Embodied Carbon Policy Development in the Upper Midwest

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ABSTRACT

Embodied carbon considerations and requirements have been included in the Minnesota Sustainable Building Guidelines (B3) for over twenty years. Initially, the program focused on collecting whole building life cycle assessments to build a data set for determining future standards. As operational carbon emissions are approaching net zero by 2030, the carbon emissions from construction become more important. Therefore, the program is evolving to include a unique approach to embodied carbon that integrates whole building life cycle assessments in the predesign phase and collecting Environmental Product Declarations (EPDs) for concrete, steel, rebar, asphalt, and other materials during the construction phase. These materials must comply with embodied carbon limits anticipated between 2026-2028 as part of Minnesota's Buy Clean legislation, which applies to vertical (building) sector material procurement and horizontal (road and bridge) construction. The guidelines include input from government, universities, industry, and non-profit organizations. The process and outcomes can serve as a model for making the business case to scale up low embodied carbon construction in the Upper Midwest.

Introduction

The Minnesota Sustainable Building Guidelines (B3) (CSBR 2021) have included embodied carbon requirements for over twenty years. A life cycle assessment (LCA) is a methodology for quantifying a product's environmental impact over time. The International Standards Organization (ISO) has created procedures for developing LCAs. While several environmental indicators are included in LCA data, global warming potential (GWP) data is used to create environmental product declarations (EPDs). The use of EPDs as standardized reporting tools for disclosing the global warming potential (GWP) of construction materials is increasingly prevalent in public procurement policies for materials in construction projects. EPDs are already used by consumers in the building industry to assess environmental impacts, enabling policymakers to build and improve upon the existing standards (Graves 2022). Initially, the B3 program's approach was to collect assembly-level LCA data to prepare for setting requirements. However, the improvement and expansion of EPDs for materials in the building construction sector in the last ten years and increased knowledge and embodied carbon tools for design teams have allowed the guidelines to transition to integrating carbon reduction targets for projects. In addition, the Minnesota Legislature passed the "Buy Clean" bill in 2023 that will mandate the collection of EPDs and the setting of product GWP limits for concrete, asphalt, structural steel, reinforcing steel, and potentially other materials for state-constructed buildings and roads (Buy Clean Minnesota 2023). These requirements will roll out over the next eight years. While "Buy Clean" policies are helping to advance the use of EPDs and potentially embodied carbon codes like the Embodied Carbon Code published by the New Buildings Institute, this is only one aspect of a comprehensive set of tools and policies for significant embodied carbon reductions in the building sector. (New Buildings Institute, 2023).

An embodied carbon policy approach must integrate (1) Whole Building Life Cycle Assessment (wbLCA) to drive carbon reduction decision-making during project design, (2) procurement standards that collect EPDs and limit GWP of high-impact materials, and (3) prescriptive design guidelines that can achieve additional embodied carbon reductions. A whole building LCA is a tool to provide an assessment of the embodied carbon impact of a whole building. wbLCAs and EPDs are created from life cycle assessments, the functional units are different with EPDs focused on a product and wbLCA focused on a building. The intent of a wbLCA is to include the impact of all materials used in the buildings, or a part of the building like structure and envelope, throughout the life cycle of the building. Like energy modeling, architects, engineers, or their consultants should perform wbLCAs throughout the design process to actively inform the design of a building (CLF 2021*)*. wbLCAs can be challenging with a wide range of inputs and assumptions in the models. However, their use in the early stages of a project can help teams effectively evaluate alternative design choices. Early project design stages typically offer the best opportunity for significant reductions in embodied carbon, energy use and other environmental impacts, in large part due to decisions such as site selection, systems selection, and other key project choices that once set are often hard to change at later phases of design.

In addition to wbLCAs and EPDs or other procurement requirements, embodied carbon reductions can also be achieved with prescriptive guidelines. These types of guidelines fall into at least two categories. The first involves industry- or system-wide strategies that have documented impacts on carbon reduction. For example, designing with certain lower embodied carbon structural systems and minimizing use of rigid insulations and other high-impact materials result in significant savings and do not necessarily need to be documented with an extensive wbLCA on every project. wbLCAs can compare numerous possible combinations of materials or track nearly every product in a project, despite limited carbon impacts of some materials, and are often time-intensive and complex. Through running wbLCAs on template buildings and case study projects, documented high-impact strategies can be translated into prescriptive guidelines, which can be applied to new projects to achieve significant carbon reductions with much less time and analysis effort. The second category of prescriptive guidelines aims at addressing project decisions and impacts that are more difficult to quantify or are not captured by wbLCA, especially those relating to performance or construction methods that drive the design, which might drive up the project's carbon if not taken into consideration. For example, the decision to use a high-strength, fast-curing concrete mix on a parking garage may be driven by the construction schedule, not the structural performance, which would have resulted in a more carbon-intensive concrete, but with a slight change to the construction scheduling and sequencing would result in a substantial carbon savings that same structure would have had a lower impact. Identifying decision-drivers and areas of projects with carbon reduction potential through prescriptive guidelines can greatly impact whole project carbon reduction.

