Buy Clean Indicators

Approaches for Measuring Policy Effectiveness

November 2024

Carbon Leadership Forum

About the Carbon Leadership Forum

The Carbon Leadership Forum accelerates the transformation of the building sector to radically reduce the greenhouse gas emissions attributed to materials (also known as embodied carbon) used in buildings and infrastructure. We research, educate, and foster cross-collaboration to bring the embodied carbon of buildings and infrastructure down to zero.

Authors

The research team from the Carbon Leadership Forum (CLF) and the Life Cycle Lab at the University of Washington (UW) College of Built Environments:

- Brook Waldman, Low-Carbon Products Lead, CLF
- Jordan Palmeri, Senior Researcher, UW*
- Kathrina Simonen, Professor, UW
- Meghan Lewis, Program Director, CLF

Author contributions: Writing — original draft: B.W.; Writing — review and editing: J.P., K.S., M.L., B.W.; Conceptualization: J.P., K.S.; Methodology: J.P., B.W.; Visualization: B.W.; Funding acquisition: K.S., M.L.

*Jordan Palmeri is also a part-time Senior Manager of the Low Carbon Products team at the CLF. His contributions to this work were in his role as Senior Researcher at UW.

Competing interests statement: The Carbon Leadership Forum receives gifts from sponsors, including manufacturers and trade associations, which are listed here: https://carbonleadershipforum. org/our-sponsors/.

Acknowledgments

The research team would like to thank Dr. Cecilia Springer of Global Efficiency Intelligence and Charlie Martin of BlueGreen Alliance for their thoughtful and insightful reviews of a report draft. Their feedback led to many improvements. We would also like to thank the Sea Change Foundation for supporting this research at the University of Washington.

This research and project began while the CLF was hosted at UW. After the CLF became an independent nonprofit in the spring of 2024, this project continued as a collaboration between UW and CLF staff. The UW team appreciates the CLF's commitment to disseminating this work broadly. The CLF team appreciates UW's continued technical support of the publication.

Citation

Waldman, B., Palmeri, J., Simonen, K., and Lewis, M. (2024). *Buy Clean Indicators: Approaches for Measuring Policy Effectiveness*. Carbon Leadership Forum.

Copyright

Cover Image by arielrobin from Pixabay.

Contents

Executive Summary

Buy Clean is a procurement policy approach incorporating low-carbon requirements into government construction materials purchasing. One major goal of Buy Clean policies is to reduce industrial greenhouse gas (GHG) emissions by driving down the emissions intensity of construction materials manufacturing. With so much recent and ongoing activity around Buy Clean policy passage and implementation, policymakers and their collaborators would benefit from (i) a clearly articulated Buy Clean theory of change, and (ii) tools to evaluate Buy Clean policy effectiveness.

Theory of Change

We propose a Buy Clean *theory of change* that connects specific policy interventions to a policy goal via desired outcomes. A desired outcome is a condition that the policy intervention (hopefully) causes to happen. It is also a precondition for the goal to occur. This report focuses on Buy Clean's climate goals, particularly on the embodied carbon (EC) of construction materials — i.e., the GHG emissions arising from their production (the focus of Buy Clean and this report) as well as their transportation, installation, maintenance, and disposal.

Our proposed theory of change focuses on the climate goals of Buy Clean and defines the following components, also outlined in Figure 2:

1. Common Buy Clean **policy interventions** directed toward this goal:
    - require EPDs
    - institute robust EPD requirements
    - Implement global warming potential (GWP) limits
    - incentivize lowest carbon purchases, in conjunction with limits
2. Buy Clean **desired outcomes** that provide the link between the interventions and the goal:
    - reduced embodied carbon from agency procurement
    - shifted industrial production practices
    - better GWP data and reporting
    - creation of low-carbon markets
3. Major **policy goal:** improved material emissions intensity. (Buy Clean has many goals. In this report, we focus specifically on this goal.)
   A material's *emissions intensity* is the amount of GHG emissions that arise from producing a unit of that material. This report often refers to a material's emissions intensity as its average global warming potential (GWP), the metric used to track climate change impact in environmental product declarations (EPDs).

Indicators and Metrics

For assessing policy effectiveness, we propose a series of **indicators and associated metrics** (summarized in Table 1) to measure the extent to which the desired outcomes have been achieved.

Table 1. Proposed outcomes, indicators, and metrics for tracking Buy Clean policy success.

Desired outcome	Indicator	Metric
Reduced agency procurement EC	Reduced average EC per unit material	Average GWP per unit per material procured by an agency over a given period, compared to baseline performance
Shifted industrial production practices	Uptake of current best practices	Number of facilities that incorporate current best practices into their production processes
	Innovative changes to industrial processes	Number of facilities that incorporate innovative changes into their production processes
	Industry-average product type GWP	(a) Reported GWP in industry-average EPD for a given product type, and changes over time (b) Average GHG emissions at industrial facilities based on reporting to EPA and/or states
Better GWP data and reporting	EPD availability	Number of EPDs (for a given product type), and changes over time
	Streamlined EPD production	Resources (amount of time and/or money) required to generate an EPD (per product category)
	EPD accessibility	Number of PCRs and/or digital EPDs aligned with accessibility/usability standards
	More specific data in EPDs	(a) Number of PCRs that specify supply-chain-specific data requirements (b) Average percent supply-chain-specificity score across EPDs in a product type
	More consistent data in EPDs	(a) Number of PCRs with prescriptive background data selection requirements (b) Number of publicly available background LCI datasets that meet quality and operability criteria for construction product EPDs
	LCA knowledge, education, and use in policy	(a) Number of government staff who understand LCA basics, measurable with surveys (b) Number of programs developed that build upon Buy Clean policies
Creation of low-carbon markets	Commercialization of new low-carbon practices	Number of low-carbon products (defined by the measurement and reporting mechanisms described above) available in the market
	Low-carbon product startup companies	(a) Number of startups related to Buy Clean materials (b) Number of those startups that big companies purchase
	Reduced production costs	Levelized cost of a low-carbon product over time
	Reduced procurement prices	Reduced average price per given low-carbon product

Using and Prioritizing Indicators

This report includes an initial gap analysis that assesses the current state of information required for implementing the proposed indicators and what additional resources would be needed to start using the indicators.

Different policies have different desired outcomes, and we do not expect any agency or organization to have the resources to track all possible indicators. Therefore, we also provide a framework for prioritizing indicators to help agencies and organizations choose which indicators to invest resources into tracking. The prioritization framework includes the following steps:

1. For a given indicator, score it according to the following three factors using a simple Likert scale (1–3):
    a. GWP impact: *To what extent does the item relate to substantial emissions reductions?*
    b. Buy Clean causality: *To what extent does the Buy Clean policy directly cause the change?*
    c. Feasibility to measure: *How easily could someone (government agency, consultant, independent non-profit, etc.) establish a system and track the indicator and its associated metric(s) over time?*
2. Combine the scores for each factor above by multiplying them together to generate an *indicator score*. The combined indicator scores will be somewhere between 1 (lowest/worst score) and 27 (highest/best score).
3. Follow the above two steps for any/all indicators under consideration. Use the combined scores to rank or prioritize the set of potential indicators.

Conclusions and Recommendations

In this report, we articulate a Buy Clean theory of change and propose a set of indicators for tracking Buy Clean policy effectiveness in reducing industrial greenhouse gas emissions from building materials. We hope that agencies and organizations that implement or evaluate Buy Clean policies can use this resource to build policy evaluation frameworks that suit their needs.

We also hope that other active organizations in the Buy Clean policy space will build upon and refine the initial proposals here and propose similar indicators for tracking labor and economic growth goals as a complement to the climate goals described in this report. Ultimately, more robust policy evaluation can inform new policies and help improve existing policies as agencies modify or add interventions.

Introduction

Buy Clean is a procurement policy approach incorporating low-carbon requirements into government construction materials purchasing. Buy Clean policies require environmental product declarations (EPDs) for reporting the impacts of producing building materials. EPDs account for greenhouse gas emissions across the life cycle of a product as global warming potential (GWP), expressed in carbon dioxide equivalents (CO_2e). Many policies also utilize maximum GWP values to limit the greenhouse gas impacts of their purchases. Other policies use incentives to provide purchasing preference for the lowest carbon materials on the market. The first Buy Clean procurement policy was introduced in the US via the 2017 passage of the Buy Clean California Act (BCCA). Since then, multiple states, cities, regional authorities, and the US federal government have enacted similar policies. Federal agencies are currently integrating billions of dollars dedicated to low-carbon construction materials into government spending via the Inflation Reduction Act (Office of the Federal Chief Sustainability Officer, 2023).

Taking time to assess policy effectiveness and impacts can support the refinement of existing programs and better development and implementation of similar policies in other jurisdictions. This report aims to contribute to this effort by (a) articulating Buy Clean policy goals and a related theory of change, (b) proposing a series of indicators and associated metrics that could be used to assess Buy Clean policy effectiveness at meeting those goals, and (c) presenting a prioritization method to help agencies choose which indicators to include in a policy assessment framework.

