Evaluating the Carbon Intensity of Materials Used in Automotive Products

Guidance Document

May 2022

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Established Scope

- The Suppliers Partnership for the Environment (SP) Sustainable Materials Work Group works to promote collaboration amongst automotive manufacturers and suppliers to increase use of sustainable practices, processes, and materials in the production and content of vehicles, and to incentivize sustainable innovation.
- While there are established definitions of certain key terms related to the topic of sustainable materials that have been developed by other organizations, investigation by SP indicates a range of definitions and interpretations of such terms may be in use across industry today. We are not aware of any organization that has developed a commonly accepted definition of key terms for measuring the use of sustainable materials in the automotive industry to date.
- Therefore, an SP Sustainable Materials Definitions Sub-team was formed with the objective to develop straightforward common definitions of key terms related to sustainable materials to minimize duplication of effort and promote consistent approaches in communications with suppliers, sustainability reporting and measuring industry progress.
- SP is collaborating with the Automotive Industry Action Group (AIAG) in the development of these definitions to promote common, consistent language across industry. Currently, common definitions and processes have been developed for measuring the use of recycled content and renewable content in automotive products.
- The purpose of the guidance document is to introduce the concept of carbon intensity and outline a straightforward and consistent approach for evaluating carbon intensity information for materials used in automotive products.

Next Steps: Going forward, the SP Sustainable Materials Definitions Sub-team intends to build on learnings from this process to address common definitions for additional aspects of sustainable materials where needed.

Glossary of Key Terms

- **Carbon Footprint.** Net amount of *total* greenhouse gas (GHG) emissions and GHG removals, expressed in CO_2 equivalents (CO_2e). [based on GHG Protocol]

- **Carbon Intensity.** Total carbon footprint per functional unit.

- **Carbon Neutrality.** Carbon Neutrality means that any carbon dioxide (CO2) emissions into the atmosphere associated with an entity, product or activity are balanced with the same amount of renewable energy credits and/or carbon dioxide removals from the atmosphere over a specified period. Many generally understand this to mean a net balance of zero CO_2 emissions, but there is not yet a global consensus on how this term is defined and measured. Some companies will add qualifiers to carbon neutrality statements, for example limiting carbon neutrality to Scope 1 and 2 emissions. It is important to understand the boundary conditions that accompany carbon neutrality statements to support consistency and comparability[1].

- **CO_2 equivalent (CO_2e).** The universal unit of measurement to indicate the global warming potential (GWP) of each of the seven greenhouse gases, expressed in terms of the GWP of one unit of carbon dioxide. It is used to evaluate releasing (or avoiding releasing) different greenhouse gases against a common basis. [based on GHG Protocol]

- **Cradle-to-Gate Inventory.** A partial life cycle of a product, from raw material extraction through to when the product leaves the reporting company's gate (e.g., immediately following the product's production). Downstream emissions are excluded. [based on GHG Protocol]

- **Cradle-to-Grave Inventory.** Removals and emissions of a studied product from raw material extraction through to end-of-life. [based on GHG Protocol]

- **Downstream Emissions.** Indirect GHG emissions from sold goods and services. Downstream emissions also include emissions from products that are distributed but not sold (i.e., without receiving payment). [based on GHG Protocol]

- **Energy Intensity**. Total source energy used per functional unit, so that using less energy to produce a product or material reduces the intensity.

- **Functional Unit.** The basis on which environmental impacts, carbon intensity and energy intensity will be compared; the units of the denominator in carbon intensity and energy intensity calculations. Examples of functional units include, but are not limited to: per unit mass of material produced, per sold product, per dollar of sales revenue, per hour of service provided, per unit mass of material sold, per unit of energy consumption, etc.

- **Greenhouse Gases (GHGs).** For the purposes of the GHG Protocol standard, GHGs are the seven gases covered by the United Nations Framework Convention on Climate Change (UNFCCC): carbon dioxide (CO_2); methane (CH_4); nitrous oxide (N_2O); hydrofluorocarbons (HFCs); perfluorocarbons (PFCs); sulphur hexafluoride (SF_6); and, nitrogen trifluoride (NF3).

- **Operational boundaries.** The boundaries that determine the direct and indirect emissions associated with the business operations owned or controlled by a company.

- **Organizational boundaries.** The boundaries that determine the operations owned or controlled by a company for the purpose of calculating its GHG emissions.

1 Note that additional guidance on terms and definitions related to carbon neutrality is expected to be published by SP in the near future.

- **Scope 1: Direct GHG emissions.** Direct GHG emissions occur from sources that are owned or controlled by the company, for example, emissions from combustion in owned or controlled boilers, furnaces, vehicles, etc. and emissions from chemical production in owned or controlled process equipment. [based on GHG Protocol]

- **Scope 2: Purchased electricity, indirect GHG emissions.** Scope 2 accounts for indirect emissions from the generation of purchased or acquired electricity, steam, heat, or cooling consumed by the reporting company. Purchased electricity is defined as electricity that is purchased or otherwise brought into the organizational boundary of the company. Scope 2 emissions physically occur at the facility where electricity is generated. [based on GHG Protocol]

- **Scope 3: Other indirect GHG emissions.** All indirect emissions not included in Scope 2 that occur in the value chain of the company, including both upstream and downstream emissions. Scope 3 emissions are a consequence of the activities of the company but occur from sources not owned or controlled by the company. Some examples of Scope 3 activities are extraction and production of purchased materials; transportation of purchased fuels; and use of sold products and services. [based on GHG Protocol]

