HowGood Product Carbon Footprint

Methodology and Governance

Version 4.0, October 2025

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1. Executive Summary

This document provides an overview of HowGood's Product Carbon Footprint (PCF) methodology and governance framework for ensuring that it adheres to external frameworks and product standards, including the GHG Protocol Product Standard, ISO 14067, The Carbon Trust Product Carbon Footprint and Model Assurance Requirements, Science Based Targets initiative (SBTi) Forest, Land and Agriculture Guidance (FLAG) and the GHG Protocol's Land Sector and Removals (LSR) Draft Guidance.

HowGood has spent more than 18 years mapping global supply chains to build the world's largest database on food sustainability. To ensure that the model is aligned with globally recognized frameworks and reflects the latest scientific research, HowGood's research team conducts agricultural research on GHG emission factors, focusing on crop/location specificity where available. The team reviews life cycle assessment (LCA) studies and selects those that best align with our source selection criteria, prioritizing the most similar crop/location combinations if a proxy is needed. Research updates are reviewed by subject matter experts and tested before being released and communicated to customers. Any material changes to HowGood's PCF model are subject to review by The Carbon Trust, in addition to annual re-certification and review.

Members of HowGood's research, product and engineering teams have access to the emissions factor database, with training and protocols in place to ensure that values are updated correctly. On the customer side, contracted users have access to HowGood's PCF calculations, with access to varying levels and methods of training.

Public communication of HowGood's PCF calculations is permissible upon submission of a validation request, in which HowGood's research team reviews to ensure the legitimacy of customer data inputs. Once approved, customers can communicate their PCFs through various channels and seek support from the HowGood team on implementation and best practices.

2. HowGood's Product Carbon Footprinting Methodology

HowGood's PCF calculations seek to give customers high quality product carbon footprints even when they do not have visibility into primary supplier or sustainability data. PCFs are calculated based on business activity data, which makes product carbon footprinting more accessible and scalable for any organization. Customers can provide different types of business activity data, including formulation data, manufacturing data, transportation data, and packaging data. Activity data provided are then used to calculate the emissions associated with each life cycle stage and the overall PCF. The list of inputs and activities that influence the calculations for each life cycle stage can be found in section 2.2.1.

2.1 Standards Referenced for HowGood's PCF Methodology

HowGood's PCF methodology is built on the following external frameworks and product standards:

- Greenhouse Gas Protocol Product Life-Cycle Accounting and Reporting Standard (commonly referred to as the GHG Protocol Product Standard)
- ISO 14067:2018 Carbon Footprint of Products
- The Carbon Trust Model Assurance Requirements for Assurance (version 1.0)
- The Carbon Trust Product Carbon Footprint Requirements for Assurance (version 3.0)
- Science Based Targets initiative (SBTi) Forest, Land and Agriculture Guidance (FLAG)
- Greenhouse Gas Protocol Draft Land Sector and Removals Guidance final version expected in Q4 2025. HowGood will adjust any relevant metrics (land use change, carbon removals) once final guidance is released if necessary.
- Product Environmental Footprint. HowGood's PCF is generally aligned to the climate portion of PEF. Notable exceptions are default scenarios for transportation, retail, and use and not all category rules have been assessed.

2.1.1 Validity of Results and Critical Review

When PCF results are referenced, they should be accompanied by the version of the methodology document associated with the calculation. HowGood provides timestamped reports of individual PCF calculations that include the relevant data sources and inputs that were used. For reporting purposes, customers should reference PCFs for the relevant year. Additional terms on the validity of results are included in customer contracts.

HowGood has an ongoing engagement with the Carbon Trust to annually perform limited assurance on the PCF model. At the time of this writing assurance was performed in accordance with:

- Greenhouse Gas Protocol Product Life-Cycle Accounting and Reporting Standard
- ISO 14067:2018 Carbon Footprint of Products
- The Carbon Trust Model Assurance Requirements for Assurance (version 1.0)
- The Carbon Trust Product Carbon Footprint Requirements for Assurance (version 3.0)

2.1.2 Functional Unit

All PCFs are calculated and reported as per kg of consumable product.

2.1.3 Description of the Reference Flow

As per ISO 14067 guidance, the functional unit is defined as 1 kg of final product, representing the basis for quantifying inputs, outputs and environmental impacts. Accordingly, the reference flow refers to the specific quantity of materials and energy required to produce and deliver 1 kg of the product at the defined system boundary. The life cycle impacts are normalized to this reference flow, ensuring comparability across products in the food system.

2.1.4 Excluded Steps

While the product carbon footprint is largely complete, there are some exclusions at various life cycle stages. We reference these exclusions for convenience here, but each carbon life cycle stage has further details.

Table 1: Exclusions by Carbon Life Cycle stage

Carbon Life Cycle Stage	**Exclusions**
Land Management*	Manufacturing of Equipment Ancillary materials
Upstream Processing	Overhead Operations Employee transportation Manufacturing of Equipment
Manufacturing	Overhead Operations Employee transportation Manufacturing of Equipment

Packaging	Transportation of waste
Storage/Distribution Center (Optional)	Overhead Operations
Retailer	Overhead operations Waste
Disposal	Transportation of waste Overhead Operations

* The Land Management stage of a product's life cycle, also referred to as the "on-farm" life cycle stage, represents where the crop or commodity originates including farm or farm equivalents such as orchard, ranch, landing dock for wild caught seafood, aquaculture facility, mineral mine, etc. Throughout this document, the mention of Land Management or "on-farm" can represent any relevant farm equivalency.

2.1.5 Cut Off Rules

HowGood allows for 100% of the ingredients on the product label to be accounted for, so that all inputs are represented.

2.2 Calculating Product Carbon Footprints

HowGood's methodology for calculating GHG emissions is developed in accordance with the GHG Protocol. The methodology covers the collection of HowGood's research data and customer activity data, the mapping of customer activity data to impact data, and the calculation of emissions factors at different stages of a product's life cycle. The methodology was designed to work with varying degrees of activity data from limited activity data with only product names to detailed data across formulation, manufacturing, transportation, and packaging.

1. **Research Data Collection:** HowGood draws on a diverse collection of data sources, including peer reviewed journal articles to calculate the CO_2e values used within the product carbon footprint. For each data source, HowGood performs a data quality assessment based on the age and comprehensiveness of the findings. For more information on how we score the quality of the emissions factors, please refer to Section 3.1.

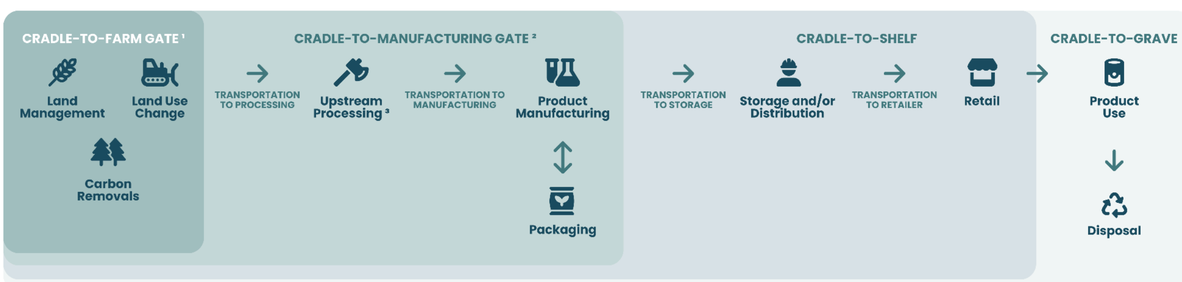
2. **Customer Activity Data Mapping:** Once the data is collected and analyzed, HowGood conducts a proprietary process of mapping each ingredient and its allocation of impacts to its source crop, animal or material. Using global import/export data and HowGood industry partnerships, HowGood then maps each source crop to its corresponding geographic location to account for the specific on-the-ground practices, impacts, and risks in each locale.

When limited activity data is provided, HowGood assigns data-driven location assumptions and an industry-average profile for every ingredient in a product (please refer to Section 3.2 for more information).

2.2.1 Carbon Life Cycle Stages

HowGood calculates GHG emissions at each stage of the carbon life cycle that can be aggregated into different system boundaries (see Figure 1). No additional GHGs are included in the inventory. Weighting factors for delayed emissions, aircraft emissions, offsets and avoided emissions are not included in the inventory results.

Figure 1. HowGood Carbon Life Cycle System Boundaries



1. Cradle-to-farm gate also reflects forest, land, and agriculture contribution to emissions
2. Cradle-to-manufacturing gate (with packaging) includes packaging, if packaging details are provided.
3. For ingredients with nested materials, this includes material manufacturing and any additional legs of transportation associated.

2.2.1.a. Land Management

This stage covers GHG emissions due to the growing and harvesting of the material used to create an individual ingredient in a product. The material could be a crop, animal, mineral, or petroleum product, and accordingly, reference to “farm” henceforth represents farm or the equivalent such as ranch, mine, dock for landing wild caught seafood, etc. You will find this section is longer and more detailed than the others because most of the emissions for food products comes from the farm. Consequently, our research team has prioritized detailed accounting methods for this stage of the product’s life cycle.

Table 2: Relevant data for land management

Relevant Data Provided by Customers	Relevant Data Used in Calculation(s)
• Ingredient • Ingredient Weight • Crop Sourcing Location	• On-Farm GHGs from LCAs (EF) • Allocation Ratio (AR)

$$Land\ Management\ =\ EF\ *\ AR$$

HowGood asks customers to provide a source location for the crops used in their products and/or ingredients. If the customer does not know the location where the crop was grown, HowGood applies a proxy using global production and trade data to ascertain where the crop would likely be grown.

GHG impact is calculated as kilograms of CO_2 equivalent per kilogram of the primary commodity ingredient (kg CO_2e/kg) before any factory or processing emissions. On-farm processing, cooling or fermentation, and off-farm cleaning and sorting are included, when relevant to the production of that crop. GHGs are collected at farm gate, which includes all on-farm processes including primary inputs like fertilizer, pesticides, herbicides, and farm machinery fuel needs. Manufacturing of equipment, removals, and land use change are excluded from this value. Harvesting losses are included in the final yield of the product. Additional waste is excluded as it is rarely specified in agricultural LCA studies. Biogenic emissions and removals are assumed to be neutral for crops, with the exception of rice where biogenic methane emissions are included in the final value. Some biogenic emissions are included for animals.

Identifying sources for on-farm GHGs

Measurements are directly sourced from location and crop-specific Life Cycle Assessments (LCAs) from all over the world as well as environmental assessments. Some frequent journals we consult include International Journal of Life Cycle Assessment, Journal of Sustainable Energy & Environment, Journal of CleanerProduction, Carbon Management (TandFonline), Agricultural Systems (elsevier), and Sustainability (MDPI). When searching for the on farm GHGs for a crop and location, our research team prioritizes ISO 14044 LCAs from peer reviewed journals, which use geographically relevant data inventories. We prefer studies to be within the past 5 years. While these conditions cannot always be met, we use the most accurate and reliable data available and regularly update our database when higher quality data becomes available.

Consistent with the GHG Protocol, carbon sequestration is not included at this time. If a supplier can provide specific measurements meeting the GHG Protocol requirements for removals, then sequestration (removals) can be included in a separate metric (see Carbon Removals).

HowGood Origin Location Proxy Identification Process

Sufficient research does not exist on the emissions associated with producing crops and animals outside of main commodities and conventional methods. Therefore, we sometimes must select a proxy value to represent a specific material and location.
When choosing a proxy value, we always ensure that:

- The System Boundary and life cycle stage are correct: (cradle-to-farm gate and land management)
- The functional unit is kg CO_2e/kg. We also specify whether it is fresh or dry weight (whenever this information is known)
- The production system is the conventional/dominant one for the origin location

When a land management GHG value for an origin location is not available both in primary (e.g., LCA study) and secondary (e.g., collection of carbon footprint values) sources, a proxy value is necessary. In this case, we use the following internal proxying protocol to identify the most appropriate comparable data.

Option 1:
Our first option in selecting a proxy value is to look for an origin in a similar taxonomy (at least family, preferably genus or order); with similar crop/commodity type, yield, and agricultural management practices; and, in the same location or climatic/ecological region.

Option 2:
If an origin in a similar taxonomy, with comparable yield and in the same region cannot be found, we look for a similar crop/commodity (e.g., similar botanical characteristics or same crop category) for the same location (preferable) or same climatic region.

Option 3:
If a similar crop/commodity for the same location cannot be found, we search for the same crop from a location in a different region considering the relevance of factors such as climate and growing practices. When taking this route, we ensure that the original source has high quality data.

2.2.1.b. Land Use Change

By default, HowGood uses a statistical LUC (sLUC) emissions factor (EF) for land use change. When primary data are available, direct land use change (dLUC) or jurisdictional direct land use change (jdLUC) can be calculated. In these cases, dLUC and jdLUC values will be noted in the source of the EF. Otherwise, sLUC is measured in kilograms of carbon dioxide equivalent per kilogram of product (kg CO_2e / kg), and takes into account the following factors.