Buy Clean Goals and Theory of Change

A *theory of change* describes how and why we expect a desired change to occur, connecting what a program does with its desired goals (Center for Theory of Change, 2023). This report proposes a Buy Clean theory of change, defining the following components and their relationships in the context of Buy Clean policies.

- policy goal: what the policy aims to accomplish, often one component of a broader goal
- policy intervention: a specific, objective activity that the policy implements
- desired outcomes: a condition that the policy intervention aims to bring about. (These are also preconditions to achieving the policy goal.)

These above items provide the context for *what* an evaluation would be trying to assess, and thus they set the stage for the primary focus of this report — the indicators and metrics that describe *how* one would evaluate a Buy Clean policy:

- indicator: measurable signal that demonstrates the extent to which the desired outcome has been achieved
- metric: how the indicator is measured

Buy Clean Goals

Buy Clean weaves together multiple policy priorities to address several different goals related to climate change, labor, economic growth, trade, environmental impacts, and others (BlueGreen

Alliance, 2022). In this report, we focus on climate goals. Buy Clean is one piece of a broader policy portfolio strategy with a major goal of driving down industrial greenhouse gas emissions, with a particular focus on the embodied carbon of construction materials. The *embodied carbon* (EC) of construction materials refers to the greenhouse gas (GHG) emissions arising from their production (the focus of Buy Clean and of this report) as well as their transportation, installation, maintenance, and disposal. Building and infrastructure material embodied carbon is a significant contributor to climate change, responsible for roughly 17% of annual global GHG emissions (Lambert & Lewis, 2024), but EC is often undercounted in GHG accounting systems (Hasanbeigi & Springer, 2018).

Total embodied carbon emissions are a function of two major variables: (a) *material emissions intensity* — the emissions associated with producing a given unit of construction material; and (b) *material quantity* — the amount of material produced and consumed. Emissions intensity is a *supply-side* issue, as it is a function of a product's manufacturing processes and supply chain. Quantity is a *demand-side* issue, as it is a function of agency and owner choices to purchase materials

Many complementary policies and programs aim to address one or both major variables. Buy Clean predominantly focuses on the first variable in this equation — its primary *policy goal* is to *improve material emissions intensity* (i.e., to reduce the per-unit embodied emissions of materials). Most Buy Clean policies set global warming potential (GWP) limits. These limits, such as BCCA's limit of 890 kg CO_2e *per metric ton* of rebar (DGS, 2024), act on a per-unit basis to drive down emissions intensity.

Other policies and programs aim to address the other variable in the embodied carbon equation — material quantities. CLF's *Scaling Buy Clean Policy* report discusses many complementary policies, including ones addressing material consumption (Palmeri et al., 2024).

Figure 1 illustrates this concept of a set of complementary programs, all aimed towards reducing embodied carbon emissions, where Buy Clean is one policy in that set.

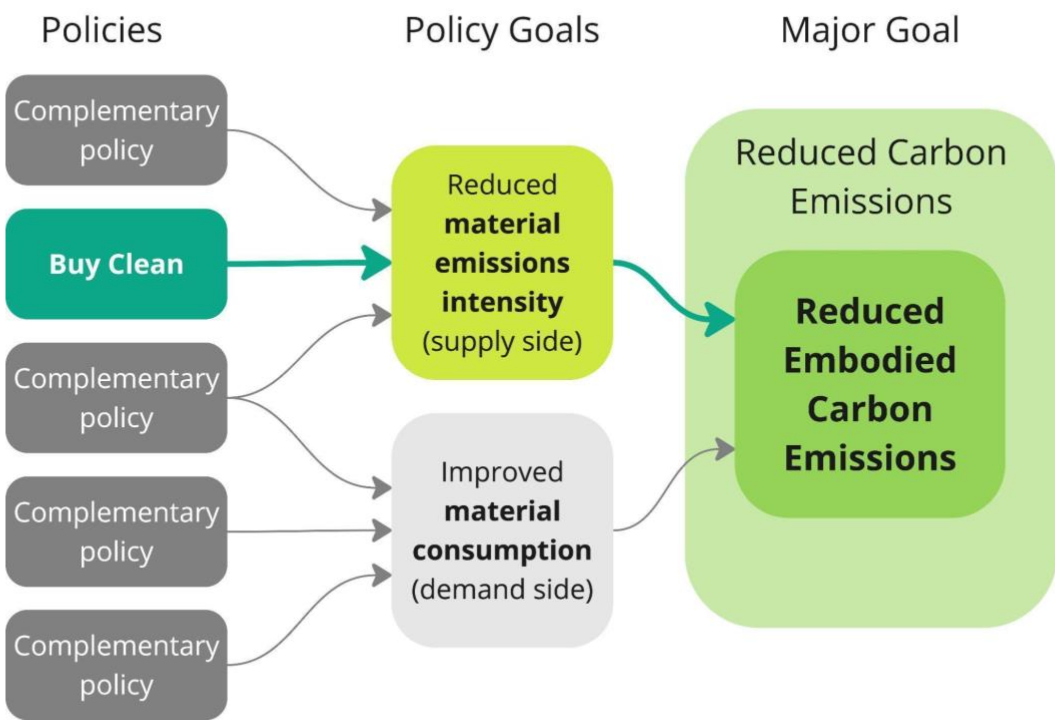

Figure 1. Buy Clean policy goal in context. Buy Clean — which aims at bringing down material emissions intensity — is one policy type in a broader portfolio of policies that share the goal of reducing embodied carbon emissions. Buy Clean also has other goals besides reducing carbon emissions (not shown in the diagram) that are outside of this report's scope.

Theory of Change: Linking Buy Clean Policy Goals to Interventions

As described above, one of Buy Clean's major goals is to reduce the embodied carbon emissions intensity of construction materials. A policy's *interventions* — the specific activities that the policy implements — aim to address that goal.

Buy Clean policies typically include some combination of the following interventions (CLF, 2024; Waldman et al., 2024):

- require EPDs
- institute requirements for "robust EPDs" (i.e., more reliable and comparable EPDs)
- implement GWP limits
- incentivize lowest carbon purchases (in combination with limits)

A *theory of change* connects a program's particular interventions to its broader goal by defining *desired outcomes* that (hopefully) result from the interventions. The desired outcomes also serve as preconditions for achieving the goal (Center for Theory of Change, 2023). That is, the interventions bring about the outcome. And that outcome is a precondition for realizing the goal.

In this report, we propose that Buy Clean policy has the following major desired outcomes:

- reduced emissions of agency-procured construction materials
- shifted industrial production practices

- better GWP data and reporting
- creation of low-carbon markets for conventionally carbon-intensive materials

Buy Clean's policy interventions (e.g., setting GWP limits) aim to lead to desired outcomes (e.g., shifts in industry). And these outcomes are preconditions for the overall goal of reducing embodied carbon emissions. So, they are both *outcomes* and *preconditions*, and we consider them as one or the other depending on the context. (From the vantage point of the policy interventions, they are the desired outcomes; from the vantage point of the policy goal, they are the preconditions.) In this way, the outcomes serve as a link between the policy's objective activities and the bigger goal. Figure 2 illustrates the relationship between the interventions, desired outcomes, and policy goals.

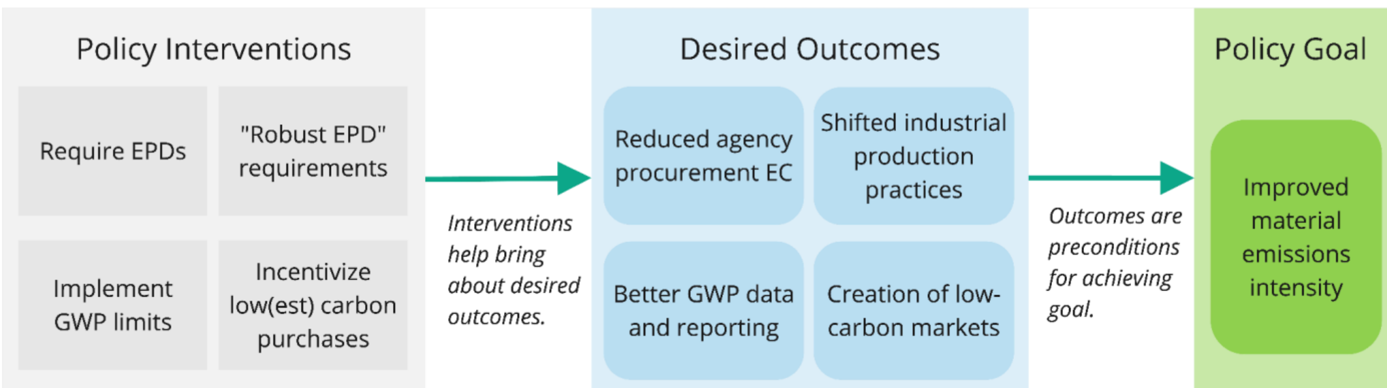

Figure 2. Buy Clean policy theory of change. Policy interventions help bring about the desired outcomes. The desired outcomes serve as preconditions for the achievement of the policy goal.

For each major outcome, we propose one or more *indicators* that can be used to help determine the success of Buy Clean policies towards the outcome and the goal of emission reductions. The next section of this report covers in detail each desired outcome and its associated indicators.