- **Upstream emissions.** Indirect GHG emissions from purchased goods and services, capital goods, fuel- and energy-related activities (not included in Scope 1 and Scope 2), upstream transportation and distribution, waste generated in operations, business travel, employee commute and upstream leased assets. Often companies will only report the known and/or significant portions of their upstream Scope 3 emissions. Companies should be transparent in identifying which Scope 3 emissions are included in their calculations and the rationale for any upstream emissions that have been excluded. [based on GHG Protocol]

Introduction

As leading automakers proactively work toward long-term goals of achieving carbon neutrality, it is expected that suppliers take an active role in striving to reduce greenhouse gas (GHG) emissions from their businesses as far as possible.

The ability to understand the total carbon footprint of a company is one critical tool for customers and other stakeholders to evaluate progress in absolute carbon reduction toward the end goal of carbon neutrality. However, it can be difficult to assess the upstream sustainability impacts of individual material, process and technology choices when looking at a company's total carbon footprint alone.

Energy intensity is another valuable tool to support carbon neutral decision-making. With a transition to low-carbon fuels or renewable electricity, higher costs, availability, and energy storage considerations may require a change to manufacturing techniques, therefore energy conservation will continue to increase in importance.

Together with corporate carbon footprint and energy intensity, product / material carbon intensity information can help one to better understand and evaluate the carbon impacts and decarbonization potential of specific input materials and technologies within their value chain. High quality cradle-to-gate carbon intensity information can support users in identifying upstream carbon hotspots and in assessing opportunities for sourcing / implementing 'lower-carbon' or carbon-neutral materials, products, and manufacturing processes.

While there are several established definitions and methodologies related to carbon reporting and reduction, there is an opportunity to promote the use of more common and consistent carbon-related terms and definitions specific to the goals of the automotive industry.

The purpose of this guidance document is to introduce the concept of carbon intensity and outline a straightforward and consistent approach for assessing carbon intensity information for input materials. This document is intended as the beginning of a larger conversation on opportunities to reduce carbon intensity and ultimately improve the consistency and quality of carbon-related reporting and decision-making along the supply chain.

We fully expect that this document will not answer all questions a company may have but it is intended to provide a common framework to build from as companies work toward long-term industry goals of carbon neutrality and improved sustainability.

Key Concepts & Definitions

Carbon Footprint. Net amount of *total* greenhouse gas (GHG) emissions and GHG removals, expressed in CO_2 equivalents (CO_2e).

- A carbon footprint can be considered as the total GHG emissions caused directly and indirectly by an individual, organization, event, or product.

- For companies that produce multiple products, carbon footprint can be represented in individual product or product families, or as the total for the entire company. The former is often defined as “product carbon footprint”, governed by the ISO 14067:2018 standard and the Product Categories Rules (PCRs, established based on ISO14027), and certified by the International Environmental Product Declaration (EPD) System. The latter is often defined as corporate GHG inventories, which include Scope 1, Scope 2, and Scope 3 emissions, and can be developed following established standards, such as the GHG Protocol, the ISO14064-1:2018, and the Global Reporting Initiative (GRI) Standard.

- **Product carbon footprint is calculated by summing the emissions resulting from the specified stages of a product’s or service’s lifetime (e.g., material production, manufacturing, transportation, use, and end-of-life) as defined by the user.** The carbon footprint of a product or service generally accumulates as it moves along the supply chain but can be reduced along the way through the use of carbon capture utilization and storage technologies.

- Throughout a product’s lifetime, or life cycle, different GHGs may be emitted, such as carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O), each with a greater or lesser ability to trap heat in the atmosphere. These differences are accounted for by the global warming potential (GWP) of each gas, resulting in a carbon footprint in units of mass of carbon dioxide equivalents (CO_2e).

- CO_2 equivalents (CO_2e) are the universal unit of measurement to indicate the global warming potential (GWP) of each of the seven greenhouse gases.[2] CO_2e values are calculated by multiplying the mass of each GHG by the gas' 100-year global warming potential (GWP) from the IPCC Fifth Assessment Report, 2014 (AR5) (or the most current GWP factors). Using CO_2e to quantify GHG emissions data allows assessments of total GHG emissions to be compared on a common basis.

- The system boundary of a carbon footprint calculation should be stated along with the CO_2e emissions reported. For product carbon footprint, ISO 14067 recommends assessment of carbon footprint across the lifecycle of the product, from raw material extractions, transport, processing, product distribution, end use, and disposal (e.g., in landfills). This type of carbon footprint is called “cradle to grave”. For EPDs, the system boundary is set at the product manufacturing facility, which represents a partial carbon footprint, or “cradle-to-gate” carbon footprint.

- For corporate carbon footprint, following the Greenhouse Gas Protocol, at minimum, the manufacturing process Scope 1 (direct facility emissions) and Scope 2 (indirect emissions from purchased electricity) should be included in the GHG Inventory calculations. It is recommended that relevant upstream Scope 3 emissions (e.g. from the production and transportation of purchased raw materials) also be included to account for significant GHG emission sources within the automotive supply chain.

