A BUILDING BLOCK FOR CLIMATE ACTION: REPORTING ON EMBODIED EMISSIONS

C2ES CLIMATE INNOVATION 2050

by

Chris Kardish
Center for Climate and Energy Solutions

November 2022

Achieving net-zero emissions will require large scale change across all sectors of the economy, and efforts to drive this transition are intensifying. Over the past several years, through the Climate Innovation 2050 initiative, the Center for Climate and Energy Solutions (C2ES) has engaged closely with leading companies across diverse sectors to examine challenges and solutions to decarbonizing the U.S. economy by 2050. As we laid out in *Getting to Zero: A U.S. Climate Agenda*, reaching net-zero will require large-scale change, but it will also require us to address a number of discrete and urgent challenges. To inform policymakers considering these near- and long-term questions, C2ES launched a series of *"Closer Look"* briefs to investigate important facets of the decarbonization challenge, focusing on key technologies, critical policy instruments, and cross-sectoral challenges. These briefs will explore policy implications and outline key steps needed to reach net-zero by mid-century.

EXECUTIVE SUMMARY

Greenhouse gases can be emitted across various stages of a product's life cycle, from raw materials and manufacturing to disposal. These emissions are often referred to as a product's "embodied emissions." Currently, the most common way of reporting product-level data on embodied emissions is through an environmental product declaration (EPD), a standardized document providing quantified information on environmental impacts, as well as use of materials and resources, across the life cycle of a product. EPDs rely both on international standards to provide a high-level framework and on more granular product-level rules developed by stakeholders.

To date, nearly all policies requiring companies to report embodied emissions using EPDs have accompanied initiatives to advance clean public procurement at the state level. The federal government and Congress have also taken significant steps since late 2021 to broaden Buy Clean—a set of policies designed to prioritize procurement of lower-carbon materials—nationally. EPDs are relevant to other climate-related policies as well, including product standards, building codes, and potentially trade policies. There are numerous ways, however, that EPDs and the data they rely on fall short, presenting hurdles to making product-level reporting more useful and widespread. These

include significant gaps in primary data at various stages in products' life cycles; the inability to compare products that develop EPDs based on different reporting rules, databases, and software tools; the fact that product-specific EPDs are still often unavailable; and a lack of uniformity in EPD rules across states and the federal government.

There are tangible steps that governments and stakeholders that develop reporting rules can take to overcome the challenges and shortcomings associated with EPDs, including:

- *Updates to the rules for EPD development to address data gaps:* requiring more primary data and more reporting on post-production life cycle stages where relevant.
- *Standardization to improve comparability and consistency:* improving standardization on the use of secondary data and life cycle analysis tools, enhancing efforts to improve the quality and availability of secondary data in the United States, and working to achieve greater consistency on EPD requirements in state and federal Buy Clean initiatives.
- *Incentives to increase EPD availability:* providing education, assistance, and financial incentives to manufacturers (especially small and mid-size manufacturers) to support their production of EPDs. EPD availability can also be boosted through the expansion of Buy Clean laws.

In addition, the private sector will need to engage suppliers more actively to improve the availability of product-level data, exerting influence where possible but also working cooperatively with suppliers and through industry groups and initiatives. One opportunity to expand product-level reporting is through approaches that focus narrowly on embodied emissions (as opposed to comprehensive assessments of environmental impacts), but these approaches still require product-level reporting rules to allow comparability between products. There are also efforts underway to expand the availability of product-level data by harnessing technology, supplier engagement, and simplified reporting, with some platforms emerging that focus on greening private-sector value chains.

INTRODUCTION

Companies face growing demands to understand and report on emissions generated across the various stages of a product's life cycle, which are often referred to as a product's "embodied carbon" or "embodied emissions"—the overall emissions footprint of a product from cradle to grave, though most attention typically goes to the earlier stages around production.

Embodied emissions ultimately occur because a product is made for a purchaser or consumer to acquire and use. Purchasing and consuming companies interested in reducing their contributions to climate change are paying increasing attention not only to their own direct emissions ("scope 1" under the Greenhouse Gas Protocol's accounting standard), but also to the indirect emissions embodied in goods and products they use (part of their "scope 3" emissions, which include emissions across an organization's value chain).[1] (See Table 1 for more information on emission scopes.)

Emissions from corporate supply chains are 11.4 times higher on average than emissions from companies' own operations, which makes embodied carbon an inevitable part of the climate agenda.[2] Given growing pressure from investors and regulators to disclose information on and address scope 3 emissions, efforts by companies to decarbonize their supply chains and address embodied emissions are likely to accelerate. Setting climate goals that encompass scope 3 emissions is increasingly becoming the norm. Ninety-six percent of the more than 1,000 companies that have climate targets approved by the Science-Based Targets Initiative include scope 3 emissions in their targets, which is required by the initiative when scope 3 emissions represent more than 40 percent of a company's overall emissions.[3]

Because embodied emissions stem from purchases and consumption of products, the actions and policies to address them often fall on the demand rather than supply side of the economy. That makes policies to address embodied emissions different from policies that target direct (scope 1) emissions from producers of goods. (Of course, one company's scope 3 emissions are some other company's scope 1 emissions.) The most prominent example of a demand-side policy is low-carbon public procurement, or "Buy Clean" poli-

TABLE 1: Emission scopes under the Greenhouse Gas Protocol Accounting Standard

SCOPE	DEFINITION	EXAMPLES OF EMISSIONS SOURCES
Scope 1	Direct emissions from sources that are controlled or owned by an organization	Combustion of fuels on site to produce electricity or heat; use of transport fuels in a company-owned fleet; emissions from chemical or physical transformation of raw materials in industrial processes
Scope 2	Indirect emissions from purchased energy	Electricity use and thermal energy purchased and transmitted from another source that generated the energy
Scope 3	All other indirect emissions that occur in a company's value chain	Upstream: purchased goods and services used by an organization to produce another good; extraction, production, and transport of fuels and energy purchased or acquired by an organization; transportation and distribution of purchased products Downstream: transportation and distribution of products sold by a company; processing of products sold by the organization and processed by another company downstream (e.g., manufacturers); emissions from end use of goods and services

Source: adapted from Greenhouse Gas Protocol

cies, where governments set emissions standards for materials sourced by contractors for public projects. The aim is to leverage government purchasing power to create demand for low-carbon products and reward lower-carbon producers in supply chains. Other policies that are likely to draw on embodied emissions data include building codes, product standards, and trade-based measures.

While there are innumerable products in supply chains, the current policy and accounting focus for embodied emissions is on building and construction materials. These materials are very emissions intensive to produce and thus carry significant embodied emissions. They are also widely used in the economy, affecting all sorts of infrastructure. For example, the buildings sector accounts for about 11 percent of global greenhouse gas emissions exclusively from carbon embodied in common construction materials such as steel, concrete, and glass.[4] Likewise, embodied carbon can account for up to a quarter of a transportation infrastructure project's life cycle emissions, even factoring in vehicle traffic during the operational phase.[5] An estimated 32 percent of embodied emissions from construction in the United States between 2008 and 2018 was attributed to public construction projects, which underscores why Buy Clean policies are attracting growing interest.[6]

Whether it is companies or governments acquiring the products and goods, widespread availability of high-quality data on embodied emissions is fundamental—as the adage says, what gets measured gets managed. Product-level data on embodied emissions are a key building block for companies to identify and address emissions hot spots within their value chains. Similarly, Buy Clean policies cannot be implemented without reliable, product-level data on embodied emissions. Although policies and actions on embodied carbon rely on emissions data at a product level (or at least would be significantly enhanced by it), efforts to build this crucial knowledge infrastructure are still in the early stages of development—especially outside of building and construction materials and some electronics-based products.

This paper begins by reviewing some of the technical methods for reporting embodied emissions data, as well as the current U.S. policies that require or seek to advance such reporting. It then explores the shortcomings of that reporting and the challenges in scaling it, such as gaps in data availability. The paper concludes with a review of ways to improve the reliability and availability of embodied emissions data.

ENVIRONMENTAL PRODUCT DECLARATIONS

Currently, the most common way of reporting product-level data on embodied emissions is through an EPD, a standardized document providing quantified information on environmental impacts, as well as use of materials and resources, across the life cycle of a product.

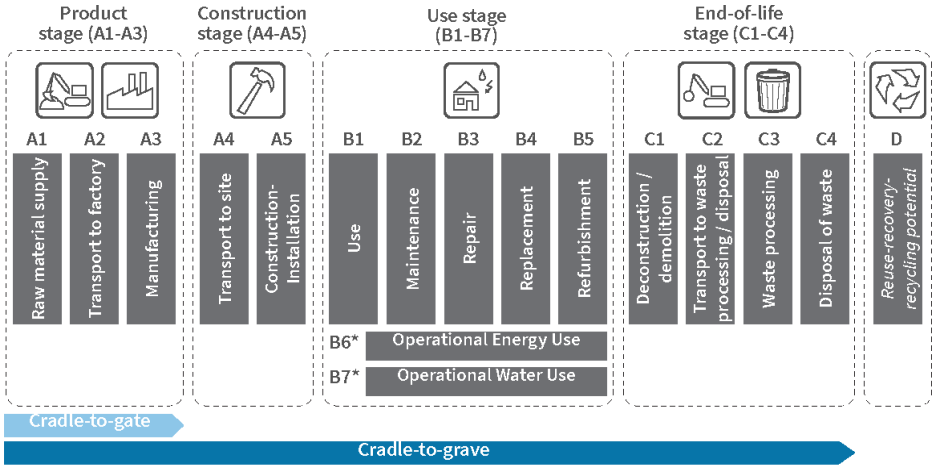
INTERNATIONAL STANDARDS AND LIFE CYCLE ASSESSMENT

The International Organization for Standardization (ISO) sets overarching guidelines and procedures for environmental impact evaluations (and many other things). Several ISO standards are relevant to EPDs, and they often rely on and interact with each other.