Policy Evaluation: Indicators and Metrics

The theory of change section above outlines a Buy Clean policy's objectives and activities — what it aims to do and the building blocks to get there. That still leaves open the question of how well the policy as implemented is meeting its objectives, especially since a Buy Clean policy's desired outcomes are not always clearly visible or measurable. To answer this question, agency staff and their collaborators could apply a Buy Clean evaluation framework that would include a series of (i) indicators — signals that demonstrate the extent to which the desired outcomes have been achieved; and (ii) metrics — measurements that quantify the indicator's presence. The indicators and metrics "help evaluate overall program impact and promote improvement of program components…[and] help illustrate and communicate the performance of a program and engage relevant partners to support or deliver a program's activities" (Srivastava et al., 2024).

To support the development of Buy Clean evaluation frameworks, this report proposes several indicators and associated metrics that agencies and partners can use to track policy success. Table 1 summarizes the proposed indicators and associated metrics for each desired outcome.

There is not always a direct linear relationship between policy, outcomes, and indicators. We generally focus here on the many cases where the Buy Clean policy influences the outcomes. (For example, a policy requires EPDs, which spurs demand, resulting in more companies producing more EPDs.) But it's also the case that the relationship can happen in the other direction. (More EPD availability might make it more likely for a policy to be passed.) So, while we generally focus here on indicators that help demonstrate the effects of policy, it's important to remember that all these factors work together in an ecosystem, where conditions can affect and reinforce each other non-linearly.

The following sections provide further descriptions of each indicator and metric, organized by the four desired outcomes.

Desired Outcome: Reduced Embodied Carbon of Agency-Procured Construction Materials

Indicator: Reduced average GWP per unit of construction material

Reducing an agency's overall construction material embodied carbon emissions is a function of both (i) efficiency, i.e., the GWP per unit of material consumed; and (ii) consumption, i.e., how many units of material are consumed. Buy Clean policies particularly focus on the first item of efficiency. Ideally, there are complementary policies and other initiatives aimed at the second item — minimizing the total amount of material used, especially for higher-carbon materials.

This indicator most directly links the policy with the goal of emissions reductions, as agencies can use the interventions of GWP limits and/or targets to ensure that the average GWP per unit of material that the agencies procure will decrease over time. The other indicators on this list are equally important (and potentially much more significant in impact), but less direct.

Metric: average GWP per unit per material procured by an agency over a given period, compared to baseline performance. Table 2 provides a sample scheme for tracking procurement GWP over time by product type.

- Baseline = average GWP per unit product type before policy implementation of GWP limits/targets/etc. based on (a) collected data per agency, weighted by quantities procured; and/or (b) industry-average data.
- Successive years (years 2, 4, 6, etc.) = average GWP per unit product type (e.g., X kg CO_2e per metric ton rebar), weighted by quantities procured.

Table 2. Sample basic tracking of weighted average GWP per unit product type over time.

		Average GWP (kg CO_2e per unit)			
Product Type	Unit	Year 0 baseline	Year 2	Year 4	Year 6
Rebar	Metric ton	XXX	XX	X	#
Cement	Metric ton	YYY	YY	Y	#

Desired Outcome: Shifted Industrial Production Practices

By stimulating and guaranteeing demand for low-carbon products, Buy Clean policies can affect the broader industry, beyond agency procurement. If a cement or steel or insulation company shifts its manufacturing facility's production process, those shifts can potentially result in lower emissions for products destined for non-agency procurement.

For example, "approximately half of the [USA] annual CO_2 emissions associated with cement consumption is associated with public construction…[C]hanges in U.S. cement plants to reduce GHG emissions would impact the CO_2 intensity of all cement produced and sold even to non-government funded construction projects" (Hasanbeigi et al., 2021).

Indicator: Uptake of current best practices in industrial processes

The implementation of GWP limits at or near the industry average GWP per material encourages the broader uptake of current industry best practices. Dell (2020) refers to this "threshold" approach for a Buy Clean policy's emission standard as a *deployment policy* (because it is effective at encouraging uptake of existing technologies and practices), and not an *innovation policy* (because "it does not promote the commercialization of new practices that are much cleaner"). As discussed in the next indicator below, a Buy Clean policy with a multi-threshold approach could more directly drive innovation.

Metric: number of facilities that incorporate current best practices into their production processes

(See Tables 3 and 4 for a proposed scheme that combines the measuring of this and the next indicator/metric.)

Indicator: Innovative changes to industrial processes

In addition to pushing the industry towards broader use of current best practices, Buy Clean policies can also help spur innovative changes. Other approaches to Buy Clean emission standards besides the single-threshold approach can incentivize new practices. Examples are a multi-threshold approach that includes a substantially lower target in addition to an industry-average limit, and a "cap" approach that creates a tradable compliance instrument (Dell, 2020).

Green public procurement programs such as Buy Clean can jumpstart innovation since they "establish demand certainty and build confidence in the existence of future markets for low-carbon materials, which enables suppliers to justify high switching costs and research and development (R&D) expenditures" (Hasanbeigi et al., 2021).

Metric: number of facilities that incorporate innovative changes into their production processes

The above two indicators and their metrics (number of facilities that incorporate current best practices and/or innovative changes) could be measured by:

1. List current industrial process technologies and practices and categorize each as (i) "baseline", (ii) "current best practice", or (iii) "innovative changes."
2. A snapshot survey of industrial processes by plant, focusing on "current best practice" and "innovative changes." Ideally, incorporate production volumes into tracking.

3. Compare over time.

Tables 3 and 4 serve as examples of industrial process technology categorization and tracking of technology adoption over time, respectively.

Table 3. Example production processes for cement and steel in the US, categorized by level of EC influence (current best practice and innovative change). All content in the table is from Hasanbeigi et al. (2021).

Level of EC influence	Cement	Steel
Current best practice	**Energy efficiency:** waste heat recovery (WHR) technologies, high-efficiency clinker cooling and grinding processes, the use of multi-stage preheater/pre-calciner kilns, strategic energy management, smart sensors, advanced analytics, etc. **Fuel switching:** Switching away from coal and petroleum coke to lower-carbon fuels such as natural gas or waste biomass that are locally available and can be easily used in cement plants with current technology **Clinker substitution** with supplementary cementitious materials (SCM)	**Energy efficiency:** waste heat recovery, coke dry quenching (CDQ), Top-Pressure Recovery Turbine Plant (TRT) **Fuel switching**: replace coal or petroleum coke with natural gas, biomass, biogas
Innovative change	**Alternative binders** such as limestone calcined clay **No-carbon fuels** – e.g., green hydrogen (though hydrogen is not an efficient fuel for steel production), renewable natural gas, or electrification of process **Carbon capture, utilization, and storage (CCUS)**	**CCUS** **Hydrogen from renewable energy** in direct reduced iron (DRI) production **Electrolysis of iron ore**

Table 4. Example scheme for tracking the number of plants in a given industry employing current best practices and innovative changes. Each "#" refers to the number of plants employing the given practice. Practices are from Hasanbeigi et al. (2021).

	Practice	Year 0	Year 2	Year 4	etc.
Current best practice	Waste heat recovery	#	#	#	#
	Coke dry quenching (CDQ)	#	#	#	#
	Top-pressure recovery turbine plant (TRT)	#	#	#	#
	Lower carbon fuels — natural gas, biomass, biogas	#	#	#	#
Innovative change	Green hydrogen DRI	#	#	#	#
	CCUS	#	#	#	#
	Electrolysis of iron ore	#	#	#	#
Total plants sampled		#	#	#	#

Indicator: Industry-average product type GWP

As manufacturing companies make production changes like those described in the previous two indicators, industry-wide emissions intensity will come down. Industry-average EPDs — published by industry associations and based on a representative sample of facilities from multiple companies — report industry-average GWP based on a given production year. Thus, successive versions of an industry-average EPD for a given product type over time should provide a useful indicator of emissions intensity reductions.

Note that changes in industry-average EPD-reported GWP over time can correspond to other factors, in addition to changes in actual emissions. The sample of which companies and facilities submit data for the industry EPD, the LCA methods and assumptions employed (e.g., allocation methods or system boundary), and the background data selected are all examples of factors that might change from one industry-average EPD version to the next and affect the reported GWP. Therefore, the use of this indicator should include analysis and an approach to account for these other factors, to better gauge the extent to which the changes in reported GWP correspond to actual emissions changes (rather than changes in LCA decision-making and data).

Another option to track industry-average GWP over time is to use GHG emission data that industrial facilities report to the EPA and state agencies as part of their air operating (also known as "Title V") permits and/or through the EPA's Greenhouse Gas Reporting Program (GHGRP). For example, the EPA compiled a snapshot of USA cement industry carbon intensities (25th percentile, median, and 75th percentile) using 2019 GHGRP data (EPA, 2021). The EPA provides GHGRP data publicly on its website (EPA, 2024b).

Metrics:

a. reported GWP in industry-average EPD for a given product type, and changes over time
b. average GHG emissions at industrial facilities based on reporting to EPA and/or states

Desired Outcome: Better GWP Data and Reporting

Buy Clean policies have the power to improve GWP data and reporting by elevating the awareness of embodied carbon and LCA, pushing for more robust data in EPDs, and advancing the existing structures of data tracking and reporting. This elevation can lead to changes outside of the direct influence of those policies.

