RMI

Buy Clean and Beyond

A Guide to Reaching Net-Zero Embodied Carbon in State-Owned Building Projects

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About RMI

RMI is an independent nonprofit, founded in 1982 as Rocky Mountain Institute, that transforms global energy systems through market-driven solutions to align with a 1.5°C future and secure a clean, prosperous, zero-carbon future for all. We work in the world's most critical geographies and engage businesses, policymakers, communities, and nongovernmental organizations to identify and scale energy system interventions that will cut greenhouse gas emissions at least 50 percent by 2030. RMI has offices in Basalt and Boulder, Colorado; New York City; Oakland, California; Washington, D.C.; and Beijing.

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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. Public- and private-sector stakeholders must act now to establish pathways to decarbonizing building and infrastructure design and construction, including reducing emissions from building material supply chains. By addressing embodied carbon in state-owned projects, government agencies can achieve substantial emissions reductions while shifting broader construction markets toward lower-carbon practices.

This report outlines how state governments can develop a roadmap to reach net-zero embodied carbon emissions from public building projects over time. Four core strategies are outlined in this report:

A robust "Buy Clean" procurement program with emissions standards for major building materials, a clear path to increasing the stringency and climate impact of these targets over time, and incentives for manufacturers to provide materials with deeper embodied carbon savings,

Pilots and policies that incentivize or require the purchasing of advanced, **deeply decarbonized materials,**

Whole-project embodied carbon performance standards to enable holistic benchmarking of state-owned building projects,

A climate-smart portfolio planning framework that captures the embodied carbon value of preservation, renovation, and adaptive reuse of existing buildings.

RMI Graphic

Adopting a multifaceted approach to reducing embodied carbon from state buildings will yield significant carbon savings over time, helping state governments achieve their climate reduction goals while moving the market toward net-zero embodied carbon buildings for all.

The most common strategy adopted by state governments today is a construction material procurement policy known as Buy Clean. An incrementally aggressive Buy Clean standard for building materials can be paired with three other complementary strategies to achieve a building portfolio with net-zero embodied carbon.

The second strategy includes pilot projects, minimum quotas for procurement, and advanced purchasing commitments to catalyze markets for disruptive, deeply decarbonized materials, such as zero-carbon cement, zero-carbon steel, mass timber, and bio-based insulation and finish materials.

The third strategy sets embodied carbon benchmarks at the project level. Creating a whole-project emissions standard will give project teams flexibility in how they achieve emissions reductions through design choices in addition to construction material procurement. This policy approach can incentivize smart, material-efficient design choices and, more importantly, incentivize uptake of deeply decarbonized materials, including bio-based materials, as viable alternatives to traditional building materials. Over time, whole-project emissions standards can be set to zero or carbon-"positive" levels.

The final strategy includes portfolio planning, which has a critical role to play in changing the type of building projects pursued by state governments. A "climate-smart" portfolio planning approach that addresses changing space needs due to post-pandemic work and reduces the amount of ground-up new construction should be considered. In this scenario, new growth in the portfolio is increasingly accommodated through acquisition or leasing of existing buildings for renovation, providing embodied emissions savings through building reuse.

Introduction

Reducing greenhouse gas (GHG) emissions in the next 20 years is critical to achieving the Intergovernmental Panel on Climate Change's target of keeping average global warming below 1.5°C and staving off the worst effects of the climate crisis. For the building and construction sector, this imperative increases the time value of carbon emitted in the near term and puts emphasis on mitigating embodied climate impacts from new construction of buildings and infrastructure. The *time value of carbon* refers to the concept that removing emissions in the near term is more valuable than any promised future emissions reductions, as actions in the next 10 years will be critical to limiting the worst impacts of climate change.

Embodied carbon impacts result from material extraction, production, transportation to construction sites, construction processes, and end-of-life disposal of demolished projects.[1] As influential consumers of construction materials in the United States, state governments play a critical role in reducing embodied GHG emissions from materials manufacturing and construction projects and catalyzing transformative change in building material supply chains.

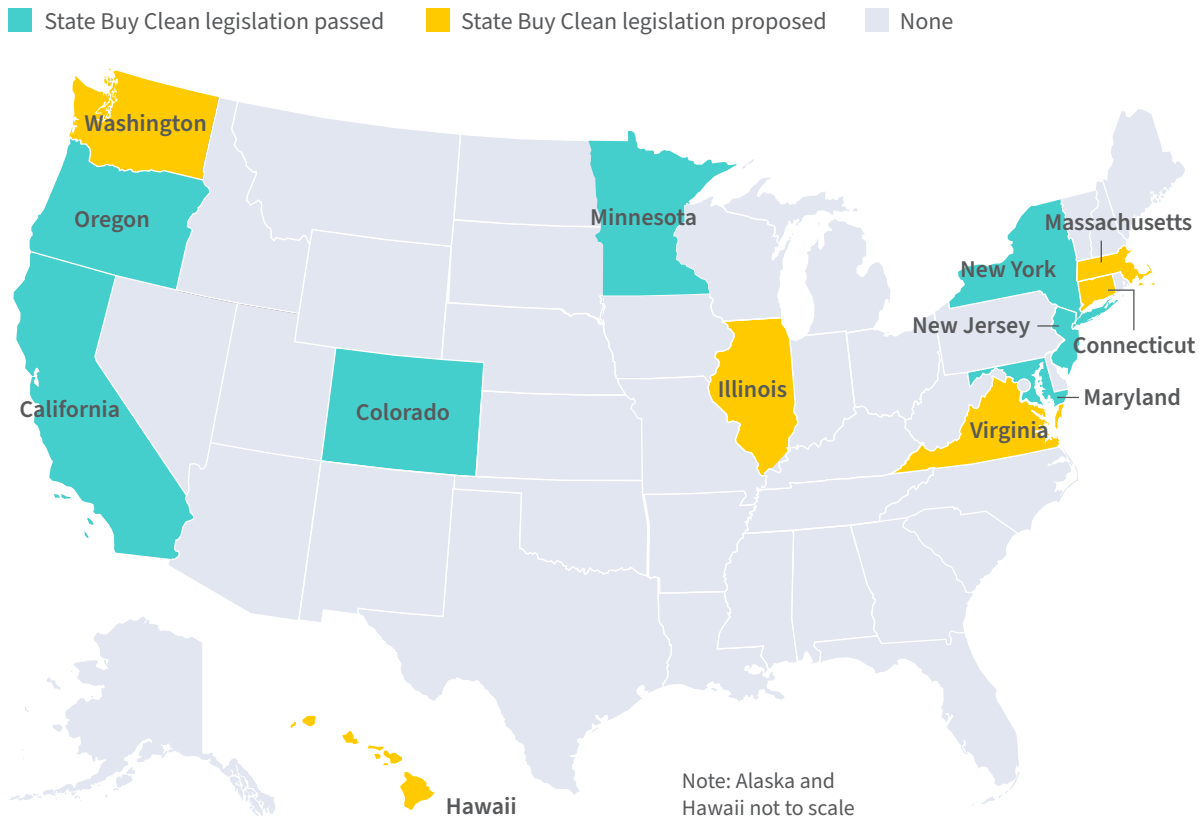
In this report, RMI provides a framework that state agencies can use to create a roadmap for reaching net-zero embodied carbon emissions from public building projects. The strategies underpinning the roadmap include a Buy Clean policy for building materials with effective incentive programs paired with a whole-project embodied carbon standard and climate-smart portfolio planning. State governments with existing Buy Clean policies should adopt and integrate whole-project embodied carbon standards and climate-smart portfolio planning practices to achieve greater emissions reductions and put state-owned buildings on a path to net-zero embodied carbon.

