Findings and Recommendations on the Use of Lower Carbon Materials in the Statewide Building Code and Other Means for Reducing Greenhouse Gas Emissions Attributable to Building Materials

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1 Executive Summary

Within the walls, floors, and foundations of our buildings is an often-overlooked source of climate pollution commonly referred to as embodied carbon — the millions of tons of carbon emitted during the extraction, manufacturing, transport, construction, and end-of-life disposal of the materials that surround us.

Globally, materials used in the construction of buildings represent about 7% of total global GHG emissions.[1] In Oregon, this number is estimated at 14.4%, based on the 2021 statewide consumption based emissions inventory.[2] In the US, efforts to decarbonize buildings have primarily focused on reducing operational carbon, known as the emissions arising from heating, cooling, lighting the building, and so on, while neglecting the significant role of embodied carbon. As energy codes and regulations continue to drive down operational emissions, the proportion of building emissions stemming from embodied carbon is expected to increase.

Significant opportunities to reduce these emissions exist. Studies indicate that embodied carbon reductions of up to 30% can be achieved with little to no cost premiums in typical buildings.[3] Political ambition to move the market towards realizing these reductions has grown significantly over recent years. The Federal government has added an unprecedented level of funding for advancing research, testing, reporting, and application of low embodied carbon materials and construction practices through the 2021 Bipartisan Infrastructure Law (BIL) and 2022 Inflation Reduction Act (IRA). As early as 2017, Oregon policymakers have utilized executive orders, legislation, and programs and initiatives to address embodied carbon emissions and help meet Oregon's goal to reduce state-wide GHG emissions by 45% below 1990 levels by 2035.[4] Local governments in Portland and Eugene have also outlined embodied carbon reductions in climate action plans, and Portland was one of the first jurisdictions to pilot and later require low carbon concrete for city-owned projects.[5]

These actions and more have primed the market for a comprehensive building code regulation that would define a new standard of embodied carbon performance for buildings across the

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[1] Michelle Lambert and Meghan Lewis, *Policy Toolkit Factsheet Series, Embodied Carbon 101*, CLF, June 2024, https://carbonleadershipforum.org/embodied-carbon-101-v2/.

[2] Oregon Department of Environmental Quality, *Opportunities to Reduce Greenhouse Gas Emissions Caused by Oregon's Consumption,* Prepared for the Oregon Legislature in accordance with HB 3409 (2023), September 12, 2024, https://www.oregon.gov/deq/mm/Documents/HB3409Sec52CBEReport.pdf

[3] Urban Land Institute, *Embodied Carbon in Building Materials for Real Estate,* ULI, https://knowledge.uli.org/-/media/files/research-reports/2019/greenprint-embodied-carbon-report-final.pdf?rev=00b6e53d7ff94f53bd55c3f57ee1352c&hash=7D5F88EB02E2FF2C8106349322B9075C, Ryan Zizzo and Kelly Doran, *Regulating Embodied Emissions of Buildings: Insights for Ontatrio's Municipal Governments*, August 2022, and Tracy Huynh, Chris Magwood, Victor Olgyay, Laurie Kerr, and Wes Sullens, *Driving Action on Embodied Carbon in Buildings*, RMI and U.S. Green Building Council (USGBC), 2023, https://drive.google.com/file/d/1VD7RvQdLg7PWAUF2N97Q0-PAhes-k80Z/view.

[4] State of Oregon Office of the Governor, "DIRECTING STATE AGENCIES TO TAKE ACTIONS TO REDUCE AND REGULATE GREENHOUSE GAS EMISSIONS," 2020, accessed September 24, 2024, https://www.oregon.gov/gov/eo/eo_20-04.pdf.

[5] Portland.gov, "Current Sustainable Procurement Initiatives, Low-Carbon Concrete Initiative," City of Portland, accessed September 24, 2024, https://www.portland.gov/procurement/sustainable-procurement-program/sp-initiatives

state. The 2023 Oregon House Bill 3409 requires Oregon's Department of Consumer and Business Services, Building Codes Division to draft a report of findings and recommendations on options for reducing embodied carbon emissions of materials used in building construction. This report provides recommendations on the integration of embodied carbon requirements in the statewide building code, as well as an analysis of non-code-based approaches for tracking and reducing the embodied carbon of building materials. Each recommendation outlines the objective of the policy, a recommended timeline, and pathways for implementation and enforcement.

Evaluated options for code-based strategies include:

(1) a prescriptive method: establishing embodied carbon reporting requirements and global warming potential (GWP) limits for specific building materials;
(2) a performance-based method: incorporating provisions to conduct a whole-building life cycle assessment that demonstrates a reduction in global warming potential (GWP) compared to a baseline at the building level; and
(3) centering building reuse: introducing compliance options that incentivize building reuse to avoid the high embodied carbon emissions associated with new construction.

Key recommendations for each strategy are documented in the table below.

Table 1-1: Summary of code-based recommendations

Code Approach	Recommendation for Oregon
Prescriptive: Material-Specific Limits	• Set a percent-reduction goal and timeline for embodied carbon, consistent with Oregon's sector-wide energy efficiency goals set in EO 20-04 and HB 3409. Consider setting a target at 60% below 1990 levels by 2035. • At minimum, include the global warming potential impact of embodied carbon in the scope. Consider promoting other low-impact material attributes other than GWP, such as recycled, reused, salvaged, or regionally-sourced materials. • Apply provisions to commercial and multifamily project types. As an alternative, focusing solely on commercial buildings can also realize significant reductions. • Apply provisions to projects above 100,000 square feet in size, with the intent to reduce the size threshold over time. • At minimum, focus on high-emitting structural materials including concrete, steel, wood, and glass. Consider incorporating others after considering the

	availability of adequate data, potential impacts on greenhouse gas reductions, and market readiness and feasibility. Other products may include Mechanical, Electrical, and Plumbing (MEP) products and assemblies; glass; insulation; interior finishes; aluminum; and masonry. ● Require or give priority to product-specific EPDs through a points-based system. ● Start by setting GWP limits at 125% of the industry-average values by material to align with other precedents and allow for industry adjustment and learning. Reduce GWP limits over time to ultimately match the 60% reduction goal for embodied carbon. ● Integrate new requirements into the materials-focused chapters of the base code.
Performance: Whole-Building Life Cycle Assessment	● Set a percent-reduction goal and timeline for embodied carbon, consistent with Oregon's sector-wide energy efficiency goals set in EO 20-04 and HB 3409. Consider setting a target at 60% below 1990 levels by 2035. ● At minimum, include consideration of embodied carbon impacts (measured in global warming potential) in the scope. Consider requiring that WBLCAs consider other impact categories other than GWP as well. ● Apply provisions to commercial and multifamily project types. ● Apply provisions to projects above 100,000 square feet in size, with the intent to reduce the size threshold over time. ● At minimum, require that the physical scope of the WBLCA include the structure and enclosure of the building. In addition, consider incorporating some options for considering other building elements including interior finishes and service system: these may include Mechanical, Electrical, and Plumbing (MEP) products and assemblies; glass; insulation; interior finishes; aluminum; and masonry. ● At minimum, require inclusion of life cycle stages A1-A4, B1-B5, C1-C4. ● Set reference study period at 60 years per most precedents. ● Require or give priority to product-specific EPDs. ● Point to highly-referenced standards on LCA software, methodology, and data including ISO 14040, ISO 14044, ISO 14025, ISO 21930, ISO 3221931, EN 15805, and EN 15978. ● Start with an achievable reduction requirement to get project teams in the practice of hitting these limits. Achievable reduction requirements demonstrated by other policies have landed around 10% lower than a baseline building or 350 kg CO_2e/m^2. As more data becomes available for percentage-reductions and total caps that are achievable for projects in the region, revisit these requirements to push for higher reductions. ● Introduce provisions in a new mandatory appendix with reference to it in the Construction Documents section in Chapter 1 of the base code.
Promote Building Reuse	● Set a percent-reduction goal and timeline for embodied carbon, consistent with Oregon's sector-wide energy efficiency goals set in EO 20-04 and HB 3409. Consider setting a target at 60% below 1990 levels by 2035. ● The building code cannot mandate building reuse. Rather, incentivize alterations and additions that choose to pursue adaptive reuse over new construction by exempting these projects from prescriptive and performance-based embodied carbon provisions.

	● Apply provisions to projects above 100,000 square feet in size, with the intent to reduce the size threshold over time. ● Maintain at least 45 percent of the existing building's primary structure and enclosure in additions and alterations. ● Insert a compliance table for different project types into normative appendix with reference to the appendix in Section 107, which addresses construction documents submittals. Incorporate prescriptive, performance, and reuse requirements into the appendix.

Source: New Buildings Institute

The performance-based approach represents the greatest potential for reducing embodied carbon emissions, with a potential to realize a 50% reduction compared to a business-as-usual baseline, if the most stringent option were chosen. This approach is also anticipated to be the costliest to users of the code, adding an estimated $15,000 fee for performing WBLCA services. A material-based approach and building reuse pathway would also lead to significant GHG emissions savings, between 28-42 percent and 32-34 percent, respectively, and with lower cost impacts to code users.

The report also includes recommendations for other, non-code-based strategies that can complement efforts in code to further achieve embodied carbon reductions. These recommendations include the following:

1. Collect data for accurate benchmarking and tracking progress.
2. Encourage change through public procurement policies.
3. Advance circular economy through deconstruction, disassembly, and material reuse.
4. Promote design and construction best practices to reduce waste and embodied carbon.
5. Build out materials-based policy ecosystems to support code efforts.
6. Financially reward high achievers.

Using Oregon's Equity Pillars, a discussion on how best to develop and implement the recommended embodied carbon code and non-code approaches in ways that fully support an inclusive, healthy, and equitable present and future for all Oregon residents is included. How these approaches may impact communities in rural Oregon differently than communities in urban Oregon is also analyzed, and potential mitigation strategies are suggested in cases where approaches may negatively impact rural communities.

The need to address embodied carbon is urgent. The IPCC reports that limiting warming to the Paris target – and avoiding the worst-case impacts of the climate crisis – is contingent on global GHG emissions peaking by 2025 at the latest.[6] Because the impact of GHG emissions in the atmosphere is cumulative and because there is a limited amount of time to reduce them, carbon reductions achieved today are more valuable than carbon reductions achieved in the future. Focusing on embodied emissions in buildings, especially those associated with the early phases of buildings' life, are important because of the timing at which they occur – these are the first emissions from a new building. Code-based policies hold critical potential to address this bulk of

[6] Working Group III, "The Evidence Is Clear: The Time for Action Is Now. We Can Halve Emissions by 2030.," The Intergovernmental Panel on Climate Change, April 4, 2022, https://www.ipcc.ch/2022/04/04/ipcc-ar6-wgiii-pressrelease/.

emissions, as they impact decisions made early during the design process, which directly and most substantially influence early production and construction activities. Prioritizing these immediate emissions will help to more quickly stop the accumulation of GHGs in the atmosphere, improving the likelihood that the world reaches its GHG peak sooner.

2 History and Overview of Embodied Carbon

Over the past century and a half, the planet has experienced an unprecedented level of warming. Planetary temperature records illustrate that the climate, which, for millions of years cycled regularly through periods of warmer temperatures and ice ages, has veered drastically from these patterns since the latter half of the nineteenth century. Today, this sharp increase in global surface temperatures is both stark and undeniable; in the decade between 2011 and 2020, temperatures reached 1.1°C above those observed during the late 1800s. The period since 1970 recorded the fastest increase in any 50-year period over the last 2,000 years.[7]

The changing climate has already impacted weather, ecological, and human systems across the globe.[8] Communities and ecosystems along the world's coastlines are threatened by shrinking sea ice and rising sea levels. Water systems have been disrupted by stronger storms and more frequent flooding in some regions, and drought in others. Weather extremes combined with water stress have upset food and energy security. Human lives, health, and livelihoods are threatened by heatwaves, wildfires, intense precipitation, hurricanes and stronger storms.[9]

If the underlying causes of these changes are left unaddressed, the consequences are expected to amplify. Vulnerable communities, who have historically contributed the least to the problem, are and will continue to be disproportionately affected.

Worldwide, the scientific community has come to the consensus that human activities are responsible for the changing climate. Observed increases in greenhouse gas (GHG) concentrations in the atmosphere over the past few centuries are clearly linked with human activities and correlate with the temperature increases observed since the Industrial Revolution during the second half of the nineteenth century. The sun's energy, trapped in the atmosphere by GHGs, has radiated back to the earth's surface and has led to a steady increase in the world's temperature. Two of the GHGs most responsible for this heating effect are carbon

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[7] Katherine Calvin et al., "IPCC, 2023: Climate Change 2023: Synthesis Report. Contribution of Working Groups I, II and III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, H. Lee and J. Romero (Eds.)]. IPCC, Geneva, Switzerland.," First (Intergovernmental Panel on Climate Change (IPCC), July 25, 2023), https://www.ipcc.ch/report/ar6/syr/downloads/report/IPCC_AR6_SYR_LongerReport.pdf

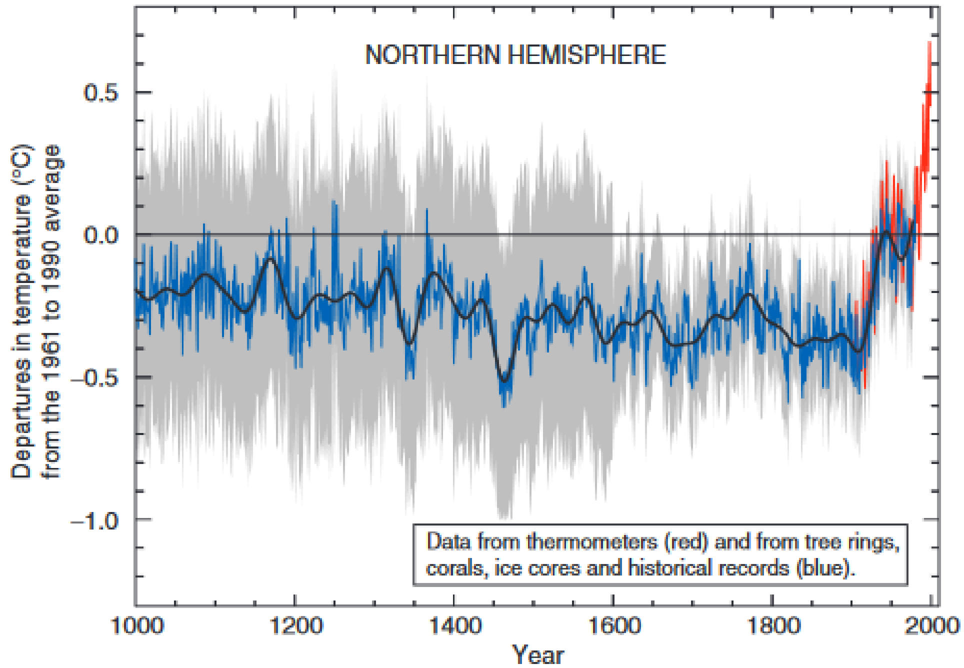
[8] "Climate Change Impacts," National Oceanic and Atmospheric Administration, August 13, 2021, https://www.noaa.gov/education/resource-collections/climate/climate-change-impacts

[9] "Climate Change and Human Health" (National Institute of Environmental Health Sciences, February 2024), https://www.niehs.nih.gov/sites/default/files/health/materials/climate_and_human_health_508.pdf

dioxide (CO_2) – the most abundant – and methane – the second-most abundant, which traps exponentially more heat than CO_2 over a short term.[10]

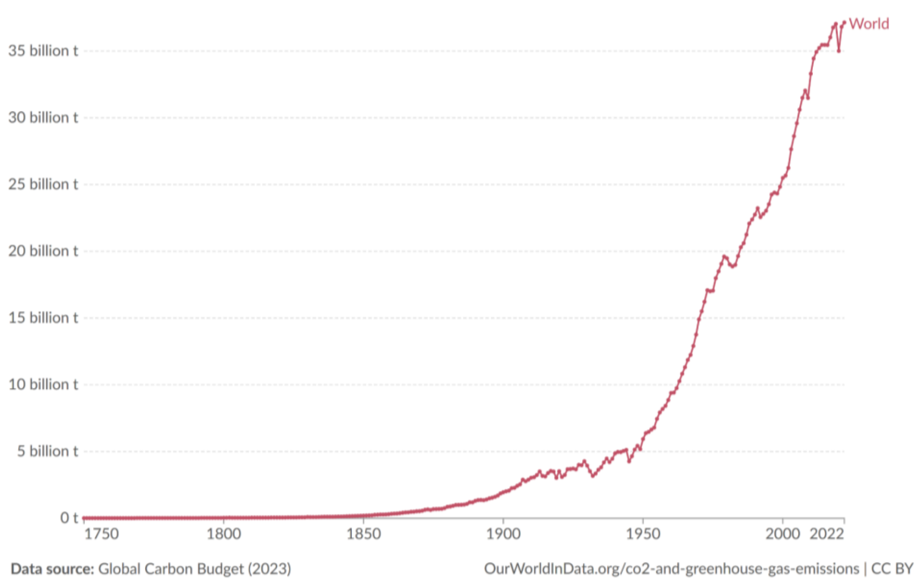
[10] "Importance of Methane," U.S. Environmental Protection Agency, November 1, 2023, https://www.epa.gov/gmi/importance-methane

Figure 2-1: Variations in the Earth's temperature over the last 1,000 years



Source: Intergovernmental Panel on Climate Change:
https://www.ipcc.ch/site/assets/uploads/2018/07/WG1_TAR_SPM.pdf

Figure 2-2: Annual CO2 emissions since 1750



Source: Our World in Data: https://ourworldindata.org/co2-emissions

In recognition of the urgency and seriousness of this problem, international, national, and subnational governments have enacted policies aimed at mitigating the deleterious impacts of climate change by cutting their GHG emissions. Among the most formative was the 2015 Paris Agreement, which set targets to keep global warming well below 2°C and preferably below 1.5°C. Per the Paris Agreement, countries report their plans for curbing emissions through Nationally Determined Contribution reports (NDCs).

195 out of 198 parties signed on to the Paris Agreement, including the United States. Across the country, states and jurisdictions have also committed to the goals of the Paris Agreement, setting carbon reduction targets as well as strategies to most effectively meet them. The state of Oregon is among those who have committed to taking climate action. As a member of the U.S. Climate Alliance, the state has committed to implementing policies that act in service of the Paris targets. In 2020, [Executive Order No. 20-04](https://www.oregon.gov/gov/eo/eo_20-04.pdf) (EO 20-04) set the state emissions reduction target at 45% below 1990 emissions levels by 2035, and at least 80% by 2050.[11] EO 20-04 also directed state agencies – including the Department of Consumer Business Services, Building Codes Division (BCD) – to identify and prioritize actions that reduce GHG emissions cost-effectively and in ways that will help vulnerable populations adapt to climate impacts.

Following on the heels of these sweeping actions, in 2023, Oregon's House Bill 3409, concerning energy use in residential and commercial structures, directed the BCD to:

- Adopt energy efficiency goals for 2030 for new residential and commercial buildings that represent at least a 60% reduction in annual regulated site energy consumption compared to 2006 energy codes
- Agree on metrics on baseline and reductions based on best practice and academic research
- Update the Oregon Reach Code to keep up with changes in the statewide building code
- Provide reports to the Legislative Assembly on progress every 3 years.

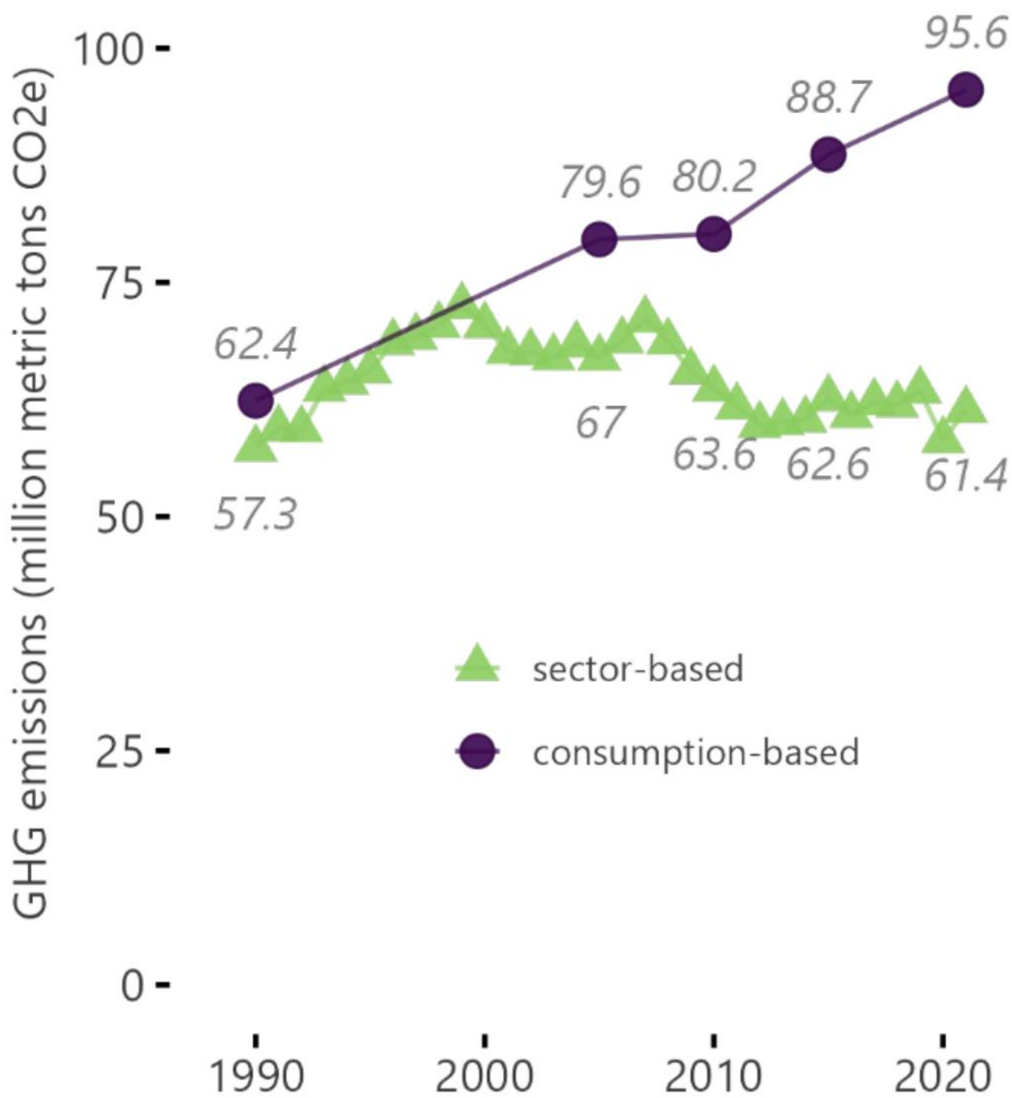
The need to continue advancing and evolving these and similar policies aiming to mitigate climate change becomes increasingly clear as global CO_2 emissions continue to rise; in 2023, emissions increased by 1.1%, bringing atmospheric concentrations to a new record high at 37.4 billion tonnes.[12] In Oregon, consumption-based emissions – which count the emissions associated with purchases from goods that come from out of state – are also increasing: from 62.4 million metric tons of CO2e in 1990 to 95.6 million metric tons in 2021, at 53 percent increase. Supply chains and production of materials make up a considerable portion of this.[13]

Figure 2-3: Oregon's consumption- and sector-based emissions, 1990-2021

[11] State of Oregon Office of the Governor, "DIRECTING STATE AGENCIES TO TAKE ACTIONS TO REDUCE AND REGULATE GREENHOUSE GAS EMISSIONS" (2020), https://www.oregon.gov/gov/eo/eo_20-04.pdf

[12] "CO2 Emissions in 2023 Executive Summary," The International Energy Agency, March 2024, https://www.iea.org/reports/co2-emissions-in-2023/executive-summary

[13] Oregon Department of Environmental Quality, *Opportunities to Reduce Greenhouse Gas Emissions Caused by Oregon's Consumption: Prepared for the Oregon Legislature in accordance with HB 3409 (2023)*, DEQ, September 2024, https://www.oregon.gov/deq/mm/Documents/HB3409Sec52CBEReport.pdf.



Source: Oregon Department of Environmental Quality (DEQ)

Buildings and the built environment are responsible for a significant portion of these emissions. At present, building operations and construction-related activities are responsible for approximately 39% of humanity's GHG emissions: 7% of that comes from the processes involved with materials used in the construction of buildings.[14] Per a September 2024 report from Oregon's Department of Environmental Quality (DEQ), Oregon buildings and infrastructure are responsible for 29% of the state's total consumption-based emissions, with construction

[14] "Bringing Embodied Carbon Upfront," World Green Building Council, 2019, https://worldgbc.org/advancing-net-zero/embodied-carbon/ and Carbon Leadership Forum, *Policy Toolkit Factsheet Series, Embodied Carbon 101*, CLF, June 2024, https://carbonleadershipforum.org/embodied-carbon-101-v2/.

materials accounting for 14.4%.[15] Concrete alone comprised 1% of the state's total emissions in 2015, generating approximately 887,000 million MT of GHGs; this is the to the emissions associated with 190,000 passenger vehicles on the road for a year.[16]

2.1 Introduction to Embodied Carbon in Oregon

The GHG emissions associated with the entire life cycle of buildings and infrastructure are referred to as embodied carbon: this includes their materials, construction activities, and end-of-life disposal.

Historically, policies that have targeted the reduction of the built environment's climate impact have focused on the operations associated with buildings' uses: the amount of pollution generated by fuel consumption from mechanical systems used to heat, cool, or light a building. While this focus has been critical, it has not accounted for the full scope of buildings' climate impacts. Additionally, as clean energy policy and efficiency standards and practices ratchet down operational carbon emissions, embodied carbon will continue to become a larger share of buildings' carbon footprint.

It is important to consider operational and embodied carbon emissions in tandem, as they both represent substantial opportunities to improve buildings' impacts on the climate. Balancing a consideration of operational carbon with embodied carbon emissions often requires an evaluation of tradeoffs: how emissions savings made in one area can offset additional emissions in another. For example, strategies to improve buildings' operational energy efficiency, such as improving building envelope thermal performance, will trade off with an increased amount of insulation, which are high in embodied carbon. Applying a whole-life perspective to buildings can make the realization of high-performing buildings with low embodied carbon possible.

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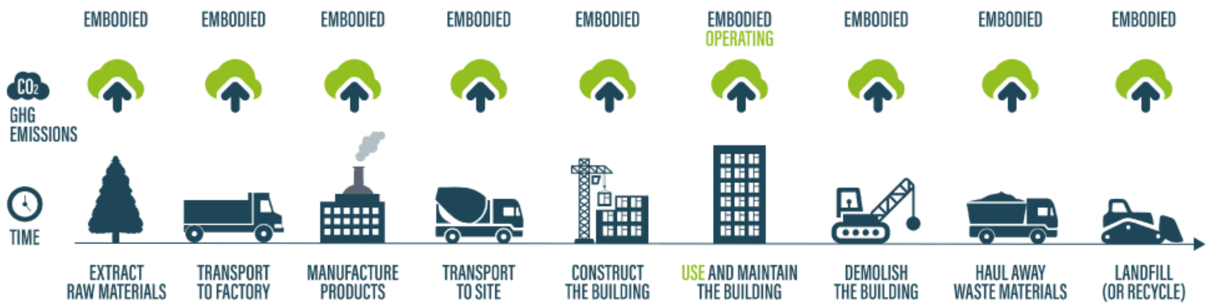
[15] Oregon Department of Environmental Quality, *Opportunities to Reduce Greenhouse Gas Emissions Caused by Oregon's Consumption: Prepared for the Oregon Legislature in accordance with HB 3409 (2023)*, DEQ, September 2024, https://www.oregon.gov/deq/mm/Documents/HB3409Sec52CBEReport.pdf.

[16] "Concrete," The Oregon Department of Environmental Quality, 2022, https://www.oregon.gov/deq/mm/production/Pages/Concrete.aspx.

Figure 2-4: Embodied and operational emissions throughout a building's life cycle



Source: Buildpass

In Oregon, expanding the scope of GHG reductions accounting beyond operational carbon has led to a more complete understanding of how the state has progressed relative to its 2035 and 2050 targets. The state's sector-based inventory considers the energy used by buildings in the state and has shown a reduction in GHG inventory. However, consumption-based emissions accounting has expanded the state's scope of inventory to account for other sources such as the production of materials and furnishings used during construction and remodeling. These and other processes included in the consumption-based inventory have offset these reductions. Oregon's rising consumption emissions are eclipsing all state efforts to decarbonize, and the state will not reach its climate goals without addressing the embodied emissions associated with building materials and construction.

The recent emergence of embodied carbon in the policy landscape has aimed to expand consideration for buildings' climate impacts substantially, to encompass emissions generated during material extraction, production, transportation, installation, and end-of-life disposal or recycling.

These initiatives are not new to Oregon: the state's policy landscape has included a focus on advancing low embodied carbon construction for several years. In 2017, Oregon Executive Order No. 17-20 directed state agencies to consider options to reduce the embodied carbon of building materials. In 2022, the Oregon Buy Clean Legislation (House Bill 4139) required the Department of Transportation to conduct life cycle assessments for construction and maintenance materials used for public infrastructure projects.[17] In 2023, the Oregon Climate Omnibus Bill (HB 3409) directed state agencies to identify opportunities within the state building code and other means to reduce embodied carbon emissions; to set sustainable design standards for state buildings; and to oversee that capital projects meet requirements.[18]

State agency initiatives and programs have also followed suit. These have included the following activities:

[17] "House Bill 4139," Oregon State Legislature, June 3, 2022, https://olis.oregonlegislature.gov/liz/2022R1/Measures/Overview/HB4139.
[18] "House Bill 3409," Oregon State Legislature, July 27, 2023, https://olis.oregonlegislature.gov/liz/2023R1/Measures/Overview/HB3409.

- The Oregon Department of Transportation (ODOT) will conduct low emissions materials construction pilots to test the use of low carbon materials in its projects.[19]
- The Department of Environmental Quality (DEQ) is collaborating with the Oregon Concrete and Aggregate Producers Association (OCAPA) to develop a voluntary program for concrete producers to generate EPDs for their mixes.[20]
- DEQ is supporting the City of Portland in their Low-Carbon Concrete Initiative, which requires EPDs for concrete mixes used on City projects, and will eventually set embodied carbon limits.[21]
- DEQ is providing training for designers looking to produce a life cycle assessment (LCA).
- DEQ is co-leading a Pacific Coast Collaborative (PCC) initiative to use zoning, building code, and permitting processes to require design and construction teams to measure and reduce their embodied carbon.[22]

Finally, the need to address embodied carbon is urgent, as earlier action can go a long way to mitigate the worst of the anticipated impacts of climate change. The IPCC reports that limiting warming to the Paris target – and avoiding the worst-case impacts of the climate crisis – is contingent on GHG emissions peaking by 2025 at the latest, and reducing them by 43% by 2030.[23] With regard to buildings and their life cycles, doing justice to this urgency requires a focus on the upfront embodied emissions associated with the early phases of buildings' construction and materials. Additionally, focusing on the early phases of a buildings' life – from the extraction and production of materials through the construction phase – comprises a significant portion of the total embodied carbon a building will be responsible for throughout its life.[24] A joint University of California, Berkeley and University of Washington study of 30 real buildings in California found that an average of 80% of a building's life cycle embodied carbon impacts over its lifetime takes place in the phases leading up to a building's completion before occupancy.[25] Code-based policies hold critical potential to address this bulk of emissions, as they impact decisions made early during the design process, which directly and most substantially influence early production and construction activities. Prioritizing these immediate

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[19] "Carbon Reduction Program," Oregon Department of Transportation, 2024, https://www.oregon.gov/odot/climate/pages/carbonreductionprogram.aspx.

[20] "Concrete Environmental Product Declaration (EPD) Program," The Environmental Council of the States, n.d., https://www.ecos.org/smm-projects/oregon-concrete-environmental-product-declaration-epd-program/.

[21] "Current Sustainable Procurement Initiatives," City of Portland, Oregon, 2024, https://www.portland.gov/procurement/sustainable-procurement-program/sp-initiatives.

[22] "Vision and Action Plan for a Low-Carbon Pacific Coast Construction Sector" (Pacific Coast Collaborative, 2024), https://pacificcoastcollaborative.org/wp-content/uploads/2024/01/PCC-Low-Carbon-Construction-Vision-and-Action-Plan-011124.pdf.

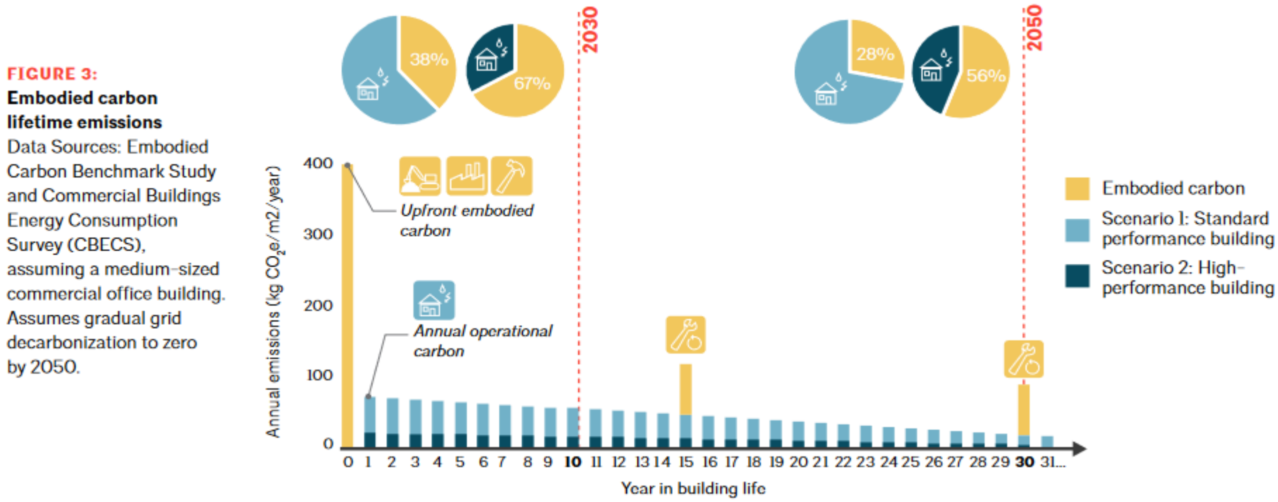
[23] Working Group III, "The Evidence Is Clear: The Time for Action Is Now. We Can Halve Emissions by 2030.," The Intergovernmental Panel on Climate Change, April 4, 2022, https://www.ipcc.ch/2022/04/04/ipcc-ar6-wgiii-pressrelease/.

[24] Meghan Lewis et al., "Part I: Introduction to Embodied Carbon," in AIA-CLF EMBODIED CARBON TOOLKIT FOR ARCHITECTS (AIA-CLF, 2021), https://content.aia.org/sites/default/files/2021-10/21_10_STN_DesignHealth_474805_Embodied_Carbon_Guide_Part1.pdf.

[25] Brad Benke et al., "The California Carbon Report: An Analysis of the Embodied and Operational Carbon Impacts of 30 Buildings" (The Carbon Leadership Forum, May 2024), https://carbonleadershipforum.org/california-carbon/.

emissions will help to more urgently stop the accumulation of GHGs in the atmosphere, improving the likelihood that the world reaches its GHG peak sooner.

Figure 2-5: Embodied emissions over the lifetime of a building



Source: American Institute of Architects and Carbon Leadership Forum

2.2 Voluntary and Regulatory Embodied Carbon Activity for Buildings

Policies aimed at cultivating a stronger understanding as well as a mechanism for managing embodied carbon have targeted better quantification, reporting, and reduction of embodied emissions. These strategies have striven to guide developers, designers, contractors, and procurers towards making more informed decisions about selecting sustainable materials, adopting eco-friendly construction practices, and striving for a more carbon-efficient built environment.

Political ambitions to reduce embodied carbon have been growing at the national level. The 2021 Bipartisan Infrastructure Law (BIL), and 2022 Inflation Reduction Act (IRA) in particular, have introduced an unprecedented level of federal funding for advancing research, testing, reporting, and application of low embodied carbon materials and construction practices to create greater market certainty.[26] The IRA allocates $250,000,000 towards an EPD assistance program supporting projects that improve the transparency and disclosure of embodied carbon emissions data in the US across all construction materials: the Oregon Department of Environmental Quality (DEQ) was among the 38 grant recipients to receive funding for

[26] "H.R.5376 - Inflation Reduction Act of 2022," Public Law No. 117-169 (2022), https://www.congress.gov/bill/117th-congress/house-bill/5376/text?q=%7B%22search%22%3A%5B%22inflation+reduction+act%22%2C%22inflation%22%2C%22reduction%22%2C%22act%22%5D%7D&r=1&s=1.

manufacturers to generate EPDs for concrete, asphalt, steel, wood, and other products.[27] The US Environmental Protection Agency (EPA) also received a separate $100,000,000 stream of funding through the IRA to develop an eco-label for low embodied carbon construction materials to help purchasers easily identify low embodied carbon products form their competitors.[28] This will help support the interim efforts underway, led by the US General Services Administration (GSA), to set low-carbon material requirements for projects receiving funding from the IRA. These requirements have already begun to push providers of concrete and cement, asphalt, steel, and glass to advance their decarbonization efforts at hastened rates and to demonstrate the feasibility of infusing these technologies in the broader market.

Other ambitious and broad-reaching initiatives exist, which aim to engage jurisdictions and practitioners to reduce their embodied carbon. In the private sector, voluntary building rating systems and professional GHG reduction commitment programs are building capacity for low embodied carbon construction and driving reductions. These programs have aimed to jump-start a low embodied carbon construction industry in the US and to prime the market for jurisdictions to adopt more comprehensive regulation through building codes.

A number of voluntary green rating systems include embodied carbon reporting and reduction requirements. The U.S. Green Building Council (USGBC) Leadership in Energy and Environmental Design (LEED) grants projects credits for quantifying embodied carbon emissions and additional points for realizing specified levels of reduction. The International Living Future Institute (ILFI) Living Building Challenge (LBC) and Zero Carbon Certification also requires teams to quantify and reduce their embodied carbon, encouraging a holistic, building-level approach to reduction rather than viewing materials and products in isolation.

In addition to voluntary green building rating systems, voluntary commitment programs and initiatives target specific groups related to embodied carbon. These include:

- Architecture 2030's "2030 Challenge" aims for a 65 percent embodied carbon reduction in "all new buildings, infrastructure, and associated materials" by 2030, and a total reduction by 2040.
- The American Institute of Architects' "AIA 2030 Commitment" supports the 2030 Challenge, targeting carbon neutrality.
- The Urban Land Institute's "Net Zero Imperative" Initiative focuses on both embodied and operational carbon and is aiming to globalize its effort.
- The Carbon Leadership Forum's MEP 2040 Challenge aims for net zero operational carbon in projects by 2030 and net zero embodied carbon by 2040, calling for "[a]ll systems engineers [to] advocate for and achieve net zero carbon in their projects."
- The Structural Engineering Institute's SE2050 targets net zero by 2050 and pushes for the prioritization of less or less impactful structural materials by participating firms.

[27] "Summaries of the FY 23–24 IRA 60112 Grant Selections: Reducing Embodied Greenhouse Gas Emissions for Construction Materials and Products" (U.S. Environmental Protection Agency, July 2024), https://www.epa.gov/system/files/documents/2024-07/2024-epd-grant-summaries-ira-60112-final-7.15.24.pdf.
[28] "Label Program for Low Embodied Carbon Construction Materials," U.S. Environmental Protection Agency, August 15, 2024, https://www.epa.gov/greenerproducts/label-program-low-embodied-carbon-construction-materials.

- C40 Cities Clean Construction Declaration calls for cities to pledge to achieve 50% embodied carbon emissions by 2030 (30% by 2025). Two North American cities – Los Angeles and Mexico City – have signed on to the C40 Declaration.
- The World Green Building Council (WGBC) has set a target of achieving net zero embodied carbon by 2050 (40% by 2030) and SE 2050's goal of achieving net zero embodied carbon structural systems by 2050.
- Infrastructure 2050 urges infrastructure professionals to understand, reduce, and ultimately eliminate embodied carbon in infrastructure projects by 2050.
- Other membership organizations through the Carbon Action Network (CAN) such as materialsCAN, ownersCAN, and homebuildersCAN support reduction commitments by acting as communities of practice, in which members of the building industry improve their awareness, test case studies, and share resources on embodied carbon strategies that are relevant to their respective practices.

In recent years, states and cities have similarly demonstrated their commitment to taking action on embodied carbon by setting their own targets. In North America, states and jurisdictions are charged by their Climate Action Plans and other climate policies to reduce the carbon impacts associated with their buildings and infrastructure. Embodied carbon-focused strategies are often identified as key mechanisms for realizing substantial reductions; in many of these cases, local actions requiring or incentivizing embodied carbon reductions are motivated by these reduction targets. In other cases, these initiatives help realize broader net zero emissions goals that address both operational and embodied carbon.

A summary of North American states and cities with embodied carbon targets is provided in Table 2-1.

Table 2-1: Notable North American state and local embodied carbon (EC) policy targets and strategies

Policy	Targets	Strategies
Embodied Carbon-Specific Targets: 40% by 2030-2035		
Vancouver Climate Emergency Action Plan	40% by 2030 (city-wide: new buildings and construction)	• EC limit for large buildings: 800 kg CO2e/m2 • All new buildings over 7 stories: 10% reduction compared baseline • Zoning limits for EC in new developments
California AB 2446	40% by 2035; 20% by 2030 (state-wide)	• Focus on materials production stage • CALGreen: encouraging building reuse, LCA generation, EPD submission
Boulder Climate Action Plan	40% by 2031 (city-wide)	• Require new construction to conduct analysis of embodied energy; subsidies to offset costs • Partner with communities on purchasing low carbon building materials for future city operations
Austin Climate Equity Action Plan	40% or max. 500 kg CO2e/m2 (per project) by 2030 (city-wide)	• Low EC design specs for city-funded projects • Incentivize low EC materials

		• Educate stakeholders on materials best practices • Stimulate decarbonization with local producers
Embodied Carbon-Specific Targets: 50% by 2030-2033		
Los Angeles Clean Construction Declaration	50% by 2030; 30% by 2025 (city-wide: new buildings, major retrofits, infrastructure)	• Calculate EC of city buildings as baseline • Deliver industry training on EC3 tool • City infrastructure pilot projects • Work with general contractors • Adaptive Reuse Ordinance • LCAs required for municipal projects • Diversion of construction and demolition waste from disposal for all municipal projects • Require LCAs in planning permissions
Mexico City Clean Construction Declaration	50% by 2030; 30% by 2025	• Address construction waste and recycling • Promote recycled concrete in new construction • Government purchasing of sustainable and recycled materials • Focus on recycled materials in public works • LCA for government purchasing
New York City PlaNYC	50% embodied carbon by 2033 (city-wide: new buildings, infrastructure, major retrofits) Carbon neutrality by 2050; 40% by 2030 (city-wide: embodied and operational)	• Local Law 97: Emissions reduction goals; clean construction efforts from city's capital projects agencies • Executive Order 23: Low carbon concrete specifications, EPD submissions, low-emission vehicles, and equipment, LCAs, agency action plans for capital projects • Performance-based standards and low embodied carbon specifications for common building materials by 2025 • Green construction training in Economic Development Corporation (EDC) (2023)
Net Zero by 2050 (No Embodied Carbon-Specific Target)		
Portland Climate Emergency Workplan	Net zero carbon by 2050; 50% by 2030 (city-wide: operational and embodied)	• Low-carbon alternatives • Adaptive reuse • Whole-building LCAs • Concrete: Low-Carbon Concrete pilot projects; EC thresholds for concrete in city projects • Deconstruction of Buildings Law • Parking Compliance Amendments Project • Residential zoning design standards with recommended low embodied carbon materials
New York State Scoping Plan	Net zero by 2050; 40% by 2030; 85% by 2050 from 1990	• Buy Clean Concrete mandate

	levels (state-wide: operational and embodied)	• Executive Order 22: Require state agencies to reduce embodied carbon in new construction, significant renovations, adaptive reuse • Require EPDs for building materials where available • Adopt methods for GWP calculation
Toronto Green Standard Version 4	Net zero by 2040 (city-wide: operational and embodied); "near zero" emissions for new construction by 2030; 50% for existing buildings by 2030	• Limits 350 kg CO2e/m2 (mandatory) and 250 kg CO2e/m2 (incentivized) for new city-owned buildings
Phoenix Climate Action Plan	Carbon neutral by 2050 or sooner; new construction net-positive in energy and materials by 2050 (city-wide)	• New buildings within city designed to Living Building Challenge, Net-Positive Design, or equivalent by 2050 • Develop EC calculators applicable to climate zone
Evanston, Illinois Climate Action and Resilience Plan	Carbon neutrality by 2050 (operational and embodied); zero waste by 2050	• Focus on reducing construction and demolition waste • Recycling and reuse requirements
King County 2020 Strategic Climate Action Plan	50% by 2030; 95% by 2050 (county-wide: operational and embodied)	• Low EC building materials in capital projects • Focus on consumption and materials management • Recovery and reuse • Reusable wood market • Strong building codes • Work on capital portfolios • Specify low EC building materials in capital projects
Miscellaneous		
Oregon Executive Order 20-04	45% by 2035; 80% by 2050	• Low emissions materials pilots in transportation projects • Voluntary EPD program for concrete producers • Local low-carbon concrete initiative support • LCA training for designers • Investigation of zoning, building code, permitting strategies to reduce EC
San Francisco Climate Action Plan	40% by 2040; 30% by 2025 (city-wide: new buildings, retrofits, infrastructure)	Updates to municipal green code: • Embodied carbon checklist for projects >10,000 SF

		• New construction, major renovations >10,000 SF: 10%+ EC reduction on projects per LCA (2024-2026) • Municipal construction projects: Material Reduction and Recovery Plan; Construction and Demolition Debris Recovery Ordinance; source separation; prioritize material reuse and recovery • Municipal construction projects >10,000 SF submit EC reduction strategies checklist • Tenant Improvements: Conduct LCA per LEED 4.1 CAP future actions: • Max. allowance values for EC of buildings • Transition to low-GWP refrigerants • Codes and regulations facilitating use of new materials and building technologies • Incentives, policies, guidelines for adaptive reuse of existing buildings and design and procurement of low-carbon structural materials for new construction • Amend existing building policies to require deconstruction and increase source separation of materials • Develop guidelines for tenant improvement projects • Expand and cultivate regional building material reuse markets • Advance best practices for "Design for Disassembly" and "Buildings As Material Banks"
Oakland 2030 Equitable Climate Action Plan	84% by 2050; 56% by 2030 (city-wide)	• Concrete code for new construction limits EC emissions • Improved EC performance standards in building code updates (materials and material-efficient building practices) • 2024: Track annual embodied emissions from city construction expenditures • 2025: Establish max. GHG performance thresholds

Source: New Buildings Institute

2.3 Methodologies for Quantifying Greenhouse Gas Emissions

The most common methodologies for quantifying embodied greenhouse gas emissions fall into two categories: the material level and the building level.