Indicator: EPD availability

The availability of EPDs can (a) indicate the influence of policy in terms of its push for more availability of EC data; and (b) is an important criterion for broader EC reduction and tracking success. (To track product-level reductions, we need EPD data.)

Metric: number of EPDs and changes over time for a given product type and region, as found in the Embodied Carbon and Construction Calculator (EC3) tool database (Building Transparency, 2023).

Note that the way one might measure this depends on the regionality of the product type. For product types with relatively long average transport distances and/or concentrated production (relatively few manufacturing plants), such as steel or glass, it would make sense to look at the collection of Buy Clean policies in aggregate, and the total collection of EPDs for the category (national or North American totals).

For product types with relatively short transport distances and dispersed production (i.e., many manufacturing facilities spread out across the country), such as ready-mixed concrete and asphalt mixtures, a state's policy would more likely have a local impact. Thus, where there's a local/regional component, an agency could analyze a state with implemented policy and a "control" state without policy and determine EPD counts over time by product type (likely focusing on concrete or asphalt as a local material).

For example, at the time of recent analysis (November 2023), there were more concrete EPDs in Minnesota (a state with a passed Buy Clean policy that includes concrete in its scope) than in the six surrounding states combined (none of which have a passed Buy Clean policy). When calculated relative to concrete use (using cement use as a proxy), Minnesota has more than eight times the number of EPDs than those surrounding states combined. A similar trend is true if comparing the number of concrete EPDs per capita. See Table 5.

Table 5. Comparison of concrete EPD counts by region with and without concrete-focused Buy Clean policy. Populations from 50states.com (2023). EPD counts from EC3 tool (Building Transparency, 2023). Cement consumption data from USGS National Minerals Information Center (2024).

			Concrete EPD count		
Region	Description	Population	Total	Per 1 million residents	Per 1 million tons portland cement use
Minnesota	Passed a Buy Clean policy with concrete in its scope	5.6 million	1,256	224	208
Iowa, Illinois, North Dakota, South Dakota, Wisconsin, and Michigan	Six states surrounding MN — have not passed a Buy Clean policy	33.8 million	873	26	24.2

Figure 3 illustrates this comparison by showing concrete EPD growth (relative to cement use) over time in each of these two geographies. Figure 4 provides a more general look at the number of digitized concrete EPDs currently in the EC3 database for the U.S. and southern Canada.

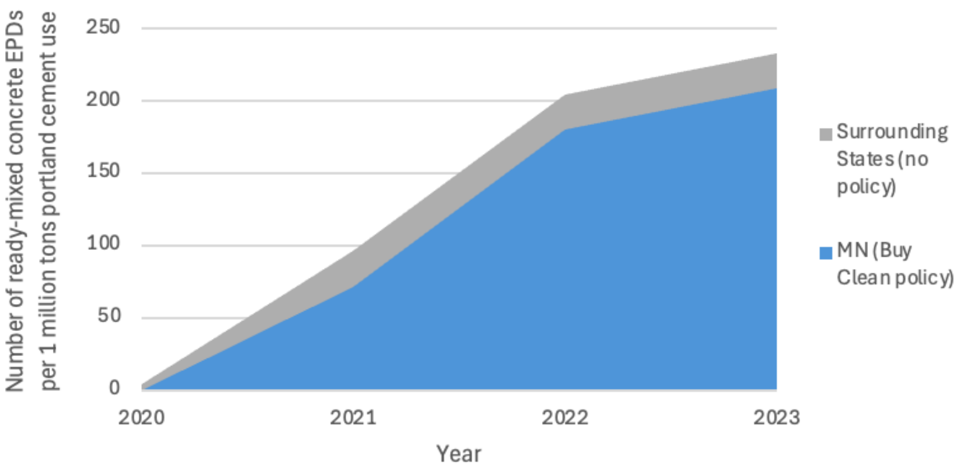

Figure 3. Differences in growth of EPD numbers between a state with a Buy Clean policy (Minnesota) and six surrounding states with no Buy Clean policy (Iowa, Illinois, North Dakota, South Dakota, Wisconsin, and Michigan). The counts shown are relative to cement consumption to roughly normalize by economic structure and the overall market for cement/concrete. EPD data pulled from EC3 November 2023 (Building Transparency, 2023). Cement consumption data from USGS National Minerals Information Center (2024).

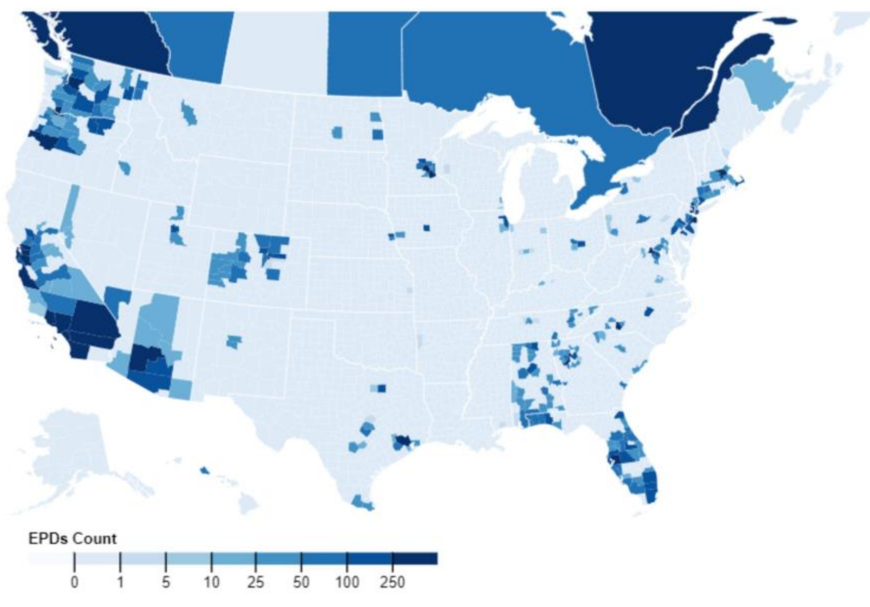

Figure 4. Number of digitized concrete EPDs ("EPDs count") in EC3 by location — USA and southern Canada. Data and image from EC3 January 2024 (Building Transparency, 2023).

As mentioned, this is likely not a linear relationship, but rather more like a feedback loop. The existence of a substantial collection of EPDs can help demonstrate the viability of a Buy Clean policy, making it more likely to pass. That is, it is possible that more EPD availability can lead to policy, in addition to policy leading to more EPD availability.

Note that EC3 is a dynamic tool; it is always incorporating new EPDs, retiring out-of-date EPDs, developing new features, fixing bugs, improving categorization, etc. Therefore, while EC3 may not be a perfect count of available EPDs, it is still the quickest tool available for reviewing available EPD counts by state and is designed to enable this type of analysis.[1]

Indicator: Streamlined EPD generation

One barrier to EPD availability is the resource-intensiveness required from manufacturers to produce EPDs. Thus, reducing the time and/or money required to generate EPDs could be a sub-indicator and metric of EPD availability.

Buy Clean policies have prompted industries to invest in streamlined processes for creating EPDs, particularly via user-friendly EPD generator tools that allow manufacturers to produce EPDs more quickly, easily, and at lower cost. An EPD generator tool often incorporates pre-built category-specific LCA models, background LCI data, foreground data collection guidance/templates, and administrative content and formatting to conform to the relevant PCR. This allows the tool user to enter (only) data specific to their company and facility processes, while the tool does the rest of the work in the background to generate an EPD, greatly simplifying EPD production and verification (Lewis et al., 2023).

Due to such a streamlined process, EPD generator tools have the power to lead to companies producing many more EPDs for a given product type, which directly relates to EPD availability. Concrete provides an excellent example. Due in large part to the multiple available concrete EPD generator tools that have made producing concrete EPDs so accessible, there are over 100,000 concrete EPDs in the EC3 database — approximately 84% of all EPDs in EC3 (Building Transparency, 2023).

Metric: resources (amount of time and/or money) required to generate an EPD

Indicator: EPD accessibility

Ideally, people (policymakers, procurement officers, designers, etc.) can access, sort, filter, and interpret EPDs in a user-friendly way. EPDs should be machine-readable to support their incorporation into databases and as data sources for policy tracking and other LCAs such as whole-building LCA, roadway LCA, and EPDs for products downstream in the supply chain. openEPD is one example of a digital format to address those goals (openEPD Forum, 2024). The EC3 tool is a free online database of digitized EPDs (Building Transparency, 2023).

A related outcome is that individual EPDs are more accessible in the sense that a user can read an EPD and relatively easily understand what the EPD contains, what it means, and how to use it, for example, to compare to another similar product or a policy threshold.

One could develop an EPD accessibility/usability standard that captures the above items to include, for example, the following criteria:

- EPDs are in a digitized format on EC3 or a similar accessible database.
- EPDs are freely and publicly available.

[1] One should expect a handful of bugs and discrepancies in a dynamic database like EC3. Counts pulled straight from EC3 are likely good indicators of actual published counts for categories with large numbers of EPDs (such as ready-mixed concrete) since a handful of discrepancies will not significantly impact the total counts. For categories with relatively few EPDs, some additional QA of EC3 data may be helpful to ensure accuracy.