Establishing a Buy Clean Policy

Current Actions by US States

Public procurement of concrete, steel, and other construction materials is a growing priority for climate action in many states across the country. The policy model known as Buy Clean was first implemented in California in 2017, and policies covering various construction materials were subsequently signed into law in Colorado, Maryland, Minnesota, New Jersey, New York, and Oregon (see Exhibit 1). At the national level, the federal government's adoption of Buy Clean will prioritize the use of American-made, lower-carbon steel, concrete, asphalt, and glass products in federally funded projects (see Exhibit 2, next page). As momentum for Buy Clean implementation continues to build, public procurement policies will accelerate the transition to clean manufacturing in the United States, while significantly reducing the carbon impact of state-owned construction projects.

Exhibit 1 **Buy Clean legislation passed and proposed in the United States**



RMI Graphic. Source: RMI analysis

Exhibit 2 Construction materials covered under current Buy Clean legislation

	Cement and Concrete Mixtures	Asphalt and Asphalt Mixtures	Structural Steel	Reinforcing Steel Bar (Rebar)	Engineered/ Structural Wood	Flat Glass	Mineral Wool Board Insulation
California			✓	✓		✓	✓
Colorado	✓	✓	✓	✓	✓	✓	
Maryland	✓						
Minnesota	✓	✓	✓	✓			
New York	✓						
New Jersey	✓						
Oregon	✓	✓	✓	✓			
US General Services Administration	✓	✓					
US Buy Clean Task Force	✓	✓	✓	✓		✓	

RMI Graphic. Source: RMI analysis

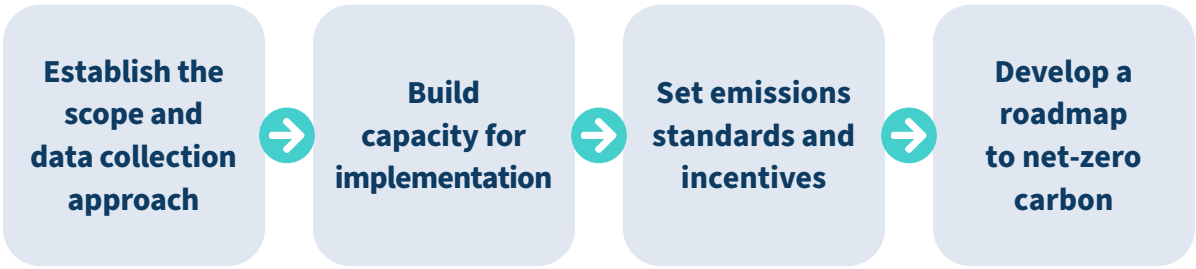
What Is Buy Clean?

Buy Clean, or green public procurement, is an emerging policy mechanism by which governments seek to reduce the environmental impact of building and transportation material supply chains by establishing emissions disclosure and performance standards for key product categories. This demand-side policy leverages the large purchasing power of the public sector.

Although Buy Clean can be deployed to address a variety of environmental considerations related to public procurement, such as vehicle fleets or building refrigerants, the focus of Buy Clean policies in the United States has been on construction materials for new construction, renovations, infrastructure, and maintenance.

Streamlining State Buy Clean Implementation

As state governments develop Buy Clean policies, certain fundamental near-term actions will facilitate a streamlined policy rollout. The following section describes key building blocks for state Buy Clean implementation.



1. Establish the scope and data collection approach

- **Identify priority project types and materials to be included in the state Buy Clean policy.** Prioritization criteria include scale of project, timeline, quantity and type of procured material, and carbon intensity of procured materials. States should reference historic procurement data to determine high-volume, high-emissions projects and identify upcoming opportunities for low-carbon procurement pilots.

- **Establish a standard for Environmental Product Declaration (EPD) reporting for product suppliers and provide financial support for EPD generation.** EPDs are third party–verified documents written in conformance with international standards that report the environmental impacts of a product on the basis of supplier data and life-cycle assessment data. Requiring EPD reporting by builders will increase demand for EPDs across material categories and inform emissions standards.

    - Provide financial support (such as tax credits or direct assistance funds) to manufacturers for the development of EPDs, prioritizing small and medium-sized enterprises (SMEs) and minority-owned businesses. Maryland and Massachusetts are two states that provide direct financial assistance to manufacturers to alleviate the up-front costs of EPD generation and publication.

2. Build capacity for implementation

- **Review, align, and report on existing sustainable procurement guidelines and requirements** (e.g., recycled content, regional content, bio-based material preferences). How are these requirements administered? Do they have an existing impact that would align with the goals of low-carbon procurement? How can manufacturers or suppliers with compliant EPDs be included in existing state-preferred product databases?

- **Develop standardized administrative protocols for submitting and evaluating compliance documentation for a Buy Clean policy**, including an online portal for supplier reporting requirements that connects to and builds on existing industry tools and databases. Summary

and comparison processes should be automated to facilitate review. How will data be reported by project teams and suppliers? When and how will this data be reviewed for compliance? The strategy should include cost and carbon data collection to track program impact.

- **Conduct outreach and stakeholder engagement** with varied material suppliers, including small businesses, to advance the Buy Clean policy. Understand manufacturer pain points and seek ways to address or work with them.

- **Conduct education campaigns within the state government** to increase knowledge of low-embodied-carbon procurement strategies. Offer training and provide guidance to design teams.

3. Set emissions standards and incentives

- **Establish global warming potential (GWP) base standards for priority materials identified in Building Block 1. The minimum recommended material categories for early standard setting are concrete (by mix strength) and structural steel components.** These prescriptive standards are set in kilograms of carbon dioxide equivalent (kg CO_2e) per functional unit of product and based on industry EPD surveys. Setting base emissions standards up front for the concrete and steel industries is recommended because an increasingly large pool of manufacturers in these industries have developed EPDs for their products and these are the primary sources of embodied carbon in building projects.[2] GWP limits can be set using existing research or new state-conducted research.[3] Base standards, or limits, are intended to initially exclude materials with the highest carbon impact. The limits can be adjusted over time to reflect industry best practices. This report provides recommended GWP targets for these major building material categories.