Embodied carbon that is reported at the material level relies on environmental product disclosures (EPDs) as the primary mechanism for reporting. The content and methodology behind producing EPDs are determined through a series of ISO standards and Product Category Rules. This materials-based approach in code is referred to as prescriptive.

Building-level embodied carbon is determined using a whole building life cycle assessment (WBLCA); the code approach to addressing emissions at this level is typically referred to as performance-based.

Global Warming Potential (GWP) is the most common metric for measuring and evaluating materials' greenhouse gas emissions over a product's or building's lifecycle. GWP is reported in units of carbon dioxide equivalent (CO2e), a measurement that normalizes and combines the impact of the various greenhouse gasses involved throughout the life cycle, relative to an equivalent unit of carbon dioxide, over a given period of time. The typical unit for reporting on GWP is kg CO_2 equivalent units (kg CO_2e), also commonly referred to as a carbon footprint.

2.3.1 Material-Level Quantification

Material-level quantification and reporting involve generating Environmental Product Declarations (EPDs) to assess and communicate the environmental impact of construction products. EPDs are independently-verified documents that report the environmental data from a life-cycle assessment (LCA) of a material in accordance with international standards.

EPDs are often referred to as "nutrition labels" for building products, because they report a variety of life-cycle impacts, including global warming potential, acidification, eutrophication, ozone depletion, and smog formation. EPDs can include additional manufacturer and product data, such as materials, manufacturing processes and locations, and resource use. EPDs are intended to be published for consumers to use in their material selection process and are valid for up to five years.

Table 2-2: Example of a hypothetical EPD for an asphalt mix design (courtesy of National Asphalt Pavement Association)

TRACI Impact Indicator	Unit	Materials	Transport	Production
Global Warming Potential	kg CO_2-Equiv.	83.4	11.8	168
Ozone Depletion	kg CFC-11-Equiv.	1.81e-08	5e-10	8.55e-11
Acidification	kg SO_2-Equiv.	0.486	0.0577	1.08
Eutrophication	kg N-Equiv.	0.0263	0.00373	0.0207
Smog Air	kg O_3-Equiv.	8.23	1.81	13.3

Note: Impacts for Test Mix 1, a dense-graded Superpave asphalt mixture, categorized as a hot-mix asphalt mixture, produced within a temperature range of 100 to 250°F.

Source: Federal Highway Administration[29]

EPDs are verified by independent third parties who impartially review them before their publication. These parties ensure the accuracy and reliability of the EPD and evaluate it for compliance with international standards that dictate the development of EPDs.

The International Standards Organization (ISO) identifies three types of environmental claims; when it comes to the embodied carbon of building products, policies will consistently call for Type III EPDs:

- **Type I:** third-party verified labels based on criteria set by a third party; governed by ISO 14024
- **Type II:** self-declarations made by manufacturers and retailers; governed by ISO 14021
- **Type III:** third-party verified product information based on life cycle impacts; governed by ISO 14025

EPDs are governed by product category rules (PCRs), which dictate how practitioners perform the LCA to develop an EPD of that product category. PCRs lay out methodologies for generating EPDs, describing aspects that include:

- Description of the product
- Goal and scope of assessment including system boundary, description of data and its quality, inputs and outputs to be considered
- Data aspects such as methods of collection, calculation, and classification of material and energy flows
- Environmental impacts to be considered

[29] "TECH BRIEF: ENVIRONMENTAL PRODUCT DECLARATIONS Communicating Environmental Impact for Transportation Products" (U.S. Department of Transportation, March 2021), https://www.fhwa.dot.gov/pavement/sustainability/hif21025.pdf.

- Presentation in the final report.

Examples of PCR-governed product categories include structural steel, rebar, and ready-mix concrete. These are developed by program operators in an open process that allows industry stakeholders to review the draft PCR, ask questions, and share comments. Participating stakeholders may include manufacturers, material suppliers, consumers, trade associations, nongovernmental organizations, public agencies, LCA practitioners, and certification bodies.

EPDs are the predominant tool for GWP disclosure in the building and construction industry. Building professionals use EPDs to evaluate the environmental impacts of a product and to compare data between functionally equivalent products. They are also used to benchmark current practice and guide future improvements.The reporting of a material's GWP allows for comparisons of the carbon footprint of different products.

EPDs exist at different resolutions, the two most common being product-specific and industry-wide. Product-specific EPDs represent products that come from a specific manufacturer, and include manufacturer-specific EPDs, representing a family of products all produced by one manufacturer; product-specific EPDs, representing a specific product produced by one manufacturer; and facility-specific EPDs, representing a specific product produced at one facility by one manufacturer. Industry-wide EPDs represent multiple manufacturers within an industry and report values as averages of the industry as a whole. These EPDs are particularly helpful for benchmarking national and regional environmental impacts of particular product types.

Over the last decade, the number of manufacturers producing EPDs for their products has grown exponentially worldwide and in the US. In Oregon, several efforts are underway to increase the prevalence of EPDs on the local market. The Department of Environmental Quality (DEQ) is collaborating with the Oregon Concrete and Aggregate Producers Association (OCAPA) to develop a voluntary program for concrete producers to generate EPDs for their mixes. DEQ is also supporting the City of Portland in their Low-Carbon Concrete Initiative, which requires EPDs for concrete mixes used on City projects, and will eventually set embodied carbon limits. Additionally, the state was recently awarded a federal grant to help manufacturers generate EPDs for building products. This is further detailed in the section of this report entitled, *A Summary of the State of the Market.*

2.3.2. Building-Level Quantification

Whole Building Life Cycle Assessment (WBLCA) reporting and reduction evaluates the environmental impact of a building throughout its lifecycle, calculating total carbon emissions for the complete life cycle of a building.

WBLCAs can cover as many parts of the building as there is available data. Typically, WBLCA policies call for a consideration of the materials that go into a building's structure and enclosure. The impact of building materials and construction is broken down into the various life cycle stages, spanning from the extraction of raw materials through to the disposal of materials at the end of a building's life. Assumptions about future life cycle stages are made within the scope of a reference study period – or the extent into the future a WBLCA anticipates – which typically spans somewhere between 60 and 100 years.

This assessment tends to focus on a range of impact categories, among which climate change (reported in global warming potential, or GWP) is one. Other categories include impacts on land use, resource use, ozone layer depletion, human health effects, ecotoxicity, smog, acidification, and eutrophication. Resource and land use refer to the extraction of resources at paces that are too fast for replenishment to keep up, leading to depletion. Land use changes including deforestation have serious impacts on biodiversity and ecosystems. Eutrophication and acidification refer to the proliferation of acidifying or nutrient-heavy substances, such as nitrogen and phosphorus, which harm soils and water bodies, affecting crop growth, ecosystems, and "dead zones" in marine and freshwater environments. Finally, under human health and environmental toxicity, the production of chemicals, radiation, or air pollution that cause human health issues and damage natural environments in the immediate and long terms, are considered.

By considering the range of these categories, the practice of conducting WBLCA offers the opportunity for project teams and policymakers to understand the impacts of construction projects on a more comprehensive level. With regards to global warming potential, WBLCAs provide insights into a building's carbon footprint and efficiency, which are typically reported as carbon impact per square foot as well as the quantity of material used.

2.3.3 Quantification Methodologies in Existing Standards

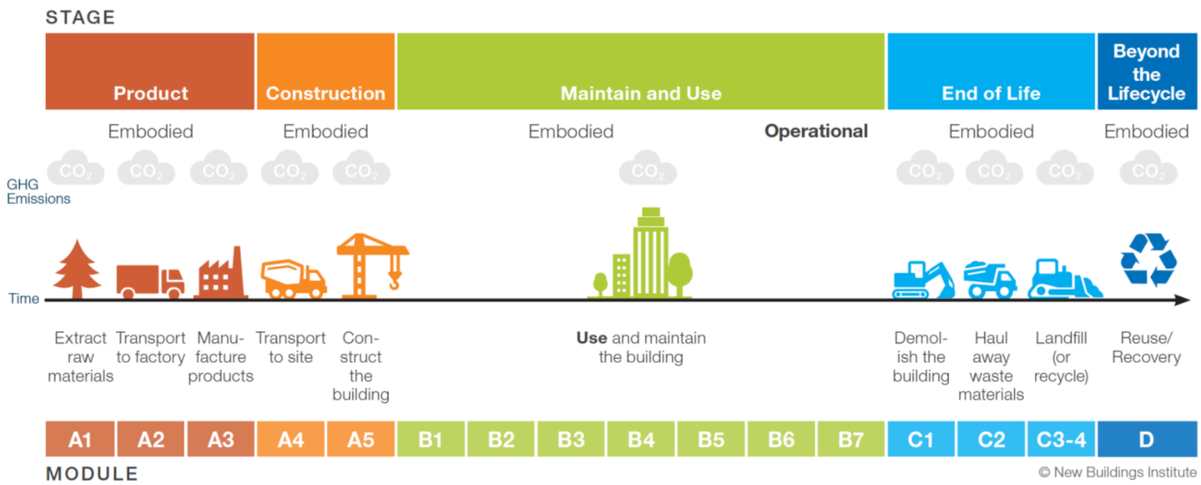
A number of standards exist to direct the methodologies to quantify greenhouse gas emissions, both embodied and operational.

EN 15978: The European Committee for Standardization (CEN) is an association of the National Standardization Bodies of 34 European Countries, which is responsible for developing the body of European Standards (EN). These are technical standards focused on products, materials, services, and processes related to energy, the environment, construction, and other sectors.[30]

EN 15978 (Sustainability of construction works — Assessment of environmental performance of buildings) is the primary European whole building LCA (WBLCA) standard that provides calculation rules for assessing the environmental performance of new and refurbished buildings. EN 15978 provides specific requirements and topics including the appropriate use of EPDs in a WBLCA; setting the scope, system boundary, and reference study period for the assessment; evaluating scenarios for construction, use, and end-of-life by life cycle module; calculation rules for particular modules; adding up gross material quantities for construction waste; applying replacement rates for different building components; and others. A new version of EN 15978 will be published imminently. The standard also defines the terminology that is conventionally used to define the life cycle stages of a building: these are detailed in Figure 2-6 below.

Figure 2-6: Building lifecycle stages and modules

[30] "About CEN," CEN, the European Committee for Standardization, 2024, https://www.cencenelec.eu/about-cen/.



Source: New Buildings Institute from EN 15978

The RICS Guide: The Royal Institution of Chartered Surveyors (RICS) is a professional body that develops and enforces international standards that are focused on sustainability and climate resilience in land management, real estate, construction, and infrastructure. Over 130,000 RICS accredited professionals across 140 countries evaluate compliance with standards for valuable, operating, and developing real estate.

The RICS Whole Life Carbon Assessment for the Built Environment builds on EN 15978 and is, at present, the most detailed guide for accounting for a building's whole-life carbon (operational and embodied). The document's calculating and reporting framework aligns with EN 15978 for built projects to enable comparability and usability of results from whole-life carbon assessments. The guide outlines the types of calculations, as well as assumptions, that should be applied to each phase of a building's life cycle, as defined by EN 15978. These include baseline material specifications to be compared against project scenarios; default transportation distances for products and materials; average values for construction site emissions; expected life spans for common products; typical recovery rates for EOL scenarios; requirements for accounting and reporting of biogenic carbon and carbonation; and a reporting template as an appendix. While this standard is intended primarily for a UK audience, it is globally applicable (to all RICS members) and geographic adjustments are highlighted to enable the requirements and guidance to be applied outside the UK.

International Green Construction Code (IgCC) / ASHRAE 189.1: The International Code Council (ICC) leads the drafting and publication of a collection of 15 building safety codes – including the International Building Code (IBC), International Residential Code (IRC), and International Green Construction Code (IgCC). These act as model codes that are commonly adopted across the world, including by jurisdictions in all 50 states and the District of Columbia. The IgCC was developed collaboratively by the ICC, the American Institute of Architects (AIA), the US Green Building Council (USGBC), and ASHRAE. The complete technical content of the IgCC is referenced in ASHRAE Standard 189.1. ICC and ASHRAE Codes and Standards are formulated through consensus processes accredited by the American National Standards Institute (ANSI).

The IgCC/ASHRAE 189.1 is an overlay to other ICC model codes and provides minimum requirements for the siting, design, construction, and operation of high-performance green buildings. Chapter 9, which addresses materials and resources, houses most of the standard's provisions around embodied carbon. The chapter has a mandatory prescriptive section, requiring project teams to provide 30 EPDs from not less than 20 different building products, which together must equal 25% of product costs. All products that cost more than 5% of the estimated material costs must have EPDs, and teams must report the GWP and functional units of all products. Project teams may then choose from a choice of conducting a WBLCA or adopting additional prescriptive requirements addressing the use of recycled and salvaged material content, regional materials, and biobased products. ASHRAE 189.1 supplements this embodied carbon accounting in Chapter 7 and Normative Appendix D, which present a methodology that quantifies the GWP of a building's operations over a time period.

Commonly referenced standards by embodied carbon codes, standards, and guides:

1. **ISO 14040:** Principles and framework of LCA
2. **ISO 14044:** Guidelines for conducting an LCA
3. **ISO 14025:** Principles and procedures of type III EPDs
4. **ISO 21930, EN14978, ISO 21929-1:** Criteria for LCA software and calculation methodology
5. **ISO 21930 and EN 15804:** Criteria for data sets

Forthcoming Standards

Current standards present a patchwork of approaches that presents inconsistencies regarding the scope of required analyses and assumptions integrated into accounting. A growing recognition of the need to formulate conventions around embodied carbon accounting has led to the development of new standards that are currently in the works and are anticipated to be released in the coming years. The processes to develop these standards are bringing in a wide range of stakeholders to garner feedback from the vast array of disciplines that will be impacted and using these standards: these include policymakers, architects and engineers, developers and homebuilders, materials and product manufacturers, LCA software developers, energy modelers, and climate advocates.

The proposed ASHRAE/ICC Standard 240P for Evaluating Greenhouse Gas (GHG) and Carbon Emissions in Building Design, Construction and Operation will be published in 2025 and will provide a quantification method for evaluating and reporting GHG emissions of a building over its full life cycle. The standard will establish minimum modeling standards, including consistent procedures, data, and reporting formats that can be referenced by policies, codes, and other standards that address new and existing building performance. The standard will cover both embodied and operational emissions and be internationally applicable.

Expected in late 2024 or early 2025, the proposed RESNET 1550 standard will also provide a methodology for calculating and reporting the embodied carbon, which can be used for all building types but is intended primarily for residences and dwelling units.This standard will define the scope for calculating embodied carbon and the methodology for conducting calculations across the product life cycle stages (A1-A3) of a residential project. While this standard will not set benchmarks or require embodied carbon reductions in its first iteration, the methodology published can be referenced by other policies that do set reductions targets or requirements. This standard can stand alone, but is designed to be integrated into the existing assessments that take place through the HERS rating system.

Finally, LEED is evolving its methodology for embodied carbon accounting in its latest version. The version 5 public review draft, prescribes assumptions and methodologies for both performance-based and prescriptive accounting. On the performance side, the new version sets requirements for the temporal and physical scope of a WBLCA, baseline comparisons, building product replacement cadences, and data specificity. On the prescriptive end, the standard establishes GWP limits by material; these thresholds reference existing policies and industry research.

3 Summary of Embodied Carbon Programs

A number of national, subnational, and model codes and standards in recent years have incorporated requirements for embodied carbon reductions. These tend to take either a prescriptive or a performance-based approach.

A prescriptive approach sets limits at the product or material level. Accounting for this level of information is done by submitting an environmental product declaration (EPD). GWP limits set by codes and standards tend to either be static values or benchmarked against a percent of industry-wide or average values.

A performance-based approach addresses embodied carbon at the project level, often setting GWP limits defined by a total limit per building or square footage, or as a percentage reduction compared to a baseline building, or a “business as usual” building that demonstrates equivalency with the proposed design as it relates to size, scope, function, energy performance, materials and structure, and other components. The most common approach for this accounting is through the generation and submission of a whole building life cycle assessment (WBLCA), which compares the proposed design to a modeled baseline or against a set embodied carbon cap.

In addition to codes and standards, other policy mechanisms include public procurement, reuse, waste, and circulation policies.These are described in further detail in Section 5 of this report.

3.1 Prescriptive: Requiring Low Carbon Building Materials

Policies targeting the reduction of carbon emissions associated with building products require the disclosure and verification of GWP data via EPDs. Procurement policies known as Buy Clean are the most frequent example of policies using EPDs in the United States. The state of Oregon, as well as the US General Services Administration (GSA) and the states of California, Colorado, New York, New Jersey, and Maryland all require EPDs from material suppliers and for those suppliers to meet GWP thresholds that become increasingly stringent over time. Policymakers often require the submission of product- or facility-specific EPDs and reference data from industry-wide EPDs to set GWP thresholds.

Promotion of low embodied carbon materials is also achieved through integrating GWP limits set at the material level in code – this is also known as a prescriptive approach. At this point in time, prescriptive policies tend to target the materials that tend to have the highest climate impact: particularly, concrete and cement, steel, asphalt, glass, wood, and insulation. GWP thresholds, measured per unit of material, for material product categories are typically hard caps or percentages based on industry or regional averages.

The U.S. General Services Administration (GSA) has made large strides in setting prescriptive requirements for four key materials: concrete and cement, asphalt, steel, and glass. The Administration's updated P100 Facilities Standards for the Public Buildings Service now requires that new construction and major renovations target a 20% reduction in their embodied carbon, compared to a project-specific baseline, and sets materials-specific requirements: GWP limits for concrete based on strength class, manufacturing techniques for asphalt, and type III EPDs for both. Projects receiving funding from the 2022 Inflation Reduction Act (IRA) must adhere to additional material requirements for concrete and cement, asphalt, steel, and glass: these are listed in the Interim IRA Low Embodied Carbon Material requirements.[31]

Canada's Standard on Embodied Carbon in Construction also provides a schedule of requirements for carbon footprint reductions and disclosures for concrete, requiring the use of the highest-resolution EPDs available or, in the absence of available EPDs, robust data derived using LCA methods. The total project GWP from ready-mix concrete must be at least 10% less than that of the baseline mix in the Regional Industry Average EPD for each strength class.

California also has a suite of policies that together work on reducing the embodied carbon of building materials, with a focus on concrete. One CALGreen compliance option requires EPD submission for steel, glass, mineral wool, concrete, requiring demonstration of a lower GWP compared to regional averages. In addition, California Assembly Bill (AB) 2446 requires the California Air Resources Board (CARB) to develop a framework for measuring and reducing the carbon intensity of building materials in new buildings. Senate Bill (SB) 596 builds on this by requiring CARB to develop a strategy for the cement sector in particular. AB 43 authorizes the establishment of an embodied carbon trading system, which would inform the framework for measuring the average carbon intensity of materials.

Other notable North American prescriptive policies include the following.

- The Portland Low Carbon Concrete Initiative requires city-procured concrete to meet a GWP threshold per strength class.
- Marin, CA was the first county in the United States to adopt a Low Carbon Concrete Code, under which new local building projects must choose from two pathways to comply: a total cement limit, or a GWP limit met for each concrete mix in a distinct strength category.
- Santa Monica, CA has recently followed suit by adopting its own Low Embodied Carbon Concrete Requirements.
- The Denver Green Code requires projects using the voluntary code to meet specific GWP limits for concrete and steel products. For concrete, the total CO_2e value of mixes must not exceed a certain maximum value and must have a product-specific type III EPD. For steel, type III EPDs submitted for a minimum of 75% of steel products, based on cost or weight, must be provided.

[31] "Interim IRA Low Embodied Carbon Material Requirements" (U.S. General Services Administration, May 16, 2023), https://www.gsa.gov/system/files/Interim%20IRA%20LEC%20Material%20Requirements%20-%20used%20in%20Pilot%20May%202023%2005162023.pdf.

- Under Toronto’s Waterfront Green Building Requirements, buildings can choose to use 50% recycled metal in steel and rebar, low-carbon concrete (with 25% Supplementary Cementitious Materials), or timber products certified by the Forest Stewardship Council.
- The Vermont Building Energy Code has an optional credit for GWP reporting of insulation materials.

3.2 Performance-Based: Whole Building Life Cycle Analysis (WBLCA)

Several European countries have made significant progress on pushing for WBLCA-based policy strategies. These include the European Union’s Energy Performance of Buildings Directive (EPBD); Denmark’s Strategy for Sustainable Consumption; France’s *Réglementation Environnementale* (RE2020); and the Netherlands’ Policy of the Environmental Performance of Buildings.

In North America, performance-based policies are also beginning to emerge. These tend to require reductions at the building level using two types of metrics: absolute whole-building caps or percentage reductions over a baseline value.

The Toronto Green Standard, for example, is the first in North America to cap the embodied carbon in new city-owned buildings at 350 kg CO_2e/m^2, with a voluntary limit of 250 kg CO_2e/m^2. These limits must be demonstrated through a WBLCA. While this standard is voluntary for privately-owned new buildings, incentives to participate are offered through the Toronto Green Standard (TGS) Development Charge Refund Program.

Vancouver, Canada’s Building Bylaws, have also set an embodied carbon cap for large buildings at 800 kg CO_2e/m^2, or a 10% reduction compared to a baseline for all new buildings over 7 stories. Requirements around what constitutes an acceptable baseline are further defined by the City of Vancouver Embodied Carbon Guidelines.

The California Green Building Standards Code (CALGreen) also has a performance-based pathway option; project teams that opt for this pathway must produce a WBLCA that demonstrates a 10% lower embodied carbon emissions level than a baseline project design. Following the direction that the state has set, the San Francisco Municipal Green Building Requirements similarly require construction on city-owned properties over 10,000 square feet to use an embodied carbon checklist and demonstrate a 10% GWP reduction using a WBLCA.

The Minnesota Sustainable Building Guidelines (B3) have had a WBLCA requirement since its Version 3.0 was published in 2017, asking project teams for buildings of at least 20,000 square feet in size to submit a WBLCA that reduces the project’s GWP by at least 10% compared to a reference building. EPDs must be also submitted to verify commitment to using specified projects. Under these requirements, project teams must document this 10% GWP reduction by using one of three compliance paths: WBLCA, Assembly-Level LCA, or Material-Level LCA. The WBLCA pathway helps to consider comprehensive strategies such as optimizing assemblies’ shape, layout, and surface area. The Assembly-Level LCA has a slightly smaller focus compared to the whole building option, and requires the model of a portion of a representative building. Finally, the Material-Level LCA requires the use of the state’s B3 LCA Material

Selection Calculator to document the project's primary construction materials and evaluate material substitutions to reduce GWP.[32]

At this point in time, setting locally-relevant benchmark values requires more information gathering. The City of Los Angeles, for example, has identified a potential solution to this data gap as requiring WBLCA for municipal projects and calculating the embodied carbon of city buildings in order to set a local baseline value. In California, projects complying with the CALGreen WBLCA option are voluntarily submitting project data to CLF to better inform the formulation of a future baselines. New York State Executive Order 22 also focuses on reporting and disclosure of commonly used construction materials by requiring design teams on their projects to calculate the embodied carbon of the whole project and submit EPDs when available. Finally, the City of Toronto has also undergone a benchmarking study for buildings in the Greater Toronto-Hamilton Area.

Local relevancy can vary by material based on a region's typical sourcing practices. Concrete and cement products, for example, are more likely to be sourced locally; data based on regional products is therefore more accurate. Steel, by contrast, may come from farther away; expanding the geographic breadth from which data is pulled, up to the national scale, may therefore warranted.

3.3 Requiring Procurement of Low Carbon Building Materials

Public procurement policies are useful mechanisms for priming the market to be ready for the eventual adoption of prescriptive requirements in code. Often, public agencies will adopt procurement practices for publicly owned, operated, constructed, and funded projects in order to encourage industry shifts towards lower-carbon materials. Buy Clean policies use a combination of disclosure, incentives, and standards to leverage the significant purchasing power of public agencies to encourage a shift toward lower-carbon options in the broader construction materials market. Typically, these initiatives target the most carbon-intensive materials: concrete, steel, asphalt, glass being among the most common. These policies are often put forward with the expectation that, once the market has been primed to shift toward lower-carbon materials and product manufacturers have adjusted their practices, new prescriptive or performance-based requirements may impact private development. The same Buy Clean policies can also be adopted by the private sector.

The U.S. GSA is the largest player in enacting procurement policies at the federal level, incentivizing and supporting advancements in low embodied carbon materials through grants and preferentially awarded contracts for manufacturers whose production processes yield lower embodied emissions and pollutants, using type III EPDs as the primary data source for assessment of these materials. Additionally, federally-funded projects subject to the Administration's P100 or IRA funding are subject to the GSA's embodied carbon material requirements.

States and cities have also enacted their own Buy Clean programs. These include the following.

[32] "B3 Guidelines New Buildings and Major Renovations Version 3.2 Revision 02" (University of Minnesota, June 2024), https://www.b3mn.org/wp-content/uploads/B3GuidelinesVersion32r02_Small-Sites-Updates-Final.pdf.

- The Oregon Department of Transportation (DOT) has a program to track the greenhouse gas emissions associated with concrete, asphalt pavement, and steel in DOT projects.
- The Oregon Department of Administrative Services (DAS) Procurement Services established a statewide sustainable procurement policy in 2023. Among other things, this requires Executive Branch agencies, boards, and commissions to consider products with lower amounts of embodied carbon. In particular, new building construction or major renovations, as well as horizontal infrastructure projects, must request EPDs for specific materials like concrete, steel, and asphalt, and, where feasible, report on the project's GHG impacts with a WBLCA. Projects must also implement GHG reduction specifications where feasible, and prioritize deconstruction and salvage of building materials. DAS utilizes OregonBuys, the state's automated eProcurement tool, to streamline this process.
- The Buy Clean California Act (BCCA) requires state agencies, the University of California, and California State University systems' construction projects to meet specific GWP limits for structural steel, concrete reinforcing steel, and light and medium density mineral wool board insulation.
- New York City Executive Order 23 requires capital project agencies to make their best efforts to incorporate low-carbon concrete specifications and to submit EPDs for concrete used in capital projects.
- New York State Buy Clean sets embodied carbon limits for concrete mixes used in public building projects funded by the state.
- Colorado Buy Clean requires state-funded construction projects to meet specific GWP limits for asphalt, concrete, glass, post-tension steel, concrete reinforcing steel, and wood structural elements.
- The Port Authority of New York and New Jersey Low Carbon Concrete Program sets low GWP limits for concrete and requires EPDs for concrete, steel, and asphalt.
- Austin's Resolution No. 20230420-024 directed the city to explore a plan to transition all future city contracts and projects to low embodied carbon concrete by requiring submittal of EPDs by concrete producers and developing a strategy to pilot mix designs; the city will also establish a standard for low embodied carbon concrete.
- The Buy Clean Buy Fair Minnesota Act (2023) mandates the collection of EPDs and will roll out requirements around GWP limits for concrete, asphalt, structural steel, reinforcing steel, and potentially other materials for state-constructed buildings and roads over 8 years.
- Washington state's Buy Clean, Buy Fair Act (2024) requires embodied carbon reporting for concrete, steel, and wood products for projects over 100,000 square feet, building on the development of a database to track data and manage compliance.

3.4 Circular Economy: Deconstruction and Adaptive Reuse

Several policies lay focus on the end of life of buildings in order to decrease the burden of construction and demolition debris on landfills. Promotion of a circular economy, in which buildings and their products are cycled back into use at the end of the duration of their use, are promoted by policies that promote responsible deconstruction as well as building reuse.

Building reuse, or adaptive reuse, refers to the process of retaining and renovating the structure, enclosure, or other portions of an existing building. This process offers significant reductions for embodied carbon, as, if the existing building had not been reused, it would have been fully demolished and replaced with a newly constructed building on that location.

A 2011 study by Preservation Green Lab, Skanska, Green Building Services, and others found that reuse of a variety of building types could realize between 4 and 46 percent embodied carbon savings compared to new construction operating at an equivalent energy performance level.[33] Moreover, it can take between 10 and 80 years for new buildings designed with energy efficiency features to overcome the environmental impacts associated with the construction process. Scaling the practice of reuse across a state or city's building stock can realize significant reductions: a look at the city of Portland, for example, found that retrofitting and reusing all single-family homes and commercial office buildings instead of demolishing them over next 10 years could realize carbon reductions reaching around 231,000 metric tons of CO2, equivalent to about 15% of the county's total reduction target.

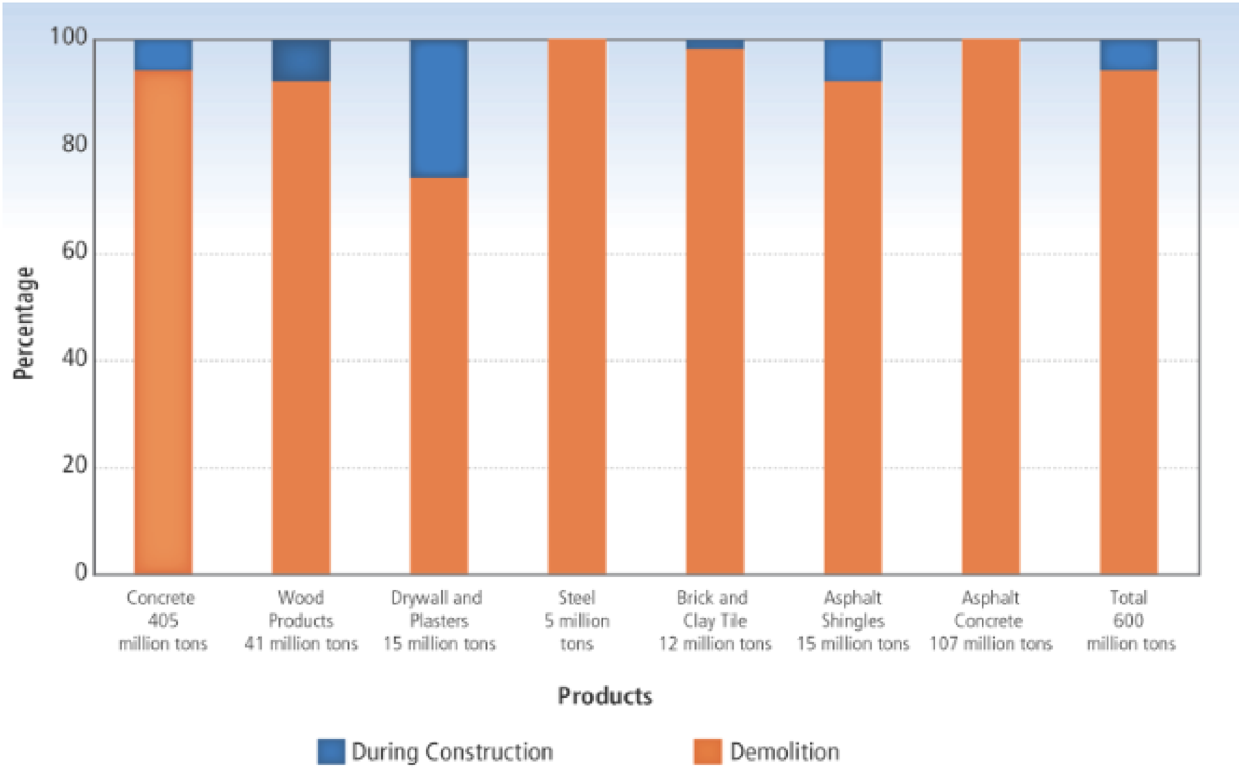
In addition, construction and demolition materials debris constitute a large source of waste in the United States; globally, an estimated third of the world's overall waste can be attributed to construction. More than 90 percent of the debris generated from building materials takes place as a result of demolition practices; a large portion of this debris ends up in landfills.[34] [35]

Figure 3-1: Contribution of Construction and Demolition Phrases to Total 2018 Construction and Demolition Debris Generation

[33] Patrice Frey, Liz Dunn, and Ric Cochran, "The Greenest Building: Quantifying the Environmental Value of Building Reuse" (National Trust for Historic Preservation Preservation Green Lab, 2022), https://living-future.org/wp-content/uploads/2022/05/The_Greenest_Building.pdf.

[34] "Advancing Sustainable Materials Management: 2018 Fact Sheet" (U.S. Environmental Protection Agency, December 2020), https://www.epa.gov/sites/default/files/2021-01/documents/2018_ff_fact_sheet_dec_2020_fnl_508.pdf.

[35] Norman Miller, "The Industry Creating a Third of the World's Waste," BBC, December 15, 2021, https://www.bbc.com/future/article/20211215-the-buildings-made-from-rubbish.



Source: US EPA

Deconstruction is the process of disassembling buildings so that their materials can be reused in new contexts including building projects. Recycling building products that would otherwise constitute waste alleviates the burden that the on-site common practices of contracts and builders have on landfills. Instead of populating the landfill, construction waste materials including concrete and concrete rubble, construction ceramics, timber, wood, glass, plastics, steel, iron, aluminum, excavated soil, and Styrofoam, can be recycled for new construction projects.[36] Additionally, creating a robust local marketplace of reused materials represents a significant opportunity to cut the high upfront emissions associated with extracting and producing new materials for construction projects. Finally, building out a market of recycled materials can realize substantial economic benefits: in 2016, the US EPA observed that recycling construction and demolition materials resulted in 230,000 new jobs.[37]

Several policies focused on reducing the impact of building materials also focus on the end-of-life of buildings and their materials and products, cultivating reuse through a circular economy and avoiding the high embodied carbon impact associated with new construction and sourcing raw materials.

In Portland, the city's Deconstruction Ordinance requires all single-family houses and duplexes – built in or before 1940 or designated as a historic resource – seeking a demolition permit to be

[36] Banu Sizirici et al., "A Review of Carbon Footprint Reduction in Construction Industry, from Design to Operation," Materials 14, no. 20 (October 15, 2021): 6094, https://doi.org/10.3390/ma14206094.
[37] "Recycling Economic Information (REI) Report," U.S. Environmental Protection Agency, July 16, 2024, https://www.epa.gov/smm/recycling-economic-information-rei-report.

fully deconstructed instead of mechanically demolished.[38] When this ordinance was adopted in 2016, Portland became the first city in the country to ensure that valuable materials would be salvaged for reuse instead of crushed and landfilled.

Los Angeles County's Construction and Demolition Debris Recycling Ordinance amends the county's Utilities Code to require at least 50 percent of the construction and demolition debris (by weight) generated on sites for projects exceeding $100,000 to be recycled or reused.[39] Project teams must submit a recycling and reuse plan (RRP) in order to be issued a permit, and additional reporting following the project's completion is required. Los Angeles City also promotes adaptive reuse at the building level through its Adaptive Reuse Ordinance, which amends the city's Zoning Code to make it easier to convert vacant office and commercial spaces into housing. This ordinance demonstrates the important impacts that policy promotion of reuse can have not only on the environment, but also on the city's significant housing crisis.[40]

San Antonio also has a Deconstruction and Circular Economy Program, which requires residential structures up to fourplexes, as well as detached accessory structures, to be deconstructed rather than demolished if they were built during or before 1920 or if they are designated as historic, within a Neighborhood Conservation District, and built on or before 1945.[41] In addition, the city supports a Material Innovation Center at its Port San Antonio campus, a former Air Force base that now serves as a center for material repair, reuse, and innovation aimed at providing the materials needed to spur a robust ecosystem of building reuse.[42]

Furthermore, Boulder, Colorado's Sustainable Deconstruction Requirements require all full structure removal and major remodeling projects to divert 75% of the materials generated from deconstruction projects (by weight), including a minimum of three material types, away from the landfill.[43] This provision is enforced by requiring submission by project teams of a refundable deconstruction deposit of $1 per square foot of the structure being taken down.

Mexico City has also demonstrated that making significant strides in reducing the waste associated with its construction activities is possible. Since 2018, the city has nearly tripled its annual waste recycling.[44] This change is primarily driven by a 2021 policy mandating that construction and demolition waste from public and private works be disposed of at recycling

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[38] "Deconstruction Requirements," City of Portland, Oregon, 2020, https://www.portland.gov/bps/garbage-recycling/decon/deconstruction-requirements.

[39] "ORDINANCE NO. 2005-0004" (Los Angeles Public Works Division, March 30, 2004), https://pw.lacounty.gov/epd/CD/cd_attachments/CD_ordinance.pdf.

[40] "Citywide Adaptive Reuse Ordinance Fact Sheet" (Los Angeles City Planning, 2022), https://planning.lacity.gov/odocument/6725f347-7fdb-42fa-aa6e-44c37f8fa999/Fact_Sheet_-_Adaptive_Reuse_Ordinance.pdf.

[41] "Deconstruction Requirements," San Antonio Reuse, October 1, 2022, https://www.sareuse.com/deconstruction.

[42] "Material Innovation Center at Port San Antonio," San Antonio Reuse, 2024, https://www.sareuse.com/mic.

[43] "Sustainable Deconstruction Requirements," City of Boulder, 2024, https://bouldercolorado.gov/services/sustainable-deconstruction-requirements.

[44] Eliza Galeana, "Mexico City Triples Construction Waste Recycling in Six Years," Mexico Business News, April 10, 2024, https://mexicobusiness.news/infrastructure/news/mexico-city-triples-construction-waste-recycling-six-years.

plants, rather than cast into landfills or the natural environment. Projects are also required to use recycled materials for projects' non-structural elements. These policies are bolstered by the city's commitment of $200 million, directed toward improving recycling infrastructure; city officials are optimistic that these changes will result in positive public health improvements.

4 The State of the Market for Embodied Carbon in Oregon

Over the last decade, the scale and importance of embodied carbon emissions in the built environment has come into the spotlight. In 2013, embodied carbon reduction was introduced in LEED (Leadership in Energy and Environmental Design), the most widely used green building rating system.[45] Since then, the United States has seen a surge of federal and state-level action plans, policies, and programs aimed at reducing the embodied carbon of construction materials. Today, policy and voluntary programs continue to be the primary drivers in embodied carbon reductions.

Industry forerunners are already demonstrating the significant embodied carbon emissions reductions that can be achieved through simple, no- and low-cost strategies. Still, there are challenges to widespread adoption of low embodied carbon construction:

- The market for low embodied carbon materials is underdeveloped and inconsistent across geographic regions. The related market for EPDs is also new.
- Whole Building Life Cycle Assessments (WBLCAs) are underutilized and are limited by data gaps and inconsistencies.
- There is a lack of strong incentives for real estate developers to reduce embodied carbon in most jurisdictions.

Despite these challenges, there are clear opportunities to achieve early wins on embodied carbon. Replacing high embodied carbon materials with similar low embodied carbon materials, reusing existing buildings or salvaged materials, and designing buildings that use materials more efficiently are proven strategies accessible to industry practitioners today.[46] An RMI report indicates that reductions of embodied carbon between 19% and 46% are possible for little to no cost premium on common types of new buildings constructed in the Pacific Northwest.[47] An infusion of federal funding through the Bipartisan Infrastructure Bill and Inflation Reduction Act, along with new state and local policies are creating greater market certainty for low embodied carbon materials and construction practices.

Building and construction material consumption comprises approximately 14.4% of Oregon's consumption-based emissions.[48] Figure 4-1 from Oregon's 2021 consumption-based GHG

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[45] Leadership in Energy and Environmental Design (LEED), *LEED Reference Guide for Building Design and Construction*, LEED, November 2013, https://www.usgbc.org/resources/leed-reference-guide-building-design-and-construction.

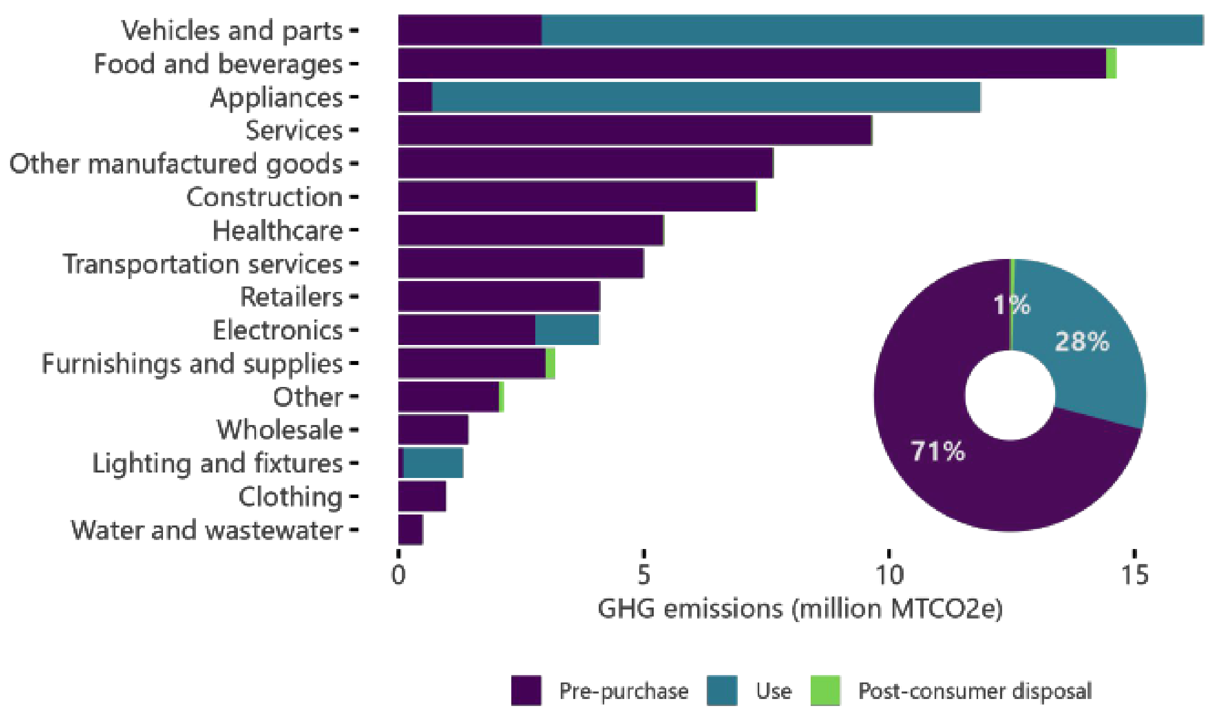
[46] Tracy Huynh et al., *Driving Action on Embodied Carbon in Buildings*, RMI and U.S. Green Building Council (USGBC), 2023, https://rmi.org/insight/driving-action-on-embodied-carbon-in-buildings/.