- EPDs and databases allow for policy-related sorting or filtering options (like Figure 5)
- One can understand and find key information (PCR, product type and performance characteristics, GWP and other LCA results, key data sources, etc.) in the digitized and/or PDF versions of EPDs.

Metric: number of PCRs and/or digital EPDs aligned with accessibility/usability standards

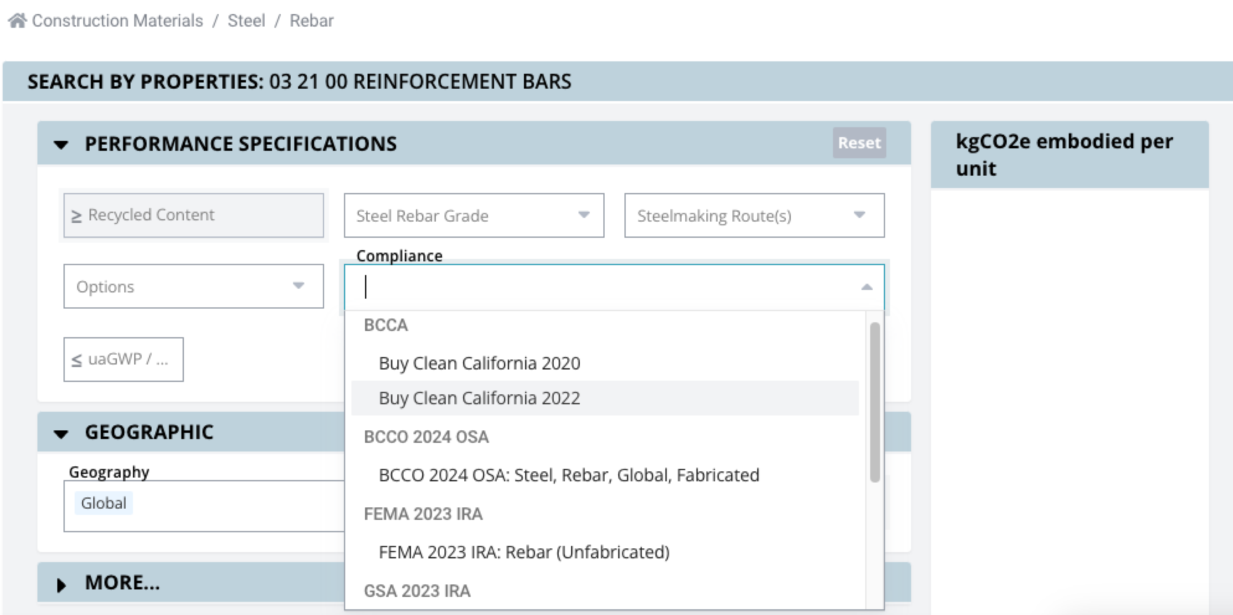

Figure 5. Screenshot of EC3 tool showing search and filter options that include Buy Clean policy compliance. Image from Building Transparency (2023).

Indicator: More specific data in EPDs

Buy Clean policies, by including requirements for EPDs beyond what is in the current PCR, can drive EPD improvements.

Metrics:

a. number of PCRs that specify supply-chain-specific data requirements (and/or require specific data for key upstream processes)
b. average percent supply-chain-specificity score across EPDs in a product type [data is not currently available, but expected to be in the future]

A PCR provides the requirements and guidance for EPDs produced for a given category in that program. This includes both the requirements for the underlying LCA (e.g., requirements for what processes are or are not counted in the system boundary, or any data quality and data selection requirements) and the requirements for what is reported in the EPD (e.g., whether results for a set of life cycle stages can be reported in aggregate or if they must be reported separately).

PCRs, like other stands, exist on a range between flexibility (allowing the PCR to be applicable across products, practitioners, software tools, evolving data sets, and time) and prescriptiveness (to ensure consistent results between the EPDs that conform to the PCR). Given that flexibility, "LCA practitioners often have limited guidance when developing EPDs, resulting in inconsistencies between EPDs even from the same program" (Bhat et al., 2022).

The best place to address such inconsistencies is in the PCRs and other governing standards. The EPA is developing PCR Criteria in support of its label program for low-embodied-carbon construction materials (EPA, 2024a). The American Center for Life Cycle Assessment (ACLCA) developed its 2022 ACLCA PCR Guidance (aka "ACLCA PCR Open Standard") to address this issue by adding further requirements for PCRs to adopt that would result in EPDs more suitable for three levels of use cases, — (1) transparency, (2) procurement, and (3) data sources — depending on the extent of prescriptive requirements.

An example of a procurement use-case requirement from the ACLCA PCR Guidance is below. Such a requirement aims at increasing EPD reliability for procurement decisions by reducing the uncertainty associated with the use of average or generic (non-facility-specific) data to model significant processes in a product's supply chain.

> "For EPDs seeking procurement-level conformance with this guidance, the PCR shall require that EPDs use facility-specific data for upstream unit processes that cumulatively contribute 50% or more to the disclosed total global warming potential" (Bhat et al., 2022).

"Supply-chain-specific" data refers to such facility-specific data, including for upstream processes such as the manufacture of the input ingredients. Pending future publication and PCR adoption of ACLCA guidance on this subject, EPDs will calculate and report supply chain specificity scores. EC3 is already set up to incorporate and display this information. So, while metric (b) is not feasible in the present, it may serve in the future as a useful metric for this indicator once PCRs and EPDs begin to implement supply chain specificity reporting.

Barring such direct changes to PCRs to improve EPD reliability, or perhaps as a stopgap measure, Buy Clean policies can add similar requirements that advance the usefulness of EPDs in policy, beyond those currently in the PCR.

Examples of existing approaches for addressing data specificity include:

- California: Where a company produces the same product at multiple facilities in different locations, PCRs typically allow the averaging of data from multiple manufacturing facilities to provide a single company-average GWP value (and other impacts) for the product. Such averaging can obscure the sometimes-significant range of impacts between particular facilities (due to differences in, e.g., production technologies or grid electricity sources), and it reduces the reliability/accuracy of the EPD's results.

On the other hand, the BCCA requires EPDs that report facility-specific GWP. This requirement directly led to manufacturers placing additional facility-specific GWP results in their EPDs. (Figure 6 is an example.) It has also prompted PCR committees to consider revising PCRs to accommodate and/or require such reporting.

Facility-Specific GWP100 Results

Nucor hot-rolled structural product may be shipped from one of two different mills. The results presented previously represent a production-weighted average of these facilities. To understand how the GWP may vary between sites, facility-specific GWP100 results are presented below, per metric ton. As mill products may be shipped to any number of fabricators, the US average AISC fabricator data was used for both sites and therefore does not change. Results are also presented for beam at the mill level, which excludes impacts from the additional material requirements associated with the scrap generated during fabrication.

Table 8: Facility-specific GWP100 results, per 1 metric ton

GWP [kg CO2 eq.]	A1	A2	A3	Total	Cradle-to-Gate, Mill Product
Nucor Steel Berkeley	1.71E+03	1.07E+01	1.10E+02	**1.83E+03**	**1.60E+03**
Nucor Yamato Steel	8.75E+02	1.07E+01	1.10E+02	**9.96E+02**	**8.16E+02**

Figure 6. Example of hot-rolled structural steel section EPD with facility-specific GWP results. This is in addition to the main LCA results (not shown) that are based on an average of data across multiple facilities. Image from Nucor Corporation (2021).

- Minnesota: Most PCRs allow EPDs to use generic or average data (and do not require supplier- or facility-specific data) to model upstream processes outside the manufacturer's direct operational control. For example, a steel deck manufacturer might use generic steel production data, or a concrete manufacturer might use generic cement data.

On the other hand, Minnesota's Buy Clean Buy Fair Act requires facility-specific data for significant upstream processes. The act requires *supply-chain-specific* EPDs, which the act defines as an EPD "that includes specific data for the production processes of the materials and components composing a product that contribute at least 80 percent of the product's [A1-A3 GWP]" (Office of the Revisor of Statutes, 2023). This greatly improves the reliability and accuracy of EPDs for certain products where most impacts happen upstream of the final company's manufacturing processes, such as concrete, for which cement production is the main contributor to the concrete's overall GWP. Any concrete EPD submitted to comply with this law will need to use facility-specific (rather than company- or industry-average) cement data.

- Colorado: Most North American EPDs have a "cradle-to-gate" scope, meaning they cover raw materials production (module "A1" in LCA), transport of raw materials to the manufacturing plant (A2), and manufacturing (A3). While some EPDs do include data for module A4 - transport from the manufacturing plant to the construction site, this data is generally based on generic scenarios (e.g., a "typical" or "average" transport distance and mode of transport). In reality, A4 impacts can vary significantly based on the actual mode(s) and distance of transport to the actual site.

To address this, the Buy Clean Colorado Act requires additional specific data for transportation beyond the factory gate. For any product transported over 100 miles from the place of manufacture to the construction site, the state requires the reporting of distance, weight, and transportation mode to facilitate the calculation of transport impacts (though this won't immediately be considered as criteria for material procurement) (Vigil, 2022).