1. **Land conversion or transition** - Whether land conversion or transition has occurred within a landscape or jurisdiction over the preceding 20 years, in the form of deforestation or drained soils. We include pasture in our calculations, in addition to traditional cropland. This data is reported by 245 countries to the United Nations Food and Agriculture Organization (FAO).

a. **Product allocation factor:** We take the shared responsibility approach to allocating emissions to any crop that was grown in a given jurisdiction that has experienced land use change. This approach attributes land use change emissions based on the percentage of land that a crop has occupied during a given year.

b. **Time discounting:** We take a linear discounting (or "20 year decline") approach to distributing emissions over the 20-year assessment period. This approach weights recent land use change heavier than it weights older land use change.

2. **Crop location** - We consider the jurisdiction of the crop's location, at a national level.
3. **Crop yield** - We take into account the production yield of the crop in order to calculate land use change emissions per kilogram of product.
4. **Allocation ratio** - We take into account the allocation ratio value for the ingredient in relation to the crop based on crop processing occurring at the upstream processing facility level (e.g., raw cacao beans are processed into cocoa paste, which is then processed into cocoa butter and cocoa powder). Please refer to Section 2.3.3 for more information on the process.
5. **Regional feed mix** - For animal-based ingredients, we consider the breakdown of pasture, soy and palm oil in the typical animal feed mixes regionally as well as the amount of feed required to produce the ingredient. For farmed aquatic species, we consider the soy in the typical diet as well as how much feed is required by the species. Regional feed mixes are typically reflective of the crops that are predominantly grown in a region, the affordability of crops and generally accepted animal welfare standards. As we increase the granularity of our Land Use Change assessment, we will add additional feed ingredients to reflect the variability of feed mixes throughout the world.

Table 3: Relevant data for LUC

Relevant Data Provided by Customers	Relevant Data Used in Calculation(s)
• Ingredient • Ingredient Weight • Crop Sourcing Location	• sLUC (EF) • Allocation Ratio (AR)

$$LUC = EF * AR$$

HowGood's calculation of Land Use Change emissions may be updated according to the final LSRG (expected to be released at the end of 2025).

2.2.1.c. Carbon Removals

The impact of Carbon Removals is calculated as kilograms of CO2 equivalent per kilogram of the primary commodity ingredient. Carbon removals include things like improving forest management practices, and enhancing soil carbon sequestration on working lands.

The GHG Protocol specifies that including removals in a GHG inventory requires primary data, ongoing monitoring (and reporting of removals as emissions if monitors are lost), traceability, and quantitative uncertainty estimates.

In accordance with the GHG Protocol guidance, HowGood can calculate carbon removals with the stock difference method if customers are able to provide the following primary data inputs.

Stock Change accounting (for land emissions and removals):

- Biomass
- Dead organic matter (DOM)
- Soil Carbon Pools

2.2.1.d. Transportation to Processing

This stage covers the emissions due to transportation between the farm and ingredient processing locations. It also includes all transportation involved in pre-processing or manufacturing of inputs used in the final product, up to the final transportation to the manufacturing facility. This is relevant for complex products that contain nested or component products with intermediate transportation and manufacturing stages of the product life cycle.

Table 4: Relevant data for transportation to processing calculations

Relevant Data Provided by Customers	Relevant Data Used in Calculation(s)
• Ingredient • Ingredient Weight • Crop Sourcing Location • Processing Location • Manufacturing location (of components)	• Distance between locations (300+ regions creating approximately 45,000 routes between them) • Mode of transportation (8 modes of transportation, each with 3 emissions factors) • Refrigeration requirements of the commodity (none, refrigerated, or frozen) • Allocation Ratio (AR)

$$Transportation = distance * EF * AR$$

$$where\ EF\ is\ driven\ by\ the\ refrigeration\ requirements\ and\ mode\ of\ transport$$

To create this metric, we multiply the weight-distance traveled by the emissions factor of the mode of transportation used. We use the 2023 Global Logistics Emissions Council (GLEC) standard, a GHG Protocol approved industry source for global transport emissions, as our source for emissions factors. Backhauling and empty trips are included in the GLEC emissions factors. Emissions factors are based on tonne-kilometers converted to kg-kilometers to normalize against 1 kg of product maintained in the HowGood database. HowGood customers don't always have visibility into the methods and distances of transportation between the farm and processing location so HowGood uses proxy data in line with specification from the GHG Protocol.

Transportation distances are calculated using arc distance calculations between state, country, or region centroids. For example, the distances traveled within the same state in the United States are set at half the distance across the selected state. When the farm and processing locations are both within the same country, half the distance across the country is used.

Transportation within North America is assumed to be via truck. Transportation between countries outside of the United States is assumed to be via ship.

All transportation stages downstream of this transport stage follow the above methodology using an abbreviated formula that excludes the AR term of the equation. This transportation stage from farm to processing is an exception as the only transportation stage with allocation ratio applied to account for the amount of input raw materials that are required to be transported to generate 1 metric ton of ingredient. If you are transporting X ton of corn to produce 1 metric ton of high fructose corn syrup, this stage multiplies the per kg transport emissions by X to reflect the amount of raw material transported.

As our customer base and knowledge grows, HowGood updates this proxy data using more detailed modes, including regional data outside of the US. In addition, we are able to accept more detailed transportation distances and modes of transport when the customer can provide this primary data.

2.2.1.e. Upstream Processing

Upstream Processing is an assessment of the energy it takes for the factory processing needs of a given ingredient and the likely fuel(s) needed for that process. Some ingredients are highly processed and require considerable energy to convert them from raw source material into a product that is ready for market. This stage also includes the manufacturing of nested products used as ingredients within a more complex, final product (hereafter referred to as "materials").

Table 5: Relevant data for upstream processing

Relevant Data Provided by Customers	Relevant Data Used in Calculation(s)
• Ingredient • Ingredient Weight • Processing Location	• Processing and manufacturing type energy requirements by fuel (100+processing types)

• Material Manufacturing Location • Material Manufacturing Type	• Grid mix at relevant locations (calculated across 300+ regions) • Fuel type emissions factors (7 fuel types)

$$Upstream\ Processing\ =\ \sum_{fuels} fuel\ EF\ *\ energy$$

Ingredients are assessed for energy requirements of processing after they arrive at the factory and before combination into final products. For example, wheat flour would have all stages of milling's energy requirements assessed. That would include washing, grinding, sorting, and sifting, and bleaching when applicable. Excluded from this energy value are overhead operations, employee transportation, and manufacturing of the equipment. HowGood then uses the grid mix at the processing location to calculate the associated emissions due to the ingredient processing.

In many cases, as it is with some extracts, or supplements, multiple parts of the processing have been accounted for where industry standards can be applied (e.g.,for safflower extract applies alcohol solvent extraction/spray drying process). We account for each part of the processing where that information is provided or where we can safely make standard processing assumptions. Where this information is not available or assumptions cannot be safely made, and an ingredient has multiple processing types associated, the most energy intensive processing type is used.

Many times customers do not have insights into where their ingredients are processed. In this case, the location of the processing facility in relation to the farm location is determined by specific research on the nature of the crop, economic considerations, and processing specialization. Most crops are processed on or near the farm where they are grown. In this case, the same location as the farm will be chosen. There are a few specialty crops which tend to be processed away from the farm in specific regions. HowGood assesses which crops fall into this category by analyzing trade data and checking literature for references, where available.

We use region grid mix values to determine how much kg CO_2e is emitted per unit of energy when the likely fuel to be used in a process is electricity. We have these grid mix values for US states and most countries and are still developing methodology to calculate them for other compound regions (sub-national and supra-national). For fuel types other than electricity (e.g.,direct burning of natural gas, coal, biomass etc), we use the carbon intensity of the applicable fuel. This enables us to give biogenic CO_2 emissions data required by many disclosure bodies as a separate metric. Biogenic emissions are not included in this value.

2.2.1.f. Transportation to Manufacturing

This stage covers the emissions due to upstream transportation of all materials to the final manufacturing facility.

Table 6: Relevant data for transportation to manufacturing

Relevant Data Provided by Customers	Relevant Data Used in Calculation(s)
• Processing Location • Ingredient Weight • Manufacturing Location	• Distance between locations (300+ regions creating approximately 45,000 routes between them) • Mode of transportation (8 modes of transportation, each with 3 emissions factors)

See Transportation to Processing for details.

2.2.1.g. Product Manufacturing

Manufacturing is an assessment of the energy it takes for the factory manufacturing needs of a given product.

Table 7: Relevant data for product manufacturing

Relevant Data Provided by Customers	Relevant Data Used in Calculation(s)
• Manufacturing Type • Manufacturing Location	• Energy required by Manufacturing Type (80+ manufacturing types) • Grid mix at Manufacturing Location (calculated across 300+ regions) • Fuel type emissions factors (7 fuel types)

$$Manufacturing = \sum_{fuels} fuel\,EF * energy$$

To calculate GHGs associated with product manufacturing, HowGood uses the product type/sales category and location of the manufacturing facility. Products are grouped into categories based on similar manufacturing processes. Customers can choose the manufacturing type which best describes their product, or HowGood can make a reasonable assumption based on the sales category.

The energy needs of each process or subprocess associated with the production line is collected/estimated from energy or environmental assessments and life cycle inventories as MJ/kg product per fuel type. They can include refrigeration and lighting but exclude overhead operations, employee transportation, and manufacturing of the equipment. We base our estimates on the manufacturing category of the product (frozen entree, cold case milk, chips & snacks, juice beverages, etc). For example, the manufacturing energy required to make yogurt or kefir would include mixing of ingredients (fruit, etc), culture/fermentation process, sterilization of equipment, sterilization of jar/vessel, heat sealing process, and refrigeration.

HowGood then uses the total energy consumption and the carbon intensity of electricity at the manufacturing location and/or emissions factors of the other fuels to calculate the associated emissions due to the product manufacturing.

When customers have conducted product LCAs and can provide manufacturing energy data with enough granularity to map to our inclusions and exclusions, we can ingest that data and create a customer and product(s) specific manufacturing type.

See Upstream Processing for limitations and planned changes.

Fugitive emissions

Fugitive emissions during product manufacturing are relevant for several product types including meat, dairy, and fruits and vegetables. Some refrigerated or cold case products may have significant refrigerant use during storage, retail, or home use, but not a significant use during the manufacturing stage and therefore not a significant amount of fugitive emissions[1].

Primary data

If a customer has primary data for their manufacturing facilities, we can accept these values from the customer and compute the relevant emissions as a custom emissions factor. Data needed:

Table 8: Relevant data for manufacturing (when available)

Relevant Data Provided by Customers	Relevant Data Used in Calculation(s)
• Fuels burned on site for relevant year • Electricity consumed on site for relevant year • Amount of recharged refrigerants • Total production volume of the facility in the relevant year	• Fuel type emissions factors • Grid mix at Manufacturing Location (calculated across 300+ regions) • Refrigerant emissions factors

Waste Generated in Operations

Manufacturing waste is assumed to be 5% by default. Customers with exact data on the amount of waste produced and the fates of the waste produced can pass this data along to the data ingestion team for custom waste in operations data.

[1] Greenhouse Gas Protocol. (2019). Scope 1 and 2 inventory guidance: Use this tool to prepare a GHG inventory and quantify Scope 1 and 2 emissions. World Resources Institute. https://ghgprotocol.org/sites/default/files/Guidance_Handbook_2019_FINAL.pdf

Customers can also provide their ingredient data as the amount of ingredient needed to produce 100 kg of product to account for waste. Please refer to HowGood's Help Center article for more information on how impact can be calculated for products where ingredients outweigh the final product.

2.2.1.h. Product Packaging

Option 1 – Cut Off Method

HowGood requests the specifics of each layer of packaging as well as the recycled content of the materials. The weight of the material, the number of times the packaging can be reused, and the number of consumer units within the packaging layer all contribute to the final packaging emissions.

Table 9: Relevant data for packaging with the Cut Off Method

Relevant Data Provided by Customers	Relevant Data Used in Calculation(s)
• Packaging weight • Consumer units • Number of uses	• Manufacturing region • Packaging material energy requirements by fuel (40+ packaging materials) • Net weight of product • Weight of packaging

$$Packaging = \frac{1}{product\ weight} \sum_{packaging\ materials} (transportation + \sum_{fuels} fuel\ EF * energy) * packaging\ weight/uses/consumer\ units$$

Packaging material energies capture the energy requirements and likely fuels from extraction through production. Transportation of packaging materials to the manufacturing location is included. Transportation of waste is excluded at this time. Biogenic emissions from combustion of biomass materials are calculated separately and not included in the packaging emissions stage. Other biogenic emissions and removals are assumed to be neutral.

The recycled content method (commonly referred to as the Cut-Off method, and also referred to as the 100-0 method) is used to allocate emissions due to recycling. For product footprint boundaries that exclude end of life emissions, recycled content is the appropriate method, per GHG Protocol Product Standard Box 9.3. For this reason, the Cut Off Method is used in the cradle-to-manufacturing gate and cradle-to-shelf product carbon footprints. When choosing to produce a cradle-to-grave carbon footprint, the Circular Footprint Formula (CFF) is used. See Circular Footprint Method for more details.

Definitions of the packaging inputs available can be found in Table 10.

