



Buy Clean California Limits

A Proposed Methodology for Assigning Industry-Average GWP Values for Steel, Mineral Wool, and Flat Glass in California

REPORT | JANUARY 2022



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The Carbon Leadership Forum is a non-profit industry-academic collaborative at the University of Washington. We are architects, engineers, contractors, material suppliers, building owners, and policymakers who work collaboratively, pioneering research, creating resources, and incubating member-led initiatives for greatest collective impact. Our goal is to accelerate transformation of the building sector to radically reduce and ultimately eliminate the embodied carbon in building materials and construction.

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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

This research was funded by the ClimateWorks Foundation. We would like to thank Amlan Mukherjee and Jordan Palmeri for providing review.

Citation

Carlisle, S., Waldman, B., DeRousseau, M., Miller, L., Ciavola, B., Lewis, M., and Simonen, K. (2021). *Buy Clean California Limits: A Proposed Methodology for Assigning Industry-Average GWP Values for Steel, Mineral Wool, and Flat Glass in California*. Carbon Leadership Forum, University of Washington. Seattle, WA.

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EXECUTIVE SUMMARY

'Buy Clean' is a type of procurement policy that establishes construction material purchasing requirements for government agencies with the goal of reducing industrial emissions associated with government procurement and creating a market for lower carbon construction materials. The Buy Clean California Act (BCCA), the first policy of this type introduced in the United States, was passed into law by the State of California in October 2017. Buy-clean policies are now being explored at the federal, state, and local levels across the United States.

Buy-clean policies focus on reducing **cradle-to-gate embodied carbon**, or the greenhouse gas emissions arising from the raw material extraction, transportation, and manufacturing of construction materials. Embodied carbon is measured as **global warming potential** (GWP).

The BCCA requires the California Department of General Services (DGS) to set limits on the maximum allowable GWP per unit for structural steel, concrete reinforcing steel, flat glass, and mineral wool board insulation used on certain State projects. DGS is directed to set these limits at the industry average using data from facility-specific environmental product declarations (EPDs) or industry-wide EPDs based on domestic production data.

The goal of *Buy Clean California Limits: A Proposed Methodology for Assigning Industry-Average GWP Values for Steel, Mineral Wool, and Flat Glass in California* is to propose industry-average GWP values for eligible materials using a methodology that meets the following criteria:

1. meets the requirements and intent of the BCCA;
2. is representative of typical manufacturing production;
3. is constrained to high quality, published LCA data sources that are available as of December 2021.

Buy-clean policies vary in their design. Evaluating policy design - such as which type of limit and how many limits should be required as part of a buy-clean policy - is out of the scope of this report.

The research team used the following steps to assign industry-average GWP values to each category:

1. Define the product category.
2. Gather and assess the available LCA data.
3. Evaluate the representativeness of available data sources to select one of the following methods:
 - Method A: Use the collection of product-specific EPDs (including facility-specific EPDs) to calculate an average.
 - Method B: Use the industry-wide EPD value.
 - Method C: Use the industry-wide EPD and adjust the value to fill in representativeness gaps.
 - If none of these options prove adequate, because there is not yet sufficiently representative data, then the category is not yet ready for a reliable GWP limit.
4. Assign a GWP value.

Cradle-to-gate embodied carbon

Includes the greenhouse gas emissions arising from the raw material extraction, transportation, and manufacturing of construction materials. In an LCA, this includes stages A1-A3.

Global warming potential

The potential climate change impact of a product or process as measured by an LCA, reported in units (typically kg) of carbon dioxide equivalent (CO₂e).

Life cycle assessment (LCA)

LCA is a systematic set of procedures for compiling and examining the inputs and outputs of materials and energy, and the associated environmental impacts directly attributable to a building, infrastructure, product or material throughout its lifecycle (ISO 14040: 2006).

Table 1 summarizes the product categories and proposed GWP limit values.

Table 1. Buy Clean California Act Proposed Industry-Average Global Warming Potential (GWP) Limit Values

Eligible Material	Subcategory	Proposed GWP limit
Structural Steel	Hot-Rolled Structural Sections (unfabricated)	1,080 kg CO ₂ e / metric ton
	Hollow Structural Sections (unfabricated)	1,710 kg CO ₂ e / metric ton
	Plate (unfabricated)	1,590 kg CO ₂ e / metric ton
Concrete Reinforcing Steel	Rebar (unfabricated)	920 kg CO ₂ e / metric ton
Flat Glass		1,430 kg CO ₂ e / metric ton
Mineral Wool Board Insulation	Light Density	3.33 kg CO ₂ e / m ² RSI-1
	Heavy density	8.16 kg CO ₂ e / m ² RSI-1

In order for GWP limits to be effective they must be scientifically derived, transparent in their underlying methodology, and clear in scope and definition. Improving the availability and quality of LCA data through improvements to product category rules, increasing access and transparency of data, and increasing participation from manufacturers will support the effectiveness of future buy-clean policy development.

1. INTRODUCTION

Decarbonizing the industrial sector is critical to meeting global and domestic greenhouse gas (GHG) emissions targets, which are responsible for approximately 38% of global greenhouse gas emissions.¹ Two industrial sectors alone, cement and steel, comprise approximately 15% of global GHG.² As top purchasers of steel, cement, concrete, and other carbon-intensive construction materials, federal and state procurement in the United States is a key policy lever for addressing these industrial emissions and creating a market for lower carbon construction products.³

‘Buy Clean’ is a type of procurement policy that establishes construction material purchasing requirements for government agencies. Buy-clean policies focus on reducing **cradle-to-gate embodied carbon**, or the greenhouse gas emissions arising from the raw material extraction, transportation, and manufacturing of construction materials. Embodied carbon is measured as **global warming potential (GWP)**, using a methodology called **life cycle assessment (LCA)**. The GWP of a product can tell you the carbon footprint for all or a portion of a product’s life cycle.

The Buy Clean California Act, Public Contract Code § 3500-3505, was the first buy-clean legislation introduced in the United States, passed into law by the State of California in October 2017. Buy-clean policies are now being explored at the federal, state, and local levels across the United States.

Buy-clean policies vary in their design: the policy elements described in this document are specific to Buy Clean California. Two components that are key to understanding this report:

- **Disclosure:** Requirement to disclose the carbon footprint of covered products using a facility-specific environmental product declaration (EPD). An EPD is a third-party-verified document that reports the environmental impacts of a product, including GWP, based on a product LCA.
- **Limits:** Requirements that a product’s carbon footprint be below a maximum allowable GWP value (e.g. limit) established by a government agency or third party. These limits may decrease over time at intervals to reflect decreases in the industry average GWP due to reductions in industrial emissions.⁴

Each buy-clean policy has a different scope (e.g., which materials and projects are eligible), regulatory framework, incentives (or lack thereof), and mechanisms for implementation. The type of limit to be set by the named agency may also vary depending on the policy design.

For example, Buy Clean California and Buy Clean Colorado require limits to be set at industry-average, whereas the other policy proposals recommend higher thresholds. Other policies, such as the CLEAN Future Act introduced in the U.S. House of Representatives in 2021, propose a two-tiered approach requiring one GWP value set at industry average for broader implementation and a second GWP value setting a high performance standard to incentivize innovation.

Evaluating the emissions impact of these policy design choices - such as which type of limit and how many limits should be required as part of a buy-clean policy - is out of the scope of this report.

Cradle-to-gate embodied carbon

Includes the greenhouse gas emissions arising from the raw material extraction, transportation, and manufacturing of construction materials. In an LCA, this includes stages A1-A3.

Global warming potential

The potential climate change impact of a product or process as measured by an LCA, reported in units (typically kg) of carbon dioxide equivalent (CO₂e).

Life cycle assessment (LCA)

LCA is a systematic set of procedures for compiling and examining the inputs and outputs of materials and energy, and the associated environmental impacts directly attributable to a building, infrastructure, product or material throughout its lifecycle (ISO 14040: 2006).

1. Dell, R. (December 2020), *Build Clean: Industrial Policy for Climate and Justice*. <https://www.climateworks.org/report/build-clean-industrial-policy-for-climate-and-justice/>
2. IEA (2019), *World Energy Balances*.
3. Hasenbeigi, A. and Khutal, H. (2021), *Scale of Government Procurement of Carbon-Intensive Materials in the United States*, <https://www.globalefficiencyintel.com/scale-of-government-procurement-of-carbonintensive-materials-in-us>
4. California State Legislature, “Buy Clean California Act,” 2021, https://leginfo.ca.gov/faces/codes_displayText.xhtml?division=2.&chapter=3.&part=1.&law-Code=PCC&article=5

The goal of this document is to propose a methodology and values for assigning industry-average global warming potential (GWP) limits that meet the following criteria:

1. meets the requirements and intent of the BCCA;
2. is representative of typical manufacturing production;
3. is constrained to high quality, published LCA data sources that are available as of December 2021.

Section 2 of this document includes background information and interpretation of the BCCA's guidelines for setting limits and illustrates what is required to meet the language and intent of the BCCA.

Section 3 provides an overview of data availability and proposed industry-average GWP value for the materials in the scope of the BCCA (structural steel, carbon steel rebar, flat glass, and mineral wool board insulation), and Section 4 provides a summary of opportunities for improvements to the LCA data ecosystem that impact the methodology as described in this document.

2. INTERPRETING THE BUY CLEAN CALIFORNIA ACT

The Buy Clean California Act (BCCA) was one of the first procurement policies to require agencies to set GWP limits and to require disclosure of environmental product declarations (EPDs) for certain materials used for state construction projects. BCCA tasks the Department of General Services (DGS), in consultation with the California Air Resources Board (CARB), with setting GWP limit values at the industry-average for four eligible material categories: structural steel, concrete reinforcing steel, flat glass, and mineral wool board insulation.

This section provides an overview of five key concepts as they relate to determining the scope and methodology for setting GWP limit values in alignment with the language and intent of the BCCA: product categories, life cycle stages, geography, representing the industry as a whole, and uncertainty and tolerances.

