamily, Retail, Hotel
Adaptive Reuse Policy Calculator				
C0 Baseline	**100% new construction** (no policy introduced)	1-4 Family, Commercial, Multifamily, Institutional	Single Family, Commercial, Multifamily	N/A
C1	**5%** of growth is adaptive reuse	1-4 Family, Commercial, Multifamily, Institutional	Commercial, Multifamily	N/A
C2	**10%** of growth is adaptive reuse	1-4 Family, Commercial, Multifamily, Institutional	Commercial, Multifamily	N/A
C3	**30%** of growth is adaptive reuse	1-4 Family, Commercial, Multifamily, Institutional	Single Family, Commercial, Multifamily	N/A
Housing Size Policy Calculator				
D0 Baseline	**0%** reduction (no policy introduced)	1-4 Family, Multifamily	Single Family, Multifamily	Single Family, Multifamily
D1	**20%** reduction in unit size	1-4 Family	Single Family	N/A
D2	**10%** reduction in unit size	Multifamily	Multifamily	Multifamily
D3	**30%** of units are micro-units	Multifamily	Multifamily	Multifamily
D4	**20%** reduction in unit size	1-4 Family, Multifamily	Single Family, Multifamily	Single Family, Multifamily

3.1 City of New York

The research team used projected floor area growth from the New York City's 80x50 Technical Working Group report[28] to calculate the carbon reduction potential for four types of policies. The data available in the report represented future growth projections for 1-4 family residential, multifamily residential, commercial, and institutional building types by total area. Internal assumptions were used to fill multiple data gaps for the City of New York's growth projections including estimates of typical building heights, construction types, and other variables that affect embodied carbon. To read more about the methodology for Projecting Construction Growth for Pilot Cities, see Appendix A.1.

Figures 6 and 7 show the highest potential carbon saving scenarios from each prototype calculator for New York City.

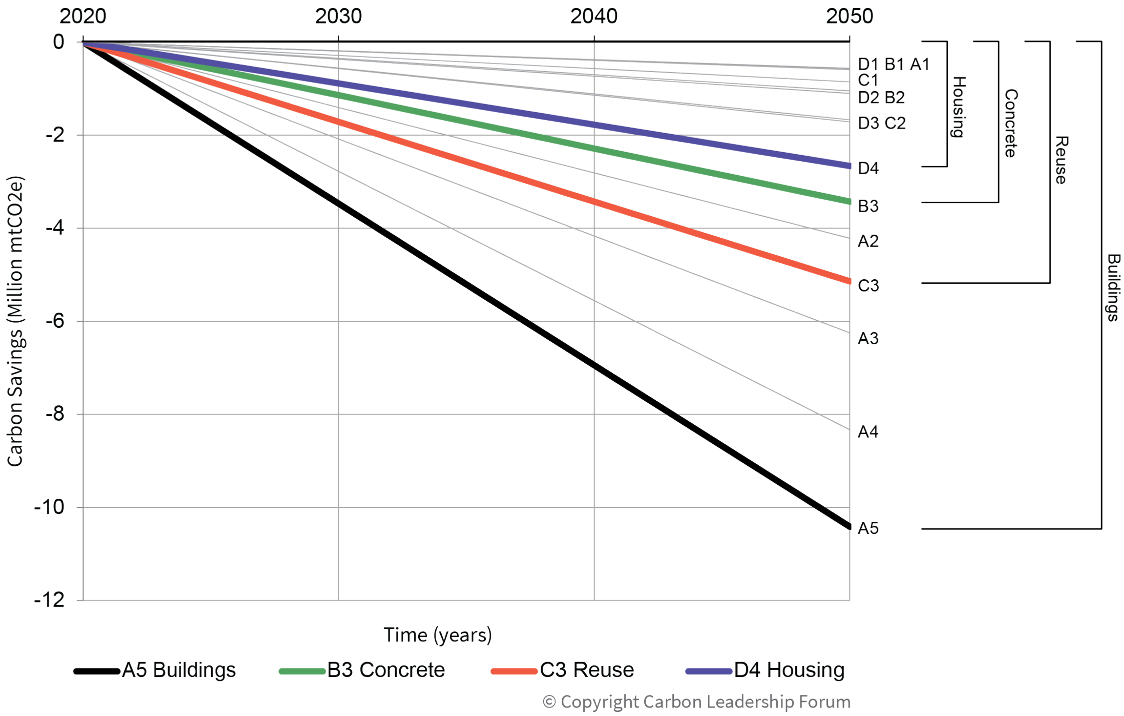

Figure 6. Preliminary cumulative carbon savings results for City of New York comparing all scenarios studied and illustrating maximum reduction (i.e., the most progressive policy scenario analyzed) from each prototype calculator in bold.

28 New York City Mayor's Office of Sustainability. (2016). *One City Built to Last Technical Working Group Report.* http://www.nyc.gov/html/gbee/downloads/pdf/TWGreport_2ndEdition_sm.pdf.