For embodied carbon to reach the same level of savings that the industry has achieved with operational carbon via energy modeling, all three of the tools discussed above - wbLCAs, EPDs, and prescriptive requirements - need to be integrated into a comprehensive embodied carbon policy.

Embodied Carbon: What is it? Why is it important?

The greenhouse gas emissions attributed to materials used in buildings and infrastructure are known as embodied carbon. Typically, the green building movement has focused on global greenhouse gas emissions from building operations (18.2%) or the building sector's impact on transportation (13.4%) (WRI 2023). However, the industrial sector emissions for materials used in construction are as much as 24.8%, which is also significant. In addition, if emissions are prioritized for their immediate impact on climate change, the embodied carbon associated with building materials and the construction process is even more critical.

When a building is built, it has already created a significant environmental impact due to the carbon emissions of material manufacturing, fabrication, transport, and the construction process. In addition, over the building's 50-to-80-year life, its systems will be renovated, maintained, and replaced. This increases the overall embodied carbon impact of the building and when combined with operational carbon, results in an increase in the total carbon footprint. Upfront embodied carbon emissions (Figure 1) from the initial construction could equate to 5-10 years of operational carbon for a standard (code-compliant) building, but for a high-performance or net zero building, upfront carbon could be comparable to 20-30 or even more years of operational carbon.

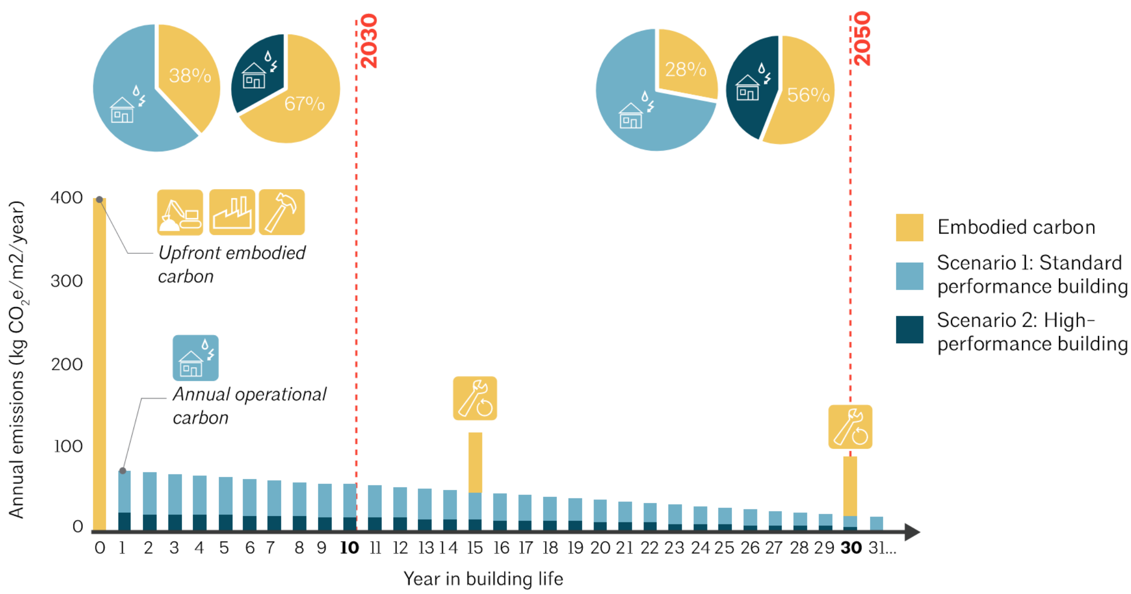

Figure 1: Embodied carbon lifetime emissions. *Source*: CLF 2021.

As buildings become more efficient and lower their operational carbon emissions, embodied carbon emissions tied to the construction and maintenance of buildings are increasingly critical. Programs like Architecture 2030, globally, and Sustainable Building 2030 (SB2030) in Minnesota target net zero operations by 2030 for new buildings and significant renovations. While the achievements of Architecture 2030 have been mixed, more than 85% of the projects in Minnesota are hitting their SB2030 targets. However, both programs continue to drive the building sector toward an overall net zero carbon goal.