2.1 Product categories

An important principle of comparative LCA is that products or materials should be compared on the basis of their function. This is an essential component of defining product categories for buy-clean policy that can be reasonably assigned to one maximum GWP value.

Within a broader category (e.g., "structural steel"), there may be multiple product type sub-categorizations (e.g., hot-rolled structural sections, HSS, and plate steel). These product subcategories - each to be assigned a unique GWP limit - are based on functional equivalence and corresponding GWP values. The BCCA includes four eligible material categories: structural steel, carbon steel rebar, flat glass, and mineral wool board insulation. Structural steel includes three product subcategories (described above) and mineral wool includes two (heavy and light).

2.2 Life cycle stages

The BCCA and other buy-clean policies typically focus on impacts from manufacturing, corresponding to the life cycle stages A1 (raw material supply), A2 (transportation), and A3 (manufacturing) reported in an EPD. This also aligns with the minimum scope required by **product category rules (PCR)** and therefore found in current EPDs.

2.2.1 Treatment of Fabricated Steel Products

The BCCA states that, “when setting the initial industry average, the department may exclude emissions that occur during fabrication stages, and make reasonable judgments aligned with the product category rule.”⁵

Many steel EPDs (both product-specific and industry-wide) are for fabricated products, and therefore require additional calculations to account for the exclusion of fabrication-related emissions. For the purpose of setting limits based on unfabricated products, excluding A2 impacts (from transport from producer to fabricator) and A3 impacts (due to fabrication processes such as welding, cutting, shaping, etc.) is appropriate for a steel EPD whose A1-A3 value represents a fabricated product (such as the industry wide EPDs for hot-rolled sections, plate steel, and rebar). This has been applied in all steel case studies in this report.

An additional step would be required to align the declared unit across fabricated and unfabricated EPDs. Due to the scrap generated during fabrication, the production of 1 metric ton of fabricated product (the declared unit of a fabricated steel EPD), requires slightly more than 1 metric ton of unfabricated material. The methodology described in this document uses GWP values directly from the IW-EPDs, prioritizing simplicity and the use of publicly available data.

Appendix 1 goes into further detail on the alignment of fabricated and unfabricated EPDs and provides a potential alternative approach for calculating GWP limit values for each of the relevant steel products in the case studies.

2.3 Geography

The BCCA states that limits should be established using: “industry wide environmental product declarations based on *domestic production* data in its calculation of the industry average.”⁶ While ‘domestic production’ would literally refer to products made in the USA, this methodology asserts that it is reasonable to include goods produced in North America (including USA and Mexico and Canada), based on the realities of North American trade, manufacturing practices, and existing structure of LCA data.

2.4 Representation of the industry as a whole

The BCCA requires that the GWP limits be set at the “industry-average of facility-specific global warming potential emissions”, determined by:

*“consulting recognized databases of environmental product declarations. If the department determines that the facility-specific environmental product declarations available do not **adequately represent the industry as a whole**, it may use industry wide environmental product declarations based on domestic production data in its calculation of the industry average.”⁷*

Product category rule (PCR)

A PCR is a set of specific rules and guidelines for developing Type III environmental declarations for one or more product categories. Well-developed PCRs establish reporting requirements, system boundaries, require a backing LCA report, and are harmonized with adjacent PCRs.

PCR development must meet standards set by the International Organization for Standardization (ISO), which include participation from a range of stakeholders and a public comment and review process. PCRs must be reviewed and updated every 5 years at a minimum.

5. California State Legislature, “Buy Clean California Act,” 2021, https://leginfo.ca.gov/faces/codes_displayText.xhtml?division=2.&chapter=3.&part=1.&lawCode=PCC&article=5

6. Ibid.

7. Ibid.

In order to be considered representativeness of an industry, a data source should meet the following criteria.⁸

Representativeness Criteria

- **Production volume:** *is an **adequate total volume** of the overall market production represented in the data? Is the data **production-weighted**? Alternatively, is there sufficient available production or consumption data to perform a weighted average calculation?*
- **Geography:** *is the range of geographic location of facilities adequately represented? In this case, does the collection of data points represent N. American production?*
- **Time:** *are the data recent and relevant? Are the EPDs or other documentation valid (generally 5 years from publication)? Is the background data still in conformance?*
- **Technology/production practices:** *is the range of technology types and production methods used in the manufacture of the product adequately represented? (e.g., EAF- and BOF-produced steel)*
- **Supply chain and material inputs:** *is the range of type and GWP of material ingredients upstream-of-the-manufacturing facility represented? (e.g., stone and slag inputs for mineral wool production)*
- **Methodological consistency:** *have the data sources used consistent background modeling practices (do they follow a consistent PCR), are data sets, allocation methods, or other modeling decisions harmonized?*

The following data limitations currently exist in calculating a representative industry average from EPDs:

- Not all manufacturers produce EPDs, and not all facilities from a given manufacturer have an EPD.
- Production volumes are not reported in product-specific EPDs, nor is that data regularly available.
- Not all manufacturers/facilities are represented in industry-wide EPDs.

While industry-wide EPDs (IW-EPDs) do not cover all manufacturers, they typically cover a large proportion of the market and their results are often more representative of the industry as a whole for two key reasons:

1. **IW-EPDs are production-weighted.** Production-weighted averages seek to avoid the danger of one or two very small, unusual producers dramatically moving the average value to a level in which it cannot credibly represent “typical” or “average” production. For example, the IW-EPD for Hot Rolled Structural Sections by the American Institute of Steel Construction (AISC, 2021) is only based on three North American manufacturers, but together these manufacturers represent 90% of North American production.

8. These criteria are in alignment with data quality and representativeness requirements as defined by international standards set by the International Standards Organization (ISO) in standards ISO 14044: *Environmental management — Life cycle assessment — Requirements and guidelines* and ISO 21930: *2017 Sustainability in buildings and civil engineering works — Core rules for environmental product declarations of construction products and services* and with other guidance on data quality assessment in the context of LCA, such as the guidance published by the EPA:

Edelen, A. and W. Ingwersen (2016). *Guidance on Data Quality Assessment for Life Cycle Inventory Data*. U.S. Environmental Protection Agency, Washington, DC, EPA/600/R-16/096. Available at https://cfpub.epa.gov/si/si_public_record_Report.cfm?Lab=NRML&dirEntryId=321834.

2. IW-EPDs must meet representativeness criteria.⁹ For a collection of facility-specific EPDs to meet this representativeness criteria requires significant additional analysis to ensure that the time, geography, and data sources (for example) have been completed consistently by different practitioners.

For these reasons, an industry-wide EPD is very likely to be the most representative data source option currently available for a given product type.

2.5 Uncertainty and Tolerances

The proposed methodology in this document does not add a tolerance to account for EPD data uncertainty or to compensate for current limitations in available data.¹⁰ The methodology avoids additional “tolerance factors” for the following reasons:

- Peer-reviewed, transparently-published IW-EPDs account for the variability of supply chains and manufacturing practices by sampling a range of manufacturers and adding adjustment factors to create production-weighted averages that provide the best approximation of “typical production.”
- Adding a tolerance factor requires clear, transparent methodology and robust analysis of background life cycle inventory data that is not currently publicly available. Without such analysis, it is neither possible to arrive at a credible tolerance factor, nor is it clear that the uncertainty and variability would result in a limit being increased or decreased.

While there are considerable challenges in harmonizing LCA and addressing sources of uncertainty, the research team determined that adding a tolerance factor is a political decision, rather than a technical one.

9. ISO 21930: International Organization for Standardization (2017) *Sustainability in buildings and civil engineering works — Core rules for environmental product declarations of construction products and services* (ISO Standard No. 21930: 2017).

10. In setting the first round of GWP limits for the BCCA (which have since been replaced), DGS had chosen to add a tolerance to the baseline average to establish the GWP limit “since EPDs have a level of uncertainty in the reported GWP.” These “tolerance factors” have since been removed.

California Department of General Services, “Buy Clean California Act”, 2021, <https://www.dgs.ca.gov/PD/Resources/Page-Content/Procurement-Division-Resources-List-Folder/Buy-Clean-California-Act>

3. PROPOSED VALUES AND METHODOLOGY

This section provides proposed industry-average global warming potential (GWP) values for eligible materials as required by the Buy Clean California Act (BCCA), alongside a summary of available LCA data and justification for each value.

Generally, the research team used the following steps to assign each industry-average GWP value:

1. Define the product category.
2. Gather and assess the available LCA data.
3. Evaluate the representativeness of available data sources to select one of the following methods:
 - Method A: Use the collection of product-specific EPDs (including facility-specific EPDs) to calculate an average.
 - Method B: Use the industry-wide EPD value.
 - Method C: Use the industry-wide EPD and adjust the value to fill in representativeness gaps.
 - If none of these options prove adequate, because there is not yet sufficiently representative data, then the category is not yet ready for a reliable GWP limit.
4. Assign an industry-average GWP value.