- **Provide incentives or purchasing commitments to accelerate the purchase of advanced low-carbon building materials above and beyond the minimum standards established in the Buy Clean policy. Types of incentives and purchasing commitments include:**

  - Performance-based tax credits for material suppliers that deliver products with GWP scores that fall below the established baseline. New Jersey's Low Embodied Carbon Concrete Leadership Act (LECCLA) awards tax credits of up to 8% of the total cost of the contract for concrete producers that deliver at least 50 yards of concrete with GWP scores falling below the baseline, validated through EPDs.

  - Minimum quotas for procurement of deeply decarbonized products in key material categories that are covered by Buy Clean. For example, states can establish a stretch GWP threshold for concrete and steel products that must be met for a percentage of product procured.

  - Competitive bidding protocols to evaluate eligible bids based on carbon performance in addition to cost. This idea has been considered by policymakers, most recently as part of New York's Low Embodied Carbon Concrete Leadership Act (LECCLA). Early drafts of this policy proposal included a bid discount for project teams that demonstrated the lowest GWP concrete mixes, increasing their competitiveness among the bid pool.

Sample Policy

In 2022, the US General Services Administration (GSA) announced that it would implement an EPD disclosure standard for concrete and asphalt materials in construction, modernization, and paving projects.[4] Concrete suppliers also have to demonstrate compliance with maximum emissions standards set by GSA. The GWP standards vary by mix strength and align approximately with the National Ready Mixed Concrete Association's national average GWP value, as reported in its industry-wide EPD.

These limits constitute a reasonable and achievable first step to reducing the embodied carbon impact of procured concrete. GWP targets are not established for asphalt materials because documentation is lacking in the industry. Thus, the asphalt standard focuses on requiring EPD disclosure in order to accelerate EPD creation by asphalt suppliers. These documents can then be used to benchmark performance. In the near term, prescriptive environmentally preferable asphalt production practices are enumerated in the policy to achieve some beneficial impact reduction. GSA's policy will be the first to pilot EPD reporting and optimization in material procurement for federal construction projects. Lessons learned from this pioneering effort will undoubtedly inform emerging intra-agency Buy Clean standards. Exhibit 3 shows GSA's standards.

Exhibit 3 Maximum GWP limits for GSA low-embodied-carbon concrete (CO_2e kg/m³)

Specified Compressive Strength (f'c in PSI)	Standard Mix	High Early Strength	Lightweight
Up to 2,499	242	326	462
2,500–3,499	306	413	462
3,500–4,499	346	466	501
4,500–5,499	385	519	540
5,500–6,499	404	546	–
6,500 and up	414	544	–

Note: These numbers reflect a 20% reduction from GWP (CO_2e) limits in proposed code language: ***Lifecycle GHG Impacts in Building Codes***, New Buildings Institute, January 2022.

RMI Graphic. Source: US General Services Administration, **https://www.gsa.gov/cdnstatic/Low embodied carbon concrete SOW language 3-29-22_0.pdf**

4. Develop a roadmap to net-zero carbon

- **Adopt a roadmap to address materials' embodied carbon and carbon intensity to reach net-zero procurement targets.** Consider all materials, such as aluminum, insulation, glazing, acoustic ceiling tile, flooring materials, gypsum board, and asphalt. Include year-over-year goals for reducing carbon intensity (kg CO_2e/unit of material) and increasing material suppliers' EPD reporting to support robust standard setting.

The following section includes information on how to track embodied carbon emissions in state-owned building portfolios and suggests embodied carbon limits for concrete, steel, and other materials to help create a roadmap for reaching net-zero procurement targets by 2050.

Path Forward for State Buy Clean Policies

Although momentum for Buy Clean policies is growing across the United States, few states track embodied carbon emissions in their own building portfolio, making the impact of Buy Clean difficult to estimate. For states that do not track these emissions, it is still possible to estimate the embodied carbon footprint of a building portfolio by conducting a quantification analysis using historical state and proprietary construction data. The results from the analysis can then be used to project the impact of Buy Clean and other embodied carbon mitigation strategies. To help state agencies get started, this section describes steps for the analysis.

Suggested embodied carbon limits for concrete, steel, and other materials based on industry roadmaps are also included below. These limits can be used to chart a path toward an embodied carbon emissions reduction goal for state-owned projects, such as net-zero embodied carbon by 2050; however, state agencies may choose to conduct their own research on materials covered under their Buy Clean policy and how they should ramp down carbon limits over time to follow industry development or reach an emissions reduction goal for their building portfolio.

Quantifying the Embodied Carbon Footprint of State Buildings

Quantifying the embodied carbon emissions in a state's building portfolio can be a valuable time investment. This exercise can inform how carbon emissions limits for Buy Clean policies evolve over time and support policymakers in developing a broader set of solutions to achieve robust embodied carbon reductions. The goal of the analysis should be to create prototypical whole-building material profiles that estimate the embodied carbon footprint of state building projects, including new construction and renovations. To build these profiles, the analysis should include three components:

1. **Construction rate:** Estimated annual construction by a state government
2. **Material quantities:** How much and what kind of high-impact materials are used in the construction of state buildings
3. **Material impact:** The emissions impact of each material type

Construction Rate

Data from a state's real estate portfolio can be used to estimate the annual construction rate and primary building types built and maintained by a state government. Projecting the growth trajectory for a state portfolio should follow this process.

First, conduct a statistical analysis of the state's real estate portfolio data set and include guidance from state staff on anticipated portfolio planning trends. Organize data into broad building typologies, such as commercial (offices, schools, laboratories, hospitals), residential, and industrial (warehouses, data centers, industrial operations).

Estimate the projected square footage of building projects by the state government from the present day until 2030, 2050, or another milestone, while considering two primary growth rates for projected construction:

- **Typical growth trajectory:** Presumed growth based on a normalized historical average of the past 10 years of construction
- **Tapered growth trajectory:** A low-growth scenario, capturing anticipated changes in space needs resulting from the COVID-19 pandemic as well as a climate-smart approach to portfolio planning that reduces new construction and accommodates growth through increased renovation of existing buildings

Finally, include anticipated cyclical renovation and modernization of existing assets in the portfolio. Develop construction rate estimates for ground-up new construction, interior fit-out of newly leased space, and interior fit-out and modernization of existing assets.

Material Quantities

After generating a projection of the annual construction rate, collect data to estimate quantities of common building materials used in typical construction projects for each major building type. Material quantity estimates can be generated using data from proprietary construction cost estimating software, which typically offers an expansive record of North American building cost and material data. Analysis teams should clearly define the scope of the material quantity estimates with a list of materials to be included in the analysis. Exhibit 4 shows common construction material categories. Including structural, enclosure, and interior elements of a building (while excluding mechanical, electrical, and plumbing equipment) is recommended given availability of current embodied carbon emissions data.