Decarbonizing the grid and employing all-electric, net zero-energy buildings are essential strategies for reducing emissions from the building sector. However, integrating embodied carbon into the overall building sector climate change strategy is also critical. The reuse of existing buildings design changes to utilize low-embodied carbon alternatives, "Buy Clean" procurement programs, and prescriptive guidelines can dramatically reduce upfront embodied carbon, and when coupled with high-performance or net zero operations strategies, can substantially reduce the overall net carbon emissions for the life of a building.

Minnesota Sustainable Building Guidelines (B3)

B3 is a sustainability program for state-funded buildings. The program was created by the State of Minnesota in 2001 and developed by a team led by the Center for Sustainable Building Research (CSBR) at the University of Minnesota. Unlike other green building programs, it focuses on measured performance improvements, using a list of required metrics instead of a menu of potential options. The program is structured to provide a feedback loop to the state's building design, construction, and operations industry. Elements of the program are used through all phases of the development of state-funded buildings in Minnesota, from predesign through design and construction, and for ten years of operations. (Graves and Smith 2018).[1]

History

The Minnesota Office of Environmental Assistance (OEA) funded the development of the Hennepin County Sustainable Design Guide in 1995. (Graves and Smith 2018). Collaborators included HOK Architects, local architects and landscape architects, the University of Minnesota, and the Hennepin County Environmental and Facilities Management Departments. In 1999, The Hennepin County Guidelines were modified and transferred to the University of Minnesota, where they became known as the Minnesota Sustainable Design Guidelines. These guidelines were adopted by several public agencies in Minnesota for use on public buildings and served as a precursor to national green building programs like LEED (Leadership in Energy and Environmental Design).

The team developed the first version that went into effect on January 15, 2004, for all new buildings funded by State general obligation bonds. It was designed to be compatible with national guidelines such as LEED while maintaining regional relevance and impact. Adopting LEED was considered, but the development team decided to expand upon B3 because it was more specific to Minnesota's needs and could go further than LEED in some areas, such as energy efficiency, greenhouse gas emissions, and embodied carbon. Unlike LEED, the B3 is a set of requirements, not a checklist of optional items. Finally, the state desired, and the team implemented, a set of guidelines that is more performance-based rather than prescriptive. Updated versions have been released, with the current version 3.2 released in 2020.

[1] This reference applies to the entirety of the “B3” section.

Integration of Embodied Carbon in Minnesota's Sustainable Building Guidelines

The initial versions of the guidelines used for projects from 2004-2006 included guidelines aimed at reducing embodied carbon emissions, including an analysis of the reuse of existing facilities and space reductions to reduce the amount of new construction. Version 2.0 of B3 added a requirement to perform a Life Cycle Assessment (LCA) of Building Assemblies; design teams were required to evaluate at least two alternative scenarios for building assembly material choices on the project. Assemblies documented were foundations, beams and columns, intermediate floors, roofs, exterior walls, windows, and interior partitions. The following metrics were included: global warming potential, air pollution index, water pollution index, primary energy, and solid waste produced over the material's life cycle. The analysis was calculated over a 60-year life cycle. Project teams could run the Athena Environmental Impact Estimator software directly for a more customized approach, or alternatively, utilize a spreadsheet tool for these calculations, which included pre-run assembly scenarios based on the Athena Impact Estimator software. In addition, teams were encouraged to use BEES (Building for Environmental and Economic Sustainability) software or other tools to perform assembly-level LCAs during and beyond the design development phase. Versions 2.1 and 2.2 included the requirement of meeting a custom benchmark for total assemblies GWP, calculated in the Athena EcoCalculator.

In 2017, B3 version 3.0 was released, requiring a Whole Building Life Cycle Assessment (wbLCA) to reduce global warming potential by a minimum of 10% from a reference building, and the submission of product life cycle assessments via Environmental Product Declarations (EPDs). (CSBR 2021). Project teams are required to document emissions reduction of the building's construction materials through building massing, structural design, dematerialization, and alternative assembly and material selection. This guideline is met by documenting GWP reduction using one of three listed compliance paths below:

(1) Whole-Building LCA Approach:
This path can be used for any building and provides a way to evaluate the impacts of a comprehensive set of reduction strategies. These include whole-building strategies such as changes to the building plan to optimize assemblies' shape, layout, and surface area. Impacts from assembly and material selections may also be documented using this path. Following this path, whole-building LCA models must demonstrate a 10% reduction in GWP, at a minimum. The basis for this reduction is a comparison between the Selected Building Design and the Reference Building. This compliance path, including definition of requirements for the Reference Building, closely follows the requirements of USGBC, "Materials and Resources Credit: Building Lifecycle Impact Reduction," LEED Building Design and Construction v.4, with several key changes (CSBR 2021, Guideline M.1).

(2) Assembly-Level LCA Approach:
This path requires utilizing an LCA model of a representative building portion to document a 10% reduction in GWP. This approach is fundamentally similar to Path 1, but a smaller functional unit based on structural bays or another representative unit is modeled instead of the whole building.