[2] carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), sulfur hexafluoride (SF_6), nitrogen trifluoride (NF_3)

- When reporting carbon footprint, it is critical to be transparent about the GHG compounds included. It is a best practice for companies and organizations to distinguish between carbon footprint including CO_2 emissions only, CO2e of the three major GHG compounds (CO2, CH4, and N2O), or CO_2e of all seven families of GHG compounds. Companies should be prepared to share carbon footprint information in the aggregate and/or disaggregated by each constituent greenhouse gas when needed, excluding the impact of offsets or credits.

A carbon footprint could be calculated for products, groups of products, specific manufacturing facilities, corporate wide, etc. A couple examples follow:

- *Product carbon footprint (PCF)* is an analysis of the GHG emissions associated with one or more products.
- *Corporate carbon footprint (CCF)* is an analysis of the GHG emissions of a company.

Both PCF and CCF are typically calculated following general standards for life cycle assessment (ISO 14044), carbon footprints of products (ISO 14067), as well as the Greenhouse Gas Protocol Product Standard, the Greenhouse Gas Protocol Corporate Standard, and the Greenhouse Gas Protocol Scope 3 Standard.

The sum of the life cycle emissions of each product produced by a company should approximate the company's total corporate carbon footprint. The PCF is used when evaluating the impact of an individual product or group of products within the supply chain. A PCF claim will typically be expressed in total tons of CO_2e or as tons of CO_2e reduction compared to another product or process.

References for Further Information

- Greenhouse Gas Protocol Corporate Standard: The GHG Protocol Corporate Accounting and Reporting Standard provides requirements and guidance for companies and other organizations that are preparing a corporate-level GHG emissions inventory.
- Greenhouse Gas Protocol Corporate Value Chain Standard: The Corporate Value Chain (Scope 3) Standard allows companies to assess their entire value chain emissions impact and identify where to focus reduction activities.
- Greenhouse Gas Protocol Product Standard: The Product Standard can be used to understand the full life cycle emissions of a product and focus efforts on the greatest GHG reduction opportunities.
- ISO 14044: specifies requirements and provides guidelines for life cycle assessment (LCA) including definition of the goal and scope of the LCA, the life cycle inventory analysis (LCI) phase, the life cycle impact assessment (LCIA) phase, the life cycle interpretation phase, reporting and critical review of the LCA, limitations of the LCA, relationship between the LCA phases, and conditions for use of value choices and optional elements.
- ISO 14064: specifies principles and requirements for the quantification and reporting of GHG emissions and removals at the organizational level (part 1), project level (part 2), and provides guidance for verifying and validating GHG statements (part 3).
- ISO 14067: specifies principles, requirements and guidelines for the quantification and reporting of the carbon footprint of a product, in a manner consistent with International Standards on life cycle assessment (LCA).
- CDP: Companies can disclose carbon footprint information through CDP in response to a request from an investor, a customer, or both. CDP provides guidance that describes what information to provide, the required format, and where to find tools or further information to construct answers to its climate change questionnaire.
- International Sustainability Standards Board (ISSB): The ISSB is developing IFRS Sustainability Disclosure Standards, including outlining requirements for the identification, measurement, and disclosure of climate-related financial information, as well as overall requirements for disclosing sustainability-related financial information relevant to sustainability-related risks and opportunities.

Energy Intensity (EI). Total *source energy* used per functional unit.

- Energy Intensity (EI) measures the amount of source energy it takes to produce one functional unit of material or product.
- Source energy represents the total amount of raw fuel that is required to operate the process. It incorporates all transmission, delivery, and production losses.
- **The energy intensity of a material or product (or embodied energy) is calculated by dividing the source energy required to produce a material or product or to provide a service (the numerator) by a functional unit (the denominator), for example per unit mass of material produced**.
    - For example, energy intensity may be calculated using the following formula: EI = Total Energy used to manufacture *x* kgs of Material A expressed in MJ (megajoules) / *x* kgs of Material A = # MJ of energy/kg of Material A.
    - Number of products sold, total sales revenue, and hours of service provided are some examples of other functional units. Note that one company's product could be another company's intermediate material.
    - A statement of the covered scopes of emission (boundary conditions) should accompany a statement of energy intensity, for example Scopes 1&2 or cradle-to-gate.

Carbon Intensity (CI). Total carbon footprint per functional unit.

- **Carbon Intensity (CI) is calculated by dividing the Carbon Footprint required to produce a material or product or to provide a service, expressed in mass of CO_2e emissions (the numerator), by a functional unit (the denominator), for example per total sales revenue.**
    - For example, carbon intensity may be calculated using the following formula: CI = Total CO_2e emissions to produce Product B expressed in tons / Total Product B Sales Revenue expressed in $ = # tons CO2e/$ of sales revenue.
    - Mass of material sold, number of products sold, total energy consumption, and hours of service provided are some examples of other functional units.
    - A statement of the covered scopes of emission (boundary conditions) should accompany a statement of carbon intensity, for example Scopes 1&2 or cradle-to-gate.
- A physical intensity ratio (e.g., total tons of product) is an option when aggregating or comparing data across businesses that have similar products.
- An economic intensity ratio (e.g., total revenue) is an option when aggregating or comparing data across businesses that produce different products. An economic intensity ratio based on total revenue is a metric commonly used by investors in analyzing climate-risks.