Exhibit 4 Major materials used in new construction and interior fit-outs

Concrete	Steel	Wood and Insulation	Finish and Fit-Out Materials
• Ready-Mix Concrete (by mix strength)	• Rebar	• Lumber	• Gypsum Board
• Cement Board	• Open-Web Steel Joists	• Plywood	• Vinyl
• Concrete Masonry	• Structural Steel	• Insulation Blanket	• Paint
	• Steel Decking	• Insulation Board	• Carpet
	• Cold Formed Steel	• Glazing	• Acoustic Ceiling
	• Plate Steel	• Glazing Aluminum Mullions	• Ceramic Tile
			• Other (e.g., Aluminum Extrusions)

RMI Graphic. Source: RMI analysis

Material Impact

To measure the embodied carbon impact of construction, building materials are grouped into product categories that accomplish the same function, such as insulation and floor finishes. The International Organization for Standardization sets product category rules (PCRs) for each category that stipulate requirements and guidelines for developing EPDs. These declarations are the building blocks of emissions data reporting in the building sector. More simply, EPDs are the third party–verified "nutrition label" for the environmental impact of each product.

The Carbon Leadership Forum (CLF) is a nonprofit organization that develops research and toolkits to support policymakers and industry members developing knowledge on embodied carbon measurement protocols. In 2023, CLF released a **material baseline report**,[5] which provides GWP benchmarking data for building materials produced in North America. The data outlined in the report presents industry average emissions intensity values for each material based on current North American EPDs representing standard practices. The GWP values reported in the CLF material baseline report include only the up-front emissions from life-cycle stages A1–A3 and do not include those from transportation, construction, maintenance, or end of life. Manufacturer-produced EPDs typically cover only these up-front emissions, and these life-cycle stages are the focus of procurement policy standards such as Buy Clean.

The final step in the analysis is to combine data from construction rate and material quantity estimates with the CLF baseline GWP benchmarks to develop prototypical whole-building material profiles for use in quantifying the embodied carbon footprint of state building projects. The data can provide estimates for embodied carbon emissions of building materials for new construction or interior fit-outs for each building type, or estimate the embodied carbon emissions distribution of common building materials across all building projects (see example *Assessment of Embodied Carbon in Federal Buildings*, next page). Analysis teams can estimate the types of future building projects to be completed by the state government and the associated embodied carbon impact.

Once this analysis is complete, agencies can use the data to project emissions savings from Buy Clean and other embodied carbon reduction policies. Because the profiles are limited in types of reference building and limited to the A1–A3 life-cycle stages, they should not be used as reference benchmarks for whole-building life-cycle assessment (WBLCA) performance standards (see *What Is a Whole-Building Life-Cycle Assessment?*).

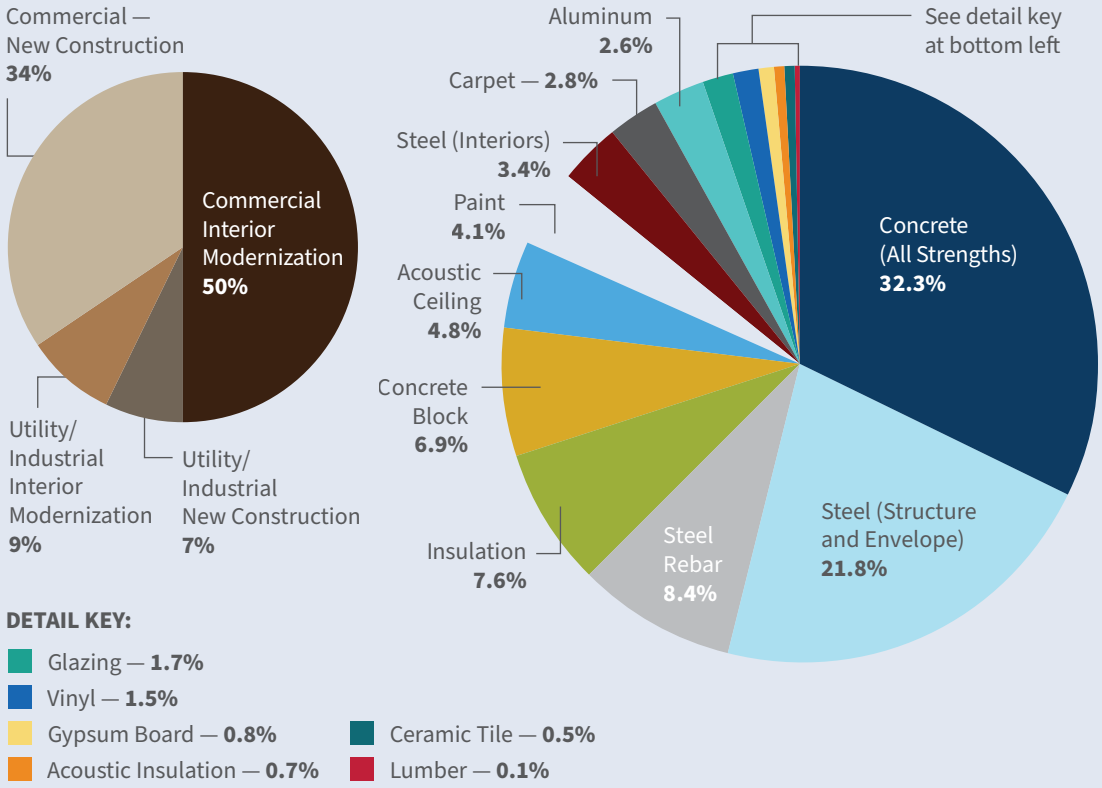
What Is a Whole-Building Life-Cycle Assessment?

The overall climate impact of a building project is best understood through a whole-building life-cycle assessment. Life-cycle assessments (LCAs) are organized into stages A, B, and C, which capture up-front, operational, and end-of-life environmental impacts, respectively. WBLCAs thus include emissions associated with extraction, manufacturing, and installation of building materials (life-cycle stages A1–A5), as well as those incurred during the operational (B1–B7) and end-of-life (C1–C5) stages. Material reuse, recovery, and recycling that occur through diversion from a landfill are not typically included within the LCA boundary for the original building or material. Those are categorized in a separate life-cycle stage (D). Environmental benefits from reuse and recycling are attributed to the building or product that uses the recovered materials. Protocols for conducting LCAs are described in international standard ISO 14044.

Assessment of Embodied Carbon in Federal Buildings

Using the steps described in this report, RMI quantified the embodied carbon footprint of federal buildings. The 2022 analysis was intended to inform standards on priority materials and emissions standards for Buy Clean policy, as well as to support policymakers developing a broader set of solutions to achieve robust embodied carbon reductions over time. The results of the analysis are shown in Exhibit 5, which describes the distribution of project types estimated to be completed by the federal government on an annual basis, and shows how these project types translate to a distribution of annual embodied carbon impact. A summary of the analysis can be found in RMI's ***Roadmap to Reaching Zero Embodied Carbon in US Federal Building Projects*** report.