Table 2 summarizes the results for each eligible material and primary data source. Due to the current data availability for the specific material types included in the BCCA, Method B was used across all subcategories. **Different methods may be appropriate for material categories that are not included in BCCA, but that is out of the scope of this report.**

Table 2. Buy Clean California Act Proposed Industry-Average GWP Values

Eligible Material	Subcategory	Proposed GWP value	Primary data source
Structural Steel	Hot-Rolled Structural Sections (unfabricated)	1,080 kg CO ₂ e / metric ton	IW-EPD: <i>Fabricated Hot-Rolled Structural Sections</i> . American Institute of Steel Construction (AISC), 2021. (A1 value)
	Plate (unfabricated)	1,590 kg CO ₂ e / metric ton	IW-EPD: <i>Fabricated Steel Plate</i> . American Institute of Steel Construction (AISC), 2021. (A1 value)
	Hollow Structural Sections (unfabricated)	1,710 kg CO ₂ e / metric ton	IW-EPD: <i>Hollow Structural Sections</i> . Steel Tube Institute (STI), 2021. (A1-A3 value)
Concrete Reinforcing Steel	Rebar (unfabricated)	920 kg CO ₂ e / metric ton	IW-EPD: <i>Fabricated Steel Reinforcement</i> . Concrete Reinforcing Steel Institute (CRSI), 2017. (estimated A1 value)
Flat Glass		1,430 kg CO ₂ e / metric ton	IW-EPD: <i>Flat Glass</i> . National Glass Association (NGA), 2019. (A1-A3 value)
Mineral Wool Board Insulation	Light Density	3.33 kg CO ₂ e / m ² RSI-1	IW-EPD: <i>Light and Heavy Density Mineral Wool Board</i> . North American Insulation Manufacturers Association (NAIMA), 2018. (A1-A3 values)
	Heavy density	8.16 kg CO ₂ e / m ² RSI-1	

3.1 Structural Steel // Hot-Rolled Structural Sections

3.1.1 Category Description

Hot-rolled structural steel sections are rolled steel shapes such as angles, channels, parallel flange sections, and tees¹¹. They are commonly used in building, bridge, and industrial projects. BCCA considers the GWP of steel manufacturing, excluding fabrication (cutting, bolting, welding, etc.)¹² Therefore, compliant calculations should report raw material extraction through steel-making and hot rolling.

Manufacturing and Driving Variables

In North America, hot-rolled structural steel sections are manufactured from secondary steel in electric arc furnaces (EAFs).¹³ At the EAF steel mill, the liquid steel is cast into near-net shapes, which go to the rolling mill. At the rolling mill, these near-net shapes are re-heated and passed through pairs of rollers to reduce the thickness and create the desired shape for the structural sections.

The most important factor in the GWP of hot-rolled steel is whether it was produced using the EAF or BOF route, where the EAF route is significantly lower in GWP than BOF. Other factors that influence GWP for steel production are the percentage of scrap steel used and the emissions intensity of the electric grid where the steel is produced (especially if the EAF route is used). Secondly, the hot rolling process contributes to the GWP of the final structural product, but is less than the GWP impact associated with steel production.

3.1.2 Available Data

PCR: *Product Category Rule (PCR) Guidance for Building-Related Products and Services - Part B: Designated Steel Construction Product EPD Requirements*. UL, 2020.

Industry-wide EPD: *Fabricated Hot-Rolled Structural Sections* by the American Institute of Steel Construction (AISC) published in 2021. This IW-EPD is based on three North American producers which together represent 90% of North American production.¹⁴

Product-Specific EPDs: There are currently 39 available product-specific EPDs for this category and only 6 of them are applicable to BCCA GWP limit-setting.¹⁵

Figure 3 illustrates the spread of GWP values for hot-rolled structural section product EPDs. The average GWP of the applicable EPDs (924 kg CO₂e per metric ton) is less than the reported GWP value in the North American industry-wide EPD (1080 kg CO₂e per metric ton of unfabricated sections).¹⁶ There are many EPDs that are not applicable, and these EPDs have a wider distribution of GWP than the applicable EPDs. (Reasons for non-applicability include any of: different PCR, outside of geographic scope, inclusion of fabrication impacts.)

3.1.3 Proposed GWP value

Industry-average GWP = 1,080 kg CO₂e / metric ton of unfabricated hot-rolled structural sections.

Justification

Based on Method B, the proposed value is the A1 (for unfabricated sections) GWP result from the industry-wide EPD. This EPD is adequately representative of the industry as a

11. Hot-Rolled Structural Steel sections meet the requirements of the Standard Specification for General Requirements for Rolled Structural Steel Bars, Plates, Shapes and Sheet Piling (ASTM A6-19)

12. For an unfabricated steel EPD, this includes stages A1-A3. For a fabricated steel EPD, this includes A1 only.

13. American Institute of Steel Construction (AISC). (2017). Hot-rolled Structural Steel Sections: Life Cycle Inventory Methodology Report. <https://www.aisc.org/globalassets/why-steel/the-global-warming-potential-of-hot-rolled-structural-steel.pdf>

14. American Institute of Steel Construction (AISC). (2017). Hot-rolled Structural Steel Sections: Life Cycle Inventory Methodology Report. <https://www.aisc.org/globalassets/why-steel/the-global-warming-potential-of-hot-rolled-structural-steel.pdf>

15. Based on EPDs found in EC3 Database, December 2021.

16. American Institute of Steel Construction (AISC). (2021). *Environmental Product Declaration - Fabricated Hot-Rolled Structural Sections*.

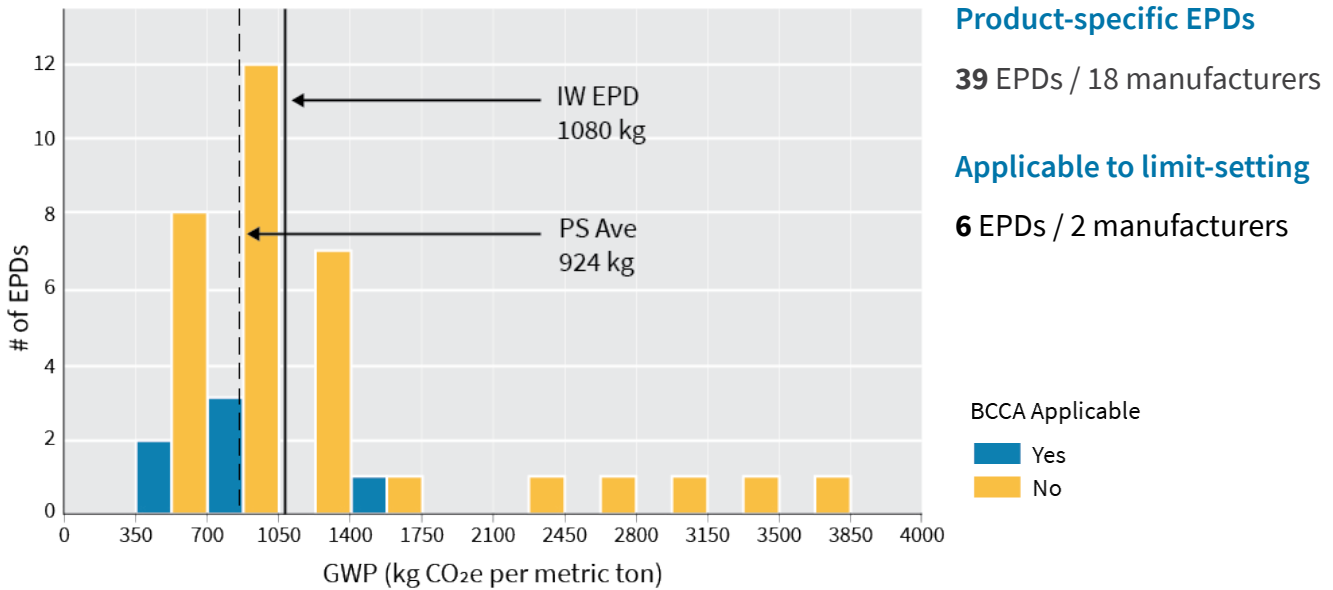


Figure 3. Hot-Rolled Structural Section EPDs: Distribution of product-specific EPD GWP values for hot-rolled structural sections compared with the industry-wide EPD value. Source: EC3 database, December 2021. BCCA Applicable EPDs (indicated in blue) are EPDs for North American products that meet the product category description and follow the PCR identified by DGS. “PS Ave” is the average of the applicable product-specific EPD values.

whole, as assessed by the *Representativeness Criteria* above, including: the EPD represents a substantial majority (90%) of North American production and includes production-weighting by mill. It is third-party-reviewed to ensure it follows the PCR, including a data quality assessment documented in its background report. On the other hand, there are only 8 applicable product-specific EPDs (from two manufacturers), without accompanying data on production volume or market share. Thus the collection of available product-specific EPDs is not adequately representative of the industry.

3.2 Structural Steel // Plate Steel

3.2.1 Category Description

Steel plate is steel sheet material that can be cut and welded to make more complex structural products. It is manufactured to a broad range of thicknesses and is used in applications where super-structural framework and high durability is required. Steel plate is used in construction of buildings, bridges, foundations, and heavy machinery. BCCA considers the GWP of steel manufacturing, excluding fabrication (cutting, bolting, welding, etc.).¹⁷ Therefore, compliant calculations should report raw material extraction through steel-making and plate production.

Manufacturing and Driving Variables

In North America, steel plates are manufactured from both EAF- and basic oxygen furnace (BOF)-produced steel. Steel is cast into slabs, which go to the rolling mill. There, the slabs are sent through a series of rollers until it reaches the desired thickness of the steel plate.¹⁸

The most important factor in the GWP of steel plate is whether the steel was produced using the EAF or BOF route (where EAF is significantly lower GWP than BOF). Other factors that influence GWP for steel production are the percentage of scrap steel use and the emissions intensity of the electric grid where the steel is produced (especially if the EAF route is used) and rolled.

3.2.2 Available Data

PCR: *Product Category Rule (PCR) Guidance for Building-Related Products and Services - Part B: Designated Steel Construction Product EPD Requirements.* UL, 2020.

Industry-wide EPD: *Fabricated Steel Plate* by the American Institute of Steel Construction (AISC) in 2021. This IW-EPD is based on three (out of four total) major US producers, which represents approximately 70-80% of North American production.^{19,20}

Product-Specific EPDs: There are currently 7 available product-specific EPDs for this category and only 2 of them are applicable to BCCA GWP limit-setting.²¹

Figure 4 illustrates the spread of GWP values for steel plate product EPDs. Notably, there are only two applicable product-specific EPDs (with the correct PCR, from North America, and include unfabricated GWP values). They have an average GWP of 1420 kg CO₂e per metric ton, which is lower than the industry-wide unfabricated GWP value of 1590 kg CO₂e per metric ton. The five non-applicable product EPDs - all from outside of North America - all have a greater reported GWP than the industry wide EPD value. This may be due to higher rates of BOF- vs. EAF-produced steel for steel plate produced outside of North America.