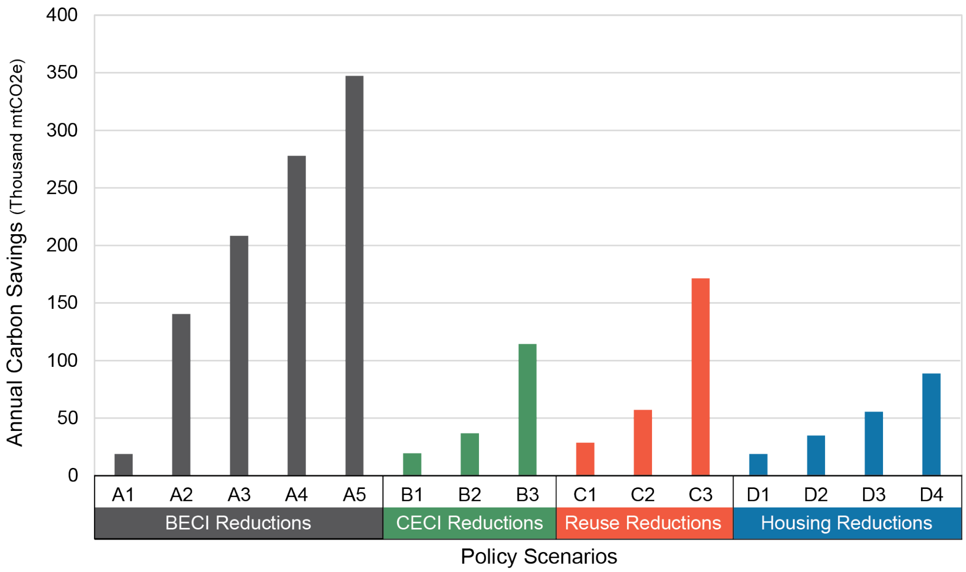

Figure 7. Preliminary annual carbon savings results for the City of New York comparing all reduction scenarios from each prototype calculator.

This section summarizes initial takeaways that demonstrate the potential of this type of calculator to inform decision-making. However, as these calculators are designed currently as a proof-of-concept, results are directionally accurate and do not yet allow for detailed comparisons. See Appendix B for a discussion of the research and data required to increase the functionality of the calculators for use in decision-making.

Preliminary takeaways include:

- The largest policy opportunity (i.e., largest carbon savings potential) of the scenarios evaluated is requiring reductions in building embodied carbon intensity (BECI)—such as the 50% reduction targets in alignment with the Clean Construction Declaration evaluated in BECI Scenario A5. Even a 30% reduction in BECI (Scenario A3) was still greater than any other scenario from the concrete, reuse, or housing policy calculators.
- The second largest policy opportunity is Reuse. Scenario C3 evaluates the potential of incentivizing adaptive reuse (as opposed to new construction) for about 30% of the growth for commercial, residential, and institutional building stock (approximately 0.23% of the existing building stock area).
- Of the building use types studied, multifamily residential presents the largest opportunity for embodied carbon intensity reduction policies in New York City. This is largely due to multifamily residential having the largest projected growth by 2050. For example, requiring a 40% reduction in BECI for multifamily construction alone has about the same impact as requiring 75% reductions in the embodied carbon of concrete for all commercial, multifamily, and institutional buildings.
- While 1-4 family housing units are the largest unit sizes studied for New York City, they still represent the lowest potential for embodied carbon reductions from unit size changes. This is due to the relatively small amount of projected growth area for 1-4 family houses when compared to multifamily, as well as the less carbon-intensive construction of 1-4 family houses.

- This study only evaluated relatively small percentage reductions in embodied carbon (10-50%). Larger reduction requirements would result in much larger carbon savings potentials.

Figures 8-11 demonstrate the graphic output of each prototype calculator, showing the projected total embodied carbon emissions of the baseline scenario and reduction scenarios from 2020-2050. To see additional results for each city from the prototype calculators, see Appendix C.

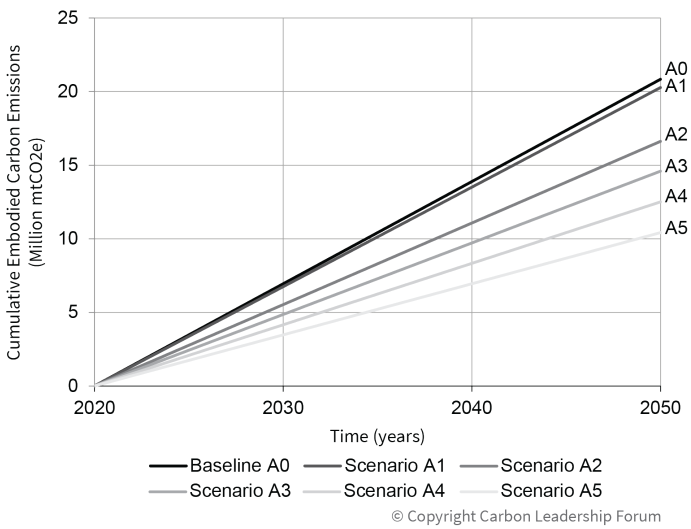

Figure 8. Preliminary building embodied carbon intensity scenarios for New York City displaying estimates of cumulative embodied carbon emissions of the baseline scenario and three reduction scenarios from 2020-2050.