Table 10: Definitions of packaging activity data inputs

Activity Data	Description / Definition
Packaging Unit Type	The following options are available: 1. **Consumer Unit** - The individual product unit that the end customer consumes after purchase. 2. **Selling Unit** - The packaged product that the end customer purchases from a retailer. 3. **Tray / Crate** - The shipping box or container that the manufacturer or distributor ships the product to the retailer in. 4. **Pallet / Transportation Unit** - The pallet or other transportation unit that the manufacturer or distributor uses to stack the trays/crates/shipping boxes onto for transport.
Consumer Units	The number of Consumer Units per packaging layer.
Material	The material the selected Packaging Unit is made from. Choose from 80+ packaging material options.
Region	The region in which the Material was manufactured. It takes into account the manufacturing type of that particular layer of packaging, and the grid mix in the region in which it was manufactured.
Material Weight	The weight of the packaging layer (kg/unit of packaging).
Uses	The average number of times that Packaging Unit Type can be reused.

Option 2 - Circular Footprint Method

The Circular Footprint Formula (CFF) is used to allocate emissions between recycled content and its corresponding virgin material. This allocation method is used when calculating cradle-to-grave footprints. Since customers must specify the amount of recycled material used in the packaging, no assumptions are made for R1 values.

$$Packaging\ CFF = (1 - R1) * E_V + R1 * (1 - A) * E_V * (Qsin/Qp) + R1 * A * E_{recycled}$$

The relevant data for the Circular Footprint Formula are the same as the relevant data for the Cut Off Method (see Table 9). Please refer to Section 2.3.3 for more details on End of Life Allocation. Default values for various materials can be found in Appendix F.

2.2.1.i. Transportation from Manufacturing to Storage (Optional)

For those products that will travel to a warehouse or distribution center between being manufactured and going to retail shelves, we account for emissions due to transportation between the manufacturing facility and the storage facility.

Table 11: Relevant data for manufacturing to storage

Relevant Data Provided by Customers	Relevant Data Used in Calculation(s)
• Manufacturing Location • Warehouse Location	• Distance between locations (300+ regions creating approximately 45,000 routes between them) • Mode of transportation (8 modes of transportation, each with 3 emissions factors) • Refrigeration requirements of the product

See Transportation to Processing for details.

2.2.1.j. Storage/Distribution Center (Optional)

Keeping products in a storage or distribution location prior to retail impacts a product's total emissions.

Table 12: Relevant data for storage/distribution center

Relevant Data Provided by Customers	Relevant Data Used in Calculation(s)
• Warehouse Location • Product Cold Storage Requirements	• Grid Mix at Warehouse Location (calculated across 300+ regions) • Warehouse Cold Storage Energy (constants)

$$Storage = energy * EF$$

We are including cold storage emissions and excluding emissions related to other overhead costs at the distribution center or storage facility. HowGood recognizes that a product may have many storage or distribution centers. However, since our final unit is kg CO_2e/kg final product, we ask customers to choose a single location that best represents their data, and we ask if their product requires refrigeration. Storage is assumed to be 30 days for refrigerated products, and an emissions factor was provided for frozen products but the storage time was unspecified in the source.

If customers own their own distribution or storage facilities, or if they have primary data for this life cycle stage, custom data can be accepted. Requested data are the same as custom manufacturing data requirements (see Product Manufacturing for more details).

2.2.1.k. Transportation to Retailer

This stage covers the emissions attributed to a product being transported to the retailer. If a product has spent time at a distribution or warehouse facility, the starting point for this journey is considered to be the location of said center. If not, we assume the product has traveled directly from the manufacturer to the retailer.

Table 13: Relevant data for transportation to retailer

Relevant Data Provided by Customers	Relevant Data Used in Calculation(s)
• Manufacturing Location **OR** Warehouse Location • Retail Location • Product Cold Storage Requirements • (optional) Mode(s) of transportation • (optional) Distance(s) of travel	• Distance between locations (300+ regions creating approximately 45,000 routes between them) • Mode of transportation (8 modes of transportation, each with 3 emissions factors)

See Transportation to Processing for details on default assumptions.

Since customers tend to have the most information on this transportation phase, HowGood offers further options for customization. If a customer has detailed data for their downstream transportation, they can provide the mode(s) of transportation between waypoints using HowGood's default distances, or they can customize the distances if that data is available to them.

2.2.1.l. Retailer

A product's next stage is to go to the retailer to be purchased by the user.

Table 14: Relevant data for retailer

Relevant Data Provided by Customers	Relevant Data Used in Calculation(s)
• Retail Location • Product Cold Storage Requirements	• Grid Mix at Retail Location (calculated across 300+ regions) • Retailer Cold Storage Energy (constants)

$$Retailer\ = energy\ *\ EF$$

A significant amount of emissions at this stage are due to refrigerants and energy required for cold storage. Other emissions at the retailer are due to overhead operations which we have excluded from our analysis, consistent with the GHG protocol methodology. For this reason, in line with the GHG Protocol, we utilize only the energy required for cold storage at the retailer stage and fugitive emissions from refrigerants. This energy is combined with the average grid mix of the retailer location to calculate the final emissions at this stage. HowGood recognizes that retailers are rarely in a single location. However, since our final unit is kg CO_2e/kg final product, we ask customers to choose a single region that best covers the area where a product is sold. Out of scope for this analysis is the emissions due to a customer traveling to and from the retailer. Waste at the retailer is also excluded.

Fugitive emissions from refrigerants are accounted for based on if the category of product requires cold storage or not. A default value of 0.06 kg CO2e/kg chilled product (assumed refrigerant is R404a) is added to the retailer stage, unless the product is from the dairy category in which case we use 0.0028 kg CO2e/kg of product (assumed refrigerant is Solstice® N40)[2].

The emissions for refrigerated or frozen storage at the retailer was taken as an average value for meat and vegetables. We assume an average storage time of 30 hours for chilled products and 96 hours for frozen products.

2.2.1.m. Product Use

The penultimate stage of a product's life cycle (and the reason it was produced in the first place) is to be consumed. Emissions from the use phase of a product can vary greatly depending on if it needs cold storage as well as the length and method required for cooking, if necessary. To gain this knowledge for a broad customer base we ask the customer only if their product requires refrigeration and if it requires cooking.

Table 15: Relevant data for product use

Relevant Data Provided by Customers	Relevant Data Used in Calculation(s)
• Retail Location • Product Cold Storage Requirements • Product Cooking Requirements	• Grid Mix at Retail Location (calculated across 300+ regions) • Consumer Use Cold Storage Energy (constants) • Consumer Use Cooking Energy (constants)

HowGood uses average values for refrigeration and cooking energy needs. We assume chilled products were stored for 4 days and frozen products were stored for 82 days. Assuming a product will be used where it is sold, we then combine this energy required with the grid mix to gain the final emissions calculation. We assume no waste of the consumable product. Cooking energy is an area of planned improvement.

If a customer has detailed information on how their product is used, we can adjust the emissions of the use phase based on storage type (ambient, refrigerated, frozen), cooking time, method, and location of use.

[2] https://www.epa.gov/greenchill/advanced-refrigeration-technologies

2.2.1.n. Disposal

Once a product has been consumed, the disposal of the associated packaging must be examined.

Table 16: Relevant data for disposal

Relevant Data Provided by Customers	Relevant Data Used in Calculation(s)
• Packaging Material(s) • Packaging Weight(s) • Product weight • Retail region	• Packaging material EFs (disposal) (20+ materials) • Retail region fates of waste

Various packaging materials and amounts have different associated emissions. Using the recycled content method specified in the GHG Protocol, we calculate these disposal GHGs using the packaging weight, material, and ratio information collected from the packaging phase. Consistent with the GHG Protocol, we assume all materials are disposed of via landfill. This is a desired area of improvement as regionality can have a large impact on how products are disposed of.

Out of scope for this phase are the emissions due to transportation of the waste and overhead costs of the waste/recycling facilities.

2.2.1.o. Biogenic Emissions

Biogenic emissions are carbon released as carbon dioxide or methane from combustion or decomposition of biomass or biobased products. Per ISO 14067, we calculate biogenic carbon emissions separately from fossil based emissions. Biogenic emissions are accounted for in two main areas:

Combustion of biomass fuel

For any processing, manufacturing, or packaging processes which use a biomass fuel, biomass emissions are calculated in the same way as fossil based carbon:

$$\textit{Biogenic } CO_2e = \textit{biomass fuel required per kg of product x EF}$$

Biogenic emissions from food waste

During manufacturing, there is typically food waste. Where customer data is available, we can account for the exact loss in the system. When customer data is not available, we assume 5% loss of ingredients during product manufacturing. 42.6% of the loss is assumed to be anaerobically digested and 2.5% assumed to be landfilled. The emissions from decomposition are calculated as:

Biogenic CO_2e = ∑ (total mass of waste × proportion of total waste being treated by waste treatment method × emission factor of waste treatment method)

Biogenic emissions calculations are rolled up into a single value for 2 system boundaries: cradle-to-manufacturing gate and cradle-to-shelf.

*Cradle-to-manufacturing gate biogenic emissions = (processing biogenic emissions + manufacturing biogenic emissions) * 1.05 + manufacturing waste emissions*

*Cradle-to-shelf biogenic emissions = (processing biogenic emissions + manufacturing biogenic emissions) * 1.05 + manufacturing waste emissions + packaging biogenic emissions*

Any other biogenic emissions not mentioned in this phase or previous phases are excluded, most notably on-farm biogenic emissions (see Land Management for more details).

2.3 Data Collection and Underlying Methodological Framework

2.3.1 Source of Emissions Factors

2.3.1.a. Land Management

Emission factors for the on farm stage are sourced from internationally recognized scientific studies that quantify greenhouse gas emissions from agricultural practices. Measurements are directly sourced from location and crop-specific Life Cycle Assessments (LCAs) from all over the world as well as environmental impact assessments. Some frequent journals consulted from recognized publishers: International Journal of Life Cycle Assessment (Springer), Journal of Sustainable Energy & Environment, Journal of Cleaner Production (Elsevier), Carbon Management (TandFonline), Agricultural Systems (Elsevier), Sustainability (MDPI). When secondary data are not available for a specific crop and location, emissions factors are determined according to the options described in Section 4.2.1.

2.3.1.b. Land Use Change

For Land Use Change emissions, we use regionally and commodity specific factors from:

- Food and Agriculture Organization of the United Nations Statistical Division (FAOSTAT)
- Global Livestock Environmental Assessment Model (GLEAM)

2.3.1.c. Transportation to Processing

Emission factors for transportation to processing facilities are derived from databases that estimate greenhouse gas emissions per unit of transport activity. Our sources include:

- National government databases such as the US EPA that offers detailed emissions factors for various vehicle classes and fuel types and the UK DEFRA emissions factors widely used for life cycle assessments providing emissions per tonne-kilometer for different models (road, sea, rail) and vehicle types including refrigerated transport.
- Commercial and logistics supply chain tools such as the GLEC Framework by Smart Freight Centre which provides tailored emissions for supply chains, especially in food logistics including refrigerated. This data incorporates average emission factors based on industry fleet data.

2.3.1.d. Upstream Processing

Emission factors for upstream processing are obtained from databases and models that capture the energy use in industry operations. These factors quantify greenhouse gas emissions per unit of processed output (e.g.,per kg of flour, oil or pasteurized milk). The main sources include:

- National greenhouse Gas inventories such as EPA, DEFRA which provide emission factors for fossil fuel use and industrial energy use.
- Industry reports and Associations. This includes recognized organizations such as IFEU, FAO, USDA, Franklin Association, International Dairy Federation, among others that publish process specific emissions data based on industry standard measurements. These are often the source of region specific factors and reflect the average or best-practice technologies.
- Scientific literature and peer-reviewed studies. Academic research provides emission factors estimates when industry standard data is unavailable. They provide data on electricity and fuel consumption per unit of product. This data includes peer-reviewed techno-economic assessments, processing handbooks, doctoral and master thesis from recognized universities and technical institutions.

When no data is available, equipment data from manufacturers could be used to model the processing type using industry standard conditions collected from sources mentioned above.

2.3.1.e. Transportation to Manufacturing

We use the same emission factors sources for the transportation of goods to manufacturing as we do for other transportation stages in the supply chain.

2.3.1.f. Product Manufacturing

Emission estimates for the manufacturing stage are based on the same categories of sources used for upstream processing, including LCA databases, industry reports, and scientific literature.

2.3.1.g. Product Packaging

Emission factors for product packaging are primarily sourced from Plastics Europe database, industry reports and scientific literature which quantifies the emissions associated with the production of packaging materials expressed per kg of packaging material.

Industrial Standard reports include:

- Plastic Europe. It provides Environmental product Declaration (EPD) and life cycle inventories for various plastic materials including, PET, DHPE, LDPE, PP, PVC.
- European Federation of Corrugated Board Manufacturers (FEFCO) is also included as a source for paper and cardboard packaging including recycled paper.
- Other packaging organizations that publish data for plastics, steel and aluminium such as *Franklin association* and *The Aluminium Association*.

Scientific literature and academic studies. We use peer-reviewed studies that provide packaging specific emission data, energy use for materials such as bio-plastics, compostable films, multilayer, and other innovative packaging materials.

2.3.1.h. Storage/Distribution Center (Optional)

Emission factors for food storage are derived from peer-reviewed studies from scientific journals or academic institutions. Also, industry benchmark and research reports provide the energy use in storage facilities which can be translated to emissions using grid specific factors from EPA or eGRID. Data for refrigerant emissions are sourced from IPCC emission factors, DEFRA and Greenhouse Gas Inventory Guidance for direct fugitive emissions.