- Understanding the upstream factors influencing best-case carbon intensity will be important to the value chain as decarbonization efforts progress. Therefore, a full “cradle-to-gate” (Scope 1 + Scope 2 + Upstream Scope 3) reporting of carbon intensity is encouraged to allow for more accurate comparison of manufacturers or products and monitoring progress.

- Care should be taken to understand what GHGs are included in reported carbon intensities. Some companies/organizations distinguish between carbon intensity including CO_2 emissions only and GHG or CO_2e intensity including the CO_2e emissions of all seven greenhouse gases. Companies should be prepared to share carbon intensity information in the aggregate and/or disaggregated by each constituent greenhouse gas when needed, excluding the impact of offsets or credits.

Additional Considerations

- There are a range of both benefits and drawbacks that should be considered in selecting the most appropriate carbon intensity calculation method.

- In certain instances, an individual company may elect to limit its calculation of carbon intensity and/or carbon footprint to a specific boundary in line with guidance in established international standards. Companies should be transparent in reporting their calculation methods, including any estimation or assumptions, and maintain data necessary to substantiate reporting for each material.

- Carbon intensity information should first be calculated based on the carbon emissions associated with a product or material as manufactured. If offsets or renewable energy credits have been allocated, the carbon intensity after offsets/credits may be calculated separately and this second figure should be reported together alongside the original carbon intensity of the product as produced. Companies should be transparent in reporting the allocation of any offsets or credits and maintain data necessary to substantiate all data reported.

- Unless a company has substantiation for all express and reasonably implied claims, they should clearly and prominently qualify any carbon intensity and/or carbon footprint claims. Companies may minimize the risk of unintended implied claims by clearly stating the boundaries, models and assumptions used in their calculations. Refer to GHG Protocol standards and guidance documents for more details.

- Companies should be aware of national and local regulations that may require reporting of carbon and climate-risk information using specific methods and formats.

Carbon Footprint and Intensity Models & Databases

There are several different life cycle assessment (LCA) models and databases (DBs) commercially available that may be used to support evaluation of carbon footprint and intensity information, some of which are summarized below**.** There is not currently an industry consensus standard regarding this topic.

Note that SP is not endorsing or recommending any particular model or organization listed in this document but only providing information on some of the available resources that may be considered.

GREET

- Free; Excel or .Net based energy and carbon intensity life cycle model developed by Argonne National Lab.
- GREET 2.0 Vehicle-Cycle Model includes a comprehensive default emission factor database for vehicle components and materials to support cradle-to-gate modeling and is expanding globally.
- Argonne GREET Model (anl.gov)

GaBi DBs

- Commercial; comprehensive life cycle inventory database developed by Sphera and provided within the LCA Software GaBi and if licensed via Sphera potentially also in selected other LCA software like Umberto (commercial software offered by iPoint) or OpenLCA (open source software offered by GreenDelta).
- Multiple industries and regions supported.

ecoinvent

- Commercial; comprehensive life cycle inventory database offered by the ecoinvent center and accessible via numerous licensing partners in comprehensive LCA software like SimaPro, GaBi Software, iPoint Product Sustainability, Umberto, OpenLCA, and multiple others, an overview is available by ecoinvent.
- Multiple industries and regions supported.

Questions to consider when evaluating carbon intensity information may include:

- What background database and/or model was used in the calculation?
- Which version of the model was used?
- What boundaries were used in the calculations?
- What assumptions were used in the calculations?
- Does the carbon intensity calculation include only CO_2 emissions or the CO_2e emissions of the seven GHGs?

Illustrative Case Studies

Three case study scenarios were prepared to illustrate:

1. The importance of understanding boundary conditions when comparing reported carbon intensity values.
2. The usage of carbon and energy intensity metrics to aid in decarbonization decision-making.

The steel value chain was selected for the purposes of the first two case examples due to its diversity of manufacturing pathways and emission drivers, and the large quantity of available public information on decarbonization pathways for the steel industry. Illustrative cradle-to-gate modeling for fictious steel manufacturing companies was completed using the GREET Excel Model Platform. An additional case example explores the use of carbon intensity information in evaluating bio-based resins.

Similar illustrative case studies may be developed for other material value chains following a comparable process. Please note that SP is not endorsing or commenting on the sustainability impacts of any organization, material, or technology in the following case studies but only providing information on some of the scenarios that may be considered in evaluating carbon intensity information.