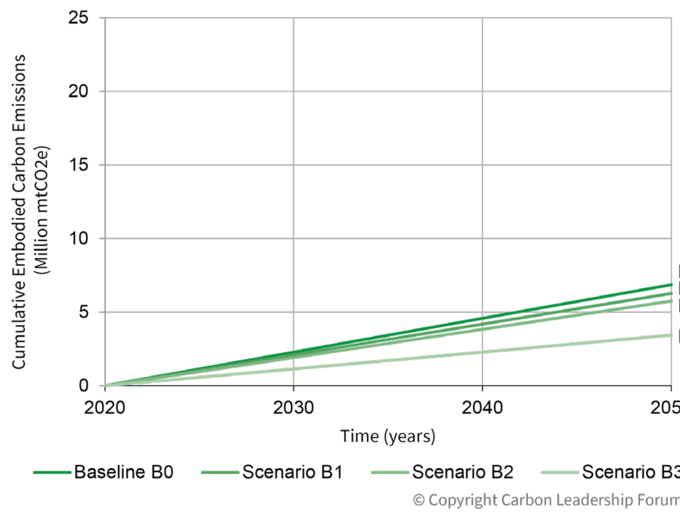

Figure 9. Preliminary concrete embodied carbon intensity scenarios for New York City displaying estimates of cumulative embodied carbon emissions of the baseline scenario and three reduction scenarios from 2020-2050. Results displayed as averages between high and low ranges. Data represents the impacts from concrete only.

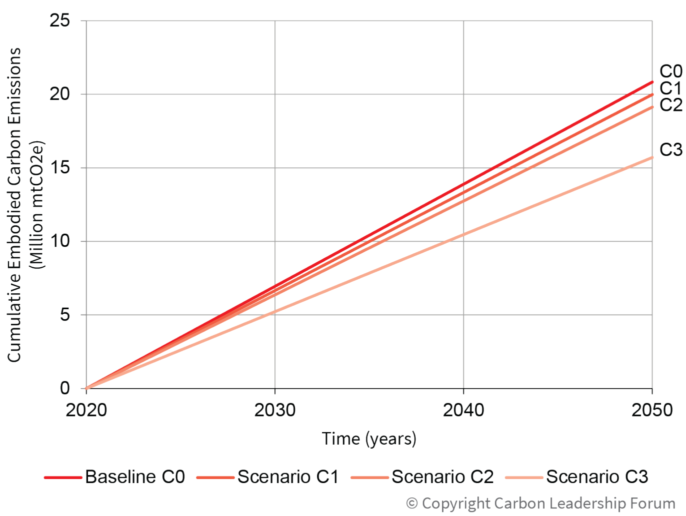

Figure 10. Preliminary adaptive reuse scenarios for New York City showing estimates of cumulative embodied carbon emissions of the baseline scenario and three reduction scenarios from 2020-2050.

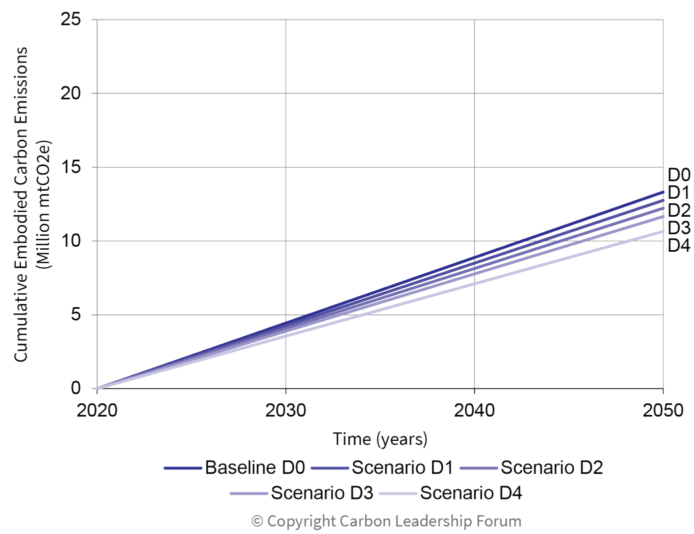

Figure 11. Preliminary housing policy results scenarios for New York City showing estimates of cumulative embodied carbon emissions of the baseline scenario and four reduction scenarios from 2020-2050.

3.2 City of Portland

The research team used projected floor area growth from the City of Portland's 2007 analysis of baseline building stock and future growth (data provided directly from the City of Portland) to calculate the carbon reduction potential for the four types of policies. The data available in the report represented future growth projections for single family residential, multifamily residential, and commercial building types by total area. Internal assumptions were used to fill multiple data gaps for the City of Portland's growth projections, including estimates of typical building heights, construction types, and other variables that affect embodied carbon. To read more about the methodology for Projecting Construction Growth for Pilot Cities, see Appendix A.1.

Figures 12 and 13 show the highest potential carbon saving scenarios estimated using each prototype calculator for the City of Portland.