Exhibit 5 **Estimated annual federal building project type distribution (left) and estimated federal carbon emissions distribution of common building materials (right)**



RMI Graphic. Source: RMI analysis

Industrial Outlook (Concrete and Steel Industry Targets)

In creating a path forward for a state Buy Clean policy, it is important to set clear emissions targets and trajectories for priority materials so industries have clear market signals. It is particularly important to set a mid- to long-term outlook for these targets, as these will inform capital investments by material producers who seek to comply. A pathway to net-zero emissions requires a targeted approach to emissions standards for high-volume, high-impact materials used for building structures — specifically, concrete, steel rebar, and structural steel. A strong demand signal for materials that meet low-embodied-carbon procurement guidelines will drive broad-based emissions reporting by the building construction industries.

The following section describes RMI's recommended emissions reduction targets for concrete and steel based on an analysis of industry decarbonization roadmaps published by sector leaders. Near-term GWP standards for the purchase of steel and concrete aim to match industry best practices that are being implemented by leading manufacturers today. Sector-specific roadmaps have been used to establish mid- to long-term GWP thresholds. RMI used a five-year cycle for the adoption of new emissions benchmark standards.

Concrete Targets

Concrete is a structural material made of cement, aggregate, and water. Cement, and its primary component, clinker, is the most carbon-intensive element of concrete production. In the near term, most concrete-sector carbon reduction will come from mix designs with a focus on minimizing clinker. In the long term, responsibility will fall on cement manufacturers to decarbonize their operations. This analysis summarizes reductions in concrete through six primary levers.

The methods and estimated reduction percentages were generated from three primary sources. These were the National Ready Mixed Concrete Association's (NRMCA's) *Cradle-to-Gate Life Cycle Assessment of Ready-Mixed Concrete Report — Version 3.2*; the Global Cement and Concrete Association's (GCCA's) *2050 Cement and Concrete Industry Roadmap*; and the International Energy Agency's (IEA's) *Achieving Net Zero Heavy Industry Sectors in G7 Members* analysis.[6] These associations are, respectively, a leading industry advocate, a collective of the world's leading cement and concrete companies, and an agency that focuses on implementing policies aimed at drastically lowering CO_2 emissions from heavy industries in the Group of Seven nations and beyond.

The six methods considered for reduction in this analysis, with descriptions paraphrased from NRMCA, GCCA, and IEA, and the applicable percentage reduction from baseline in 2022 are below.

1. **Efficiency in concrete production (14%):** Optimized mix design, optimized constituents, and better quality controls

2. **Savings in cement and binders (12%):** Portland clinker cement substitution, improved mix purity, and replacement with supplementary cementitious materials

3. **Decarbonization of electricity (6%):** Decarbonization of the electricity grid where cement and concrete production facilities are sited

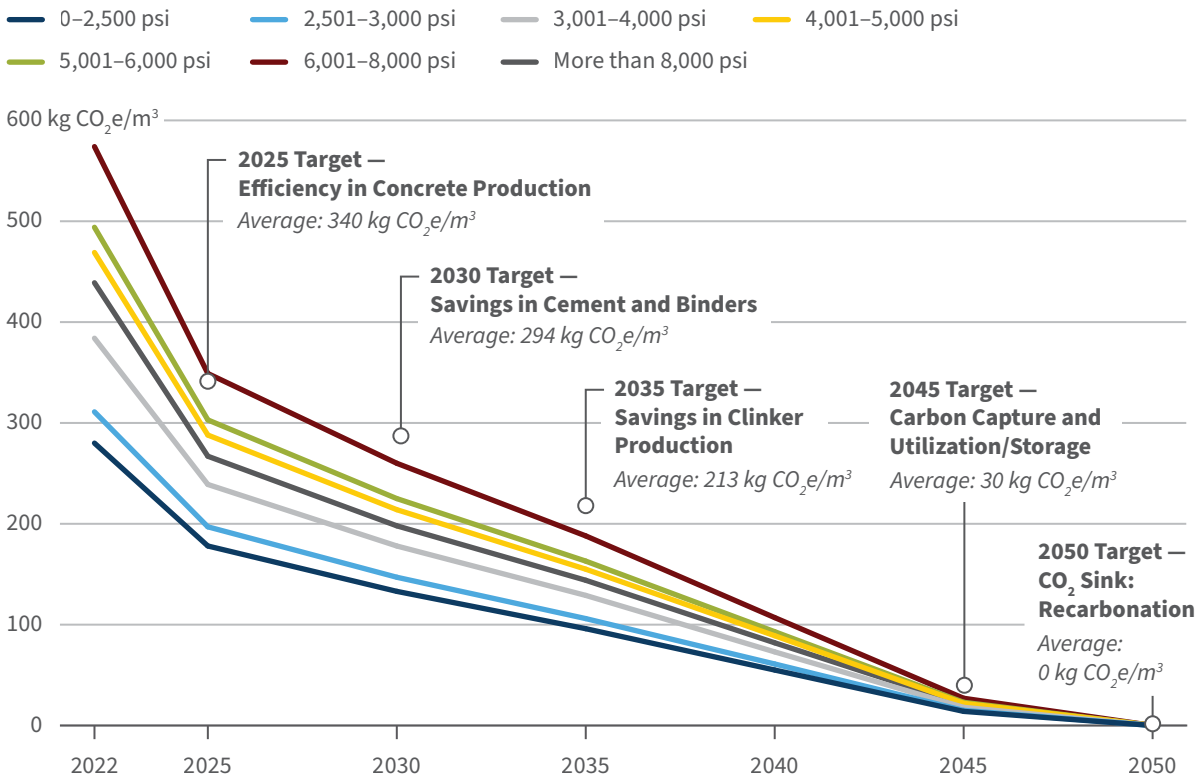
4. **Savings in clinker production (14%):** Increased thermal efficiency and use of alternative/waste fuels, decarbonated raw materials, and hydrogen fuel sources

5. **Carbon capture and use/storage (46%):** Direct, on-site carbon capture and sequestration at cement plants

6. **CO_2 sink: recarbonation (8%):** Uptake of the CO_2 emitted during cement production reabsorbed into the concrete as a carbon sink

The methods above are organized in ascending order of complexity and cost, from the perspective of the concrete producer. Near-term reductions can be achieved by strategies such as efficient mix design, with more robust decarbonization enabled by investments by cement manufacturers. Exhibits 6 and 7 (on the next page) show RMI's proposed national GWP benchmarks for concrete in future five-year increments, organized by compressive strength of concrete. States may choose to adjust benchmarks given the regional differences in concrete production.

Exhibit 6 Recommended national federal procurement targets for various concrete strengths to achieve net zero by 2050



Note: The method in bold is the priority method that should be applied during the previous period to achieve the desired target GWP target.