The main standard providing guidance and procedures for completing EPDs is ISO 14025, which aims to allow comparison of environmental impacts between products that serve the same function.[7] (European Product Environmental Footprints (PEFs), which are very similar to EPDs, also follow ISO 14025.) There are other ISO standards for reporting on the environmental impacts of products, but ISO 14025 is preferred for embodied emissions because it offers quantified and comprehensive data based on other ISO standards for rigorous product life cycle analysis.[8] This allows for direct comparisons between products, assuming they follow the same rules on reporting (described further below). EPDs under ISO 14025 are relatively technical documents that are meant for business-to-business transactions. Ecolabels that are meant for consumers are based on ISO 14024, which allows products to demonstrate that they meet specific performance and sustainability criteria.[9]

ISO 14025 provides guidance for how to set reporting requirements for specific products. The reporting requirements for a specific product (e.g., hot-rolled structural steel or prefabricated wood) are spelled out in documents known as Product Category Rules (PCRs). PCRs are administered by a program operator, which often is the same entity that ultimately verifies submitted EPDs. PCRs are developed through consultations with stakeholders, including manufacturers, trade associations, purchasers, public agencies, and experts in life cycle environmental assessments.[10] They are often specific to a region and typically require reporting on environmental impacts. Information on emissions, referred to as the product's global warming potential (GWP), is typically expressed in terms of carbon dioxide equivalent (CO2e) per metric ton of a product (or however a single unit of the product is defined).[11] Beyond global warming potential, PCRs typically require reporting on impacts such as land and water acidification, impacts to waterways, secondary air pollutants, depletion of various natural resources,

Figure 1: LCA stages for building and construction materials



*Operational carbon stages that are typically excluded from life cycle assessments focused on embodied carbon.

Source: Carbon Leadership Forum

impacts on biodiversity, ozone depletion, and impacts on human health. ISO 14025 outlines what needs to be specified by the PCRs, including how a unit of the product is defined ("declared unit"), the stages of its life cycle environmental impacts that must be included, the process and associated emissions that must be accounted for within these stages ("system boundary"), data requirements, procedures for conducting the life cycle assessment (LCA), and standards that must be met to allow for comparability with other reporting products.[12] While the process of establishing PCRs and submitting EPDs is grounded in international standards provided by ISO, there is no government oversight.

For LCA principles and procedures, ISO 14025 relies on two other standards, ISO 14040 and ISO 14044. LCA underlies EPDs by providing a systematic method for evaluating a product's environmental impacts across its life cycle, breaking it down into its various processes, inputs, outputs, and use of resources. The ISO LCA standards do not specify what stages of the product's life cycle need to be included in the product rules, but they do provide guidelines for PCRs to consider and outline key phases, including acquisition of raw materials, distribution and transportation of materials to a manufacturing facility, and inputs and outputs in the main manufacturing process.[13] While the precise LCA stages that are required vary across PCRs, building materials are typically broken down into modules across five stages: product stage, construction stage, use stage, end-of-life stage, and reuse-recovery/recycling-potential stage, which is supplemental (Figure 1).[14] These stages are defined in ISO 21930, which applies specifically to building and construction materials. Reporting requirements typically center on the product stage (modules A1–A3), though PCRs may also make additional stages optional. This so-called "cradle-to-gate" stage is often the source of the most embodied emissions since it encompasses key material inputs, transportation of materials to a manufacturing site, and the manufacturing process.[15]

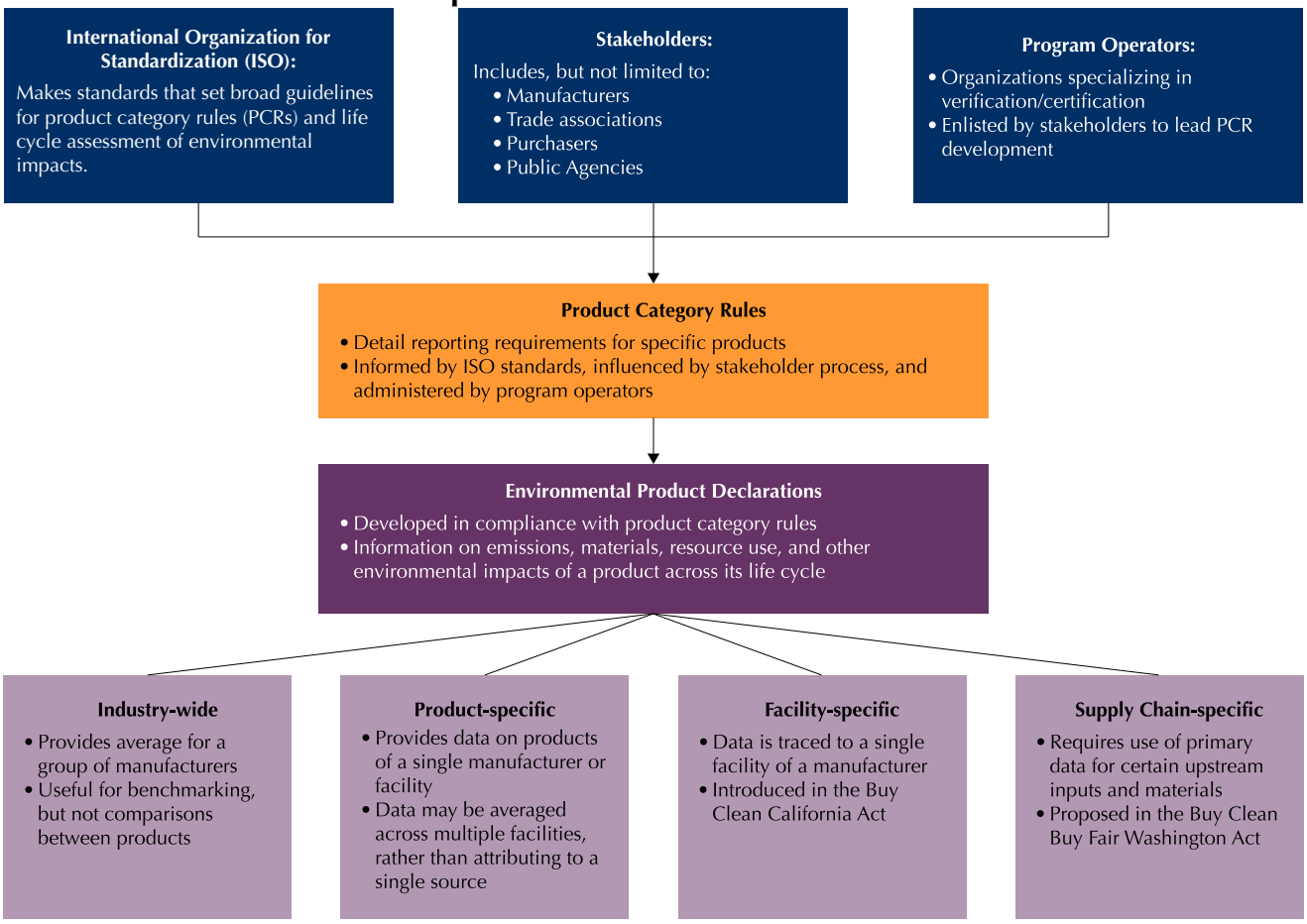
DATA SOURCES AND REPORTING SPECIFICITY

It is commonplace in EPD development and other forms of carbon accounting to use secondary data where primary data are not available. Primary data refers to plant-specific or process-specific data, which comes directly from the entity that collected the data (e.g., a supplier of an input). Secondary data are more generic and are typically provided by a life cycle inventory database, which pools data for a variety of inputs and processes at various levels of granularity. Some secondary datasets have regional focuses, while others are global. Many of them are free to access.[16] It is especially common to use secondary data for the upstream phases prior to manufacturing. For instance, secondary data are often used to cover the extraction and refinement of fuels used as inputs in a manufacturing process or during transport of supplies. PCRs typically allow secondary data but set guidelines on its use and documentation, though these guidelines rarely include specifying which particular data sources are acceptable.

EPDs vary in their level of reporting specificity. The most common types of EPDs are "industry-wide" and "product-specific." An industry-wide EPD provides average GWP and other environmental impacts for a product or range of products for a group of manufacturers. These are typically produced by trade associations. While industry-wide EPDs do not allow for comparisons between products, they do provide useful data for benchmarking and setting GWP thresholds for a product category, as evidenced in California's clean public procurement law (described in more detail below). Product-specific EPDs provide data on the products of a single manufacturer, but this data may be weighted and averaged across multiple facilities rather than tied to a specific facility. Both industry-average and product-specific EPDs are likely to contain a combination of primary and secondary data, since the former is essentially an aggregation and average of the latter, and the use of secondary data for product-specific analyses is common. The process of developing the different types of EPDs is summarized in Figure 2.