Indicator: More consistent data in EPDs for better comparability

Buy Clean policies have been an impetus for improving EPD comparability, including a push for more consistent background data. The CLF's *Advancing the LCA Data Ecosystem for Policy* (Lewis et al., 2023) and the ACLCA Open Standard addendum *Guidance for Assessing Data Quality of Background Life Cycle Inventory (LCI) Datasets* (Mukherjee & Bhat, 2022) describe the problems that result when different EPDs use different data sets to model the same upstream processes. Even with the same foreground data, differences in background data selection from one EPD to another can lead to "incomparable outcomes" (Mukherjee & Bhat, 2022). The addendum recommends that PCRs "should identify and prescribe the most suitable, publicly available background LCI datasets for their products…limiting EPD developers to only select foreground data "(Mukherjee & Bhat, 2022). As more PCRs are generated and updated, the PCR Open Standard and addendum may facilitate a trend towards more prescriptiveness regarding background data selection.

In addition to this indirect impact, Buy Clean policies have the power to stipulate certain data selection requirements beyond those in the PCRs, like the indicator above regarding data specificity requirements. For example, a Buy Clean policy could require EPDs to use a certain data set to model localized grid electricity consumption. (While this is possible, there are no current examples of this as far as the authors know.)

To minimize access barriers to consistent background data, the best-case scenario is that PCRs and/or policies prioritize the use of high-quality, up-to-date, public LCA background data (rather than fee-for-use proprietary databases). A public LCA dataset that is suitable for prescribed use in EPDs would pass data quality standards such as those provided by the ACLCA and would be operable with any/all LCA software tools. Starting with these basic components, one could develop more specific criteria for assessing the suitability of public data sets for widespread or prescribed use.

Metrics:

a. number of PCRs with prescriptive background data selection requirements
b. number of publicly available background LCI datasets that meet quality and operability criteria for construction product EPDs

Indicator: LCA knowledge, education, and use in policy

Buy Clean policies prompt demand for basic LCA knowledge among government staff (as well as manufacturers and others). Such knowledge includes, for example, the relationship between international ISO standards, PCRs, and EPDs; how to find EPDs; and how to interpret/use EPDs. When agencies act on that demand, more staff will gain LCA knowledge, which allows them to more effectively implement and communicate about the policy.

This also builds up government and general LCA knowledge, which can help set the stage to implement other LCA-based policies/programs that build off Buy Clean. For example, in 2023, the California Green Building Standards Code (CALGreen) implemented embodied carbon emission control requirements for nonresidential building projects over 100,000 square feet and school projects over 50,000 square feet, building upon California's and other Buy Clean policies. The new

CALGreen EC requirements include three pathways, one of which is like Buy Clean — requiring the project to submit EPDs for steel, glass, mineral wool, and concrete products used on the project, demonstrating lower-than-average GWP (Malinowski, 2023).

Metrics:

a. greater government staff understanding of LCA basics, measurable with surveys
b. the number of LCA-based policies/programs developed that build upon Buy Clean

Additional LCA-related indicators outside of Buy Clean policy sphere of influence

Like the other indicators in this section above, the following indicators similarly demonstrate improved LCA practices, knowledge, data, and uptake (the desired outcome). Unlike the other indicators above, these are much less likely to be a result of a Buy Clean policy. They are included here to illustrate that many complementary programs and policies must work in concert to achieve the desired outcomes and, by extension, the bigger goal of embodied carbon reduction. Since they are very relevant to a robust overall LCA ecosystem, we include them here, but with only minimal description since they are less directly relevant to Buy Clean policy.

Indicator: Architects and engineers using WBLCA tools

Metric: number of architects and engineers (and/or firms) using WBLCA tools; and/or number of projects where architects/engineers use WBLCA; measurable via surveys

Indicator: Participation in EC-focused LEED credits

Metric: number of EC-focused LEED credits pursued on an annual basis

Indicator: EPD integration into WBLCA tools

Metric: number of WBLCA tools that incorporate EPDs; number of EPDs a given tool incorporates; (should include guidance around appropriate use of EPDs in WBLCA, e.g., safeguards for different system boundaries, LCIA methods, treatment of biogenic carbon, etc.)

Desired Outcome: Creation of Low-Carbon Markets

As mentioned above, green public procurement programs can provide demand certainty, which removes some barriers to R&D innovations and switches to lower-carbon practices. The combination of increased demand (via Buy Clean) and associated increased market competition, in conjunction with the increased supply due to innovations and switches, can promote the expansion of low-carbon markets for construction materials (Hasanbeigi et al., 2021). Policy-prompted investment could help create low-carbon material markets in a similar way that policy led to investment and deployment in the USA wind and solar industries (Dell, 2020).

Indicator: Commercialization of new low-carbon practices

Metric: number of low-carbon products (defined by the measurement and reporting mechanisms described above) available in the market.

Indicator: Low-carbon startup companies

One way the market responds to increased demand and opportunities for commercialization is the formation of new startup companies focused on low-carbon construction materials. Such startups could be focused on novel manufacturing technology and/or methods for advancing data availability and accuracy. A growth in such startups indicates the growth of low-carbon markets. When a large company purchases a small startup, this investment can signal the business value of the startup's concept. Thus, start-up acquisition can be another indicator of low-carbon market creation and growth.

Metrics:

a. number of startups related to Buy Clean materials
b. number of those startups that big companies purchase

Indicator: Costs/prices of certain low-carbon products

Costs to manufacture low-carbon products can come down due to economies of scale, as companies scale up production after investing in new technologies. Prices to purchase low-carbon products can also come down, both as a function of the reduced costs mentioned above and due to increased competition (Hasanbeigi et al., 2021). Reduced production costs and purchase prices of low-carbon products over time can signify the development of low-carbon markets.

The case of LED light bulbs — their increased production and uptake, along with reduced costs and prices as production scaled, offers a positive example of policy intervention and its impact on green procurement. "As hoped, the stringent legislation and efficiency requirements introduced by governments led to a drastic fall in the price of LED lighting products, accelerating market penetration by making them economically viable for billions of people" (Rapid Transition Alliance, 2021).

The production of low-carbon materials often involves initial capital investment. Additionally, operational costs can fluctuate significantly over time due to, e.g., changes in technology, energy prices, or costs placed on carbon. Therefore, any metric would need to account for these factors in order to meaningfully track the production costs of low-carbon products over time, with apples-to-apples comparison from one date to the next. The *levelized cost* of a product accounts for the upfront capital expenditure and the ongoing operational, energy, and maintenance costs over the facility's lifetime (Reichelstein & Rohlfing-Bastian, 2014) and can also include carbon costs. Because it can account for all these factors, levelized cost is an appropriate metric for tracking and comparing the cost of low-carbon products over time.

Metrics:

a. levelized cost of a low-carbon product (e.g., one metric ton of low-carbon cement or low-carbon steel) over time [though data may not be publicly available]
b. reduced average price per given low-carbon product [though this may come after initial increased prices when supply lags behind increased demand]

Putting the Indicators to Use

We envision that federal and state agencies could use the proposed Buy Clean theory of change and indicators and metrics to develop policy evaluation frameworks. NGOs and Industry associations could play supporting roles by providing data collection and industry knowledge as well as helping ensure that data and processes are up to date. The following subsections — *Current state and gaps* and *Scoring method for prioritizing indicators* — provide initial resources for taking the proposed ideas here and operationalizing them into implementable evaluation frameworks.

Indicators and Metrics: Current State and Gaps

In consideration of how to operationalize the presented indicators and metrics, CLF performed an initial analysis of the current state of existing available information and resources and the gaps — i.e., what would be required beyond the current state in order to use the indicators and metrics. Table 6 documents this initial analysis.

Table 6. Indicators and metrics: current state and gaps regarding available information and resources.