(3) Material-Level LCA Approach:
This path requires the team to use the B3 LCA Material Selection Calculator to document the building's primary construction materials. This compliance path can be used to evaluate like-for-like material substitutions of functionally equivalent materials to reduce GWP (e.g., exchanging one type of cladding for another). This compliance path is limited to building projects utilizing one dominant structural and enclosure type, which must comprise at least 60% of the building's structural volume and exterior surface area, respectively.

A whole-building LCA model representing the project's final design is required regardless of the chosen GWP reduction compliance path for buildings with an area greater than or equal to 20,000 square feet. Approved wbLCA software and tools currently include Tally LCA, OneClick LCA, or Athena Impact Estimator. In addition to demonstrating the minimum reduction in GWP through Life Cycle Assessment, project teams are also required to provide documentation for at least five different permanently installed products sourced from at least five different manufacturers that either have a product-specific declaration of lifecycle assessment conforming to ISO 14044 that reports impacts from at least cradle-to-gate, or a Type III Environmental Product Declaration (EPD) which conforms to ISO 14025, 14040, 14044, and others. Product-specific Type III EPDs are preferred; however, industry-wide Type III EPDs are acceptable and are weighted as half of a product for compliance purposes.

As of June 2022, 42 projects had submitted information on LCA in B3. These projects encompass a variety of building types, including supportive housing, classrooms, visitor centers, community centers, vehicle maintenance facilities, and warehouses. The Whole Building LCA (wbLCA) pathway is currently the most common compliance path with 27 projects utilizing this method. The Material-Level LCA approach was utilized by 12 projects, and only three projects pursued the Assembly-Level LCA pathway. Most projects used the Athena Impact Estimator as the modeling tool for embodied carbon, followed by Tally, and one project used One Click LCA. A review of the submissions found that most teams were not creating WBLCA until late in the design phases for compliance with the program instead of earlier in the process, as intended by the guideline and recommended by the Carbon Leadership Forum (CLF) in Figure 2.

Goal	Use a WBLCA	Use an EPD
Measure the embodied carbon savings from building reuse	●	
Identify hot spots at the beginning of a project	●	
Estimate the carbon footprint (GWP impact) of a whole building	●	
Compare the carbon footprints of two building designs	●	
Compare the carbon footprint impact of two systems/assemblies (e.g., steel vs. mass timber; facade options, etc.)	●	
Compare the carbon footprint per unit of two functionally equivalent products from the same (or different) manufacturers (see the checklist above)		●
Compare the carbon footprint of a specific product to third-party targets (see section "Benchmarking Materials") during product selection and procurement		●

Figure 2: Whole building LCA and EPDs for embodied carbon goals. *Source*: CLF 2021.

The program results show that B3 projects are consistently able to achieve over a 10% reduction in global warming potential, with the reference building wbLCAs providing valuable insights into which assemblies have the greatest reduction potential. However, the data are not suitable for creating embodied carbon benchmarks because of the uncertainties inherent in the data sources, variations between tools, consistency of modeling approach, and inputs of individual modelers. Numerous opportunities exist to improve the quality, consistency, and utility of wbLCAs in the program, such as:

- Incorporating carbon analysis in earlier design stages to identify high-impact strategies for reducing embodied carbon.
- Providing additional training on how to conduct wbLCAs, and how to interpret and utilize the results to reduce embodied carbon.
- Providing guidance on high-impact strategies
- Creating more detailed modeling protocols for wbLCA.
- Providing a detailed review of submitted documentation.

The embodied carbon approach in the B3 is evolving to include a hierarchy of decisions for project teams to consider building reuse versus new construction, whole building design, optimization of structural system choices, assembly optimization, substitutions of materials, and product specifications. This approach follows the guidance published by CLF, shown in Figure 2, on when to use Whole Building LCA (wbLCA) versus Environmental Product Declarations (EPDs) to achieve embodied carbon goals for projects.

The next version of B3 will continue to integrate EPDs, the emerging work of Buy Clean initiatives in states and by the federal government and the development of code language by New Buildings Institute (2023) and others. In addition, the guidelines will explore carbon analysis early in design, utilizing wbLCAs or approved early-phase conceptual wbLCA tools, to understand the relative impact of different design decisions to find the right balance between prescriptive and performance-based requirements and develop multiple pathways to success. The B3 will continue to evolve to align with the Minnesota Buy Clean program as high-embodied carbon materials are identified and GWP limits are set over the next several years, incorporating future embodied carbon policy updates.