States have introduced additional categories of reporting specificity, which are not defined by the ISO or other standard-setting bodies.[17] The Buy Clean California Act introduced the term "facility-specific EPD", which is a subset of product-specific EPDs in that it requires tracing GWP and other impacts to a single facility of a manufacturer.[18] The idea is to provide a more accurate measure of environmental impact by avoiding taking averages across a company's facilities, which may produce the same good with different life-cycle emissions. Measures in Washington state introduced the term "supply-chain-specific EPD", which requires the use of primary—rather than secondary—data for inputs and materials used in the production process in cases where these upstream sources of emissions account for

FIGURE 2: How EPDs are developed



Source: C2ES

at least 80 percent of the product's total cradle-to-gate GWP. This would require, for example, that a ready-mix concrete maker use independently verified data directly from its cement supplier rather than using an average for the cement industry in the United States or a specific region in the United States as reported in a life cycle inventory database.[19] PCRs themselves do not dictate whether an EPD needs to be industry-wide or product-, facility-, or supply-chain-specific and, as mentioned above, usually allow for the use of secondary data in upstream supply chains.[20]

U.S. POLICIES RELATED TO EPDS AND EMBODIED EMISSIONS

Producing EPDs has become increasingly common among some sectors over the past 15 years, particularly building and construction materials, thanks to green building certification systems like Leadership in Energy and Environmental Design (LEED). Public policies in the United States involving the use of EPDs, however, have only emerged more recently, at the federal, state, and sometimes local levels. For these policies, widespread availability of reliable data on embodied emissions is essential.

CLEAN PROCUREMENT

To date, nearly all policies requiring companies to report embodied emissions using EPDs have accompanied

public procurement initiatives. Clean procurement efforts aim to stimulate demand for lower-carbon goods, which necessarily requires an understanding of which goods are actually lower-carbon. EPDs can be used to set limits on the emissions intensity of materials that can be used by contractors in projects and to verify that individual suppliers meet the threshold. Clean procurement is a potentially valuable mitigation lever, sending a market signal and giving lower-carbon producers a competitive advantage, which is especially important in the absence of other policies (e.g., carbon pricing) that are more politically challenging to adopt.

Clean procurement has its roots in the private sector, especially West Coast companies that established rules for contractors on sourcing materials to construct office buildings and other projects.[21] While private-sector procurement remains a key lever to reduce emissions across value chains to reach climate targets, public procurement can play a central role in achieving greater scale, strengthening standards, and further de-risking clean procurement.

Given the amount of public money at play and the fact that materials like cement and steel are among the most emissions-intensive products in the world, Buy Clean policies are currently centered specifically on construction materials. Clean procurement laws will likely expand beyond construction materials at some point, but the availability of reliable, product-level data is likely to lag behind. Since 2017, and especially since 2020, a growing number of state and local governments have implemented Buy Clean laws, and the Biden Administration has engaged the federal government in the Buy Clean effort as well. See Table 2 for a breakdown of Buy Clean laws and regulations.

State and local

Interest in clean public procurement is growing at the state and local level. Several have successfully passed legislation in recent years, joining California as Buy Clean states, with nine states introducing bills in 2021.[22]

California enacted the first clean public procurement program in the United States in 2017 with the Buy Clean California Act (AB 262). The law requires the California Department of General Services to set maximum GWP levels for materials sourced by contractors for public projects, including structural steel, concrete reinforcing steel ("steel rebar"), flat glass, and mineral wool board insulation.[23] California has considered adding concrete to the Buy Clean Act with supply-chain-specific EPDs but has not yet acted on legislation.[24] Because some of those product categories also have sub-categories in which GWP can vary significantly, California further divided structural steel into three different products and mineral wool board insulation into two different products.[25] California designated a specific PCR that must be used to develop EPDs for each material, along with the program operator.

To determine the limits on GWP, which were set in January 2022, California relied on industry-wide EPDs created by various trade associations that provide averages for each product that are representative of a wide group of producers. These industry-average EPDs often accounted for the vast majority of U.S. production in those categories. Although the baselines were established using industry-wide EPDs, compliance with the act requires contractors that win public bids to provide facility-specific EPDs for covered materials that are to be used in the project. This requirement allows for a more granular assessment of emissions, but it may prove challenging for some contractors to obtain from their suppliers, since single-facility EPDs are much less commonly available than product-specific, company-wide EPDs that report an average across multiple facilities.[26] Contractor-submitted EPDs only need to span the production/product stage (modules A1–A3), which includes raw materials through manufacturing. (Figure 1) The EPD is not allowed to come from a fabricator (which is typically the last production facility to process the good by providing services such as bending, welding, cutting, drilling, or other final touches), since fabrication is typically a very small percentage of the embodied emissions in basic materials and is often handled by small-to-medium-size businesses for whom EPDs can represent a significant burden.[27]

Other states' policies are more recent and in earlier stages of development, with fewer details beyond what is specified in legislation and delegated to state agencies to implement. For instance, none have identified specific PCRs, program operators, or GWP limits for covered materials.

Colorado passed the Buy Clean Colorado Act (HB 21-1303) in July 2021. The law directs the Office of the State Architect to establish, by January 2024, limits on GWP for a range of construction materials used in public

projects. The law covers a wider set of products than California's, including cement and concrete, asphalt and asphalt mixtures, and wood structural elements, while also explicitly allowing for the creation of sub-categories of materials. Like California, though, the Office of the State Architect is required to base the maximum allowable GWP of each material on the average as determined by industry-wide EPDs.[28] The limit for each material must be regularly evaluated and potentially reduced further based on industry conditions. The law requires contractors that successfully bid for public projects to submit EPDs conforming with ISO 14025 "or similarly robust life cycle assessment methods" for all covered materials but does not specify whether the EPD must be facility-specific or product-specific.[29]

New York State passed the Low-Embodied-Carbon Concrete Leadership Act (SB 542A) in December 2021. The law directs the New York Office of General Services to establish requirements for the procurement of low-embodied-carbon concrete in public projects within a year, in consultation with a stakeholder group and with consideration of industry standards.[30] The Office of General Services is required to explore the use of incentives, including bid credits, to encourage the use of low-carbon cement in public projects. The law provides no detail on how the state will evaluate embodied emissions, aside from requiring the Office of General Services to examine the use of an "expedited product evaluation protocol;" this was a change from an earlier version of the bill that specified a product-specific EPD conforming with ISO 14025 would be required.[31]

Oregon passed the Buy Clean Oregon Act (HB 4139) in March 2022. The law requires the Oregon Department of Transportation to collect product-specific EPDs conforming with ISO 14025 from public contractors for a variety of steel, concrete, and asphalt products, as well as other materials determined later with the advice of a technical advisory committee.[32] By 2025, the department must establish a program that assesses the greenhouse gas content of covered materials, conducts life cycle assessments of their construction and maintenance activities, and devises strategies for reducing embodied emissions, though unlike some other clean public procurement acts, the law does not specify setting GWP limits for materials. Within Oregon, the city of Portland initiated a low-carbon concrete program in 2019 that requires product-specific EPDs from contractors' suppliers and sets maximum GWP thresholds, meaning Portland will move ahead with firm limits on embodied carbon content before the rest of the state.[33]

In Washington state, the Buy Clean Buy Fair Washington Act (HB 1103) was introduced in 2021; while it did not pass, it included some unique elements worth noting.[34] As discussed earlier, the bill would have introduced the first supply-chain-specific EPD requirement in the United States. Unlike other states, it also would have included reporting requirements on working conditions where the materials were produced. Though the law failed to pass, provisions were added to the 2021–23 state budget to create a database to collect supply-chain-specific EPDs and labor information from state construction projects and conduct pilot projects for data collection.

Minnesota has taken a similar step toward supply-chain-specific EPDs for construction materials by commissioning a study on their feasibility, economic costs, and environmental benefits as part of an energy omnibus bill passed in 2021.[35] Minnesota has actively considered clean public procurement laws since 2019 in various forms and with different requirements. For instance, House File (HF) 2204[36] would have required the collection of facility-specific EPDs, similar to California's law, while HF 3702 would have allowed for product-specific EPDs.[37]

State-level action on the collection of data on embodied emissions will likely continue in the years ahead, with the potential for further divergences in requirements.

Federal

Federal action on clean procurement has the potential to achieve a scale far beyond what any single state could achieve. It has been estimated that a federal program covering only steel and cement could reduce emissions between 5.6 and 28 million metric tons of carbon dioxide annually—the equivalent of between 1.2 and 6.1 million cars' emissions per year.[38] Notably, this estimate does not include indirect impacts such as broader shifts in the cement and steel markets toward lower carbon products.

The General Services Administration (GSA), which manages federal buildings, issued procurement standards for concrete and asphalt in March 2022, marking the first Buy Clean policy to apply beyond a state or locality. Contractors are required to provide product-specific EPDs for all concrete and asphalt mixes. For concrete, the GSA established GWP limits for different mix types and strength classes based on a 20-percent reduction from the thresholds suggested in a study from the New Buildings Institute that drew on

36,000 publicly accessible EPDs in the United States.[39] For asphalt, the GSA is not setting GWP limits but rather is mandating sustainable production criteria, such as recycled content and other rules concerning inputs used in production.[40] EPDs for asphalt are generally less available in the United States than for concrete and some other materials, which makes it more challenging to establish a credible baseline with GWP limits. Both standards define specific PCRs and program operators. GSA is expected to expand its standards to other products over time.