2.3.1.i. Transportation to Retailer

We use the same emission factors sources for the transportation of goods to manufacturing as we do for other transportation stages in the supply chain.

2.3.1.j. Retailer

Emission factors for food storage are derived from peer-reviewed studies published in scientific journals and by academic institutions. In addition, industry benchmarks and research reports provide energy consumption data for storage facilities, which can be converted into emissions using grid-specific factors, such as those from the U.S. EPA or eGRID. Data for refrigerant-related emissions are sourced from established references including IPCC emission factors, the UK DEFRA database, and Greenhouse Gas Inventory Guidance for estimating direct fugitive emissions.

2.3.1.k. Use

Emission factors for product use are derived from peer-reviewed studies published in scientific journals and by academic institutions. In addition, industry benchmarks and research reports provide energy consumption data for usage, which can be converted into emissions using grid-specific factors, such as those from the U.S. EPA or eGRID. Data for refrigerant-related emissions are sourced from established references including IPCC emission factors, the UK DEFRA database, and Greenhouse Gas Inventory Guidance for estimating direct fugitive emissions.

2.3.1.l. End of Life

Emission factors for the end of life stage are obtained from scientific research, government inventories and life cycle assessment papers that account for emissions associated with food waste treatment and disposal.

- National databases include the U.S. EPA and UK DEFRA factors for waste disposal such as landfill, composting, incineration.
- Scientific literature. This provides specific emission factors for waste treatment and includes peer-reviewed scientific papers from recognized journals.

2.3.2 Geographical Representativeness

HowGood allows for national, sub-national, and supranational selection at most life cycle stages. The exception to this is on-farm, where we are limited by the available literature. New locations are added as requested by customers. When data for the exact location cannot be found, a proxy is selected (please refer to Appendix C).

2.3.3 Allocation Procedure

2.3.3.a. Allocation overview

One of the more complicated parts of GHG accounting across the entire food system is assessing the amount of raw material impact to allocate to a single ingredient produced. An allocation procedure is a method to distribute the total environmental impacts of a multi-input/output production system among its multiple outputs.

For example, to allocate impacts of orange juice powder we need to account for the impacts from growing the whole oranges (functional unit, kg oranges) and any intermediate processing to make the orange juice powder (juicing and drying) and any other outputs made when juice powder is processed such as the orange oil (from orange peel). In such systems, the allocation procedure ensures that each output of the system (i.e. kg orange juice powder, kg orange oil) receives a fair share of the associated environmental burdens. Allocation is of prime importance when products share common inputs, energy or emissions and provides transparency on the impact distribution.

This allocation procedure follows ISO 14040/44 guidelines and GHG Protocol Product standard, interpreted from the ISO allocation hierarchy (see Table 17) for application in food and agricultural systems and prioritized as follows:

Table 17: Allocation hierarchy

Step	Procedure
1	Avoid allocation, if possible
2	Align with legislative guidance (often economic)[a]
3	Align with sectoral recommendations (often economic)[a]
4	Consider biophysical allocation (e.g., based on mass, protein and dry matter content, volume, energy content, chemical composition, number of units, etc. of co-products)
5	Consider economic (e.g., based on the market value of co-products) or other allocation (e.g., based on the land area-time needed to produce co-products)

[a]Steps 2 and 3 have been added to this hierarchy to include legislative and sectoral recommendations, considered the industry standard for allocation.
Source: Adapted from from ISO-14040/44 and GHG Protocol Product Standard

The above hierarchy aligns with the draft LSRG allocation recommendations, when economic allocation factors or allocation ratios are available in steps 2 and 3 (Table 17) – legislative requirements and sectoral recommendations, referred to hereafter as industry standards. Industry standards typically provide economic allocation factors, and those factors rarely cover outputs beyond the second level of a commodity tree . Some of those third or higher-level outputs derived from the commodity are often widely used in the food system and by following economic allocation alone, the carbon accounting community does not have a reference point for their allocation factors (please refer to Appendix A for definitions).

Both biophysical and economic allocation have weaknesses. When physical allocation is applied without any assessment of market-based value (see Step 1 in *Figure 2*), impacts may be allocated inaccurately. An example of physical allocation weakness outlined in (ISO 14044:2006/Amd 2:2020) assumes two co-products in almonds production, the nut and the shell (assuming approximately 50% mass each). This weakness is valid when the assessment of co-products considers the shell as a co-product. The authors argue that this assessment is incorrect and the shell should be classified as waste or a by-product used in animal feed, which will adjust the allocation procedure (Steps 1, 2a, 2d, and 2e).

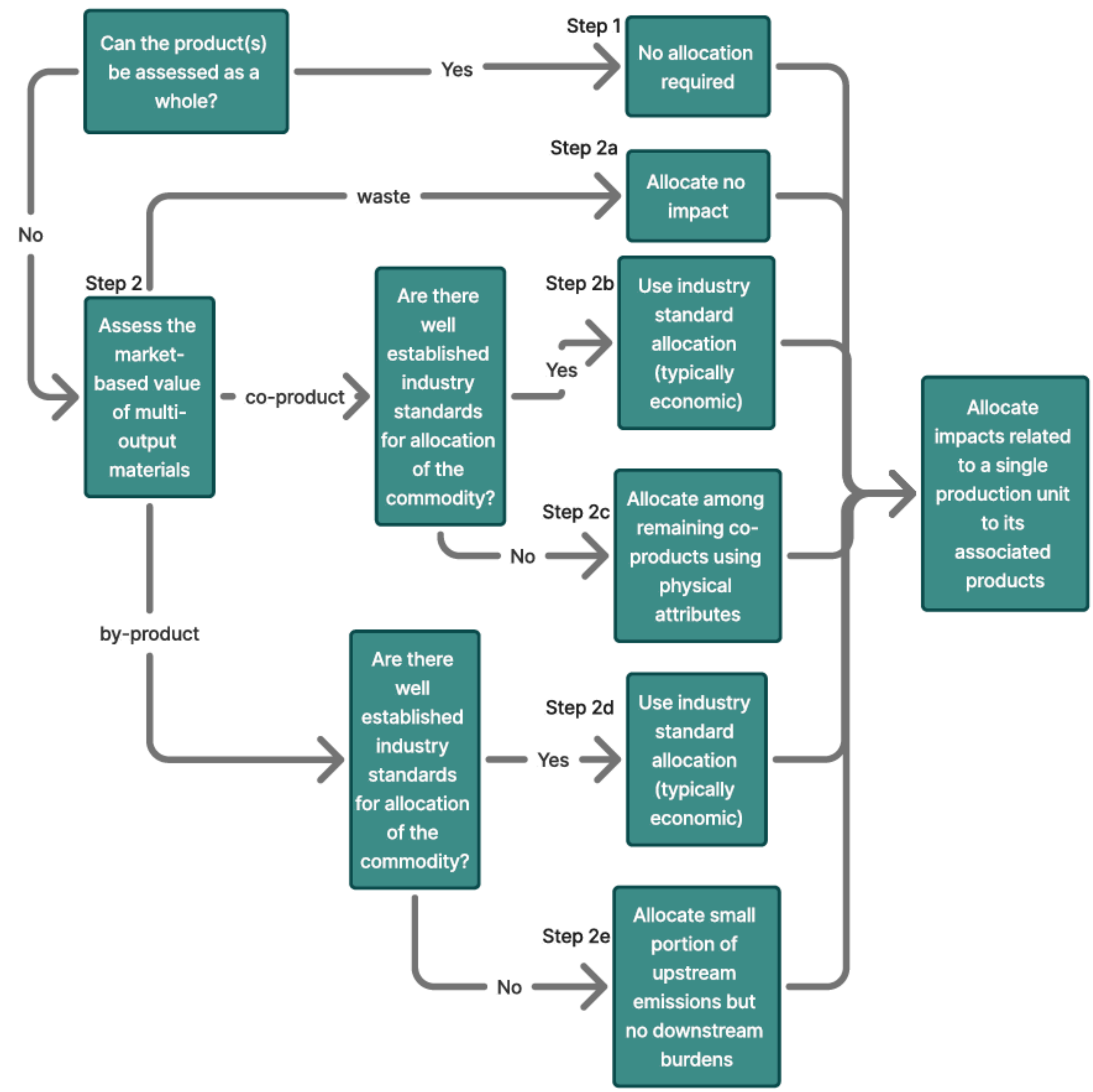
One limitation of the economic allocation approach is the lack of reliable economic data for co-products beyond the 2nd level of a commodity tree. Economic allocation requires the use of a representative average of market prices to ensure consistency and reliability, which is specified in the ISO 14044 methodology that emphasizes the importance of using representative data. To address this, market price data should be collected over a relevant period. The Livestock Environmental Assessment and Performance Partnership (LEAP) (FAO, 2016) guidelines recommend using a 5-year average, and the method suggests gathering at least five years of price data to account for market fluctuations and to establish a representative economic basis for allocation. Pricing data are often unavailable for all co-products that could be derived from a commodity tree or for lower-volume traded commodities. Another limitation of economic allocation is the risk of underestimating the impacts. Co-products with low economic value (by-products) are usually treated as waste, and they receive zero allocation, however, some of them are often used in a finished good, thus, they should carry part of the impact responsibility. One example is fruit and vegetable trimmings including peels, stems or seeds that are used for extraction of valuable components (pectin or colorants).

In cases such as cacao extract noted above, the following method may be applied to follow the LSRS recommendation of allocating impacts while managing limitations of industry standard allocation factors and for less studied commodities that do not have published industry standard allocation factors.

2.3.3.b. Allocation procedure

Within a single commodity, multiple materials are considered as co-products, by-products, or waste, in the system. The decision tree in Figure 2 addresses how to allocate emissions when a raw material results in multiple products. This decision tree provides a structured approach for selecting the most appropriate allocation pathway, ensuring that environmental impacts are accurately distributed among the resulting products. By systematically guiding the allocation process, the decision tree helps reflect products' contribution to the total environmental impact.

Figure 2. Decision tree for allocating impacts to waste, co-products and by products.



In Figure 2, the branches of the decision tree illustrate the sequence of decision points and criteria used to determine the allocation pathway.

Step 1. We begin by identifying products within the commodity tree that can be assessed as a single functional system, this means broadening the basis of comparison to include all co-products of a system, so impacts are assessed per expanded functional unit which means these are expressed per all outputs produced together in the system, therefore avoiding the need for allocation. For example, if a wheat processing facility produces both wheat flour and wheat bran, the functional unit can be expanded from reporting only per 1 kg of wheat flour to include both outputs (1 kg wheat flour and 0.36 kg of wheat bran). Thus, the overall environmental impact is reflected for the entire system.

According to ISO 14044, allocation should be avoided where possible, with system subdivision and system expansion proposed as preferred approaches. System subdivision involves disaggregating the unit process into sub-processes, allowing inputs and outputs to be directly assigned to specific products. ISO 14044 defines system expansion as the inclusion of a functionally equivalent product system that is assumed to be substituted by the co-product, thereby crediting the system with the environmental burdens avoided by displacing another product on the market. However, in attributional LCA practice, the term "system expansion" is sometimes also used to refer to the expansion of the functional unit to include all co-products thus avoiding allocation by redefining the product system to account for all outputs jointly. While this approach, referred to as functional unit expansion, is used in this context, it is important to note that it is not the method referred to by ISO 14044 when describing system expansion.

Step 2. If the production system cannot be subdivided or allocation can not be avoided, step 2 involves a market value classification to determine the functionality of these outputs whether they contribute to human consumption or animal feed, while also considering their market - based value. Market-based value assessment is a method for classifying outputs among co-products, by-products, or waste in multi- processing systems. This classification is reflected in the industry standard sources that use economic allocation (see step 2b) or can be performed by researching each output's functional role, intended use, and market significance (see more of classification criteria in HowGood, 2025). For example, in a fruit processing system producing fruit puree and peel, the puree has high market relevance and in this example is the primary driver of economic value, while the peel is a lesser driver of demand but contains compounds such as pectin or fiber with lower value in the market; the method assigns category "co-product" to the puree and "by-product" to the peel based on these functional contributions.

By analyzing market-based value and the functionality of the outputs, we ensure that the outputs are appropriately classified as co-products, by-products and waste, reflecting their economic significance and functional relevance which refers to the primary function of a specific output within the production system based on its intended function, demand or role in the supply chain.

We have defined the outputs of the commodity according to their market-based value classification:

> Waste: This term is defined in the ISO-14044 as substances or objects which the holder intends, or is required, to dispose of and will not be further processed or utilised. When waste materials are intended for further processing such as drying for use as animal feed they are no longer classified as waste but are instead reclassified as by-products, given their continued functional and economic value within the system. Examples include peels and scraps of fruits and vegetables that are not used for animal feed and are discarded; leaves and stems in flowers or herbs that are discarded. For this category, no impact is allocated and its contribution is redistributed among the co-products and by-products.

> Co-products: This is the reference product of the system. According to the ISO-14044 this means any of two or more products coming from the same unit process or production

system. For instance, wheat grain, wheat flour, wheat gluten. Co-products are those considered to have high value, especially relative to by-products (see below), which are products with low economic value.