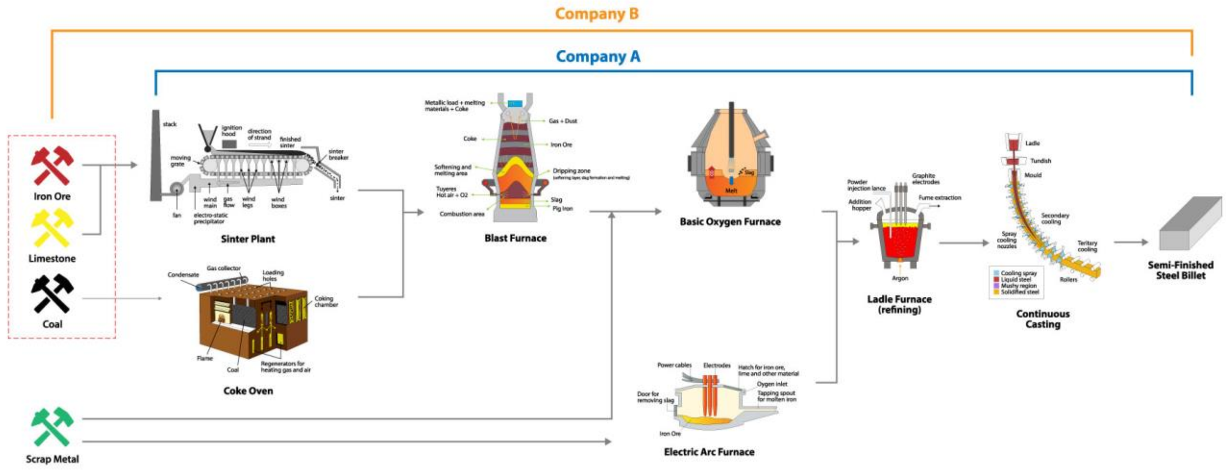
Key Takeaways from the Case Studies

- Companies seeking to make more sustainable material choices will want to consider a broad range of factors, for example: electric energy intensity, carbon intensities for different sources of electric power, carbon intensities for various production methods and sourcing processes, and more.
- Carbon intensity information may be dependent upon a range of factors, such as: production methods, energy sources, the mix of starting raw materials, fossil fuel choice, the geographic location of the process (which may limit energy supply options, transportation emissions, etc.), the models and assumptions used in calculating carbon information, and more.
- Understanding reported carbon and energy intensities requires knowledge of the boundary conditions they represent, for example Scope 1, Scope 1&2, cradle-to-gate, etc. and if the CO_2e emissions of all seven GHGs are included. Similarly, statements about reductions in carbon or energy intensity require knowledge of the baseline year reductions are being determined from.
- Understanding the upstream factors influencing best-case carbon and energy intensity will be important to the value chain as decarbonization efforts progress. Therefore, when comparing material options, the use of full “cradle-to-gate” boundaries are encouraged to allow for comparison of manufacturers or products and monitoring progress. In the absence of complete upstream Scope 3 CO_2e emissions data, reliable emissions data from significant Scope 3 activities that can be obtained should be included, for example significant portions of upstream Scope 3 CO_2e emissions for purchased goods and services (reference the GHG Protocol Corporate Value Chain Standard for more information about Scope 3 emission categories).
- Carbon and energy intensity metrics are important tools to help companies in their decision-making regarding sustainable material choices. However, practical sustainable material choices are about more than simply choosing the lowest carbon intensity production method or the method with the highest recycled material content. For example, cost, quality, and the volume of material available from various production methods are key considerations in evaluating the feasibility of any particular option.

<u>References used in preparing the following case study scenarios include:</u>

- Argonne National Laboratory. (2021, October 11). *GREET Excel Model Platform.* Retrieved from greet.es.anl.gov: https://greet.es.anl.gov/greet.models
- EIA. (2021). *Approximate Heat Content of Coal and Coal Coke.* Washington, DC: EIA.
- Fan, Z., & Friedmann, J. (2021). *Low-Carbon Production of Iron & Steel: Technology Options, Economic Assessment, and Policy.* New York: Center on Global Energy Policy at Columbia.
- PWC. (2020). *Scope 1, 2, and 3 Emissions Calculation Methodology 2020.* Melbourne: Rio Tinto.
- Vogl, V., Ahman, M., & Nilsson, L. (2018). Assessment of hydrogen direct reduction for fossil-free steelmaking. *Journal of Cleaner Production*, 203. 736-745.
- Worldsteel Association. (2021). *Life Cycle Inventory (LCI) Study -- 2020 Data Release.* Brussels: Worldsteel Association.

Case Study 1: Importance of Cradle-to-Gate Boundary



Mining operations for iron ore, limestone, and coal used in traditional Blast Furnace/Basic Oxygen Furnace (BF/BOF) steelmaking represent the beginning of the supply chain, or the raw material “cradle.” Some steel manufacturers are more vertically integrated than others and own and operate such raw material mines.

Company A: Steel Manufacturer, no mine operations	**Scope 1 & 2 “Company Footprint”**	**Scope 1, 2 & Upstream 3 “Cradle-to-Gate”**
Iron Ore Mining	n/a	0.11
Limestone Mining	n/a	0.00
Coal Mining	n/a	0.14
Steel Making	2.01	2.01
Reported Carbon Intensity	**2.01**	**2.25**

Company B: Steel Manufacturer, with mine operations	**Scope 1 & 2 “Company Footprint”**	**Scope 1, 2 & Upstream 3 “Cradle-to-Gate”**
Iron Ore Mining	0.11	0.11
Limestone Mining	0.00	0.00
Coal Mining	0.14	0.14
Steel Making	2.01	2.01
Reported Carbon Intensity	**2.25**	**2.25**

When a manufacturer reports their total company Scope 1 & 2 emissions, only the emissions directly related to their operations and purchased electricity are reported. This represents their “company footprint.” In this example, “Company A” purchases the mined raw materials they need and will report only process emissions from the coke oven through the semi-finished steel billet, but “Company B” that owns and operates their raw material mines will also include the emissions from those raw material mining and mineral processing operations.

When a manufacturer reports Scope 1, 2 and upstream Scope 3 emissions, this represents a “cradle-to-gate” scenario, where all emissions from the extraction of raw materials to the manufacturing of the semi-finished steel billet are reported. In this hypothetical example, both companies report equal carbon intensities when both use cradle-to-gate boundaries.