Minnesota Embodied Carbon Policy

While embodied carbon policy started with the B3 (B3) for the building sector in 2004, state policy makers requested a review and recommendations to broaden the scope on embodied carbon reduction in 2020. As a result, the Center for Sustainable Building Research (CSBR) at the University of Minnesota was tasked with providing research and recommendations to the Minnesota Legislature by 2022.

2022 Report - Construction Materials: Environmental Impact Study

In 2022, the Center for Sustainable Building Research (CSBR), in collaboration with the Carbon Leadership Forum (CLF), published a Construction Materials Environmental Impact

Study at the request of the Minnesota Legislature (CSBR 2022).[2] The report provides an overview of low environmental impact material policies, focusing on using environmental product declarations (EPDs). The report provided:

- A review of Type III EPDs available for concrete, unit masonry, metal, and wood.
- A review and summary of embodied carbon programs in other states and countries.
- An analysis of the feasibility, economic costs, and environmental benefits of using EPDs for state construction.
- Policy recommendations that the State of Minnesota could adopt around low-carbon construction material procurement.

Environmental product declarations. Environmental Product Declarations (EPDs) are independently verified documents that report the environmental impacts of a product, including its global warming potential (GWP), based on life cycle assessment (LCA) models. EPDs are written in conformance with international standards and must include the production life cycle stage at a minimum, also known as "cradle-to-gate", which encompasses raw material extraction, material processing, transportation, manufacturing, and fabrication. The use of EPDs as standardized reporting tools for disclosing the GWP of construction materials is increasingly prevalent in public procurement policy. EPDs are already used by consumers in the building industry to assess environmental impacts, enabling policymakers to build and improve upon the existing standards described in this section.

The development of EPDs and product category rules (PCRs) are governed by standards developed by the International Standards Organization (ISO), including ISO 14025, 14027, 14040, 14044, 21930, and others. Each material's PCR dictates methodological decisions that are relevant and fine-tuned to the material supply chain of that product category (e.g., concrete, floor coverings, insulated metal panels, etc.). A PCR dictates which life cycle stages and scopes must be included in the LCA, which background data sources are acceptable or mandatory, and other modeling choices such as allocation method and impact assessment method.

International Standards Organization (ISO) standards identify three types of environmental declarations for products: Type I declarations are third-party verified labels based on criteria set by a third party and are governed by ISO 14024. Type II declarations are self-declarations made by manufacturers or retailers and are governed by ISO 14021. Type II claims are not third-party verified. Type III declarations contain quantified product information based on life cycle impacts and are governed by ISO 14025. Type III claims must be third-party verified. Of these three types of declarations, Type III declarations are preferred for embodied carbon policy because they are third-party verified and contain the greatest amount of "quantified environmental information on the life cycle of a product," which helps "enable comparisons between products fulfilling the same function" (ISO 14025:2006).

There are two primary categories of Type III EPDs:

(1) Type III product-specific EPDs, which represent products manufactured by a single supplier or manufacturer. This type of EPD can be used to compare functionally

[2] This reference applies to the entirety of the 2022 Report section.

equivalent products that follow the same product category rules. Within this category of EPDs, there are three subtypes:

    (a) Manufacturer-specific EPDs, which represent a family of products produced by a single manufacturer
    (b) Product-specific EPDs, which represent a specific product produced by a single manufacturer
    (c) Facility-specific EPDs, which represent a specific product produced at a single facility by a single manufacturer.

(2) Type III Industry-wide EPDs, which represent multiple manufacturers within an industry. These types of EPDs are meant to provide an average of the industry as a whole. Industry-wide EPDs are useful for benchmarking what an average product's impact may be for a particular region. Industry-wide EPDs cannot be compared to each other, but they may be used to understand how product-specific EPDs relate to the average as a whole.

Policy recommendations and next steps. The report made policy recommendations based on key policy components outlined in CLF's Embodied Carbon Policy Toolkit (CLF 2022). Low environmental impact material policies typically include three to five components that answer the following questions:

- Scope: Which materials and projects are impacted by the policy?
- Data disclosure: What type of environmental and project data must be submitted to comply with the policy?
- Standards: Should materials or projects exceed a global warming potential (GWP) threshold?
- Incentives: Is financial and educational support available for manufacturers and companies that comply with the policy?
- Compliance: What is the timeline for submitting and implementing each policy component?

CSBR and CLF recommended that the state of Minnesota start simply with a short list of high-impact materials for which EPDs are already available. In addition, to maximize success in the development and implementation of a Buy Clean program, the team emphasized the importance of early and active engagement of stakeholders throughout the process. (Graves, Lewis, Huang, Simonen, Mosiman, Kutschke, 2021).