By-products: This term is not defined in ISO-14044, however, extensive research and industry expert input as well as ecoinvent definitions (ecoinvent, 2025) have allowed us to define this term as materials that have been produced as unintended products with the lowest economic value for human consumption or animal feed.

Step 2a: For substances or objects which the holder intends, or is required, to dispose of and will not be further processed or utilized (waste), no impact is allocated. Standard documents providing economic allocation factors implicitly redistribute impacts from waste to co-products and by-products via mass fraction. In cases where economic allocation factors are not available, this redistribution is made as part of the calculation.

Step 2b: We evaluate the availability of existing industry standard allocation factors for co-products to determine the respective emissions. These standards can be well recognized documents as the EU's Product Environmental Footprint Category Rules (PEFCR), which are rulesets describing how to calculate the environmental footprint of a specific set of products (such as dairy or pet food, in addition to general category rule guidelines). In this type of document allocation factors are provided or the allocation method is already established. Step 2b includes products with available data where allocation factors are widely considered the industry standard. An economic allocation approach is typically, but not always applied (i.e., based on the relative market value of each co-product). Examples of these documents are:

- FAO Livestock Environmental Assessment and Performance Partnership (LEAP) guidelines (2015)
- GHG accounting Manual for Cocoa from World Cocoa Foundation (Quantis, & World Cocoa Foundation, 2025).
- Technical supporting document on Soy conversion factors (Round Table on Responsible Soy Association, 2020).
- Product Environmental Footprint Category Rules general guidance (PEFCR; European Commission, 2021)
- PEFCR for dairy products (2025)
- PEFCR feed for food producing animals (2024)

Step 2c: When no available allocation factors in industry standards or sectoral guidance are published, further interpretation of the ISO 14040/44 guidelines for scalability in the food and agricultural system is presented here. In this approach, co-products are first identified and classified using a market-based value classification (step 2) and then the environmental impacts are allocated among them based on biophysical attributes such as mass, protein content, dry matter content, etc (step 2c). Biophysical allocation precedes economic for two reasons: alignment with both the GHG Protocol Product Standard allocation requirements and the ISO hierarchy in Table 17, and because a market-based value classification was performed according the definitions presented above, providing what can be best described as a proxy-economic allocation when economic allocation factors are not available. As noted above, this classification of market-based value is an essential step to avoid known weaknesses of physical allocation. By aligning biophysical allocation with the market-based value (step 2 + step 2c), the method offers a more representative distribution of the impacts, and allows for broader coverage of co-products in the industry.

Step 2d: The allocation of impacts to by-products first requires the identification of existing industry standards having relevant allocation factors. Examples of these are the PEFCR documents, such as the PEFCR general guidance in which by-products for different types of meats (beef, pork and sheep) are allocated in a range between 0.5-3.5%. In those cases, standard factors are taken for the calculations.

Step 2e: When no available allocation factors for by-products are published as industry standard data, these are assigned a small portion of the total impact allocation (i.e., 0.5% - 5%). This range has been considered according to research (FAO 2016, European commission, 2021) specific to similar products in other industries for instance: for fiber-rich products such as hulls, shells, we use 3% that is consistent with public data (FAO, 2016) for soy hulls based on economic allocation. In cases where multiple by-products are generated from the same processing stream within a given category and economic factors are not available, we apply a proportional mass-based approach to distribute the small percentage of impact allocated to that stream proportionally, based on the mass of each by-product relative to the original input material.

The allocation approach presented here was designed specifically for food and agricultural systems in alignment with the ISO 14040/44 hierarchical guidance and GHG Protocol Product Standard to ensure appropriate allocation of impacts. This approach avoids allocation if possible, follows industry and sectoral guidance when relevant, provides an option for instances when industry standard data don't exist, and prioritizes the allocation of impacts to high value co-products.

Our application of allocation factors applied using this hierarchy combined with the appropriate mass balance value gives us our allocation ratio. Mass balance is the principle that for any system, the total mass of inputs must equal the total mass of outputs including co-products, by-products, and waste products. A simple example is you need the input of approximately six kilograms of oranges to make the co-product output of one kilogram of orange juice concentrate. We also allow customers to provide data for how much raw material is required to create a final ingredient. Learn more about the calculation in HowGood, 2025.

Our final on-farm, LUC, and carbon removal GHG emissions factors for an ingredient have the allocation ratio value built into the final value that is provided to customers.

2.3.3.c. End of Life Allocation – Circular Footprint Formula

In the carbon footprint of food products, packaging is treated as a separated subsystem with its own material flows, lifespan, supply chain and end of life process different to the product it contains. While a food product is consumed, packaging is often subject to different recovery, recycling and disposal pathways. Because of these differences, packaging requires a dedicated allocation approach.

The Circular Footprint Formula is a recycling allocation approach which seeks to give credits and burdens to both the users of recycled materials and those who produce materials which will be recycled at the end of life. More credit goes to the user of recycled materials if there are plenty available, whereas for materials where there is high demand but low supply of recycled materials, more credit is given to the makers of the virgin material which will be recycled at the end of life.

Since HowGood requires that customers specify if a material is recycled, and by how much, R1 is assumed to be 1 if a 100% recycled material is chosen.

Default A and Qsin/Qp values are available in Annex 6.6

$$Packaging\ CFF\ =\ (1\ -\ R1)\ *\ E_V\ +\ R1\ *\ (1\ -\ A)\ *\ E_V\ *\ (Qsin/Qp)\ +\ R1\ *\ A\ *\ E_{recycled}$$

The CFF is used only for the material acquisition phase of packaging in cradle-to-grave PCFs. The end of life phase is calculated based on the fates of waste of the material.

3. HowGood's Data Quality Scoring Methodology

For each carbon life cycle stage (see *Figure 1*), the EF data quality score (DQS) is computed as a weighted average of each underlying EF's data quality score and the materiality of that EF to the life cycle stage. The final EF data quality score is the summation of the EF DQS of each life cycle stage weighted by the materiality of that stage. Cradle-to-grave isn't currently offered to customers for use as a public facing PCF and DQS scoring ends with cradle-to-shelf.

3.1 EF Data Quality Scoring Methodology

Each life cycle stage DQS criteria and formula are detailed below. The DQS value in each stage's formula represents the sum of selected option scores, one option per criteria, relevant to the life cycle stage and normalized to a 0-100 scale.

3.1.1. Land Management

Table 18: Land Management Scoring Criteria

Criteria	Options	Option score	Example
Type of source	Primary peer-reviewed research	3	LCA study published on scientific journal OR externally peer-reviewed industrial LCA paper
	Primary non-peer-reviewed research - organization	2	Primary LCA study from renowned organization (FAO, Carbon Footprint, etc) or academia (e.g., thesis)
	Primary non-peer-reviewed research - industry	1	Industry non-peer reviewed LCA paper
	Secondary research	1	Collection of carbon footprint estimates without detailed methodology
Agricultural input data	Mostly direct measurements	3	Mostly field data
	Mostly qualified/reliable estimates	2	Mostly high quality secondary data such as reliable estimates (e.g.,extension reports, USDA dataset), expert opinion, questionnaire
	Mostly non-qualified estimates (general assumptions) or unknown	1	Input data mostly based on general assumptions or unspecified, or N/A if not agricultural commodities
Field emission data	Direct measurements of emissions	6	GHG emissions directly measured
	Processed based models or	6	GHG emissions estimated with

	Tier-3 methods (complex models)		processed-based models (e.g.,DAYCENT, CENTURY, DNDC, etc.), where local where local conditions (soil, climate) are taken into account
	Empirical models or Tier-2 methods (intermediate/simplified models)	4	Emissions estimated with empirical models based on simplified equations (limited number of variables considered), but where local conditions are taken into account
	Emissions factors or Tier-1 methods (basic methods) or N/A	2	Emissions estimated with emission factors where local conditions are not taken into account, or incomplete, or unknown, or N/A if not agricultural commodities
Functional Unit (kg CO2e/kg)	GHG value available in the study	6	Total GHG value (kg CO2eq/kg product) is reported OR it can be calculated from information available in the study
	GHG value can be estimated with information available in the source	3	The total GHG value can be reasonably estimated (but not exactly calculated) from information available in the study (e.g.,estimated from figures or rough estimate based on information available in the study)
	GHG value can be estimated with information available in other source	1	The source does not provide information to calculate/estimate the total GHG value, but it can be estimated using a different source
Study scale	Study matching HowGood location scale (country or state/province scale)	3	GHG at state or country level: e.g., average GHG value for corn cultivation in the state of Iowa
	Large multi-site study at HowGood location scale	3	Large subnational area, OR 2+ large farms study, OR multi-site (4+) study (academic trials or small farms): e.g., average GHG value for corn cultivation from 4 research trials located in the state of Iowa
	Small multi-site study at HowGood location scale	2	Single large farm study OR 2/3-site study (academic trials or small farms): e.g., average GHG value for corn cultivation from 2 research trials or small farms located in the state of Iowa
	Lower or higher scale than HowGood location: single site or broader region	1	Single site study (academic trials or small farms), OR regional study (e.g.,North America), OR multi-scale/multi-location

			(e.g.,some consumption studies) OR unclear
Temporal assessment	Study published 2015-present	3	-
	Study published 2005-2014	2	-
	Study published before 2005	1	-

Formula:

For each emissions factor (EF) contributing to the product's Land Management EF and the DQS of the source used to derive the EF,

$$Land\ Management\ DQS\ =\ (1/Land\ Management\ EF)\ *\ \sum(EF\ *\ DQS)$$

3.1.2. Land Use Change

Table 19: sLUC Scoring Criteria

Criteria	Options	Option Score
Temporal assessment	0-3 years since latest year in LUC assessment	5
	4-5 years since latest year in LUC assessment	3
	5+ years since latest year in LUC assessment	1
Completeness	No gaps; default source (e.g.,UNFCCC)	5
	Gaps filled by high quality source	4
	Gaps filled with estimates or in house models	2
	Data gaps	1
Proxy	No proxy	5
	Proxy using FAO codes (e.g., use linseed for chia seed)	4
	Proxy using other or n.e.c. categories	2
	Proxy 0 LUC (assuming if not reported in the country, not grown in significant quantities)	1
Diet completeness (animal feed, unless otherwise noted)	Plant (100%)	5
	>75%	4
	>50%	3
	> 25%	2
	less than 25%	1
LUC coverage	Includes all 3 categories (deforestation, soil draining, and fire)	5

	2 out of 3 (includes deforestation)	4
	1 out of 3 (deforestation only)	3
	Excludes deforestation (includes either other category)	1
Spatial granularity	Subnational	5
	National	4
	Regional (supra-national)	2
	Global	1

<u>Formula:</u>
For each emissions factor (EF) contributing to the product's sLUC EF and the DQS of the source used to derive the EF,

$$Land\ Management\ DQS\ =\ (1/sLUC\ EF)\ *\ \sum(EF\ *\ DQS)$$

3.1.3. Transportation to Processing

Due to transportation having an overall small contribution to the final PCF and lack of data granularity for this stage of a product's life, a single DQS is used for all transportation stages. The score was determined by the criteria below.

Table 20: Transportation Scoring Criteria

Criteria	Option	Option Score
Distance	Customer provided	5
	Google maps/ other road distance estimates	3
	Arc distance	1
Mode	Customer provided	5
	Representative Mode (e.g.,not person car)	3
	Not representative mode (e.g.,commuter train)	1
Temporal assessment	< 5 years	5
	5 - 10 years	3
	> 10 years	1
Regionality	Regional EF	5
	Regional Proxy	3
	Global	1
Completeness	Complete (well to wheel)	5

	Limited	1

Formula:

$$Transportation\,DQS\ =\ DQS$$

3.1.4. Upstream Processing

HowGood calculates processing emissions based on the energy *and* likely fuel(s) used in the various processes. Because we use this two-pronged approach to calculating emissions during processing, we also used a two-pronged approach to calculating the DQS.

The data quality of the energy required for a given process was scored according to the processing type assessment below. The data quality of the fuels used in the processing steps were scored against the Fuel Assessment criteria below. These two values are combined to give the final DQS along with the EFs themselves.

We take a conservative approach to this DQS. Because the final EF is only as good as the assumptions beneath it, the fuel score acts as a penalty on the processing score. For example, if the fuel score is 80 and the processing type DQS is 67, the final score will be 80/100*67 = 54.

Table 21: Processing Scoring Criteria

Criterion	Options	Option Score
Energy consumption source	Direct measurements	5
	Validated sources (from LCI)	4
	Specification sheets (machinery)	3
	HowGood Modeled	3
	Theoretical (ranges in paper)	2
	Secondary sources (from LCA)	1
Novelty of the process	Industry standard	5
	Novel process	2
Granularity	Fuel Breakdown	5
	Partial breakdown	3
	No Breakdown	1
FU	HowGood's FU is available in the study	5
	HowGood's FU can be calculated with information available in the source	5
	HowGood's FU can be calculated with information available in another source	3
	HowGood's FU can only be estimated	1

Completeness	Complete (all stages included)	5
	Main stages included ("partial")	3
	Limited	1
Temporal assessment	< 5 years	5
	5-10 years	3
	>10 years	1

Fuel Assessment

Each Fuel was assessed against the following criteria. However, when we assessed the prevalence of each fuel within our database we noticed that natural gas and grid energy makes up the majority of energy in our database (see Table 22).