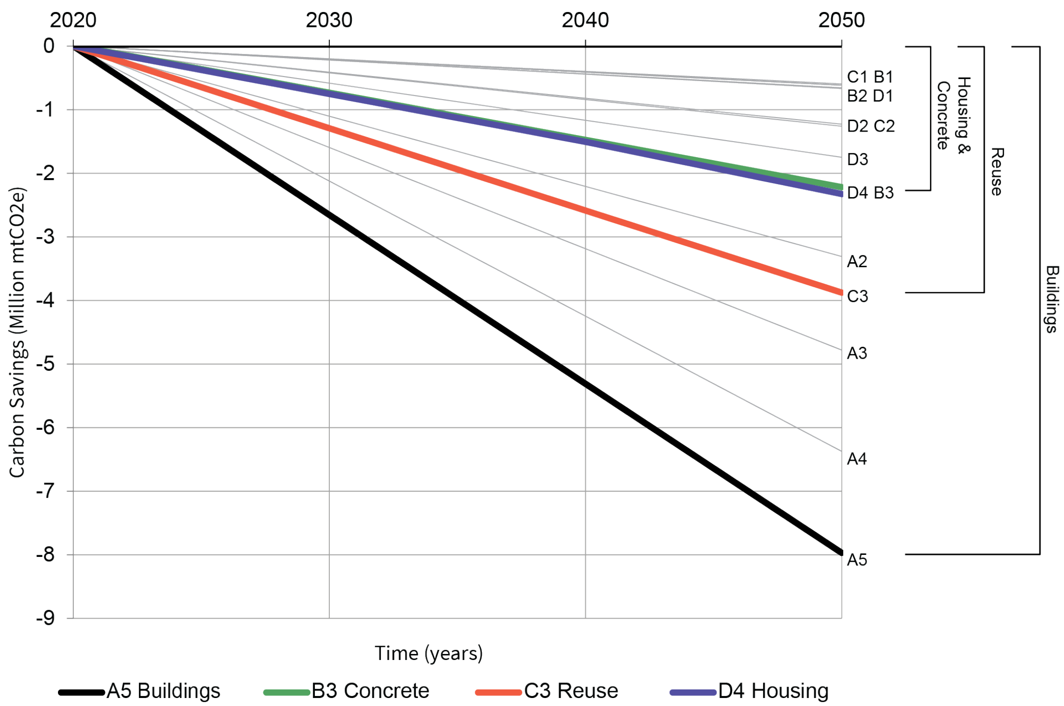

Figure 12. Preliminary cumulative carbon savings results for City of Portland comparing all scenarios studied and illustrating maximum reduction (i.e., the most progressive policy scenario analyzed) from each prototype calculator in bold.

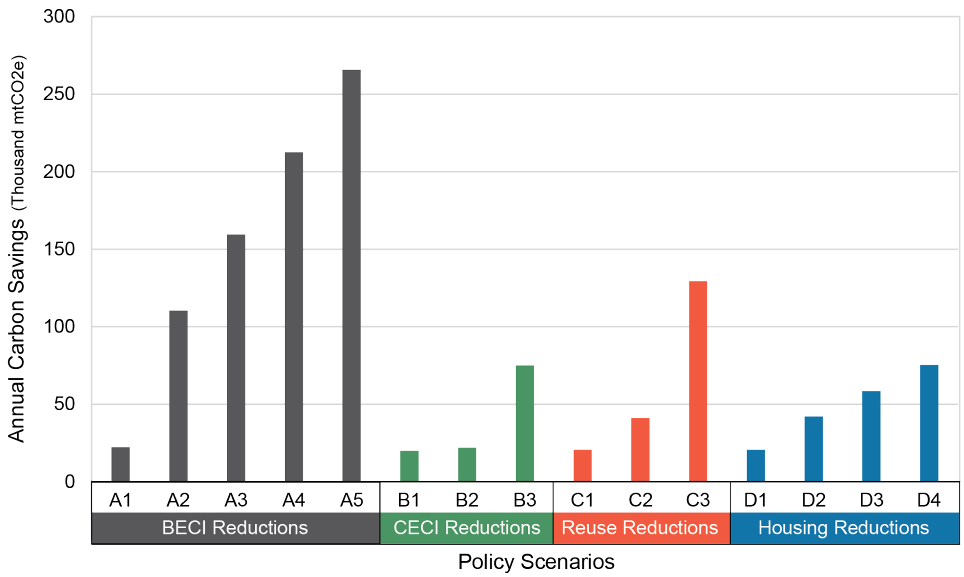

Figure 13. Preliminary annual carbon savings results for City of Portland comparing all reduction scenarios from each policy calculator.

This section summarizes initial takeaways that demonstrate the potential of this type of calculator to inform decision-making. However, as these calculators are designed currently as a proof-of-concept, results are directionally accurate and do not yet allow for detailed comparisons. See Appendix B for a discussion of the research and data required to increase the functionality of the calculators for use in decision-making.

Preliminary takeaways include:

- Commercial and multifamily residential both represent significant opportunities for embodied carbon policy. For example, Scenarios B1 and B2 have the nearly the same carbon savings potentials.
- The largest policy opportunity (i.e., the largest carbon savings potential) of the scenarios evaluated is requiring reductions in building embodied carbon intensity (BECI), such as the 50% reduction targets in alignment with the Clean Construction Declaration evaluated in Scenario A5. Even a 30% reduction in BECI (Scenario A3) is still greater than any other scenario from the concrete, reuse, or housing policy prototype calculators.
- The second largest policy opportunity is Reuse. Scenario C3 evaluates the potential of incentivizing adaptive reuse (as opposed to new construction) for about 30% of the growth for commercial and residential and building stock (approximately 0.23% of the existing building stock area).
- This study only evaluated relatively small percentage reductions in embodied carbon (10-50%). Larger reduction requirements would result in much larger carbon savings potentials.