Other federal departments are likely to follow GSA in establishing embodied carbon limits on materials sourced by contractors. The Biden Administration established a Buy Clean Task Force as part of a sweeping executive order on climate change in December 2021.[41] The Task Force is charged with formalizing a wider federal policy, including specific materials to be covered, EPD reporting and verification procedures, recommendations for technical assistance to suppliers, and suggested pilot programs for federal departments. Some departments have already started collecting data and launching pilot programs, including the Department of Transportation and Department of Defense.[42] In September 2022, the Biden Administration announced it would first prioritize the purchase of lower-carbon steel, concrete, asphalt, and flat glass across the federal government and provide instructions for agencies to integrate Buy Clean policies into procurement processes.[43] The White House's Buy Clean effort will also apply to federally-funded construction projects in addition to agency procurement decisions.

The 117th Congress has also sought to create EPD and Buy Clean programs, successfully in the case of the former. The Inflation Reduction Act, passed via budget reconciliation in August 2022, appropriates $250 million to the Environmental Protection Agency (EPA) to implement a program to "support the development, enhanced standardization and transparency, and reporting criteria" for EPDs, as well as to distribute grants and technical assistance for businesses to produce EPDs.[44] The law also included $100 million for a program under the EPA to label construction materials that have substantially lower embodied emissions and $2 billion to the Federal Highway Administration to leverage that labeling system to provide reimbursement of incremental

TABLE 2: EPD requirements of Buy Clean laws and regulations in the United States

YEAR	JURISDICTION	POLICY TEXT	TYPE OF EPD	STATUS	IMPLEMENTS GWP LIMITS
2022	Federal—GSA	*Facilities Standards (P100)*	Product-specific	Passed	Partially
2022	Virginia	*SB 272*	Not specified	Proposed	No
2022	Illinois	*HB 5564*	Not specified	Proposed	Yes
2022	Oregon	*HB 4139*	Product-specific	Passed	No
2021	Federal—Congress	*H.R. 5376—Inflation Reduction Act*	Not specified	Passed	No
2021	Federal—Congress	*H.R.1512—CLEAN Future Act*	Facility-specific	Proposed	Yes
2021	Washington state	*HB 1103*	Supply chain-specific	Proposed	No
2021	New Jersey	*A5223*	Product-specific	Proposed	Yes
2021	Colorado	*HB 21-1303*	Product-specific	Passed	Yes
2021	California	*AB-1365*	Supply chain-specific	Proposed	Yes
2021	New York State	*SB 542A*	Not specified	Passed	No
2020	New Jersey	*S3091*	Not specified	Passed	Yes
2019	Local—Portland	*Concrete Requirements*	Product-specific	Passed	Yes
2019	Minnesota	*HF 2204*	Facility-specific	Proposed	Yes
2019	Minnesota	*HF 3702*	Product-specific	Proposed	No
2017	California	*AB-262*	Facility-specific	Passed	Yes

Sources: Carbon Leadership Forum, Natural Resources Defense Council, BlueGreen Alliance, and C2ES.

costs and incentives to jurisdictions that source low-carbon goods for projects.

An earlier but unsuccessful bill, the CLEAN Future Act, went further both in terms of EPD development and procurement, since it would have established an expansive Buy Clean program across the federal government. The bill included similar authorization for the EPA to enhance the quality of EPDs, though with the explicit directive to also improve the availability of underlying LCA data and harmonization of LCA approaches. It included significantly more guidance—calling specifically for facility-specific EPDs—and would have given the EPA authority to go beyond a wide initial list of construction materials. It would have explicitly allowed the EPA to designate existing PCRs or lead the creation of new PCRs where none exist or where existing rules are considered inadequate. The CLEAN Future Act also would have established a publicly accessible database of EPDs.[45]

OTHER POLICY AREAS

While public procurement has been the dominant policy avenue for EPD requirements, other policy routes are also possible. For example, climate policy has historically focused on building codes that govern energy use as opposed to the codes that govern construction materials, but reliable data on embodied emissions could make building codes even more powerful climate policy tools. Setting rules on embodied emissions through building codes would allow public authorities to reinforce Buy Clean policies and extend them to the private sector to have a more holistic impact.

Building code regulations on embodied emissions are still in their infancy. Marin County in California is the first—and so far, only—jurisdiction in the United States to incorporate embodied emissions in its building codes, requiring that new buildings use low-carbon concrete.[46] Researchers and advocates see opportunities for more jurisdictions to leverage product-level data to set prescriptive limits on the embodied emissions of construction materials used in a project. Eventually, such data could enable whole-building regulations that widen the scope of mitigation opportunities to areas such as more efficient use of materials in building design and reuse of materials after deconstruction.[47]

Product-level data on embodied emissions could likewise enhance the accuracy and effectiveness of trade-based climate policies, an emerging set of tools aimed at preventing the offshoring of emissions and safeguarding the competitiveness of domestic industries. Carbon border adjustments, for example, impose fees on imported goods based on their embodied emissions and potentially provide rebates for domestic producers that export their goods. While they have historically been considered a means of ensuring any domestic carbon price also extends to imported goods, some policymakers in the United States support a border adjustment in the absence of a specific domestic carbon price.[48] This is seen by some policymakers as a way of capitalizing on the carbon efficiency of U.S. production relative to many major trading partners and forging a better domestic climate for investment in mitigation by creating a more level playing field on an embodied-emissions basis.[49] Carbon border adjustments often rely on assumed or default values of foreign producers' emissions intensity (e.g., an average in the sector in the country of origin) because of challenges with data availability. Product-level embodied carbon data could be useful for verifying the emissions of foreign producers that are subject to the border fee.

Such an approach was envisioned in the proposed Clean Competition Act, which would have allowed importers to provide an independently verified EPD to demonstrate a lower emissions intensity than whatever default value is applied for the sector. One could envision U.S. exporters doing the same to reduce an import charge under the European Union's proposed carbon border adjustment mechanism.

Last, but certainly not least in terms of emissions reduction potential, reporting on embodied carbon through an EPD or other mechanism could support the enforcement of clean product standards. Clean product standards could be viewed as a way of broadening Buy Clean to an entire product market by setting a maximum allowable level of embodied emissions per unit of a good and requiring firms that make covered products to provide proof of compliance. As such, Buy Clean laws could be seen as a precursor to clean product standards, to build demand and begin to shift product markets. The clean product standards would tighten over time according to a predictable schedule and could cover imported goods while exempting domestic exports to address competitiveness concerns. Tradability of compliance credits that producers can earn if they perform below the benchmark could be added to make the program more market-friendly and to better incentivize firms.[50]

BOX 1: A 2030 roadmap for embodied emissions reporting

Supporting widespread availability and quality of product-level data on embodied emissions can help the United States achieve its 2030 climate target by helping to facilitate strong climate policies and private-sector actions to reduce supply-chain emissions. The availability of high-quality data on embodied emissions underpins or could significantly enhance a variety of policies, particularly clean procurement and potentially future clean product standards. By 2030, to meet long-term climate goals, a robust system of EPDs will be required to enable internal company decisions with significant emissions impacts (e.g., capital stock turnover), as well as to allow companies to position themselves in jurisdictions where EPDs and other forms of product-level emissions assessments increasingly become a market norm.

There is little data on the emissions-reduction potential of clean procurement, but one study found that a program covering only steel and cement used in federally funded projects could reduce emissions between 5.6 and 28 million metric tons of carbon dioxide annually, the equivalent of between 1.2 and 6.1 million cars' emissions per year.[1] There are a number of challenges to scaling up reporting on embodied emissions at the product level and some interventions that could help.

Incentivize the creation of EPDs and other mechanisms of reporting on embodied emissions

Firms that make construction materials such as steel and cement are currently the most likely to provide product-level data on embodied emissions, most commonly in the form of an EPD, but even within the construction materials sectors EPD availability is limited for many specific products and in many parts of the United States. It is even harder to find product-level reporting on embodied emissions outside of the construction materials sector. Increasing EPD availability requires governments to first demonstrate demand through policies such as Buy Clean laws, but it also requires education, assistance, and financial incentives, especially for small and mid-size manufacturers.

The private sector will need to step up its engagement with suppliers to encourage them to provide product-level data, including through CDP and new emerging platforms for reporting. Critically, this reporting does not necessarily need to come from an EPD, which reports on a range of environmental impacts beyond embodied emissions, and thus there are simpler alternatives, such as carbon footprint reporting, that are still grounded in robust life-cycle analysis. This engagement may require exerting influence where a company accounts for a large portion of a supplier's revenue, but there are also opportunities for more cooperative approaches.

Address data gaps

Product-level reporting often requires the use of secondary data (i.e., generic data that provides industry averages) for sources of emissions upstream from a manufacturer. However, in cases where these upstream sources account for huge portions of a product's life-cycle emissions (e.g., cement in concrete), using secondary data means an EPD or other product-level report is less accurate and ultimately less useful. The rules that govern EPD development, known as product category rules, should be updated to include major sources of upstream emissions where relevant. Governments can encourage this through participation in these stakeholder processes or through policymaking that requires such reporting.

Ensure greater standardization

Comparability of product-level data, even in cases where products followed the same reporting rules, remains a significant challenge. This is in part because companies may use different background data sets (i.e., secondary data) that are needed to report on the many inputs that go into a product or different reporting tools that help them make calculations. This is typically allowed in the rules and guidelines that govern reporting, but this needs to change. Governments can facilitate this change through participation in the stakeholder processes that create reporting rules or by mandating specific sources for all uses of secondary data.