3.2.3 Proposed GWP value

Industry-average GWP = 1590 kg CO₂e / metric ton of unfabricated plate steel.

17. For an unfabricated steel EPD, this includes stages A1-A3. For a fabricated steel EPD, this includes A1 only.

18. Metline Industries, "How to Manufacture Steel Plates & Sheets?" <https://steelplates.in/how-to-manufacture-steel-plates-sheets/>

19. These numbers relate to plate producers for all applications, not only those that produce plate for use in construction. Cross, J. & Puchtel, M. (2022, January 12). AISC, Personal communication [Personal interview].

20. The A1 value represents unfabricated steel plate, and is based on the background dataset for North American steel plate, published by the American Iron and Steel Institute (AISI).

21. Based on EPDs found in EC3 Database, December 2021.

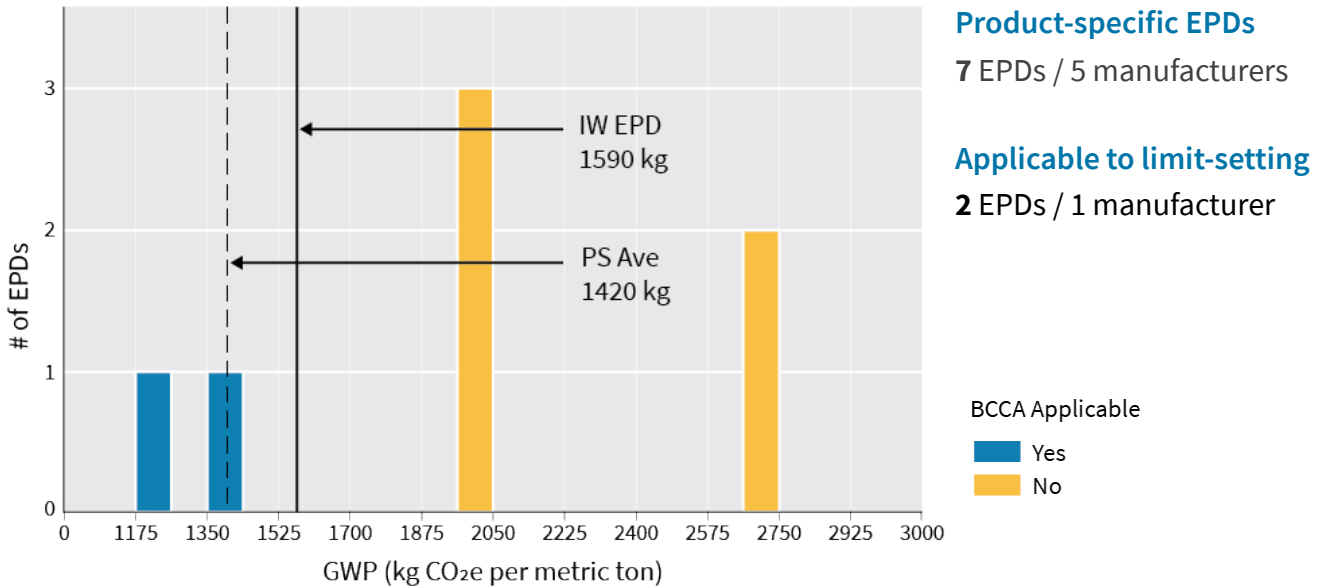


Figure 4. Plate Steel EPDs: Distribution of product-specific EPD GWP values for plate steel compared with the industry-wide EPD value. Source: EC3 database, December 2021. BCCA Applicable EPDs (indicated in blue) are EPDs for North American products that meet the product category description and follow the PCR identified by DGS. “PS Ave” is the average of the applicable product-specific EPD values.

Justification

Based on Method B, the proposed value is the A1 (for unfabricated plate steel) GWP result from the industry-wide EPD. This EPD is adequately representative of the industry as a whole, as assessed by the *Representativeness Criteria* above, including: the EPD represents a majority (approximately 70-80%) of North American production and includes production-weighting by mill. It is third-party-reviewed to ensure it follows the PCR, including a data quality assessment documented in its background report. On the other hand, there are only two product-specific EPDs applicable to GWP limit-setting. Thus, the collection of available product-specific EPDs is likely not adequately representative of the industry.

3.3 Structural Steel // Hollow Structural Sections

3.3.1 Category Description

Hollow Structural Sections (HSS) are cold-formed, welded steel tubes used for welded or bolted construction of buildings, bridges, and other structures as well as a wide-range of manufactured products. They are produced in square, round, and rectangular shapes to meet structural design requirements. BCCA considers the GWP of steel manufacturing, excluding fabrication (cutting, bolting, welding, etc.).²² Therefore, compliant calculations should report raw material extraction through steel-making and HSS production.

Manufacturing and Driving Variables

Liquid steel is cast into slabs or billets and transformed into steel coil via hot rolling, or cast directly into sheet for coil using a cast-strip process, minimizing secondary rolling. In North America, hot-rolled coil is manufactured from both EAF- and BOF-produced steel.²³ Unlike for hot-rolled structural sections, HSS production involves an additional step after hot rolling in order to create the hollow shape. HSS producers transform the coil into its final tube shape via cold forming and welding. Currently there are three technologies used to produce HSS in North America, which include the electric resistance welding process, the form-square weld-square process, and the submerged arc weld process.²⁴

Note that there is currently one North American HSS producer with its own melt shop to produce steel coil, which it then uses to produce HSS. Other North American HSS producers purchase coil produced elsewhere, in order to produce HSS. As an HSS-producing facility would likely lack data on the origins or GWP of their purchased steel coil, 'facility-specific' data in this case may apply only to the final stage of production (and not to the initial steel making or hot rolling).

The most important factor in the GWP of HSS is whether it was produced using the EAF or BOF route, where the EAF route is significantly lower than BOF. Other factors that influence GWP for steel production are the percentage of scrap steel used and the emissions intensity of the electric grid where the steel is produced (especially if the EAF route is used). Secondly, hot rolling (to create steel coil), and cold forming and welding (to produce HSS from coil) can significantly contribute to GWP impact due to energy use for reheating and electricity inputs.

3.3.2 Available Data

PCR: *Product Category Rule (PCR) Guidance for Building-Related Products and Services - Part B: Designated Steel Construction Product EPD Requirements.* UL, 2020.

Industry-wide EPD: *Hollow Structural Sections.* Steel Tube Institute (STI), 2021. This IW-EPD is based on 8 (out of approximately 10-12 total) North American manufacturers which together represent approximately 60-65% of North American production.^{25, 26}

Product-Specific EPDs: There are currently 11 available product-specific EPDs for this category and only 5 of them are applicable to BCCA GWP limit-setting.²⁷

The applicable EPDs for GWP limit-setting have an average GWP of 1312 kg CO₂e per metric ton and all fall below the GWP value reported in the industry-wide EPD (1710 kg CO₂e per metric ton). Since these EPDs are all from one manufacturer and since production volume data is unavailable, it is likely more representative to use the industry-wide EPD for limit setting. Other non-applicable product EPDs – those from different regions and/

22. For an unfabricated steel EPD, this includes stages A1-A3. For a fabricated steel EPD, this includes A1 only.

23. From the HSS IW-EPD: "Hot-rolled coil data that form the basis of the hollow structural sections production represent a mixture of electric arc furnace and basic oxygen furnace technologies, although the ratio reflects who participated in worldsteel's analysis and may not reflect production today." STI, 2021.

24. Steel Tube Institute of North America, "Hollow Structural Sections - Dimensions and Section Properties" <http://www.cim.mcgill.ca/~paul/HollowStruct.pdf>

25. The eight participating companies are listed in the EPD. Approximate representation of North American production based on STI data, shared by Cross, J. & Puchtel, M. (2021, November 29). AISC, Personal communication [Personal interview].

26. Unlike the other three steel categories in this document, the industry-wide EPD for HSS is for unfabricated products. Thus the A1-A3 result (rather than only A1 for the other three steel product types) is the BCCA-relevant GWP value.

27. Based on EPDs found in the EC3 database, December 2021.

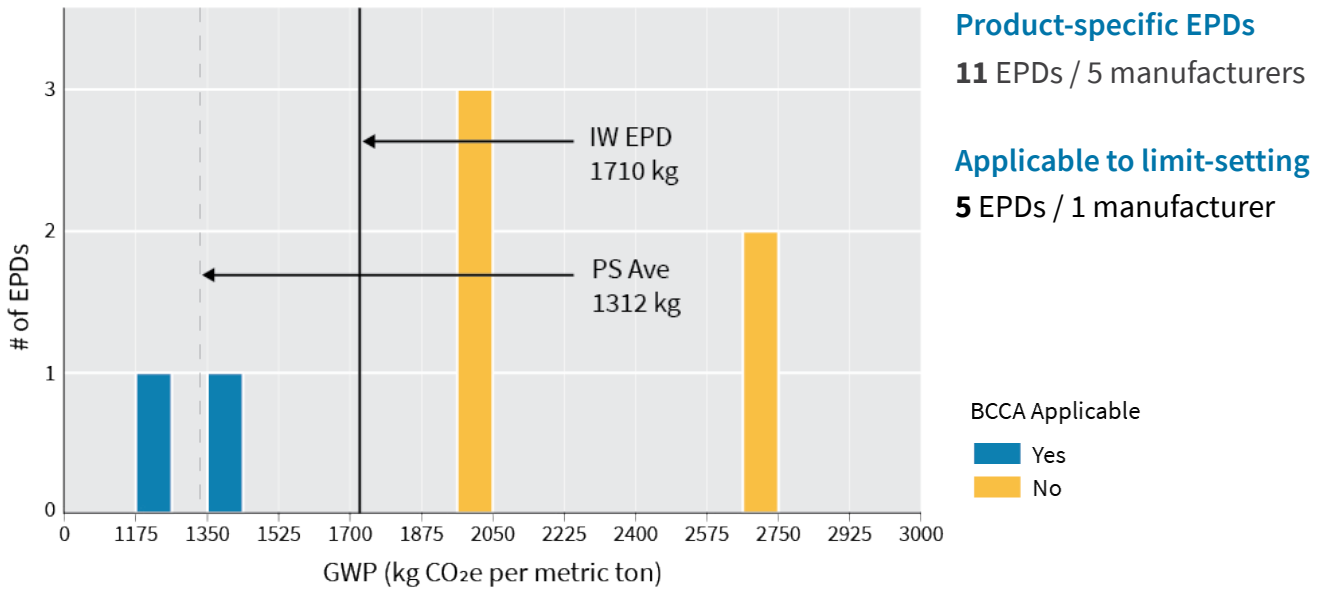


Figure 5. Hollow Structural Steel Sections: Distribution of product-specific EPD GWP values for HSS compared with the industry-wide EPD value. Source: EC3 database, December 2021. BCCA Applicable EPDs (indicated in blue) are EPDs for North American products that meet the product category description and follow the PCR identified by DGS. “PS Ave” is the average of the applicable product-specific EPD values.

or ones that use a different PCR – show a greater spread of GWP values, which may be due to both the source of the steel (i.e., EAF vs. BOF), as well as methodological choices for calculating GWP.