In this hypothetical case study, limiting the emissions reporting boundaries to Scope 1 & 2 will portray “Company A” as having a 10.7% lower carbon intensity at their manufacturing gate than “Company B”, despite having an equal carbon intensity when also including all the associated upstream Scope 3 emissions.

Case Study 2: Carbon & Energy Intensity Reviews in Steel Production

The manufacturing methods throughout the value chain are important considerations when comparing carbon intensities and understanding the potential to decarbonize a process.

In the case of steel manufacturing, traditional blast furnace/basic oxygen furnace (BF/BOF) steelmaking requires the combustion of solid fossil fuels in the ironmaking process. There is no way to leverage electricity from renewable sources to decarbonize ironmaking when the BF process relies on coke as a feedstock for its energy, physical, and chemistry needs.

Direct Reduced Iron (DRI) processes employ the use of a heated reducing gas (pure hydrogen or a blend of hydrogen and carbon monoxide) to directly drive off oxygen from iron ore in the form of water, carbon monoxide, and carbon dioxide. Direct reduced iron can be charged directly in an electric arc furnace (EAF) like recycled scrap steel and therefore does not require reduction in a blast furnace to produce iron for subsequent steelmaking.

Sourcing low CO_2e hydrogen for the DRI process represents a challenge for the sector. To meet energy and carbon intensity goals, alternative hydrogen production and carbon capture storage and utilization technologies are currently being explored. Two alternative hydrogen production technologies were considered in this case study: electrolysis and methane pyrolysis.

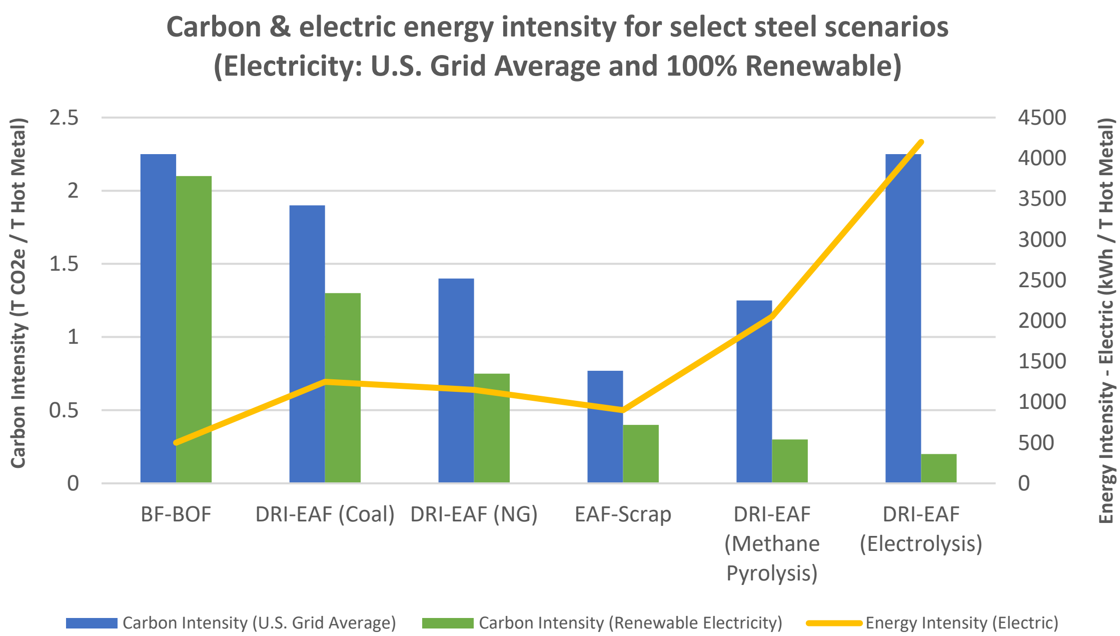
A report on low-carbon production methods for iron and steel published by the Center on Global Energy Policy was referenced to calculate and compare carbon intensities of several illustrative scenarios before and after an assumed energy transition to fully renewable electricity.

Electric energy intensity was also modeled to provide an illustrative reference to estimate operational costs, renewable energy demand requirements, and energy storage needs for the electricity-based solutions.

Technology	Description
BF-BOF	Traditional combustion-based steelmaking process
DRI-EAF (NG)	DRI process based on steam methane reforming (SMR) with natural gas as a feed
DRI-EAF (coal)	DRI process based on coal gasification with coal as a feed
DRI-EAF (methane pyrolysis)	DRI process based on low carbon intensity hydrogen from methane pyrolysis
DRI-EAF (electrolysis)	DRI process based on low carbon intensity hydrogen from electrolysis
EAF-Scrap	EAF with recycled scrap as a feedstock

Example of types of questions to consider in decarbonization decision-making:

- Is new technology required? Does it exist today?
- To what extent can renewable electricity decarbonize the cradle-to-gate process emissions?
- Is there enough scrap to support the industry shift to alternate production methods?
- What magnitude of capital and operational costs can be expected?



In this case study, the production methods with the lowest carbon intensities are based on electricity from renewable sources. This is because process energy and chemical requirements are satisfied by renewable (low CO_2e) power and not coal-based electric power or fossil fuel combustion-based reactions that result in large quantities of CO_2e products, as in the BF-BOF process.