EPD SHORTCOMINGS AND OBSTACLES TO SCALING

Although a range of policies rely on or could be more effective with reliable data on embodied emissions, there are numerous ways that EPDs and the data they rely on fall short. These problems are hurdles to scaling up EPDs and making them more useful.

DATA GAPS

One challenge with EPDs is that there are currently significant gaps in primary data at various stages in products' life cycles. For many products (e.g., concrete and many common aluminum, masonry, wood, insulation, and steel products), the majority of emissions occur during upstream life cycle phases, from raw materials that are later used in the manufacturing process, but as noted earlier, it is very common to use secondary data for the upstream phases.[51] This is necessary, given the sheer number of inputs and processes that LCAs measure, many of which individually account for relatively small portions of the overall environmental impact of a product. However, this means that an EPD might be using primary data for just 10–30 percent of embodied emissions in the critical production stage of LCA, significantly diminishing the accuracy and utility of the assessment. In practice, in a government procurement program this could mean that two products that actually have significantly different emissions profiles when using primary data from their suppliers could be treated the same because they were allowed to use generic data that provides average performance information and minimizes those differences. Where there is potential for large differences in product life cycle emissions, the use of secondary data makes it more challenging to truly distinguish between players in the market and thereby undermines the purpose of reporting in the first place—letting information drive market decisions.

If EPDs expand beyond basic materials to more complex products (e.g., machinery, fashion, electronics, fast-moving consumer goods), this problem may become more pronounced, since upstream emissions tend to increase as the number of steps in a product value chain rise.

While the problem in the early stages of a product's life cycle is the lack of primary data, a problem in the later stages can be the absence of relevant data in an EPD. For some products, substantial emission impacts occur at later LCA stages, such as the use and end-of-life stages. For instance, many insulation products have significant impacts on reducing operational emissions, but as was shown in Figure 1, operational energy use is typically considered an optional part of the use stage and is often excluded from LCAs on embodied emissions. Such data are rarely required in PCRs and is not yet widely available in EPDs.[52] In practical terms, taking the building insulation example, this means that a city trying to make informed decisions on embodied carbon for the construction of a public building would lack crucial data that could impact the life-cycle emissions of a structure over a span of decades.

COMPARABILITY

A business may want to rely on product-specific EPDs to compare different products and select one with a lower environmental impact, but that is not as simple as it sounds. For one thing, product EPDs that were developed using different PCRs (e.g., if the products were from different regions) are incomparable, since differences in the rules for measuring environmental impacts may lead to different results. Even EPDs that followed the same PCRs can have incomparable results. As mentioned previously, it is common for EPDs to use secondary, generic data from life cycle inventory databases, but those databases often vary in their sources and regional specificity, which means EPDs that use secondary data from different databases may be incomparable. Secondary databases also often lack transparency on their sources and are inconsistently updated.[53] Since different LCA software and tools rely on different underlying databases, they too can lead to inconsistent results.[54]

California faced this challenge directly when initially attempting to set GWP limits by taking an average of product-specific EPDs from each product type; the inconsistencies the state found in the use of secondary data would have required adding a significant margin of error to the baseline to account for uncertainty.[55] Instead, the state ultimately used industry-wide EPDs to set GWP limits.

AVAILABILITY

For many looking to address embodied emissions, a fundamental obstacle is that product-specific EPDs are still not widespread and therefore are often unavailable. As clean procurement begins to expand from basic materials to more complex end products, the gap will

only become more magnified, as the number of suppliers from whom a company needs data increases.[56]

The availability of product-specific EPDs tends to vary significantly by state and sector. EPD availability tends to be highest on the West Coast, particularly California, as well as in states such as New Jersey, New York, and Colorado—generally reflecting where state and local policy action and demand from large corporate buyers are strongest.[57] With respect to sectors, it is difficult to assess the percentage of an industry in the United States that has produced EPDs, but concrete is likely the highest by far, reflecting a longer-standing industry practice and the fact that slight variations in mixes commonly result in new EPDs.[58] Some construction material sectors, however, have far fewer EPDs, even in states with the highest EPD availability; for example, there are few EPDs in existence for masonry, aluminum, and wood products.[59]

Obtaining EPDs in sectors outside of construction materials—such as machinery, electronic equipment, furniture, apparel, or automobiles—is even more challenging, given the greater complexity of the products and the earlier stage of development for product-level assessments in these industries. Development of PCRs, likely by trade associations and industry groups, is a critical first step, but it is a time- and resource-intensive process that likely requires a demand signal from downstream users in the marketplace. Fortunately, there are alternatives to EPDs to expand reporting on embodied emissions that are explored in the next section.

Challenges with EPD availability are likely to be magnified for states seeking facility- or supply- chain-specific EPDs. As noted earlier, these are not required in PCRs, so the availability of such EPDs is extremely limited. A 2019 report in Washington state, for instance, found that only 10 percent of concrete suppliers, no structural steel fabricators, 30 percent of rebar fabricators, and no structural wood or clay masonry producers in the state had facility-specific EPDs.[60] California similarly found limited availability of facility-specific EPDs in the sectors covered under its Buy Clean law.[61]

PATCHWORK OF REQUIREMENTS

A degree of uniformity in EPD rules across states and the federal government would support wider market uptake, helping establish embodied emissions reporting as an industry norm. By making compliance less burdensome, consistent requirements may also help facilitate expansion of reporting to industries outside of construction materials. The patchwork of EPD requirements across states with Buy Clean laws can make EPD production a burden. Efforts from some states to push beyond product-specific EPDs (e.g., to supply-chain-specific EPDs), while well-intentioned and essential over the long term, present a challenge for scaling EPD production. Different rules in different states mean firms might have to produce different EPDs for the same product to participate in public projects.

POLICY RECOMMENDATIONS

Making reliable product-level data on embodied emissions widely available is essential for a variety of climate policies and actions, including public sector Buy Clean policies and private sector scope 3 emissions reporting and targets. Fortunately, there are tangible steps that governments and the private sector can take to overcome the challenges and shortcomings associated with EPDs. Many of these steps have already been identified by expert groups such as the Carbon Leadership Forum, Third Way, CDP, the BlueGreen Alliance, and the World Business Council for Sustainable Development (WBCSD).

UPDATING PCRS TO ADDRESS DATA GAPS

Because relying on generic data for most emissions reporting does not significantly enhance transparency and serves as a weaker basis for climate action, PCRs should be updated to require primary data for key upstream processes that constitute large portions of a product's embodied emissions.[62] Setting a high floor for what counts as a "large portion" of embodied emissions, such as Washington state's proposed requirement for supply-chain-specific data for processes that account for at least 80 percent of cradle-to-gate emissions, can avoid placing too large a reporting burden on manufacturers. The market is not yet ready to accommodate such a push

for primary upstream data, but it is time for the market to catch up, and government has an important role to play in achieving this.

In addition to upstream data, PCRs should be updated to require reporting on LCA stages beyond cradle-to-gate (e.g., use, end-of-life) in cases where significant emissions occur at later points in a product's life cycle or where a product is likely to strongly impact energy use during operation of a project. Industry groups already have a strong sense of where the most significant emissions impacts occur in a product's life cycle, so they are well placed to contribute to discussions on expanding mandatory reporting phases.

Changes to PCRs are ultimately in the hands of the stakeholders that shape them, especially industry representatives and program operators, but governments can help drive these changes. For instance, state governments and the federal government can signal to the market that such reporting will increasingly become the norm through EPD reporting requirements and can provide funding for the lengthy processes involved in updating PCRs. Updates are typically done every five years, but more frequent updating may be required in the future—though this likely requires additional financial support.[63] Federal and state governments could also participate directly in processes to update PCRs. It is possible that the federal government could go even further and perhaps set its own PCRs where existing rules are inadequate (as the CLEAN Future Act would have empowered the EPA to do). The Inflation Reduction Act does not explicitly direct the EPA to evaluate existing PCRs and establish its own PCRs where necessary, but it could reasonably be interpreted to fall within the law's directive.

STANDARDIZATION TO IMPROVE COMPARABILITY AND CONSISTENCY

Improving the comparability of product-level data on embodied emissions is critical to enabling climate policy and private sector action. Greater standardization is needed on the use of secondary data and LCA tools, as well as alignment between data sources.[64] PCRs should specify which secondary data sources and tools can be used; some recent PCRs are moving in this direction, but a greater shift is needed.[65] Governments—but particularly the federal government—should signal the need for standardization to program operators through policymaking and participation in processes to update PCRs.

An open-source, comprehensive inventory database to provide secondary data specific to the United States or North America would significantly improve consistency and comparability.[66] Most of the best background data currently comes from Europe, where LCA has a longer history.[67] The federal government began developing open-source data through cross-agency collaboration in 2014, launching what is now known as the Federal LCA Commons, but this largely decentralized approach requires significantly more funding to better integrate data across agencies to fill gaps and better ensure the system can facilitate the development of truly comparable EPDs.[68] In addition to boosting funding for this effort, the federal government could require the use of the LCA Commons in Buy Clean requirements to improve comparability and consistency of EPDs. There are also other efforts underway to create national or North American life cycle inventory datasets, such as a coalition housed by the American Center for Life Cycle Assessment, but these efforts require financial support and coordination, likely from the federal government.[69] The impact of improving the quality and availability of secondary data in the United States could help facilitate reporting on embodied emissions more broadly, including to sectors beyond construction materials.