The study found that concrete and steel (including structural steel and reinforcing steel products) were the most common materials in low-carbon procurement policies. Additional materials included in low-carbon procurement legislation included engineered wood, asphalt, flat glass, insulation, and masonry. If limits are to be included in the policy, it was identified that subcategories must be developed for each material. For example, the Buy Clean California Act consists of three subcategories of structural steel products (hot-rolled structural steel sections, hollow structural sections, and structural steel plate).

In addition to consideration of different material subcategories, GWP compliance requirements would need to allow for the differences in vertical and horizontal construction. For example, different requirements might be needed to account for the variation in concrete mix designs used for paving or roads versus building floor slabs, due to a difference in cement quantities required to achieve performance criteria. Several adopting Buy Clean states have distinguished the Department of Transportation as a separate authorized agency for establishing limits for horizontal construction, separate from building applications, for this reason.

It is typical for low environmental impact material policies to follow a "carrot and stick" approach, using both incentives and regulations to encourage emissions reduction. In this case, the "stick" refers to the maximum global warming potential (GWP) limits, while the "carrot" refers to incentives.

Buy Clean California (BCCA 2022) and Buy Clean Colorado (BCCO 2024) set initial GWP limits at the industry average of the eligible materials, requiring the identified agency to re-visit the limits at established intervals to adjust limits to reflect lower industry averages. As required by the Buy Clean California Act, the California Department of General Services (DGS) established maximum acceptable GWP limits for steel (hot-rolled structural steel sections, hollow structural sections, structural steel plate, and concrete reinforcing steel), flat glass, and both light-density and heavy-density mineral wool board insulation based on the industry average of facility-specific GWP for that material. Beginning on January 1, 2025, and every 3 years thereafter, the California DGS will review the maximum acceptable GWP for each material and may adjust the limit downward to reflect industry improvements (BCCA 2023). The Buy Clean Colorado Act tasked the Office of the State Architect (OSA) with setting GWP limits for asphalt, ready-mix concrete, cement, flat glass, steel (post-tension steel, concrete reinforcing steel, structural hot-rolled, hollow structural sections, plate steel), and wood structural. As of January 1, 2024, the Colorado OSA has published limits for all, except post-tension steel, for which there was no sufficient data to set a valid threshold. The OSA is required to update the GWP limits at a minimum of every 4 years. However, OSA may update established limits on an annual basis determined by the availability of EPDs, as EPDs have a 5-year life (BCCO 2024). By setting boundaries, policymakers can anticipate a certain reduction in emissions over time. To align with global climate targets, policies may automatically introduce long-term carbon reduction timelines to reduce targets over time.

A range of incentives can be used to encourage the construction materials industry to reduce their impact over time. Incentives can be significant for addressing equity concerns by providing additional technical assistance, financial stimulus, and alternative compliance pathways for small or disadvantaged businesses. Agencies may award a performance bonus to general contractors at project completion for materials or projects that achieve a specific reduction in emissions associated with materials. Public agencies have yet to use this approach for embodied carbon, which is similar to the bonus clause often included in construction contracts, whereby a bonus is awarded for accelerated project schedules or other cost, schedule, and quality considerations.

To aid in policy compliance and successful program implementation, education and training will play an important role, including the availability of informational sessions and training opportunities internally for staff and externally for impacted stakeholders, such as manufacturers, contractors, and others in the building design and construction community. Third-party organizations and freely available resources can and should be leveraged to deliver cost-effective educational opportunities.

2022 report conclusion.

The report provided background research on the availability of environmental product declarations (EPDs) for concrete, unit masonry, metal, wood, and engineered wood, highlighting potential indicators of market-readiness for each material and examining intricacies to material requirements that would need to be considered in order to integrate GWP limits into future projects. Similar policies were reviewed from other states and federal, municipal, and international policies. It was determined that it is feasible to design a policy to minimize the economic costs of capital construction while providing the benefit of reducing embodied carbon of the materials for state construction projects. A policy requiring EPDs for high-embodied carbon materials in state construction projects would complement the design strategies in the B3 (B3) for new construction and renovations. Additionally, a policy requiring the submission of EPDs for materials such as asphalt and concrete would also result in a reduction in embodied carbon of horizontal construction projects, currently beyond the scope of B3. This report and its findings played a substantial role in advancing policy in Minnesota in the years to follow.