The DRI-EAF with hydrogen sourced from electrolysis or methane pyrolysis and EAF-Scrap processes represent the lowest possible carbon intensities once renewable power is available.

Despite having the lowest potential carbon intensity in this case study, DRI-EAF based on electrolysis has the highest energy intensity, which is an important consideration for operational costs and the scale of renewable electric power demand.

Understanding the upstream factors influencing best-case carbon and energy intensity will be important to the value chain as decarbonization efforts progress. Therefore, a full “cradle-to-gate” reporting is encouraged to allow for comparison of manufacturers or products and monitoring progress.

Please note that SP is not endorsing or recommending any scenario but only providing information through a case study example regarding items to consider when making sustainability related choices from available scenarios.

Case Study 3: Low-Carbon Bio-Based Resin Scenario

The Green Product Sales Pitch

Castor Composites' new line of bio-based resins achieves a reduction of 45,000 T CO_2e per year compared to their 100% fossil-based resins and can be used for production of a variety of injection molded parts. The new product utilizes 50% castor oil blend to achieve equivalent product performance as the fossil-based resin. Castor Composites offers this new drop-in alternative product at a 20% price premium with 100,000 T per year of production capacity using an all-electric manufacturing process powered by renewables.

Due to challenges with impurity management that cause a slight difference in performance, Castor Composites' product is not able to be produced with recycled feedstocks and is not able to be recycled.

The Initial Purchase Decision

A purchasing manager is impressed by the significant carbon footprint reduction, bio-content, renewable electricity use and equivalent product performance claimed by Castor Composites and places an order, confident that this purchase will support their own product's path to carbon neutral and renewable content goals. They are pleased with their 10,000 T purchase at only a 15% price premium. Their remaining demand is filled with low-cost resins produced with fossil-materials – the same as they have always done.

As they begin to source the resin, their engineering team confirms their own product carbon footprint shows a net reduction because of the new sourcing mix, and the customer is satisfied that their annual product carbon footprint reduction and purchasing goals will be met this year. All that is needed to hit their goals next year is to buy a little bit more of this new product from Castor Composites for a negotiated volume growth pricing discount. The customer maintains a strong relationship with Castor Composites to ensure they stay ahead of their competitors in their cost-effective carbon neutral sourcing plan, receive a significant performance bonus for meeting their annual goals, and are invited to attend Castor Composites' golf outing.

Sourcing Challenges in a Dynamic Market Environment

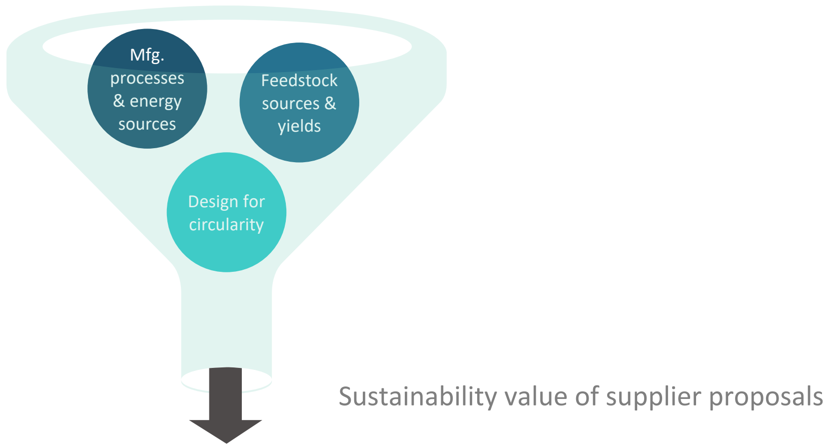
Unknown to the customer, the castor oil used by Castor Composites is in high demand since many resin suppliers are looking to incorporate it into their products. A competitor of Castor Composites, Plastic Co, recently signed a long-term low-cost contract with the main castor bean farm conglomerate.

Plastic Co's castor oil-based resins have a different sustainability case. Their 80% castor oil-based resin performs slightly differently but achieves an impressive 100,000 T CO_2e carbon footprint reduction compared to their fossil-based resins, has 300,000 T per year of production capacity, allows for feedstock substitution, and final composite products can be pyrolyzed into feedstock to produce new resins at the end of their service life.

The next year, because of Plastic Co's supply contract, Castor Composites is only able to offer 50,000 T of the castor-oil based resin and pushes through a 20% price increase passing on their feedstock price premiums. The customer is allocated only 5,000 T for a much higher price, putting their sourcing and GHG reduction commitments at risk, and requiring the engineering team to rush an approval of Plastic Co who only agrees to supply 2,500 T at a 25% premium since they sold out of product in the prior year. The customer's internal stakeholders are frustrated by the setback, higher prices, and extra qualification work and finger pointing starts.

Additional Due Diligence is Performed

The purchasing manager now understands that they need to think differently to understand the real sustainability value of their suppliers. They also understand they need to work more collaboratively and perhaps with a contract for key suppliers. However, they aren't sure which supplier offers the most sustainable business case to justify a closer working relationship. They consider that Plastic Co offers a higher bio-content product and a larger carbon footprint reduction, with the ability to use recycled feedstocks, and provide feedstock security, so maybe they are a better supplier.