[47] Matt Jungclaus et al., *Reducing Embodied Carbon in Buildings: Low-Cost, High-Value Opportunities*, RMI, 2021, http://www.rmi.org/insight/reducing-embodied-carbon-in-buildings.

[48] Oregon Department of Environmental Quality, *Oregon's Consumption-Based Greenhouse Gas Emissions, 1990-2021*, DEQ, September 2024, https://www.oregon.gov/deq/mm/Documents/mm-Reporton2021CBEI.pdf

inventory reveals that construction is among the six highest-emitting categories that make up nearly two-thirds of all emissions across the state.[49] These emissions arise from materials that are sourced from within the state (32%), from other states in the US (42%), and from international imports (26%).[50]

Figure 4-1: 2021 Oregon consumption-based greenhouse gas emissions, by category and life-cycle phase (Million MT CO2e)



Source: Oregon Department of Environmental Quality, Oregon's Consumption-Based GHG Emissions, 1990-2021

Emissions associated with construction in Oregon have increased by 26.4% between 2005 and 2015, and 11.3% between 2015 and 2021.[51] Oregon has made important steps to show that reducing these emissions is a priority issue and is a leader amongst US state governments in advancing low embodied carbon policy. The earliest state-level action was the 2017 Executive Order No. 17-20 which directs Oregon agencies to consider options to reduce the embodied carbon of building materials. In 2019, the city of Portland created a Low Carbon Concrete Initiative to reduce the overall carbon intensity of concrete mixes used on city-owned projects.

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[49] Oregon Department of Environmental Quality, *Oregon's Consumption-Based Greenhouse Gas Emissions, 1990-2021*, DEQ, September 2024, https://www.oregon.gov/deq/mm/Documents/mm-Reporton2021CBEI.pdf

[50] Oregon Department of Environmental Quality, *Oregon's Consumption-Based Greenhouse Gas Emissions, 1990-2021*, DEQ, September 2024, https://www.oregon.gov/deq/mm/Documents/mm-Reporton2021CBEI.pdf

[51] Oregon Department of Environmental Quality, *Appendix A and B: Oregon's Greenhouse Gas Emissions through 2015: An assessment of Oregon's sector-based and consumption-based greenhouse gas emissions*, DEQ, May 2018, https://www.oregon.gov/deq/FilterDocs/OregonGHGreportAB.pdf and Oregon Department of Environmental Quality, *Oregon's Consumption-Based Greenhouse Gas Emissions, 1990-2021*, DEQ, September 2024, https://www.oregon.gov/deq/mm/Documents/mm-Reporton2021CBEI.pdf

This program established a product-specific EPD requirement, conducted pilot tests of lower-carbon concrete mixes, and defined embodied carbon limits for concrete mixes. Since 2020, there have been numerous additional state and local policies and programs to support low embodied carbon materials and construction, which have laid the groundwork for requirements in state-wide building code. A summary of these policies is available in the pages below.

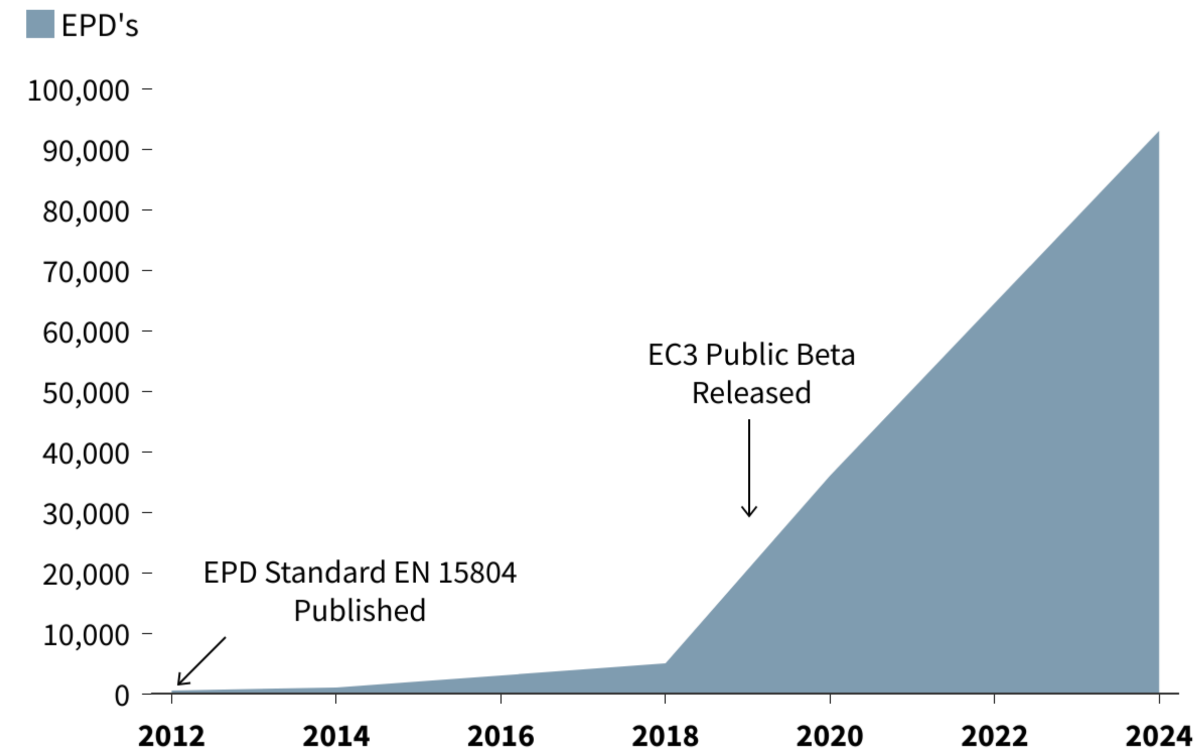
4.1 Where we are Today: Measurement and Procurement Practices in Embodied Carbon, Tools and Resources, Labeling Programs, and Building Certifications

Industry professionals measure embodied carbon at two scales: per individual material through Environmental Product Declarations (EPDs), and per building through Whole-Building Life Cycle Assessments (WBLCAs). For a definition of these terms, refer to the *Methodologies for Quantifying GHG Emissions*, *History of Embodied Carbon*, or the glossary. The use of both types of measurement has increased substantially in the last decade, however neither has reached full adoption.

Over the last decade, the number of manufacturers producing EPDs for their products has grown exponentially worldwide and in the US. Online databases help project teams identify and compare EPD data between products and competing manufacturers. Previous to these databases, project designers would reach out to individual manufacturers to request these documents, or they would be posted for download on manufacturers' websites. Since the launch of the Embodied Carbon in Construction Calculator (EC3) tool in 2019, a first-of-its-kind, free online database of construction material EPDs, there have been over 93,000 EPDs added to its database, with over 81,000 EPDs belonging to US manufacturers.[52] Figure 4-2 below shows the global growth in EPDs from 2012 through 2024.

Figure 4-2: Estimated growth in number of EPDs between 2012 and 2024 based on data from Andersen et al (2019) and the EC3 tool. Note that not all EPDs are published to EC3.

[52] Embodied Carbon in Construction Calculator (EC3) Tool, buildingtransparency.org, data retrieved July 24, 2024, https://buildingtransparency.org/ec3.



Global EPD publication count after 2018 estimated using number of EPD's reported in the EC3 database.

Source: Graphic generated by RMI using data from Andersen et al (2016) and Building Transparency

The availability of EPDs is inconsistent across material categories and across regions in the US. The number of EPDs available from ready-mix concrete manufacturers in Oregon is approximately 7,500, whereas in Oklahoma, a state with a population comparable to that of Oregon, the number of EPDs available from concrete manufacturers is only 3. This disparity is likely due to differences in demand for EPDs from the design and construction community, as well as the early establishment of embodied carbon policy in Oregon.

The vast majority of EPDs available on the market today are associated with concrete products, leaving many data gaps to fill related to other commonly used construction materials. Table 4-1 details the number of EPDs available in EC3 for different material categories and highlights the heavy trend towards concrete EPDs at the state and national level.

Table 4-1: Number of product-specific EPDs from the US and Oregon state available in EC3. Note that not all EPDs are published to EC3.

Product	Number of product-specific EPDs from Oregon based manufacturers available in EC3	Number of product-specific EPDs from US based manufacturers available in EC3
Asphalt paving	314	4,024
Ready-mix Concrete	7,508	72,364
Steel	6	240
Glass	0	26

Wood products	7	17
Insulation	8	251

Source: Data gathered from Building Transparency's EC3 on July 24, 2024

Project teams using low embodied carbon materials may need to procure materials from manufacturers located further away, including out of state, however a majority of construction materials (68% total) are already sourced from outside of Oregon state.[53] Asphalt paving and ready-mix concrete are the exception. These are local materials that are only suitable for transport within an approximate 90-minute radius of the project site. Although it may seem as though EPDs for ready-mix concrete are plentiful, the geographic spread within the state is inconsistent, with fewer manufacturers serving remote areas. For more information on the geographic differences of material availability in Oregon, see section 6.10 *Geographic Differences and Impacts on Urban and Rural Communities.*

Several current factors will serve to increase the number of EPDs on the market across all material categories. The Federal Inflation Reduction Act of 2022 allocates $250,000,000 towards an EPD assistance program supporting projects that improve the transparency and disclosure of embodied carbon emissions data in the US across all construction materials.[54] In July of 2024, the EPA announced 38 grant recipients to various manufacturers, industry associations, and universities with projects that improve EPD data, develop tools and resources that generate EPDs faster and more cost effectively, and provide financial assistance to manufacturers in producing EPDs. Among the winning proposals, $3,500,000 is granted to the International Code Council in partnership with Oregon DEQ and Washington state.[55] The funding will go towards Pacific Northwest manufacturers to generate EPDs for concrete, asphalt, steel, wood, and products with very few or no EPDs such as salvaged wood, tile, paint, windows, and roofing.

Another stream of funding through the Inflation Reduction Act allocates $100,000,000 to the EPA to develop an eco-label for low embodied carbon construction materials to help purchasers easily identify low embodied carbon products from their competitors. The draft program includes a tiered labeling format based on carbon intensity data from EPDs and a central registry of certified products to help facilitate procurement. The label program will improve comparability of emissions impacts between products and increase the value proposition for manufacturers to produce EPDs. The program is currently focused on four key priority materials: concrete, steel, asphalt, and glass. The few other eco-labels for building products in the US are focused on sustainable forestry for wood products, however none explicitly distinguish between high or low-embodied carbon products.

[53] Oregon Department of Environmental Quality, *Appendix A and B: Oregon's Greenhouse Gas Emissions through 2015: An assessment of Oregon's sector-based and consumption-based greenhouse gas emissions*, DEQ, May 2018, https://www.oregon.gov/deq/FilterDocs/OregonGHGreportAB.pdf

[54] US Environmental Protection Agency, "Reducing Embodied Carbon of Construction Materials through the Inflation Reduction Act," accessed August 18, 2024, https://www.epa.gov/greenerproducts/reducing-embodied-carbon-construction-materials-through-inflation-reduction-act.

[55] US Environmental Protection Agency, "Summaries of the FY 23-24 IRA 60122 Grant Selections: Reducing Embodied Greenhouse Gas Emissions for Construction Materials and Products," accessed August 18, 2024, https://www.epa.gov/system/files/documents/2024-07/2024-epd-grant-summaries-ira-60112-final-7.15.24.pdf.

State level funding to increase the number of EPDs on the market also exists. In 2018, the Oregon Department of Environmental Quality partnered with the Oregon Concrete and Aggregates Producers Association (OCAPA) to provide resources and funding for concrete producers to develop EPDs. Over the three years this program was active, over 1500 EPDs were produced.[56] Since 2023, the Massachusetts Clean Energy Center, a state economic development agency, in partnership with the Massachusetts Concrete and Aggregate Producers Association has a grant program intended to partially offset the costs of producing EPDs for Massachusetts concrete ready-mix producers. The grant program provides $3,000 per plant demonstrating publication of at least 5 third party verified EPDs.[57] Maryland's Buy Clean legislation sets aside funding for a similar EPD assistance program.

These funding programs, along with existing federal and state policies that require EPDs, sends a clear demand signal to manufacturers to invest in EPDs and disclose the carbon impact of their products.

Like EPDs, the use of Whole Building Life Cycle Assessments (WBLCAs) to measure embodied carbon in buildings is also gaining momentum. WBLCA are powerful assessments that consider both operational and embodied carbon over the full course of a building's life. Some green building rating systems use WBLCA to various degrees, including LEED, a widely used rating system which introduced a WBLCA option in 2013. A description of the green building rating systems that employ WBLCA is found in the paragraphs below.

Beyond LEED and other building rating systems, momentum has only recently picked up for policies that include WBLCA options and requirements. In August 2023, California became the first state to approve a whole-building embodied carbon assessment pathway in CALGreen, the statewide green building code. Starting in July 2024, project teams pursuing this compliance option will be required to conduct a WBLCA and demonstrate a 10% reduction in embodied carbon from a baseline. Other states are focused on training. In 2022, Oregon's Department of Environmental Quality (DEQ) funded WBLCA training and 1 year free subscription to LCA software for licensed architects in Oregon state.[58]

Several WBLCA tools and software are available to practitioners today. Some integrate into existing building-information modeling (BIM) software while others are stand alone. A few popular WBLCA tools are listed below:

- Athena Impact Estimator
- GaBi
- OneClick LCA
- SimaPro
- TallyLCA

Policies requiring specific reporting or reduction requirements through WBLCA must include specific guidance on the use of approved tools and software to ensure comparable results due

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[56] From written correspondence with Oregon's Department of Environmental Quality, June 12, 2024.

[57] Massachusetts Concrete & Aggregate Producers Association, "EPD Grant Program," accessed August 18, 2024, https://www.macapa.org/epd-grant-program/

[58] AIA Oregon, "Life Cycle Assessment & Tally", accessed August 18, 2024, https://www.aiaoregon.org/events/2022/8/4/life-cycle-assessment-amp-tally

to variability related to WBLCA software, including scope, methodology, and use of background data. Even with these parameters in place, ensuring the reliability and comparability of WBLCA results is a challenge. The use of different software can result in different estimates for the same building project. The ECHO Project (Embodied Carbon Harmonization and Optimization) is a collaborative group of organizations working to ensure that all embodied carbon reporting at the whole building and whole project scale in the US follow the same definitions and scopes to alleviate current variations that impede comparison, benchmarking, and setting targets.[59]

Beyond WBLCA tools, many other assessment tools and software exist for architects, engineers, and consultants to measure embodied carbon impacts and reduction options in building projects. These tools range in scope and the degrees of resolution provided, from quick calculators that focus on individual materials or assemblies to detailed building evaluations. The Carbon Leadership Forum maintains a list and description of existing tools and software for the evaluation of embodied emissions in buildings.

These tools can be very powerful for evaluating decisions that influence the environmental impacts of buildings and building materials, but the sheer number of options can lead to confusion for inexperienced practitioners. Choosing the most appropriate tool for the type of measurement or evaluation required and only conducting comparisons with results from the same tool will achieve the best results.

Green building certifications have been used by building practitioners in the US for more than 30 years. These certification programs provide a framework for minimizing the environmental impacts of building design through various criteria and requirements. Building operational emissions and energy efficiency are a large focus of each program; however, a small number of programs have included embodied carbon reduction requirements in recent editions, including:

- LEED (Leadership in Energy and Environmental Design) Building Design + Construction (BD+C), Version 4.1
    - Rewards strategies related to measuring embodied carbon through EPDs or WBLCAs, building and/or material reuse, sustainable sourcing of materials, and waste diversion
- International Living Future Institute (ILFI), Living Building Challenge
    - Requires embodied carbon reductions demonstrated through WBLCAs, encourages carbon sequestering materials, sustainable sourcing, and waste diversion
- International Living Future Institute (ILFI), Core Green Building Certification
    - An entry-level standard to ILFI's Living Building Certifications, this standard requires a WBLCA assessment with a one-to-two page narrative describing actions taken to reduce building-level embodied carbon and a comparison of embodied carbon intensity of interior materials compared to industry baseline.
- International Living Future Institute (ILFI), Zero Carbon Certification
    - Requires project team to verify that the operational and embodied carbon emissions of the project have been neutralized.

[59] ECHO Project, "Embodied Carbon Harmonization and Optimization," accessed August 18, 2024, https://www.echo-project.info/

- New buildings and building renovation projects must demonstrate a 20% reduction in embodied carbon, source products and materials with a lower than industry average carbon footprint, and offset 100% of the remaining embodied carbon emissions associated with the project.

- Green Building Initiative's (GBI) Green Globes for New Construction (NC)
  - Rewards strategies related to measuring embodied carbon through EPDs or Whole-Building LCAs, building and/or material reuse, supply chain waste minimization, and designing buildings for future deconstruction. T

Among these rating systems, LEED is the most popular standard in the US, and it has inspired many policies seeking to reduce the climate impact of the built environment. A new version of LEED set to be released in 2025 will have a much greater emphasis on embodied carbon, including incremental points for embodied carbon reductions between 10-40%.[60]

Other notable rating systems include ILFI's Core Green Building Certification and Zero Carbon Certification. Oregon Metro's Sustainable Building and Sites Policy for new buildings and major renovations owned by Metro requires qualifying projects to meet ILFI's Core Green Building Certification and Zero Carbon Certification standard, or apply for an exemption.[61]

4.2 Existing Oregon Policy and Programs Related to Low Embodied Carbon Construction

Oregon is a leader amongst US state governments in advancing low embodied carbon construction. State executive orders and legislation focus on advancing low embodied carbon construction for state-owned projects and identifying opportunities to reduce embodied carbon emissions through building codes and other means. State programs and initiatives for data collection, pilot projects, and funding for EPDs, will help support these policies. At the municipal level, both Eugene and Portland have included embodied carbon reduction in their Climate Action Plans. Portland has passed several notable policies that tackle embodied carbon reductions from different angles, including building deconstruction, sustainably sourced wood pilots, and lifting minimum parking requirements. Portland's low carbon concrete initiative is one of the nation's earliest policy efforts to test, measure, and deploy low embodied carbon materials.[62] All of these existing policies and programs have laid the groundwork for future requirements in state-wide building code.

<u>State Executive Orders</u>

a. Oregon Executive Order No. 17-20 (2017)

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[60] USGBC, *LEED v5 Rating System Building Design and Construction: New Construction*, First Public Comment Draft, April 2024, https://www.usgbc.org/sites/default/files/2024-04/LEED-v5-BDC-New-Construction-Public-Comment-1.pdf

[61] Oregon Metro, *Metro Sustainable Buildings and Sites Policy*, July 14, 2023, https://www.oregonmetro.gov/sites/default/files/2023/07/18/sustainable-buildings-and-sites-policy-20230714.pdf

[62] Carbon Leadership Forum, "Embodied Carbon Policy Toolkit, Policy Tracking Map," accessed August 18, 2024, https://carbonleadershipforum.org/clf-policy-toolkit/

        i. Directs state agencies to consider options to reduce the embodied carbon of building materials,
        ii. DAS, ODOE, and DEQ published a guidance memo to assist state agencies in compliance with the Executive Order. DEQ continues to provide technical assistance to state projects, including the Mill Creek Resiliency Building.

b. Oregon Executive Order No. 20-04 (2020)
    i. Requires that every three years, Oregon's Building Codes Division (BCD) evaluate and report on Oregon's progress towards achieving the goals for new residential and commercial buildings, and options for achieving these goals over the next three code cycles,
    ii. Requires BCD to adopt building energy efficiency goals for 2030 for new residential and commercial construction, representing a 60% reduction in new building annual site consumption of energy from the adopted 2006 Oregon codes,
    iii. Requires BCD to adopt a reach code when the ORSC Chapter 11 and OSSC Chapter 13 energy provisions are updated.

State Legislation

c. Oregon House Bill 2001 (2019)
    i. Requires cities with populations greater than 10,000 to allow duplexes, and cities with populations greater than 25,000 to allow middle housing, on lots zoned as single family
d. Oregon Buy Clean Legislation HB 4139 2022
    i. Requires Department of Transportation to conduct life cycle assessments for select construction and maintenance materials used for public infrastructure projects
e. Oregon Climate Omnibus Bill 3409 of 2023
    i. Direct state agencies to identify opportunities within state building code and other means to reduce embodied carbon emissions,
    ii. Directs state agencies to oversee all capital projects to meet certain requirements, and to set requirements for developing sustainable design standards for state buildings,
    iii. Directs DEQ to update the CBEI and identify opportunities to reduce consumption-based emissions.

State Initiatives and Programs

f. Oregon Consumption-Based Emissions Inventory
    i. Tracks state-wide consumption of construction materials
g. Carbon Reduction Program- Federal Grant to State DOT
    i. ODOT will conduct low emissions materials construction pilots. The projects will apply incremental costs to test the use of low carbon materials and study the outcomes,
    ii. 2024 call for small urban and rural area transportation projects. ODOT will grant a total of $12 million to projects in small cities and rural portions of

counties (less than 200,000 population) for projects that reduce GHG emissions from transportation, including low carbon materials.

h. Oregon DEQ and Concrete and Aggregate Producers Association (OCAPA) EPD program
   i. Voluntary program for concrete producers to generate EPDs for their products.
   ii. During the length of this program, over 1500 EPDs were produced.
i. Oregon's Climate Equity and Resilience Through Action (CERTA) Grant (2024)
   i. Oregon's DEQ received $197,181,796 funded through EPA Climate Pollution Reduction Grants (CPRG),
   ii. Over $25.2 million will be allocated towards building reuse, with a focus on converting existing vacant or underutilized buildings to housing and space-efficient housing.

Local Government Policies and Programs

j. Eugene Climate Action Plan 2.0 (2020)
   i. Lists several actions for reducing embodied carbon, including increase allowance of ADUs, low-carbon concrete for city roads, and perform annual audits to maximize material recovery
k. Portland Climate Emergency Workplan (2022)
   i. Directs Bureau of Planning Services to support policies such as low-carbon material alternatives, adaptive reuse, whole-building LCAs.
l. Portland Low Carbon Concrete Initiative (2019)
   i. Goal to reduce the overall carbon intensity of concrete mixes used on City projects. Established a product-specific EPD requirement, conducted pilot tests of lower-carbon concrete mixes, and defined GWP thresholds for concrete mixes.
m. Portland Sustainably Sourced Wood (2022)
   i. Sponsored pilot projects that identified sustainably-sourced options for procurement of wood
n. Portland Deconstruction Program (2019)
   i. Requires deconstruction for single-dwelling structures built in 1940 or earlier, or if the structure is designated as a historic resource
o. Portland Parking Compliance Amendments Project (2022)
   i. Requires the city to remove or severely restrict the amount of minimum parking mandates within the zoning codes
p. Lake Oswego Municipal Code Update: Demolition Tax (2022)
   i. A law that requires all residential projects which remove 50% or more of the surface area of exterior walls and foundations are required to pay the demolition tax. Projects that manually deconstruct the building with a certified contractor are exempt. Manual deconstruction is required for all units built in the year 1940 or earlier.
q. Metro's Build Small Coalition
   i. Supports research, policy, education, and partnerships to promote creation of and access to smaller housing

    ii. Based on DEQ research that shows that reduced housing size is the most effective way to reduce material and energy emissions in homes.

r. Metro's Sustainable Buildings and Sites Policy
    i. Requires new building or renovation projects owned by Metro that are at least 2,000 sq ft and at least $1,000,000 in total project costs to achieve ILFI's Core Green Building Certification and Zero Carbon Certification.

Cross- Government Collaboratives:

s. West Coast Climate Materials Management Forum
    i. A collaboration of state, local, and tribal governments that develop ways to institutionalize sustainable materials management practices.

t. Pacific Coast Collaborative (PCC) Low Carbon Construction (LCC) Task Force (2021):
    i. Launched in 2021, the task force is a joint effort to advance low-carbon materials and methods in building and construction projects across the Pacific Coast regional economy. The task force includes leaders from the states of California, Oregon, Washington, and the province of British Columbia, who worked together to create a shared regional Vision and Action Plan to accelerate innovation, investment, and market development for low embodied carbon materials, released in 2024. The Plan outlines three pathways to move the Pacific Coast region towards the vision of reducing embodied carbon in construction:
        1. Build regional demand for low-carbon construction
        2. Encourage growth of regional supply of low-carbon construction materials and services
        3. Build strategic partnerships

    Oregon's Department of Environmental Quality is the point of contact for the PCC's LCC Task Force.

While each of these policies and programs address different critical aspects of embodied carbon, there is no comprehensive policy that mandates embodied carbon reductions for private sector buildings. The various policies and programs described above have primed the market for incorporating embodied carbon reduction targets in the statewide building code, which will raise the floor on the standard of embodied carbon performance for private and public sector buildings across the state. For practitioners facing future embodied carbon requirements, numerous free and accessible resources such as embodied carbon roadmaps, guidance documents, frameworks, and workshops and webinars, are available from leading US NGOs and nonprofits, including:

- American Council for an Energy-Efficient Economy (ACEEE)
- Architecture 2030
- Building Transparency
- Carbon Leadership Forum (CLF)
- National Resources Defense Council (NRDC)
- New Buildings Institute (NBI)
- Rocky Mountain Institute (RMI)

- Urban Land Institute (ULI)
- And others.

Non-profit industry stakeholder groups support US professionals in learning and education, connecting with other stakeholders, and encouraging decarbonization commitments. Typically free to join, these groups cover many stakeholders involved:

- Architecture 2030 challenge, for architects
- HomebuildersCAN (climate action network), for large homebuilders
- Infrastructure2050, for civil engineers
- MEP2050, for mechanical, electrical, and plumbing engineers
- OwnersCAN (climate action network), for large portfolio building owners
- SE2050, for structural engineers

Professional associations such as the American Institute of Architects (AIA) and industry organizations such as the National Ready-Mix Concrete Association (NRMCA) and others, offer embodied carbon resources and training for their members.

4.3 Where We're Headed: Projections of Future Markets

In the US today, reductions in embodied carbon are driven by a combination of legislation and voluntary programs. According to CLF's embodied carbon policy tracking map, there are active embodied carbon policies at the state, city, or municipal level in 19 states across the US.[63] Governments declaring a climate emergency have recognized embodied carbon as an opportunity to quickly reduce emissions, resulting in numerous federal and state-level legislation, with more on the way. Although material-level policies are more common in the US currently, we can expect a transition towards building-level policies similar to the policy developments seen in Europe and Canada over the last decade.[64]

The impact of increased regulation will affect stakeholders across the industry, from material manufacturers and suppliers, building owners, architects and engineers, and construction professionals. The demand on manufacturers to disclose emissions data and decarbonize their products in the concrete, steel, and other current priority industries will spread to a much broader range of product manufacturers in the near future. More instances of professionals employing design strategies that reduce the overall embodied carbon impact of buildings will influence how we source, use, and dispose of construction materials overall. Embodied carbon literacy will continue to grow, with more harmonized tools and quantification methods available to help streamline the integration of embodied carbon into daily design and construction processes.

Within material manufacturing, concrete and steel will remain important in building construction for the foreseeable future. The pressure to decarbonize concrete and steel has resulted in

[63] Carbon Leadership Forum, "Embodied Carbon Policy Toolkit, Policy Tracking Map", accessed September 9th 2024, https://carbonleadershipforum.org/clf-policy-toolkit/

[64] Tracy Huynh, Chris Magwood, Victor Olgyay, Laurie Kerr, and Wes Sullens, Driving Action on Embodied Carbon in Buildings, RMI and U.S. Green Building Council (USGBC), 2023, https://rmi.org/insight/driving-action-on-embodied-carbon-in-buildings/

innovations and breakthrough technologies that, combined with grid decarbonization, make possible a future where the embodied carbon of these materials reaches near zero emissions. Several concrete and steel net-zero roadmaps and industry commitments have been created, including the Global Cement and Concrete Association's 2050 Net Zero Roadmap, National Ready Mixed Concrete Association's "Strength Through Transparency," and Steel Zero. These roadmaps reveal that reaching near zero emissions in these industries is contingent on technology innovation. Several low-cost interventions available today can make small but effective gains in emissions reductions, while other technologies that can all but eliminate the carbon footprint of these materials are under development but may be a decade or more away from implementation.[65]

Over recent years, the federal government has made available an unprecedented level of funding for the decarbonization of US cement, concrete, and steel manufacturing through the 2021 Bipartisan Infrastructure Law, 2022 Inflation Reduction Act, and other actions. Federal incentives range from loans, grants, and tax credits, to education and technical assistance, and focus on incorporating funding for technology research, development, demonstration, and deployment.[66] With this infusion of funding, we should see the concrete, cement, and steel industries move along the path to decarbonization.

While concrete and steel are high-emitting materials, some materials used to construct buildings store more carbon than they emit during the manufacturing process. These materials, known as carbon-storing or carbon-sequestering materials, can be biogenic (plant based) or mineral, and include a range of products from those that are well-established to those that are experimental. Some common carbon-storing materials include lumber and other timber products, cellulose insulation, and compressed straw panels.[67] Mineral based products such as microbe-grown cement are much less common, but a substantial amount of research and innovation is underway at universities and labs. Carbon-storing building products offer the building industry an opportunity to reverse the carbon flow from the sector. By using these materials, it is possible for buildings to become sites for large amounts of carbon storage.[68]

Today's market for carbon-storing building products other than timber is small, but increased demand from the building industry and government support for R&D and manufacturing could increase market readiness in the near future. In 2022, the federal Department of Energy awarded a total of $39 million to 18 projects that prioritize overcoming barriers associated with carbon-storing buildings, including scarce, expensive and geographically limited building

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[65] Christina Theodoridi, "Biden Administration Announces Landmark Industrial Funding," NRDC, March 25, 2024, accessed August 8, 2024, https://www.nrdc.org/bio/christina-theodoridi/biden-administration-announces-landmark-industrial-funding

[66] Catherine Grossman and Rebecca von dem Hagen, "Government Funding Opportunities to Help Decarbonize the Steel Industry," Third Way, January 18, 2024, accessed August 8 2024, https://www.thirdway.org/memo/government-funding-opportunities-to-help-decarbonize-the-steel-industry

[67] Tracy Huynh et al., Driving Action on Embodied Carbon in Buildings, RMI and U.S. Green Building Council (USGBC), 2023, https://rmi.org/insight/driving-action-on-embodied-carbon-in-buildings/

[68] Tracy Huynh et al., Driving Action on Embodied Carbon in Buildings, RMI and U.S. Green Building Council (USGBC), 2023, https://rmi.org/insight/driving-action-on-embodied-carbon-in-buildings/

materials.[69] A 2024 EPA grant program awarded over $6.5 million to hemp and bamboo building material industry partners for the development of EPDs.[70] Products such as hemp and straw panel building components have been included in recent versions to the International Residential Code, paving the way for these materials to scale quickly.[71] These are just a few examples of how carbon-storing materials are quickly gaining momentum.

Demonstrating the value of low embodied carbon to real estate investors is another area that has been gaining momentum in the US and elsewhere. For real estate companies, the embodied carbon emissions associated with building materials and construction comprise a sizable portion of scope 3 emissions impacts, however most real estate companies in the US are not in the practice of measuring these emissions. Scope 3 emissions are the indirect emissions in a company's value chain, not including indirect emissions from the generation of purchased energy consumed by a company (these are known as scope 2).[72] The US Securities and Exchange Commission (SEC) publishes rules that require public companies of a certain size to disclose their scope 1 and scope 2 greenhouse gas emissions data, but not their scope 3 data.[73] Starting in 2026, the State of California's Climate Corporate Data Accountability Act will require disclosure of scope 3 data for all companies that make more than $1 billion in annual revenue.[74] Because emissions disclosure communicates climate risk to investors and the public, this landmark bill will begin to reveal that for many large real estate companies, embodied carbon has become a risk of non-compliance and of losing reputational credibility.

At present, there is no industry consensus on scope 3 accounting rules for commercial real estate, however guidance from entities such as RMI, UKGBC, and Lendlease have started to address this. As many as 69% of investors are likely to increase their stake in companies that successfully manage sustainability issues while 42% have divested in companies that haven't demonstrated compliance.[75] The landscape of carbon disclosure is changing rapidly, and

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[69] US Department of Energy, "DOE Announces $39 Million for Research and Development to Turn Buildings into Carbon Storage Structures," June 13, 2022, accessed August 8, 2024, https://www.energy.gov/articles/doe-announces-39-million-research-and-development-turn-buildings-carbon-storage-structures

[70] US Environmental Protection Agency, "Summaries of the FY 23-24 IRA 60112 Grant Selections: Reducing Embodied Greenhouse Gas Emissions for Construction Materials and Products", accessed August 8, 2024. https://www.epa.gov/system/files/documents/2024-07/2024-epd-grant-summaries-ira-60112-final-7.15.24.pdf

[71] 2024 International Residential Code without Energy (IRC), "Appendix BL Hemp-Lime (Hempcrete) Construction," accessed August 8, 2024, https://codes.iccsafe.org/content/IRC2024P1/appendix-bl-hemp-lime-hempcrete-construction and 2018 International Residential Code (IRC), "Appendix S Strawbale Construction," accessed August 8, 2024, https://codes.iccsafe.org/content/IRC2018/appendix-s-strawbale-construction

[72] CDP, *CDP Technical Note: Relevance of Scope 3 Categories by Sector,* https://cdn.cdp.net/cdp-production/cms/guidance_docs/pdfs/000/003/504/original/CDP-technical-note-scope-3-relevance-by-sector.pdf

[73] PWC Viewpoint, "SEC adopts climate-related disclosure rules," March 7, 2024, accessed August 24, 2024, https://viewpoint.pwc.com/dt/us/en/pwc/in_briefs/2024/2024-in-brief/ib202402.html

[74] Thomson Reuters, "Companies need to integrate climate reporting across functions to comply with California's new law," October 20, 2023, accessed August 24, 2024, https://www.thomsonreuters.com/en-us/posts/esg/california-climate-reporting-law/

[75] Auri Mas and Anish Tilak, *The Business Case for Reducing Embodied Carbon: 9 Investments Commercial Real Estate Developers Can Make Today,* RMI, July 25, 2024, https://rmi.org/the-business-case-for-reducing-embodied-carbon-9-investments-commercial-real-estate-developers-can-make-today/

companies are soon likely to see the value in reporting embodied carbon in annual scope 3 disclosures and demonstrating substantial reductions in their building projects.

5 Analysis of Options: Methodology and Lens

Sections 6 and 7 of this report outline code- and non-code-based options for the state's consideration to quantify, track, and reduce the embodied carbon associated with building materials and construction. Each option outlines the objective of the policy, a recommended timeline, and pathways for implementation and enforcement. These sections also lay out the typical parameters and decisions that go into the formation of the various proposals.

An essential part of understanding the impact of these proposals on the state is to evaluate how these processes interact with the overall picture of its initiatives on racial equity, diversity, equity, and inclusion (DEI).

The categories of focus of Oregon's Racial Justice Council offer a basis for developing pillars for use as a lens to deepen support for DEI. The intent is not to use these pillars to identify new recommendations, but rather to identify how best to develop and implement the recommended embodied carbon code and non-code approaches in ways that fully support an inclusive, healthy, and equitable present and future for all Oregon residents. This means that impacts beyond embodied carbon will be included in some recommendations: the work on embodied carbon opens a door to creatively amplify beneficial synergies with related systems beyond the buildings themselves under the pillars of consideration.

The six categories are listed below, each with a description covering how this lens relates directly to the building industry and how the pillar is used throughout this research and analysis report by the consultants to inform Department of Consumer and Business Services (DCBS) work. The examples illustrate how current policies in other jurisdictions have positioned carbon reductions (both operational and embodied) to support their equity and inclusion goals.

In the sections on code- and non-code-based options, these pillars will be used to open the thought processes to expand beyond embodied carbon, with the hopes that these will inform how DCBS and other state entities can implement the work and achieve greater benefits across state systems.

5.1 Equity Assessment Pillars

5.1.1 Criminal Justice Reform and Policy Accountability

Transforming the building industry through a focus on embodied carbon avoidance provides opportunities to preserve the fabric of community, which can potentially improve connections to nature, reduce vehicle miles traveled (VMT), increase local economic resilience and strength, and improve human health outcomes. Improving the material cycle to reduce embodied carbon can also provide opportunities to define fair labor practices.

Identifiers include:

1. Opportunities to increase recognition of the value of the workforce at all levels. Growth of knowledgeable and skilled labor in manufacturing and construction can be supported by calling for a living wage, healthy and local green jobs, unions, and career paths.
2. Non-code approaches to increasing community connectivity while restoring or adaptively reusing existing buildings can increase planted and shaded areas, connections to multi-modal systems, resilience, activity areas and services.
3. There is a measurable (25%) reduction in domestic disturbance calls in affordable housing projects that have immediate access to usable green spaces for the residents.[76]

Examples include:

1. The Future of Climate Action | City of Boulder focuses on the creation and support of thriving communities as a strategy in reducing carbon. Linked and supportive documentations cite a circular economy goal, with health and wellbeing of humans as one of the 7 pillars of that approach.
2. Embodied Carbon in the Built Environment | Portland.gov builds on success in adaptive reuse to reduce embodied carbon, and sets climate and health standards for existing buildings.
3. New York City PlaNYC looks to larger-systems impact in carbon reduction through cool roof strategy and investment in city-wide pool access, along with setting max indoor temperature policy.

5.1.2 Housing and Homelessness

New and adaptive design and construction must focus on the health of occupants, stewardship of the environment, and long-term affordability. Reuse of existing buildings for accessible and affordable housing is a vehicle for significant embodied carbon reduction and housing access goals while maintaining the physical fabric of established communities of all scales from rural to urban.

Identifiers include:

1. Code approaches to define performance and building affordability for the long-term, ensuring affordable housing remains affordable for both owners and residents.
2. Non-code vehicles to encourage or require building reuse through development policies, especially re-use strategies for adapting commercial spaces into housing if that opportunity exists in a community or region. Inclusion of community benefit organizations (CBO) engagement in those development policies to ensure housing strategies include anti-displacement guidance and community voices.

Examples include:

1. 2022 - Assembly Bill 2446 (Holden, Chris), Embodied Carbon Emissions: Construction Materials (Chaptered) | California Air Resources Board focuses on affordable housing and embodied carbon reductions with equity measures for reduced carbon without cost increases.

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[76] Catherine O. Ryan, William D. Browning, & Dakota B. Walker (2023). *The economics of biophilia: Why designing with nature in mind makes financial sense.* Second edition. New York: Terrapin Bright Green, LLC. http://www.terrapinbrightgreen.com/report/eob-2

2. Los Angeles Clean Construction Declaration prioritizes building refuse tight to metro proximity.
3. CLIMATE ACTION PLAN | City of Phoenix focuses on complete streets, cool corridors, and local food sources, all of which support affordability and access for all, including non-homed residents.

5.1.3 Economic Opportunity

One of the strongest ways to reduce carbon is through a focus on local or regional supply of materials and resources, including labor. Improvements to neighborhoods should be beneficial to the communities that already live, work, play, heal, and learn there. As material awareness grows, a preference for locally sourced materials can be established and help to create economic vibrancy.

Identifiers include:

1. In code options, seek ways to define local labor, local products, and local services.
2. In non-code options, include “local” for products, education needs, and financial support mechanisms through project goal-setting and city policies. When buildings are reused or renovated under guidance including embodied carbon goals, the improvements could lead to dramatic price increases and gentrification if this risk is not managed. Identify supportive policies and procedures that focus on anti-displacement. These can include resident-owner requirements, community benefit agreements (CBA) and tax-relief programs tied to existing building and property improvements.

Examples include:

1. Scoping Plan - New York's Climate Leadership & Community Protection Act contains a 35% minimum and a goal of 40% of all funding through the NYS Climate Law for disadvantaged communities, with definition of these parameters set with 45 data points.
2. Clean Construction Declaration Mexico City includes incentives to increase recycled material use and recycling processes. Also a support of teleworking to improve living wage job access.

5.1.4 Health Equity

Health and safety have always been central to energy and building codes, and now the definition of health and safety is expanding to be informed by the societal health impacts of climate change and GHG emissions, as well as the hyper-localized toxic burden of fossil fuel use.

Identifiers include:

1. Opportunities for use of EPDs in code-based options for GHG information as well as other aspects such as smog creation to inform purchasing goals and support growth of local low-carbon manufacturing.
2. In non-code, focus on connections with larger-scale systems such as transit. Any public RFPs along with policies to guide private projects, can serve to connect and expand walkability, resilience, green corridors, and result in human health improvements.

Examples include:

1. Los Angeles Clean Construction Declaration has a focus on electrification of construction equipment.
2. King County 2020 Strategic Climate Action Plan uses the cost of carbon in determining goals for carbon reductions in operations.

5.1.5 Environmental Equity

GHG reduction is a goal for operational and embodied carbon, construction practices, manufacturing, and transport.

Identifiers include:

1. The risks and benefits at larger systems-scales are typically beyond the direct impact of the codes, yet can be integral to non-code recommendations such as policies, incentives, and guidance documents. Foster recognition of common spaces as a valuable service in communities of all sizes for resilience and health. One application of this lens is to ask, "where can this action achieve even deeper reductions by considering related systems".

Examples include:

1. CLIMATE ACTION PLAN | City of Phoenix focuses on walkable communities and reduction of single-occupancy vehicle (SOV) trips by 60%. Also buildings focused related to mobility connections.
2. King County 2020 Strategic Climate Action Plan has a forestry focus supporting immigrant and refugee farmers.

5.1.6 Education Recovery

A challenge in code approaches is that the code is only one step. Another is resources for education and awareness of implementation pathways, and a third is positioning the work for truly effective enforcement.

Identifiers include:

1. For code- and non-code options, it is important that equitable implementation strategies, education, and enforcements do not favor the wealthy or well-positioned.

Examples include:

1. Evanston, IL Climate Action and Resilience Plan has an outreach and behavior change focus for mitigation.
2. CLIMATE ACTION PLAN | City of Phoenix calls for the development of an accessible embodied carbon calculator as well as incentives for adoption.

5.2 Summary of Case Studies

Many existing policies, all of which address equity at various levels, were looked at to help inform the analytic lens described in this section. In Table 5-1, the six pillars as created by Oregon's Racial Justice Council are used as a high-level scanning guide to identify the approaches in engaging in equitable solutions in these policies.

The readily-evident approaches are listed in the Key Aspects column, and then these are judged against the six pillars, color-coded to indicate the areas where the effects would be felt. Some of these have a direct impact, such as clearly-defined financial structures to support disadvantaged communities in a carbon transition. Some are softer, though no less important. These tend to be synergistic benefits such as tree canopies and walkability programs that will support community connection and potentially reduce violence and crime. Although many of these are not directly tied to embodied carbon code language and policies, they have the potential to reduce carbon emissions overall through a focus on diversity and resilience improvements in the local economy and labor, increase of building reuse, reduction in heat island impacts, and increase in density of neighborhoods.

In sum, there are two aspects that are not strongly represented throughout this landscape of policies, and one additional reflection.

One aspect is the lack of a dominant focus on existing buildings. There are a few great examples of attention to existing building reuse, density of urban centers, and/or deconstruction approaches, but, for the most part, the interest in preferential adaptive reuse and in recognizing the positive impacts of such reuse on embodied carbon avoidance as well as on most of the equity pillars is light or missing.