The federal government is also ideally situated to play the role of convener and standard setter to achieve greater consistency on EPD requirements in state and federal Buy Clean initiatives. Buy Clean laws are spreading relatively quickly but remain nascent, so now is an ideal time to ensure a high degree of convergence. It appears that the Inflation Reduction Act, combined with a Buy Clean push from the Biden Administration, could provide an opportunity to promote harmonization, which could lead to wider market uptake and greater scale.

INCENTIVES TO INCREASE EPD AVAILABILITY

Governments play a critical role in addressing the lack of available product-level data on embodied emissions. At both the state and federal levels, governments should provide education, assistance, and financial incentives to manufacturers to support their production of EPDs. California and Oregon have already provided such support, and any state with a mandatory Buy Clean law should follow suit.[70] The Inflation Reduction Act provides both grants and technical assistance to manufacturers to develop EPDs, though it does not specify how this aid will be targeted. Federal and state support should

be targeted to small and mid-size manufacturers that are new to EPD development and for whom embodied emissions reporting constitutes a significant burden.

While the Inflation Reduction Act provides some crucial first steps, the CLEAN Future Act would have more directly sought to expand EPD availability within construction materials and beyond. Under the sort of national program envisioned under the CLEAN Future Act, the EPA could have promoted the continued development of EPDs in construction materials sectors while expanding reporting requirements to other sectors. The CLEAN Future Act would have also offered financial and technical assistance for small and mid-sized manufacturers and would have created a Climate Star performance labeling program (initially voluntary) that draws from embodied emissions data. The lack of a similarly expansive program in the Inflation Reduction Act means the Biden Administration will need to lead in establishing limits on embodied emissions in federal agencies' procurement decisions, as the GSA is already doing. These efforts to scale EPD availability through the leverage of federal buying power will enhance the effectiveness of the EPA program funded under the Inflation Reduction Act to support EPD development. The two efforts in tandem could potentially replicate what the CLEAN Future Act sought to do.

ALTERNATIVE APPROACHES TO EXPAND PRODUCT-LEVEL EMBODIED EMISSIONS REPORTING

The availability of EPDs for construction materials is likely to increase quickly amid recent and future federal and state policymaking, but product-level data to help private companies reduce supply-chain emissions is likely to lag. The demand for such reporting, along with the gaps, is clear. For example, two-thirds of corporate members in CDP's Supply Chain Program reported in 2021 that product-level data is vitally needed for driving decarbonization, but only 2 percent of their suppliers that report through the program provide this level of granularity.[71]

In the absence of product-level data, purchasers and consumers can still take some near-term actions that likely reduce scope 3 emissions. A variety of ecolabels are well established in many product markets that offer some assurance of energy efficiency and emissions reductions. For example, the EPA's Environmentally Preferable Purchasing Program provides recommendations across numerous sectors, including electronics, construction, and some fast-moving consumer goods such as hand soap.[72] Programs such as Energy Star provide reliable information on energy consumption for many common products, and proxy information on a company or facility's climate ambition is available through the Energy Star Industrial Program and through various forms of annual greenhouse gas reporting (through both voluntary and mandatory mechanisms). Companies, however, are likely to find it challenging or impossible to credibly claim quantified reductions without granular, product-level emissions data that allows them to establish a baseline and measure the impact of a supply chain intervention.[73]

For the private sector, increasing the availability of product-level embodied emissions reporting requires increased supplier engagement. In cases where a company accounts for a significant portion of a supplier's revenue, this can include exerting influence, but there are cooperative strategies too, including providing technical assistance, capacity building, and incentives to suppliers. Within groups such as CDP's Supply Chain Program, nearly all member companies are engaging their suppliers, but only 38 percent of suppliers are engaging within their own supply chains.[74] Even the suppliers that report almost never provide product-level data. In most cases, these suppliers are likely not able to submit product-specific EPDs even if they want to, because PCRs and other program infrastructure are not yet in place. Demand is growing for other ways to expand reporting on embodied emissions at the product level, particularly for goods outside of construction materials.

Fortunately, there are other standards and reporting mechanisms available or in development with the potential to broaden reporting on embodied emissions, including product-level standards and methodologies that do not require the development of PCRs and sectoral backing. Unlike PCRs in typical EPD programs that require reporting on a broad set of environmental impacts (e.g., land, air, and water impacts), the alternative approaches available or under development tend to focus exclusively on greenhouse gas emissions. Consideration of the holistic environmental impact of a product makes producing PCRs and EPDs more costly and time-intensive, and mechanisms exist or are emerging to meet the strong market demand for a narrower focus on global warming potential.

For example, the Greenhouse Gas Protocol, which developed the most widely practiced system of organizational greenhouse gas accounting in use

today, also has a product-level standard (based on ISO's LCA standards 14040 and 14044) that allows for quantified LCA tracking of a single product over time. However, a product-level assessment developed using the Greenhouse Gas Protocol's Product Standard does not allow for comparisons between products, since it does not apply product-level rules (such as PCRs) to ensure consistent reporting in key aspects, such as data type and quality, units of analysis, system and temporal boundaries, and allocation (i.e., attribution of emissions to a single product in a manufacturing process that results in multiple products).[75] Similarly, some of the certification organizations that act as program operators for EPDs also offer services that provide a narrower greenhouse gas footprint verification, based on ISO's product carbon footprint standard 14067 (which relies on the two LCA standards but is focused solely on greenhouse gas quantification). Again, the standard does not allow for comparison between products absent assurances that the footprint analyses were conducted using identical requirements and methods.[76]

Another effort to expand product-level LCA data focuses on harnessing technology, supplier engagement, and consistent and simplified reporting. The World Business Council for Sustainable Development, working with the Greenhouse Gas Protocol and other organizations, announced the launch of the Carbon Transparency Partnership in March 2021. The initiative, which is still under development, aims to expand product-level reporting on embodied emissions to make scope 3 supply chain emissions more transparent. The initiative intends to go well beyond construction materials, expanding initially into chemicals, petrochemicals, fast-moving consumer goods, and other sectors.

The initial Carbon Transparency Partnership reporting framework, released in November 2021, provides guidelines on accounting, scope and boundary, use of data (including secondary data), other required elements for data exchange, and verification.[77] The initiative prioritizes cradle-to-gate reporting using primary data. Rather than developing new product rules, the reporting framework relies on existing standards and more granular product rules where those are available for a sector, while encouraging participating companies and relevant stakeholders to develop more detailed product or sectoral rules where those are not yet available. The initiative will extend to the use and end-of-life LCA stages at a later point, given complexity and methodological challenges, but companies can report that data if it is already available. While companies can use secondary data where no primary data is available, they are required to report the share of primary data that contributed to the overall GWP figure for a product.

Under the Partnership, World Business Council for Sustainable Development is also developing a secure platform that enables suppliers to report product-level data in whatever format the data is available. The platform for secure data exchange and supplier engagement is key to addressing the gap in primary data. The platform establishes a link between different supply chain actors, allowing a single supplier to immediately provide data to all relevant downstream companies through an open and decentralized network infrastructure that promises interoperability with other reporting platforms. Companies will need to work with their suppliers to ensure they report using the platform. Industry buy-in around the use of existing product rules for calculations—or collaboratively establishing new ones among key stakeholders—will also likely be crucial for the success of the initiative, as will sufficiently assuring companies that the exchange of data will not compromise proprietary information. The initiative announced its first successful exchange of data across its technology platform in April 2022.[78]

Related C2ES Publications:

Getting to Zero: A U.S. Climate Agenda
https://www.c2es.org/document/getting-to-zero-a-u-s-climate-agenda/

Catalyzing Investment with a National Climate Bank
https://www.c2es.org/document/catalyzing-investment-with-a-national-climate-bank-lessons-from-subnational-green-banks/

Clean Heat Pathways for Industrial Decarbonization
https://www.c2es.org/document/clean-heat-pathways-for-industrial-decarbonization/

Engineered Carbon Dioxide Removal: Scalability and Durability
https://www.c2es.org/document/engineered-carbon-dioxide-removal-scalability-and-durability/

C2ES would like to thank The Bernard and Anne Spitzer Charitable Trust, the William and Flora Hewlett Foundation, and Roger Sant and Doris Matsui for their support of this work. We would also like to thank Dave Grossman of Green Light Consulting for his contributions to this work.

ENDNOTES

1 World Business Council for Sustainable Development (WBCSD), *Pathfinder Framework: Guidance for the Accounting and Exchange of Product Life Cycle Emissions* (Geneva, Switzerland: WBCSD, 2021), *https://www.wbcsd.org/contentwbc/download/13299/194600/1*.

2 CDP, *CDP Global Supply Chain Report 2020* (London, United Kingdom: CDP, 2021), *https://cdn.cdp.net/cdp-production/cms/reports/documents/000/005/554/original/CDP_SC_Report_2020.pdf?1614160765*.

3 Science Based Targets Initiative, *Scaling Urgent Corporate Action Worldwide: Science Based Targets Initiative Annual Progress Report, 2021* (Washington, DC: SBTI, 2022), *https://sciencebasedtargets.org/resources/files/SBTiProgressReport2021.pdf*.