Table 22: Various fuel contributions to total processing energies

Fuel	Contribution to Processing Energy
Biomass	3%
Grid (electricity)	29%
Hard Coal	0%
Heavy Fuel Oil	0%
Light Fuel Oil	0%
Natural Gas	68%
Total	100%

This, along with the fact that non-biogenic emissions from biomass fuel account for only 11% of emissions from biomass, we use a combined fuel score based on a conservative grid fuel DQS and the natural gas DQS only for the Upstream Processing data quality rating.

Table 23: Fuel Scoring Criteria

Criterion	Options	Option Score
Fuel Proxy	No	5
	Yes	2
Location	National or subnational match	5
	National or subnational proxy	3

	Regional proxy	3
	Global proxy for fuel with global supply chains (petroleum, NG)	3
	Global proxy for fuel with local supply chains (wood/biomass)	1
Temporal assessment	< 3 years old	5
	3 - 6 years	3
	> 6 years	1
System boundary	Complete: Cradle-to-grave	5
	Partial: e.g., Cradle-to-manufacturing-gate, Manufacturing-gate-to-grave	1
Location use proxy	Source region and HowGood region for use match AND no greater levels of granularity available	5
	Source region and HowGood region for use match AND greater levels of granularity available	4
	Source region and HowGood region for use do NOT match	2
Granularity	Yes	5
	No	2

Formula:

$$Processing\ DQS\ =\ (1/Upstream\ Processing\ EF)\ *\ \sum(Fuel\ DQS/100\ *\ Processing\ Type\ DQS\ *\ EF)$$

Upstream Processing EF can include the manufacturing emissions if intermediate products are present in the final product. The DQS of the intermediate manufacturing is included in this case by the following formula:

$$EF\ DQS\ =\ \frac{Processing\ EF * Processing\ DQS + Manufacturing\ EF * Manufacturing\ DQS)}{Processing\ EF + Manufacturing\ EF}$$

$$Upstream\ Processing\ DQS\ =\ \frac{1}{Upstream\ Processing\ EF}\sum(EF\ *\ EF\ DQS)$$

For more details on how the Manufacturing DQS is derived, please refer to Product Manufacturing.

3.1.5. Transportation to Manufacturing

Due to transportation having an overall small contribution to the final PCF and lack of data granularity for this stage of a product's life, a single DQS is used for all transportation stages. The score was determined by the criteria below.

See Table 20 for scoring criteria

Formula:

$$Transportation\ DQS\ =\ DQS$$

3.1.6. Product Manufacturing

Similar to Upstream Processing, we assess both the manufacturing source(s) and the fuel(s) source(s) for Manufacturing. However, all fuels are assessed and used in the DQS calculation for manufacturing. Please refer to Section 2.4 for more information.

Table 24: Product Manufacturing Scoring Criteria

Criterion	Options	Option Score
Energy consumption source	Direct measurements	5
	Validated sources (from LCI)	4
	Specification sheets (machinery)	3
	HowGood Modeled	3
	Theoretical (ranges in paper)	2
	Secondary sources (from LCA)	1
Novelty of the process	Industry standard	5
	Novel process	2
Granularity	Fuel Breakdown	5
	Partial breakdown	3
	No Breakdown	1
FU	HowGood's FU is available in the study	5
	HowGood's FU can be calculated with information available in the source	5
	HowGood's FU can be calculated with information available in other source	3
	HowGood's FU can only be estimated	1
Completeness	Complete (all stages included)	5
	Main stages included ("partial")	3
	Limited	1
Temporal assessment	last 5 years	5
	5-10 years	3
	>10 years	1

Accuracy of the manufacturing type to the sources	Source processing stages matches HowGood's type	5
	Source process type. stages matches partially HowGood's type (50% of stages)	3
	Source process type. stages do not match HowGood's type (Proxy) (<50% of stages)	1

Table 25: Fuel Scoring Criteria

Criterion	**Options**	**Option Score**
Fuel Proxy	No	5
	Yes	2
Location	National or subnational match	5
	National or subnational proxy	3
	Regional proxy	3
	Global proxy for fuel with global supply chains (petroleum, NG)	3
	Global proxy for fuel with local supply chains (wood/biomass)	1
Temporal assessment	< 3 years old	5
	3 - 6 years	3
	> 6 years	1
System boundary	Complete: Cradle-to-grave	5
	Partial: e.g., Cradle-to-gate, Gate-to-grave	1
Location use Proxy	Source region and HowGood region for use match AND no greater levels of granularity available	5
	Source region and HowGood region for use match AND greater levels of granularity available	4
	Source region and HowGood region for use do NOT match	2
Granularity	Yes	5
	No	2

Formula:

The manufacturing DQS is based on the fuel(s) score(s) of the fuel(s) used in the manufacturing type and the score of the manufacturing type itself.

$$Total\ energy\ =\ \sum Fuel\ energy$$

$$Fuel\ DQS = \frac{1}{total\ energy}\sum(Fuel\ energy * Fuel\ DQS)$$

$$Manufacturing\ DQS = (1/Manufacturing\ EF) * \sum(Fuel\ DQS/100 * Manufacturing\ Type\ DQS * EF)$$

3.1.7. Product Packaging

Table 26: Packaging Scoring Criteria

Criteria	Option	Option Score
Granularity	Fuel Breakdown	5
	Partial breakdown	3
	No Breakdown	1
Completeness	Complete (all stages included)	5
	Main stages included ("partial")	3
	Limited	1
Energy consumption source	Direct measurements	5
	Validated sources (from LCI)	4
	Specification sheets (machinery)	3
	HowGood modeled	3
	Theoretical (ranges in paper)	2
	Secondary sources (from LCA)	1
Temporal assessment	< 5 years	5
	5 - 10 years	3
	> 10 years	1
Regionality	Regional EF	5
	Regional proxy	3
	Global	1

Formula:

$$Packaging\ DQS\ =\ DQS$$

3.1.8. Transportation from Manufacturing to Storage (Optional)

Due to transportation having an overall small contribution to the final PCF and lack of data granularity for this stage of a product's life, a single DQS is used for all transportation stages. The score was determined by the criteria below.

See Table 20 for scoring criteria

Formula:

$$Transportation\ DQS\ =\ DQS$$

3.1.9. Storage/Distribution Center (Optional)

Table 27: Storage/Distribution Scoring Criteria

Criteria	Option	Option Score
Energy consumption source	Direct measurements	5
	Validated sources (from LCI)	4
	Specification sheets (machinery)	3
	HowGood Modeled	3
	Theoretical (ranges in paper)	2
	Secondary sources (from LCA)	1
Temporal assessment	< 5 years	5
	5 - 10 years	3
	> 10 years	1
Regionality	Regional EF	5
	Regional Proxy	3
	Global	1
Granularity	Food specific time stored	5
	Default time stored	3

Formula:

$$Storage/Distribution\ DQS\ =\ DQS$$

For primary data quality scoring criteria, see Table 24.

3.1.10. Transportation to Retailer

Due to transportation having an overall small contribution to the final PCF and lack of data granularity for this stage of a product's life, a single DQS is used for all transportation stages. The score was determined by the criteria below.

See Table 20 for scoring criteria.

Formula:

$$Transportation\ DQS\ =\ DQS$$

3.1.11. Retailer

Table 28: Retailer Scoring Criteria

Criteria	Option	Option Score
Energy consumption source	Direct measurements	5
	Validated sources (from LCI)	4
	Specification sheets (machinery)	3
	HowGood Modeled	3
	Theoretical (ranges in paper)	2
	Secondary sources (from LCA)	1
Temporal assessment	< 5 years	5
	5 - 10 years	3
	> 10 years	1
Regionality	Regional EF	5
	Regional Proxy	3
	Global	1
Granularity	Food specific time stored	5
	Default time stored	3

Formula:

$$Retailer\ DQS\ =\ DQS$$

3.1.12. Use of Sold Products

Table 29: Use phase scoring criteria

Criteria	Option	Option Score
Energy consumption source	Direct measurements	5
	Validated sources (from LCI or databases)	4
	Specification datasets (machinery)	3
	HowGood Modeled	3
	Secondary sources from LCAs	2
	Theoretical ranges or generic values	1
Temporal assessment	< 5 years	5
	5 - 10 years	3
	> 10 years	1

Regionality	Regional EF	5
	Regional Proxy	3
	Global	1
Granularity	Food specific time stored/cooked	5
	Default time stored/cooked	3

Formula:

$$Use\ DQS = DQS$$

3.1.13. End of Life

Table 30: End of Life scoring criteria

Criteria	Option	Option Score
Granularity	Fate of Waste Breakdown	5
	Partial breakdown	3
	No Breakdown	1
Completeness	Complete (all stages included)	5
	Main stages included ("partial")	3
	Limited	1
Emission factor source	Direct measurements	5
	Validated sources (from LCI, databases)	4
	Secondary sources (metadata from LCA)	3
	Theoretical ranges or generic values (from publications)	1
Temporal assessment	< 5 years	5
	5 - 10 years	3
	> 10 years	1
Regionality	Regional EF	5
	Regional proxy	3
	Global	1

Formula:

$$End\ of\ Life\ DQS = DQS$$

3.1.14. Biogenic Carbon

Biogenic carbon is accounted for in two main areas:

- Combustion of biomass fuel
- Emissions of food waste during manufacturing

Table 31: Biogenic Scoring Criteria

Criterion	Options	Option Score
Fuel Proxy	No	5
	Yes	2
Location	National or subnational match	5
	National or subnational proxy	3
	Regional proxy	3
	Global proxy for fuel with global supply chains (petroleum, NG)	3
	Global proxy for fuel with local supply chains (wood/biomass)	1
Temporal assessment	< 3 years	5
	3 - 6 years	3
	> 6 years	1
System boundary	Complete: Cradle-to-grave	5
	Partial: e.g., Cradle-to-manufacturing gate, Manufacturing gate-to-grave	1
Location use Proxy	Source region and HowGood region for use match AND no greater levels of granularity available	5
	Source region and HowGood region for use match AND greater levels of granularity available	4
	Source region and HowGood region for use do NOT match	2
Granularity	Yes	5
	No	2

Biogenic carbon calculations are rolled up into a single value for 2 system boundaries: cradle-to-manufacturing gate and cradle-to-shelf. As such, we also have 2 formulas for the biogenic DQS.

$$DQS_F = Biomass\ fuel\ biogenic\ emissions\ DQS$$

$$DQS_W = Biogenic\ food\ waste\ emissions\ DQS$$

$$Cradle\ to\ Manufacturing\ Gate\ Biogenic\ DQS = \frac{DQS_F[(1+waste\ ratio)(biomass\ fuel\ EF)]+DQS_w*biogenic\ food\ waste\ EF}{cradle\ to\ gate\ biogenic\ EF}$$

$$Cradle\ to\ Shelf\ Biogenic\ DQS\ = \frac{DQS_F[(1+waste\ ratio)(biomass\ fuel\ EF)+packaging\ biomass\ fuel\ EF]+DQS_w*biogenic\ food\ waste\ EF}{cradle\ to\ gate\ biogenic\ EF}$$

3.1.15. Cradle-to-Manufacturing Gate

The final PCF data quality score is each life cycle stage's DQS weighted by that stage's contribution to the cradle-to-manufacturing gate EF.

Formula:

$$Cradle\ to\ Manufacturing\ Gate\ DQS\ = \frac{1}{Cradle\ to\ Manufacturing\ Gate\ EF} * \sum(EF\ *\ DQS)$$

3.1.16. Cradle-to-Shelf

The final PCF data quality score is each life cycle stage's DQS weighted by that stage's contribution to the cradle-to-shelf EF.

Formula:

$$Cradle\ to\ Shelf\ DQS\ = \frac{1}{Cradle\ to\ Shelf\ EF} * \sum(EF\ *\ DQS)$$

3.1.17. Cradle-to-Grave

The final PCF data quality score is each life cycle stage's DQS weighted by that stage's contribution to the cradle-to-grave EF.

Formula:

$$Cradle\ to\ Grave\ DQS\ = \frac{1}{Cradle\ to\ Grave\ EF} * \sum(EF\ *\ DQS)$$

3.2 Activity Data Quality Scoring

Scoring the emissions factors for quality is one half of a PCF data quality assessment. The other half of the assessment is the activity data quality score. Activity data is the data provided by the customer. Activity data include:

- Ingredients
- Ingredient weights
- Ingredient processing location(s)
- Crop sourcing location(s)
- Custom transportation inputs
- Product manufacturing type

- Product manufacturing location
- Primary facility data
- Retail location
- Product use
- Packaging materials, weights, sourcing locations

The data quality of the final assessment depends on both the quality of emissions factors used and the quality of the activity data. Additionally, activity data quality assessments along with EF DQS provide the customer with insight on where to focus their efforts for primary data collection (since overall data quality is weighted by each stage's contribution to the final PCF).

HowGood cannot assess with certainty when activity data provided is primary, secondary, or assumed. Therefore, the activity data assessment must be completed by the customer. In this section, we offer guidance on one way this can be done, but it is the responsibility of the customer to design a process that works for their business and needs.