RMI Graphic. Source: RMI analysis

Exhibit 7 RMI's proposed GWP targets for concrete ready-mix, by strength

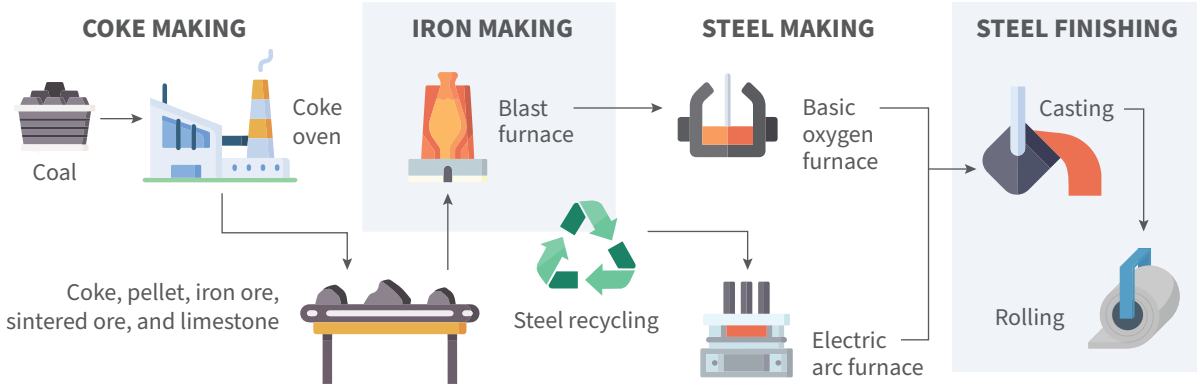
Year	0–2,500 psi (kg CO_2e/m^3)	2,501–3,000 psi (kg CO_2e/m^3)	3,001–4,000 psi (kg CO_2e/m^3)	4,001–5,000 psi (kg CO_2e/m^3)	5,001–6,000 psi (kg CO_2e/m^3)	6,001–8,000 psi (kg CO_2e/m^3)	More than 8,001 psi (kg CO_2e/m^3)
2022	280	311	384	469	494	574	439
2025	178	197	239	288	303	349	267
2030	133	147	178	214	225	260	198
2035	96	106	129	155	163	188	144
2040	55	61	73	89	93	107	82
2045	14	15	18	22	23	27	21
2050	0	0	0	0	0	0	0

RMI Graphic. Source: RMI analysis

Steel Targets

Steel is created through two primary methods, blast furnace–basic oxygen furnace (BF-BOF) production and electric arc furnace (EAF) production. BF-BOF produces markedly more carbon emissions because it requires coal as a primary ingredient and the furnaces must be heated to over 1,800°F to smelt the iron ore to yield liquid iron. EAF production, used in over 70% of US steel production, bypasses the initial emissions-intensive steps of BF-BOF by melting scrap steel, direct reduced iron (DRI), and/or pig iron to produce molten steel.[7] Exhibit 8 offers an overview.

Exhibit 8 Steps in traditional BF-BOF production and EAF production

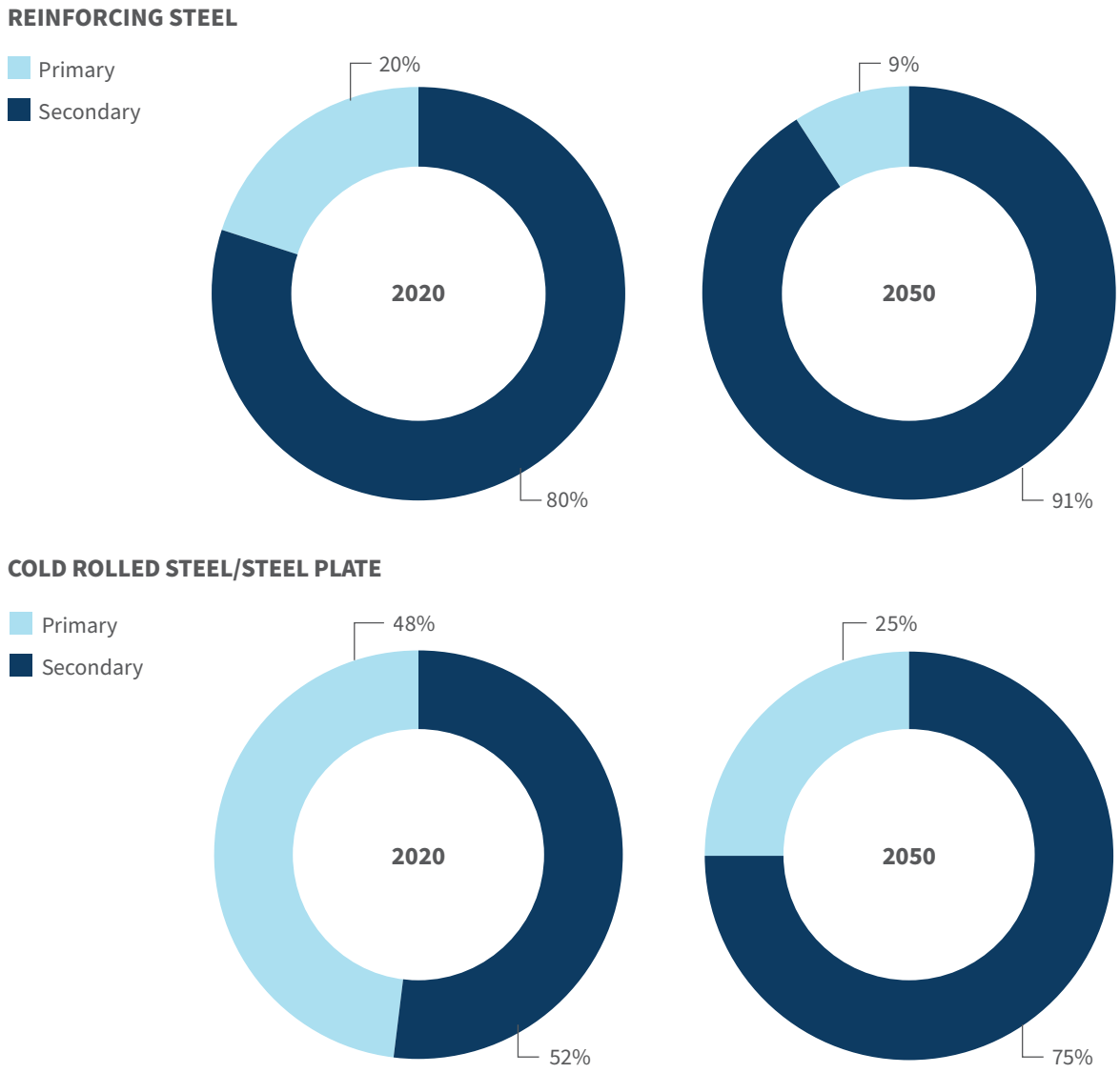


RMI Graphic. Source: World Coal Association, **https://www.worldcoal.org/coal-facts/coal-steel/**

GWP benchmarks for steel were developed using the IEA's *Net Zero by 2050*.[8]

To best determine the methods and timelines for steel decarbonization in the United States, this analysis split steel into two broad categories: steel reinforcing bar and structural steel. These steel products have varying percentages of primary and secondary steel and are thus produced in varying quantities by BF-BOF and EAF methods. Within the category of structural steel, there is variation in makeup of primary and secondary steel in plate steel, open-web joists, and hot-rolled structural sections. Broadly speaking, however, the key distinction in steel product categorization is between structural steel and steel reinforcing bar. Steel reinforcing bar is mostly produced with secondary steel and has a significantly lower GWP baseline than other steel products. Exhibit 9 shows the typical makeup of today's reinforcing steel products compared with other steel products and compared with projections for 2050.