3.3.3 Proposed GWP value

Industry-average GWP = 1710 kg CO₂e / metric ton of unfabricated HSS.

Justification

Based on Method B, the proposed value is the A1-A3 GWP result from the industry-wide EPD. This EPD is adequately representative of the industry as a whole, as assessed by the *Representativeness Criteria* above, including: the EPD represents a majority (60-65%) of North American production and includes production-weighting by producer. It is third-party-reviewed to ensure it follows the PCR, including a data quality assessment documented in its background report. On the other hand, there are only five product-specific EPDs (from one manufacturer) applicable to limit-setting for BCCA, without accompanying data on production volume or market share. Thus the collection of available product-specific EPDs is likely not adequately representative of the industry.

3.4 Concrete Reinforcing Steel // Rebar

3.4.1 Category Description

Steel reinforcement bar (or rebar) is used to resist tension forces in reinforced concrete and reinforced masonry structures. The surface of rebar is often deformed with ribs or indentations to promote a better bond with concrete and reduce the risk of slippage. It is used in bridges, buildings, skyscrapers, homes, warehouses, and foundations. For BCCA, the following are included: carbon steel bars, low-alloy steel bars, zinc-coated steel bars, and epoxy-coated steel bars.²⁸ DGS includes coated rebar in the scope of its limits, however the current PCR does not include coated rebar. This issue should be harmonized in the upcoming version of the concrete reinforcing bar PCR. BCCA considers the GWP of rebar manufacturing, excluding fabrication (cutting, bending, welding, etc.).²⁹ Therefore, compliant calculations should report raw material extraction through steel-making and rebar production.

Manufacturing and Driving Variables

In North America, rebar is produced primarily from secondary steel in EAFs.³⁰ Liquid steel is cast into billet shapes, which go to the rolling mill. At the rolling mill, these shapes are typically re-heated and passed through rollers to reduce the shape to the appropriate size, and, where applicable, add ribs. Finally, coatings are added if applicable.

The most important factor in the GWP of rebar is whether it was produced using the EAF or BOF route. Secondly, the hot rolling process contributes to the GWP of the final product. Other factors that influence GWP for steel production are the percentage of scrap steel used and the emissions intensity of the electric grid where the steel is produced (especially if the EAF route is used) and milled. According to the industry-wide EPD, rebar made in the USA uses 98% steel scrap via EAF technology.³¹

3.4.2 Available Data

PCRs: *Product Category Rule (PCR) Guidance for Building-Related Products and Services - Part B: Designated Steel Construction Product EPD Requirements.* UL, 2020.

Previous version used for some currently valid EPDs, including the industry-wide EPD: *North American Product Category Rule for Designated Steel Construction Products*, version 1.0. SCS, 2015.

Industry-wide EPD: *Fabricated Steel Reinforcement* by the Concrete Reinforcing Steel Institute (CRSI). 2017.³² This IW-EPD is based on data from 24 manufacturing facilities owned by 4 companies. Percentage of N American production covered is not disclosed.

Product-Specific EPDs: There are currently 75 available product-specific EPDs for this category and only 17 of them are applicable to BCCA GWP limit-setting.³³

Figure 6 illustrates the spread of GWP values for rebar product EPDs in EC3 December, 2021. BCCA-compliant EPDs follow the appropriate PCR, are facility-specific, and report results for unfabricated products. Their (unweighted) average GWP (785 kg CO₂e per metric ton) is lower than the reported GWP value in the North American industry-wide EPD (approximately 920 kg CO₂e per metric ton).³⁴ The applicable EPDs are from 3 manufacturers, who may have slightly lower-than-average GWP products. The non-applicable

28. California Department of General Services, "Buy Clean California" <https://www.dgs.ca.gov/PD/Resources/Page-Content/Procurement-Division-Resources-List-Folder/Buy-Clean-California-Act>

29. For an unfabricated steel EPD, this includes stages A1-A3. For a fabricated steel EPD, this includes A1 only.

30. From the industry-wide EPD: "Steel made in the US from 98% recycled steel scrap via electric arc furnace (EAF) technology". Concrete Reinforcing Steel Institute (CRSI). (2017). Environmental Product Declaration - Fabricated Steel Reinforcement. ASTM. ; Concrete Construction, a resource for contractors and specifiers, states that "all domestically produced rebar is made from at least 97% recycled scrap steel for normal grades (ASTM A615 or A706)": https://www.concreteconstruction.net/how-to/materials/from-old-cars-comes-rebar_o

31. Concrete Reinforcing Steel Institute (CRSI). (2017). Environmental Product Declaration - Fabricated Steel Reinforcement. ASTM.

32. Concrete Reinforcing Steel Institute (CRSI). (2017). Environmental Product Declaration - Fabricated Steel Reinforcement. ASTM. Note that the industry EPD, based on an expired 2015 version of the PCR, will itself expire in 2022, and will presumably be replaced in 2022 by an updated industry EPD based on the current 2020 PCR version.

33. Content is for "steel made in the US from 98% recycled steel scrap via electric arc furnace (EAF) technology", and does not include coated rebar products, per the (now expired) governing PCR. Based on EPDs in the EC3 database, December 2021.

34. The reported A1-A3 value of 0.979 metric ton (979 kg) CO₂e / metric ton rebar represents fabricated rebar. The A1 (unfabricated) value is not reported separately in the EPD, but is estimated here to be approximately 94% of this total, based on Figure 2 of the EPD. This yields an estimate of 0.92 metric ton (920 kg) CO₂e / metric ton unfabricated rebar.

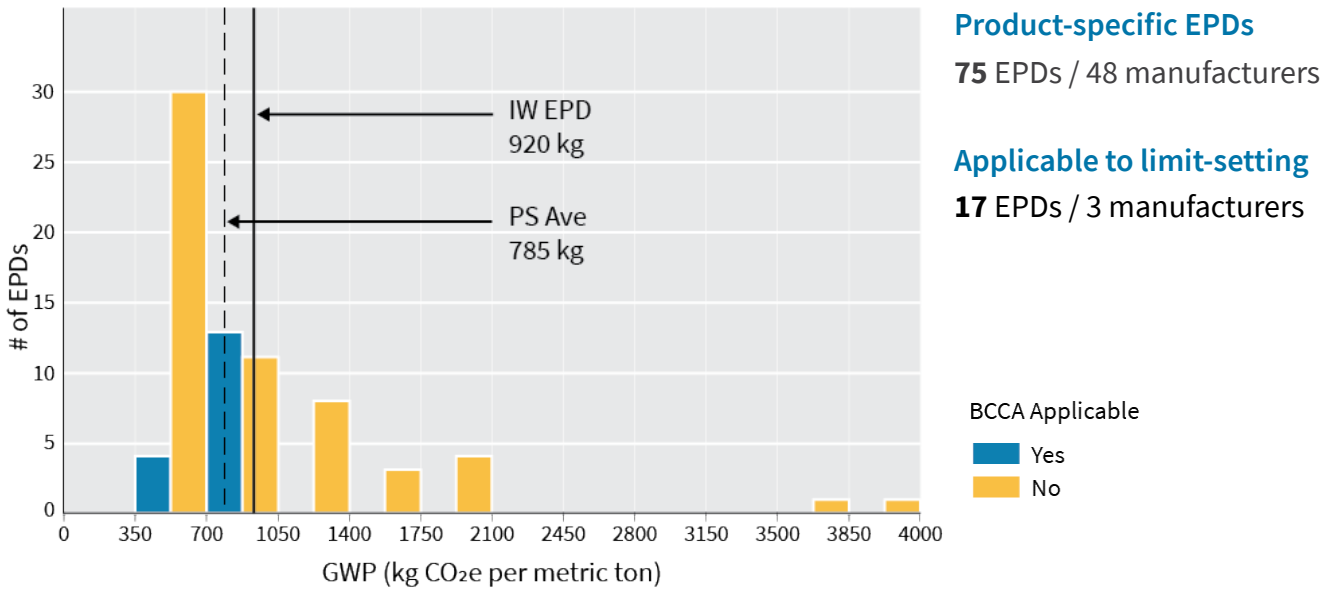


Figure 6. Concrete Reinforcing Steel EPDs: Distribution of product-specific EPD GWP values for rebar compared with the industry-wide EPD value. Source: EC3 database, December 2021. BCCA Applicable EPDs (indicated in blue) are EPDs for North American products that meet the product category description and follow the PCR identified by DGS. “PS Ave” is the average of the applicable product-specific EPD values.

EPDs have a wider distribution of GWP than the applicable EPDs, including two Australian rebar EPDs with significantly higher GWP impacts of nearly 4,000 kg CO₂e per metric ton of rebar.