Indicator	Metric	Current state	Gaps
Reduced average EC per unit material	Average GWP per unit per material procured by an agency over a given period, compared to baseline performance	Most policies include GWP limits; some track procurement over time, but this varies a lot by agency in terms of what and how they track.	Baseline data from before limit implementation (most agencies do not have this); consistent tracking mechanisms for EPD GWP values over time; consistent tracking of quantities in order to track (a) production-weighted average emissions intensity and (b) total EC emissions over time
Uptake of current best practices	Number of facilities that incorporate current best practices into their production processes	Sometimes this information can be found directly through industry contacts but can also be found via public records requests for air quality permits of permitted facilities. Permits typically have descriptions of current technologies used in the facility.	System and effort to track across industry; this data is not always available, especially for industries/facilities that don't require air quality permits.
Innovative changes to industrial processes	Number of facilities that incorporate innovative changes into their production processes	[same as item above]	[same as item above]
Industry-average product type GWP	Reported GWP in industry-average EPD for a given product type, and changes over time	Industry-average EPDs for most major construction materials, typically with a five-year life. The CLF Material Baselines reports track industry-average GWP over time for North American construction products (e.g., Waldman et al., 2023).	Industry EPDs vary in their representativeness -- this would benefit from more manufacturer participation; not all product types have industry-average EPD; would need the deliberate effort to track changes over time;

Indicator	Metric	Current state	Gaps
	Average GHG emissions at industrial facilities based on reporting to EPA and/or states	EPA and states require GHG emissions reporting for certain industrial facility permit holders.	Resources/time for state agencies and/or EPA to compile reported data; would take additional efforts to account for imports.
EPD availability	Number of EPDs (for a given product type), and changes over time	EC3 has most of this data. Also available from each program operator, but not in an easily trackable format.	EC3 can be used as a tracking tool, but EPD availability not systematically reported beyond the CLF Material Baseline reports; additional QA of EC3 data would improve tracking accuracy.
Streamlined EPD production	Resources (amount of time and/or money) required to generate an EPD (per product category)	Manufacturers, consultants, and tool developers each know cost/timeline for their domain.	Not tracked industry-wide; stakeholders may not share their cost/timeline data.
EPD accessibility	Number of PCRs and/or digital EPDs aligned with accessibility/usability standards	Efforts such as ACLCA PCR Guidance (Bhat et al., 2022) and EPA's Draft PCR Criteria (EPA, 2024a) provide some usability/accessibility criteria	An EPD accessibility/usability standard does not yet exist in any formal way, as far as the authors are aware. Likely the most effective way to establish and track would be to incorporate such a standard into PCR Guidance/criteria for PCRs to adopt.
More specific data in EPDs	Number of PCRs that specify supply-chain-specific data requirements	The information is in the PCRs.	No known standardized tracking mechanism in place. Probably easier/better to track at the PCR level than the EPD level. Track how many PCRs meet, e.g., ACLCA Open Standard or EPA Criteria.
	Average percent supply-chain-specificity score across EPDs in a product type	ACLCA is in process of developing guidance for calculating and reporting supply chain specificity scores. EC3 is set up to incorporate and display this information.	ACLCA guidance is not yet finalized/published. After that, PCRs would need to adopt the guidance for this metric to be viable.
More consistent data in EPDs	Number of PCRs with prescriptive background data selection requirements	These PCRs exist.	No known standardized tracking mechanism in place. Probably easier/better to track at the PCR level than the EPD level. (PCRs: an organized effort to count and track which PCRs do this;
	Number of publicly available background LCI datasets that meet quality and operability criteria for construction product EPDs	Existing LCI data quality assessment schemes such as Mukherjee et al. (2022) that focus particularly on publicly available LCI data; anecdotally, people working on the Federal LCA Commons datasets know about the quality and operability of the data	Potential to build on/refine existing data quality assessment schemes; organized effort to apply such a scheme to public datasets such as those in the Federal LCA Commons.
LCA knowledge, education, and use in policy	Number of government staff who understand LCA basics, measurable with surveys	More staff are becoming more knowledgeable about carbon emissions and LCA [anecdotal]	Formal system to assess and track agency staff knowledge;

Indicator	Metric	Current state	Gaps
	Number of programs developed that build upon Buy Clean policies	Some new policies that build off Buy Clean [anecdotal]	No clear criteria (though subjective criteria may suffice).
Commercialization of new low-carbon practices	Number of low-carbon products (defined by the measurement and reporting mechanisms described above) available in the market	New products keep popping up [anecdotal]	Research and analysis to track, plus more definition of what would count
Low-carbon product startup companies	Number of startups related to Buy Clean materials	New startups keep popping up [anecdotal]	[same as item above]
	Number of those startups that big companies purchase	[same as item above]	[same as item above]
Reduced production costs	Levelized cost of a low-carbon product over time	Levelized cost – presumably any given company has the data to track their own levelized costs.	That data isn't publicly available, so problematic for doing any kind of tracking across the sector- or industry.
Reduced procurement prices	Reduced average price per given low-carbon product	Agencies presumably keep data on the expenses of procured materials	Way to track this over time

Scoring Method for Prioritizing Indicators

Agencies and their collaborators can use one or many of the indicators proposed here as part of an evaluation framework to track and assess a Buy Clean policy's effectiveness related to four different desired outcomes (Table 1). Different agencies and programs will have different needs and priorities. And it is unlikely that any given agency will have the resources or desire to track all the proposed indicators. Therefore, creating an evaluation framework will involve prioritizing and choosing indicators to measure. To help narrow the list of potential indicators one might decide to spend resources on to evaluate a policy's success, CLF developed the following simple approach to ranking/prioritizing.

1. For a given indicator, score it according to the following three factors:
    a. GWP impact: *To what extent does the item relate to substantial GWP reductions?*
    b. Buy Clean causality: *To what extent does the Buy Clean policy directly cause the change?*
    c. Feasibility to measure: *How easily could someone (government agency, consultant, independent non-profit, etc.) establish a system and track the indicator and its associated metric(s) over time?*

For each factor, assign the indicator a simple Likert scale quantitative score (1,2, or 3, where 1 = least and 3 = most).

2. Combine the three individual factor scores by multiplying them together to generate an *indicator score*. The combined indicator scores will be somewhere between 1 (lowest/worst score) and 27 (highest/best score).

3. Follow the above two steps for any/all indicators under consideration. Use the combined scores to rank or prioritize the set of potential indicators.

This proposed approach is a first step — a method for agencies to start with and test and build off. It is intentionally crude and adaptable per policy or agency. The various factor scores (and resulting indicator scores) will vary based on geography, policy scope, agency resources, existing data tracking infrastructure, and personal judgment of the person doing the scoring. Thus, any scoring effort should be helpful for a given agency or policy. However, the scoring approach does not aim to provide universal prioritization or ranking across agencies or policies.

Examples: Applying the Scoring Method

The CLF applied the above method to calculate indicator scores for three example indicators. Each factor score for each indicator includes an accompanying narrative explaining the rationale for the "1," "2," or "3" factor score.

Example Indicator: Reduced average EC per unit material
Desired outcome: Reduced embodied carbon of agency-procured construction materials
Metric: average GWP per unit per material procured by an agency over a given period, compared to baseline performance.
Indicator full description

Indicator score = 2 × 3 × 3 = 18, based on the following factor scoring:

GWP Impact: factor score = 2
Narrative: Unlike many of the other indicators, this one relates directly to GWP quantification. Depending on the scale of the jurisdiction's construction activity and the material types included in the policy, there is potential for substantial GWP reductions.

Buy Clean causality: factor score = 3
Narrative: Among all the proposed indicators, this one is the most directly related to Buy Clean policy — where there is the clearest causal link between the policy intervention and the indicator.

Feasibility to measure: factor score = 3
Narrative: If agencies are tracking their EPD and material quantity data, the average GWP per unit of material is straightforward to track and measure. In terms of how current numbers compare to baseline performance, the feasibility depends on how one defines *baseline* since most agencies do not have historical procurement GWP data to compare. (If, on the other hand, one defines *baseline* as industry-average GWP for the product type,

that is more feasible to implement but possibly less representative of actual agency procurement and associated GWP reductions.)

Example Indicator: Innovative changes to industrial processes
Desired outcome: Shifted industrial production practices
Metric: Number of facilities that incorporate innovative changes into their production processes.
Indicator full description

Indicator score = 3 × 2 × 2 = 12, based on the following factor scoring:

GWP Impact: factor score = 3
Narrative: Similar to the "Uptake of current industrial process best practices" indicator above, if companies make innovative changes to industrial processes, this can greatly drive down emissions for all construction in the region (not just public projects).

Buy Clean causality: factor score = 2
Narrative: Manufacturers need to be confident in market demand to invest in production changes. Buy Clean provides a measure of confidence that eligible public projects will be interested in lower-carbon products and sets transparent requirements that can be replicated by the private sector. Again, like the previous indicator, Buy Clean can influence the broader industry by providing confidence in demand for low-carbon products, though there may not always be a clear line between policy and industrial practices.

Feasibility to measure: factor score = 2
Narrative: Again, the feasibility of tracking the metrics associated with this indicator depends on the nature of the industry — particularly how concentrated or distributed it is.

Example Indicator: EPD availability
Desired outcome: Better GWP data and reporting
Metric: number of EPDs (for a given product type), and changes over time.
Indicator full description

Indicator score = 2 × 2 × 3 = 12, based on the following factor scoring:

GWP Impact: factor score = 2
Narrative: To choose lower-carbon products, and for policies to set meaningful GWP limits or thresholds, there needs to be a substantial pool of EPDs that represent the breadth of the market for a given product type.

Buy Clean causality: factor score = 2
Narrative: Growth in EPD availability can be an indicator of Buy Clean's success (i.e., the policy is causing EPD growth). As noted above, this can also be a precursor to Buy Clean success (i.e., more EPDs facilitate the passing and implementation of the policy).

Feasibility to measure: factor score = 3
Narrative: The EC3 tool allows for relatively easy tracking of EPD counts over time by

product type and/or region. For example, this allowed the GSA to measure the number of new policy-applicable EPDs made available during their pilot phase (GSA, 2023). (Note that it does help to incorporate manual QA into the process to catch mis-characterized or duplicate EPDs from EC3's dataset.)

Conclusions and Future Work

At the time of this report's publication in the summer of 2024, there are only five government jurisdictions implementing GWP limits through Buy Clean policies — California, Colorado (limits for buildings only), US General Services Administration (GSA), City of Portland (Oregon), and the Port Authority of New York and New Jersey. New York plans to implement limits in 2025 and Minnesota and Maryland in 2026. As more policies are passed and implemented, it will be helpful to continue learning from the successes and challenges of existing Buy Clean policies.