Another aspect that is absent is attention to the behavior change, education, and implementation that is necessary to realize embodied carbon reduction and work toward a circular economy. The reports, policies, and summary materials are all well-developed, and some programs mention workforce development or other industry-focused education, but nearly none of them discuss outreach, behavior change, and education for the building users, the communities, or the legislation and policy makers.

One last reflection is that most of the distinct embodied carbon reduction policies and goals do not discuss much more than setting targets or proof methods. In a high-level review there is no evidence of using the pillars, or similar, in implementation planning to define the larger system impacts and define how to achieve them intentionally. In the table, the impacts into the pillars are left blank in those rows, not because there is no potential here, but instead because EC has been primarily addressed as a material and procurement issue, and defined through the math of carbon measurement.

Table 5-1: Landscape analysis of existing climate policies and fulfillment of Oregon's Racial Justice Council equity pillars

Legend

CJ Criminal Justice	**HH** Housing and Homelessness	**EO** Economic Opportunity	**HE** Health Equity	**EE** Environmental Equity	**ER** Education Recovery

Policy	CJ	HH	EO	HE	EE	ER	Key Strategies
40% by 2030-35 w/EC targets							
Vancouver Climate Emergency Action Plan	■		■	■	■		By 2030, 2/3 of all trips on foot, bike, or transit, using improved bus speeds, remote and flexible work hours, res parking permits, create parking maximums

	OC from buildings cut in half by 2030 from 2007 levels
	EC reduced 40% from 2018 - EC limits, support of low-carbon materials w/ easier access and better pricing
California AB 2446	EC and OC tied to housing goals, rising material costs, and evolving market
	LCA of new res > than 5 units or non-res 10,000 sf A1-A3
	Products available in region of project, and at cost of < 5% increase
Boulder Climate Action Plan	Allow time and resources to address climate change equitably
	Work WITH communities and strengthen community capacity to thrive
	Count all emissions (creation and purchase of goods and foods)
	Land use policies
	Financial systems
Austin Climate Equity Action Plan	Maintain community inclusivity
	Just transition, cultural preservation, accessibility, affordability, health
	Business focus on BIPOC owned to support improved sustainability
	EC reduction of 40% by 2030
	Equitable water use at community scale, access to local food
	Anti-displacement, and focus on land-use, equitable tree cover, resilience
	50% of trips not in SOV (single occupancy vehicles)
50% 2030-33 w/EC targets	
	EC reduction of 50% by 2050 and 30% by 2025 (new construction)

Los Angeles Clean Construction Declaration							Working groups to create roadmap inc tenants
							Training in EC3 tools
							Market signals and drive reductions through procurement
							Construction equipment electrification through focus groups and swap-out incentives, also preference points in contracting
							Prioritize building reuse w/ incentives tied to metro proximity (since 1999)
Mexico City Clean Construction Declaration							Recycled material use and improved/increased recycling processes
							Support of teleworking
							EPDs for proof EC and Circular economy w/multidisciplinary work groups
							Incentives for cool roofs and more
							Metropolitan-scale efforts
New York City PlaNYC							Max summer indoor temp policy, reform home energy assistance
							30% tree canopy goal, connected network of green spaces, training, incentives.
							Install cool roofs, invest in pools, city-wide
							EC and performance standards for materials by 2025
							Financing tools to support LL97
							Climate education, green training, and entrepreneurship incentives/support
							Water systems, transportation, food, and circular economy goals
net zero by 2050 no EC targets							
							Climate and health standards for existing buildings (EJ focus)

Portland Climate Emergency Workplan							City focus on green building
							EC policies to reduce through adaptive reuse, WBLCA, and material choices
							Clean industry - circular, clean, decarb…
							Compact and mixed use development
							Anti-displacement by working with existing communities
							Internal cost of carbon (for operational) to inform all city decisions
New York State Scoping Plan							40% investment under Climate Law for disadvantaged communities
							Co-design programs, seek meaningful public input, focus on intersectionality
							Just Transitions (culture, jobs, training, collaborative planning, resilience +)
							Community scale solutions
							Market transparency on building costs
Toronto Green Standard Version 4							Reused materials exempted from BEAM calcs. in res. 250kgCO2e/m3
							CaGBC methodology for carbon calcs. <350 kgCO2e/M2 or extra low at 250
							Voluntary system w /refund program increases for participation
Phoenix Climate Action Plan							Circular economy incentives
							Air quality focus and inclusivity/ equity charge
							Living building challenge net-positive goals for all in-city construction by 2050
							Walkable complete streets, cool corridors, local food, reduce SOV trips 60%
							Low-carbon refrigerant transition
							EC calculator development, incentives, and standards for private sector work
							Outreach and behavior change focus on mitigation

Evanston, Illinois Climate Action and Resilience Plan	Vulnerable populations focus on resilience
	Zero waste by 2030
	Building projects focused on mobility connections
King County 2020 Strategic Climate Action Plan	Partnering with Cities for GHG reductions (larger systems approach)
	Cost of carbon (operational) included in planning
	Transit, city center development, and vehicle usage equitable pricing
	Equitable implementations of WA state clean energy transformation act
	Social justice and equity integrated into all capital projects
	Low-embodied materials in construction projects
	Zero waste food systems
	Forestry focus supporting immigrant and refugee farmers
	Obtain 25 equity open space opportunity sites for urban green space
Miscellaneous	
Oregon Executive Order 20-04	45% below 1990 by 2035 (operational carbon), energy use and utility transitions
	Consult with Environmental Justice Task Force
	Focus on impacted communities, working w/ all agencies
	Landfill emissions in combinations with neighboring states
	Food Waste reduction goal of 50% by 2030 (industry, retailers, jurisdictions)
	Public process w/ Housing and Community re: affordability and EJ issues
	Carbon sequestration and storage planning (also re:building projects)
San Francisco Climate Action Plan	Use of Racial and Social Equity Assessment tool
	Affordability, education, financial incentives, diversity of workforce, etc.
	Reducing life-cycle impacts on buildings and materials is a key strategy.
	Community workshops

[Oakland 2030 Equitable Climate Action Plan]()	CJ	HH	EO	HE	EE		Use of Racial Equity Impact Assessment throughout the process.
	CJ				EE		Prevent displacement (in Transportation and Land use)
	CJ	HH	EO		EE		Car-free access
		HH		HE			All electric buildings by 2040
				HE	EE		Reduce life-cycle emissions of buildings
	CJ		EO	HE	EE	ER	Food, repair, deconstruction
	CJ			HE	EE		Tree canopy, carbon farming, open space

Legend:

CJ	Criminal Justice	**HH**	Housing and Homelessness	**EO**	Economic Opportunity	**HE**	Health Equity	**EE**	Environmental Equity	**ER**	Education Recovery

Source: New Buildings Institute

6 Code-based Analysis

The Oregon Structural Specialty Code (OSSC) covers the "construction, reconstruction, alteration, and repair of buildings and other structures."[77] As the major document that regulates the design and development of these building activities across the state, it represents one of the most substantial opportunities to address the embodied carbon of the built environment.

The OSSC is a statewide code that contains portions of the International Building Code (IBC), International Fire Code (IFC), and International Existing Building Code (IEBC); Oregon's Building Codes Division (BCD) has the authority to amend these provisions to meet the state's unique goals, priorities, and circumstances. The code is applicable to projects spanning across the state, and locally-adopted amendments are not allowable without BCD approval. At present, no approved local amendments exist.

ORS 455.020(1) covers BCD's overarching authority and purpose of the state building code, which includes providing "reasonable safeguards for health, safety, welfare, comfort, and security of the residents of this state who are occupants and users of buildings." An integration of embodied carbon into the building code's provisions can bring the policy a long way towards realizing its purpose, considering the substantial impacts that embodied carbon is already

[77] "Section 101 Scope and General Requirements," in 2022 Oregon Structural Specialty Code with Amendments (State of Oregon, 2023), https://codes.iccsafe.org/content/ORSSC2022P2/chapter-1-scope-and-administration#ORSSC2022P2_Ch01_SubCh01.

having on the climate as well as the state's communities and economy, as described in earlier sections of this report.

The following code-based options may be used as independent, standalone strategies, or in tandem by providing compliance pathways that address each of these options. Providing a variety of ways to reduce embodied carbon emissions allows for the flexibility of teams – including designers, engineers, clients, general contractors, and material providers – to choose an option that best suits the unique conditions of their project. This structure can also place a higher value on actions that might realize more avoided carbon emissions – such as building reuse. The three strategies assessed in this chapter are:

- Prescriptive GWP Limits for Materials (Section 6.1)
- Performance Approach: Whole Building Life Cycle Assessment (Section 6.2)
- Compliance Options for Encouraging Building Reuse (Section 6.4)

6.1 Prescriptive Approach: GWP Limits for Building Materials

Policies targeting the reduction of carbon emissions associated with building products require the disclosure, verification, and reduction of GWP data via EPDs. For more background on material-level reporting and prescriptive policies, see Sections 1.3, 2.1, and 2.3 of this report, respectively.

Prescriptive requirements will, at minimum, require reporting of some products that are chosen for a building project. This reporting involves generating and submitting EPDs to assess and communicate the environmental impact of construction products, and to help project teams compare materials choices with other, potentially lower GWP, alternatives.

Policies may also set embodied carbon caps, expressed in GWP, which products must meet. Some materials-based policies will focus on materials contributing high levels of embodied carbon, which are found in buildings' structure and envelope, such as concrete, steel, wood, glass, and insulation. Others might require that submitted EPDs are representative of a substantial portion of a project, but remain silent on which materials must be represented.

These decisions associated with crafting a prescriptive-based embodied carbon code, along with other decisions, are detailed in the following sections.

6.1.1 Policy Overview

- **Timeline:** Initiate code development in Year 1 of new code cycle for inclusion in next adoption.
- **Data Requirements:** EPD submissions to prove compliance.
- **Enforcement Strategies:** Ensure code compliance review is contingent upon receipt of applicable materials per adopted code. Refer to Section 6.6 on Implementation and Enforcement for more details.

6.1.2 Options for EPD Requirements

Some policies require that EPDs be submitted for particular material types – commonly, materials found in buildings' structure and enclosure. These materials are often the focus of this because they are accountable for significant greenhouse gas emissions throughout their production phases – the structure and substructure of a building can typically account for up to 80 percent of a building's upfront embodied carbon.[78] Other policies are agnostic on material types, only requiring that a certain portion of a total project be represented by submitted EPDs.

<u>Option 1: EPD Requirements for Certain Materials</u>

Most prescriptive embodied carbon codes require that EPDs be submitted for specific materials, typically ones that are incorporated into the building's structure and enclosure. These constitute concrete, steel, aluminum, wood, glass, and insulation.

Table 6-1 captures the materials that are covered by major prescriptive codes and policies, including Buy Clean. Policies focused purely on concrete have been omitted. The policies listed in the table notably include provisions not only for reporting, but also for demonstrating some sort of reduction in GWP – this aspect of the provision is addressed in the Section 6.1.3 on Options for Setting GWP Limits.

Information about Oregon material-specific strategies represented by its Buy Clean legislation is also provided in this table for comparative reference.

Table 6-1: Materials covered by major prescriptive codes and policies

	Oregon Buy Clean	**GSA Interim IRA Guides**	**CALGreen & CA Buy Clean**	**WA Buy Clean, Buy Fair**	**Denver Green Code**	**CO Buy Clean**	**MN Buy Clean, Buy Fair**
Asphalt	√	√				√	√
Concrete / Cement	√	√	√	√	√	√	√
Steel	√	√	√	√	√	√	√
Glass		√	√			√	

[78] Paula Melton, "The Urgency of Embodied Carbon and What You Can Do About It," *BuildingGreen*, September 10, 2018, https://www.buildinggreen.com/feature/urgency-embodied-carbon-and-what-you-can-do-about-it.

Board / Foam Insulation			√ (Mineral wool board only)				
Structural / Engineered Wood & Composites				√		√	

Source: New Buildings Institute

Some jurisdictions have chosen to focus their embodied carbon code efforts solely on concrete, as it is one of the largest culprits in carbon emissions. These have included Marin's first-ever Low Carbon Concrete Code, under which local building projects must choose to comply with either a total cement limit or a GWP limit for each concrete mix, distinguished by strength category. Santa Monica, California also recently passed its own Low Embodied Carbon Concrete Code. A suite of other procurement policies has also set prescriptive requirements for city-procured concrete, including the Portland Low Carbon Concrete Initiative, New York State Buy Clean, New York City Executive Order 23, and Austin's Resolution No. 20230420-024.

The materials commonly referenced by prescriptive codes and policies are chosen because they are accountable for significant GHG emissions throughout their production phases. Fortunately, reducing the production-phase embodied carbon associated with these major materials is already achievable. Several strategies have been identified for each material to reduce its respective emissions throughout its production: high-impact methods for each material are captured in Table 6-2. It is rare and not recommended for codes to prescribe the particular strategies that embodied carbon be reduced for materials, as this can constrain project teams' abilities to creatively and flexibly identify strategies that work for the specific circumstances of the project. However, understanding what these methods are can help to illustrate how required reductions in code are in fact feasible today. It is important to note that an unintended consequence of omitting some low embodied carbon materials, such as mass timber, from material-specific policies is that these materials may not be considered in schematic design due to a focus in funding the reduction of emissions from included materials, i.e. steel and concrete. This perverse incentive can unintentionally lead building projects to not select materials which are inherently low in embodied carbon, such as mass timber and other bio-based materials.

Table 6-2: High-impact strategies to reduce embodied emissions associated with construction materials

Material	EC Reduction Strategies
Concrete / Cement	● Incorporate blended cements including portland-limestone cement (PLC) ● Use supplementary cementitious materials (SCMs) including fly ash, slag cement, silica fume, ground glass pozzolan, and others. ● Specify water-reducing admixtures to reduce cement content. ● Power cement and concrete production with low-carbon energy.

Steel	● Use steel made with scrap content in an electric arc furnace, as opposed to virgin steel made in a basic oxygen furnace. ● Power electric arc furnaces with low-carbon energy.
Aluminum	● Source products with >90% recycled content ● Power factories with low-carbon energy
Wood	● Source timber locally and use low-carbon transport methods to reduce transportation emissions. ● Source products from sustainably managed forests. Note that sustainable forestry certification may be cost-prohibitive, especially for small local wood producers, and may not always be associated with meaningfully better forest management practices. ● Design timber for easy disassembly and reuse in future buildings. ● Use timber with bio-based adhesives when possible. ● Power wood processing facilities with low-carbon energy.
Glass	● Increase use of recycled cullet to reduce waste, energy, and raw materials ● Use furnaces that utilize Oxy Fuel technology, which reduces natural gas by infusing pure oxygen to produce higher temperatures ● Design burners and nozzles to decrease energy use
Board & Foam Insulation	● Use bio-based alternatives ● Use lower-GWP blowing agents ● Mineral wool: increase renewable energy at furnace

Source: New Buildings Institute

<u>Option 2: Material-Neutral Policy</u>

Instead of requiring EPDs for certain specified products, policies might require that a minimum amount of EPDs be submitted, regardless of the material they represent. This may be formulated as a set number of EPDs per square foot of construction, or set as a threshold, such as a percentage relative to the total project cost, weight, or volume.

The IgCC is one major precedent that stays silent on material types. Chapter 9 on Materials and Resources contains requirements for all projects to submit EPDs that represent all of the following:

- at least 25% of total estimated cost of building products
- at least 30 EPDs total
- at least 10 different manufacturers
- at least 20 different building products
- all building products that exceed 5% of the total cost of the project.

LEED v4.1 contains similar provisions, requiring the use of EPDs representing at least 20 different products from at least 5 different manufacturers. However, the public review draft of the upcoming version 5 of LEED notably veered from this strategy and includes EPD and GWP limits for many of the materials listed under Option 1.

The Minnesota Sustainable Building Guidelines (B3) also require that EPDs be submitted in addition to the LCA, which represent at least 5 different products from at least 5 different manufacturers.[79] The B3 Material-Level LCA option is another example that does not prescribe which materials must have EPDs, but does require that they represent a building's structure and enclosure. The Guidelines specify that this strategy be used only when a project has a dominant structure and enclosure type that represents at least 60% of the building's structural volume and exterior area, and when the project utilizes material categories that are well accounted for by the B3 LCA Material Selection Calculator. The Guidelines also note that this strategy is best used for evaluating material substitutions but is less suitable for considering broader-level GWP reduction strategies: this is something a WBLCA or assembly-level assessment would better address. For this reason, projects are also required to submit WBLCA models at the end of the design phase.

Giving Preference to Data Specificity

The IgCC and LEED give priority to type III EPDs, because they provide a greater level of specificity. Under the IgCC, product-specific EPDs are counted as one product for the purposes of compliance, while regional- and industry-wide EPDs are counted as one-half. LEED counts product-level critically reviewed life cycle assessments, product-specific EPDs that are internally reviewed, and industry-wide EPDs as one product; product-specific EPDs with third-party certification are counted as 1.5.

Requiring product-specific EPDs is a strategy that is suitable for Oregon. Table 6-3 describes the number of product-specific EPDs from Oregon-based manufacturers for various construction materials, compared to the number of EPDs that were available in other states that succeeded in moving forward with prescriptive policies. As captured in Table 6-3, California, Colorado, and Washington exhibited a lower number of product-specific EPDs upon adoption of their prescriptive code requirements and Buy Clean policies in 2022, 2021, and 2024, respectively. For some materials, where data from previous years were not available, current-day values were utilized. Even today, there is a lower number of product-specific EPDs in states with existing policies than there are EPDs in Oregon today.

Table 6-3: Number of product-specific EPDs in states with Buy Clean or prescriptive policies

[79] "B3 Guidelines New Buildings and Major Renovations Version 3.2 Revision 02" (University of Minnesota, June 2024), https://www.b3mn.org/wp-content/uploads/B3GuidelinesVersion32r02_
Small-Sites-Updates-Final.pdf.

Product	Number of product-specific EPDs from Oregon-based manufacturers available in EC3	Number of facility-specific (as required by Buy Clean) EPDs in California in 2023**	Number of product-specific EPDs in California (as allowed for by CALGreen prescriptive approach)	Number of product-specific EPDs in Colorado in 2021, upon adoption of Buy Clean	Number of product-specific EPDs in Washington state in 2024, upon adoption of Buy Clean
Asphalt	314	Not covered	291*	177*	88
Ready-mix concrete	7,508	Not covered	18,934*	471	3,279
Steel reinforcement bar (rebar)	2	11	1*	1	2
Structural steel	2	26	5*	0*	6
Flat glass	0	1	3*	0*	1
Wood products	7	Not covered	0*	0*	2
Insulation	8	1 (mineral wool only)	9*	4*	4

* No information from past years available. EPD data for 2024 shown in lieu of past data.

** California Buy Clean calls for the use of facility-specific EPDs; there is a lower level of awareness about these than about product-specific EPDs, and the numbers in the table demonstrating the availability of facility-specific EPDs reflects that. However, even with this lower number and general awareness, California was still able to move forward with its Buy Clean policy. Under CALGreen, product-specific EPDs may also be submitted, and more products – such as concrete – are covered compared to the state's Buy Clean policy.

Source: Embodied Carbon in Construction Calculator (EC3), https://buildingtransparency.org/ec3, accessed August 8, 2024 and September 30, 2024; Buy Clean California Act Obstacles and

Effectiveness Report, https://www.dgs.ca.gov/PD/Resources/Page-Content/Procurement-Division-Resources-List-Folder/Buy-Clean-California-Act, RMI

6.1.3 Options for Setting GWP Limits

Reporting is an important first step for collecting information on materials and their environmental impacts, and for getting product teams into the practice of considering these attributes when they make design decisions. However, reporting itself will not result in reductions in embodied carbon: this is where GWP limits play a role.

Industry-average GWP values for many materials can be easily accessed through online EPD repositories such as Building Transparency's Embodied Carbon in Construction Calculator (EC3) tool. In this tool, users can select specific material categories and find industry-average values for varying scales ranging from local to global.

In 2023, the Carbon Leadership Forum undertook the effort of collecting the best available information on a range of building materials and setting a baselines for them based on industry averages. These can be found in CLF's 2023 Material Baselines Report, which is currently being updated to include more materials as well as region-specific values.[80]

Most material-based GWP limits that are set in policy are either explicitly or implicitly based on industry averages. New York State Buy Green, for example, sets limits for concrete at 150% of the regional baseline, determined by the National Ready Mix Concrete Association (NRMCA). The GSA IRA Interim Limits for concrete, cement, asphalt, steel, and glass, are hard caps based on the top 20%, 40%, and average of industry values. The Denver Green Code sets its concrete GWP caps based on the 50th percentile of EPDs collected through EC3. Buy Clean California caps for steel, concrete, glass, and mineral wool board insulation are set at the industry average of facility-specific GWPs for each respective material.[81] Buy Clean Colorado similarly set initial GWP limits for asphalt, ready-mix concrete, cement, flat glass, steel, structural wood at the industry average. Both Buy Clean Acts plan to reduce these values over time.

Several policies also take this type of phased approach to introducing GWP limits. Inherent in basing GWP limits on industry averages is the expectation that these will decrease over time as manufacturers adjust to new policies and improve their practices in order to stay competitive in the market. Policies also can also be more explicit in stating that their GWP limits will be reduced in future phases of a policy, so that product teams and manufacturers may plan for these next iterations. The Department of General Services (DGS) in California, for example, will review the GWP limits for all covered materials every three years and adjust accordingly; DGS is prohibited from adjusting these limits upward. In Colorado, the Office of the State Architect (OSA) must adjust GWP limits every 4 years at minimum but is permitted to make updates

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[80] Brook Waldman et al., "Carbon Leadership Forum Material Baselines for North America" (Carbon Leadership Forum, University of Washington, August 2023), https://carbonleadershipforum.org/clf-material-baselines-2023/.

[81] "Buy Clean California Act," California Department of General Services, April 19, 2024, https://www.dgs.ca.gov/PD/Resources/Page-Content/Procurement-Division-Resources-List-Folder/Buy-Clean-California-Act.

annually as EPDs are updated on a 5-year cycle. Portland's Embodied Carbon Thresholds for Concrete Mixes on City Projects similarly calls for an annual review of thresholds through 2028 to progressively lower them over time.[82]

6.1.4 Option to Include Other Low-Impact Material Attributes

While prescriptive requirements tend to focus solely on GWP, there are other attributes that materials-based codes can begin to require or incentivize. Accounting for a broader range of material qualities – such as whether they are recycled, reused, salvaged, or regionally-sourced – captures materials' environmental impacts more holistically, rather than accounting for a single attribute – GWP – in isolation. This accounting can pick up any tradeoffs that may occur between a material's GWP performance and other impacts on human health and the environment. Additionally, incentivizing recycling, reuse, and salvaging at the material level highlights the importance of waste avoidance in a way that a pure focus on carbon alone may not be able to achieve. Finally, including other attributes can increase this option's equivalency with the performance-based code option, as WBLCAs typically take into account a range of impact categories, including global warming potential, acidification, eutrophication, ozone depletion, and smog formation. These are attributes that are already accounted for in EPDs.

There are precedents that offer examples for including these other attributes. Chapter 9 of the IgCC, focused on materials and resources, includes one optional compliance pathway to utilize reduced impact materials, demonstrating attributes in two of the following four: 10% (based on cost) recycled and salvaged material; 15% (based on cost) regional materials; 5% (based on cost) biobased products; or third-party multi-attribute certification for 5 products. These options are in addition to the requirement of submitting EPDs. Another example, the LEED Materials and Resources (MR) Credit for Building Product Disclosure and Optimization, also includes an option for multi-attribute optimization, which asks that products use third-party certified products demonstrating impact reduction in at least three typical life cycle impact categories, as well as depletion of nonrenewable energy sources.

6.1.5 Options for Placement of Requirements in Oregon Code Structure

A prescriptive code that sets requirements for specific materials can integrate new embodied carbon requirements into the materials-focused chapters that populate the OSSC. One example for concrete is provided below. This text includes some variables that BCD would need to determine for suitability in the state. Recommendations for these variables and other considerations related to Oregon suitability are provided in Section 6.1.5.

Materials-based language sample:

1901.7 Embodied CO2e in Concrete Products. The CO2e of ready-mix and precast concrete shall meet the requirements in this section, and products used for compliance shall have a *product-specific Type III EPD*. Documentation of the product's kgCO2e/unit and EPDs shall be verified by a *registered*

[82] City of Portland, Oregon, *Notice of New Requirements for Concrete,* 2022. https://www.portland.gov/procurement/sustainable-procurement-program/documents/city-portland-concrete-embodied-carbon/download

design professional on the project, and a summary shall be made available to the *code official* that includes a list of each product and associated kgCO2e/unit, per the EPD.

1901.7.1 Embodied CO2e in Ready-mix Concrete Products. 90% of all ready-mix *concrete* mixes used in the *building's primary structural frame*, *secondary members*, *seismic force-resisting system*, and foundations shall not exceed the project limit (CO2Emax) determined by ***G***% of IW-EPD's kgCO2e/y3.

Exceptions:

1. Precast, shotcrete, or auger cast concrete.
2. Buildings less than ***A*** *gross floor area*.
3. Buildings where the total volume of *concrete* is less than 50 cubic yards.

Other sections of the OSSC that may incorporate new language on submitting EPDs and meeting GWP caps include:

- **720.1.1:** Embodied CO2e of Insulation Products
- **802.8:** Embodied CO2e of Interior Finishes
- **1401.2:** Embodied CO2e of Exterior Walls, Wall Coverings, Windows and Doors
    - Includes wood, basic hardboard, hardboard siding, masonry, metal, aluminum siding, cold-rolled and lead-coated copper, concrete, glass-unit masonry, plastics, vinyl siding, fiber-cement siding, insulation and finishes, and others.
- **1501.2:** Embodied CO2e of Rooftop Assemblies and Rooftop Structures Products
- **1901.7:** Embodied CO2e in Concrete Products
- **2001.2:** Embodied CO2e in Aluminum Products
- **2103.1.2:** Embodied CO2e in Masonry Construction Products
- **2201.2:** Embodied CO2e in Steel Products
- **2303.8:** Embodied CO2e of Wood Products
- **2403.6:** Embodied CO2e of Glass and Glazing Products
- **2501.3:** Embodied CO2e of Gypsum Products
- **2603.2:** Embodied CO2e of Foam Plastic Insulation Products

6.1.6 Recommendations and Suitability for Oregon

Table 6-4 outlines recommendations for a prescriptive-based code approach in Oregon, which are based on the analysis and considerations provided throughout this chapter as well as a determination for suitability in Oregon. The table also includes references to the variables outlined in the code language provided in the previous section.

Table 6-4: Recommendations for Oregon for the prescriptive code-based approach

Code	Recommendation and Suitability for Oregon
Scope and applicability of prescriptive provisions	• **Goal Setting:** Set a 60 percent reduction goal and timeline for embodied carbon, consistent with Oregon's sector-wide energy efficiency goals set in EO 20-04 and HB 3409.

	● **Impacts Considered:** At minimum, include the global warming potential impact of embodied carbon in the scope. Consider promoting other low-impact material attributes other than GWP, such as recycled, reused, salvaged, or regionally-sourced materials. ● **Project types:** Apply provisions to commercial and multifamily project types. Including both project types will maximize greenhouse gas emissions reductions by 2050 (see Section 6.7). As an alternative, focusing solely on commercial buildings can also realize significant reductions. ● **Project size:** Apply provisions to projects above 100,000 square feet in size *(variable **A** in the code language)*, with the intent to reduce the size threshold over time. This strategy is consistent with CALGreen's approach, which set the initial limit at 100,000 square feet with plans to reduce the threshold to 50,000 square feet in the following code cycle. Alternatively, consider phasing in Tier 1 and Tier 2 square footage thresholds set for Oregon's Building Performance Standards during the second cycle of code adoption. Expanding the scope of building sizes over time will give the state and the market the ability to ramp up to the learning curve of adhering to and complying with these provisions. A 100,000 square foot threshold would include approximately 18 percent of the state's building stock; reducing the threshold to 50,000 square feet would cover about 30 percent of the building stock; a 20,000 square foot minimum would account for 56 percent.
Materials included	● **Materials:** At minimum, focus on high-emitting structural materials including concrete, steel, wood, and glass. Consider incorporating others after considering the availability of adequate data, potential impacts on greenhouse gas reductions, and market readiness and feasibility. Other products may include glass, insulation, interior finishes, aluminum, and masonry. ● **Expanded materials scope:** Consider phasing in requirements for other building elements including interior finishes and service systems over time. The emissions associated with Mechanical, Electrical, and Plumbing (MEP) systems can be significant, but research and data around these are still in early stages. Track developments associated with ASHRAE 244p, focused on assessing the life cycle impacts of MEP products and assemblies, for future consideration of incorporating it into the building code. ● **Exceptions:** Consider a material-neutral approach for exception cases to provide flexibility for project teams who might not be able to fully meet requirements for a specific material. This option can also help to bring a higher focus on building data around products and materials that, to date, are overlooked by most policies – these include MEP equipment, interiors, furnishings, and other innovating materials that may be pushing reductions in GWP, but are left unaccounted for in policies that focus only on concrete, wood, steel, glass, and other major structural and envelope materials.
EPD requirements	● **EPD types:** Require or give priority to product-specific EPDs through a point-based counting system.
GWP limits (*variable **G*** in	● **Caps:** Start by setting GWP limits at 125% of the industry-average values by material to align with other precedents and allow for industry adjustment and

the code language)	learning. Reduce GWP limits over time to ultimately match the 60% reduction goal for embodied carbon by at least 60% by 2035.
Location in code	● **Code location:** Integrate new requirements into the materials-focused chapters of the base code.

Source: New Buildings Institute

6.2 Performance Approach: Whole Building Life Cycle Assessment (WBLCA)

Whole Building Life Cycle Assessment (WBLCA) reporting and reduction evaluates the environmental impact of a building throughout its lifecycle, calculating total carbon emissions for the complete life cycle of a building.WBLCAs include the operational phase, providing a full picture of how to address embodied carbon balances against operational emissions. For an introduction on building-level embodied carbon quantification and WBLCA policies, see Sections 1.3 and 2.2 of this report, respectively.

A WBLCA provision in code would, at minimum, require project teams to generate and submit a WBLCA that analyzes the climate impact of the proposed building across its life span, from cradle to grave. In addition to life cycle emissions, most approaches to WBLCA in code require the demonstration of a certain level of reduction, reported either as a percent-decrease from a baseline project or as falling under an absolute value that acts as a building-level GWP cap. The processes for determining these requirements are detailed later in this section, under Options for Reduction Requirements.

Other decisions informing a WBLCA provision in code include the physical and time-bound scope required of the WBLCA conducted; methodologies and data characteristics that must underlie the WBLCA; and where the pro+vision will be situated within the code. Considerations for these decision points are described in the sections below, including options for physical scope of WBLCA; temporal scope of WBLCA; typical reference study periods; methodology and data requirements; options for reduction requirements; and options for placement of requirements in the Oregon Structural Specialty Code.

6.2.1 Policy Overview

- **Timeline:** Initiate code development in Year 1 of new code cycle for inclusion in next adoption
- **Data Requirements:** LCA reporting structure for projects subject to WBLA compliance
- **Enforcement Strategies:** Train Building Officials to review WBLCA submission against code requirements, for baseline or set reduction levels. Ensure code compliance review is contingent upon this submission for projects subject to or selecting WBLCA. Refer to Section 6.6 on Implementation and Enforcement for more details.

6.2.2 Options for Physical Scope of WBLCA

As demonstrated in Table 6-5, WBLCA policies tend to focus on the structure and enclosure of a building, as materials incorporated into these components account for the highest amount of embodied carbon emissions.

Table 6-5: Physical scope of precedents addressing WBLCA

LEED v4.1	RICS Guide	CALGreen	ASHRAE 189.1 (per ASTM E2921)
Structure and enclosure	All element and component categories making up the built asset	Structure and enclosure	Structure, envelope, conduit, ductwork, piping, wiring and systems

Source: New Buildings Institute

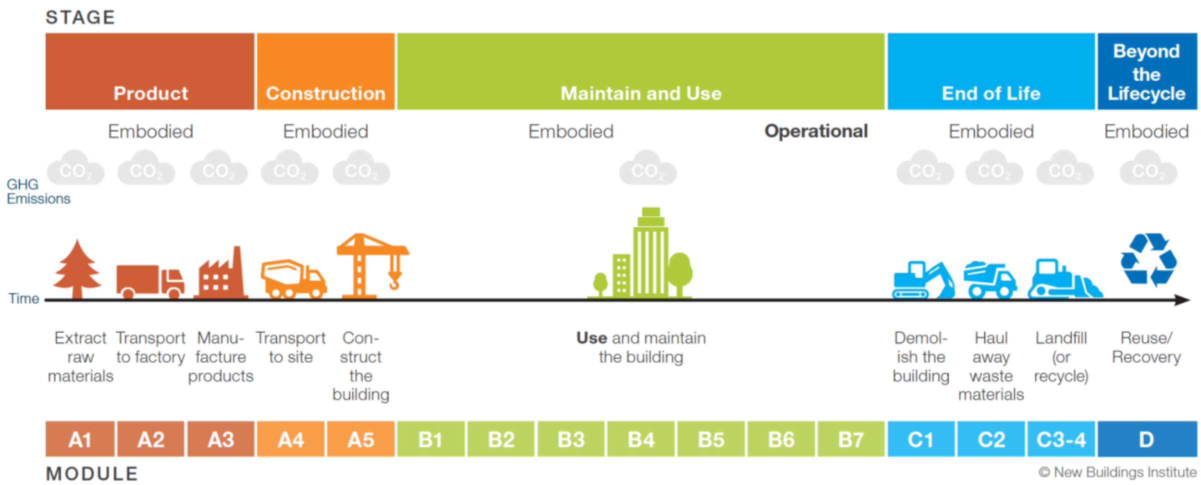
6.2.3 Options for Temporal Scope of WBLCA

6.2.3.1 Life Cycle Phases

An LCA is typically broken into four life cycle stages, which are further broken up into sub-modules. These are:

- A: Production and construction
  - A1: Raw material supply
  - A2: Transport to factory
  - A3: Manufacturing
  - A4: Transport to site
  - A5: Construction and installation
- B: Use
  - B1: Use
  - B2: Maintenance
  - B3: Repair
  - B4: Replacement
  - B5: Refurbishment
  - B6: Operational Energy
  - B7: Operational Water Use
- C: End-of-life
  - C1: Deconstruction/demolition
  - C2: Transport to waste processing/disposal
  - C3: Waste processing
  - C4: Disposal of waste
- D: Benefits and loads beyond the system boundary
  - D1: Reuse-recovery-recycling potential

Figure 6-1: Building lifecycle stages and modules.



Source: New Buildings Institute from EN 15978

WBLCA policies across the board tend to require, at minimum, the inclusion of the production, use, and end-of-life life cycles stages. Minimum requirements for included life cycle stages in major LCA policies and guidelines are detailed in Table 6-6.

Table 6-6: Life cycle scope of precedents addressing WBLCA

LEED v4.1	RICS Guide	CALGreen	ASHRAE 189.1 (per ASTM E2921)
• Cradle-to-grave • Minimum A1-A4, B1-B5, C1-C4, though A-D preferred • Gaps in sub-modules permitted as long as boundary encompasses cradle-to-grave	• Includes guidance for calculating all modules • D phase reported separately	• Cradle-to-grave (A-C), excluding B6 (operational energy)	• All life cycle stages A-C

Source: *New Buildings Institute*

Slight variations in WBLCA policy approaches include the following:

- **A0 (Pre-construction):** RICS includes an option module to account for pre-construciton on-site processes such as preliminary studies, tests, acquisition of land, and design
- **B6 and B7 (Operational Energy and Water):** These modules are typically left out of policies focused on embodied carbon, because they are often addressed through other, operations-focused policies and standards.
- **D (Benefits and Loads Beyond the System Boundary):** This phase is typically optional for inclusion; if included must be reported separately.

6.2.3.2 Typical Reference Study Periods

A reference study period refers to the extent into the future the LCA should anticipate emissions coming from the studied building. A typical duration for a reference study period is 60 years, as demonstrated in Table 6-7.

Table 6-7: Reference Study Periods defined by precedents addressing WBLCA

LEED v4.1	RICS Guide	CALGreen	ASHRAE 189.1	ASHRAE 240P	ASTM E2921-22
At least 60 years	60 years	60 years	100 years	60 years	75 years

Source: New Buildings Institute

6.2.4 Methodology and Data Requirements

Typically, criteria pertaining to software used to conduct the LCA, as well as data quality, reference external standards, documented below. Typically, external standards are referenced as containing the criteria conformed to by the software used in conducting a WBLCA. Additionally, the quality of data sets collected and used for a WBLCA has requirements, as documented in Table 6-8.

Table 6-8: Standards references by precedents addressing WBLCA

	LEED v4.1	CALGreen	ASHRAE 189.1
LCA Software / Methodology / Data Requirements	ISO 21931-2017 EN 15978:2011	ISO 21931 EN 15978	ISO 14040 ISO 14044
Data Requirements	ISO 14044 ISO 21930-2017 EN 15804	ISO 14044 ISO 21930 EN 15804	ISO 21930 ISO 14025

- **ISO 14040:** Principles and framework of LCA
- **ISO 14044:** Guidelines for conducting an LCA
- **ISO 14025:** Principles and procedures of type III EPDs
- **ISO 21930, EN14978, ISO 21929-1:** Criteria for LCA software and calculation methodology
- **ISO 21930 and EN 15804:** Criteria for data sets

Source: New Buildings Institute

6.2.5 Options for Reduction Requirements

Options to introduce building-level embodied carbon limits constitute the following: (1) require a percentage reduction over a baseline design; (2) introduce a total cap on embodied carbon; (3)

offer compliance pathways; (4) do not require a reduction, but place more stringent requirements on data quality submitted.

Option 1: Total Cap

WBLCAs can produce a final output value that represents the total GWP that a building will account for over the course of the reference study period. Policies can set a cap to that number that submitted WBLCAs must meet.

At present, the challenge associated with maximum caps is the limited availability of locally-specific, project-level data to back up any value set in policy. However, some initiatives are underway to fill this gap. In 2017, the Carbon Leadership Forum (CLF) published the first version of its Embodied Carbon Benchmark Study, which collected and analyzed building-level data from projects across the United States to determine typical GWP ranges; the CLF is currently conducting version 2 of this study to offer geographically and typologically specific benchmarks for buildings and their systems.[83] The second version of this report is anticipated for release at the end of 2024; once published, this will offer benchmark values that state and local policymakers will be able to reliably reference.

Other relevant benchmarking studies may also be referenced, including:

- Magwood et al. (2022). Emissions of Materials Benchmark Assessment for Residential Construction. https://www.passivebuildings.ca/embarc
- OneClick LCA. (2021). Carbon Footprint Limits for Common Building Types.
- Röck et al. (2020). Embodied GHG emissions of buildings – The hidden challenge for effective climate change mitigation. https://doi.org/10.1016/j.apenergy.2019.114107
- Trigaux et al. (2021). Environmental benchmarks for buildings: a critical literature review. https://link.springer.com/article/10.1007/s11367-020-01840-7
- Zimmermann et al. (2021). Build Report 2021 : Whole Life Carbon Assessment of 60 Buildings. https://build.dk/Pages/Whole-Life-Carbon-Assessment-of-60-buildings.aspx

Cities or states may also choose to conduct their own research to determine locally-specific values. This is described in further detail under Option 4.

Setting a total GWP maximum at the whole-building level is more common practice in Europe than in North America, in part due to the lack of research and data required to determine and justify the values set in policy. In response to this trend, a common tendency is to set a high cap that practitioners can reach easily – to get them into the practice of generating a whole building LCA that demonstrates a certain level of reduction – with the intent that the cap will be reduced over time.

Toronto was the first city in North America to establish a cap for new city-owned buildings at 350 kg CO_2e/m^2, with a voluntary limit of 250 kg CO_2e/m^2. This standard is notably voluntary for privately-owned new buildings: incentives to participate are offered through the Toronto Green Standard (TGS) Development Charge Refund Program. This program offers partial refunds on development charges for projects opting to adhere to these standards. The size of the refund is

[83] "CLF WBLCA Benchmark Study V2," Carbon Leadership Forum, July 2024, https://carbonleadershipforum.org/clf-wblca-v2/.

determined by a tiered system. With regards to embodied carbon, project teams can choose between two tiers: to demonstrate an emissions intensity at or below 350 or 250 kg CO_2e/m^2.

The International Living Future Institute (ILFI) Zero Carbon Certification sets a cap at 500 kg CO_2e/m^2 but is also a voluntary standard.[84] However, this value may be referenced as a precedent value, which may be decreased over time as buildings demonstrate their ability to meet this cap.

Option 2: Percentage Reduction

At present, setting a percentage-based reduction requirement is the path more commonly taken in North America, as setting absolute caps tends to require the collection of more robust data about the achievable ranges of GWP values for different building types in a region. This approach requires projects to demonstrate a certain level of reduction. It still, though, builds in flexibility for those decreases to be project-specific.

The minimum percentage reduction required tends to fall around 10%: the CALGreen performance pathway requires the completion of a WBLCA demonstrating a 10% lower embodied carbon emissions level than a baseline project design. San Francisco's Municipal Green Building Requirements similarly call for city-owned properties over 10,000 square feet to demonstrate a 10% GWP reduction using a WBLCA. The ASHRAE 189.1 performance-based pathway likewise requires either: (1) 10% improvement in two impact categories; or (2) 5% improvement in three impact categories. LEED v4.1 offers tiers for participating projects: (1) no reduction; (2) 5% reduction in GWP from a baseline building; (3) 10% reduction in GWP from a baseline building; or (4) at least 20% reduction in GWP from a baseline building. LEED also requires that reductions be demonstrated in multiple impact categories.

This method requires projects to develop a project-specific baseline building against which reductions are measured. Project teams therefore model two buildings: a "business as usual" building and the actual design. The two scenarios must have equivalency pertaining to size, scope, function, energy performance, materials and structure, and other components.

Option 3: Total Cap and Percentage Reduction Compliance Pathways

At present, there is one precedent that gives project teams the choice to demonstrate reductions in either a percent value or by meeting an absolute cap.

The city of Vancouver sets two pathways for projects to realize its embodied carbon reduction goal of 40% by 2030, relative to a 2018 baseline. These comprise an absolute and baseline (or percent-reduction) path. Through the absolute path, projects must meet a maximum GWP value; through the baseline path, projects must demonstrate a percent reduction from a baseline scenario.

In terms of its absolute path, Vancouver determined its benchmark value of 400 kg CO_2e/m^2 for all projects by collecting data on local rezoning projects since 2017. Looking at ranges for low-rise wood; high-rise concrete; low-rise concrete; high-rise wood; and low-rise steel, they chose a number that would be easy to meet in all categories: the averages in all categories were already below 400. In October 2023, at the start of the policy, the maximum GWP buildings would need

[84] "Zero Carbon Pre-Registration Success Guide" (International Living Future Institute, November 2022), https://living-future.org/wp-content/uploads/2023/04/Zero-Carbon-Success-Guide-Nov_2022.pdf.

to meet would be double that at 800 kgCO2e/m2. Then, over time, the maximum would be reduced compared to this benchmark: by January 2025, 320 (or a 20% reduction) for buildings up to 6 stories, and 360 (or a 10% reduction) for all other buildings.

The baseline (or percent-reduction) path gives a compliance option to projects that do not already easily fall under the absolute requirements. Through this pathway, a project would determine its own baseline by following the calculation methodology laid out in the city's Embodied Carbon Guidelines[85], using an early design iteration or the proposed design. The Guidelines lay out default baseline assumptions that projects may use in their calculations.

Option 4: No Reduction, With Higher Data Quality Requirements

Finally, a performance-based approach in code may not require a cap, but rather mandate the submission of more robust reporting, which can one day support a locally-informed cap.

California Assembly Bill (AB) 2446, for example, requires the California Air Resources Board (CARB) to create a framework to achieve the state's 40% net reduction in embodied carbon of construction and materials used in new construction by the end of 2035. The baseline for measuring progress toward this reduction goal will be based on data that is submitted to CARB in 2026.