4 This 11 percent figure is likely higher because it does not include non-energy process emissions i.e., from chemical conversion of raw materials; World Green Building Council (WGBC), *Bringing Embodied Carbon Upfront: Coordinated Action for the Building and Construction Sector to Tackle Embodied Carbon* (Toronto, Canada: WGBC, 2019), *https://www.worldgbc.org/sites/default/files/WorldGBC_Bringing_Embodied_Carbon_Upfront.pdf*.

5 Ramboll, *Carbon Management for Transport Infrastructure: Low Carbon Infrastructure Design* (Ramboll, 2020), *https://ramboll.com/-/media/6af4c06c5b6d49f893ead78da3e81210.pdf*.

6 "Policy Resource: 2 – What is a Buy Clean Policy?", Carbon Leadership Forum, last modified December 2020, *https://carbonleadershipforum.org/what-is-a-buy-clean-policy/*.

7 ISO 14025, Environmental Labels and Declarations – Type III Environmental Declarations – Principles and Procedures, International Organization for Standardization (2006).

8 Meghan Lewis et al., *Environmental Product Declaration Requirements in Procurement Policies: An Analysis of EPD Definitions in Buy Clean and Other North American Procurement Policies* (Seattle, WA: Carbon Leadership Forum, 2021), *https://carbonleadershipforum.org/download/17510/*.

9 Carmen Fernández Fernández, Basic Concepts on Ecodesign (Brussels, Belgium: ECOSIGN Consortium, 2018), *http://www.ecosign-project.eu/wp-content/uploads/2018/09/BASIC_UNIT10_EN_Lecture.pdf*.

10 "North American PCR Catalog: Building and Construction Materials", Sustainable Minds, last modified September 2021, *https://docs.google.com/spreadsheets/u/1/d/1lS7ukMUG1cAWnMGHKiqIvgcgeHQOeICIIH5t95InZy8/pubhtml*.

11 This usage of the term "global warming potential" is distinct from the usage to describe the heat-trapping abilities of different greenhouse gases.

12 ISO 14025, Environmental Labels and Declarations – Type III Environmental Declarations – Principles and Procedures.

13 ISO 14040, Environmental Management – Life Cycle Assessment – Principles and Framework, International Organization for Standardization (2006).

14 Meghan Lewis et al., *Environmental Product Declaration Requirements in Procurement Policies: An Analysis of EPD Definitions in Buy Clean and Other North American Procurement Policies*.

15 John Orr and Orlando Gibbons, *How to Calculate Embodied Carbon* (London, United Kingdom: The Institution of Structural Engineers, 2020), *https://www.istructe.org/IStructE/media/Public/Resources/istructe-how-to-calculate-embodied-carbon.pdf*.

16 Nora Wang Esram and Ming Hu, *Knowledge Infrastructure: the Critical Path to Advance Embodied Carbon Building Code*s (Washington, DC: American Council for an Energy-Efficient Economy, 2021), *https://www.aceee.org/sites/default/files/pdfs/Embodied%20Carbon%20in%20Buildings%2012-2-21%20final.pdf*.

17 Meghan Lewis et al., *Environmental Product Declaration Requirements in Procurement Policies: An Analysis of EPD Definitions in Buy Clean and Other North American Procurement Policies*.

18 Public contracts: Bid specifications: Buy Clean California Act, Assembly Bill 262, California General Assembly (2017), *https://leginfo.legislature.ca.gov/faces/billNavClient.xhtml?bill_id=201720180AB262*.

19 Meghan Lewis et al., *Buy Clean Buy Fair Washington Project Progress Report* (Olympia, WA: Washington Department of Commerce, 2021), *https://www.commerce.wa.gov/wp-content/uploads/2022/01/UW-Carbon-Leadership-Forum-SEEP-BCBF-Progress-Report-final.pdf*.

20 Meghan Lewis et al., *Environmental Product Declaration Requirements in Procurement Policies: An Analysis of EPD Definitions in Buy Clean and Other North American Procurement Policies.*

21 John Milko, *We Can't Cut What We Can't Count: Using Environmental Product Declarations to Measure and Reduce Embodied Carbon* (Washington, DC: Third Way, 2021), *https://www.thirdway.org/report/we-cant-cut-what-we-cant-count-using-environmental-product-declarations-to-measure-and-reduce-embodied-carbon*.

22 "2022 Embodied Carbon Policy Action", Carbon Leadership Forum, last modified December 2021, *https://carbonleadershipforum.org/looking-ahead-policy-action/*.

23 Buy Clean California Act, Assembly Bill 262, California General Assembly.

24 An act to add Section 3503.1 to the Public Contract Code, Assembly Bill 1365, California General Assembly (2021), *https://leginfo.legislature.ca.gov/faces/billNavClient.xhtml?bill_id=202120220AB1365*.

25 California Department of General Services (DGS), *Buy Clean California Act Legislative Report* (Sacramento, CA: DGS, 2022), *https://www.dgs.ca.gov/-/media/Divisions/DGS/LegReports/Accessible-Reports/2022/BCCA-Legislative-Report_final.pdf?la=en&hash=C970382B9DC8530385F0F0FFCD1928D2B7533B99*.

26 California Department of General Services, *Buy Clean California Act Legislative Report.*

27 California Department of General Services, *Buy Clean California Act Legislative Report.*

28 Concerning Measures to Limit the Global Warming Potential for Certain Materials Used in Public Projects, House Bill 21-1303, Colorado General Assembly (2021), *https://leg.colorado.gov/sites/default/files/2021a_1303_signed.pdf*.

29 Concerning Measures to Limit the Global Warming Potential for Certain Materials Used in Public Projects, House Bill 21-1303, Colorado General Assembly.

30 Relates to Provisions in State Procurement Contracts Involving the Use of Low Embodied Carbon Concrete, A2591A, New York State Assembly (2021), *https://legislation.nysenate.gov/pdf/bills/2021/A2591A*.

31 Relates to the New York State Low Embodied Carbon Concrete Leadership Act, A8617C, New York State Assembly (2019), *https://legislation.nysenate.gov/pdf/bills/2019/A8617C*.

32 Relating to Reductions of Greenhouse Gas Emissions in the State's Transportation System, House Bill 4139, Oregon State Legislature (2022), *https://olis.oregonlegislature.gov/liz/2022R1/Measures/Overview/HB4139*.

33 Notice of New Requirements for Concrete, City of Portland (2022), *https://www.portland.gov/sites/default/files/2022/Concrete%20GWP%20Thresholds%20Chief%20Engineers%20Memo%20FINAL%2020220523.pdf*.

34 Improving Environmental and Social Outcomes with the Production of Building Materials, House Bill 1103, Washington State Legislature (2021), *https://app.leg.wa.gov/billsummary?BillNumber=1103&Initiative=false&Year=2021*.

35 House File 2110, Minnesota Legislature (2021), *https://www.revisor.mn.gov/bills/text.php?number=HF2110&version=1&session=ls92&session_year=2021&session_number=0*.

36 House File 2204, Minnesota Legislature (2021), *https://www.revisor.mn.gov/bills/bill.php?b=House&f=HF2204&ssn=0&y=2021*.

37 House File 3702, Minnesota Legislature (2021), *https://www.revisor.mn.gov/bills/bill.php?f=HF3702&b=house&y=2021&ssn=0*.

38 The upper bound of this estimate assumes transformative changes from the widespread use of technologies such as carbon capture and storage in the cement industry; Ali Hasanbeigi, Dinah Shi, and Harshvardhan Khutal, *Federal Buy Clean for Cement and Steel: Policy Design and Impact on Industrial Emissions and Competitiveness* (St. Petersburg, FL: Global Efficiency Intelligence, 2021), *https://static1.squarespace.com/static/5877e86f9de4bb8bce72105c/t/614780a235d33358f77f09db/1632075952085/Federal+Buy+Clean+For+Cement+And+Steel-+Sept2021.pdf*.

39 Low Embodied Carbon Concrete Standards for All GSA Projects, General Services Administration (2022), *https://www.gsa.gov/cdnstatic/Low%20embodied%20carbon%20concrete%20SOW%20language%203-29-22_0.pdf*; the GSA standard cited the following: New Buildings Institute, *Lifecycle GHG Impacts in Building Codes*.

40 Environmentally Preferable Asphalt Standards for all GSA Projects, General Services Administration (2022), *https://www.gsa.gov/cdnstatic/Environmentally%20preferable%20asphalt%20SOW%20language%203-29-2022_0.pdf*.

41 Executive Order No. 14057, "Catalyzing Clean Energy Industries and Jobs Through Federal Sustainability", Federal Registrar, Vol. 86, No. 236 (2021), *https://www.govinfo.gov/content/pkg/FR-2021-12-13/pdf/2021-27114.pdf*.

42 White House, "Fact Sheet: President Biden Signs Executive Order Catalyzing America's Clean Energy Economy through Federal Sustainability", December 8, 2021, *https://www.whitehouse.gov/briefing-room/statements-releases/2022/02/15/fact-sheet-biden-harris-administration-advances-cleaner-industrial-sector-to-reduce-emissions-and-reinvigorate-american-manufacturing/*.

43 White House, "Fact Sheet: Biden-Harris Administration Announces New Buy Clean Actions to Ensure American Manufacturing Leads in the 21st Century", September 15, 2022, *https://www.whitehouse.gov/briefing-room/statements-releases/2022/09/15/fact-sheet-biden-harris-administration-announces-new-buy-clean-actions-to-ensure-american-manufacturing-leads-in-the-21st-century/*.