Figures 14 - 17 demonstrate the graphic output of each prototype calculator, showing the total embodied carbon emissions of the baseline scenario and reduction scenarios from 2020-2050. For additional results for each city from the prototype calculators, see Appendix C.

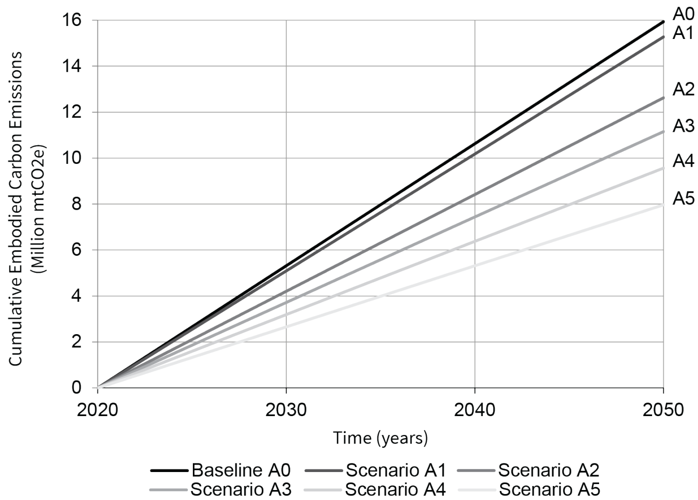

Figure 14. Preliminary building embodied carbon intensity scenarios for Portland displaying cumulative embodied carbon emissions of the baseline scenario and three reduction scenarios from 2020-2050.

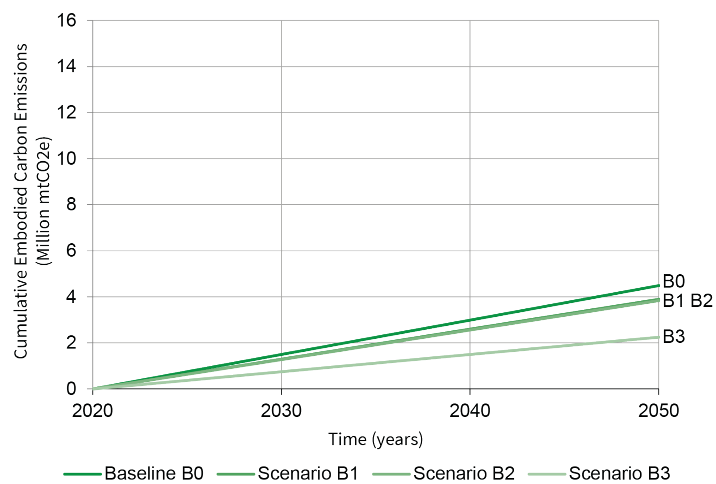

Figure 15. Preliminary concrete embodied carbon intensity scenarios for Portland displaying cumulative embodied carbon emissions of the baseline scenario and three reduction scenarios from 2020-2050. Results displayed as averages between high and low ranges. Data represents the impacts from concrete only.

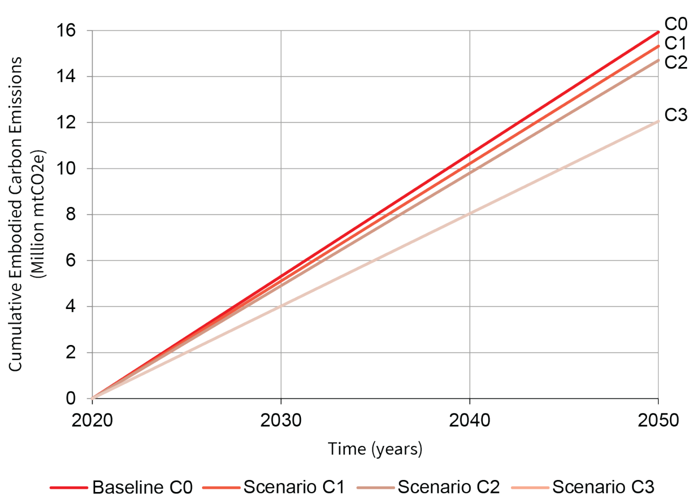

Figure 16. Preliminary adaptive reuse scenarios for Portland displaying cumulative embodied carbon emissions of the baseline scenario and three reduction scenarios from 2020-2050.

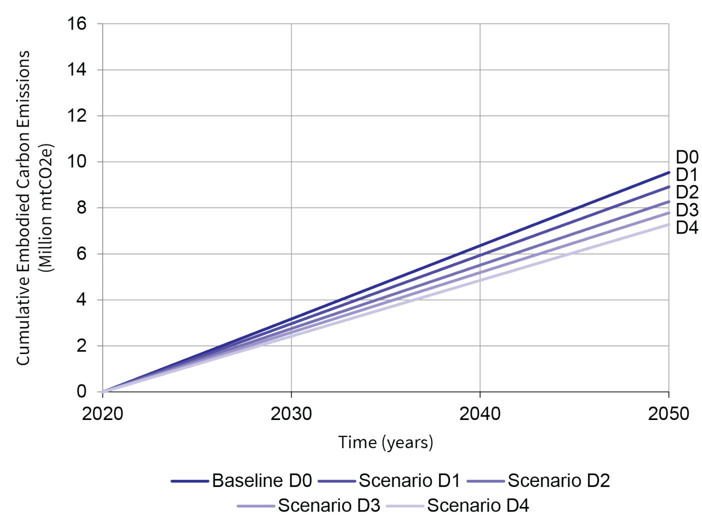

Figure 17. Preliminary housing policy scenarios for Portland displaying cumulative embodied carbon emissions of the baseline scenario and four reduction scenarios from 2020-2050.