Minnesota Buy Clean

In 2023, the Minnesota legislature passed a bill called the Buy Clean Buy Fair Minnesota Act, also referred to as Buy Clean Minnesota, that requires the state Department of Administration and the Department of Transportation to work together to create an embodied carbon policy for state building and highway construction. This aspect of the Minnesota Buy Clean program is unique in that it integrates vertical and horizontal construction into the same policy, rather than distinguishing separate state agencies to develop policy requirements for the different types of construction. It will be essential to understand opportunities where integrating makes sense, while also acknowledging where additional product subcategories or program requirements will be needed. The following timeline was established in the legislation for the development and implementation of the embodied carbon policy:

- October 1, 2023 - Establish an Environmental Standards Procurement Task Force (ESPTF)
- July 1, 2024 - Launch a pilot program to estimate Global Warming Potential (GWP) from vendors on projects
- December 1, 2025 - Deliver an initial report to the legislature
- January 15, 2026 -Establish a maximum Global Warming Potential (GWP) for concrete used in buildings
- January 15, 2028 - Establish a maximum GWP for carbon steel rebar and structural steel and, after conferring with the transportation commissioner, for asphalt paving mixtures and concrete pavement

Focus Materials

The 2023 legislation identified four Minnesota Buy Clean policy materials requiring the collection of Environmental Product Declarations (EPDs). It will set future limits on global warming potential (GWP) for concrete, asphalt, structural steel, and carbon steel rebar. The ESPTF and the Administration and Transportation commissioners can add materials to the requirements. The 2022 construction materials report, CSBR (2022), found that "additional materials …could include engineered wood, flat glass, insulation, and masonry." The work of the next few years will include reviewing the benefits and impacts of including additional materials combined with cost and supply chain requirements.

A significant challenge in preparing to set GWP limits on concrete, asphalt, and other products is that the various industries are at different stages in adopting Environmental Product Declarations. In the concrete industry, many ready-mix concrete EPDs have been created. They are spread out across the country, and numerous tools have been designed to let suppliers quickly generate EPDs. The National Ready Mix Concrete Association (NRMCA) has led efforts to create industry-wide EPDs, publish regional benchmarks (figure 3), and support the creation of product-specific Type III EPDs.

Table 1: USA ready-mixed concrete national and regional benchmarks.

	Concrete compressive strength at 28 days								
Region	2500 psi (17.2 Mpa)	3000 psi (20.7 Mpa)	4000 psi (27.6 Mpa)	5000 psi (34.5 Mpa)	6000 psi (41.4 Mpa)	8000 psi (55.1 Mpa)	LW 3000 psi (20.7 Mpa)	LW 4000 psi (27.6 Mpa)	LW 5000 psi (34.5 Mpa)
National	240	262	308	365	385	446	492	540	588
Eastern	240	264	314	378	399	472	517	573	628
Great Lakes Midwest	232	255	303	363	383	452	499	551	603
North Central	241	264	312	372	394	460	487	537	591
Pacific Northwest	235	261	316	386	408	487	518	575	632
Pacific Southwest	257	279	323	378	401	456	500	546	594
Rocky Mountains	232	255	301	358	379	440	484	532	580
South Central	226	245	286	336	356	409	468	510	555
South Eastern	247	268	309	360	382	435	478	521	562

Note: All values are benchmark GWP in kg CO^2e / m^3. All values shown are for normal-weight concrete, except where lightweight concrete is indicated in the heading as LW. *Source:* NRMCA 2022.

The amount of cement drives the embodied carbon impact of concrete in the mix design. Cement is very carbon-intensive because cement production requires significant energy input and releases CO2 as a part of the cement-making process. Most concrete EPDs, including product-specific EPDs, use generic (i.e., industry-average) GWP data for cement. This means that a typical concrete EPD does not precisely represent that concrete's embodied carbon. Another challenge has arisen due to the recent uptake in availability and more common use of Portland Limestone Cement (PLC) Type IL in concrete mix designs, which is rarely captured in the generic GWP source data that is most used based on Portland Cement Type I/II.

An additional consideration is the number of concrete manufacturers in the United States. Even though over 30 manufacturers currently have product-specific concrete EPDs, there are over 2000 concrete manufacturers in the United States. In contrast, there are only about 35 cement manufacturers in the US, five of which have EPDs.

Improving the quality of the upstream data, precisely that of cement, and increasing the adoption of supply chain–specific upstream data would significantly improve the precision of concrete EPDs. Batch-specific EPDs are also a potential next step in enhancing concrete EPDs. In Minnesota, the concrete industry has increased the number of EPDs from a few hundred in 2022 to almost 1200 in 2024—figure 4. In a recent ESPTF meeting, the market penetration of

EPDs in concrete in Minnesota was discussed, and it was noted that the number of plants equipped with tools to create EPDs on demand might be a better indicator of market adoption than the percentage of products with EPDs or total quantity of EPDs.

Additional construction materials included in the embodied carbon policy: asphalt, structural steel, carbon steel rebar, and others will need to go through a similar evolution to increase the use and availability of EPDs.