After further investigation, the purchasing manager discovers several new details:

- Castor Composites is a small start-up and did not have the leverage to negotiate a favorable contract with the castor oil farmers.
- Castor Composites total production capacity for all their products is 200,000 T per year. Their bio-feedstock offering was 50% of their total sales portfolio until Plastic Co captured the feedstock.
- Castor Composites innovative chemistry allows for a 95% feedstock yield, meaning only 5% is lost to a waste stream.
- Castor Composites has an agreement with the local solar farm to supply 100% of their electricity demand.
- Castor Composites' company associates confirm the cradle-to-gate carbon footprint for the bio-resin product was 35,000 T CO_2e when they made 100,000 T of the product, and for a similar fossil-resin product produced at the same annual volume was 80,000 T CO_2e.
- Castor Composites' product can be redesigned to become suitable for recycling via pyrolysis with close cooperation from the customer and a resin recycling expert.
- Plastic Co is the large incumbent supplier with over 2,000,000 T of production capacity per year. Their bio-feedstock offering is 15% of their product portfolio, and during their process one third of the bio-feedstock is lost to a waste stream.
- Plastic Co is operating an inefficient oil-fired boiler that will cost over $250 million to retrofit to alternative fuel or to electrify their process, which they don't expect to convert until 2040.
- Plastic Co company associates confirm the cradle-to-gate carbon footprint for the bio-resin product is 250,000 T CO_2e, and for a similar fossil-resin product produced at the same annual volume is 350,000 T CO_2e.
- The castor bean farmers are offered a contract extension from Plastic Co to expand, but the farmers can obtain higher prices if they grow corn for ethanol production to support low carbon fuels in California, so they replant their fields. Plastic Co is not able to expand their castor oil resin line and loses half of their current supply of castor beans during the renegotiation process, which forces them to raise prices even further as they work to source alternative castor beans in a tight market.

Utilizing Carbon Intensity Metrics

The purchasing manager calculates the carbon intensity of the different products based on the new information.

Castor Composites

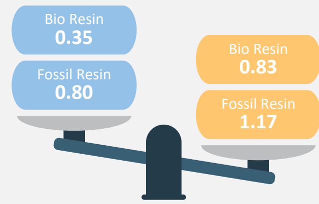
Bio Resin: 35,000 T CO_2e / 100,000 T resin = 0.35 T CO_2e / T resin

Fossil Resin: 80,000 T CO_2e / 100,000 T resin = 0.80 T CO_2e / T resin

Plastic Co

Bio Resin: 250,000 T CO_2e / 300,000 T resin = 0.83 T CO_2e / T resin

Fossil Resin: 350,000 T CO_2e / 300,000 T resin = 1.17 T CO_2e / T resin



Not only is the bio-resin from Castor Composites the best in class but the fossil-resin produced by Castor Composites carries a lower carbon intensity than the bio-resin from Plastic Co! This challenged the purchasing manager's assumption that higher bio-feedstock content and larger total carbon footprint reduction would provide the most sustainable option. Clearly the bio-resin content contributes to the reduced carbon intensity of the resins, but the manufacturing emissions from Plastic Co's boiler, as well as the lost bio-feedstock to waste streams in an inefficient process contribute in a negative way.

The Way Forward

Despite the short-term feedstock sourcing disadvantages, the purchasing manager now understands the structural advantages of Castor Composites all electric, high yield process. They are concerned that Plastic Co is monopolizing the valuable castor beans to use in a low yield process. They decide to sign a joint development agreement with Castor Composites to develop product recyclability options and alternative feedstocks with recycled resin pyrolysis oils to use when castor beans are not available and to share savings over a long-term expansion agreement. They involve a resin recycling expert to help build a circular raw material model.

Over time, Plastic Co is unable to reduce their company carbon footprint by more than 30% without replacing their boiler or installing emissions controls, and they begin to pass through price increases for the cost of carbon emissions management around the world.

Following a period of growth, Castor Composites now has the procurement leverage to negotiate a supply contract with the castor bean farmers. They pay the farmers a fair price, which allow the farmers to prioritize their fields for castor bean farming. Their recycled feedstock model also allows the bio-feedstocks to stay segregated in the market as valuable products and not be burned at the end of their life, which would contribute to additional GHG emissions. Castor Composites has grown into the new major incumbent supplier based on a cooperative and sustainable supply chain model.

<u>Please note that Castor Composites and Plastic Co are fictitious companies created for the purpose of this illustrative case study. SP is not endorsing or recommending any scenario but only providing information through a case study example regarding items to consider when making sustainability related choices from available scenarios.</u>

Conclusion

The purpose of this guidance document is to introduce the concepts of energy intensity and carbon intensity and outline a straightforward approach for assessing carbon intensity information for products, materials, and services.

Together with carbon footprint and energy intensity, carbon intensity information can help one better understand and evaluate the carbon emission impacts and decarbonization potential of specific material or product choices and manufacturing process technologies within their value chain. High quality cradle-to-gate carbon intensity information can support users in identifying upstream carbon hotspots and in assessing opportunities for sourcing / implementing ‘lower-carbon’ or carbon-neutral materials, products, and manufacturing processes. When providing information on carbon intensity, companies may minimize the risk of unintended implied claims by clearly stating the boundaries, models, and assumptions used in their calculations.

Note that this document is a simple representation of what can be a complex system and is intended for illustrative purposes only. We fully expect that this document will not answer all questions a company may have but it is intended to provide a common framework to build from as companies in the automotive industry proactively work toward long-term goals of carbon neutrality and improved sustainability.

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