While this particular strategy is not one set in the state's building code, it demonstrates the role that policy can play in building up the prevalence of data to set ambitious yet realistic reduction requirements. It is also valuable because it leverages state leadership towards lending additional relevance to code-based strategies that can complement these types of policies.

Building codes can play a similar role: expanding requirements around reporting can entail requiring product-specific EPDs as well as expanding the building components that a WBLCA must cover. Typically, existing WBLCA policies focus on structure and enclosure; expanding to other elements and systems such as interior finishes and service systems including Mechanical, Engineering, and Plumbing (MEP) can advance the build-out of information that is available for these products locally. Ultimately, this stronger set of information will help to more reliably set reduction limits that are realistic to the market conditions of the state.

6.2.6 Options for Placement of Requirements in Oregon Code Structure

Option 1: Base Code and Normative Appendix

The nature of conducting a WBLCA – which involves evaluating the materials, systems, and processes that make up a building in a comprehensive way – does not lend itself to any one specific chapter of the base code. Unlike the prescriptive approach, which addresses materials independently from one another, a WBLCA makes considerations that are all-encompassing, and distributing these requirements throughout multiple chapters of the base code would be difficult for comprehensibility, ease of implementation, compliance, and enforcement.

An appendix is therefore suitable for this type of requirement.

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[85] "Embodied Carbon Guidelines Version 1.0" (City of Vancouver, October 18, 2023), https://vancouver.ca/files/cov/embodied-carbon-guidelines.pdf.

Appendices in the OSSC can be mandatory (normative) or voluntarily adopted by jurisdictions (informative). In this case, a mandatory appendix would be accompanied by a reference to it in the base code. This reference could be placed in Chapter 1, which focuses on Scope and Application as well as Administration and Enforcement. Chapter 1 addresses the process with which a project must comply when submitting an application for a permit. In Oregon, Chapter 1 is reserved for administrative requirements, which are adopted by BCD and do not go through the code change process. Any substantive, enforceable code language would therefore be most suitable for an appendix. In terms of a reference to these enforceable provisions, Chapter 1 would be suitable, particularly for its ability to introduce the WBLCA requirement to project teams early on in the design process. Early project design stages offer significant opportunity to address more comprehensive and broad-reaching decisions that can realize substantial embodied carbon reductions: these include decisions around site selection, systems selection, and other choices that are much more difficult to change later in the design process. Placing a reference to the WBLCA at the start of the code would help to ensure that project teams are made aware of it early on.

Base code reference language sample:

Sample language referencing the WBLCA appendix in Chapter 1 is provided below.

Amend text as follows:

107.2 Construction documents.

Construction documents shall be in accordance with Sections 107.2.1 through 107.2.~~8~~9.

Add text as follows:

107.2.7 Structural information.

The *construction documents* shall provide the information specified in Section 1603.

107.2.9 Whole building life cycle assessment

A *whole building life cycle assessment (WBLCA)* performed in accordance with Appendix X of this code.

Code appendix language sample:

Below constitutes sample language for an appendix to Oregon's building code, using terminology that is consistent with the International Building Code (IBC). The text includes some variables that BCD would need to determine for suitability in the state. Recommendations for these variables and other considerations related to Oregon suitability are provided in Section 6.2.7.

X101.1 Whole building life cycle assessment (WBLCA).

A *whole building life cycle assessment (WBLCA)* performed in accordance with ISO 14040:2006 and ISO 14044:2006 shall be submitted for a new construction project with a floor area of ***A*** square feet or greater, or a *substantial improvement* project with a combined modified floor area of ***A*** square feet or greater. The *global warming potential* of the proposed building shall be no more than the greater of ***G*** lbCO_2e/square feet (***G*** kgCO_2e/m^2) or ***P*** percent of the *global warming potential* of the functionally equivalent reference building, where calculated using a whole building life cycle assessment in compliance with Sections X101.1.1 through X101.1.4 and performed in accordance with ISO 14040:2006 and ISO 14044:2006.

X101.1.1 Software and data quality.

Software used to conduct a *WBLCA* shall conform to ISO 21931-1:2022 and/or EN 15978 and shall have a data set compliant with ISO 14044 and ISO 21930 and/or EN 15804. The software shall utilize calculation methodology that is compliant with EN 15978, ISO 21931—1 and ISO 21929. Environmental impact data shall not be sourced from expired or retired data sources.

X101.1.2 Life cycle stages.

For new construction and *additions*, the *WBLCAs* shall include all modules in life cycle stages A, B, and C, as defined by EN 15978, except for operating energy and water stages (B6 and B7).

X101.1.2.1 Substantial improvements.
A *WBLCA* submitted for a *substantial improvement* to a building or structure may exclude existing and/or remaining building components.

X101.1.3 Building products.

The *WBLCA* shall include, at minimum, two (2) of the three (3) building *product* groups listed in items (a) through (c) below. The *WBLCA* shall consider all applicable items listed under each chosen group.

1. **Structure and enclosure:** *Exterior wall envelope; primary structural frame; secondary structural members; roof covering; roof deck; fenestration; load-bearing walls; interior walls and ceiling finishes* serving structural purposes; *veneer;* and internal wall components, including but not limited to *mineral board, gypsum board, particleboard, spray-applied foam plastic, and water-resistive barriers.*
2. ***Interior finishes***: *Interior surfaces, interior walls and ceiling finishes* serving decorative purposes*, interior floor finishes, interior floor-wall bases, decorative materials, trim, and nonload-bearing walls.*
3. **Service systems:** Sanitary fittings, services equipment, disposal installations, water installations, heat source, space heating and air treatment, ventilation systems, electrical installations, gas installations, lift installations, protective installations, communication installations, specialist installations.

X104.1.4 Reference study period.

The *reference study period (RSP)* shall be ***R*** years.

Option 2: Informative Appendix

Appendices in Oregon can also be voluntarily adopted by jurisdictions, rather than applying statewide. Appendix F of the Oregon Residential Specialty Code, which covers Radon Control Methods, is one example of an appendix that contains provisions that are not mandatory with the exception of certain sections.

This option would see the adoption of the appendix language provided in Option 1 but would give jurisdictions the ability to opt into adopting it. However, this option is not recommended, as it would weaken the state’s ability to reduce its statewide emissions in an ambitious and comprehensive way.

6.2.7 Recommendations and Suitability for Oregon

Table 6-9 outlines recommendations for a performance-based code approach in Oregon, which are based on the analysis and considerations provided throughout this chapter as well as a determination for suitability in Oregon. The table also includes references to the variables outlined in the code language provided in the previous section.

Table 6-9: Recommendations for Oregon for the performance code-based approach.

Code	Recommendation and Suitability for Oregon
Scope and applicability of performance provisions	● **Goal Setting:** Set a 60 percent reduction goal and timeline for embodied carbon, consistent with Oregon's sector-wide energy efficiency goals set in EO 20-04 and HB 3409. ● **Impacts Considered:** At minimum, include consideration of embodied carbon impacts (measured in global warming potential) in the scope. Consider requiring that WBLCAs consider other impact categories other than GWP as well. ● **Project types:** Apply provisions to commercial and multifamily project types. Including both project types will maximize greenhouse gas emissions reductions by 2050 (see Section 6.7). As an alternative, focusing solely on commercial buildings can also realize significant reductions. A 10 percent reduction requirement for commercial-only buildings can realize reductions only 1 percent off from a 40 percent reduction only applied to multifamily. ● **Project size:** Apply provisions to projects above 100,000 square feet in size *(variable **A** in the code language)*, with the intent to reduce the size threshold over time. This strategy is consistent with CALGreen's approach, which set the initial limit at 100,000 square feet with plans to reduce the threshold to 50,000 square feet in the following code cycle. Alternatively, consider phasing in Tier 1 and Tier 2 square footage thresholds set for Oregon's Building Performance Standards during the second cycle of code adoption. Expanding the scope of building sizes over time will give the state and the market the ability to ramp up to the learning curve of adhering to and complying with these provisions. A 100,000 square foot threshold would include approximately 18 percent of the state's building stock; reducing the threshold to 50,000 square feet would cover about 30 percent of the building stock; a 20,000 square foot minimum would account for 56 percent.
Scope of WBLCA	● **Physical scope:** At minimum, require that the physical scope of the WBLCA include the structure and enclosure of the building, as these portions tend to account for the majority of upfront embodied emissions. ● **Future physical scope:** Consider phasing in requirements for other building elements including interior finishes and service systems over time. The emissions associated with Mechanical, Electrical, and Plumbing (MEP) systems can be significant, but research and data around these are still in early stages. Track developments associated with ASHRAE 244p, focused on assessing the life cycle impacts of MEP assemblies, for future consideration of incorporating it into the building code. ● **Life cycle stages:** At minimum, require inclusion of life cycle stages A1-A4, B1-B5, C1-C4.

	• **Reference study period:** Set reference study period (*variable* ***R*** *in the code language)* at 60 years per most precedents.
Methodology and data requirements	• **EPD type:** Require or give priority to product-specific EPDs. • **Standards references:** Point to highly-referenced standards on LCA software, methodology, and data including ISO 14040, ISO 14044, ISO 14025, ISO 21930, ISO 3221931, EN 15805, and EN 15978.
Required reductions	• **Reductions:** Start with an achievable reduction requirement to get project teams in the practice of hitting these limits. Achievable reduction requirements demonstrated by other policies have landed around 10% (*variable* ***P*** *in the code language; for a 10% reduction, code language would be written as 90% of GWP of equivalent reference building*) lower than a baseline building or 350 kg CO_2e/m^2 (*variable* ***G*** *in the code language*). As more data becomes available for percentage-reductions and total caps that are achievable for projects in the region, revisit these requirements to push for higher reductions. As demonstrated in Section 6.7, the higher the reductions required, the higher the greenhouse gas emissions savings that will be realized.
Location in code	• **Code location:** Introduce provisions in a new mandatory appendix, accompanied by a reference to it in the Construction Documents (Section 107) in the base code.

Source: New Buildings Institute

6.3 Equity Considerations: Prescriptive and Performance Code Options

The following equity pillars can most directly inform code options for prescriptive and performance paths.

6.3.1 Health Equity

GHG is one metric reported in EPDs. Another one of human health value is Smog Depletion, as it begins to get into particulate matter and air quality, which tracks negative impacts at a localized level to the manufacturing or construction site. Although not necessarily a direct benefit to the location of the project in question, using this data as information will build equitable health outcomes at a larger regional scale through cleaner production and jobs.

Total carbon emissions measure the overall CO2e emitted by a building, while carbon per square foot standardizes emissions based on building size. Establishing CO2e limits by building type tailors guidelines for residential, commercial, and industrial buildings, driving innovation in design, materials, and operations for more sustainable and energy-efficient buildings.

By calling for EPDs in code to directly limit embodied carbon levels in whole-building or in specific materials such as concrete, the AHJ can gain *additional information impacting health equity* goals. Calling for EPDs in code will drive EPD creation in the market and open up opportunities for future aspects of EPDs to be used. The data on smog depletion can help move electrification throughout all sectors.

6.3.2 Environmental Equity

GHG emissions affect the climate for everyone, however, the disenfranchised are most impacted in adaptation and disaster impacts, as well as in implementations of mitigation strategies through burden of cost and access. Oregon should consider using a social cost of carbon (SCC), which puts a cost on the GHG emissions of a process (operational carbon) or potentially a product (embodied carbon) when determining embodied carbon target levels or reductions in Oregon's building code.

The social cost of carbon has been used to develop operational efficiency and electrification goals in jurisdictions including NY State. A 2020 report by ODOE lists a high-end estimate for the SCC in 2025 at $175 per ton of CO_2. This cost of carbon could be used to inform and set embodied carbon targets or reduction goals that reflect Oregon's societal health goals.

More of a description of the social cost of carbon and its use in Oregon is provided in Section 5.10 of this report.

6.3.3 Education Recovery

Any call for a shift in production or in proof mechanisms can result in uneven transitions. To address this disparity, ensure education is accessible for sourcing as well as understanding and using the information in EPDs, especially for small design firms and local manufacturers. This will support people transitioning to this work, new voices, and it is also important for economic equity and resilience.

6.4 Compliance Options Encouraging Building Reuse

Building reuse consistently realizes the most substantial amount of embodied carbon reductions compared to the other compliance pathways outlined in this chapter, by nature of the project avoiding emissions associated with demolition and new construction. A 2011 study by Preservation Green Lab, Skanska, Green Building Services, and others found that reuse of a variety of building types could realize between 4 and 46 percent embodied carbon savings compared to new construction operating at an equivalent energy performance level.[86] Moreover, it can take between 10 and 80 years for new buildings designed with energy efficiency features to overcome the environmental impacts associated with the construction process.[87] Scaling the practice of reuse across a state or city's building stock can realize significant reductions: a look at the city of Portland, for example, found that retrofitting and reusing all single-family homes and commercial office buildings instead of demolishing them over next 10 years could realize carbon reductions reaching around 231,000 metric tons of CO_2, equivalent to about 15% of the county's total reduction target.

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[86] Patrice Frey, Liz Dunn, and Ric Cochran, "The Greenest Building: Quantifying the Environmental Value of Building Reuse" (National Trust for Historic Preservation Preservation Green Lab, 2022), https://living-future.org/wp-content/uploads/2022/05/The_Greenest_Building.pdf.

[87] Patrice Frey, Liz Dunn, and Ric Cochran, "The Greenest Building: Quantifying the Environmental Value of Building Reuse" (National Trust for Historic Preservation Preservation Green Lab, 2022), https://living-future.org/wp-content/uploads/2022/05/The_Greenest_Building.pdf.

Building reuse therefore offers the greatest embodied carbon reduction opportunity to meet the urgency of curbing emissions immediately in order to meet global and state climate targets.

Opportunities to address building reuse in the code alone, however, are limited.

The Oregon Structural Specialty Code contains portions of the International Building Code (IBC), International Fire Code (IFC), and International Existing Building Code (IEBC). The scope of Oregon's code covers the "construction, reconstruction, alteration, and repair of buildings and other structures." Chapter 34 focuses on existing buildings and covers repairs, alterations, changes of occupancy, additions, and relocations of existing buildings.[88]

It is not within the authority of the building code to mandate building reuse – this is best achieved through other legislative action and policy programs. However, strategies can be employed in the code to encourage adaptive reuse or, at minimum, make it easier for applicants seeking to reuse rather than rebuild. The Oregon Building Codes Division has already recognized the important value that adaptive reuse can bring and has incorporated options within the IEBC portion of the Oregon code to encourage reuse. These strategies include administrative flexibility where hazards associated with preserving an existing building are not deemed to increase.[89]

Other code-based options that center embodied carbon can incentivize preservation of existing structures where possible. These code strategies can be used to complement other non-code-based programs focused on reuse, deconstruction and demolition, and advancing a circular economy. The prevailing strategy is found in CALGreen, which encourages reuse through providing optionality via compliance paths. CALGreen offers a choice from three pathways for compliance: (1) WBLCA; (2) prescriptive requirements; or (3) building reuse. By preserving at least 45% of an existing building's primary structure and enclosure when conducting alterations or additions, certain projects in California are relieved from the performance and prescriptive requirements to submit a WBLCA or EPDs.

6.4.1 Policy Overview

- **Timeline:** Initiate code development in Year 1 of new code cycle for inclusion in next adoption.
- **Enforcement Strategies:** Ensure code compliance review is contingent upon receipt of applicable materials per adopted code.
- **Provisions:** Maintain at least 45% of the existing building's primary structural elements and enclosure in alterations and additions.

6.4.2 Options for Placement of Requirements in Oregon Code Structure

Given the complex nature of addressing reuse in a code focused on the wide range of product types from new construction to alterations and additions, a compliance table describing the

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[88] "Section 101 Scope and General Requirements," in 2022 Oregon Structural Specialty Code with Amendments (State of Oregon, 2023), https://codes.iccsafe.org/content/ORSSC2022P2/chapter-1-scope-and-administration#ORSSC2022P2_Ch01_SubCh01.

[89] Alana Cox, "MEMORANDUM Adaptive Reuse – Existing Buildings," Oregon Building Codes Division, May 24, 2022, https://www.oregon.gov/bcd/Documents/adaptive-reuse-memo.pdf.

compliance pathway options that are available to different use cases might provide the most clarity for applicants. An example of what this table may look like is provided below. The proposed language situates all enforceable provisions associated with the three compliance pathways into a single appendix for ease of use, with reference made to it in Chapter 1 of the base code.

Base code reference language sample:

Sample language referencing the compliance pathways appendix in Chapter 1 is provided below.

Amend text as follows:

107.2 Construction documents.

Construction documents shall be in accordance with Sections 107.2.1 through 107.2.~~8~~9.

Add text as follows:

107.2.7 Structural information.

The *construction documents* shall provide the information specified in Section 1603.

107.2.9 Documentation of reduction of embodied carbon.

Construction documents submitted for the construction, *addition*, *alteration, repair,* or *substantial improvement* of any building *A* gross square feet or larger shall comply with Appendix X.

Code appendix language sample:

Below constitutes sample language for an appendix to the OSSC, using terminology that is consistent with the International Building Code (IBC). This option combines normative language for all three compliance pathways into a single appendix:

- The WBLCA compliance pathway includes the same language previously proposed and described under the performance-based approach option (Section 6.2).
- The prescriptive language consolidates the GWP limits for various materials into a single table that would appear in the Appendix. This diverges from the integration of GWP limits into materials-based chapters proposed for the prescriptive-only approach (Section 6.1).
- New language promoting building reuse as an alternate pathway is included.

The text below includes some variables that BCD would need to determine for suitability in the state. Recommendations for these variables and other considerations related to Oregon suitability are provided in Section 6.4.3.

Add text as follows:

X101 Options for Reduction of Embodied CO2e.

Projects with a floor area of ***A*** square feet or greater shall submit documents indicating compliance with embodied CO2e reduction requirements per Table X101.1.

TABLE X101.1 SUBMITTAL OPTIONS COMPLIANCE TABLE FOR REDUCTION OF EMBODIED CO2E

PROJECT	NEEDED TO COMPLY	EPD SUBMITTAL (PER SECTION X102)	WBLCA SUBMITTAL (PER SECTION X103)	PROOF OF PRESERVATION OF >X% OF EXISTING STRUCTURE (PER SECTION X104)
New Construction	Choose 1:	Option	Option	No option: does not qualify as building reuse
Reconstruction or Repair	Choose 1:	Option for new components	Option for new components	Option + comply with Chapter 34
Alteration	Choose 1:	Option	Option	Option + comply with Chapter 34
Addition	Choose 1:	Option	Option	Option + comply with Chapter 34
Change of Occupancy	Choose 1:	N/A	N/A	Option; comply with Chapter 34

X102 EPD Submittal. Project-specific product quantities shall be submitted along with *environmental product declarations* that demonstrate that the *global warming potential* of the total mass or volume of the covered products used in the project that are listed in Section X102.1 is no more than *X* percent of the values in Table X102.1, for the same total mass or volume of the covered products.

X102.1 Covered products. Covered products shall include no less than ***X*** percent of the total mass or volume of the following:

(a) Structural concrete products, including ready mix and concrete masonry units;
(b) Reinforcing steel products, specifically rebar;
(c) Structural steel products, specifically hot rolled sections, hollow sections, decking, and plate; and
(d) Structural wood products, including laminated veneer lumber, laminated strand lumber, glue laminated timber, wood framing, softwood plywood, and Oriented Strand Board (OSB).

TABLE X102.1 COVERED PRODUCT GWP VALUES

COVERED PRODUCT		GLOBAL WARMING POTENTIAL	UNIT OF MEASUREMENT
Ready mix concrete	Up to 2,499 psi	*(GWP value)*	kg CO_2e/m^3
	2,500-3,499 psi	*(GWP value)*	kg CO_2e/m^3
	3,500-4,499 psi	*(GWP value)*	kg CO_2e/m^3
	4,500-5,499 psi	*(GWP value)*	kg CO_2e/m^3
	5,500-6,499 psi	*(GWP value)*	kg CO_2e/m^3
	6,500 psi and greater	*(GWP value)*	kg CO_2e/m^3
	Lightweight, up to 2,999 psi	*(GWP value)*	kg CO_2e/m^3
	Lightweight, 2,500-4,499 psi	*(GWP value)*	kg CO_2e/m^3
	Lightweight, 4,500 psi and greater	*(GWP value)*	kg CO_2e/m^3
Concrete masonry units	Normal weight, up to 3,249 psi	*(GWP value)*	kg CO_2e/m^3
	Normal weight, 3,250-4,499 psi	*(GWP value)*	kg CO_2e/m^3
	Normal weight, 4,500 psi and greater	*(GWP value)*	kg CO_2e/m^3

	Medium weight, up to 3,249 psi	*(GWP value)*	kg CO_2e/m^3
	Medium weight, 3,250 psi and greater	*(GWP value)*	kg CO_2e/m^3
	Lightweight, up to 3,249 psi	*(GWP value)*	kg CO_2e/m^3
	Lightweight, 3,250 psi and greater	*(GWP value)*	kg CO_2e/m^3
Reinforcing steel	Rebar – unfabricated	*(GWP value)*	kg CO_2e/tonne
	Rebar – fabricated	*(GWP value)*	kg CO_2e/tonne
Structural steel	Hot-rolled sections – unfabricated	*(GWP value)*	kg CO_2e/tonne
	Hot-rolled sections – fabricated	*(GWP value)*	kg CO_2e/tonne
	Hollow structural sections – unfabricated	*(GWP value)*	kg CO_2e/tonne
	Hollow structural sections – fabricated	*(GWP value)*	kg CO_2e/tonne
	Decking	*(GWP value)*	kg CO_2e/tonne
	Plate – unfabricated	*(GWP value)*	kg CO_2e/tonne
	Plate – fabricated	*(GWP value)*	kg CO_2e/tonne
Structural wood	Laminated veneer lumber	*(GWP value)*	kg CO_2e/m^3

	Laminated strand lumber	*(GWP value)*	kg CO_2e/m^3
	Glue laminated timber	*(GWP value)*	kg CO_2e/m^3
	Wood framing	*(GWP value)*	kg CO_2e/m^3
	Softwood plywood	*(GWP value)*	kg CO_2e/m^3
	Oriented Strand Board (OSB)	*(GWP value)*	kg CO_2e/m^3

X103 Whole building life cycle assessment (WBLCA). A *whole building life cycle assessment (WBLCA)* performed in accordance with ISO 14040:2006 and ISO 14044:2006 shall be submitted for a new construction project with a floor area of ***A*** square feet or greater, or a *substantial improvement* project with a combined modified floor area of ***A*** square feet or greater. The *global warming potential* of the proposed building shall be no more than the greater of ***G*** $lbCO_2e$/square feet (***G*** $kgCO_2e/m^2$) or ***P*** percent of the *global warming potential* of the functionally equivalent reference building, where calculated using a whole building life cycle assessment in compliance with Sections X101.1.1 through X101.1.4 and performed in accordance with ISO 14040:2006 and ISO 14044:2006.

X103.1.1 Software and data quality.

Software used to conduct a *WBLCA* shall conform to ISO 21931-1:2022 and/or EN 15978 and shall have a data set compliant with ISO 14044 and ISO 21930 and/or EN 15804. The software shall utilize calculation methodology that is compliant with EN 15978, ISO 21931—1 and ISO 21929. Environmental impact data shall not be sourced from expired or retired data sources.

X103.1.2 Life cycle stages.

For new construction and *additions*, the *WBLCAs* shall include all modules in life cycle stages A, B, and C, as defined by EN 15978, except for operating energy and water stages (B6 and B7).

X101.1.2.1 Substantial improvements.
A *WBLCA* submitted for a *substantial improvement* to a building or structure may exclude existing and/or remaining building components.

X103.1.3 Building products.

The *WBLCA* shall include, at minimum, two (2) of the three (3) building *product* groups listed in items (a) through (c) below. The *WBLCA* shall consider all applicable items listed under each chosen group.

(a) **Structure and enclosure:** *Exterior wall envelope; primary structural frame; secondary structural members; roof covering; roof deck; fenestration; load-bearing walls; interior walls and ceiling finishes* serving structural purposes; *veneer;* and internal wall components, including but not limited to *mineral board, gypsum board, particleboard, spray-applied foam plastic, and water-resistive barriers.*

(b) ***Interior finishes***: *Interior surfaces, interior walls and ceiling finishes* serving decorative purposes, *interior floor finishes, interior floor-wall bases, decorative materials, trim, and nonload-bearing walls.*

(c) **Service systems:** Sanitary fittings, services equipment, disposal installations, water installations, heat source, space heating and air treatment, ventilation systems, electrical installations, gas installations, lift installations, protective installations, communication installations, specialist installations.

X103.1.4 Reference study period.

The *reference study period (RSP)* shall be ***R*** years.

X104 Documentation of building reuse. An *addition, alteration, repair,* or *substantial improvement* – where the total project area, including existing floor area, is larger than ***A*** gross square feet of occupied or conditioned space – shall submit documentation that demonstrates the preservation of no less than ***B*** percent combined of the *existing building's primary structural frame* and *exterior wall envelope,* excluding *exterior wall* covering material. *Fenestration*, insulation, portions of buildings deemed structurally unsound or hazardous, and *hazardous materials* that are remediated as part of the project shall not be included in the calculation.

X104 Compliance forms for building reuse. *Construction documents* shall clearly distinguish the measurements for existing and new elements. At minimum, forms documenting building reuse shall include the information listed in items (a) through (d) below:
(a) Area of the *existing building*(s) in square feet;
(b) Area of the aggregate addition(s) in square feet (if applicable);
(c) Existing total area and retained total area of the *primary structural frame* of the *existing building*(s) in square feet; and
(d) Existing total area and retained total area of the *exterior wall envelope,* excluding *exterior wall* covering material, of the *existing building*(s) in square feet.

6.4.3 Recommendations and Suitability for Oregon

Table 6-10 outlines recommendations for a code-based approach to promoting building reuse in Oregon, which are based on the analysis and considerations provided throughout this chapter as well as a determination for suitability in Oregon. The table also includes references to the variables outlined in the code language provided in the previous section.

Table 6-10: Recommendations for Oregon for the code-based approach providing compliance pathways that promote building reuse.

Code	Recommendation and Suitability for Oregon
Scope and applicability of new provisions	• **Goal Setting:** Set a 60 percent reduction goal and timeline for embodied carbon, consistent with Oregon's sector-wide energy efficiency goals set in EO 20-04 and HB 3409.

	• **Compliance pathway:** The building code cannot mandate building reuse. Rather, incentivize alterations and additions that choose to pursue adaptive reuse over new construction by exempting these projects from prescriptive and performance-based embodied carbon provisions. • **Project size:** Apply provisions to projects above 100,000 square feet in size *(variable **A*** in the code language), with the intent to reduce the size threshold over time. This strategy is consistent with CALGreen's approach, which set the initial limit at 100,000 square feet with plans to reduce the threshold to 50,000 square feet in the following code cycle. Alternatively, consider phasing in Tier 1 and Tier 2 square footage thresholds set for Oregon's Building Performance Standards during the second cycle of code adoption. Expanding the scope of building sizes over time will give the state and the market the ability to ramp up to the learning curve of adhering to and complying with these provisions. A 100,000 square foot threshold would include approximately 18 percent of the state's building stock; reducing the threshold to 50,000 square feet would cover about 30 percent of the building stock; a 20,000 square foot minimum would account for 56 percent.
Requirements for compliance with building reuse option	• **Amount of Building Reused:** Maintain at least 45 percent (*variable **B** in code language*) of the existing building's primary structure and enclosure in additions and alterations. This percent-threshold is consistent with CALGreen provisions, the only existing precedent of this type.
Location in code of compliance pathways	• **Code location:** Insert a compliance table for different project types into normative appendix with reference to the appendix in Section 107, which addresses construction documents submittals. Incorporate prescriptive, performance, and reuse requirements into the appendix.

Source: New Buildings Institute

6.5 Equity Considerations: Building Reuse

Building reuse has the most significant embodied carbon avoidance as a strategy. This strategy also supports the fabric of established neighborhoods, promotes beautiful structures, and requires skilled labor. If reused buildings can be used for housing, this strategy can also alleviate housing hardships and reactivate town and city centers.

6.5.1 Criminal Justice Reform and Police Accountability

A focus on building reuse has the potential to increase and maintain town and city centers, increase local job access, and uplift a community.

To access this potential through code options, consider how the implementation and enforcement mechanisms can support a local material reuse system that improves access to labor, business growth, and tracking of data.

6.5.2. Economic Opportunity

Economic opportunities can be written into implementation processes for code updates.

Consider reuse studies and implementing financial incentives that would kick in if a building can be reused by a developer. Ideally tie-in local labor agreements to increase vital local living-wage employment.

6.5.3 Education Recovery

Workforce development is a significant factor in successful building reuse strategies and should be framed to reduce economic disparity. Options for consideration are tied less to direct code language and more to the successful implementation path to achieve the call for EPDs in code for all project types, including adaptive reuse of existing buildings, and materials salvage/reuse.

Create and fund a robust workforce development program informed by CBO, focused on reuse skills, salvage, and economic development of material reuse systems. Also EPD education on sourcing, and use of the valuable information contained in EPDs.

6.6 Implementation and Enforcement

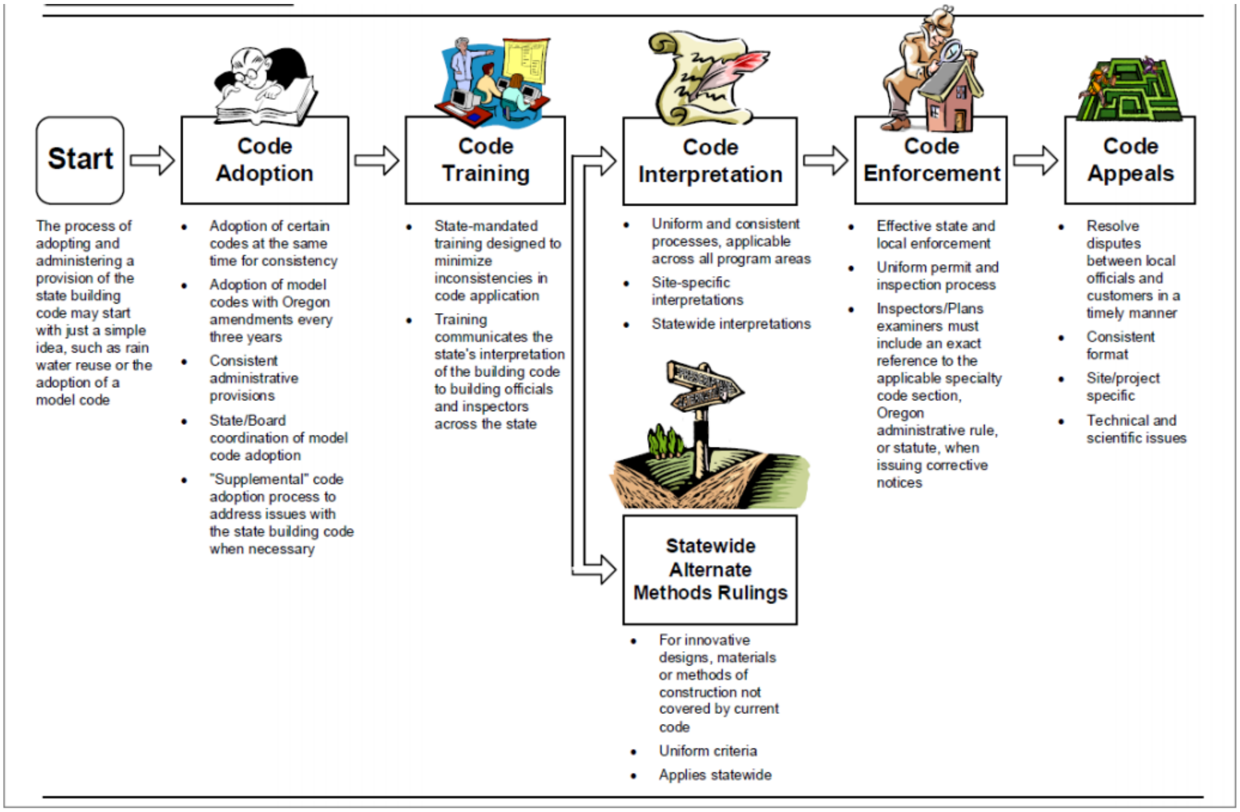
6.6.1 Implementation in Oregon

Oregon's building code is established by the state: every county and local jurisdiction is required to enforce this statewide minimum code.

At the local level, enforcement is handled by the permitting authority; jurisdictions tend to have their own approaches to permitting as well as data tracking. The state acts as a resource for jurisdictional building departments, and, when a jurisdiction does not have a Building Department, the state fills that gap. BCD has some services for some local jurisdictions for this purpose, which are limited in scope.

A typical application process for a project involves getting a permit from the local building department, who checks plans, specifications, and construction documents for compliance with the code. During construction, on-site inspections are conducted for components including structural, plumbing, mechanical, and electrical elements to confirm compliance with the submitted specifications before issuance of a Certificate of Occupancy. In Oregon, these inspectors need BCD certification for the specific type of inspection that they are conducting.

Figure 6-2: The life cycle of a code in Oregon.



Source: Oregon Building Codes Division

The success of a code provision is in large part contingent upon having processes in place that determine a project's compliance with the new requirements. This enforcement begins once codes are in effect, with ongoing adjustments and updates based on industry feedback and advancements in low-carbon technologies. This phased approach allows for a smooth transition, providing industry with the necessary time and resources to adapt to the new regulations.

The following two sections look at options to enforce embodied carbon code provisions at two points in a project's timeline: the permitting phase and the inspection phase.

6.6.2 Enforcement Strategies at Permitting Phase

Most existing embodied carbon programs practice enforcement at the permitting phase.

For all three code-based approaches discussed – prescriptive, performance, and reuse –key enforcement strategies involve robust documentation. EPDs play a critical role in the prescriptive approach, while WLBCAs are central to the performance-based approach. Both require rigorous review by building officials – the plans examiners at BCD as well as people in charge at the municipal level with the administration and enforcement of the building code – to ensure compliance. For building reuse, enforcement is focused on quantifying the percentage of a building that is preserved.

CALGreen contains provisions related to submissions that report a project's embodied carbon as well as verify that reporting.[90] For the prescriptive and performance options, project teams must submit a Responsible Designer's Declaration Statement attesting that the submitted WBLCA was conducted in accordance with the provisions of the code and assuring that the material quantities and specifications described in the assessment will be realized through the construction phase. In Oregon, this person would be the equivalent of what the Oregon building code calls the "Registered Design Professional in Responsible Charge" – the professional responsible for reviewing and coordinating aspects of the project and determining compliance with the code's submittal requirements. This might be the Architect of Record, Designer of Record and/or the owner. Building reuse projects must submit a table showing the total area of primary structural elements and building enclosure that was preserved, the newly constructed area of those categories, and the percentage of retained area for structure and enclosure. In California, in cases in which plan examiners deem submissions to be out of compliance, they would issue comments prior to permit approval. Responsible Designers must then respond to the comments and make the requested corrections to the permit set before submitting them again to their building department.

Marin County, California's Low-Carbon Concrete Code sets strict limits on cement usage and embodied carbon in construction projects. Compliance through these requirements is demonstrated through submitting concrete specifications, batch certificates, and EPDs, with provisions for exceptions in cases of hardship – this includes a lack of commercially available materials, a high cost burden relative to the overall cost of the project, and the impairment of historic buildings. Section 6.10 covers in more detail how these hardships may be addressed in Oregon. Overall, Marin's approach ensures that local construction aligns with broader carbon reduction goals. Compliance is ensured by requiring project teams to submit documentation, such as concrete mix designs, that demonstrate adherence to these limits. This documentation must be verified by a registered design professional before construction begins. Marin County also requires that EPDs be prepared according to specific standards and that they accurately reflect the concrete mix used in the project. These EPDs are reviewed as part of the permit application process, and construction cannot proceed without their approval.

6.6.2.1 Recommendations

The prescriptive approach involves setting GWP limits on specific building materials, ensuring that these materials meet established environmental performance standards. Enforcement would require the submission of EPDs for materials such as concrete, steel, wood, and other products. Compliance is verified through the submission, verification, and review of EPDs, which must demonstrate that the materials meet the established GWP limits. The enforcement strategy includes mandatory reporting, verification via a Registered Design Professional's Declaration Statement, and penalties for non-compliance, which are described later in this section.

Enforcement of WBLCA requirements would include the mandatory submission of WBLCA reports that analyze the GWP of the building's materials and systems. Depending on the code requirements, these reports may show either a percentage reduction from a baseline building or

[90] https://codes.iccsafe.org/content/CAGBC2022P3/chapter-8-compliance-forms-worksheets-and-reference-material

compliance with an absolute GWP cap. Project teams would attest to code compliance via submission of a Registered Design Professional's Declaration Statement. Building officials should be trained to review WBLCA submissions against these requirements, ensuring that project teams are not only designing for operational efficiency but also minimizing embodied carbon.

Enforcement of building reuse provisions involves incentivizing the preservation and reuse of existing structures. Compliance options include exemptions from other performance or prescriptive requirements if a significant portion of a building's structure and enclosure is reused. The enforcement strategy focuses on integrating building reuse pathways into the existing building code, with specific provisions for used materials, ensuring that reused structures meet safety and environmental standards.

- **Mandatory Submission:** For prescriptive approach, EPDs submitted for specific materials as part of the project's compliance documentation. For the performance approach, WBLCAs submitted reporting on embodied carbon emissions on a project-wide basis as part of the permitting process. For building reuse, calculations verifying percentage of existing structure and enclosure preserved in project relative to new elements.

- **Compliance Review and Verification:** Project teams submit a Registered Design Professional's Declaration Statement confirming adherence to code requirements and committing to use of specified products during construction. Responsible parties would include the Architect of Record/Designer of Record and the Owner, who would be listed with the permit application. Building officials verify that the materials meet the GWP limits as part of the overall code compliance review before issuing permits. The declaration of compliance is then signed by the General Contractor and is due in advance of the final building inspection.

- **Training for officials:** For all approaches, the Architect of Record/Designer of Record, Owner, and General Contractors should be made aware of these requirements in advance of it becoming a requirement. For the performance approach, building officials should receive training on reviewing WBLCA submissions to ensure compliance with reduction targets. For building reuse, trainings should specify how building reuse is calculated at the project level, including defining whether calculations are conducted by area, weight, volume, or cost. Building officials receive training on reviewing calculations to ensure compliance with reduction targets.

6.6.3 Enforcement Strategies at Construction and Inspection Phases

6.6.3.1 Verification

Regarding inspection-phase enforcement, the state could consider allocating responsibility to jurisdictions to perform verifications of compliance with plans that attest to the use of reported material products and check the accuracy of submitted embodied carbon calculations. Submitting these verifications would be a requirement for obtaining a Certificate of Occupancy.

Few precedents exist where mandatory embodied carbon programs require the verification of product installation of lower embodied carbon projects on-site.

One relevant example of note on the residential side is the guidelines for verification outlined by RESNET/ICC 1550, a standard currently under development that will provide a methodology for calculating and reporting embodied carbon of the product life cycle stages of a project. The intent is for Home Energy Rating System (HERS) raters – who conduct energy assessments of buildings on site – to integrate this new embodied carbon assessment into their existing energy rating processes. This will ultimately streamline the verification process. At present, whether these inspections will be required by the standard or provided as a compliance option is yet to be determined.

6.6.3.2 Penalties

In the absence of existing embodied carbon-specific examples showcasing inspection and penalties, other policies focusing on the contents of materials may be examined.

One model is exhibited by the handful of policies focused on the contents of asphalt. Over the past few decades, Austin, Texas, Washington, D.C., and other states and jurisdictions have banned the use of coal tar and high-Polycyclic Aromatic Hydrocarbons in asphalt and pavement sealant due to the substances' deleterious impacts on local watersheds and human health, including increased risk of cancer.[91]

In D.C., the District Department of Environment (DDE) enforces this ban by performing a certain number of inspections every year, conducting field tests to detect the presence of these sealants while cross-referencing contractor records.[92] If a sample extracted from the site is deemed to contain banned substances, violators – which may be the property owner, property manager, contractors hired to apply the sealant, or distributors of the products – are subject to daily fines of up to $2,500. Violators are also required to remediate the property by removing the product within 30 days of notification. D.C.'s enforcement also accounts for the fact that some materials may not be sourced from within jurisdictional boundaries. Since there are no manufacturers or distributors of tar-based sealants located within the District, enforcement is targeted at the contractors and end-users, who are local.

Austin, Texas' ban incorporates inspections into the existing daily processes of inspectors. Field staff – including inspectors, investigators, and biologists – associated with the Watershed Protection Department to inspect freshly sealed parking lots as they drive through the city fulfilling other job duties. The policy additionally regulates activity upstream by restricting the sale of these products.[93] Violations of the ban are deemed Class C misdemeanors, which are punishable by daily fines of up to $500, or $2,000 if criminal negligence is determined.

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[91] Needleman, Hannah "The Use, Impact, And Ban Of Coal Tar-Based Sealants" (2016), https://repository.library.noaa.gov/view/noaa/44055.

[92] "Coal Tar and High-Pah Pavement Sealant Ban in the District." Government of the District of Columbia Department of Energy & Environment, n.d. https://doee.dc.gov/service/coal-tar-and-high-pah-pavement-sealant-ban-district.

[93] "CHAPTER 6-6. - PAVEMENT PRODUCTS." Austin, Texas - Code of Ordinances, n.d. https://library.municode.com/tx/austin/codes/code_of_ordinances?nodeId=TIT6ENCOCO_CH6-6PAPR.

Additionally, full removal of the substance is required. Additional legal action may include jail time.

The City of Seattle's Living Building Pilot Program also utilizes penalties for failure to comply with requirements around gaining incentives related to such elements as Floor Area Ratio (FAR) and height bonuses, which cannot be feasibly undone once construction is completed. The Living Building Pilot Program grants projects additional height and FAR bonuses, as well as exemptions from Seattle Land Use Code provisions, in exchange for adhering to the Living Building Challenge, a green building certification program administered by the International Living Future Institute (ILFI).[94] Projects that receive these bonuses but fail to comply with ILFI's standards are subject to penalties of up to 5 percent of the construction value of the project.[95] Additionally, failure to submit required reporting can result in fines of $500 per day from when the reporting was due.

6.6.3.3 Recommendations

As indicated by the aforementioned RESNET example, incorporating verification processes into existing inspection visits and other job duties of inspectors and agency staff is an expeditious strategy that BCD may consider in collaboration with other state agencies such as DEQ, who are directed to protect the wellbeing and mitigate the impacts of climate change on residents and the environment.

Alternatively, if as-built inspections and verification are deemed infeasible, BCD could consider requiring the submission by project teams of an independent review of their submissions, which would include an assessment of submitted calculations, methodology, and data quality.

Requirements for remediation, while sensible for materials that actively harm the environment post-installation, are less suitable for enforcement focused on embodied carbon. For one, it is infeasible to ask that large structural materials be replaced, due to the high cost and effort associated with replacing them. Additionally, most of the upfront embodied carbon associated with their installation would already be spent by the time of inspection. The impacts of removing materials that have already spent the energy and carbon used for their production and construction would be counterintuitive, and the reconstruction required would be as good as double embodied emissions.

However, a similar system of fines shown by the D.C., Austin, and Seattle examples – which include retroactive fines – could be instituted to deter project teams from non-compliance through changing their reported materials down the line.

6.6.4 Training on New Code Requirements

[94] "Living Building Pilot - Overview." Living Building Pilot - Overview - SDCI, n.d. https://www.seattle.gov/sdci/permits/green-building/living-building-pilot-overview.
[95] "23.40.060 - Living Building Pilot Program." Seattle, Washington - Municipal Code, n.d. https://library.municode.com/wa/seattle/codes/municipal_code?nodeId=TIT23LAUSCO_SUBTITLE_IIILAUSRE_CH23.40COREREXC_23.40.060LIBUPIPR.

Education and training should be a focus of implementing any new code provision. This ensures that building officials understand how to determine compliance and that industry stakeholders can anticipate and comprehend the new policies and practices to which they will be expected to adhere.

Educating professionals on sustainable practices is essential for the widespread adoption and implementation of embodied carbon measures. By developing comprehensive training programs, hosting public workshops, integrating certification requirements, and establishing resource centers, Oregon can equip its workforce with the knowledge and skills needed to drive sustainable building practices. Continuously monitor the effectiveness of training programs and make adjustments as necessary. Collaborate with state agencies, like the Department of Energy and the Department of Administrative Services, to integrate assessment results and feedback into training and implementation strategies.