Activity Data Quality can be assessed using the criteria in Table 32.

Table 32: Activity data quality assessment criteria

Category	**Definition**	**Examples**
Data Source	Source of the activity data	Back of pack ingredient list, exact formulations from internal systems
Completeness	How completely does the data represent the emission boundary	Is there any sample or estimation
Technology	The technology involved in providing the material or service	Is a generic manufacturing type assumed or was utility data from facilities used?
Location	Region related to the emissions factor	Were default locations for crops selected or was the exact sourcing region selected? Were there any proxies selected?
Age	The time relevance of the activity data	Is the data representative of the time period for the PCF

Using the above criteria to assess the activity data inputs for each stage of the life cycle, a score should be established. One way to do this is to give criteria for Good, Medium, and Fair within each category and take an average across categories for the final score.

Table 33: Activity data quality scoring

Activity Quality Score (Qualitative)	Activity Quality Score (Quantitative)	Source	Completeness	Technology	Location	Age
Good	3	Exact recipe ingredients and weights	All facility data provided and included based on utilities and invoices	Exact manufacturing data included	Facility level or farm specific data	Current data
Medium	2	Ingredient list in order or prevalence in final formula	Most facility data is included	Similar process is represented (eg. "yogurt and kefir")	National representation	Up to 3 years old
Fair	1	Similar product formulation	Manufacturing type assumed based on sales category or brand	Generic unknown manufacturing type selected	Global average	More than 3 years old or unknown

The number of activity data inputs provided varies by customer and where their business operates within the supply chain. For example, product manufacturers are more likely to have most of the fields listed above. Retailers and food distributors may only have product name and retail location, and sometimes ingredients, which we refer to as limited activity data (or LAD). Customers with LAD should score activity data quality as fair across all life cycle stages.

Finally, once all the activity data have been assessed for each stage, the overall data quality score can be assessed by combining the activity data quality scores with the emissions factors data quality scores.

Table 34: Overall data quality scoring

	Activity DQS: Good	Activity DQS: Medium	Activity DQS: Fair
EF DQS: Good	Good	Good	Medium

EF DQS: Medium	Good	Medium	Fair
EF DQS: Fair	Medium	Fair	Fair

Example: Activity Data Quality Scoring with HowGood provided EF DQS

Let's take an example tomato sauce product packaged in a glass jar that has the following emissions and EF Data quality ratings.

Table 35: Example EF data quality scoring and ratings

Carbon Life Cycle Stage	**EF (kg CO2e/kg)**	**EF DQS**
Land Management	0.53	Medium
Land Use Change	0.02	Good
Transportation to Processing	0.3	Medium
Upstream Processing	0.07	Good
Transportation to Manufacturing	0	
Manufacturing	0.1	Medium
Packaging	0.57	Medium
Transportation to storage	0	
Storage	0	
Transportation to Retailer	0.17	Medium
Retailer	0	
Cradle-to-Shelf:	1.76	Medium

In this example, we assume:

- The customer knew the exact recipe
- The sourcing location for 80% of the ingredients was known but defaults were used for the remaining 20%
- No primary data was provided for manufacturing

Using the sample score table given above, the user scored each life cycle stage across each category, averaged the category scores, assigned a qualitative rating and calculated an overall activity score based on a weighted average of the emissions of the life cycle stage and its rating:

Table 36: Example activity EF data quality scoring

Carbon Life Cycle Stage	Source	Completeness	Technology	Location	Age	Activity Quality Score (Quantitative)	Activity Quality Score (Qualitative)	EF (kg CO2e/kg)
Land Management	3	3	3	2	3	2.8	Good	0.53
Land Use Change	3	3	3	2	3	2.8	Good	0.02
Transportation to Processing	2	2	3	2	3	2.4	Medium	0.3
Upstream Processing	3	3	2	2	3	2.6	Good	0.07
Transportation to Manufacturing								0
Manufacturing	2	1	2	2	3	2	Medium	0.1
Packaging	3	2	2	2	3	2.4	Medium	0.57
Transportation to storage								0
Storage								0
Transportation to Retailer	2	1	2	2	3	2	Medium	0.17
Retailer								0
						2.47		1.76

Finally, the user combined the EF and activity DQS to get an overall data quality rating.

Table 37: Example overall data quality rating

Carbon Life Cycle Stage	EF (kg CO2e/kg)	EF DQS	Activity DQS	Final DQS
Land Management	0.53	Medium	Good	Good
Land Use Change	0.02	Good	Good	Good
Transportation to Processing	0.3	Medium	Medium	Medium
Upstream Processing	0.07	Good	Good	Good
Transportation to Manufacturing	0			
Manufacturing	0.1	Medium	Medium	Medium
Packaging	0.57	Medium	Medium	Medium

Transportation to storage	0			
Storage	0			
Transportation to Retailer	0.17	Medium	Medium	Medium
Retailer	0			
Cradle-to-Shelf:	1.76	Medium	Medium	Medium

Looking at the data quality across the contribution to emissions, we see that 35% of the PCF has Good data quality and 65% has Medium data quality. Since packaging contributes so much to the final footprint, this should be a high priority to improve the data quality.

3.3 Differences between countries

HowGood allows customers to specify the sourcing country/region of their ingredients to further refine the PCF. On-farm and sLUC EFs are impacted by the country/region, and this typically makes up the bulk of the emissions for a PCF. Each stage that depends on a particular region or country for the calculation will be specified in the "**Relevant Data Provided by Customers"** table in each life cycle stage.

3.4 Limitation of the model

3.4.1 Country related Emission Factors

As stated in the previous section, the on-farm emissions typically make up the majority of the PCF. New sourcing locations for commodities are added when requested by customers. However, the data are not always available for crops in the sourced country. For this case, we have a proxy selection, as noted in the Appendix 6.3.

3.4.2 Uncertainty Assessment

Using a model to quantify real world data will always lead to some inaccuracies. We have tried to reduce these by being transparent in this document and training our customers on how to best leverage HowGood's PCF model. Assessing the data quality gives a good indicator of where the biggest uncertainties might lie. Some uncertainties can be difficult to remedy as customers might have limitations to data access and therefore opportunities for data improvement. In this case, it is good to be aware of any low data quality scoring areas as potential improvements, but our intention is to give companies a good place to start while collecting increasing amounts of primary activity data over time.

4. Governance

4.1 Customer data ingestion and quality control

- Customers provide data about their products by either completing the HowGood data template(s) (find the most recent templates in the company's internal shared drive) or providing output from their ERP system that includes required fields in a structure agreed upon by Research's delivery data team.
- Upon receipt of customer data, the delivery data team explores the file for consistency such as field structure and unit of measurement, and cleans or restructures as appropriate. Customer ingredients are run through the relevant algorithm and mapped to ingredients in the HowGood database and structured into products in customer workspaces. Primary data submitted by customers or suppliers are reviewed for inclusion and follow a separate workstream for custom ingredient creation. The delivery data team assigns any ingredients or raw materials in need of research to the delivery content team.
- Ingested customer data undergoes automated and manual quality control checks. Please refer to Appendix B and Appendix B.2 for quality control steps followed by the Research delivery data team to ensure accurate representation of customer data. Final step manual QC checks are assigned to the delivery content team and overseen by a data team member.
- Representing LCAs and primary data inputs - Customers that have commissioned product LCAs are invited to submit them for review by our team of LCA experts. We review each product LCA's methodology for alignment to our methodology with a focus on system boundaries, functional unit, allocation. If data for each life cycle included is disaggregated with traceable sources, we assess the quality of sources cited for modeled stages of the life cycle, and add custom values to our database and make the value available to the customer. If life cycle stage data cannot be disaggregated, the value may still be shown using the LCA-override feature. Data content team members follow a specific process documented in the Research team's internal documentation Product LCA Review Process to assess a customer's product LCA for inclusion in the database, and score it for EF data quality.
    - When customers have developed novel manufacturing processes, we can ingest information about the process steps, energy amounts and types, and ingredient input ratios using a custom data intake template "HowGood Manufacturing data template - Innovative Products".

4.2 Version control, continual review and improvement of the research model

4.2.1 Conducting emissions factor research and collecting emissions factor data

- For agricultural, or cradle-to-farm gate impacts, we prioritize the collection of primary data in coordination with our customers and their suppliers, when available. When primary data aren't available, we conduct on-farm GHG research that includes secondary data source selection and evaluation, modeling (when applicable), and proxy selection (when needed).
    - Customers can opt to use HowGood's SupplierConnect offering to engage their suppliers, and interact with the embedded FieldScope feature to enter primary farm-level activity data, when available. This primary farm activity data is factored into on-farm emissions calculations, applied to a supplier-specific material. HowGood currently powers FieldScope using Cool Farm Alliance inputs via API for a large variety of crops. While we are members of Cool Farm Alliance, we evaluate other modeling tools for key crops for methodological alignment (including frameworks like GHG Protocol's Land Sector and Removals Standard) and API availability.
    - When primary data are unavailable, HowGood's next research priority is to conduct on-farm GHG research using secondary data. The Research team will search the life cycle assessment literature for the crop/commodity and location combination of interest (e.g. wheat in Italy). We review agricultural LCA papers and select those that best align with our six quality criteria used for source selection (e.g. functional unit, system boundary, etc.). Please refer to Section 3.1 for source selection methods.
    - When no adequate source is available in the secondary data, we have two options for sourcing a value, proxying and modeling.
        - A proxy is applied for on-farm GHGs using the species of crop and geographic location to determine the most similar crop and region combination by taxonomy and practical considerations such as yield and climate. For more information, please refer to Appendix C.
        - Modeling is applied in cases where neither secondary data nor proxying would result in an acceptable data quality score. An example is a request for a species of cut flowers with no suitable LCA and no acceptable proxy in our database. In this case, our team researches relevant agronomic data for the species and growing location and enters the relevant values into our FieldScope feature to model the on-farm emissions.

    - Continual review and improvement of sources is conducted both annually and quarterly. Please refer to Appendix D for more information on the update schedule.
- HowGood's database includes upstream processing representing the most representative processing steps of ingredients and intermediary products across the food system. Research is conducted using secondary data sources (databases, peer reviewed papers and industry) to collect energy consumption, by energy type, that are stored and used to calculate emissions. When a customer or their supplier provides primary data for upstream processing that is either a novel process, an improvement on industry standard (e.g. energy efficiencies), or their activity data, we accept and reflect process details. When no primary data is available, equipment data from manufacturers could be used to model the processing type using industry standard conditions.
- HowGood's database includes manufacturing representing the main steps of manufacturing of finished goods across the food system. Research is conducted using secondary data sources (databases, peer reviewed papers and industry) to collect energy consumption, by energy type, that are stored and used to calculate emissions. When a customer or their supplier provides primary data for upstream processing that is either a novel process, an improvement on industry standard (e.g., energy efficiencies), or their activity data, we accept and reflect process details. When no primary data is available, equipment data from manufacturers could be used to model the manufacturing type using industry standard conditions.
- HowGood's database includes product packaging representing common packaging used in the food system. For the addition of packaging types requested by customers, research is conducted using secondary data sources (academic and industry) to collect and represent emissions factors. When a customer or their packaging supplier provides an LCA for a packaging material, we assess the quality of the LCA and methodological alignment for inclusion, permissions protected for the relevant customer. The HowGood team can find the latest assessment guidance in the Product LCA Review Process folder on the shared drive.
- Grid emission factors underlying warehousing/storage impacts are updated annually (please refer to Appendix D for more information on the update schedule). If customers have primary data for this stage, it can be submitted, ingested, and reflected for their organization.
- Grid emission factors underlying retail impacts are updated annually (please refer to Appendix D for more information). If customers have primary data for this stage, it can be submitted, ingested, and reflected for their organization.
- Grid emission factors underlying use impacts are updated annually (please refer to Appendix D for more information).

- End of life emissions factors are expanded as needed, and updated when new data are made available.
- Source data quality criteria and options are applied per life cycle stage and entered into a document for peer review of source data quality scoring prior to upload into the database.
- Version control is held at the product level through customers saving reports, which are retained as immutable records. See our Help Center article for how to create a report.
- Continual improvement - checking frameworks/standards; strategic updates we choose to make on metrics:
    - As research and governance bodies update and improve frameworks and standards for the reporting of agriculture and food product impacts, HowGood monitors the changes and improves our offering for our customers. We align to globally recognized frameworks (e.g.,GHG Protocol) to build our model and we make adjustments as relevant guidance is updated. In addition, a key part of carbon accounting is continued improvements across data, calculations, and increasing primary data to better reflect granularity. HowGood prioritizes these improvements based on framework/standard prominence in the market, size of expected overall product impact, data availability, and customer interest. Primary frameworks/standards we align our PCF as referenced above.

4.2.2 Process for updating key elements of the underlying research program

- After updating existing emissions factors as outlined in Section 4.2.1 and before entering in the database, follow the steps outlined in Appendix E to test and communicate changes.
- Notable updates to metrics or research on specific crops and ingredients are listed in our Research Updates for customers to review, including impacted metrics.

4.2.3 What constitutes a material change to the model

A material change to the PCF model would trigger a surveillance review by The Carbon Trust, in addition to annual re-certification and review. A material change would be constituted by one or more of the following:

- The addition or subtraction of a life cycle stage to the relevant rollup (for example, adding a metric to one or more system boundaries in the assured model).
- Replacing a term in an equation for one of the individual and relevant carbon life cycle stages.