Exhibit 9 Primary and secondary steel ratio assumptions based on steel type



RMI Graphic. Source: RMI analysis

Though steel products have different paths to net zero according to their ratios of primary to secondary steel, the methods responsible for decreasing their embodied carbon all come from three primary levers.

1. **Increasing secondary steel content:** Using as much secondary steel as possible for all products. Secondary steel can be used in EAF production, which will aid the transition away from high-polluting BF-BOF production.

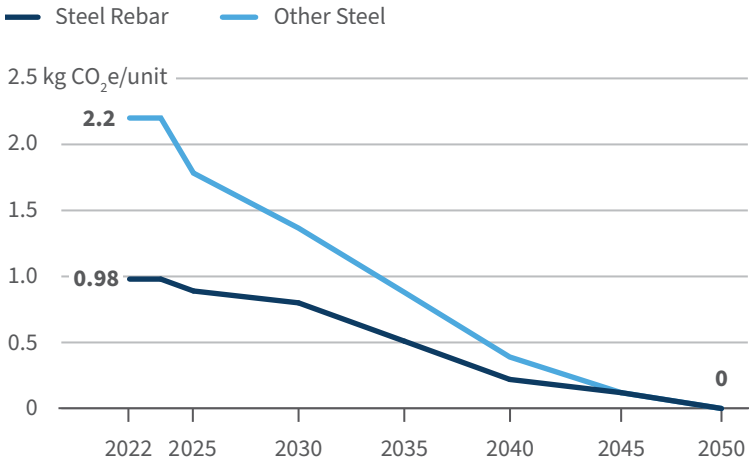
2. **Grid decarbonization:** Achieving net-zero emissions with electric furnaces is contingent on having a grid without emissions. Therefore, electric furnaces must be sited in areas that source their electricity from zero carbon–generation resources.

3. **Carbon capture, utilization, and storage:** There are limits on efficiency improvements for processes in BF-BOF production. Achieving net-zero carbon will require implementing on- and off-site carbon capture, utilization, and storage to eliminate the final percentage of emissions associated with steel production, especially for remaining blast furnaces.

RMI's analysis averaged the assumed percentage reductions of the IEA's Net Zero Emissions by 2050 and Mission Possible Partnership's Net-Zero Steel Sector Transition Strategy pathways as decade-over-decade scenarios to project a reasonably aggressive path toward net-zero procurement of steel in 2050. The pathway is shown in Exhibits 10 and 11.

Exhibit 10

RMI's recommended procurement targets for various steel types to achieve net zero by 2050



RMI Graphic. Source: RMI analysis

Exhibit 11

RMI's proposed GWP targets (in kg CO_2e/m^3) for steel materials

Year	Steel Rebar	Other Steel
2022	1.0	2.2
2025	0.9	1.8
2030	0.8	1.4
2035	0.5	0.9
2040	0.2	0.4
2045	0.1	0.1
2050	0	0

RMI Graphic. Source: RMI analysis, 2021 CLF Material Baselines Report

Emissions Targets for Buy Clean

Although steel and concrete make up an enormous share of the construction industry's carbon, many other building products also contribute. Insulation, glazing, acoustic ceiling tile, flooring materials, gypsum board, and asphalt should also be considered in state Buy Clean policies. For the purposes of this report, RMI created GWP benchmarks for other building materials using consistent emissions reduction thresholds, as shown in Exhibit 12.

Exhibit 12 RMI's proposed GWP targets for common materials

Year	Thermal Insulation ($kg\ CO_2e/m^2$–RSI)	Acoustic Insulation ($kg\ CO_2e/m^2$–RSI)	Concrete Masonry Unit ($kg\ CO_2e/m^3$)	Paint ($kg\ CO_2e/m^2$)	Acoustic Ceiling Tile ($kg\ CO_2e/m^2$)	Carpet ($kg\ CO_2e/m^2$)	Aluminum ($kg\ CO_2e/kg$)
2022	10.0	3.0	457.5	5.6	11.0	10.7	10.0
2025	6.0	2.0	413.8	5.1	8.5	9.8	6.0
2030	2.0	1.0	370.0	4.6	6.0	8.9	2.0
2035	1.8	0.9	333.0	4.1	5.4	8.0	1.8
2040	1.2	0.6	222.0	2.8	3.6	5.3	1.2
2045	0.4	0.2	74.0	0.9	1.2	1.8	0.4
2050	0	0	0	0	0	0	0

RMI Graphic. Source: RMI analysis, 2021 CLF Material Baselines Report

RMI recommends that targets be implemented in five-year cycles, or more frequently. Cumulative emissions resulting from building projects occurring during each five-year period should be reported and analyzed to track emissions reductions over time.

Beyond Buy Clean

Buy Clean offers a robust policy path to reduce the climate impact of building material supply chains, but this materials-focused approach must fit within a broader suite of strategies intended to reduce embodied carbon in the built environment. Existing Buy Clean policies have been designed to incrementally move up the "floor" for environmental performance by industry, setting emissions standards that can be met by a wide, competitive pool of material manufacturers. Although this policy strategy paves the way to move broad-based material markets toward a climate-conscious future, it does little to catalyze demand for alternative, deeply decarbonized materials or design methodologies.

In addition to Buy Clean standards, policies that support holistic embodied carbon emissions reductions include:

- Catalyzing markets for deeply decarbonized materials,
- Whole-project embodied carbon performance standards,
- Climate-smart portfolio planning.

Pilots and Policies That Catalyze Deeply Decarbonized Material Markets

Incentivizing manufacturers to deliver products with even lower embodied carbon than in the standards set forth in Buy Clean will incrementally increase the demand for low-carbon products, but more action is needed to catalyze the market for alternative, deeply decarbonized materials.

- **Advance market commitments** for key low-carbon technologies, identified through R&D. For example, public-sector commitments to procure net-zero cement, steel, or bio-based carbon-sequestering products can catalyze businesses producing these products. Advance market commitments are contracts between governments and private companies to guarantee purchase of a certain quantity of product in advance of manufacturing to ensure a viable market for establishing the business operation. A well-known example of advance market commitments is for public health initiatives such as vaccine procurement, most recently demonstrated by the federal government's advance market commitment to purchase COVID-19 vaccines.