Objective: Educate professionals on sustainable practices to drive widespread adoption and implementation of embodied carbon measures.

6.6.4.1 Pathways for Implementation

1. **Professional Training Programs:** Educating professionals on embodied carbon reduction and sustainable practices is vital for widespread adoption. Oregon should develop comprehensive training programs covering embodied carbon measures, focusing on integrating these into professional practices. Training should be offered through public workshops, seminars, and certifications, and should be updated regularly in collaboration with industry organizations and educational institutions. Effective training will ensure that architects, engineers, and contractors are equipped to implement new code requirements and sustainable building practices.
2. **Public Workshops:** Host public workshops and seminars to increase awareness about embodied carbon and sustainable construction practices. These events should be designed to engage with a broad range of community stakeholders, ensuring that information is accessible to all relevant parties. Integration of embodied carbon training into professional certification and licensing will help standardize knowledge across the industry and promote adherence to new standards.
3. **Certification Requirements:** Integrating embodied carbon reduction into professional certification requirements is crucial for standardizing sustainable practices across the building industry. Certification programs for architects, engineers, and contractors should include modules on embodied carbon, covering both theoretical knowledge and practical application. This integration ensures that all professionals involved in building design, construction, and renovation are knowledgeable about and committed to reducing embodied carbon in their projects.
    a. Certification programs should be developed in collaboration with industry organizations, educational institutions, and regulatory bodies. These programs should offer specialized tracks or credentials focused on sustainable practices and embodied carbon reduction.

   b. Designate or establish certification bodies responsible for overseeing the development, administration, and accreditation of certification programs. These bodies should work with industry experts to ensure that certification requirements are rigorous and reflect current best practices. They should also handle the evaluation and renewal of certifications to maintain high standards of professional competency.

   c. Implement systems for monitoring and evaluating the effectiveness of certification programs. This includes tracking the impact of certified professionals on reducing embodied carbon and assessing the overall contribution to sustainability goals. Feedback mechanisms should be established to continuously improve certification programs and address any gaps or challenges.

4. **Resource Centers:** Utilize BCD's training program to build up resource centers to provide professionals with easy access to information, tools, and best practices for reducing embodied carbon. Partner with organizations like the state's Department of Environmental Quality (DEQ) to develop and distribute educational materials that support the implementation of low-carbon building techniques. These centers will serve as valuable hubs for ongoing education and resources. Align training and educational efforts with state initiatives such as GWP limits for building systems, financial incentives for low-carbon projects, and collaboration with organizations like the DEQ. Create a centralized repository of resources and best practices for low-carbon design and construction.

6.6.5 Data Tracking and Collection

Collecting data from each project seeking code compliance is the easiest pathway to collecting detailed data that is valuable to informing embodied carbon regulation. Oregon's Department of Environmental Quality's Consumption-Based Emissions Inventory (CBEI) tracks construction emissions at the sector level but not per building or material. Collecting project level data can fill this gap and enrich insights derived from the CBEI. By reporting specifics on material EPDs, WBLCA results, and building reuse, and saving the data to a centralized location, agencies will have a means to measure success and a wealth of insights that can inform future adjustments to the code language and other embodied carbon reduction policies and programs. Without this data, progress can only be vaguely tracked using EPD growth statistics and construction material sales data, which may not be enough to justify future policy decisions.

There is a lack of precedent for tracking embodied carbon data in buildings through building code. As of the date of this report, California state agencies have yet to confirm how data will be collected through the California Green Building Code embodied carbon requirements, which passed in August 2023. The Office of the State Architect (OSA) of Colorado currently collects EPD data through compliance and verification submittals for projects covered under Colorado's Buy Clean legislation. Under Colorado state law, OSA is required to deliver a progress report to legislators in 2026 and will utilize the data collected to update or add to the Buy Clean bill. The submittal form includes GWP data, product name, and quantity of product for each covered material, and also requires project teams to submit a zip folder of all EPDs used in the project.

Several opportunities for information gathering exist. For each code compliance pathway option, tracking the number of projects, project type, and location of projects can reveal popularity of options over time and trends in rural vs urban regions. Automating the data collection process and storing the data in a centralized database will reduce the effort and investment required.

The timing of data collection is another key point of consideration. For the prescriptive approach, project teams will not be far enough in the design process to have selected materials from specific manufacturers at construction permitting. It is not until after construction permitting that project teams confirm suppliers and factor in embodied carbon requirements for the individual products that will be installed on site. Verifying EPDs prior to issuing the certificate of occupancy is more suitable to this process, however because the materials will already be installed, very few opportunities will be available if changes are needed for code compliance (see the *Recommendations* section in this chapter for more information). The best time to collect data for the performance approach is at construction permitting, which encourages project teams to do WBLCA earlier in the design process, giving them a chance to adjust their design based on the results. The same is true for the building reuse option, where early verification still allows for some adjustments before the project breaks ground.

Table 6-11 outlines what data to collect, when to collect it, and why, for each code option proposed in this report:

Table 6-11: Suggested data collection strategy for each code option.

Prescriptive Approach: GWP Limits for Building Materials			
Data to Collect	How data is collected	What does this data reveal?	Why track this?
-number of EPDs for each material category -for each EPD: track the name and location of manufacturer producing the EPD and the GWP of the product	-prior to issuing the certificate of occupancy, EPD data is entered into e-permitting software, which automatically stores information in a centralized location accessible to DEQ and other agencies.	-this data will help reveal trends in the embodied carbon of materials, number of EPDs on the market, which type of material manufacturers are producing them, and where those manufacturers are located	-helps set material GWP benchmarks -helps inform future EPD assistance program -helps inform where low carbon materials are being produced across the state or where they are procured from outside of Oregon.
Performance Approach: Whole Building Life Cycle Assessment (WBLCA)			
Data to Collect	How data is collected	What does this data reveal?	Why track this?
Collect GWP data results from WBLCAs (kgCO2e per square foot)	-at construction permitting, WBLCA data is entered into e-permitting software	-this data will help reveal trends in the number of project teams conducting	-helps set building level GWP benchmarks -helps inform future

	as an initial compliance step. Software automatically stores information in a centralized location accessible to DEQ or alternatively, local jurisdictions are required to report data to DEQ on a quarterly basis.	WBLCAs, the methodologies used, and the overall embodied carbon reductions in buildings	WBLCA software and methodology requirements -helps inform future WBLCA training programs
Building Reuse Option			
Data to Collect	How data is collected	What does this data reveal?	Why track this?
Number of projects that pursue this option and their location, as well as data on the original and new use of the building, the original year built, original square footage and new square footage, and what parts of the original building are retained.	-at construction permitting, data is entered into e-permitting software, which automatically stores information in a centralized location accessible to DEQ and other agencies.	The data can reveal geographic and era trends and insights into the overall feasibility and popularity of this compliance pathway	-helps inform future/existing programs that encourage building reuse

Source: RMI

6.7 Estimated Greenhouse Gas Reductions

This section anticipates the amount of greenhouse gas (GHG) emissions that could be avoided through the year 2050 if code-based approaches were implemented. All results are reported in a percentage-reduction from a baseline, which assumes a scenario where no code-based approaches are taken through 2050.

The findings and methodologies outlined in this chapter build on the work of the Carbon Leadership Forum (CLF), which developed prototype calculators to model the impacts of various embodied carbon policy strategies, including limiting the GWP of materials, requiring whole-building reductions, and increasing building reuse.

This section contains a comparison of the three code pathways described in this report from the perspective of the GHG reductions that could be realized over time. Subsequent sections of this section outline how different variations of each code approach could impact the amount of emissions reductions that are realized for each option.

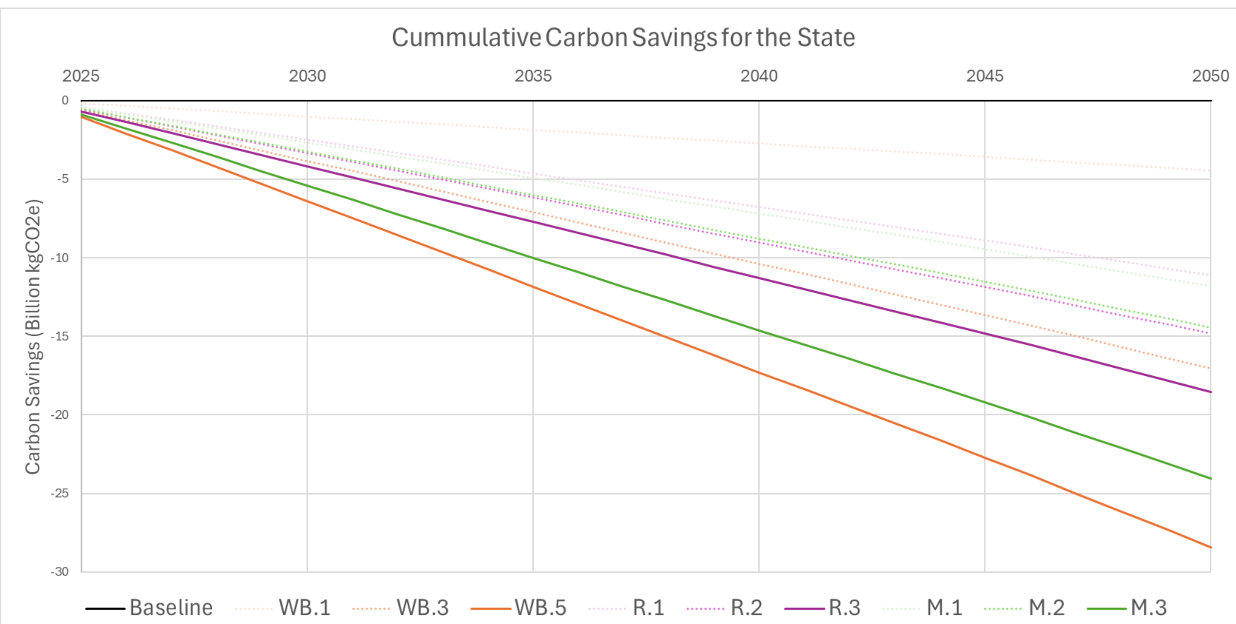
6.7.1 Comparison of Pathways

The chart below depicts the GHG emissions that could be avoided through the year 2050 by implementing the three code-based approaches described in this report – prescriptive, performance, and reuse. All scenarios are compared against the same baseline, which quantifies the GHG emissions that would occur through 2050 as a result of continued, business-as-usual activities, sans code approaches.

As shown below, a performance-based approach represents the greatest potential for reducing embodied carbon emissions, with a potential to realize a 50% reduction compared to a business-as-usual baseline, if the most stringent option were chosen. A material-based approach and building reuse pathway would also lead to significant savings, between 28-42 percent and 32-34 percent, respectively. Where emissions results fall within the wide range represented for the prescriptive approach would depend on which materials were regulated.

The graph below also captures some variations in the details of each code approach, particularly with regard to their applicability to specific building typologies and sizes. At present, this assessment assumes applicability to commercial and/or multifamily buildings that are four stories and above, which falls within scope of the Oregon State Building Code. The study also assumes no minimum size threshold. A size threshold implemented in Oregon may exclude a certain percentage of the commercial building stock.

Figure 6-3: Cumulative embodied carbon savings in MT CO2e from 2025-2050. Note material policy captures all considered materials.



Scenario Key

Whole building pathway:
WB.1: 10% reduction, commercial
WB.3: 30% reduction, commercial & multifamily
WB.5: 40% reduction, commercial &

Reuse pathway:
R.1: 30% reused, commercial & multifamily
R.2: 40% reused, commercial & multifamily

Material prescriptive pathway:
M.1: 30% reduction, commercial
M.2: 30% reduction, commercial & multifamily
M.3: 50% reduction, commercial &

multifamily	**R.3:** 50% reused, commercial & multifamily	multifamily

Source: New Buildings Institute

Note: While each policy scenario stringency is denoted as a percentage, the code language itself may be written in absolute terms.

6.7.1.1 Calculation Methodology

The calculations described in this section build on the best information available to the writers of this report at the time, regarding the current square footage and distribution of building types throughout the state. The existing multifamily building stock was estimated based on the 2020 Residential Energy Consumption Survey (RECS) data, which provided a total number of units for states in the region, including California, Hawaii, Oregon, Washington. The percentage of multifamily buildings above 3 stories, compared to all residential units in the RECS survey, was multiplied by the total residential square footage reported in the Oregon Joint Task Force on Resilience. This gave a square footage value for multifamily buildings above 3 stories in Oregon. The estimates for commercial buildings were derived by multiplying the commercial building stock values from the Oregon Joint Task Force on Resilience by the size thresholds identified in the NEEA study of the 2019 CBSA report. Estimated values projecting growth due to new construction were provided by the Oregon Department of Environmental Quality (DEQ). The final values from these methods are represented in Table 6-12.

Table 6-12: Building types used in embodied Carbon GHG calculations

Building Types analyzed in report	Total Statewide New Construction SF (2025-2050)	Current Statewide SF estimate 2024
Multifamily above 3 stories	260,959,513	644,600,000
Small Commercial (50,000 square feet or less)	596,490,454	1,473,400,000
Large Commercial (over 50,000 square feet)	261,769,192	646,600,000
Total New Construction 2025-2050	1,119,219,159	2,764,600,000

Source: New Building Institute

6.7.2 Prescriptive Approach

Four scenarios were evaluated for three major materials: concrete, steel, and engineered wood. The scenarios were:

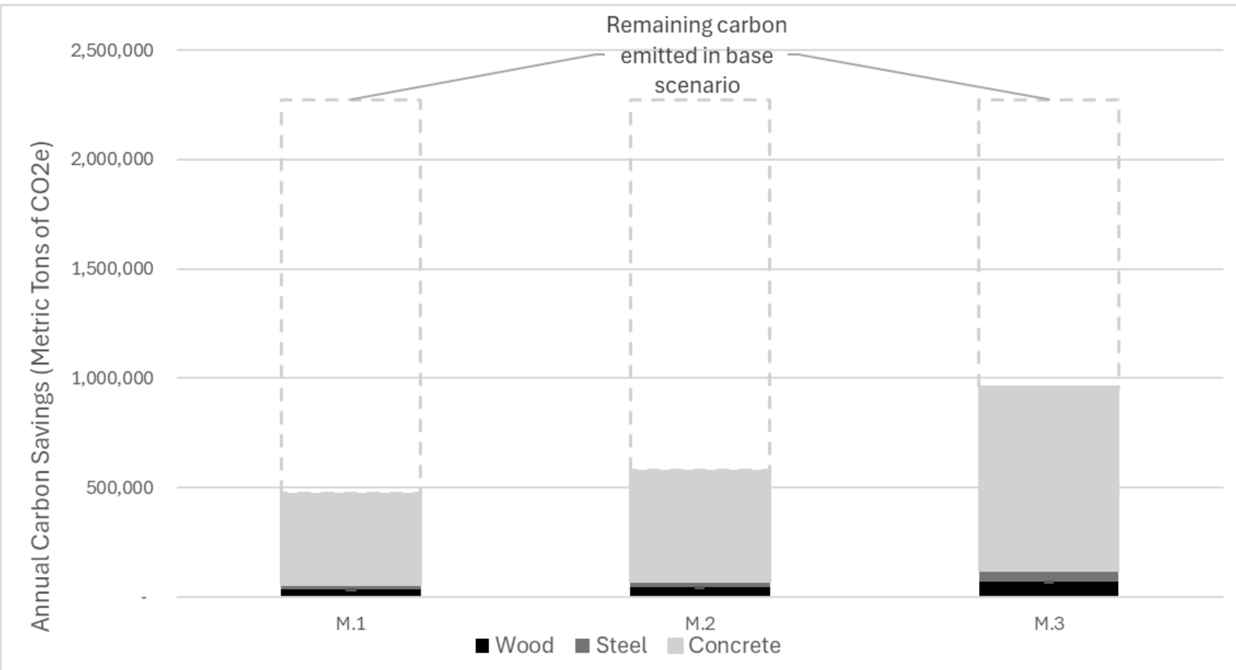
- Taking **no action**: this case was used as the baseline for all policies and scenarios
- Setting GWP limits at **30% below** industry average and applying provisions to **commercial** projects only

- Setting GWP limits at **30% below** industry average and applying provisions to **commercial and multifamily** projects
- Setting GWP limits at **50% below** industry average and applying provisions to **commercial and multifamily** projects

6.7.2.1 Summary of Results

In all scenarios, concrete realized significantly higher emissions savings compared to the other materials. Within the two scenarios that used the same required reductions value, including multifamily projects as opposed to commercial only saw marginally higher savings.

Figure 6-4: Cumulative embodied carbon savings in MT CO2e from 2025-2050 for various prescriptive-based approach scenarios.



Scenario Key

Material prescriptive pathway:
M.1: 30% reduction, commercial
M.2: 30% reduction, commercial & multifamily
M.3: 50% reduction, commercial & multifamily

Source: New Buildings Institute

Table 6-13: Anticipated GHG reductions by prescriptive approach scenario.

Prescriptive Approach Scenario	% Reduction of GHGs from Baseline Scenario by 2050
Concrete	
No Action	0%
Scenario Mc1 (30%, Commercial)	12-18%
Scenario Mc2 (30%, Commercial & Multifamily)	15-22%
Scenario Mc3 (50%, Commercial & Multifamily)	25-37%
Steel	
No Action	0%
Scenario Ms1 (30%, Commercial)	0.5-1%
Scenario Ms2 (30%, Commercial & Multifamily)	0.7-1.3%
Scenario Ms3 (50%, Commercial & Multifamily)	1.1-2.1%
Engineered Wood	
No Action	0%
Scenario Mw1 (30%, Commercial)	1-1.5%
Scenario Mw2 (30%, Commercial & Multifamily)	1.3-1.9%
Scenario Mw3 (50%, Commercial & Multifamily)	2.2-3.1%

Source: New Buildings Institute

6.7.2.2 Calculation Methodology

To assess the GHG reductions of a materials-based policy, baseline and reduction scenarios were created. These use **material quantity** by building use and size as well as the current and expected **material embodied carbon intensity** for the relevant materials.

In the methodology described below, *x* represents the policy's selected material. For example, if the policy focuses on concrete, *x* would become *C.*

Set a Baseline Scenario

A baseline value was set based on ongoing construction practices and typical local material production and use. When considering concrete, future considerations could take into account ongoing state activities targeting concrete embodied carbon reduction.

- **Material Quantity (xMQ):** The projected concrete material quantity was calculated by building type. This constituted a Material Intensity (MI) [kg/sf area], which was applied to each building typology. Each building typology was separated into its common structural systems and assumptions were applied regarding statewide percentages of these building types. The whole building type's material use was estimated for each structural system. A Regional Assessment of Buildings Material Intensities (RASMI) was utilized to determine the material intensity by common structural systems.[96] Gathering local construction waste values by material would also be valuable for quantifying typical material waste before it enters the building calculation.
- **Material Embodied Carbon Intensity (xECI):** For each material, the average carbon intensity in kgCO2e/kg was determined. Future calculations could use local case studies and EPDs. For concrete, regional data is particularly useful as production tends to occur closer to the job site. EC3 provides EPD data for regional mixes; the National Ready-Mix Concrete Association (NRMCA) also has regional baselines set for concrete. For other materials, regional benchmark values will be less relevant; a closer look at sourcing practices for steel, wood, insulation, and other products would be warranted to determine whether national or regional values would be most relevant. The 2023 CLF Materials Baseline has values for concrete, steel, and wood.
- **Building Typology Growth Area (BTGA):** Data projecting statewide total square footage growth for new construction was parsed by building use; projections for this study were drawn from the State of Oregon Joint Task Force on Resilient Buildings study, NEEA (CBECS), and 2020 RECS survey. Future inputs could instead consider local building trends and population growth projections. These can be adjusted to reflect a 2020 - 2050 growth window. The calculations assume linear growth for each building typology.

Set a Reduction Scenario

Embodied carbon was estimated based on the prescriptive GWP caps set in code. These were applied to the projected growth scenario by construction type. The policy will set either a percentage reduction for each material or a limit on material ECI, which will be applied in the calculation as *xECIr*.

Calculate the Anticipated Reduction from Baseline

The GHG reductions of a material-based policy were calculated with the following formula:

GHG Reductions of Material-Policy [%] =[Equation]

Baseline Scenario [kgCO2e] = $xECI_b$ *[kgCO2e/kg]* xMQ [kg]*

[96] Fishman, T., Mastrucci, A., Peled, Y. et al. RASMI: Global ranges of building material intensities differentiated by region, structure, and function. Sci Data 11, 418 (2024). https://doi.org/10.1038/s41597-024-03190-7

*Reduction Scenario [kgCO2e] = xECIr [kgCO2e/yd3] * xMQ [kg]*

*xMQ [kg] = BTGA [sf] * MI [kg/sf]*

6.7.3 Performance-Based Approach

Four scenarios were evaluated for this approach:

- Taking **no action**: this case was used as the baseline for all policies and scenarios
- Requiring a **10% reduction** in whole-building GWP, measured from a reference building assuming industry-average values, and applying provisions to **commercial** projects only
- Requiring a **40% reduction** in whole-building GWP, measured from a reference building assuming industry-average values, and applying provisions to **multifamily** projects only
- Requiring a **30% reduction** in whole-building GWP, measured from a reference building assuming industry-average values, and applying provisions to **commercial and multifamily** projects
- Requiring a **40% reduction** in whole-building GWP, measured from a reference building assuming industry-average values, and applying provisions to **commercial and multifamily** projects
- Requiring a **50% reduction** in whole-building GWP, measured from a reference building assuming industry-average values, and applying provisions to **commercial and multifamily** projects

6.7.3.1 Summary of Results

Despite the required reductions threshold, the three scenarios that applied to both commercial and multifamily buildings (WB3, WB4, and WB5) achieve the highest GHG reductions. This indicates that a comprehensive approach targeting both use types is most effective.

Table 6-14: Anticipated GHG reductions by performance-based approach scenario.

Performance-Based Approach Scenario	% Reduction of GHGs from Baseline Scenario by 2050
No Action	0%
Scenario WB1 (10%, Commercial)	8%
Scenario WB2 (40%, Multifamily)	9%
Scenario WB3 (30%, Commercial & Multifamily)	30%
Scenario WB4 (40%, Commercial & Multifamily)	40%
Scenario WB5 (50%, Commercial & Multifamily)	50%

Source: New Buildings Institute

6.7.3.2 Calculation Methodology

To assess the GHG reductions of a WBLCA policy, baseline and reduction scenarios were created by determining the existing **building embodied carbon intensity** by building use and size as well as the expected **building typology growth** by building use and size.

Set a Baseline Scenario using Building Embodied Carbon Intensity (BECI)

For each relevant building use and building size, a whole building embodied carbon intensity benchmark was set. The aim was for these to reflect typical design and construction practices. In the future, these would ideally be based on local data collected in WBLCAs. In the absence of sufficient local data, CLF offers standard benchmarks by building type were used; a newer study publishing an updated set of regionally-specific values for a range of building types is anticipated in early 2025.

Ex. 200 kgCO2e/m2 for 1-3 story single-family residential

Calculate Reductions with Building Typology Growth Area (BTGA)

Data projecting statewide total square footage growth for new construction was parsed by building use, considering local building trends and population growth projections. Projections for this study were drawn from the State of Oregon Joint Task Force on Resilient Buildings study, NEEA (CBECS), and 2020 RECS survey. Future inputs could instead consider local building trends and population growth projections. These can be adjusted to reflect a 2020 - 2050 growth window. The calculations assume linear growth for each building typology.

The GHG reductions of a WBLCA policy were calculated with the below formula:

GHG Reductions of a WBLCA Policy [%] = [Equation]

*Baseline Scenario [kgCO2e] = BECI [kgCO2e/sf] * BTGA [sf]*

*Reduction Scenario [kgCO2e] = (1 - % Reduction Required) * Baseline Scenario [kgCO2e]*

6.7.4 Building Reuse

Four scenarios were evaluated for this approach:

- Taking **no action**: this case was used as the baseline for all policies and scenarios
- Requiring **reuse of 30%** of the existing structure (by area) for **commercial and multifamily** projects
- Requiring **reuse of 40%** of the existing structure (by area) for **commercial and multifamily** projects
- Requiring **reuse of 50%** of the existing structure (by area) for **commercial and multifamily** projects

6.7.4.1 Summary of Results

As the percentage of the structure reused in commercial and multifamily buildings increases, the projected embodied reduction rises in a relatively linear fashion. Even a moderate increase in building reuse (Scenario R1) can realize a substantial reduction in GHG emissions by nature of the amount of new construction that is avoided.

Table 6-15: Anticipated GHG reductions by building reuse approach scenario.

Building Reuse Scenario	% Reduction of GHGs from Baseline Scenario by 2050
Increasing Building Reuse	
No Action	0%
Scenario R1 (30% of structure Commercial & Multifamily)	19-20%
Scenario R2 (40% of structure Commercial & Multifamily)	25-27%
Scenario R3 (50% of structure Commercial & Multifamily)	32-34%

Source: New Buildings Institute

6.7.4.2 Calculation Methodology

To assess the GHG reductions of a building reuse policy, baseline and reduction scenarios were created using current construction practices for the baseline and capturing reuse options for the reduction scenario.

<u>Set a Baseline Scenario</u>

The baseline scenario for assessing the GHG reductions of a building reuse policy were created using the same methodology described for the performance-based approach, which parses information by building use and size. This scenario represents the embodied carbon of state construction without any reuse.

<u>Set a Reduction Scenario</u>

The projected reductions scenario incorporates the expected **reuse of a building's structure** by use, typology, and size.

The reduction scenario was calculated by considering a policy that sets a **reuse percentage (RP)**: a percentage of a building's structure area to be preserved. Depending on the type of structure utilized by the building, there is a larger or smaller percentage of a total embodied carbon held in that structure (%WBEC). By multiplying RP by the %WBEC, the typical BECI was modified to a reduction scenario embodied carbon intensity (RECI).

Other options for assigning an embodied emissions intensity of the structural system can be found using the Carbon Avoided Retrofit Estimator (CARE), or by using case studies of retrofits done in Oregon with proper EPD documentation. Demolition and construction waste embodied carbon values added to the baseline would be valuable for providing an extra layer of validity to the saving and reductions of this sort of policy.

Calculate the Anticipated Reduction from Baseline

The values outlined above can be applied to the following calculation:

GHG Reductions of a Reuse-policy [%] =[Equation]

*Baseline Scenario [kgCO2e] = BECI [kgCO2e/sf] * BTGA [sf]*

*Reduction Scenario [kgCO2e] = RECI [kgCO2e/sf] * BTGA [sf]*

*RECI [kgCO2e] = RP * %WBEC * BECI [kgCO2e/sf]*

6.7.5 Data Sources

Table 6-16: Data sources for GHG calculations.

Input	Data Source
Building Embodied Carbon Intensity (BECI) [kgCO2e/sf]	CLF Embodied Carbon Reduction Calculator: Section on Portland Buildings
Building Typology Growth Area (BTGA): new construction, commercial and residential [sf]	Total value found in the State of Oregon Joint Task Force on Resilient Efficient Buildings, to subdivide into building Type NEEA (CBECS Study) and 2020 RECS survey had % of each building type.
Material Embodied Carbon Intensity (*xECI*) [kgCO2e/sf]	2023 CLF Material Baseline Report
Mass of construction material per unit of a building's floor area (MI) [kg/sf]	Regional Assessment of Buildings' Material Intensities (RASMI) used to calculate a buildings Material Quantity *This is also broken out by structural systems found in buildings (wood, steel, concrete, and hybrid structural systems). CLF has a table that estimates a high and low range percentage of building type construction using each structure type.*
Percent of whole building emissions (%WBEC)	CARE Data and Methodology *The embodied emissions intensity of the structural system is based on the type of structure selected: wood, hybrid, or steel and/or concrete. The emissions intensity assigned to each type of structure represents a percentage of the whole building emissions of a new building.*

Source: New Buildings Institute

6.8 Potential Cost Impacts of Code Approaches

Large Real Estate Developers, Architecture, Engineering and Construction (AEC) firms, and material manufacturers and suppliers involved with building projects over 100,000 square feet, will be the parties most affected by the proposed code approaches. Building officials in local jurisdictions will also be affected by the responsibility to enforce the new code language. This section outlines the potential cost impacts to these stakeholders, including hard costs such as software, training, and data, and soft costs such increased staff time.

Like any new regulation, all stakeholders are expected to experience an initial learning curve that requires additional time and training investment as staff learn what is required for compliance. Over time, costs related to this learning curve are expected to decrease as project teams become familiar with the requirements.

For Real Estate Developers and AEC professionals, the performance pathway requiring WBLCA is the costliest compliance path, estimated at an added cost of $15,000 to complete the WBLCA, including hard and soft costs.[97] This cost impact is negligible compared to total project costs for buildings greater than 100,000 sq ft, and AEC firms that work on projects of this scale are typically larger enterprises with sufficient staff capacity and resources to provide adequate WBLCA services.

For material manufacturers, the prescriptive pathway requiring EPDs is potentially the costliest pathway due to the expense of generating EPDs for their products, however many manufacturers in Oregon and the surrounding region have already made this investment.

6.8.1 Cost Impact to Local Building Departments

For all pathways, local jurisdictions will incur costs to enforce the code requirements, including staff training, time spent reviewing submissions and verifying compliance, and costs associated with maintaining a data collection software and a centralized database for collecting project-level embodied carbon data during the code enforcement process. Administrative costs to enforce compliance may necessitate staff increases or additional training.

A study published by the California Green Building Standards Commision for CALGreen's 2022 embodied carbon requirements, which includes similar prescriptive, performance, and building reuse requirements as proposed in this report, determines that there is a minor increase of costs to local California governments to review and check plans for compliance, however there is no "major fiscal effect on local governments to enforce the regulation."[98] Due to the similarities in code requirements and enforcement, it is anticipated that local governments in Oregon would experience a similar level of fiscal impact.

6.8.2 Cost Impacts to Professionals Using the Prescriptive Approach: Global Warming Potential (GWP) Limits for Building Materials

The prescriptive approach requires verification of compliance through product-specific Type III Environmental Product Declarations (EPDs) that disclose the carbon intensity of individual building products and materials.

AEC firms specifying and procuring materials covered under the code requirement can use EPD databases to search for, filter, and compare products with GWP limits that comply with code requirements. Once a product has been selected, users can download the EPD document for code submission and verification. The comprehensiveness of these databases depends on

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[97] California Department of General Services, Building Standards Commission, "Economic and Fiscal Impact Statement (Form 399), Attachment C- CCRC regulations 54day, Amend the 2022 California Green Building Standards Code, CCR, Title 24, Part 11," Department of General Services, March 2, 2023, https://www.dgs.ca.gov/-/media/Divisions/BSC/03-Rulemaking/2022-Intervening-Cycle/Public-Comments/GREEN-45-Day/BSC/BSC-04-22-399-PT11-Attachment-C-R1-45day.pdf?la=en&hash=E1121CBF2FEA6D07492DCD1E962D8AA1AFC43618.

[98] California Department of General Services, Building Standards Commission, "Economic and Fiscal Impact Statement (Form 399), Attachment C- CCRC regulations 54day, Amend the 2022 California Green Building Standards Code, CCR, Title 24, Part 11," Department of General Services, March 2, 2023, https://www.dgs.ca.gov/-/media/Divisions/BSC/03-Rulemaking/2022-Intervening-Cycle/Public-Comments/GREEN-45-Day/BSC/BSC-04-22-399-PT11-Attachment-C-R1-45day.pdf?la=en&hash=E1121CBF2FEA6D07492DCD1E962D8AA1AFC43618.

manufacturer participation (more information on EPD availability can be found in section 4. *The State of the Market for Embodied Carbon in Oregon*). Requesting EPDs from manufacturers directly is an alternative option.

In the US, Building Transparency's Embodied Carbon in Construction Calculator (EC3) is the most comprehensive stand-alone EPD database for construction materials. Launched in 2019, there are over 81,000 EPDs from US manufacturers listed in the tool. Users can search for specific materials in their region, compare the carbon impact (as well as other environmental factors reported in EPDs) between different products, and download product EPDs directly from the database. There is no cost to use the database.

For AEC professionals, costs associated with additional staff time spent learning how to use these databases, selecting and verifying materials that comply with the code requirements, and working with suppliers to ensure that these materials are installed on site, vary with each project and project team. No project-level data points related to the costs of this additional time could be found, however it is expected that project teams will spend less time doing these activities as they become more familiar with the process and with local manufacturers supplying complying materials. Table 6-17 outlines hourly rates for AEC professionals in Oregon:

Table 6-17: average hourly rates for architecture, engineering, and construction professionals in Oregon

	Architect	Engineer	Construction Professional
Average hourly rate in Oregon (not including overhead)	$66	$48	$25

Source: Data retrieved from ZipRecruiter.com on September 25, 2024.

Material manufacturers incur the cost of generating product-specific EPDs, including both upfront and recurring costs. To create an EPD, a manufacturer must first engage a third-party service provider to conduct an LCA of the product and compile the EPD report. The EPD is then verified by a third party before publication to various EPD databases. EPDs typically expire after five years, at which point the manufacturer must repeat the process.

The total cost of generating an EPD varies depending on the complexity of manufacturing processes for each material type. Available cost data focuses on costs to generate EPDs for ready-mix concrete materials, however manufacturers producing other types of materials may incur lower or higher costs to generate EPDs for each of their products.

Table 6-18 outlines low and high cost estimates from a survey of three prominent EPD providers in the United States. The cost for unlimited EPD access for a single concrete plant includes an initial setup fee ranging from $3,000 to $5,200 for the first year, with annual subscription fees between $1,500 and $2,990 thereafter. Some providers offer tiered pricing based on features, licensing types, or provide discounts for multiple plants. For example, a concrete company with five plants might pay an initial setup fee of $8,200 and annual fees of $4,750, which averages to

$1,640 per plant in the first year and $950 per plant in subsequent years. Separate from the setup and subscription fees, third-party verification is an additional recurring cost that varies based on the complexity of the products and the number of EPDs submitted at once. For a single EPD, verification costs can be as high as $2,000, while a bundle of up to 14 EPDs may be verified for around $10,000.[99]

Table 6-18: Costs to generate product-specific Type III EPDs for ready-mix concrete products

Cost Item	Low Estimate	High Estimate
EPD Setup Costs (one-time payment per plant)	$3,000	$5,200
Subscription Fees (annual payment per plant)	$1,500/year	$3,000/year
Verification Fees (per product EPD)	$750	$2,000

Source: RMI, "Low-Carbon Concrete in the Northeastern United States,"

Many product manufacturers have already invested in EPDs and more may choose to invest in them based on new code requirements. Research done by New Buildings Institute for the Washington State Building Code Council indicates that any product cost increase imposed by the manufacturer to alleviate the cost of EPDs is spread across consumers and negligible to individual project costs.[100]

6.8.3 Cost Impacts to Professionals Using the Performance Approach: Whole Building Life Cycle Analysis (WBLCA)

The performance approach requires project teams to generate and submit a WBLCA, which analyzes the embodied carbon impact of the proposed building over its lifespan. This additional service primarily impacts building developers and the architects, engineers, energy or green building consultants that may lead the WBLCA analysis and design solutions to reduce the overall embodied carbon impact of the building. On average, providing the WBLCA service adds an estimated $10,000 to $15,000 in costs, including both hard and soft expenses. Historical construction cost data indicates that for buildings over 100,000 square feet, the cost of

[99] RMI, "Low-Carbon Concrete in the Northeastern United States," June 27, 2022, accessed September 20th, 2024, https://rmi.org/low-carbon-concrete-in-the-northeastern-united-states/

[100] State Building Code Council, "Greenhouse Gas Emissions Reduction for Steel Products," State of Washington, 2022, accessed august 9, 2024, https://sbcc.wa.gov/sites/default/files/2022-04/095_Sections%20202%20and%202205_IBC.pdf

conducting a WBLCA represents a negligible amount, typically less than 0.07% of the total construction cost.[101]

Two broad categories of software for conducting this analysis exist: those that "plug in" to Building Information Modelling (BIM) and those that are stand alone. The costs of these tools are outlined below:

1. BIM Software and WBLCA Plug-ins:

   Building Information Modelling (BIM) is a digital representation of the physical and functional characteristics of a building, serving as a shared knowledge resource that supports decision-making throughout a building's lifecycle—from conception to deconstruction. BIM is a widely used tool for architects, engineers, and construction professionals to design, document, and manage projects collaboratively and efficiently. "Plug in" WBLCA software is available at an additional cost and is integrated into BIM programs to streamline embodied carbon assessment.

   Table 6-19: Cost of BIM and plug-in LCA software

Cost Item	Low Estimate	High Estimate
Basic License Cost (Excluding WBLCA Plug-in) (annual fee)	$660 (Autodesk Revit)	$5,000 (ArchiCAD)
WBLCA Plug-in (annual fee)	$695/year (TallyLCA)	$5,000/year (One Click LCA)
Total (annual cost)	$1,355	$10,000

   Sources: BIM Software: Autodesk Revit and ArchiCAD, LCA Tools: Tally Pricing, One Click LCA Pricing, and SimaPro Pricing on September 25th, 2024

2. Stand Alone WBLCA Tools:

   While WBLCA-compatible BIM software can streamline embodied carbon assessment, it is not strictly necessary. Project teams can use stand-alone WBLCA tools such as Tally, One Click LCA, the Athena Impact Estimator, and SimaPro, without integrating them into BIM. This is a more cost-effective option for firms that don't use BIM software. Some

[101] California Department of General Services, Building Standards Commission, "Economic and Fiscal Impact Statement (Form 399), Attachment C- CCRC regulations 54day, Amend the 2022 California Green Building Standards Code, CCR, Title 24, Part 11," Department of General Services, March 2, 2023, https://www.dgs.ca.gov/-/media/Divisions/BSC/03-Rulemaking/2022-Intervening-Cycle/Public-Comments/GREEN-45-Day/BSC/BSC-04-22-399-PT11-Attachment-C-R1-45day.pdf?la=en&hash=E1121CBF2FEA6D07492DCD1E962D8AA1AFC43618.

LCA software can be accessed for free, but these tools often come with limitations, including fewer material options, basic reporting functions, and lower precision, that may compromise the quality of the WBLCA.

Table 6-20: Cost of stand-alone LCA software

Cost Item	Low Estimate	Mid-Range Estimate	High Estimate
Yearly License Cost	$0 (Athena Impact Estimator, TallyLCA)	$695 (TallyLCA, OneClick)	$8,500 (SimaPro)

Sources: LCA Tools: Tally Pricing, Athena Impact Estimator, One Click LCA Pricing, and SimaPro Pricing

To effectively implement WBLCA, professionals need targeted training and education. This may include workshops, seminars, online courses, and webinars. These formats can be categorized based on their structure:

- **Workshops**: Hands-on, interactive sessions, often with a practical component, focusing on applying WBLCA tools in real-world scenarios.
- **Seminars**: Usually more formal presentations by experts, offering in-depth theoretical knowledge about life cycle assessment and embodied carbon reduction strategies.
- **Online Courses**: Structured, often self-paced, educational programs that can be taken remotely, focusing on both theory and practical application.
- **Webinars**: Often shorter, sometimes free, online sessions that provide updates or introductions to key concepts and tools.

Larger firms may develop in-house training programs for their staff. A breakdown of educational costs is listed in the table below:

Table 6-21: Cost of various LCA training programs

Cost Item	Low Estimate	High Estimate
Online Courses and Webinars (per person)	$0 (Free Webinars)	$500 (Coursera/EdX)
Workshops and Seminars (per person)	$200 (AIA Continuing Education)	$1,000 (USGBC Education)

In-house Training Programs (Per Company)	$5,000 (Lorman Education Services)	$20,000 (Lorman Education Services)
Time Costs (per person)	$200 (4 hours at $50/hour)	$2,000 (20 hours at $100/hour)

Sources: AIA, USGBC, Coursera, EdX, Lorman Education Services.

Beyond the direct costs of training and software, professionals need time for preparing documents for the code compliance review processes, and - if the project's WBLCA does not show compliance with the code- designing solutions for reducing the embodied carbon of the building. Among the project team, architects and engineering staff will lead this effort. In Oregon, the average hourly rate for an architect and engineer is $66/hour and $48/hour respectively, not including overhead costs.[102] No project-level data points related to the costs of this additional time could be found, however it is expected that project teams will spend less time doing these activities as they become more familiar with the WBLCA process and level of ambition required to comply with the code requirements.

6.8.4 Costs to Professionals Using the Compliance Option Including Building Reuse

Project teams pursuing the building reuse compliance option incur labor costs associated with time spent assessing the existing building, identifying which elements of the existing building can be retained for reuse, and producing the appropriate project documentation for compliance. Architects and structural engineers would collaborate on the strategy to achieve code compliance and then work with the project contractor to coordinate the construction strategies for preserving the building. No project-level data points related to the costs of staff time could be found, however because each existing building is unique the time investment for each project will vary. Table 6-22 outlines hourly rates for AEC professionals in Oregon:

Table 6-22: Average hourly rates for architecture, engineering, and construction professionals in Oregon

	Architect	Engineer	Construction Professional
Average hourly rate in Oregon (not including overhead)	$66	$50	$25

Source: Data retrieved from ZipRecruiter.com on September 25, 2024.

[102] Zip Recruiter Architect Salary in Oregon, accessed September 25th, 2024 https://www.ziprecruiter.com/Salaries/Architect-Salary--in-Oregon

6.9 Analysis of Specific Cost Accounting

Whether pursuing the prescriptive, performance, or building reuse pathways, it is possible to achieve the embodied carbon reduction requirements without impacting the overall cost of construction. Studies indicate that embodied carbon reductions of around 30% can be achieved without any upfront "green premium."[103] Embodied carbon limits set by code jurisdictions typically fall well within this scale of ambition. For instance, most large building projects will be able to achieve a code requirement that sets GWP limits at industry average for specific materials like concrete and steel, or a 10% reduction in building-level embodied carbon from a baseline with little or no added costs to the overall construction budget.[104]

The key ingredients to achieving this include a focus on embodied carbon early in a project's timeline and the ability to leverage data from EPDs or WBLCAs to inform design and material choices. There is a cost risk if project teams do not prioritize embodied carbon and plan ahead to assess compliance. Some of the cost risks include making decisions too late in the design process, looking at embodied carbon reduction strategies in a vacuum, and not leaving sufficient time to select low-embodied carbon materials and collaborate with manufacturers. These cost risks exist for the prescriptive and performance pathways outlined in this report. For the building reuse pathway, the financial risk is mainly around unforeseen challenges of repurposing an existing building, including hazardous materials, damage during demolition or deconstruction, challenges meeting code compliance, and more. These risks are inherent to any building reuse project and are not directly associated with the code option itself.

To understand the cost implications of achieving lower embodied carbon, project teams analyze both cost and carbon intensity of building designs or materials. A cost budget is a primary criterion for building design and is therefore already well understood by practitioners. Similarly, having an embodied carbon budget or goal at the outset of the project, such as meeting specific code requirements, enables project teams to strategize appropriately and alleviate financial risk. With a set goal, building professionals will discover where low costs and low embodied carbon intersect, and make appropriate judgment calls to meet both cost and emissions requirements.

6.9.1 Balancing Cost and Carbon Performance

Ideally, operational and embodied carbon emissions are both prioritized and addressed in building cost analysis to achieve the maximum cost-to-value ratio over the lifespan of a building. Most practitioners today have experience balancing project budgets with operational carbon reduction goals. Adding embodied carbon to the mix is new to many professionals across the US, while others have already expertly integrated it into their cost valuation processes. Balancing the upfront costs and future paybacks of operational carbon with initial and future

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[103] Urban Land Institute, *Embodied Carbon in Building Materials for Real Estate,* Urban Land Institute, https://knowledge.uli.org/-/media/files/research-reports/2019/greenprint-embodied-carbon-report-final.pdf?rev=00b6e53d7ff94f53bd55c3f57ee1352c&hash=7D5F88EB02E2FF2C8106349322B9075C, Ryan Zizzo and Kelly Doran, *Regulating Embodied Emissions of Buildings: Insights for Ontatrio's Municipal Governments*, August 2022 https://drive.google.com/file/d/1VD7RvQdLg7PWAUF2N97Q0-PAhes-k80Z/view.