3.4.3 Proposed GWP value

920 kg CO₂e / metric ton of un-fabricated steel rebar.

Justification

Based on Method B, the proposed value is the estimated A1 (for unfabricated rebar) GWP result from the industry-wide EPD. This EPD is adequately representative of the industry as a whole, as assessed by the *Representativeness Criteria* above. It is third-party-reviewed to ensure it follows the PCR, including a data quality assessment documented in the EPD that assesses the temporal, geographical, and technological representativeness as high. While the authors do not know the overall market share represented in the EPD, the study represents a weighted average of 24 mill facilities owned by four companies, and the CRSI website lists over 75 member companies authorized to submit the EPD to represent their product (noting that many of these are fabricators and not necessarily manufacturers). There are 17 applicable product-specific EPDs from three manufacturers, without accompanying data on production volume or market share. Thus the industry-wide EPD is assumed to be more adequately representative of the industry than the collection of applicable product-specific EPDs.

3.5 Flat Glass

3.5.1 Category Description

“Flat glass is a general term that describes all glass produced in a flat form, such as float glass, sheet glass, plate glass and rolled glass.”³⁵ Treatments (such as heat-treatment), coatings (such as low-e coatings), and other processing to create building products ready for installation (such as lamination to create insulating glass units, or IGUs) are out of scope for this material and are covered by a separate product category rule. To the best of the authors’ knowledge, there are five major manufacturers of float glass in the USA: Guardian, Vitro, Pilkington (NSG), Cardinal, and AGC (Asahi), with a total of 20 USA float glass plants.

Manufacturing and Driving Variables

Flat glass “is formulated from soda-lime silicates and metal-oxide materials. Flat glass is manufactured by mixing raw materials at high temperature and floating them onto the surface of a molten tin bath, which smooths the glass by gravity and surface tension. The flat glass ribbon is guided on rollers through an annealing lehr where it is cooled under controlled conditions to avoid buildup of internal stress until it emerges at essentially room temperature. The resulting flat glass is cut to desired sizes and is available in a range of thicknesses and surface treatment options.”³⁶

The IW-EPD shows the melting of materials via natural-gas-powered furnace is the driving factor for GWP (~40%). This is followed by GWP associated with the raw materials (i.e. silica sand, soda ash), direct emissions³⁷, and electricity.

3.5.2 Available Data

PCRs: *Product Category Rule for Environmental Product Declarations - NGA PCR for Flat Glass: UN CPC 3711*. NSF International. 2020.

Previous version used by the industry-wide EPD: *Product Category Rule for Environmental Product Declarations - GANA PCR for Flat Glass: UN CPC 3711*. NSF International. 2014.³⁸

Industry-wide EPD: *Flat Glass*. National Glass Association (NGA), ASTM. 2019. This IW-EPD is based on four (out of five total) major North American manufacturers. Percentage of production is not disclosed.³⁹

Product-Specific EPDs: There are currently 13 available product-specific EPDs for this category and only 7 of them are applicable to BCCA GWP limit-setting.⁴⁰

3.5.2 Proposed GWP value

Industry-average GWP = 1,430 kg CO₂e / metric ton of flat glass.

Justification

Based on Method B, the proposed value is the GWP result from the industry-wide EPD. This EPD is adequately representative of the industry as a whole, as assessed by the *Representativeness Criteria* above, including: the EPD represents a substantial majority (four of five) major North American producers and includes production-weighting by facility. It is third-party-reviewed to ensure it follows the PCR, including a data quality assessment documented in its background report. The average of the product-specific

35. National Glass Association (NGA). (2019). Environmental Product Declaration - Flat Glass. ASTM International. Retrieved from https://www.glass.org/sites/default/files/2019-12/NGA_EP_D_2019_12_16_signed.pdf

36. National Glass Association (NGA). (2019). Environmental Product Declaration - Flat Glass. ASTM International. Retrieved from https://www.glass.org/sites/default/files/2019-12/NGA_EP_D_2019_12_16_signed.pdf

37. The IW-EPD lists “direct emissions - process emissions reported by facilities” as a contributing factor, though it is unclear to the authors of this report what that category includes, as natural gas combustion is a separate item on the list.

38. Originally was March 31, 2019 expiry; extended to September 30, 2020.

39. National Glass Association (NGA). (2019). Environmental Product Declaration - Flat Glass. ASTM International. Retrieved from https://www.glass.org/sites/default/files/2019-12/NGA_EP_D_2019_12_16_signed.pdf

40. Based on EPDs found in EC3 Database, December 2021.

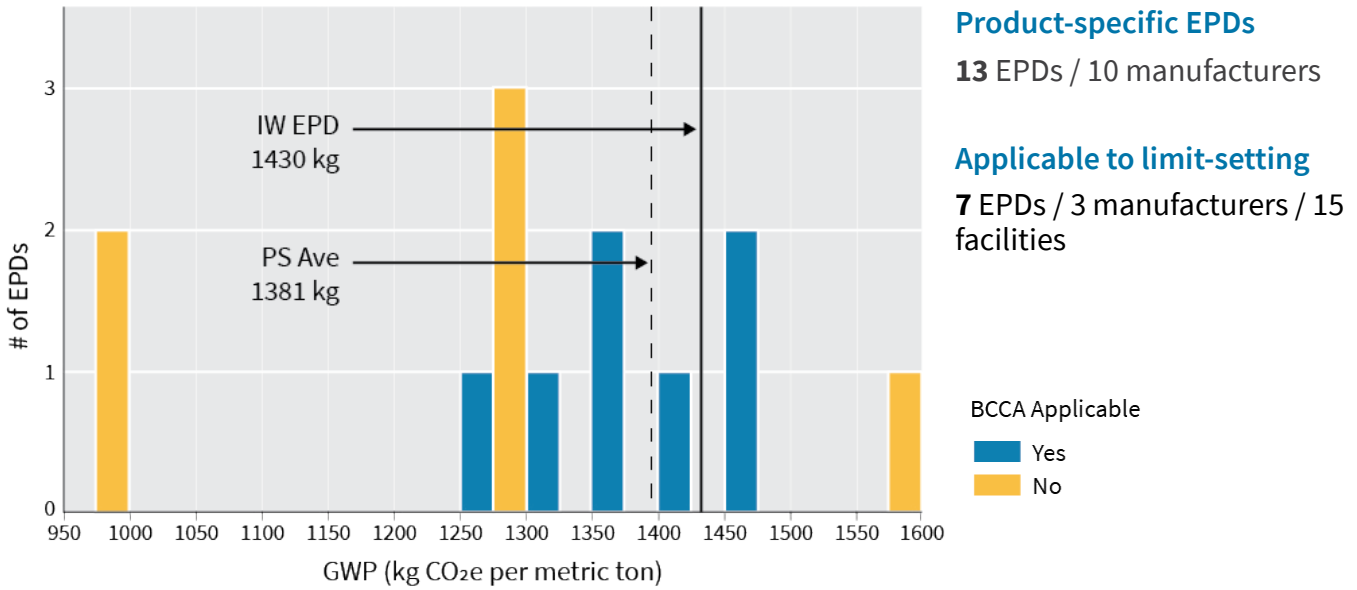


Figure 7. Flat Glass EPDs: Distribution of product-specific EPD GWP values for flat glass compared with the industry-wide EPD value. Source: EC3 database, December 2021. BCCA Applicable EPDs (indicated in blue) are EPDs for North American products that meet the product category description and follow the PCR identified by DGS. “PS Ave” is the average of the applicable product-specific EPD values.

GWP values - when weighted by number of facilities - is 1,410. As this number is not a true production-weighted average⁴¹, it is not as reliable as the industry-wide EPD value, but the fact that the two are so close to each other (only 1.4% difference) ought to add confidence to the proposed value.

41. The average in the histogram above is a simple average of EPD values, not weighted by number of facilities. As facilities vary in their production quantities, weighting by number of facilities is at best a very rough proxy for production-weighting, and hence this facility-weighted value is included here for reference only.

3.6 Mineral Wool Board Insulation

3.6.1 Category Description

Mineral wool board insulation is a semi-rigid material made of natural rock and slag and is used as thermal insulation in building envelopes. Per the industry-wide EPD, and aligning with DGS's interpretation, the category is split here to light-density (2.5 – 4.3 lbs / ft³) and heavy-density (4.4 – 8 lbs / ft³). Boards are produced in a variety of thicknesses, and with or without facings. To normalize by insulating value, the unit of measure for North American insulation EPDs is 1 m² at RSI-1.⁴² The scope in the context of BCCA is cradle to gate, or lifecycle stages A1-A3.⁴³

Manufacturing and Driving Variables

The primary basic material ingredients for mineral wool insulation are slag (a byproduct of steel production) and natural rock such as basalt or feldspar. At the production facility, the ingredients are mixed and melted in a furnace, and once molten are spun to create fine fibers. The fibers are coated with a binder, and then the fiber-binder composite is formed into boards. Finally the boards are cooled, trimmed, and packaged.

The manufacturing stage is where the major GWP impacts occur⁴⁴, with energy use for melting the feedstock materials at the furnace as the primary contributor. This energy use is either through direct burning of fossil fuels or indirect grid power generation. The two primary mineral wool feedstock materials (basalt and slag) have very different origins and different LCA considerations. Basalt is produced through hard-rock quarrying which involves digging, blasting, and crushing of bedrock. Slag is produced as a co-product of iron and steel smelting (and is currently treated in LCAs as “burdenless”, i.e., without environmental impact).

3.6.2 Available Data

PCR: *Product Category Rule (PCR) Guidance for Building-Related Products and Services Part B: Building Envelope Thermal Insulation EPD Requirements.* UL, 2020.

Industry-wide EPD: *Light and Heavy Density Mineral Wool Board.* North American Insulation Manufacturers Association (NAIMA). 2018. This EPD includes data from four facilities in Alabama, Indiana, and Mexico. Percentage of production is not disclosed.