The evaluation of current policies using indicators and metrics such as those in this report will allow agencies to better understand the degree to which those policies are meeting their goals. The knowledge gained from such evaluations can support implementing agencies to improve upon their own policies, other agencies to develop new Buy Clean policies in a more informed way, and supporters of Buy Clean and similar initiatives to prioritize where to spend resources to promote more effective policies.

This report represents a step in that direction. It builds on previous Buy Clean-focused research and reporting such as *Build Clean: Industrial Policy for Climate Justice* (Dell, 2020), and *Federal Buy Clean for Cement and Steel: Policy Design and Impact on Industrial Emissions and Competitiveness* (Hasanbeigi et al., 2021) and many others listed in the *References* section below.

Just as this report builds on previous research, we hope that others — agencies, policy advisors, implementation staff, and consultants — will build upon the presented ideas here to continue to advance the conversation and the available tools for evaluating and improving Buy Clean policies. While we provide some initial resources in the *Putting the Indicators to Use* section regarding operationalization, there are still significant steps between the conceptual ideas here and the development and implementation of full evaluation frameworks. Therefore, one way to build on this report would be for an agency to operationalize the presented indicators and metrics by developing and implementing a full policy assessment framework. This would inform how one could refine the ideas presented here, further identify gaps, and define region- and policy-specific implementation to track impact.

Additionally, research to propose similar indicators for tracking the labor and economic growth goals of Buy Clean is a necessary complement to holistically evaluate the effectiveness of Buy Clean. Potential focus areas include the following:

- indicators for labor goals
- indicators for economic growth and/or international trade of low-embodied-carbon materials
- an expanded list of environmental pollutants and associated measurable criteria for tracking environmental impacts beyond climate

More robust assessment tools can provide insights into how and where policies are meeting their goals, as well as where to focus efforts to improve or refine policies. By daylighting such successes and opportunities, indicators and metrics for measuring policy success can help us get closer to meeting our most important goals related to social, economic, and environmental well-being.

References

50states.com. (2023). “U.S. state populations” [webpage]. https://www.50states.com/population-by-state/

Bhat, C. G., Adhikari, T., Mellentine, J., Feraldi, R., Lasso, A., Swack, T., Mukherjee, A., Dylla, H., & Rangelov, M. (2022). *2022 ACLCA PCR Guidance — Process and Methods Toolkit*. American Center for Life Cycle Assessment (ACLCA). https://aclca.org/pcr/

BlueGreen Alliance (BGA). (2022). *Buy Clean: A Tool to Create Good Jobs, Cut Pollution, and Renew American Manufacturing.* https://www.bluegreenalliance.org/wp-content/uploads/2022/09/Buy-Clean-White-Paper-22-_v3_91222.pdf

Building Transparency. (2023). *Embodied carbon in construction calculator (EC3) tool* [web-based database and tool]. https://buildingtransparency.org/ec3

Carbon Leadership Forum (CLF). (2024). *Buy Clean policy comparison summary - April 2024*. [https://carbonleadershipforum.org/buy-clean-policies-overview/

Center for Theory of Change. (2023). “What is theory of change?” [webpage]. https://www.theoryofchange.org/what-is-theory-of-change/

Dell, R. (2020). *Build Clean: Industrial Policy for Climate Justice*. ClimateWorks. https://www.climateworks.org/report/build-clean-industrial-policy-for-climate-and-justice/

Department of General Services (DGS). (2024). *Buy Clean California Act.* State of California. https://www.dgs.ca.gov/PD/Resources/Page-Content/Procurement-Division-Resources-List-Folder/Buy-Clean-California-Act#:~:text=The%20Buy%20Clean%20California%20Act,limit%20for%20four%20eligible%20materials.

Hasanbeigi, A., Shi, D., & Khutal, H. (2021). *Federal Buy Clean for Cement and Steel: Policy Design and Impact on Industrial Emissions and Competitiveness*. Global Efficiency Intelligence. https://www.globalefficiencyintel.com/federal-buy-clean-for-cement-and-steel

Hasanbeigi, A. & Springer, C. (2018). *The Carbon Loophole in Climate Policy: Quantifying the Embodied Carbon in Traded Products*. https://www.climateworks.org/wp-content/uploads/2018/09/Carbon-Loophole-in-Climate-Policy-Final.pdf

Krupnick, A. (2020). *Green Public Procurement for Natural Gas, Cement, and Steel. Resources for the Future.* https://media.rff.org/documents/RFF_WP_20-17_Green_Public_Procurement_for_Natural_Gas_Cement_and_Steel.pdf

Lambert, M. and Lewis, M. (2024). *Embodied Carbon 101.* Carbon Leadership Forum. https://carbonleadershipforum.org/embodied-carbon-101-v2/

Lewis, M., Waldman, B., Carlisle, S., Benke, B., & Simonen, K. (2023). *Advancing the LCA Ecosystem A Policy-Focused Roadmap for Reducing Embodied Carbon*. Carbon Leadership Forum. https://carbonleadershipforum.org/advancing-lca-ecosystem/

Malinowski, M. (2023). “CALGreen Mandatory Measures for Embodied Carbon Reduction” [webpage]. AIA California. https://aiacalifornia.org/news/calgreen-mandatory-measures-for-embodied-carbon-reduction/

Mukherjee, A., & Bhat, C. G. (2022). *Guidance for Assessing Data Quality of Background Life Cycle Inventory (LCI) Datasets.* ACLCA. https://aclca.org/wp-content/uploads/2022-ACLCA-PCR-Guidance_Addendum_Assessing_LCI_Quality_05252022-1.pdf

National Minerals Information Center. (2024). *Mineral Industry Surveys* [cement]. USGS. https://www.usgs.gov/centers/national-minerals-information-center/cement-statistics-and-information

Nucor Corporation. (2021). *Environmental product declaration: Fabricated hot-rolled structural steel sections*. UL Environment. https://www.google.com/url?q=https://nuesteelapi-p.nucor.com/api/getFileAttachment?fileId%3D3260&sa=D&source=editors&ust=1721084437080449&usg=AOvVaw0Qoa2O1K3EIZH-Y9xpjMtc

Office of the Federal Chief Sustainability Officer. (2023). "Federal Buy Clean Initiative" [webpage]. Executive office of the President of the United States. https://www.sustainability.gov/buyclean/

openEPD Forum. (2024). "openEPD Standard" [webpage]. https://www.open-epd-forum.org/

Palmeri, J., Waldman, B., Simonen, K., & Lewis, M. (2024). *Scaling Buy Clean policy: Strategies to achieve larger embodied carbon reductions*. Carbon Leadership Forum.

Rapid Transition Alliance. (2021). "Story of change: The lightbulb moment: the rapid shift to LEDs and ultra efficient lighting" [webpage]. https://rapidtransition.org/stories/the-lightbulb-moment-the-rapid-shift-to-leds-and-ultra-efficient-lighting/

Reichelstein, S. J. & Rohlfing-Bastian, A. (2014). Levelized Product Cost: Concept and Decision Relevance. *SSRN Electronic Journal*. https://doi.org/10.2139/ssrn.2393893

Srivastava, R., Ayala, R., Tuttle, R., & Moe, A. (2024). *An Evaluation Framework for State Energy Offices' Energy Efficiency and Clean Energy Workforce Programs*. National Renewable Energy Laboratory (NREL). https://www.nrel.gov/docs/fy24osti/88796.pdf

U.S. Environmental Protection Agency (EPA). (2024a). *EPA PCR Criteria - Draft for Distribution*. https://www.regulations.gov/document/EPA-HQ-OPPT-2024-0075-0002

U.S. Environmental Protection Agency (EPA). (2024b). "Find and Use GHGRP Data" [webpage]. https://www.epa.gov/ghgreporting/find-and-use-ghgrp-data

U.S. Environmental Protection Agency (EPA). (2021). *U.S. Cement Industry Carbon Intensities (2019)*. https://www.epa.gov/system/files/documents/2021-10/cement-carbon-intensities-fact-sheet.pdf

U.S. General Services Administration (GSA). (2023). "Low-embodied carbon program details" [webpage]. https://www.gsa.gov/real-estate/gsa-properties/inflation-reduction-act/lec-program-details

Vigil, B. (2022). "HB21-1303: Buy Clean Colorado Act - Early Agency/IHE Presentation" [webpage slideshow]. Colorado Office of the State Architect. https://drive.google.com/file/d/10SULxaZIrQyH2ye6Txetbw1QfqXHAsvO/view

Waldman, B., Hyatt, A., Carlisle, S., Palmeri, J. & Simonen, K. (2023). *2023 Carbon Leadership Forum Material Baselines Baseline Report v2*. Carbon Leadership Forum. https://carbonleadershipforum.org/clf-material-baselines-2023/

Waldman, B., Lewis, M., & Palmeri, J. (2024). *Buy Clean Policies: Overview + Implementation*. Carbon Leadership Forum. https://carbonleadershipforum.org/buy-clean-policies-overview/