44 Inflation Reduction Act, H.R. 5376, 117th Congress (2022), *https://www.congress.gov/bill/117th-congress/house-bill/5376/text*.

45 CLEAN Future Act, H.R. 1512, 117th Congress (2021), *https://www.congress.gov/bill/117th-congress/house-bill/1512/text*.

46 Nora Wang Esram and Ming Hu, *Knowledge Infrastructure: the Critical Path to Advance Embodied Carbon*.

47 New Buildings Institute, *Lifecycle GHG Impacts in Building Codes* (Portland, Oregon: New Buildings Institute, 2022), *https://newbuildings.org/wp-content/uploads/2022/02/NBI_LI1.pdf*.

48 Chris Kardish, Jason Ye, and Nathaniel Keohane, *Carbon Border Adjustments: Considerations for Policymakers* (Washington, DC: Center for Climate and Energy Solutions, 2022), *https://www.c2es.org/wp-content/uploads/2022/06/carbon-border-adjustments-considerations-for-policymakers.pdf*.

49 Catrina Rorke and Greg Bertelsen, *America's Carbon Advantage* (Washington, DC: Climate Leadership Council, 2020), *https://clcouncil.org/reports/americas-carbon-advantage.pdf*

50 Various organizations have proposed tradable performance standards for industrial goods in recent years, including: Breakthrough Energy, *Manufacturing Policies from the Climate Policy Playbook* (Washington, DC: Breakthrough Energy, 2021), *https://www.breakthroughenergy.org/~/Media/Files/BEV/Playbooks/Federal/Manufacturing/USFedManuComplete.pdf*; John Feldmann and Kevin Kennedy, *Toward a Tradable, Low-Carbon Product Standard for Steel: Policy Design Considerations for the United States* (Washington, DC: WRI, 2021), *https://files.wri.org/d8/s3fs-public/toward-tradable-low-carbon-product-standard-steel.pdf*; Taryn Fransen et al., *Toward a Tradable, Low-Carbon Product Standard for Cement: Policy Design Considerations for the United States* (Washington, DC: WRI, 2021), *https://files.wri.org/d8/s3fs-public/toward-tradable-low-carbon-cement-standard.pdf*; Ben King et al., Clean Product Standard: a New Approach to Industrial Decarbonization (New York, NY: Rhodium Group, 2020), *https://rhg.com/wp-content/uploads/2020/12/Clean-Products-Standard-A-New-Approach-to-Industrial-Decarbonization.pdf*.

51 Meghan Lewis et al., *Environmental Product Declaration Requirements in Procurement Policies: An Analysis of EPD Definitions in Buy Clean and Other North American Procurement Policies*.

52 Meghan Lewis et al., Environmental Product Declaration Requirements in Procurement Policies: An Analysis of *EPD Definitions in Buy Clean and Other North American Procurement Policies.*

53 Nora Wang Esram and Ming Hu, *Knowledge Infrastructure: the Critical Path to Advance Embodied Carbon Building Codes.*

54 Nora Wang Esram and Ming Hu, *Knowledge Infrastructure: the Critical Path to Advance Embodied Carbon Building Codes.*

55 Fenestration and Glazing Industry Alliance (FGIA), "Essentials of the 'Buy Clean California' Act", FGIA News, May 15, 2019, *https://fgiaonline.org/news/essentials-of-the-buy-clean-california-act.*

56 World Economic Forum, *Net-Zero Challenge: the Supply Chain Opportunity.*

57 John Milko, *We Can't Cut What We Can't Count: Using Environmental Product Declarations to Measure and Reduce Embodied Carbon.*

58 Meghan Lewis et al., *Buy Clean Buy Fair Washington Project Progress Report.*

59 Meghan Lewis et al., *Buy Clean Buy Fair Washington Project Progress Report.*

60 Kathrina Simonen et al., *Buy Clean Washington Study* (Olympia, WA: Washington State Legislature (2019), *https://carbonleadershipforum.org/download/2422/.*

61 California Department of General Services, *Buy Clean California Act Legislative Report.*

62 Meghan Lewis et al., *Environmental Product Declaration Requirements in Procurement Policies: An Analysis of EPD Definitions in Buy Clean and Other North American Procurement Policies.*

63 Stephanie Carlisle et al., *Buy Clean California Limits: a Proposed Methodology for Assigning Industry-Average GWP Values for Steel, Mineral Wool, and Flat Glass in California* (Seattle, WA: Carbon Leadership Forum, 2022), *https://carbonleadershipforum.org/download/20433/.*

64 Stephanie Carlisle et al., *Buy Clean California Limits: a Proposed Methodology for Assigning Industry-Average GWP Values for Steel, Mineral Wool, and Flat Glass in California.*

65 Meghan Lewis et al., *Environmental Product Declaration Requirements in Procurement Policies: An Analysis of EPD Definitions in Buy Clean and Other North American Procurement Policies.*

66 Ruth Cox and John Milko, *Administrative Pathways to a Federal Buy Clean Program* (Washington, DC: Third Way, 2021), *http://thirdway.imgix.net/pdfs/administrative-pathways-to-a-federal-buy-clean-program.pdf.*

67 Kathrina Simonen et al., *Buy Clean Washington Study, Appendix C* (Olympia, WA: Washington State Legislature (2019), *https://carbonleadershipforum.org/download/2422/.*

68 Ezra Kahn, Erin Antognoli, Peter Arbuckle, "The LCA Commons – How an Open-Source Repository for U.S. Federal Life Cycle Assessment (LCA) Data Products Advances Inter-Agency Coordination", *Applied Sciences* (January 2022) *https://www.mdpi.com/2076-3417/12/2/865/htm*; Ruth Cox and John Milko, *Lessons Learned from California Buy Clean* (Washington, DC: Third Way, 2022), *http://thirdway.imgix.net/pdfs/lessons-learned-from-california-buy-clean.pdf*; Ruth Cox and John Milko, *Administrative Pathways to a Federal Buy Clean Program.*

69 Kathrina Simonen et al., *Buy Clean Washington Study, Appendix C.*

70 Kathrina Simonen et al., *Buy Clean Washington Study.*

71 CDP, *CDP Global Supply Chain Report 2021* (London, United Kingdom: CDP, 2022), *https://cdn.cdp.net/cdp-production/cms/reports/documents/000/006/106/original/CDP_SC_Report_2021.pdf?1644513297.*

72 Environmental Protection Agency, *Recommendations of Specifications, Standards, and Ecolabels for Federal Purchasing* (Washington, DC: EPA, 2022), *https://www.epa.gov/system/files/documents/2022-05/EPA%20Recommendations%20of%20Specs%20Standards%20and%20Ecolabels%20PDF_051222.pdf.*

73 Johannes Erhard et al., *Overcoming Barriers for Corporate Scope 3 Action in the Supply Chain* (Munich, Germany: World Wildlife Fund, 2019), *https://www.wwf.de/fileadmin/fm-wwf/Publikationen-PDF/WWF-Overcoming-barriers-for-corporate-scope-3.pdf*.

74 CDP, *CDP Global Supply Chain Report 2021*.

75 Greenhouse Gas Protocol, Product Life Cycle Accounting and Reporting Standard (Washington, DC: Greenhouse Gas Protocol, 2011), *https://ghgprotocol.org/sites/default/files/standards/Product-Life-Cycle-Accounting-Reporting-Standard_041613.pdf*.

76 ISO 14067, Carbon Footprint of Products – Requirements and Guidelines for Quantification and Communication, International Organization for Standardization (2012); see also Peng Wu, Bo Xia, and Xiangyu Wang, "The Contribution of ISO 14067 to the Evolution of Global Greenhouse Gas Standards—a Review", *Renewable and Sustainable Energy Reviews* (March 2015).

77 World Business Council for Sustainable Development (WBCSD), *Pathfinder Framework: Guidance for the Accounting and Exchange of Product Life Cycle Emissions* (Geneva, Switzerland: WBCSD, 2021), *https://www.wbcsd.org/contentwbc/download/13299/194600/1*.

78 WBCSD, "Partnership for Carbon Transparency (PACT) Leads First Exchange of Emissions Data Across Different Tech Solutions", April 14, 2022, *https://www.wbcsd.org/Programs/Climate-and-Energy/Climate/SOS-1.5/News/Partnership-for-Carbon-Transparency-PACT-leads-first-exchange-of-emissions-data-across-different-tech-solutions*.

BOX ENDNOTES

1 The upper bound of this estimate assumes transformative changes from the widespread use of technologies such as carbon capture and storage in the cement industry; Ali Hasanbeigi, Dinah Shi, and Harshvardhan Khutal, *Federal Buy Clean for Cement and Steel: Policy Design and Impact on Industrial Emissions and Competitiveness* (St. Petersburg, FL: Global Efficiency Intelligence, 2021), *https://static1.squarespace.com/static/5877e86f9de4bb8bce72105c/t/614780a235d33358f77f09db/1632075952085/Federal+Buy+Clean+For+Cement+And+Steel-+Sept2021.pdf*.

C2ES CENTER FOR CLIMATE AND ENERGY SOLUTIONS

The Center for Climate and Energy Solutions (C2ES) is an independent, nonpartisan, nonprofit organization working to forge practical solutions to climate change. We advance strong policy and action to reduce greenhouse gas emissions, promote clean energy, and strengthen resilience to climate impacts.

3100 CLARENDON BLVD. SUITE 800 ARLINGTON, VA 22201 703-516-4146 C2ES.ORG