Product-Specific EPDs: There are currently 18 available product-specific EPDs for light-density mineral wool board and only 4 of them are applicable to BCCA GWP limit-setting. There are currently 19 available product-specific EPDs for heavy-density mineral wool board and only 4 of them are applicable to BCCA GWP limit-setting.⁴⁵

Two companies account for all mineral wool board product-specific EPDs in North America: ROCKWOOL⁴⁶ and Owens Corning. The two companies appear to use similar manufacturing processes, and variation in reported GWP of their products may be due to the use of different background datasets⁴⁷ and/or local power grid differences.⁴⁸ Most North American product-specific EPD values fall below the industry-wide EPD value.

3.6.3 Proposed GWP values

- Light density mineral wool board = 3.33 kgCO₂e per m² Rsi-1
- Heavy density mineral wool board = 8.16 kgCO₂e per m² Rsi-1

42. This unit is 1m² at the thickness required to achieve an average thermal resistance of RSI = 1.0, where RSI (also commonly written as R_s or Rsi) is the metric unit of R-value. An RSI value of 1.0 = approximately R-5.68 in I-P units.

43. While the impacts of insulation products on a building's operational GHG emissions are significant, these are not accounted for in EPD results.

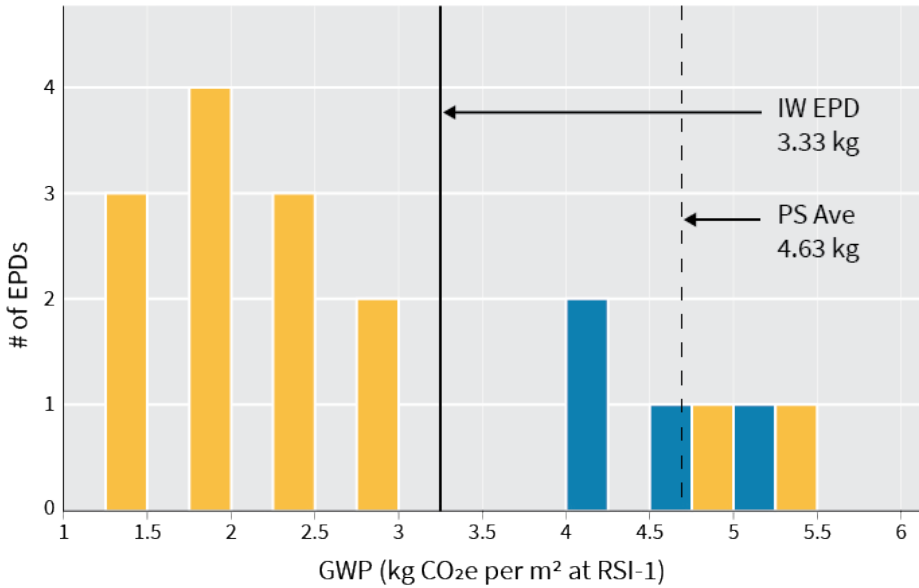
44. Approximately 89% of total A1-A3 impacts for one example product-specific EPD. Owens Corning. (2014). Environmental Product Declaration - Thermafiber Mineral Wool Insulation.

45. Based on EPDs found in EC3 Database, December 2021. Note that the numbers below are for both light- and heavy-density products.

46. ROCKWOOL's EPD for North American-produced mineral wool (which includes multiple values for separate products) does not use the applicable North American PCR, so its values are designated here as non-applicable to GWP limit setting, and are excluded from the calculated average of applicable product-specific EPDs.

47. ROCKWOOL performs their LCAs using the GaBi database, while Owens Corning usesecoinvent.

48. But, given that the two use a manufacturing process (traditional cupola) that involves the burning of fossil fuels such as coal and coke to melt the feedstock, electricity would likely be a relatively minor contributor to total GWP.



Product-specific EPDs

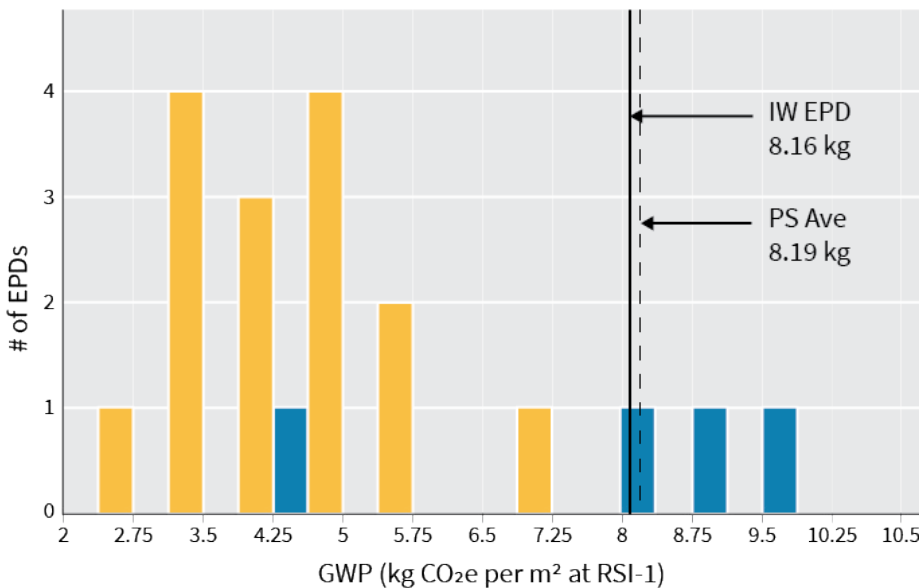
18 EPDs / 5 manufacturers

Applicable to limit-setting

4 EPDs / 1 manufacturer

BCCA Applicable
■ Yes
■ No

Figure 8. Light-Density Mineral Wool Board EPDs: Distribution of product-specific EPD GWP values for light-density mineral wool board insulation compared with the industry-wide EPD values. Source: EC3 database, December 2021. BCCA Applicable EPDs (indicated in blue) are EPDs for North American products that meet the product category description and follow the PCR identified by DGS. “PS Ave” is the average of the applicable product-specific EPD values.



Product-specific EPDs

19 EPDs / 5 manufacturers

Applicable to limit-setting

4 EPDs / 1 manufacturer

BCCA Applicable
■ Yes
■ No

Figure 9. Heavy-Density Mineral Wool Board EPDs: Distribution of product-specific EPD GWP values for heavy-density mineral wool board insulation compared with the industry-wide EPD values. Source: EC3 database, December 2021. BCCA Applicable EPDs (indicated in blue) are EPDs for North American products that meet the product category description and follow the PCR identified by DGS. “PS Ave” is the average of the applicable product-specific EPD values.

Based on Method B, the proposed values are the GWP results from the industry-wide EPD. This EPD is adequately representative of the industry as a whole, as assessed by the *Representativeness Criteria* including: the EPD uses production-weighting, is based on data from the two US companies with the largest market share⁴⁹, plus one in Mexico, and uses the same system boundaries, and background data for all products. Without production data to generate a weighted average, the collection of product-specific EPDs is considered not adequately representative of the industry at this time.

49. Though the IW-EPD does not report which companies the EPD represents, it does provide manufacturing locations that correspond to those of ROCKWOOL and Owens Corning.

4. STRENGTHENING THE LCA DATA ECOSYSTEM

The effectiveness of buy-clean policies to drive down GHG emissions depends in part on environmental product declarations (EPDs) as effective and comparable reporting tools for global warming potential (GWP). The use of EPDs is significant in establishing GWP limits, implementing policy, and tracking progress towards decarbonization goals. In order for buy-clean policies to be successful, they must rely on high quality, trustworthy, transparent, and up-to-date information.

The methodology described in this document to assign industry-average GWP values is constrained to high quality, published LCA data sources that are available as of December 2021. However, a broader range of potentially higher quality data sources may be available in the future that would impact the methodology used in this document and what methods are available for the Department of General Services and other government agencies tasked with setting GWP limits in the future.

Key opportunities to strengthen the LCA data ecosystem to support more robust policies is summarized in sections 4.1-4.3 below

4.1 Strengthening PCRs

Well-developed PCRs establish reporting requirements, set system boundaries, include a backing LCA report to act as a template for analysts, are harmonized with adjacent PCRs, and establish standards for third-party review.

The content of PCRs could be improved by including the following content:

- Set clear criteria for comparability, ensuring that any EPD created from the PCR contains enough information to know if - and to what other EPDs - it is comparable.
- Specify required background data sets and modeling methods (such as allocation, system boundaries, etc.).
- Include a publicly-accessible supporting LCA.

The process of developing and updating PCRs should improve in the following ways:

- Include more end users in PCR committees: PCRs are developed through an ISO-specified committee process requiring participation from a range of industry partners. However, in practice these are dominated by industry organizations and manufacturers. Representatives from GWP-limit-setting government agencies and other end users could participate in PCR committees, as done by the CA DGS.
- Update more frequently: PCRs must be updated every 5 years, but can be updated sooner for critical changes. Frequent updates may be required in the next 5-10 years to meet the needs of increased use.

While the PCR process is guided by ISO requirements, there is no umbrella organization for PCR committees. Increased coordination from stakeholders such as the American Center for Life Cycle Assessment (ACLCA)'s PCR committee, the Program Operator Consortium, and the Federal LCA Commons could increase harmonization across PCRs to promote quality and transparency.

4.2 Increasing Data Transparency and Access

Publication of transparent, freely available LCA data and databases for end users is critical to strengthening buy-clean policies and programs over time. Access to open data (e.g. free, publicly-accessible LCA data and models) that can be referenced and used by LCA consultants, manufacturers, and end users alike, would improve the quality and accessibility of EPDs through:

- Increasing harmonization across PCRs by enabling all PCRs to reference the same background data. This would result in increased comparability by removing the concern that different EPDs or different PCRs used different background data.
- Decreasing the cost of performing LCAs (and therefore creating EPDs). This would increase access for manufacturers creating EPDs and for Agencies and the researchers supporting their work.
- Allow for EPDs to be easily updated through indexed models that connect to consistent background life cycle inventories, such as energy grid and transportation models managed by the Federal LCA Commons.