Table 2: Valid product specific EPDs in Minnesota and other states as 2/2/2024

Material Category	Material Subcategory	Grand Total	CA	NJ	WA	OR	NY	CO	MN
		40950	21114	7875	3565	3933	1788	1414	1261
Concrete	Total	40070	20709	7840	3469	3817	1669	1321	1245
	Ready-mix	36989	18485	7774	3171	3505	1629	1229	1196
	Flowable fill	1315	865	36	150	152	23	52	37
	Shotcrete	1074	841	2	91	102	2	35	1
	Cement grout	692	518	28	57	58	15	5	11
Masonry	Total	354	231	0	39	18	42	24	0
	CMU	354	231	-	39	18	42	24	-
Steel	Total	37	13	4	9	5	3	2	1
	Rebar-steel	13	1	3	2	2	3	1	1
	Cold-formed steel	10	7	1	1	-	-	1	-
	Hot rolled	0	-	-	-	-	-	-	-
	Hollow sections	10	5	-	3	2	-	-	-
	Plate	4	-	-	3	1	-	-	-
Wood	Total	9	1	0	2	6	0	0	0
	Sheathing panels	1	1	-	-	-	-	-	-
	Wood I-joists	3	-	-	-	3	-	-	-
	Mass timber	3	-	-	2	1	-	-	-
	Composite lumber	1	-	-	-	1	-	-	-
	Non-structural wood	1	-	-	-	1	-	-	-
	Wood framing	0	-	-	-	-	-	-	-
Asphalt	Total	437	152	27	41	79	74	63	1
	Asphalt	437	152	27	41	79	74	63	1
Glass	Total	15	0	0	1	0	0	0	14
	IGU	15	-	-	1	-	-	-	14
Insulation	Total	28	8	4	4	8	0	4	
	Board	21	4	1	4	8	0	4	-
	Blanket	7	4	3	-	-	-	-	-

Data Source: EC3 (Embodied Carbon in Construction Calculator)

The expansion of EPDs will be needed to establish regional benchmarks and populate databases in preparation to create GWP limits for all these materials. The Minnesota Buy Clean program will coordinate and align with federal Buy Clean policies for setting boundaries, when appropriate. However, numerous methodologies for setting limits and performance targets are emerging across the country and globally.

Future Research Policy and Tools

As the Buy Clean Minnesota policies emerge to reduce embodied carbon in the supply chain of materials for building and transportation construction, future research will be needed to create a holistic regime to reduce carbon emissions and optimize the building industry to meet society's goals for mitigating climate change. The next generation of the B3 Guidelines will build upon the twenty-year history of integrating embodied carbon tools and strategies over the entire design process. To significantly reduce embodied carbon, reduction strategies must be considered at multiple stages of design, especially in early design phases when key project decisions become solidified. During the predesign phase, project teams should use WBLCAs or early-phase conceptual WBLCA tools to guide the project's scope and determine whether the building should be of new construction, renovation, or a combination of the two. The embodied carbon implications should also be considered when determining the project budgets and selections for structural systems and other significant components. New tools will be imperative to accurately determine tradeoffs between embodied carbon and the reduction of operational carbon emissions over the life of the building. Some tools have emerged in this area, but this type of analysis merges datasets of embodied carbon with operational carbon that have very different levels of fidelity and compares materials with various sets of product category rules (PCRs) for embodied carbon. Additional research and development are needed to provide project teams with the tools and guidance to make decisions informed by the total carbon portfolio.

There are numerous potential prescriptive design strategies with the potential to reduce embodied carbon under consideration and research. Increasing the efficiency of building designs to reduce the floor area of new buildings and/or reuse existing buildings that could serve as a strategic reserve of embodied carbon should be researched. Efficient structural design to create lighter structures and reduce sub-grade construction involving large amounts of concrete and other carbon-intensive materials is an important strategy that should become standard practice if it has not already. Alternative structural systems made from bio-based materials can store embodied carbon in building systems and be integrated with natural cycles. Mechanical and electrical system components, including refrigerants and other materials, are often omitted from the carbon discussion. Environmental Product Declarations (EPDs) should guide the selection of better choices within product categories to fine-tune embodied carbon reductions in the design phase and beyond. Still, additional research and tools will need to be further developed to be integrated into embodied carbon accounting. Another strategy is designing buildings not only for disassembly, so that their materials can be re-used at the end of their life, but also with a loose fit to today's programming needs so that they can be reconfigured to extend their useful life.

The experience with embodied carbon guidelines and policy in Minnesota will be a foundation to add new developments as the US Federal Buy Clean work is unveiled and US EPA material labeling standards are released. An integrated and comprehensive set of embodied carbon reduction strategies and policies are needed to hit the aggressive 2030 reduction targets being called for by organizations such as Architecture 2030 (65%), LETI (60%), C40 (50%), and WGBC (40%). The depth of research in embodied carbon needs to accelerate and integrate with the level of investigation, tools, and analysis developed over the last fifty years for tracking and reducing operational carbon emissions.

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