3.3 City of Austin South Central Waterfront (SCW)

The research team used projected floor area growth from the Austin South Central Waterfront (SCW) Vision Framework Plan[29] to calculate the carbon reduction potential for four types of policies. The SCW was used in lieu of available city-wide data to show the potential of the pilot calculator for evaluating planned developments or neighborhood-wide growth plans. The data available in the report represented future growth projections for multifamily residential, retail, office, and hotel building types by total area. Internal assumptions were used to fill multiple data gaps for the City of Austin SCW's growth projections including estimates of typical building heights, construction types, and other variables that affect embodied carbon. To read more about the methodology for Projecting Construction Growth for Pilot Cities, see Appendix A.1.

Figures 18 and 19 show the highest potential carbon saving scenarios estimated with each prototype calculator for the Austin South Central Waterfront.

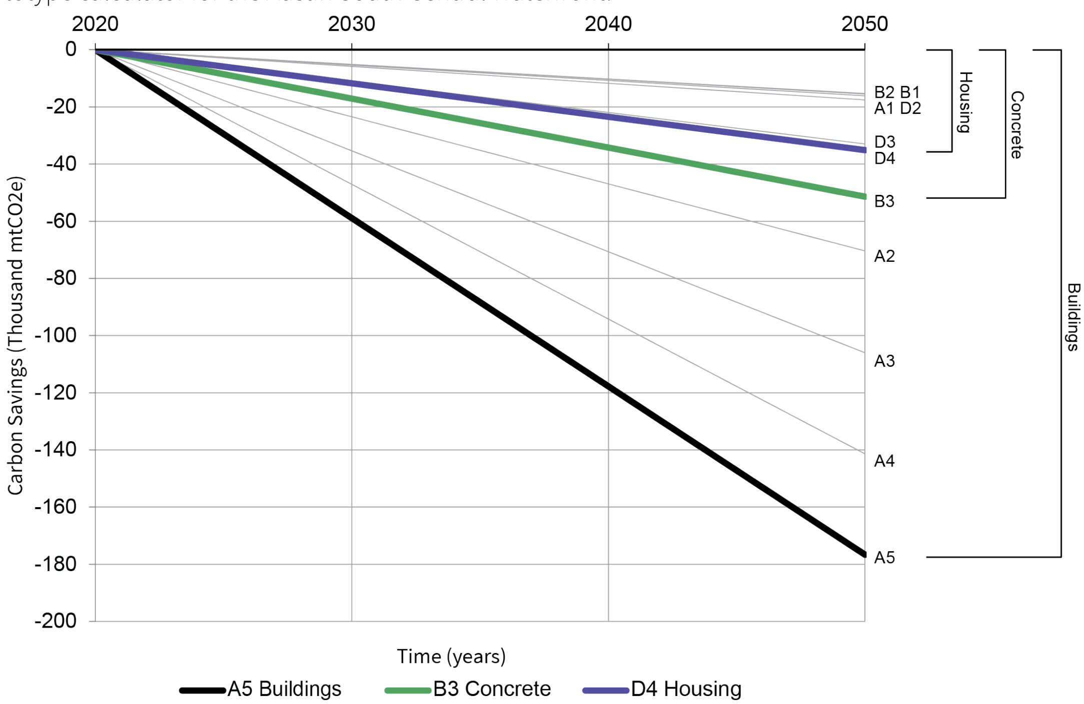

Figure 18. Preliminary cumulative carbon savings results for the City of Austin SCW comparing all scenarios studied and illustrating maximum reduction (i.e., most progressive policy scenario analyzed) from each policy calculator in bold.

29 City of Austin South Central Waterfront (SCW) Project Team. (2016). *South Central Waterfront Vision Framework Plan.* https://www.austintexas.gov/page/south-central-waterfront

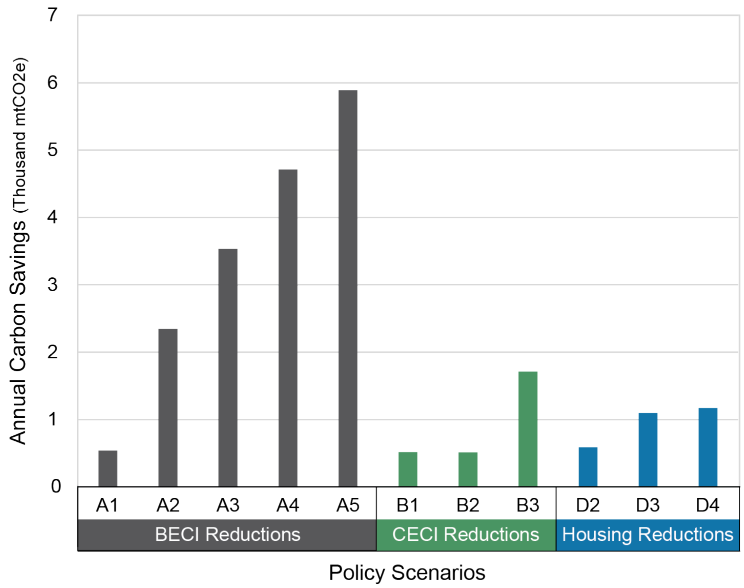

Figure 19. Preliminary annual carbon savings results for the City of Austin SCW comparing all reduction scenarios from each policy calculator.