[104] Tracy Huynh, Chris Magwood, Victor Olgyay, Laurie Kerr, and Wes Sullens, *Driving Action on Embodied Carbon in Buildings*, RMI and U.S. Green Building Council (USGBC), 2023, https://rmi.org/insight/driving-action-on-embodied-carbon-in-buildings/, and Matt Jungclaus et al., *Reducing Embodied Carbon in Buildings: Low-Cost, High-Value Opportunities*, RMI, 2021, http://www.rmi.org/insight/reducing-embodied-carbon-in-buildings.

embodied carbon emissions and cost impacts are two of the many factors project teams must consider in context rather than in a vacuum. Cost or emissions savings made in one area can offset additional costs or emissions in another.

Project teams utilize different types of economic analyses at multiple points in the design and construction process to track project budgets. These cost analyses become more detailed as the project progresses from concept to reality, and they may focus on first costs only or estimate the total life cycle cost. Additional cost analysis is not always needed to achieve cost-effective low embodied carbon performance. For instance, using low embodied carbon concrete can be a cost-neutral strategy with significant reductions in embodied carbon and does not require added cost analysis beyond what is already routine.

Teams designing large, complex projects may choose to utilize Life Cycle Costs Analysis and Whole Building LCA in tandem to help maximize cost-effective carbon reductions. Life Cycle Cost Analysis (LCCA) is an economic analysis tool that evaluates the total cost of ownership of a building over its lifespan. While LCCAs are useful for evaluating and comparing design options to determine the lowest cost over the building's life cycle, LCCA only provides insight into part of the puzzle when balancing costs and operational and embodied carbon performance. Project teams can utilize Whole Building Life Cycle assessments (WBLCA) to assess carbon impacts from cost-effective material and design choices. Using both LCCA and WBLCA for complex projects utilizing multiple embodied carbon reduction strategies will provide a more complete picture of cost and carbon performance.

6.9.2 Incremental Costs of Construction Related to the Prescriptive Approach (GWP limits for building materials)

Low-embodied carbon materials are not inherently different from high-embodied-carbon materials. Like all building products, low carbon materials will have specifications, limits, and supply chain dependencies that differentiate them from their competitors. There is no correlation between a material's cost, performance, or durability and embodied carbon.[105] Case studies have shown that reductions of embodied carbon from 20- 46% are possible with less than 1% cost premium, simply by selecting lower-embodied carbon materials.[106]

Material GWP limits in existing US regulation aims to eliminate the worst performing products and incrementally raise the floor for environmental performance by industry. Code requirements that set emissions limits based on industry average values, GSA values, EC3 "achievable" values, or CLF baseline values, as recommended in this report, should avoid the higher cost premiums associated with ultra-low embodied carbon steel and concrete products.

On the one-year anniversary of the GSA's Buy Clean program, the GSA noted that construction material manufacturers are offering low embodied carbon materials at little or no cost premium compared to their conventional equivalents.[107] Other studies show that, anecdotally, low-carbon

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[105] Tracy Huynh, Chris Magwood, Victor Olgyay, Laurie Kerr, and Wes Sullens, *Driving Action on Embodied Carbon in Buildings*, RMI and U.S. Green Building Council (USGBC), 2023, https://rmi.org/insight/driving-action-on-embodied-carbon-in-buildings/.

[106] Matt Jungclaus et al., *Reducing Embodied Carbon in Buildings: Low-Cost, High-Value Opportunities*, RMI, 2021, http://www.rmi.org/insight/reducing-embodied-carbon-in-buildings.

[107] U.S General Services Administration, "Biden-Harris Administration officials tout federal progress on spurring clean construction materials as part of Investing in America agenda," GSA, May 16, 2024, accessed September

materials that comply with existing policies are found to be cost-neutral.[108] A literature review of case-studies and reports on the incremental cost of specific materials is summarized in table 6-23 below:

Table 6-23: Summary of anecdotal evidence on incremental cost of low embodied carbon materials

Material	Incremental Cost
Concrete / Cement	● Over 55% of 130 businesses said their low-embodied carbon products cost about the same as their conventional products.[109] ● A Massachusetts supplier indicated a small cost premium for low-carbon concrete of $2-$20 per cubic yard.[110] ● Skanska Construction procured lower embodied carbon concrete at a cost negligible to the overall cost of large projects in the Puget Sound region.[111]
Steel	● Case studies of buildings in the Pacific Northwest indicate that sourcing rebar and structural steel with higher recycled content can achieve a 1-10% reduction from industry average at less than 1% cost premium of the total project budget[112]
Aluminum	No data found in literature
Wood	No data found in literature
Glass	● GSA procured American-made low carbon glass at a price that was competitive with pricing for conventional glass[113]

20th, 2024, https://www.gsa.gov/about-us/newsroom/news-releases/bidenharris-administration-officials-tout-federal-05162024.

108 Urban Land Institute, *Embodied Carbon in Building Materials for Real Estate,* Urban Land Institute, https://knowledge.uli.org/-/media/files/research-reports/2019/greenprint-embodied-carbon-report-final.pdf?rev=00b6e53d7ff94f53bd55c3f57ee1352c&hash=7D5F88EB02E2FF2C8106349322B9075C.

109 US General Services Administration, "GSA Lightens the Environmental Footprint of its Building Materials," GSA, March 30, 2022, accessed September 23, 2023, https://www.gsa.gov/about-us/newsroom/news-releases/gsa-lightens-the-environmental-footprint-of-its-building-materials-03302022

110 Rebecca Esau, Audrey Rempher, "Low-Carbon COncrete in the Northeastern United States," RMI, June 27, 2022, accessed August 9, 2024, https://rmi.org/low-carbon-concrete-in-the-northeastern-united-states/

111 Rebecca Esau, John Matson, "The Building Industry Takes Aim at "This Whole Other Chunk" of Emissions", *RMI*, March 21 2022, accessed August 9, 2024, https://rmi.org/the-building-industry-takes-aim-at-emissions/.

112 Matt Jungclaus et al., *Reducing Embodied Carbon in Buildings: Low-Cost, High-Value Opportunities*, RMI, 2021, http://www.rmi.org/insight/reducing-embodied-carbon-in-buildings.

113 U.S. General Services Administration, "Update on progress and lessons learned from the first year of our IRA LEC program," GSA, June 25, 2024, accessed September 20th, 2024, https://www.gsa.gov/real-estate/gsa-properties/inflation-reduction-act/lec-program-details/program-updates.

Board & Foam Insulation	• Insulation with the lowest carbon footprint was found to have lower or equivalent costs compared to conventional insulation.[114]

Source: RMI

Tracking accurate, up to date, and regionally specific cost data on low-carbon materials is difficult due to frequent cost fluctuations in the supply chain and inflation. No data on specific costs of materials in Oregon were found in the literature review, however this does not imply that there are no products on the market that are low carbon and cost-effective. Regulatory agencies assessing the cost of materials to include in code requirements can reach out to local suppliers directly for cost information.

6.9.3 Incremental Costs Related to the Performance Approach (WBLCA)

Building code including the performance approach requires embodied carbon measurement and reductions demonstrated through a WBLCA. To achieve this requirement, building professionals can deploy a broad number of embodied carbon reduction strategies, from selecting lower embodied carbon materials, to sourcing local materials, to designing for structural efficiency. These strategies can be mixed and matched to balance costs and emissions. Wins in one area can offset additional costs and or emissions in another.

This balancing act can increase design staff hours, especially for inexperienced firms, however the amount of time and overall cost is minimal compared to other tasks and requirements for large building projects over 100,000 square feet. Architecture, engineering, and construction firms that work on projects of this scale are typically larger enterprises with sufficient staff capacity and resources to provide adequate design services to achieve embodied carbon goals, produce WBLCAs, and coordinate the appropriate stakeholders. The American Institute of Architects California estimates that conducting a WBLCA increases an architect’s professional service fee by $10,000 - $15,000 per project, which equates to a less than 0.07% cost increase for large projects.[115]

Often solutions for lowering embodied carbon will inherently lower building material and construction costs, leading to overall project savings that outweigh additional design fees. Something as simple as prioritizing local materials can save costs and emissions arising from long-distance transportation. Right-sizing spaces, maximizing material efficiency, and eliminating unnecessary finishes will reduce the quantity of material required and therefore reduce costs and embodied carbon. Optimizing structural systems, which includes simplifying structural design to reduce the number of unique components and connections, can reduce both

[114] Chris Magwood et al., *Achieving Real Net-Zero Emission Homes: Embodied Carbon Scenario Analysis of the Upper Tiers of Performance in the 2020 Canadian National Building Code*, 2021, https://www.buildersforclimateaction.org/report---nrcan-study.html.

[115] California Department of General Services, Building Standards Commission, “Economic and Fiscal Impact Statement (Form 399), Attachment C- CCRC regulations 54day, Amend the 2022 California Green Building Standards Code, CCR, Title 24, Part 11,” Department of General Services, March 2, 2023, https://www.dgs.ca.gov/-/media/Divisions/BSC/03-Rulemaking/2022-Intervening-Cycle/Public-Comments/GREEN-45-Day/BSC/BSC-04-22-399-PT11-Attachment-C-R1-45day.pdf?la=en&hash=E1121CBF2FEA6D07492DCD1E962D8AA1AFC43618.

the carbon footprint and overall costs of a project.[116] Several project teams in Massachusetts' 2024 Embodied Carbon Reduction Challenge noted cost savings when employing mass timber construction, a material with high cost premiums, due to savings resulting from a number of factors, including faster construction and eliminating the need for ceiling and wall finishes by leaving the timber material exposed.[117]

These solutions and more could be used by a given project seeking to achieve code compliance. Project teams utilizing WBLCA during the design process will be able to identify the building elements that make the largest contribution to a project's embodied carbon emissions and determine cost-effective solutions to achieving the level of reductions required in code. Depending on where emissions thresholds are set in the code requirement, it is likely that most projects will find low cost emissions reduction solutions that comply.

6.9.4 Incremental Costs of Construction Related to Building Reuse

Reusing an existing building's structural system, which can comprise up to 80% of a building's embodied carbon, can avoid spending on new steel, concrete, and other structural materials while saving a significant amount of embodied carbon.[118] A study published by the California Green Building Standards Commision for CALGreen's 2022 embodied carbon requirements determines that the building reuse compliance option, which requires a building reuse project to maintain at least 45% of the existing building's structural elements and enclosure, would not have a significant increase in project costs and may have a reduction in costs through material conservation.[119]

6.9.5 The Social Cost of Carbon

According to Oregon's Department of Energy (ODOE), the social cost of carbon (SCC) is a measurement of the long-term economic costs associated with emitting an additional ton of carbon dioxide. A 2020 report by ODOE lists a high-end estimate for the SCC in 2025 at $175 per ton of CO2. The SCC can be used to evaluate the costs and benefits of implementing a low embodied carbon policy by comparing the cost of one unit of carbon dioxide emissions to the cost of emissions savings and/or expenditure of a specific project or policy. If a policy to prevent one ton of emissions costs less than the SCC, then the benefits of the policy outweigh the costs. There is no current Oregon policy that employs the SCC, however it can inform or be part of future policy decisions related to reducing the climate impact of buildings.

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[116] Ian Poole, *Rationalisation Versus Optimization- Getting the Balance Right in Changing Times*, iStructE, October 2020, https://www.istructe.org/IStructE/media/Public/TSE-Archive/2020/Rationalisation-versus-optimisation-getting-the-balance-right-in-changing-times.pdf.

[117] Built Environment Plus, "Project Details for the Embodied Carbon Reduction Challenge," accessed July 26, 2024, https://builtenvironmentplus.org/embodied-carbon-reduction-challenge-peoples-choice/.

[118] Urban Land Institute, *Embodied Carbon in Building Materials for Real Estate,* Urban Land Institute, https://knowledge.uli.org/-/media/files/research-reports/2019/greenprint-embodied-carbon-report-final.pdf?rev=00b6e53d7ff94f53bd55c3f57ee1352c&hash=7D5F88EB02E2FF2C8106349322B9075C.

[119] California Department of General Services, Building Standards Commission, "Economic and Fiscal Impact Statement (Form 399), Attachment C- CCRC regulations 54day, Amend the 2022 California Green Building Standards Code, CCR, Title 24, Part 11," Department of General Services, March 2, 2023, https://www.dgs.ca.gov/-/media/Divisions/BSC/03-Rulemaking/2022-Intervening-Cycle/Public-Comments/GREEN-45-Day/BSC/BSC-04-22-399-PT11-Attachment-C-R1-45day.pdf?la=en&hash=E1121CBF2FEA6D07492DCD1E962D8AA1AFC43618.

Theoretical examples of calculating the SCC in low embodied carbon construction show significant savings can be achieved from small reductions:

> Example 1:
>
> A 100,000 sq ft building has an embodied carbon intensity of 4,167 kgCO2e/sq ft[120], totalling 416,700,000 kgCO2e or 416,700 tons of CO2e. The project team reduces the building's embodied carbon intensity by 10%, saving 41,670 tons of CO2e. At the rate of $175 per ton, these savings represent $7,292,250 in SCC savings (41,670 x $175).
>
> Example 2:
>
> A 50,000 sq ft building with a concrete and steel structural system uses approximately 468,000 kg (468 metric tons) of steel reinforcing bar (rebar), which has an average embodied carbon intensity of 854 kgCO2e per 1 metric ton.[121] The project team procures rebar with an embodied carbon intensity of 435 kg CO2e per 1 metric ton (a nearly 50% decrease from industry average) from an Oregon steel manufacturer,[122] saving a total of 196,092 kgCO2e or 196.1 tons of CO2e. At a rate of $175 per ton, the carbon savings represent approximately $34,316 of social costs.

The federal government began using the SCC in 2008 in federal rulemaking, including regulatory impact analysis and environmental impact statements, to evaluate the costs and benefits with changes in emissions.[123] In 2013, the federal General Services Administration (GSA) approved a resolution to incorporate the SCC, including operational and embodied carbon in buildings, into all federal real estate investment, building design, construction, retrofit, and location decisions.[124] How the GSA does this or plans to do this remains unclear, however two existing life cycle cost analysis (LCCA) software used by the GSA have been identified as candidates for incorporating the SCC, including the National Institute of Standards and Technology's (NIST) Building Life Cycle Cost (BLCC) and Building for Environmental and Economic Sustainability (BEES).[125] OneClick LCA, a popular building life cycle assessment tool, includes an option for calculating the social cost of carbon alongside the carbon impact of a

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[120] Benke, B., Roberts, M., Shen, Y., Carlisle, S., Chafart, M., and Simonen, K. (2024). *The California Carbon Report: An Analysis of the Embodied and Operational Carbon Impacts of 30 Buildings*. Carbon Leadership Forum, University of Washington. Seattle, WA, http://hdl.handle.net/1773/51287.

[121] Concrete Reinforcing Steel Institute, *Environmental Product Declaration for Fabricated Steel Reinforcement*, September 20 2022, https://www.crsi.org/wp-content/uploads/CRSI_Industry-Wide_EPD_Sep2022.pdf

[122] Cascade Steel, *Environmental Product Declaration for Reinforcing Bar, ASTM A615, A706, A1035*, January 2022, https://buildingtransparency.org/ec3/epds/ec36n7fu

[123] Oregon Department of Energy, *Primer on the Social Cost of Carbon*, 2020, https://www.oregon.gov/energy/energy-oregon/Documents/2020-Social-Cost-of-Carbon-Primer.pdf

[124] US General Services Administration, "Advice Letters and Resolutions," accessed August 7, 2024, https://www.gsa.gov/governmentwide-initiatives/federal-highperformance-green-buildings/policy/green-building-advisory-committee/advice-letters-and-resolutions

[125] Ken Sandler, "Follow Up Discussion: Social Cost of Carbon," 2015, accessed August 7, 2024, https://www.gsa.gov/system/files/Social_Cost_of_Carbon_10-28-15_GBAC.pdf and US GSA, "GSA Green Building Advisory Committee (GBAC) FY2024 Topic Selection Meeting," 2023, accessed August 7, 2024: https://www.gsa.gov/system/files/12_7%20GBAC%20Topic%20Selection%20Meeting%20Notes.pdf?_gl=1*c7lfci*_ga*Mzc2NTcyODE2LjE3MjMwNDE5MTU.*_ga_HBYXWFP794*MTcyMzA0MTkxNS4xLjEuMTcyMzA0MjMwMC4wLjAuMA.

building design.[126] The results (in $) are displayed beside the building's carbon impact in terms of Tons of CO2e and kg CO2e/m2/year.

Oregon became the first state to establish a price on carbon through the 1997 House Bill 3283, which required new fossil fuel plants to meet a carbon dioxide emissions standard set by the Energy Facility Siting Council.[127] New facilities must offset or pay for each ton of emissions above the standard, set at 17% below the most efficient natural gas-fired facility operating in the US, however the state's price on carbon does not reflect social costs.[128]

A number of states employ the SCC to evaluate investments and policies related to environmental, transportation, or energy rulemaking, electricity regulation, natural resource valuation, and setting carbon caps or taxes.[129] Some of the earliest policy examples include Washington State Executive Order 14-00 (2014), which requires the state's agencies to account for the SCC when considering costs and benefits of energy efficiency improvements, and a 2015 mandate for Maine's Public Utility Commission to use the SCC to calculate the value of distributed solar energy resources.[130] While these are not directly related to building policy, New York and California have passed legislation to establish a SCC for use by state agencies, which could include investment decisions related to state-owned real estate.[131]

Beyond the GSA's resolution to incorporate the SCC, no other embodied carbon policies in the US currently require its incorporation, however it may be considered more often as the industry gains more awareness around its inclusion in embodied carbon emissions assessments.

6.10 Geographic Differences and Impacts on Urban and Rural Communities

6.10.1 Economic and Population Differences Across Oregon

Oregon's communities and regional economies differ substantially between Willamette Valley and other portions of the state (Figure 6-5). Willamette Valley tends to have higher population densities, more construction, and more economic activity than Oregon's other regions.

All ten counties in Willamette Valley are among the top 12 most populous in the state.[132] Among these, Polk county has seen an increase in population of 18% between the years 2010 and

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[126] Shaun Masson, "Deciding the Social Cost of Carbon," 2022, accessed August 7, 2024, https://oneclicklca.zendesk.com/hc/en-us/articles/360016978860-Deciding-the-Social-Cost-of-Carbon

[127] Oregon Department of Energy, *Primer on the Social Cost of Carbon*, 2020, https://www.oregon.gov/energy/energy-oregon/Documents/2020-Social-Cost-of-Carbon-Primer.pdf

[128] Oregon Department of Energy, *Primer on the Social Cost of Carbon*, 2020, https://www.oregon.gov/energy/energy-oregon/Documents/2020-Social-Cost-of-Carbon-Primer.pdf

[129] Cost of Carbon, "States Using the SC-GHG." accessed August 7, 2024, https://costofcarbon.org/states

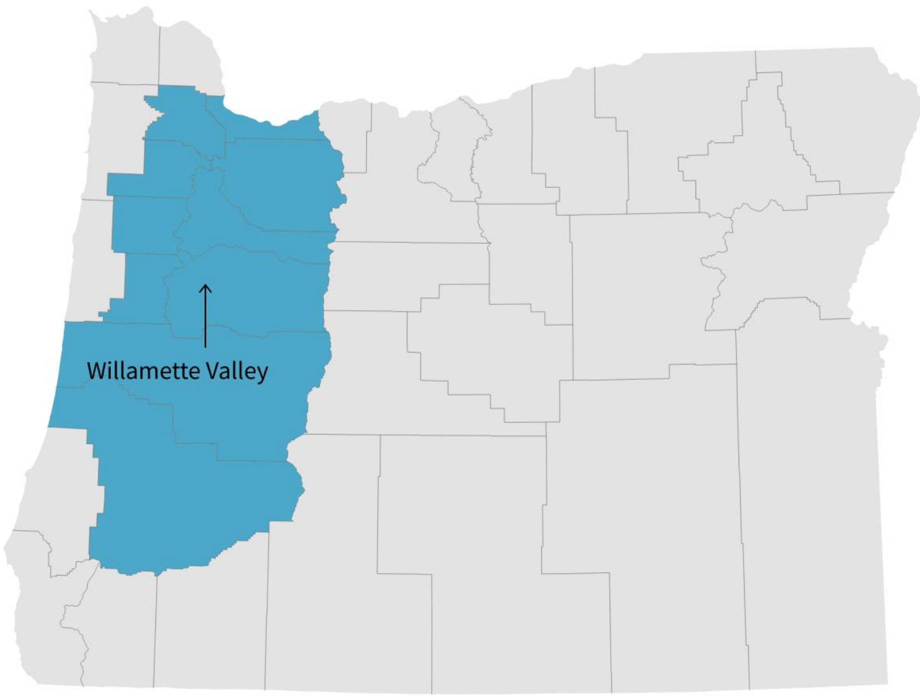
[130] Oregon Department of Energy, *Primer on the Social Cost of Carbon*, 2020, https://www.oregon.gov/energy/energy-oregon/Documents/2020-Social-Cost-of-Carbon-Primer.pdf

[131] Oregon Department of Energy, *Primer on the Social Cost of Carbon*, 2020, https://www.oregon.gov/energy/energy-oregon/Documents/2020-Social-Cost-of-Carbon-Primer.pdf

[132] Oregon Secretary of State, "Oregon Blue Book, County Populations," State of Oregon, accessed August 28, 2024, State of Oregon: Blue Book - County Populations.

2022. Other counties that have seen the highest increases in population include Crook county (21%), Clatsop county (12%), and Lincoln county (11%), all of which are located outside of Willamette Valley.[133] Population growth can indicate a surge in building activity, from new home construction and roadways to schools and commercial centers, and an associated increase in emissions directly resulting from these activities.

Figure 6-5: Counties in Willamette Valley, Oregon.



Source: RMI

Willamette Valley counties make up 80% of the top ten counties in Oregon with the highest number of construction jobs, whereas 100% of the ten counties with the fewest number of construction jobs are located outside of Willamette Valley.[134] Construction wages vary across the state, with the lowest average weekly wage estimated at $720 in Wheeler County (outside of Willamette Valley) to $1,715 in Washington County (in Willamette Valley).[135] Weekly construction wages in Willamette Valley range from $898 to $1,715, with 80% of counties

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[133] Oregon Secretary of State, "Oregon Blue Book, County Populations," State of Oregon, accessed August 28, 2024, State of Oregon: Blue Book - County Populations.

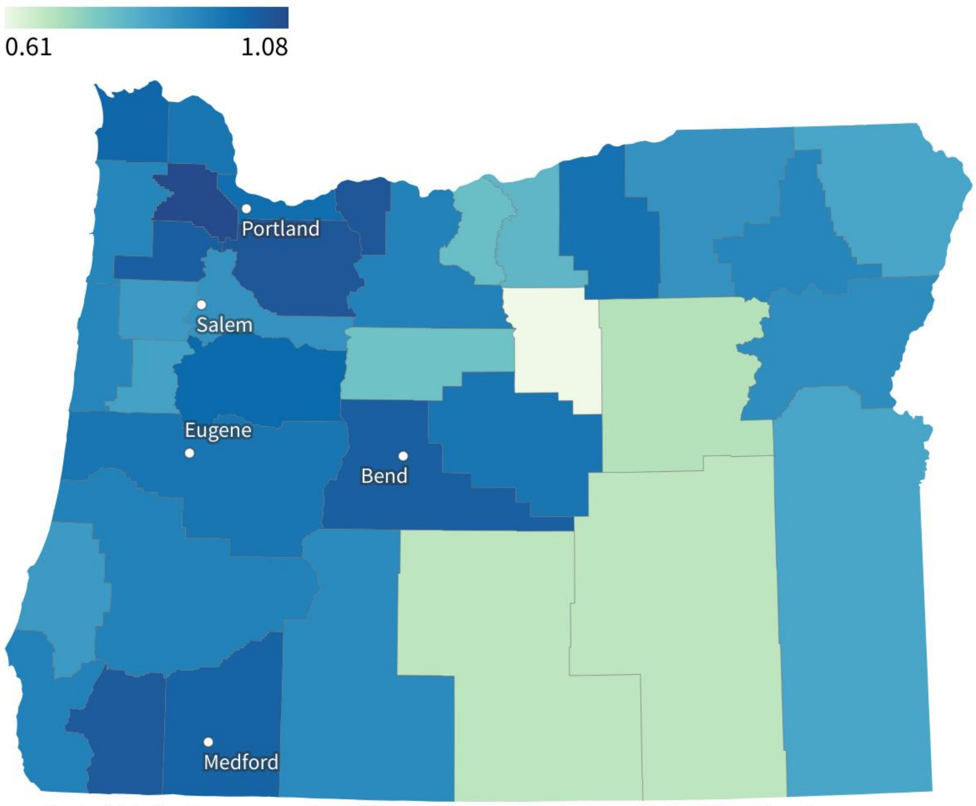
[134] Bureau of Labor Statistics, "Quarterly Census of Employment and Wages, Employment and Wages Data Viewer," accessed August 28, 2024, Private, 1012 Construction, All Counties in Oregon 2023 Fourth Quarter, All establishment sizes Source: Quarterly Census of Employment and Wages - Bureau of Labor Statistics (bls.gov).

[135] Bureau of Labor Statistics, "Quarterly Census of Employment and Wages, Employment and Wages Data Viewer," accessed August 28, 2024, Private, 1012 Construction, All Counties in Oregon 2023 Fourth Quarter, All establishment sizes Source: Quarterly Census of Employment and Wages - Bureau of Labor Statistics (bls.gov).

paying above $1000. Weekly construction wages in counties outside of Willamette Valley range from $720 to $1,510, with only 38% of counties paying above $1000.[136]

Figure 6-6 illustrates Oregon's construction employment location quotient (the proportion of all jobs which are in construction in a given area as compared to the US average proportion) across all counties. Counties in the Willamette Valley tend to have slightly higher employment location quotients for construction (ranging from 0.85 to 1.08). Oregon's eastern counties tend to have lower quotients (ranging from 0.61 to 1.04). On average, Willamette Valley tends to have higher construction employment and higher wages than Oregon's other regions, and Oregon as a whole has slightly lower construction employment concentrations than the US on average.

Figure 6-6: Construction employment quotient (proportion of all jobs which are construction-sector jobs, compared to the US average) in Oregon's counties.



A quotient of 1 indicates a proportion of jobs in construction in line with the US national average.

Source: RMI, data retrieved from Bureau of Labor Statistics on September 24, 2024

Counties with higher construction employment quotients, such as those in the Willamette Valley and the western portion of Oregon generally, are likely to have more training and support infrastructure to help workers transition to any new building practices required by code updates

[136] Bureau of Labor Statistics, "Quarterly Census of Employment and Wages, Employment and Wages Data Viewer," accessed August 28, 2024, Private, 1012 Construction, All Counties in Oregon 2023 Fourth Quarter, All establishment sizes Source: Quarterly Census of Employment and Wages - Bureau of Labor Statistics (bls.gov).

which address embodied carbon. Counties with especially low construction employment quotients, such as Lake (0.68), Harney(0.68), and Grant(0.69), may have less training and support infrastructure to help workers transition to new building practices.

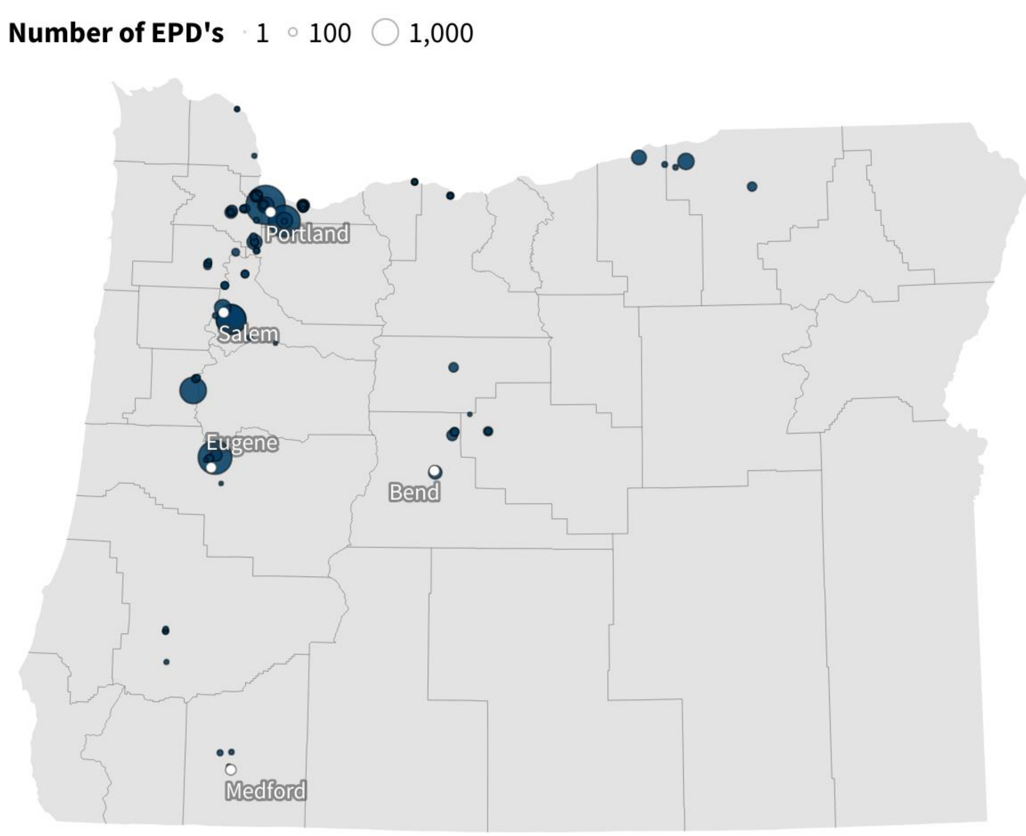
6.10.2 Building Size Differences Across Oregon

Anecdotally, Oregon's large construction projects (greater than 100,000 square feet of internal floor area) are concentrated in Willamette Valley. Fewer such projects are likely to be built outside of Willamette Valley in the coming decade due to the less urbanized nature of these counties. As such, code updates to reduce embodied carbon in large buildings will likely primarily affect projects in the Willamette Valley.

6.10.3 Differences in Material Manufacturing and Availability in Oregon

Most of Oregon's building material manufacturers are located along the I-5 and I-84 corridors with a majority in the Willamette Valley. About half a dozen manufacturers are located in central Oregon near Bend, and none are located in southeastern Oregon. The large majority of building material manufacturers who have published Environmental Product Declarations in the EC3 database are located in Willamette Valley (Figure 6-7).

Figure 6-7: Building product manufacturers in Oregon scaled by the number of EPDs each has published in the EC3 database.



Source: RMI, data courtesy of Building Transparency's EC3 database.

Table 6-24 describes the number of product-specific EPDs from Oregon based manufacturers for various construction materials, the number of manufacturers producing these materials in either Willamette Valley or outside of Willamette Valley, and the percent of manufacturers with EPDs for their products. The data reveals a few key points on the availability of products in the state:

1. Less than three manufacturers of steel reinforcement, structural steel, glass, and insulation are located in Oregon state and some of these manufacturers do not currently offer EPDs for their products. It is likely that many of these materials used in building projects are procured from outside of Oregon state.
2. More EPDs are available for ready-mix concrete than any other product. This may be attributed to the fact that ready-mix manufacturers offer a large variety of mix designs and procure EPD's for each of these. EPD creation software tools such as Climate Earth make creating EPD's for ready-mix designs cost-effective and fast. Other material manufacturers may have a smaller total number of products on offer due to the nature of other construction materials. EPDs for nearly all materials are more popular in Willamette Valley, with higher percentages of manufacturers producing EPDs for their products. This could be due to demand from increased building activity in Willamette Valley as compared with elsewhere in the state.
3. Teams with construction projects in remote areas, such as southeastern Oregon, have fewer options when it comes to sourcing industrially produced materials locally, and even fewer options when it comes to sourcing local materials with EPDs. It is likely that these projects incur higher transportation costs due to sourcing materials from longer distances as compared to projects located in the Willamette Valley.
4. Ready-mix concrete, which is brought as a wet mix to the construction site, is a highly local material, with limited travel time allowed between ready-mix plant to the construction site. Ready-mix concrete is readily available in Willamette Valley, but fewer ready-mix concrete plants serve a larger region of Oregon outside of Willamette Valley. Building projects located in areas outside of the reach of ready-mix plants are likely to use other products that can be transported long distances, such as pre-cast concrete or concrete masonry units (cinder block).

Table 6-24: Distribution of Oregon manufacturers and EPDs for various construction products

Product	Number of product-specific EPDs from Oregon based manufacturers available in EC3	Number of manufacturers located in Willamette Valley	Percent of manufacturers located in Willamette Valley with product EPDs	Number of manufacturers located outside of Willamette Valley	Percent of manufacturers located outside of Willamette Valley with product EPDs

Asphalt	314	9	66%	4	75%
Ready-mix Concrete	7,508	46	95%	20	80%
Steel Reinforcement bar (Rebar)	2	3	33%	0	0%
Structural steel	2	2	100%	0	0%
Flat Glass (for windows)	0	1	0%	0	0%
Wood products	7	2	100%	6	33%
Insulation	8	1	100%	0	0%

Source: Embodied Carbon in Construction Calculator (EC3), https://buildingtransparency.org/ec3, accessed August 8, 2024

6.10.4 Impacts of Code-Based Measures to Reduce Embodied Carbon in Oregon's Rural Counties

Code-based measures to reduce embodied carbon in Oregon could affect Oregon's rural communities differently than those in Willamette valley. Table 6-25 summarizes these differences.

Table 6-25: Potential differences in impacts associated with code-based embodied carbon mitigation measures in Willamette Valley vs. other counties in Oregon.

	Differences between Willamette Valley and Other Oregon Counties	Comments or Proposed Adjustments to Code Measures

Prescriptive Approach: GWP limits for materials	Most of Oregon's building material manufacturing and import hubs are in Willamette Valley. As Figure 6-7 shows, Willamette Valley is also home to most of Oregon's building product manufacturers who have already published an EPD in the EC3 database. Projects outside of Willamette Valley are challenged when it comes to procuring local materials and may pay higher costs for transportation of materials to the job site compared to their urban counterparts. Prescriptive GWP limits for materials reduces the number of options for complying products available to project teams, which may further increase material transportation costs for building projects outside of Willamette valley in cases where materials must be sourced from more distant qualifying manufacturers rather than closer, non-complying alternatives. Emissions associated with long transport distances could also, in theory, offset gains associated with switching to lower carbon alternatives.	The prescriptive approach could include exemptions for individual materials that are unavailable within reasonable distance to a project's location (would be different for each material). The exemption may permit the local manufacturer to submit an industry-wide EPD in lieu of a product-specific EPD for the first 1 or 2 years of the program, or alternatively require a low EPD submission threshold that still has to be met (such as EPDs submitted for materials representing 10% of the project cost, or similar language). Funding and support for manufacturers to decarbonize production and to create EPD's should prioritize manufacturers in or near underserved rural communities, and those who have not yet published an EPD.

Performance Approach: Whole building LCA	Whole building LCA's (WBLCA's) have fixed costs and labor inputs which are incurred regardless of the size and budget of the building project. Willamette Valley tends to build a higher proportion of large buildings as compared with other counties in Oregon. Larger buildings tend to have larger budgets, where the scale of fixed costs related to WBLCA compared to the overall budget is very small. As budgets get smaller, the fixed cost for WBLCA gets proportionally bigger. In regions with fewer projects with larger budgets, the cost of WBLCA can seem like a greater burden than in areas with many large budget projects.	The proposed minimum project size of 100,000 square feet for the performance approach to reduce embodied carbon mitigates the cost impacts associated with compliance for smaller buildings in all regions across the State.
Building or material reuse	More urbanized areas such as the Willamette valley tend to have greater construction and demolition activity, higher landfilling costs, higher storage costs, and lower transportation costs than more rural ones. These factors could impact businesses and communities complying with building and material reuse ordinances, however the full extent of these potential impacts is unclear. A recent building material reuse project in Boulder, Colorado illustrates the benefits of city involvement in facilitating deconstruction, storage, and construction of large buildings using reused elements. Oregon's smaller municipalities may have fewer resources to support such large projects. Building and material reuse on smaller projects	No adjustments proposed.

	may pose fewer logistical challenges. Portland, Oregon's downtown has one of the highest office vacancy rates of US cities at roughly 30% in Q4 2024. Conversion of this office space into residential units could help to address Oregon's housing shortage.	

Source: RMI

7 Non-code-based Analysis

Oregon Executive Order No. 17-20 (EO 17-20) aims to cut greenhouse gas emissions and boost energy efficiency by setting standards for energy performance, supporting low-carbon technologies, and promoting sustainable design practices. The law also introduces incentives for green infrastructure, renewable energy, and climate resilience, while modifying existing commissions and expanding responsibilities for environmental and health agencies.

A key focus is on reducing embodied carbon in the building sector, which is essential for sustainability and equity. Oregon's approach includes leveraging financial incentives, tax rebates, and innovations to create a comprehensive policy framework. This framework integrates non-code-based strategies like public procurement policies, circular economy practices, and data collection to lower the carbon footprint and support an inclusive building industry.

By emphasizing detailed data requirements, enforcement, and pilot programs, the policy aims to set clear objectives and metrics for success, positioning Oregon as a leader in sustainable construction. The goal is to demonstrate the feasibility and benefits of reducing embodied carbon and establish a model for other states to follow, ultimately fostering a more sustainable, resilient, and equitable built environment.

This section outlines non-code strategies that may support the state in reducing its overall embodied carbon. The following options are presented with the intent to complement the code-based efforts described in the previous section and may be used as independent, standalone strategies, or in tandem:

- Collect data for more accurate benchmarking
- Encourage change through public procurement
- Advance circular economy: deconstruction, disassembly, and material reuse
- Promote design and construction best practices
- Build out materials-based policy ecosystems
- Financially reward high achievers

7.1 Collect Data for Accurate Benchmarking and Tracking Progress

Collecting comprehensive data on embodied carbon is crucial for establishing benchmarks and tracking progress. Section 6.6 describes the ways that data can be thoroughly and seamlessly tracked to support code definition and refinement over time. It also outlines what a data collection program and database might look like for the state in a codes-based context.

There are also ways that non-code-based programs can support and supplement these parallel efforts taking place for codes. These include encouraging voluntary submissions, welcoming information about high-achieving projects, and conducting regular benchmarking studies. These activities and others are detailed below as well as in several subsequent sections of this chapter.

Finally, these activities are presented with the assumption that they will add on to – rather than act in lieu of – code-based efforts that ask for mandatory reporting from projects that are subject to new adopted code provisions.

Objective: To collect comprehensive data on embodied carbon, establish benchmarks, and track progress in reducing greenhouse gas emissions from building materials.

7.1.1 Pathways for Implementation

1. **State-Owned Buildings Assessment:** Develop a methodology for assessing the embodied carbon emissions associated with the construction, operation, and end-of-life of state-owned buildings. Conduct assessments in phases and utilize a centralized database for planning and setting reduction targets. Oversee capital projects involving major renovations or new constructions; from these observations, develop sustainable design guidelines considering life cycle impacts and provide technical expertise to state agencies.

2. **Voluntary Submissions:** Enhance data collection through voluntary contributions and invite private projects to voluntarily submit embodied carbon data. Offer financial

rewards, such as grants and tax credits, for early adopters and high-performing projects that utilize innovative low-carbon materials. The CLF offers a model for this in setting up a repository for California projects to submit WBLCA data as they work to adhere with the new CALGreen requirements.

3. **Benchmarking Studies:** Conduct regular studies to evaluate progress in reducing embodied carbon at the state level. Use these findings to inform policy updates and set new targets. This data can also feed into establishing GWP limits for buildings, systems, and materials. Other steps following these benchmarking studies may include:

4. **Data Harmonization:** Work with federal and local agencies to harmonize data collection methods and reporting standards.

5. **Shared Learning and Best Practices:** Leverage a centralized repository for data and best practices, providing a resource for low-carbon design and construction. These lessons may focus on the practices associated with particular industries or building systems, such as mechanical and structural, and can synergize with industry commitments around embodied carbon like MEP2040, SE2050, and AIA2030.

7.1.2 Potential Cost Impacts to Collecting Data for More Accurate Benchmarking

The costs to professionals required to report embodied carbon data for all construction projects is comparable to the costs for reporting data through WBLCAs and EPDs outlined in the prescriptive and performance code approaches. For more information, refer to section 6.8 *Potential Cost Impacts of Code Approaches.*

Local jurisdictions and the state government will incur costs associated with a data collection program, including upkeep and creation of data collection software that can be integrated with the code enforcement process, maintaining a centralized database where data can be stored and accessed by various government officials, and labor and training costs for government staff. These data will help streamline any benchmarking studies embarked upon by government agencies, which in themselves cost time and money.

No fiscal impact data for a data collection program such as described was identified for this report, likely due to the lack of existing precedents for such programs. Cost data on Oregon's consumption-based inventory (CBEI) may act as a rough proxy for such efforts. The original CBEI required staff time of about 0.4 FTE over a period of 24 months and $80,000 in contractor time, subsequent updates to the model require approximately 200-300 hours and $2,200 in data purchases, and customization for local governments typically require around 30-40 hours of staff time.[137]

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[137] The Environmental Council of the States, "Sustainable Materials Management Project Inventory: Consumption-Based Greenhouse Gas Emissions Inventory," accessed September 25, 2024, https://www.ecos.org/smm-projects/consumption-based-greenhouse-gas-emissions-inventory/.

7.2 Encourage Change Through Public Procurement

By implementing low embodied carbon requirements for publicly-funded state projects like government buildings, public works, and infrastructure projects, Oregon can set precedents and drive market transformation. By leveraging existing initiatives such as EO 17-20 and the government procurement efforts led by the Department of Administrative Services (DAS), Oregon can establish guidelines, pilot programs, and financial incentives to encourage the use of low-carbon materials and construction practices. These policies will ensure that public projects lead the way in sustainable building practices, demonstrating the feasibility and benefits of reducing embodied carbon.

Objective: To integrate low embodied carbon requirements into public funding that set a clear standard for sustainability in state procurement and encourage broader market adoption.

7.2.1 Pathways for Implementation

1. **Executive Orders and Legislation:** By implementing low embodied carbon requirements in publicly funded state projects, Oregon can drive market transformation and set a leading example for sustainable construction. Oregon's HB 3409 directs the Oregon Department of Administrative Services (DAS), in cooperation with the State Department of Energy (ODOE), to "implement a comprehensive assessment of energy use and greenhouse gas emissions of state-owned buildings." The data collected from this effort will inform strategies to reduce the greenhouse gas emissions that result from capital projects. DAS is directed to develop and implement guidelines that "take into account the building's life cycle and the life cycle of all the building's systems, components, materials, operations and maintenance."

   DAS also has a statewide sustainable purchasing policy that directs state agencies to integrate sustainability and best practices into their purchasing decisions whenever possible. This includes prioritizing products with low embodied carbon and other environmental health impacts by asking for the submission of EPDs and specifying low-embodied carbon materials in specific projects.

   DAS can build on these efforts by setting statewide GWP limits for materials used in public building projects or for building projects as a whole. Sections 3.1 and 6.1 describe how existing Buy Clean throughout the country programs have done this; these may provide a model for this type of effort.

2. **Pilot Programs:** Pilot programs can provide a tangible demonstration of the feasibility and benefits of low embodied carbon practices, helping to build industry confidence in these practices as well as requirements that may emerge from parallel code efforts. The data collected from pilot projects can also inform the development of guidelines, standards, and policies, ensuring that they are grounded in real-world experience. Successful pilot programs can also spur healthy competition and stimulate market interest and investment in low-carbon materials and technologies, accelerating the transition to more sustainable building practices. One sample pilot program may showcase low carbon concrete in a small-scale public building, to serve as a demonstration of the material's performance, cost-effectiveness, and environmental

benefits. Another pilot may test other low embodied carbon materials, such as recycled steel or engineered wood, in public projects to assess their viability and performance compared to traditional materials.