- **Pilots and demonstration projects** for emerging low-carbon technologies in concrete, steel, and other difficult-to-decarbonize industries offer key opportunities to test products and application methods. One example is the Minnesota Department of Transportation's MnROAD project, a pavement test track constructed of various advanced low-embodied-carbon paving materials. The project team collects data on each paving material's performance, installation and maintenance costs, and environmental impact. Funding for this ongoing project comes from a combination of industry, state, and federal sources.

Whole-Project Embodied Carbon Performance Standards

Just as EPDs provide life-cycle impact assessment results for individual products, for a Whole-Building Life Cycle Assessment (WBLCA), project teams develop a holistic climate impact profile for their designs. In a WBLCA, the building project is treated as the product, enabling teams to visualize the relative impact of major material categories and pursue a broader range of embodied carbon reduction strategies. A WBLCA is particularly valuable when conducted during a project's design phase, when it empowers architectural, structural, and mechanical designers to make carbon-smart choices, such as material-efficient building design and alternative structural material selection. Green building rating systems, such as the US Green Building Council's Leadership in Energy and Environmental Design (LEED) framework, include certification measures that require project teams to conduct a WBLCA and develop embodied carbon–efficient designs.

Building design professionals around the globe are increasingly familiar with WBLCA methodologies. However, a few barriers preclude wider adoption and practice. It is challenging to establish absolute GWP performance benchmarks for life-cycle carbon emissions for new building projects, given the diversity of building types and building designs. Just as a survey of reported emissions data by concrete ready-mix suppliers to establish GWP benchmarks is required in Buy Clean, a broad survey of reported WBLCA data to develop referenceable performance standards is also required.

Today, WBLCA performance is measured relative to a conventional baseline building. The LEED rating system, for example, offers two points for a 10% reduction from a baseline building modeled by each project team. Although ISO 14044 describes best practices for conducting life-cycle assessment, more data analyses, including surveys of completed WBLCAs, are needed to determine baseline performance. How much embodied carbon is in the typical new construction project or interior tenant fit-out per gross square foot of built area? The CLF is working on a multiyear study in an effort to develop numerical benchmarks for WBLCAs. Industry consensus on appropriate benchmarks will support wider adoption of WBLCA performance standards.

A WBLCA is a powerful tool for embodied carbon accounting and undoubtedly has a role to play in the broader ecosystem of embodied carbon–focused procurement policies, such as Buy Clean. Although the standards set in Buy Clean focus on decarbonizing specific building material supply chains, an embodied carbon performance standard would open up a wide range of strategies that project teams could use to achieve carbon reductions. The relationship between these two policy mechanisms is analogous to policies deployed to advance operational energy, and carbon, efficiency in the United States. A materials-focused approach can be likened to appliance standards, which drive down environmental impact in specific products, whereas WBLCA performance standards are similar to building energy performance standards, where compliance is demonstrated through whole-building energy simulations.

Implementing a whole-project LCA embodied carbon performance standard in addition to a materials-based Buy Clean approach will create a holistic metric to benchmark building projects and accelerate the pace of decarbonization. Best practices for implementation begin with a reporting-only approach in the near term, acknowledging that industry capacity building and prototypical project baselining are needed before the adoption of WBLCA GWP performance standards. After the initial reporting-only period, a WBLCA carbon intensity performance standard can be set at a modest level, equivalent to a 20% reduction from today's conventional baseline.

An advantage of a WBLCA performance standard, compared with the materials-focused approach of Buy Clean, is that it allows for a wider range of flexibility to meet compliance thresholds. First, design teams

can account for material-efficient designs that simply use fewer materials or reuse building components. Beyond material efficiency, however, whole-project embodied carbon performance standards can also capture the benefits of material substitution, setting the stage for competitive evaluation of building material options based on carbon performance.

For example, design teams can meet targets by choosing deeply decarbonized or bio-based materials, pushing conventional material suppliers to decarbonize more aggressively. A project can achieve net-zero embodied carbon through a mix of advanced and conventional building materials and ultimately achieve a carbon-positive result. Using WBLCA as a methodology for establishing embodied carbon performance standards will enable policymakers to guide the building industry to a future where buildings are repositories for carbon storage, creating a more rapid path to net-zero or carbon-positive performance.

Whole-Building LCA at GSA Example

Green procurement policies that require a WBLCA by project design teams complement Buy Clean policies. The federal GSA has developed a pilot WBLCA policy for large new construction projects. Under this measure, design teams for projects with a budget exceeding $3 million are required to conduct a WBLCA demonstrating that the proposed design achieves a 10% embodied carbon reduction from a conventional baseline project. Project teams can leverage design strategies and product specifications, such as low-GWP product procurement, to achieve this target. The intent of this measure is to collect data from projects on effective emissions reductions measures and establish federal WBLCA performance benchmarks.

Climate-Smart Portfolio Planning

Although awareness of embodied carbon reduction measures in the design and construction phases is increasing in the market today, there is a lack of information on how embodied carbon can be considered before building projects are in design — during portfolio asset planning and project conception. This phase of decision-making is particularly important for considering embodied carbon because it offers an opportunity to evaluate alternatives to new construction, notably adaptive reuse of existing, underutilized assets or prioritization of interior tenant fit-out projects in existing buildings.

State governments, like most other building portfolio owners, are rethinking their planning and growth strategy as a result of the global COVID-19 pandemic, which changed the way building floor space was used. As state governments consider adjustments to their portfolio planning strategy, embodied carbon should be integrated as a metric to inform decision-making. Renovation or adaptation of existing buildings is a powerful embodied carbon reduction strategy — one that should be valued as part of portfolio planning.

One administrative approach that state governments can use to achieve this is incorporating high-level whole-project embodied carbon intensity benchmarks as part of the planning process. As state governments grow more sophisticated in deployment and tracking of WBLCA-based embodied carbon performance standards, they can leverage this data to enable climate-smart portfolio planning.

Science-based benchmarks for embodied carbon intensity organized by prototypical building project types can be used to evaluate alternative development options during predesign phases. These benchmarks would describe projected embodied carbon emissions per unit of built floor area, similar to energy-use intensity benchmarks used for operational energy portfolio benchmarking. For example, a planning team may choose to recommend renovation of an existing facility over new construction when the embodied carbon estimate for a newly constructed building is understood in context.

Conclusion

Buy Clean policies that target the highest-emitting construction materials can immediately yield substantial GHG emissions reductions from state building projects. These policies will send clear demand signals to the market and accelerate decarbonization across the building industry's value chain. However, implementing Buy Clean and considering the job done presents a significant missed opportunity to achieve further emissions reductions and catalyze the market for advanced and deeply decarbonized materials in the US. State governments should build on Buy Clean policies by integrating strategies to encourage the uptake of deeply decarbonized materials, whole-project embodied carbon standards, and climate-smart portfolio planning practices. These strategies are the first steps to achieving a net-zero embodied carbon emissions building portfolio and leading the industry to transform our buildings from climate liabilities into climate assets.

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