This section summarizes initial takeaways that demonstrate the potential of this type of calculator to inform decision-making. However, as these calculators are designed currently as a proof-of-concept, results are directionally accurate and do not yet allow for detailed comparisons. See Appendix B for a discussion of the research and data required to increase the functionality of the calculators for use in decision-making.

Preliminary takeaways include:

- Commercial (i.e., office, retail, hotel) is the largest opportunity, closely followed by multifamily residential. Policies targeting multifamily residential and commercial would both be impactful.
- The largest policy opportunity (i.e., the largest carbon savings potential) of the scenarios evaluated is requiring reductions in building embodied carbon intensity (BECI). The 50% reduction targets in alignment with the Clean Construction Declaration evaluated in Scenario A5 is the largest potential studied. However, even a 30% reduction in BECI (Scenario A3) would still be a larger carbon savings than any option from the concrete, reuse, or housing policy calculators.
- A 50% reduction for concrete (Scenario B3) was the largest opportunity for carbon savings outside of the BECI scenarios.
- Reductions in unit size (D3) and 50% reductions in the embodied carbon of concrete for commercial, multifamily, retail, and hotel building uses (B3) resulted in similar carbon savings potentials, with concrete being slightly higher.
- This study only evaluated relatively small percentage reductions in embodied carbon (10-50%). Larger reduction requirements would result in much larger carbon savings potentials.

Figures 20 - 22 demonstrate the graphic output of each prototype calculator, showing the total embodied carbon emissions of the baseline scenario and reduction scenarios from 2020-2050. For additional results for each city from the prototype calculators, see Appendix C.

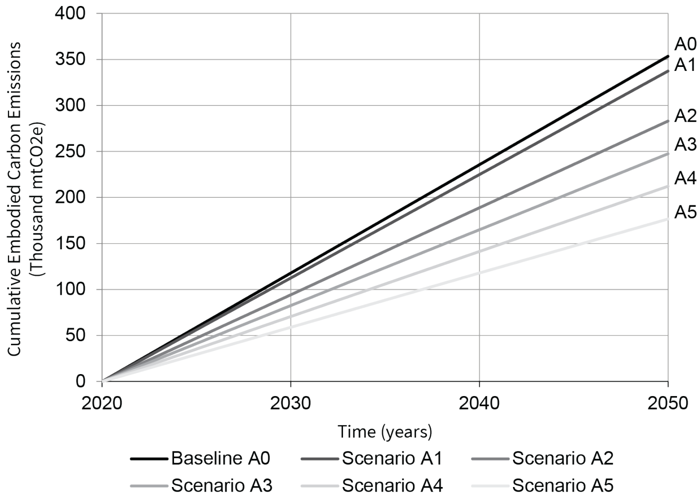

Figure 20. Preliminary building embodied carbon intensity scenarios for Austin SCW displaying cumulative embodied carbon emissions of the baseline scenario and three reduction scenarios from 2020-2050.

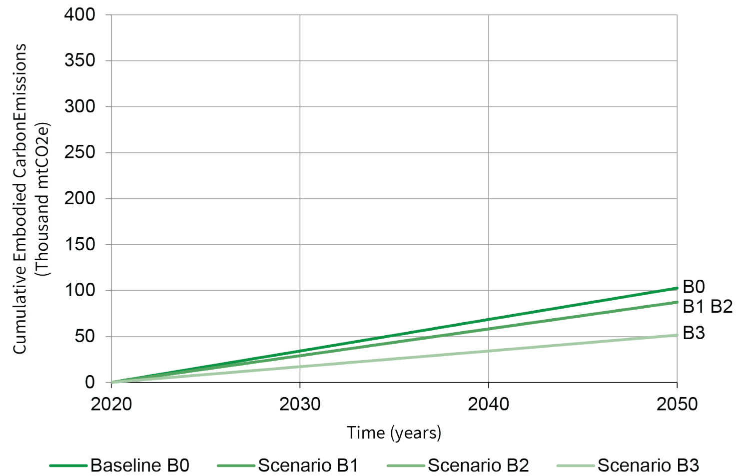

Figure 21. Preliminary concrete embodied carbon intensity scenarios for Austin SCW displaying cumulative embodied carbon emissions of the baseline scenario and three reduction scenarios from 2020-2050. Results displayed as averages between high and low ranges. Data represents the impacts from concrete only.