3. **Guidelines and Standards:** Develop comprehensive guidelines and standards for embodied carbon reduction in public projects. This program could function as an embodied carbon program similar to the State Energy Efficient Design Process (SEED) program run by the Oregon Department of Energy (ODOE). Other program examples include those in Austin and Los Angeles, described in Chapter 3, which have successfully integrated these practices. This type of initiative would require the following steps:
    a. **Baseline Data Collection:** Gather and analyze current GHG emissions data from existing state projects to establish a baseline. Require the submission of EPDs and generation of WBLCAs for municipal projects to inform future GWP limits that are ambitious but achievable.
    b. **GWP Limits:** Set GWP thresholds for different building types and/or construction materials based on the collected data and best practices from leading sustainable construction programs.
4. **Incentives:** Provide financial incentives, such as grants or tax rebates, for publicly funded projects that surpass the embodied carbon standards set for procurement projects. Develop a scoring system to prioritize funding and procurement for projects and materials that demonstrate substantial reductions in embodied carbon. This could be done for statewide materials purchasing or by setting certain building standards that bidders must meet. At minimum, bidders would be required to meet specific low-carbon sourcing criteria to be eligible for public funding. Offering financial and technical assistance to suppliers to support the development and scaling of low-carbon solutions will make meeting these requirements more feasible. At minimum, procurement policies should include consideration of structural materials as well as of the building envelope, including insulation, aluminum, glass, and cladding. Consider additional interior elements for which EPDs are available, such as interior finishes (ceiling tiles, gypsum board, and flooring), cabling, and mechanical equipment. Project teams that go above and beyond the base requirements should be rewarded through prioritization.

7.2.2 Methodology for Quantifying Greenhouse Gas Emissions

7.2.2.1 Option 1

To assess the GHG reductions of public procurement, baseline and reduction scenarios can be created using a similar methodology as the prescriptive code approach outlined in Chapter 6. Utilizing data on the breakdown of materials by building use and size, a baseline scenario can be set with a material embodied carbon intensity (ECIb); the reduction scenario will adjust the ECIr of the materials.

<u>Sample equation for concrete (C), steel (S), and asphalt (A)</u>

GHG Reductions of a Public Procurement = Baseline Scenario – Reduction Scenario

*Baseline Scenario = CECIb * CMQ + SECIb * SMQ + AECIb * AMQ*

*Reduction Scenario = CECIr * CMQ + SECIr * SMQ + AECIr * AMQ*

*xMQ = BTGA * MVF*

7.2.2.2 Option 2

If information about the quantity of materials impacted by public procurement policy is available, use that procurement data to set a benchmark of yearly purchased quantities and a material GWP limit.

Sample equation for concrete (C), steel (S), and asphalt (A)

*GHG Reductions of a Public Procurement = (C_GWPb – C_GWPr)*C_Procurement + (S_GWPb – S_GWPr)*S_Procurement + (A_GWPb – A_GWPr)*A_Procurement +*

Where;

X_GWPb = Current GWP value for a material

X_GWPr = Lower carbon GWP set by policy

7.2.3 Potential Cost Impacts to Encouraging Change Through Public Procurement

Like the prescriptive approach outlined in the Code-Based Analysis section, public procurement policies involve verification through product-specific Type III Environmental Product Declarations (EPDs) that disclose the carbon intensity of individual building products and materials. The costs associated with sourcing and installing materials with EPDs that comply with the set Global Warming Potential limit of the policy are the same as those outlined in section 6.8.2: *Costs Impacts to Professionals Using the Prescriptive Approach*. The largest cost impact falls on manufacturers needing to generate EPDs for their products in order to compete for bids on state-owned projects and comply with the procurement policy.

Offering grants or tax rebates for projects exceeding embodied carbon standards can alleviate the cost of generating EPDs and motivate manufacturers to further reduce the emissions associated with their products.

Material manufacturers are required to meet global warming potential (GWP) thresholds set by public procurement policies. Initially, these thresholds are set at reasonable levels to eliminate the worst performing products on the market, however they may increase over time to encourage more holistic industry decarbonization. Implementing decarbonization strategies for materials like concrete and steel, the two primary building materials with the largest carbon footprint (11% and 10% of total global emissions respectively), involves a range of costs for manufacturers, from quick, low-cost solutions to significant capital investment.[138]

- **Concrete:** Manufacturers can reduce embodied carbon in concrete through a broad range of strategies and technology. The most cost-effective strategy is to substitute cement- the main binder used in concrete- with supplementary cementitious materials

[138] Architecture 2030, “Actions For A Zero Carbon Build Environment: Embodied Carbon,” accessed September 25, 2024, https://www.architecture2030.org/embodied-carbon-actions/.

(SCMs), such as fly ash, ground glass, natural pozzolans, and blast furnace slag. SCMs are waste and by-product materials that are cost competitive in most instances. Substituting cement with SCMs can deliver up to 80% emissions reductions for a given concrete mix design.[139] The price of SCMs vary regionally, with most costs incurred through transportation. As a result, SCMs can be cheaper than cement in locations close to a source.[140] In some cases, concrete containing SCMs can be produced without added costs beyond the capital costs associated with storing the SCM at the ready-mix plant. Other sources indicate an increase in production costs by 10% to 30%.[141]

- **Steel:** Steelmaking is a mix of primary manufacturing (from ore) and recycling. In primary steelmaking, iron ore is processed using an integrated blast furnace/basic oxygen furnace (BF/BOF) system that relies on high-temperature combustion of fossil fuels. In secondary steelmaking (recycling), an Electric Arc Furnace (EAF) is used to melt existing steel and recycle it into a new steel product. According to a 2023 scientific study, steel products from a typical US BF-BOF facility have an average carbon emission intensity of 1,990 kg/MT CO2e and cost an average of $439/MT to produce, whereas steel from US EAF facilities have an average carbon emissions intensity of 270 kg/MT CO2e and cost an average of $365/MT to produce.[142] For the average materials-based policy, complying steel products will typically come from EAF facilities that can maximize the ratio of recycled steel content in its products. The carbon footprint of these products can be further reduced if the EAF facility utilizes renewable electricity from hydroelectric, renewable hydrogen, solar, or wind sources. EAF facilities that run on 100% renewable energy are 8% to 13% more expensive to operate than BF/BOF facilities but can reduce emissions by up to 90-95%.[143]

7.3 Advance Circular Economy: Deconstruction, Disassembly, and Material Reuse

Promoting the careful dismantling of buildings for material reuse can substantially reduce waste and embodied carbon. It can also have a significant health impact by reducing exposure to hazardous substances embedded in buildings, such as lead and asbestos.

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[139] Charles Cannon, Valentina Guido, and Lachlan Wright, *Concrete Solutions Guide: Actionable Solutions to Lower the Embodied Carbon of Concrete*, RMI, 2021, https://rmi.org/our-work/concrete-solutions-guide/.
[140] West Coast Climate & Materials Management Forum, "About Supplementary Cementitious Materials," accessed August 9, 2024, https://westcoastclimateforum.com/cfpt/concrete/aboutscm
[141] Charles Cannon, Valentina Guido, and Lachlan Wright, *Concrete Solutions Guide: Actionable Solutions to Lower the Embodied Carbon of Concrete*, RMI, 2021, https://rmi.org/our-work/concrete-solutions-guide/.
[142] Guiyan Zang, Pingping Sun, Amgad Elgowainy, et al., Cost and life cycle analysis for deep CO2 emissions reduction of steelmaking: Blast furnace-basic oxygen furnace and electric arc furnace technologies, International Journal of Greenhouse Gas Control, Volume 128, September 2023, https://www.sciencedirect.com/science/article/abs/pii/S1750583623001287#:~:text=A%20typical%20U.S.%20BF%2DBOF,decarbonization%20technologies%20and%20energy%20prices.
[143] World Economic Forum (WEF). "Net-Zero Industry Tracker." Accessed September 2024. https://www3.weforum.org/docs/WEF_Net_Zero_Tracker_2023_REPORT.pdf.

To lead in advancing the circular economy, Oregon may consider building on city-level deconstruction ordinances such as the City of Portland's, increasing funding, and establishing Material Innovation Centers. This strategy may include mandating deconstruction on public projects, providing contractor training, and launching public awareness campaigns. Collaboration with cities with successful models and tracking material flows can enhance the effectiveness of these initiatives, fostering local employment and sustainable practices.

Objective: Advance the circular economy by emphasizing the careful dismantling of buildings to increase the availability of salvage materials, thereby reducing waste and embodied carbon associated with new building materials.

7.3.1 Pathways for Implementation

1. **Deconstruction Ordinances:** Mandate deconstruction for public projects and incentivize deconstruction activities for private projects. This will involve tracking salvaged materials and mandating material reuse for public projects. Through energy and emissions assessments, DAS could assess the energy use and greenhouse gas emissions of state-owned buildings, using existing data and contractor services as needed. DAS could also develop and implement criteria and guidelines for sustainable design in state capital projects, focusing on life cycle considerations and incorporating data from various sources.
2. **Funding and Training:** Increase funding for deconstruction initiatives and provide training for contractors. Partner with local organizations to develop workforce development programs focused on deconstruction and material reuse. Produce metrics to measure the growing number of trained contractors as well as reused materials. Partner with local organizations for program implementation.
3. **Material Innovation Centers:** Establish participating centers to manage salvaged materials, including storage, quality confirmation, and resale. Use successful models from cities like San Antonio and Los Angeles as a guide. Develop a searchable database to store and analyze data from state agency assessments, aiding in planning and setting reduction targets for energy use and emissions.
4. **Public Awareness Campaigns:** Launch public awareness campaigns to highlight the benefits of deconstruction and material reuse. Engage with stakeholders through workshops and seminars to promote best practices and develop engagement metrics from these campaigns to track public participation and awareness.

7.3.2 Methodology for Quantifying Greenhouse Gas Emissions

To quantify the GHG reductions from promoting a circular economy, data from a representative sample of deconstruction and reuse projects and on landfill methane emissions can be utilized. The methodology considers three primary components: embodied carbon savings (ECR), emissions associated with deconstruction and transportation (DTE), and landfill methane savings (LMER).

<u>Sample equation:</u>

GHG Reductions of a Circular Economy = ECR - DTE + LMER

Where:

*ECR = Embodied Carbon Reduction = ((ECB - (QMS * ECMS)) * QF * REF)*

*DTE = Deconstruction and Transportation Emissions = (EDC + ETC + EPC) * EF*

*LMER = Landfill Methane Emissions Reduction = WM * LFM * GWP of CH4*

Variables;

QMS = Quantity of Material Salvaged (kg or m^2)

ECB = Embodied Carbon of Building (kg CO2e)

ECMS = Embodied Carbon of Material Salvaged (kg CO2e/kg or m^2)

EDC = Energy for Deconstruction (btu)

ETC = Energy for Transportation (btu)

EPC = Energy for Processing (btu)

EF = Emission Factor (kg CO2e/btu)

LFM = Landfill Methane Emission Factor (kg CH4/ton)

WM = Waste Material Diverted from Landfill (tons)

QF = Quality Factor, reflects the potential reduction in embodied carbon due to material quality improvement through processing

REF = Reuse Efficiency Factor, reflects the percentage of salvages material reused

Note: The Global Warming Potential (GWP) of CH4 is a conversion factor to equate methane emissions to CO2 equivalent emissions.

7.3.3 Potential Cost Impacts to Advancing Circular Economy

Deconstruction is the methodical process of dismantling the building to maximize the reuse potential of the materials and divert waste from the landfill. Deconstruction has a higher upfront cost compared to traditional building demolition, however it can be more economical than demolition if the value of materials salvaged and tax breaks received through their donation is more than the cost of labor and time spent dismantling the building.

The economic benefit of deconstruction with material recovery over traditional demolition and disposal is generally determined by several factors:

- The **value of the materials** recovered,
- The **cost of disposal**,
- The **cost of transporting** the materials, and
- The **cost of the additional labor** for material recovery

Salvaging materials through deconstruction not only reduces the environmental impact of materials that would otherwise end up in a landfill, but also reduces the tax burden on local communities for landfill upkeep, the potential increases to landfill disposal costs, and the potential need to ship materials elsewhere when landfills become too full.

The deconstruction process is much more intricate than a standard demolition job and will require additional time, labor, and therefore cost, to complete. Although the upfront cost of a demolition project might be far less than the cost of hiring a deconstruction team, the items recovered during deconstruction are often appraised at tens of thousands of dollars or more in value.[144] Once salvaged, these materials can be donated to a local material reuse center and are eligible for a Federal tax deduction. The value of the tax savings from the donation of appraised materials often results in a lower overall cost as compared to demolition.

Table 7-1: Average project and cost differences for deconstruction versus demolition of a typical home

	Deconstruction	Demolition
Typical project time (for 1400 ft^2 home)	10 - 15 business days	2 business days
Typical crew size (for 1400 ft^2 home)	6 - 8	2 - 3
Estimated total labor hours (for 1400 ft^2 home)	480 - 960	32 - 48
Salvaged materials appraisal cost (general flat fee estimate)	$ 2,500	$ 0
Physical lowering of house, disposal of debris, including salvaged materials appraisal cost - Estimated cost (per square foot)	$ 16.83	$ 7.26
Appraised Material Donation Value per Square Foot	$ 45.44	$ 0

Sources: Portland State University Report – The Economics of Residential Building Deconstruction in Portland, OR ; The ReUse People

Note that deconstruction and demolition costs as well as appraisal values will vary based on the location, age, style, and condition of the house, the type of construction and materials used, landfill rates and other factors.

Table 7-2 below exhibits an example based on a compilation of nationwide projects, comparing a typical home demolition to a deconstruction project with appraised donation of salvaged materials. The example assumes a 2,400 ft^2 house with a two-car attached garage, asphalt shingle roof, wood siding, drywall, raised foundation, single-pane wood windows and tongue and groove hardwood floors.

Table 7-2: Example cost breakdown for the deconstruction and demolition of a 2,400 st ft home:

	Deconstruction	Demolition
Physical lowering of house and disposal of debris	$28,000	$8,000
Removal of concrete and hardscape	$5,000	$5,000
Appraisal of salvaged materials *	$2,500	$0

[144] The ReUse People, "Residential Deconstruction," accessed on September 25th, 2024, https://thereusepeople.org/residential-deconstruction/

Total costs	*$36,300*	*$13,000*
Appraised donation value **	$100,000	$0
Tax savings (after-tax value of donated materials) ***	$35,000	$0
Total after-tax cost (total costs less after-tax value of donated materials):	***$ 1,300***	***$13,000***

** Appraisal costs may be deductible on Schedule A of IRS Form 1040.*
*** Total materials to be salvaged (lumber, cabinets, plumbing and electrical fixtures, doors, windows, etc.) would*
generally appraise at $87,500 to $120,000 in good reusable condition.
**** Assuming a combined federal and state tax bracket of 35% and an approximate appraisal-estimate average of $100,000, the after-tax cash value is $35,000.*
Source: The ReUse People

Deconstruction and disassembly require a different skill set than traditional demolition. Training programs for deconstruction focus on methods for carefully dismantling structures so that materials can be preserved and reused. This includes learning about safe disassembly techniques, material sorting, and waste minimization.

Table 7-3: Programs available for deconstruction training:

Program/Workshop	Description	Cost
Build Reuse - Deconstruction Contractor Training	A textbook-based program offering foundational knowledge in building deconstruction.	From $100
Delta Institute - 24-Hour Deconstruction Course	A 24-hour training program for demolition workers, leading to a BMRA Designated Deconstruction credential.	From $450
The ReUse People (TRP) - Deconstruction Worker and Contractor Training	Comprehensive training including workshops, worker certification, and contractor training, covering various aspects of deconstruction.	From $1,000
Deconstruction Institute - Reuse Consulting	Provides a range of deconstruction training programs, including hands-on workshops and consulting services.	From $500

Source: RMI

7.4 Promote Design and Construction Best Practices

Code-based strategies can set the minimum regulatory floor of requirements for project teams to address embodied carbon. This can be done by mandating GWP reporting and WBLCA submission, setting embodied carbon reduction criteria, and incentivizing reuse. Non-code-based strategies build on this by illustrating how projects can go beyond these base baseline requirements. They can also demonstrate the ways that certain best practices can help project teams achieve standards set in code in efficient and cost-effective ways.

Promoting the sharing of resources and lessons learned, as well as building off of the momentum set by various industry commitments, can help to drive widespread adoption of sustainable practice, some of which may go beyond code.

Objective: Share resources and provide education to encourage the use of low-carbon materials, material efficiency, and sustainable construction practices that go beyond code.

7.4.1 Pathways for Implementation

1. **Systems-Level Assessments and Reporting:** Encourage evaluation of embodied carbon at the building systems level—including structural, envelope, interior, and mechanical, electrical, and plumbing (MEP) systems. Leverage industry commitments, such as MEP2040, SE2050, and AIA2030, to drive broader adoption of low-carbon technologies and practices. Develop standardized reporting frameworks and provide training to professionals on conducting and interpreting these assessments. Establish a searchable database for data collected to aid systems designers aiming to reduce their GWP. These efforts can ultimately help to set GWP limits for various building systems and materials.
2. **Highlight Material Efficiency:** Assessing embodied carbon at the building level brings light to one of the simplest and most cost-effective ways to reduce GWP: material efficiency through optimized design. Illuminating this strategy can push designers to consider the ways that their decisions can impact the overall impact of a project early on in the design process, before any procurement decisions are even made. This can be done by ensuring that the amount of materials called for in a project design are optimized for the intended structure and use. In practice, this might mean choosing modular and prefabricated construction; minimizing the overall volume of concrete in the building design; or avoiding the overspecification of concrete mix strength.
3. **Financial Incentives for Innovation:** These may include tax credits, tax deductions, or rebates to projects that incorporate innovative low-carbon materials and construction techniques. This option is described in further detail in a future option: *Financially Reward High Achievers.*
4. **Recognition Programs and Awards:** Partner with organizations such as Built Environment Plus and the Energy & Environmental Building Alliance (EEBA) to highlight and celebrate high-performing projects and professionals in embodied carbon reduction. Winners may be rewarded in the form of awards, certifications, funding for future projects, or public acknowledgment to enhance a project's reputation and provide marketing benefits. Public recognition can entail providing plaques, certificates, or digital badges that can be displayed on project sites and in promotional materials. Award-winning projects can also be featured in the media, case studies, industry reports, and through press releases to enhance visibility.

5. **Resource Sharing:** Create a centralized repository of case studies in best practices from which other product teams can glean insights into design practices, ease of implementation, lessons learned, and financial impacts.

7.4.2 Methodology for Quantifying Greenhouse Gas Emissions

To assess the GHG reductions of material efficiency, baseline and reduction scenarios will be created using a similar methodology as the materials-based code framework. Utilizing data on the breakdown of materials by building use and size, a baseline scenario can be set with material embodied carbon intensity (ECI). The reduction scenario will adjust the material quantity (xMQ).

<u>Sample equation for concrete (C), steel (S), and asphalt (A)</u>

GHG Reductions of a Public Procurement = Baseline Scenario – Reduction Scenario

*Baseline Scenario = CECI * CMQ + SECI * SMQ + AECI * AMQ*

*Reduction Scenario = CECI * CMQr + SECI * SMQr + AECI * AMQr*

*xMQ = BTGA * MVF*

*XMQr = BTGA * (MVF * % Reduction in Policy)*

7.4.3 Potential Cost Impacts to Promoting Design and Construction Best Practices

Building practitioners will use EPD and WBLCA tools and software to meet the global warming potential limits and reporting requirements set in this policy. Refer to section 6.8.2: *Costs Impacts to Professionals Using the Prescriptive Approach* and section 6.8.3: *Costs Impacts to Professionals Using the Performance Approach* for details on the costs associated with EPDs and WBLCAs.

Offering grants or tax rebates for projects exceeding embodied carbon standards can alleviate compliance costs and motivate project teams to utilize innovative low-carbon materials and construction techniques.

7.5 Financially Reward High Achievers

Oregon is poised to lead the charge in reducing embodied carbon and advancing sustainable building practices by implementing a comprehensive suite of financial incentives. These incentives are designed to drive meaningful changes in the construction industry by making sustainable choices more attractive and accessible. By offering targeted tax credits and grants for projects that surpass established embodied carbon standards, Oregon aligns financial benefits with environmental performance.

Objective: Provide financial rewards to encourage the adoption of low-carbon building practices.

7.5.1 Pathways for Implementation

1. **Tax Credits:** Tax credits and grants are powerful tools to incentivize the adoption of low-carbon building practices and drive significant reductions in embodied carbon. Offer tax credits and grants for projects that exceed embodied carbon standards. Implement a program similar to New Jersey AB 5223, which provides incentives for concrete producers and state-funded projects that overperform on embodied carbon metrics.

   Tax credits would reward projects that exceed requirements in code or use innovative low-carbon materials and strategies. Incentives can also be offered based on project performance, material use, or overall carbon reduction. These can lower costs for developers and promote the use of sustainable materials and techniques. In practice, this option may provide a percentage of the project cost as a tax credit to encourage higher investment in sustainable practices. Alternatively, tax deductions could be granted for expenses related to the procurement and use of low-carbon materials and technologies. Finally, fee waiving for zoning allowances and system developments could be awarded. These options can lower the overall cost for developers and property owners and render very low-carbon projects more achievable.

2. **Grants:** Provide financial support for construction, renovation, research, and pilot projects focused on low-carbon practices. This helps reduce financial barriers and stimulates innovation.

3. **Rebates:** These may be offered based on the actual performance of a building in reducing carbon emissions or energy use compared to established benchmarks. This ensures that incentives are tied to tangible outcomes

4. **Bid Incentives:** Implement bid discounts for projects that achieve substantial reductions in embodied carbon. For example, offer a percentage discount on project bids for those demonstrating use of low-carbon materials or innovative construction techniques that meet or exceed set carbon reduction targets. Define clear qualification criteria for these discounts, such as specific carbon reduction thresholds, use of certified low-carbon materials, or incorporation of advanced carbon capture technologies.

   a. **Performance-Based Tiers:** Establish a tiered incentive structure where higher levels of embodied carbon reduction are rewarded with greater bid advantages. For example, projects achieving over 20% carbon reduction might receive a larger discount than those achieving 10%.

   b. **Scoring System:** Develop a scoring system to evaluate and rank projects based on their carbon reduction achievements, with higher scores translating to more substantial bid incentives.

5. **Certification Programs:** Provide grants, tax credits, and recognition for projects using innovative low-carbon materials and techniques. Enhance existing green building certifications like LEED and Living Building Challenge by offering additional financial incentives for achieving these standards.

6. **Market the Incentives:** Partner with financial institutions, streamline application processes, and raise public awareness to maximize the impact of these incentives.

7.5.2 Potential Cost Impacts to Financially Rewarding High Achievers

Financial incentives can be a significant motivator for practitioners to not only meet the basic policy requirements but achieve an even greater level of embodied carbon reductions. Using the Social Cost of Carbon metric of $175 per ton of GHG emissions, the cost of financial incentives to state or local governments can be measured against the emissions reductions that each recipient achieves. It is helpful to keep in mind that multiple projects will be positively affected as each recipient will apply the new knowledge and insights they gained while pursuing the incentive to the future projects they work on.

7.6 Implementation and Enforcement

For non-code-based options, enforcement may be fulfilled through incentives.

Buy Clean California's focus on state-funded projects means that failure to comply with GWP thresholds leads to ineligibility for state contracts. Projects must provide accurate and complete documentation to pass the compliance checks. State agencies are required to review and verify that the submitted EPDs meet the established GWP thresholds. The California Department of General Services (DGS) oversees the collection and verification of these reports. Projects that do not comply with these requirements are ineligible for state contracts. Suppliers must demonstrate through their EPDs that their products do not exceed the GWP limits. If the GWP of a material exceeds the allowed threshold, it cannot be used in state-funded projects. State agencies may conduct on-site inspections and review documentation to verify that the materials used in construction projects adhere to the GWP limits. Non-compliance can result in penalties, project delays, or disqualification from future state contracts.

In addition, the Austin Green Building Program encourages sustainable design practices by awarding credits for strategies that reduce the embodied carbon of materials. The program uses a points-based rating system where buildings accumulate points based on sustainable practices, including those that reduce embodied carbon. Compliance is enforced by requiring that buildings meet specific thresholds to achieve certification at various levels (e.g., 1-star, 2-star, etc.). Buildings must submit detailed documentation demonstrating that they have implemented the necessary green building measures to achieve their desired rating level. Points are awarded for specific strategies and actions that meet the program's criteria, and the total points determine the building's overall rating. Legislative enforcement occurs by requiring that certain types of projects (e.g., city-funded or large-scale developments) meet a minimum rating level to receive approval. Builders and developers who achieve higher sustainability ratings under the program receive various benefits, such as expedited permitting processes, tax incentives, and increased marketability of their properties.

7.6.1 Recommendations

These examples showcase how incentives can promote best practices, innovation, and market transformation towards low-carbon building practices. These strategies may include setting specific GWP limits and utilizing standardized tools like EPDs to provide measurable benchmarks and transparency. Accountability is reinforced through economic incentives, such as bid discounts and credits, which directly link compliance to financial benefits. Additionally, enforcement encourages innovation by creating a regulatory environment that rewards the adoption of cutting-edge, low-carbon technologies. This, in turn, drives market transformation by making sustainability a key competitive factor in the construction industry.

7.7 Equity Considerations: All Non-Code Options

Language impacting labor practices, sourcing, financial structures or any larger-system goals cannot be clearly included in code language. Code Options are by the historic purpose of codes focused on health and safety protections. The inclusion of embodied carbon considerations in code is a step beyond safety within a building to societal safety, and the language of code supports this well, however, codes must also be applicable at the level of state oversight, and are often informed by international standards processes.

The established Equity Pillars that are used throughout this report are most powerful when applied with locational specificity, to inform HOW projects are implemented. What lens, what questions need to be asked to build equity? Provided below are some considerations for the state in informing non-code options that build on the main intent of embodied carbon reductions while expanding attention to equity issues.

7.7.1 Criminal Justice Reform and Police Accountability

A walkable and cohesive community, with access to services, homes, jobs, and amenities, can support wellness at all levels and is a powerful synergistic eco-system in reducing carbon. A focus on building reuse has the potential to increase and maintain town and city centers, increase local job access, and uplift a community Ensuring that industry transitions are supported by accessible trainings is vital, and thinking about how jobs can support living wages, families, and career-path clarity are all facets in a thriving life and healthy community.

Oregon can consider and support ordinances to encourage building reuse through feasibility studies tied to certain levels of developer investment in the community. Include community benefit organizations (CBO) and community voices in definition of project goals to ensure they truly support community needs. Any public procurements could include requirements for local labor, fair wages, and communications/ trainings in the languages of the local workforce, perhaps as part of preferential scoring for selection. With this attention to co-benefits, the focus will remain on the culture, style, resilience, and success of the local people.

7.7.2 Housing and Homelessness

We are faced with less of a need for commercial buildings, and an increasing need for healthy, affordable homes, especially affordable homes within access to jobs, needed services, and transportation options. Adaptive building reuse is an opportunity to re-activate downtown areas with housing while providing a dramatic avoidance of up-front carbon. Collection of data can inform the reach of policies and targeted investments for greatest gain, and adjusting zoning and focusing on community resources within 15-minute access to affordable housing or areas with the presence of many un-homed can build toward access, over time, to homes and improved health.

Oregon can consider adaptive reuse prioritization through ordinances as mentioned above. In order to protect against reuse that is only a profit engine, ensure the needs of the existing community are met with inclusion of CBO in the planning and implementation of these policies.

Although form-based zoning may be beyond the abilities of the state, clarifying the impact of moving away from use-based zoning in reducing carbon and in increasing access and equitable living, not tied to use of cars, can be impactful over time. Data collection that includes transportation and travel times between home/school/jobs can provide a more complete understanding of building reuse, housing, and non-use-based zoning benefits. Ensure that data collection efforts do not disproportionately burden small businesses and community organizations by providing support and resources for compliance. Provide outreach for data collection in the languages of the community. Make data publicly available to promote transparency and accountability, enabling communities to track progress and hold stakeholders accountable.

7.7.3 Economic Opportunity

In any transition of an industry there will be entities that can afford to make the changes and those that cannot. To ensure economic opportunities for all and a growth in diversity of local, minority-owned, and small businesses, any incentives should be directed to those traditionally underrepresented.

To build a focus on embodied carbon, Oregon can continue to implement policies that offer financial support of EPD generation and creation of education on how to source and use EPDs. Procurements at the state level can call for low-carbon materials and reporting and can also include fair-wages and local labor as a preference in selection to support local and state workforce while reducing embodied carbon. Reserve a portion of financial incentives for small developers and minority-owned businesses to promote inclusivity and diversity in the building sector.

Speed the development of the local salvage and reuse economy by prioritizing workforce development programs keyed to re-use that support local employment and focus on training and employing individuals from disadvantaged communities. Provide business development grants to start-ups to catalog, stock, and deliver salvaged building components and materials. Promote job opportunities within disadvantaged communities through targeted outreach and partnerships with local organizations. Promote local sourcing of materials to reduce transportation emissions and support local economies, particularly benefiting small and disadvantaged businesses. Encourage the use of recycled supplementary cementitious materials (SCMs) such as Ground Glass Pozzolans (GGP) to reduce carbon footprints and provide economic boosts to local industries.

7.7.4 Environmental Equity

Embodied carbon reductions have several levels of impact on environmental equity, and that equity is best achieved in policies and programs that support considerations of beneficial impact potentials beyond single buildings. An unfortunate impact of building reuse and of higher-quality building and development can often be displacement of the existing communities and culture, and measures must be taken to protect against displacement while improving economic vitality and healthy, beautiful buildings in those communities.

Prioritize projects that incorporate community resources and amenities by inclusion of Community Benefit Organizations and community voices in development incentive planning, to define those needs. Define “affordable” based on actual local mean income data, and an understanding of the neighborhood-level affordability needs, which can vary especially between rural and urban environments. This locally-specific definition can then be included when setting any development and housing unit goals. Ensure spaces and approaches to improve accessibility, such as multi-modal infrastructure and ADA paths, also link to larger and adjacent systems when creating policies for development, infill, or financial incentives such as tax abatement benefits. Reserve tax credits for local developers or developers including CBOs in planning. Set a policy for urban centers to focus on tree coverage, increase rainwater permeability, and improve access to green spaces, beginning with poorer and disenfranchised communities, to increase resilience of the communities and reduce Urban Heat Island burdens. Use zoning and planning processes to decrease car-focused space use and increase equity and access through public and multi-modal transit approaches.

7.7.5 Health Equity

Human Health is a community goal as well as a personal one. Although a focus on embodied carbon does not directly support individual health, it does support communal health through a reduction in GHG emissions and particulate emissions reductions at the manufacturing sites and transportation routes. Human health improvements can also be achieved when a focus on embodied carbon starts to lead us to less-processed, natural, and local products, also instigating reconnections to natural systems. This reconnection to nature can be fostered by non-code work such as zoning, or requirements for buildings to include sheltered outdoor areas which also support significant co-benefits in walkability and community resilience.

Without changing how EPDs are called for, non-code approaches can build on additional EPD information, such as manufacturing location and smog, to inform future procurement goals for the state. Ensure that any data collection on projects does not disproportionately burden small businesses and local communities and include incentives to support the transition.

Oregon can promote sourcing of materials from the region to reduce transportation emissions and increase potential for a regional and circular material system. Regional materials can also reinforce a culture and geographic vernacular of design. Encourage the use of local recycled supplementary cementitious materials (SCMs) to further reduce carbon footprints and build material circularity. Consider a preference in planning policies for bio-based materials in a building and the use of such materials in plazas and walkable areas between buildings, such as exposed mass-timber, wood floors, or wood pavilions and plaza/park furnishings.

7.7.6 Education Recovery

Often codes and policies are developed without a well-developed plan for the transition, including education of the workforce at all levels, and education/communication with the community itself. Oregon can seek to identify equitable ways to implement and educate to achieve faster traction in embodied carbon reductions

Workforce development is a significant factor in successful building reuse strategies and should be framed to reduce economic disparity. Create and fund a robust workforce development program informed by CBO, focused on reuse skills, salvage, and economic development of material reuse systems. Encouragement of start-up businesses can also be considered.

Partnering to create education with a BIPOC or woman-owned business, providing the education in places that provide daycare and easy transit access, and providing simple whole-food snacks are all ways to ensure better education access for development of needed skills. Also consider offering scholarships and financial support and hosting the education sessions in the impacted community. Conduct outreach to underrepresented groups to encourage participation in training programs and workshops.

In any state-funded reuse or new projects, include a requirement for living wage, training, or other labor-focused equity measures. Although many A+E firms are now familiar with EPDs, there is tremendous opportunity to accelerate the transition if professional organizations such as AIA (American Institute of Architects) and SEI (Structural Engineering Institute) require continuing education on carbon reduction as part of state licensure. The state could require proof of similar education in any public RFPs. Provide tailored support and resources for small businesses and minority-owned enterprises to help them comply with new requirements and adopt sustainable practices.

7.8 Geographic Differences and Impacts on Urban and Rural Communities for Non-Code-Based Approaches

For information on differences in construction, the built environment, and material manufacturing and availability, refer to section 6.10 *Geographic differences and impacts on urban and rural communities* in the Code-Based Analysis section of this report.

7.8.1 Impacts of Non-Code Based Measures to Reduce Embodied Carbon in Oregon's Rural Counties

Non-code based measures to reduce embodied carbon in Oregon could affect Oregon's rural communities differently than those in Willamette valley. Table 7-4 summarizes these differences.

Table 7-4: Potential differences in impacts associated with non-code-based embodied carbon mitigation measures in Willamette Valley vs. other counties in Oregon.

	Differences between Willamette Valley and Other Oregon Counties	Comments or Proposed Adjustments to Measures
Data & Benchmarking: Collect comprehensive data on embodied carbon to establish benchmarks and track progress.	The fixed costs of embodied carbon reporting comprise a greater proportion of total project costs for smaller projects. Smaller firms have fewer resources to devote to reporting.	Initial minimum building size limits (e.g. 100,000 square feet) can limit reporting burdens to projects most able to afford them. As the costs of LCA and EPD reporting decrease over time through

		automation, skills development, and streamlined data infrastructure, minimum project size limits could be reduced. Alternatively, the state could reimburse analysts for all LCA reporting costs on smaller projects until these costs fall enough to be more readily absorbed into building project budgets. Incentives should preferentially reward smaller and more rural AEC firms.
Public Procurement: Implement low embodied carbon requirements in publicly funded projects to set a precedent and drive market transformation.	Smaller and more rural local governments may have fewer resources to implement and enforce public procurement policies, pilot programs, and incentives. These programs could also result in higher associated construction costs for more rural regions due to increased transport distances from low embodied carbon manufacturers.	The state should provide preferential support (funding, training) for smaller and more rural municipalities to enact low embodied carbon public procurement policies, pilot programs, and incentives. Exemptions or greater compliance flexibility for projects that are unable to source low embodied carbon materials or products within a reasonable distance should be supported (the definition of “reasonable distance” should be defined per material category to reflect differences in typical transportation distances for each category).

Circular Economy (Deconstruction, Disassembly, and Material Reuse): Promote the careful dismantling of buildings to salvage materials for reuse, reducing waste and embodied carbon.	Smaller and more rural local governments may have fewer resources to implement and enforce building circularity ordinances and provide associated training, outreach, funding, and innovation support. Remote areas may not have the material volume needed to sustain a local material innovation center and may need to ship disassembled building products long distances to reach donation centers.	The state should provide preferential support (funding, training) for smaller and more rural municipalities to enact building circularity programs. Consider the location of material innovation centers to maximize volume and minimize material transportation distances. Locate material innovation centers in geographically distributed population centers or next to landfills where materials would otherwise go if they were demolished.
Design & Construction Best Practice: Encourage the use of low-carbon materials and efficient construction practices to reduce waste and embodied carbon	Building projects in rural areas have reduced access to low embodied carbon materials and may pay more to transport them longer distances to the job site compared to projects located in Willamette Valley. Forested and agricultural areas have potential to develop new economic opportunities from developing carbon-storing materials using agricultural waste or timber products. Best practice resources may bias towards larger and more urban projects, because these are most likely to be the first and most common projects to decarbonize.	Incentives should preferentially reward smaller and more rural building projects and AEC firms. Rural projects are at a disadvantage when it comes to sourcing industrially produced materials locally and may instead demonstrate embodied carbon reduction through alternative design strategies such as structural efficiency or building reuse. Demonstrating these gains through WBLCA should be encouraged and incentivised. Design & Construction Best Practices should reward the use of carbon-storing bio-based materials to help stimulate rural manufacturing economies.

		Resources should specifically incorporate perspectives and case studies from smaller and more rural projects and firms.
Material Policy Ecosystems: Introduce complementary policies to support embodied carbon reduction in construction materials.	Smaller building material manufacturers may have fewer resources to procure EPDs and invest in decarbonization technology. Small businesses are defined as fewer than 500 employees.	The state should provide preferential EPD funding and training support to small building material manufacturers, especially those located in or near underserved communities. Help small manufacturers secure funding to invest in decarbonization technology by setting up state led support programs or working with local industry associations.
Financial Incentives: Provide financial rewards to encourage the adoption of low-carbon building practices.	Smaller and more rural building projects are likely to have higher associated costs to decarbonize, due to fixed costs associated with decarbonization, increased transport distances to low embodied carbon material manufacturers, and fewer resources for smaller and more rural AEC firms.	State tax credits and grants should provide preferential support to small and rural building projects and manufacturers that decarbonize over and above requirements. Small projects can be defined as below the square footage threshold in the code requirement.

Source: RMI

8 Glossary of Terms

Term	Definition
Boundary conditions	*Used to define what is included in a life-cycle assessment (LCA) study. The most common boundary conditions are cradle to gate, cradle to site, and cradle to grave.*
Carbon dioxide equivalent (CO_2e)	*A measure used to compare the impact of various greenhouse gasses (GHGs) based on their global warming potential (GWP).* CO_2e *approximates the time-integrated warming effect of a unit mass of a given GHG relative to that of carbon dioxide* (CO_2)*. The following GWP values are used based on a 100-year time horizon: 1 for CO_2, 25 for methane (CH_4), and 298 for nitrous oxide (N_2O).*
Carbon footprint	*The total amount of greenhouse gas (GHG) emissions associated directly and indirectly with a product, building, individual, organization, or event. Carbon footprint is measured in the units of kg or tons of carbon dioxide equivalent* (CO_2e)*, commonly expressed as global warming potential (GWP).*
Carbon sequestration	*The process of capture and long-term storage of atmospheric carbon dioxide (CO_2) in durable, mineral form.*
Carbon storage	*The process of capturing and durably storing atmospheric carbon dioxide (CO_2) via photosynthesis in biomass (material of biological origin) materials.*
Cradle to gate	*A boundary condition associated with embodied carbon, carbon footprint, and life-cycle assessment (LCA) studies. The boundary includes all activities starting with the extraction of materials (the cradle), their transportation, and the manufacturing activities that get the material or product ready to leave the factory gate (life-cycle modules A1 through A3).*

Cradle to grave — *A boundary condition associated with embodied carbon, carbon footprint, and life-cycle assessment (LCA) studies. The boundary includes all activities starting with the extraction of materials (the cradle), their transportation, manufacturing activities, delivery, installation, use and maintenance, disassembly, and disposal (life-cycle modules A1 through C4).*

Diversity — *The honoring and including people of different backgrounds, identities, and experiences collectively and as individuals. It emphasizes the need for sharing power and increasing representation of communities that are systemically underrepresented and under-resourced. These differences are strengths that maximize the state's competitive advantage through innovation, effectiveness, and adaptability.*

Embodied carbon — *The greenhouse gas (GHG) emissions arising from the manufacturing, transportation, installation, maintenance, and disposal of products and materials.*

End-of-life carbon — *The greenhouse gas (GHG) emissions associated with deconstruction and demolition, transport from site, waste processing, and disposal phases of a building material's life cycle (life-cycle modules C1-C4).*

Environmental Product Declaration (EPD) — *The quantification of the environmental impacts of a product, throughout the product's life cycle, such as global warming potential, smog creation, ozone depletion and water pollution, in a single, comprehensive report. At a minimum, EPDs include cradle-to-gate stages (i.e., raw material extraction/supply, transport, and manufacturing), but can also cover a cradle-to-grave analysis, which includes transportation to a site, installation, use, maintenance and end of life (i.e., recycling or disposal. EPDs are governed by International Standard (ISO) 14025.*

Equity — *The acknowledgement that not all people, or all communities, are starting from the same place due to historic and current systems of oppression. Equity is the effort to provide different levels of support based on an individual's or group's needs in order to achieve fairness in outcomes. Equity actionably empowers communities most impacted by systemic*

	oppression and requires the redistribution of resources, power, and opportunity to those communities.
Global Warming Potential (GWP)	*An index for estimating the relative global warming contributions of GHG emissions expressed in kg* CO_2 *equivalent units (kg* CO_2e*), commonly referred to as a carbon footprint.*
Greenhouse Gas (GHG)	*Any gas that contributes to anthropogenic global warming including, but not limited to, carbon dioxide, methane, nitrous oxide, hydrofluorocarbons, perfluorocarbons, and sulfur hexafluoride.*
Inclusion	*A state of belonging when persons of different backgrounds, experiences, and identities are valued, integrated, and welcomed equitably as decision-makers, collaborators, and colleagues. Ultimately, inclusion is the environment that organizations create to allow these differences to thrive.*
Industry-wide EPD	*A disclosure of the environmental impacts of a range of individual products from a group of manufacturers. Industry-wide EPDs represent typical manufacturing impacts for a type of product but are not specific to any one individual product.*
Life-Cycle Assessment (LCA)	*A compilation and evaluation of the inputs, outputs, and the potential environmental impacts of a product system or whole building throughout its life cycle. This is consistent with the definition found in ISO 14044:2006.*
Life-Cycle Cost	*The total cost of acquiring, operating, supporting and (if applicable) disposing of the Product being acquired.*
Life-Cycle Costing	*An analysis method that quantifies Life-Cycle Costs, including the costs of acquiring, operating, supporting, and disposing of a product. The method may also include any additional costs*

	that relate to adverse impacts of a product, for example, impacts to the environment or public health.
Low Carbon Material	*Construction materials and products that have substantially lower levels of embodied greenhouse-gas emissions associated with all relevant stages of production, use, and disposal, as compared to estimated industry averages of similar materials or products.*
Operational carbon	*Includes the greenhouse gas (GHG) emissions associated with the operational use of the building. This includes all carbon from energy required to heat and power the building, including but not limited to lighting, plug loads, heating and cooling, and cooking.*
Product category rule (PCR)	*Defines the rules and requirements for developing Type III EPDs for a group of products that fulfill an equivalent function.*
Product-specific EPD	*A disclosure of the environmental impacts for a specific product and manufacturer across multiple facilities.*
Racial Equity	*Actions that close the gaps so that race can no longer predict any person's success, which simultaneously improves outcomes for all. To achieve racial equity, we must transform our institutions and structures to create systems that provide the infrastructure for communities to thrive equally. This commitment requires a paradigm shift on our path to recovery through the intentional integration of racial equity in every decision.*
Scope 1 emissions	*Direct greenhouse gas (GHG) emissions that occur from sources that are controlled or owned by the reporting organization.*
Scope 2 emissions	*Indirect greenhouse gas (GHG) emissions associated with the production of energy that a reporting organization purchases.*

Scope 3 emissions — *Indirect greenhouse gas (GHG) emissions associated with the reporting organization's value chain. These emissions are not produced by the company itself and are not the result of activities from assets owned or controlled by the reporting organization. Scope 3 emissions include all sources not within an organization's Scope 1 and 2 boundary.*

Social Cost of Carbon — *The dollar-value of climate change damages imposed by an additional ton of carbon dioxide (CO2) emissions or its equivalent.*

Third-party Sustainability Certification — *A transparent, research-based verification (e.g., ENERGY STAR) for a product or service by an accredited, independent organization that formally documents compliance with specific sustainability standards.*

Whole-building Life Cycle Analysis (WBLCA) — *An analysis of an entire building system and components, including inputs, outputs, and potential environmental impacts of a product or system over its lifetime, from initial extraction of raw materials through manufacture, distribution, use, and final disposal.*

Whole-life carbon — *Emissions from all life-cycle stages, encompassing both embodied and operational carbon together (i.e., modules A1 to C4, with module D reported separately).*