As an increasing number of EPDs are collected, it is also important to locate them in free, publicly-accessible databases and to report results in a digital format (not just a PDF) to enable easy analysis and comparison by end users. Movements to digitize the EPD development process are underway, such as the openEPD, a digital EPD format in North America.⁵⁰

4.3 Increased Participation

Buy-clean policies will require a rapid increase in the number of products and manufacturers with EPDs. This will increase quantity and quality of data for the private sector for use in procurement as well, increasing the potential for embodied carbon reductions associated with buy-clean.

EPD generation needs to become easy and inexpensive to meet the growing need for product and manufacturer specific embodied carbon data for decision-making. Decreasing the cost and difficulty of creating an EPD would not only level the playing field for smaller manufacturers, but would also improve data quality by allowing companies to quickly update their EPDs to address any changes in PCRs or policy requirements.

In addition to access to open LCA data and EPD databases, the creation of tools for the creation of EPDs that follow the requirements set by PCRs could significantly reduce the cost and time required to generate new EPDs.

50. Building Transparency. (January 10, 2021). OpenEPD. BuildingTransparency. <https://www.buildingtransparency.org/openepd/>

5. CONCLUSION

The methodology used in this report seeks to assign industry-average GWP values that are representative of typical manufacturing production and are constrained to high quality, published LCA data sources.

As described in Section 3.1-3.6, industry-wide environmental product declarations (EPDs) currently provide the most representative data source for assigning industry-average global warming potential (GWP) values for structural steel, reinforcing steel, mineral wool insulation, and flat glass products. While industry-wide EPDs do not cover all manufacturers, they typically cover a large proportion of the market, are production-weighted, and meet key representativeness criteria (as described in section 2.4). Additional research may show that data sources (e.g. different types of EPDs) prove to be more representative for material categories excluded from the Buy Clean California Act, requiring use of Methods A or C described in section 3.

The effectiveness of buy-clean policies to drive down GHG emissions depends in part on EPDs as effective and comparable reporting tools for GWP. In order for buy-clean policies to be successful, they must rely on high quality, trustworthy, transparent, and up-to-date information.

Increased requirements for EPDs through legislation and private sector action has increased pressure on the LCA data ecosystem - including EPDs, the product category rules (PCRs) that set rules for EPDs, and background LCAs - to (1) become more consistent and transparent and (2) enable manufacturers to create EPDs more easily and rapidly. Strengthening the content and development process for PCRs, increasing data transparency and access, and increasing the number of products and manufacturers with EPDs, will all support this transition to a stronger LCA data ecosystem that can support effective use of LCA data, EPDs, and limits in policies.

APPENDIX I: STEEL FABRICATION SCRAP AND ACCOUNTING METHODS

As mentioned in section 2.2.1, there are EPDs for both fabricated and unfabricated steel products. For a fabricated product EPD, the A1 value excludes the fabrication impacts of cutting, welding, shaping, etc. However, the A1 value still includes additional impacts beyond the production of 1 metric ton of unfabricated steel. Due to the scrap generated during fabrication, the production of 1 metric ton of fabricated product (the declared unit of a fabricated steel EPD), requires slightly more than 1 metric ton of unfabricated material. Therefore, in a fabricated product EPD, the A1 value represents the production of more than 1 metric ton of material, with a scrap level that is not always disclosed, and is not consistent across products and supply chains.⁵¹

In an ideal future scenario, a policy would be clear regarding how to address this issue in implementation, and there would be consistent and transparent data regarding fabrication scrap rates that would allow for straightforward conversions between fabricated and unfabricated scenarios. The PCR would require EPDs to report scrap rates, and could provide a standardized industry-average rate per product type. Then one could easily convert between the two options (including or excluding fabrication scrap impacts) for any EPD.

In the present scenario, this is not the case. The BCCA policy leaves some room for interpretation, the PCRs do not prescribe a fabrication scrap rate, and most EPDs (including the industry-wide EPDs) do not report scrap rates or other information for aligning the declared units and corresponding GWP values between fabricated and unfabricated EPDs.

An exception is one manufacturer's EPDs that include both GWP results - one result for the production of the amount of unfabricated steel that ultimately yields 1 metric ton of fabricated steel plus the small amount of scrap generated during the fabrication process, and one result for the production of 1 metric ton of unfabricated steel only. The following example is from Nucor's EPD (2021) for plate steel⁵² includes, for the Hertford facility,

- A1 GWP = 1,340 kg CO₂e (This is the impact due to the production of 1 metric ton of unfabricated steel plate, plus the additional unfabricated material that ultimately ends up as scrap generated during fabrication.)
- Cradle-to-Gate Mill Product GWP = 1,240 kg CO₂e (This includes the production of 1 metric ton of unfabricated steel plate only.)

In this case, one can calculate that the EPD assumes a fabrication scrap rate of approximately 1.08 (derived by dividing 1,340 by 1,240). This could also be expressed as 8%, or 0.08 metric tons (80 kg) of scrap generated during the fabrication process that yields 1 metric ton of fabricated steel plate.

GWP [KG CO ₂ EQ.]	A1	A2	A3	TOTAL	CRADLE-TO-GATE, MILL PRODUCT
Hertford	1.34E+03	4.46E+01	9.67E+01	1.49E+03	1.24E+03

Figure 10. Example from product-specific EPD that includes GWP values for both: unfabricated steel plate to yield 1 metric ton of fabricated steel plate, including fabrication-generated scrap (A1 value), and 1 metric ton of unfabricated steel plate only ("Cradle-to-Gate Mill Product" value).⁶⁰

If every fabricated steel EPD included this information, it would be straightforward to align between unfabricated and fabricated EPDs. But, presently, this type of EPD is an exception, and most - including the industry EPDs - do not include this information. As such,

51. From the rebar IW-EPD: "To ensure mass balance of the rebar fabrication process, input rebar was adjusted to equal fabricated rebar plus steel scrap outputs." Concrete Steel Reinforcement Institute. (2017). Environmental Product Declaration - Fabricated Steel Reinforcement.

52. Nucor Corporation. (2021). Environmental Product Declaration - Steel Plate. UL. https://assets.ctfassets.net/aa1cfbwhqog/3Gr6Rl-hLgD5rqYS29dfK1f/449e70a27bfb89d6d6ed-31019ab3a98e/101.1_Nucor_Corporation_EP_D_Fabricated_Structural_Plate.pdf

there are two potential approaches for aligning declared units to address this problem:

- Approach 1:** In the case of an IW-EPD that includes fabrication, set the limit for the amount of unfabricated steel necessary to produce 1 ton of fabricated steel. This allows for simply using the A1 value of the IW-EPD or a product-specific EPD. This is the method currently proposed in this report. The advantage of this approach is its simplicity and explicit reliance on publicly available industry-wide data. The trade-off is that this can lead to a scenario that is not quite apples-to-apples, where an unfabricated EPD is being compared to a limit established based on a fabricated EPD.
- Approach 2:** Set the limit for 1 ton of unfabricated steel only. This approach requires additional calculations for three of the four steel categories to exclude scrap from the value in the industry EPD to account for an average scrap rate. This approach is similar to the one described by DGS for the GWP limits published in January 2022.⁵³ Industry-wide data on scrap generation is not currently available, so this method is reliant on either: non-public information (as is the case with the hot-rolled sections and plate examples below), or a very small data sample from one manufacturer (as is the case with the rebar example below).

The difference between these two approaches is approximately 3-8%. See Table 2 for scrap rate estimates and GWP limit values based on these alternate approaches.

Table 2. GWP limit values for steel: proposed and alternative approaches regarding treatment of fabrication-generated scrap. The scrap rate equals the estimated quantity of unfabricated steel required to produce 1 unit of fabricated steel. (For example, 1.0771 means that it takes 1.0771 metric tons of unfabricated steel to produce 1 metric ton of fabricated steel, and in the process generating as scrap the remaining 0.0771 metric tons.) Note that H SS is not included here as the IW-EPD used to generate the proposed GWP limit is for unfabricated HSS.

Eligible Material	Subcategory	Approach 1 <i>(based on A1 value in IW-EPD)</i>	Approach 2 <i>(excludes scrap from fabrication)</i>		
			Scrap Rate Estimate	GWP value <i>IW-EPD A1 value / scrap rate</i>	Data source: <i>Fabrication scrap quantity</i>
Structural Steel	Hot-Rolled Structural Sections (unfabricated)	1,080 kg CO ₂ e / metric ton	1.0771	1,000 kg CO ₂ e / metric ton	<i>EPD Background Report - Fabricated hot-rolled sections, plates, and hollow structural sections. AISC, 2021⁵⁴</i>
	Plate (unfabricated)	1,590 kg CO ₂ e / metric ton	1.0771	1,480 kg CO ₂ e / metric ton	<i>EPD Background Report - Fabricated hot-rolled sections, plates, and hollow structural sections. AISC, 2021</i>
Concrete Reinforcing Steel	Rebar (unfabricated)	920 kg CO ₂ e / metric ton	1.036	890 kg CO ₂ e / metric ton	<i>EPD - Steel Concrete Reinforcing Bar and Merchant Bar Products. Nucor Corporation, 2021.⁵⁵</i>

In the longer term, the authors expect this alternative approach (#2) to be more viable, as policies clarify their positions and requirements regarding this issue, as PCRs improve to be more prescriptive regarding scrap rates, and as more EPDs - particularly the updated versions of the industry-wide EPDs - include the relevant information.

53. State of California Department of General Services. (2022). Buy Clean California Act Legislative Report. Available at <https://www.dgs.ca.gov/Resources/Legislative-Reports>

54. Information provided by and available from AISC. (2021).

55. Nucor Corporation. (2021). Environmental Product Declaration - Steel Concrete Reinforcing Bar and Merchant Bar Products.