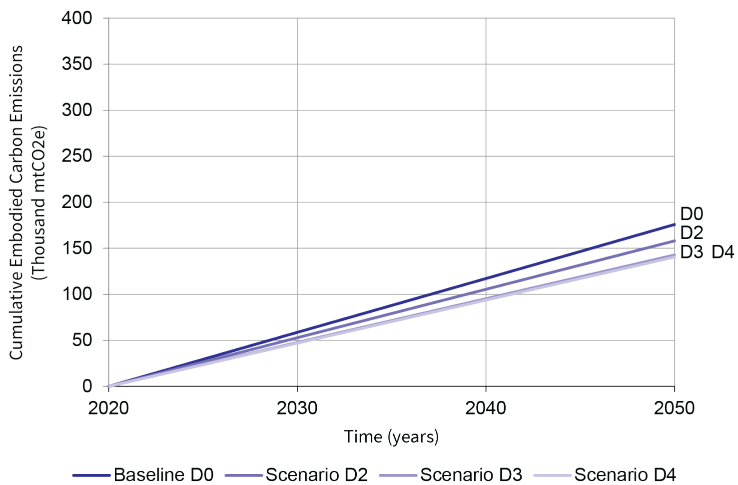

Figure 22. Preliminary housing policy scenarios for Austin SCW displaying cumulative embodied carbon emissions of the baseline scenario and three reduction scenarios from 2020-2050.

3.4 Summary of Feedback from Cities

In January 2022, the CLF and C40 teams presented the results of each case study to individuals from each of the cities in the proof-of-concept study. Overall, each city found the concept helpful and useful for advancing embodied carbon policies within their city. The types of feedback received fell into five major categories:

Use in communicating policies:

The pilot cities all agreed on the value of such a tool. They could see themselves using the calculators for internal discussion with their immediate teams for draft policy development as well as to engage others such as city planners, zoning departments, and other stakeholders. Furthermore, they could envision using the calculators alongside other metrics and benefits of the policies to aid in making political cases for the adoption of embodied carbon reduction policies at Mayoral, City Council, or Commissioner levels.

They also recommended the following additions to the calculators (or calculator interfaces) that could help communicate results and the importance of embodied carbon policies:

- easily shareable or exportable results that could be combined with other analyses;
- communicating co-benefits (in addition to direct embodied carbon benefits) for each policy, such as density, public health impacts, or reduced demolition or other local pollution impacts;
- including comparable carbon metrics as outputs (e.g., coal-fired power plant emissions, cars off the road);
- finding ways to communicate the challenges associated with each policy to non-experts, such as strength or cure-time issues related to low-carbon concrete policies; and
- integrating associated "costs" with each policy.

Use in developing policies:

- All three pilot cities found the building embodied carbon intensity reduction policy, low-carbon concrete policy, and adaptive reuse policy calculators to be most relevant to their work. The housing policy calculator was identified as needing the most future development.
- They thought it was great how the calculators were set up to be able to compare different scenarios and see where the largest opportunities could be achieved.
- In several cases, the scope of the policy calculators (i.e., which policies were being assessed) spurred conversation as to whether the cities should consider new types of policies that they had not previously considered. For example, several teams were surprised to see how impactful the BECI reductions could be and appreciated how a policy could be flexible for architects, engineers, and contractors to achieve the targets, which they had not previously considered. Another team highlighted that the adaptive reuse calculator was exciting to see, given the recent availability of vacant buildings and potential for reuse.

- One team highlighted that the regional baselines and benchmarks the calculators are built with would be very important on their own, and that the ability for users to calibrate these baselines in the tools (i.e., if they had agency-specific data, for example) would be helpful.

Additional functionality and data gaps:

Pilot cities were asked to highlight which additional functionality or data gaps for the calculators would be a high priority for the research team to address in future stages of development for each calculator. The priorities indicated by each pilot city are integrated into Tables B1-B2 in Appendix B.

Pilot cities also highlighted the following opportunities to expand the functionality of the calculators:

- allowing users to modify the global warming potential (GWP) baseline values in the BECI reduction policy and low-carbon concrete policy calculators;
- including more granular building typologies (e.g., hospitals or schools rather than 'institutional') to align with the Commercial Buildings Energy Consumption Survey (CBECS) categories

Political challenges:

While discussing the functionality and potential for each calculator in communicating the importance of embodied carbon policies, the pilot cities shared thoughts related to the political challenges associated with each policy in the scope of this proof-of-concept study.

Although the politics associated with each policy framework are not the focus of these calculators, they are relevant to what type of functionality and user interface could be included to improve the utility for cities. For example, several pilot cities identified low-carbon concrete policies as "low-hanging fruit" that are relatively politically straight-forward and feasible, especially with low reductions that don't pose cost or construction challenges. This would influence how quickly that type of policy could be passed, which would in turn impact the total reductions achievable by 2050. This could be addressed by the calculators in the future by:

- allowing users to input the year that a policy is introduced
- allowing for stepped limits
- accounting for the time value of carbon

Some of these comments were related to how the calculators could be framed. For example, one city suggested framing the adaptive reuse calculator as reduced demolition, rather than adaptive reuse. Another city highlighted the political challenges associated with the term "density" in their city.

These framing questions could be addressed by:

- allowing cities to export the data and communicate it with more politically friendly terminology for their local context (assuming that communication did not change the scope of what was actually measured); and

- conducting a survey to a broader range of C40 cities to request feedback on preferred terminology used by the calculators, after additional development of each calculator.

Other comments and suggestions:

Cities were also interested in understanding how the calculator estimates related to consumption-based accounting. This would be a helpful topic to address in educational resources in the future.

Some cities also had additional ideas on how current or future city-specific data sources could be used to fill data gaps, such as typologies, demolition/reuse, unit sizes, and building height. These recommendations have been included in Appendix B.