- A systemic change to underlying research for the agricultural, ingredient processing or manufacturing stages of the life cycle.
- A change in our allocation method resulting in a 5% change to cradle-to-manufacturing gate Co2e value in aggregate across the system.

4.3 Internal Assurance Process

4.3.1 Metrics updates

Assurance for metrics and calculations making up metric equations are conducted as follows:

- After a metric is drafted or updated by our Metrics Architect, a minimum of one subject matter expert (SME) in carbon and life cycle assessment (not the metric architect) peer reviews new metric drafts or proposed changes to metric equations for logic outlined in the framework or standard followed (e.g., GHG Protocol Product Standard) and correctness of calculations in each equation term.
- Once the new metric is built (or existing metric updated) by our engineering team in staging, the Metrics Product Manager and the Metrics Architect test the resulting output in our staging environment to check the build is accurate.
- A final review is completed by a carbon SME to test values returned for the metric against expected values.

4.3.2 Research Process

Internal assurance involves peer review of new research and research updates as follows:

- Team members will conduct new emissions factor (EF) research adhering to the following guidelines:
    - HowGood's GHG Source Evaluation Guide to choose sources and values across emissions factors (on-farm, ingredient processing, product manufacturing, transportation, etc.).
    - Proxy Application & Identification Guidelines (see Appendix C) to identify situations when proxying is acceptable and how to select a proxy.
    - New research will include the assignment of the appropriate statistical land use change (sLUC) value by looking up the appropriate value in this sLUC lookup file, and following the video instructions for animal feed.

    - New research will evaluate if biogenic emissions are relevant, and if identified as relevant, will be recorded separately as biogenic for the appropriate life cycle stage of the PCF.
    - Concurrent with the research of new EFs, the researcher will record the results of the data quality scoring relevant to the EF as a data source, and activity data. (Data quality scores are entered into a document for review prior to upload into the database.)
    - Concurrent with the research of new EFs, the researcher will record the publication year of the data source.
    - When researching a new manufacturing type, evaluate the ratio of waste to ingredients.
- Unless conducted by a senior carbon SME, EFs are peer reviewed by another SME.
- Audits of cradle-to-farm gate EFs undergo review by senior carbon SMEs, and approval or adjustment prior to being entered into the database.

4.4 Who can use the model and how

4.4.1 HowGood Employees

Only members of the Research team have full edit permissions for emissions factors in the database. Each team member is trained on how to update values, when it's appropriate to update values, and how to interact with the database without making updates. Protections against unintended database updates include a popup after clicking save displaying a deletion warning and requiring an additional confirmation click. We also maintain metadata fields such as date created, date modified, and name of the team member who last edited a record. Product Managers and Engineers have superuser status that is required for permissions-granting for many tables in our database, and interact with the same safeguards against unintended updates or edits to research tables and fields within the database unless the Research team requests a clearly defined discrete update task submitted in a workflow ticket. All other internal team members using HowGood's database are restricted from accessing the tables holding our research. Our database procedures follow company InfoSec standards including AICPA SOC 2 Type II compliance and ISO 27001:2022 certification.

4.4.1.a. Model Access Permissions and Access Points

- Backend metric code:
    - Backend python engineers
- Backend database:
    - Research team - trained content researchers and data teams

- Backend python engineers
- Frontend python engineers
- Product managers
- Frontend platform (allows for making selections but no edits to the database):
  - All HowGood employees

4.4.1.b. Model Training

When a new member joins Research, training is provided via repeated walkthroughs of the functionality of various database tables. This training covers required data inputs, outputs, and results. Following an introduction to the database, new hires are first given read-only access. At the point during or after a 2-week onboarding period, new hires are granted editing privileges to the database after verbally demonstrating clear understanding of how the database works, where edits can be made and when such edits are appropriate. Most research updates are first stored in a spreadsheet to allow for peer review, followed by testing of impacts to customers in a staging environment prior to saving edits to the database.

Depending on the impact to existing PCFs and customer interest, additional training is provided whenever a change is made to the model. Training is provided via a recorded webinar for large new additions to the model. Recorded demos are also always available for HowGood staff in our internal document repository, Notion. Smaller updates are captured with written communications in a dedicated Slack channel for internal awareness and in the Help Center for customers. Additional demos, slide decks, or how-to articles may be created and shared if necessary.

4.4.1.c. Competency of personnel performing the PCF modeling

Metric creation and updates are designed by members of the Research team with expertise in metric architecture, carbon life cycle, agriculture, and data science.

HowGood employees other than the aforementioned SMEs from Research, especially teams working with customers and prospects, receive trainings on key elements of the PCF and utilize Help Center articles as reference, such as:

- Carbon Life Cycle
- HowGood's Carbon Life Cycle module vs LCAs
- HowGood Product Carbon Footprint Metrics Methodology

4.4.2 HowGood Customers

HowGood customers provide activity data to access the results of the model, allowing them to calculate and refine PCFs for their products.

4.4.2.a. Model Access

Anyone that is contracted with us can use the model. Training is recommended, not required, and help resources exist.

4.4.2.b. Model Training

Depending on the size of the contract and customer, we have varying levels and methods of training.

Customers with smaller contracts have access to self-guided resources for training, such as:

- Free access to an online learning platform with modular courses (videos, text, quizzes)
- Help Center Articles that cover various topics
- Live opt-in advisory sessions with Customer Success Managers

Customers with larger contracts receive a series of live training sessions that cover similar, though more interactive and in-depth content. Our high-level areas of focus for these sessions:

- Understanding HowGood Metrics – *Window into our metrics & scoring methodology with a focus on PCFs*
- Introduction to Latis – *Hands-on software training with a focus on understanding PCFs and building PCFs in platform*
- Reporting, Reducing, & Communicating Impact – *Guidance and best practices on how to leverage PCFs and HowGood insights within your organization*

Our Customer Success Team primarily manages these efforts and educational content with support from our Product Marketing Team and Research team, as needed.

4.4.2.c. Interaction with PCFs

Customers typically interact with PCFs after our Research data team has ingested and loaded their activity data, mapping it to our appropriate data points and EFs. Our resident experts upload the formulas with our standard quality control processes in place (see Appendix B.2). Customers can see the PCF results but do not have the ability to alter EFs.

Following training and using training resources from the previous section, customers may update the activity data (e.g., they learn a crop's actual growing location) to an existing product to refine a PCF calculation or they can provide activity data to calculate the PCF for new products.

Customers may provide feedback and report model bugs or errors through the in-app chatbot serviced by HowGood's Product and Customer Success teams.

4.5 How to assess the PCF for customer use in public communications

When a customer would like to use PCF data for public B2C communications or claims, they must follow a validation process. The validation process is maintained in Notion where the Research team evaluates activity data provided by customers. Please refer to Section 4.6.2 for more information on communicating PCF results.

4.6 Communicating model updates and PCF results

4.6.1 Communicating model updates

When PCF model updates are planned, HowGood notifies its assurance partner, The Carbon Trust. Once PCF model updates have passed the reassurance process, the updates are communicated internally at HowGood and then externally to customers and partners.

Internal communications regarding updates to the model are initiated when reassurance is underway and include the following:

- HowGood-wide Slack messages in the channel where the responsible product manager provides weekly updates, which include any updates in the model and their implications on PCF results.
- Product Marketing-led training sessions to HowGood staff on updates to the model.
- Product Marketing-led bi-weekly update meetings with the commercial teams to explain updates to the model accompanied by the appropriate Product and Research team members to answer questions. As part of this effort, the Product Marketing team also provides these staff with a link to the updated draft version of this methodology document.
- Enablement and training materials are updated to reflect the updates to the model.

External communications regarding updates to the model are initiated when reassurance is complete and include the following:

- Messaging and enablement materials for HowGood commercial teams to communicate the updates to customers and other external parties.

- Update to the Research Log in the Help Center.
- Notifications to customers and partners via email, in-platform messages, and/or zoom meetings.
- The methodology document is updated across all external resources.

4.6.2 Communicating PCF results

Once PCFs have been generated, the Customer Success or Partnerships team will communicate to the customer that PCFs are ready.

Customers seeking to share PCFs with their customers or suppliers aligned with the Partnership for Carbon Transparency (PACT) framework, can request an export in the PACT format.

Customers that wish to communicate their PCFs in a public claim may submit a request for validation by the HowGood Research team. The Research team evaluates the activity data provided by the customer for the relevant product(s), focusing on the inputs that are relevant in calculating the cradle-to-manufacturing gate or cradle-to-shelf carbon footprint, depending on the claim they wish to make. HowGood reviews that all relevant activity data inputs are complete (e.g., ingredient inclusion percentages add up to 100% or more if a product requires greater inputs, like cheese) and reasonable (e.g., the sourcing location provided is a realistic location for that crop). For comparative claims, HowGood also ensures that the customer is not comparing against a branded product and that the inputs chosen for the comparison product are fair and relevant. Upon validation, appropriate communication of the claim in a public setting is the customer's responsibility.

Customers seeking third party verification of PCF claims for carbon labeling or other intents and purposes must complete and submit the appropriate manufacturing (standard or innovative process) data template noted in Section 4.1.

Customers can learn about the process of creating reports and requesting validation in HowGood's Help Center article.

5. Version History

Version	Date	Author	Validator
V4	2025-09-29	Lizz Aspley	JD Capuano
V3	2024-09-20	JD Capuano	Lizz Aspley
V2	2024–02-16	JD Capuano	Lizz Aspley
V1	2023-09-15	JD Capuano	Mike Kaminski

The HowGood Research team will update this governance document in accordance with changes made to processes related to governance (research process, data storage, metadata) pertaining to product carbon footprinting. Updates unrelated to the governance process won't be specified in this document, and can be found in links throughout the document.

5.1 Version Change Log HowGood PCF Methodology & Governance

Comparison between Version 3 (Sep 2024) and Version 4 (May 2025)

5.1.1 Structural & Organizational Changes

Document Structure
Version 4 significantly reorganizes content: life cycle stages are now broken into more granular subsections (e.g., "Fugitive emissions," "Primary data") and labeled consistently (e.g., '2.2.1 Carbon Life Cycle Stages').

Expanded Appendices
V4 adds new appendices including detailed schedules (e.g., Appendix D: Data source update schedule) and formula parameters (e.g., Appendix F: Circular Footprint Formula Parameters). Existing appendices have been updated (e.g., Appendix B: Data Ingestion into Latis)

Renamed Sections
Some section titles changed for clarity: e.g., "Farm-to-Farm Gate" in V3 becomes "Land Management" in V4.

5.1.2 Methodological Updates

Functional Unit
V4 formally defines the functional unit as 1 kg of final product, per ISO 14067. This was implied but not explicitly stated in V3.

Ingredient Concentration
V4 replaces the 'Ingredient Concentration (IC)' terminology with Allocation Ratio (AR) to unify methodology across multiple stages.

Cut-Off Rules
V4 formalizes a policy that '100% of ingredients on the label are accounted for,' tightening scope expectations.

Land Use Change (LUC)
Adds Jurisdictional Direct Land Use Change (jdLUC) option in V4, expanding beyond just sLUC and dLUC in V3.

Carbon Removals
V4 adds guidance on how HowGood handles removals with the stock difference method using primary data.

Transportation Modeling
V4 includes allocation ratio in farm-to-processing transport only, consistent with V3, but adds clarification on methodology logic and proxy logic.

Manufacturing Waste
In V4, waste is assumed to be 5%, with new guidance allowing customers to input data to reflect product losses.

Packaging
V4 distinguishes between two methods: Cut-Off Method and Circular Footprint Method (CFF); CFF introduced for cradle-to-grave calculations.

Fugitive Emissions
New in V4 – fugitive emissions during manufacturing (especially refrigerants) are explicitly included as an optional custom factor.

5.1.3 Data Quality & Scoring Enhancements

Data Quality Scoring (DQS)
V4 expands scoring methodology with detailed breakdown by life cycle stage (e.g., 'Land Use Change,' 'Retailer,' 'Use of Sold Products').

System Boundary Definitions
V4 clarifies scoring ranges across cradle-to-manufacturing gate, cradle-to-shelf, and cradle-to-grave, with example applications.

Activity Data Scoring
V4 includes worked examples and country variability, adding practical detail missing in V3.

5.1.4 Governance & Assurance

Carbon Trust Assurance
In V4, Carbon Trust performs annual limited assurance, and HowGood states assurance is aligned to updated standards (GHG Protocol + ISO 14067:2018).

Customer Interaction
V4 introduces more structured training requirements for internal and external users, defining who can access which system layer and what training is required.

Model Change Communication
V4 outlines a clear process for communicating updates to customers, including public-facing PCF usage guidelines.

5.1.5 New Additions

Circular Footprint Formula (CFF)
A major addition for modeling cradle-to-grave emissions with allocation for recycled content.

Proxy Identification Steps
Expanded detail on proxy logic for both emissions and activity data, including when proxies must be used.

Commodity Trees
Now elaborated in Appendix A, including update schedules and quality assessment processes.

Appendix F
Introduces formula parameters for the CFF (per PEF Annex C).

Appendix

Appendix A: Commodity Trees and Allocation Procedure

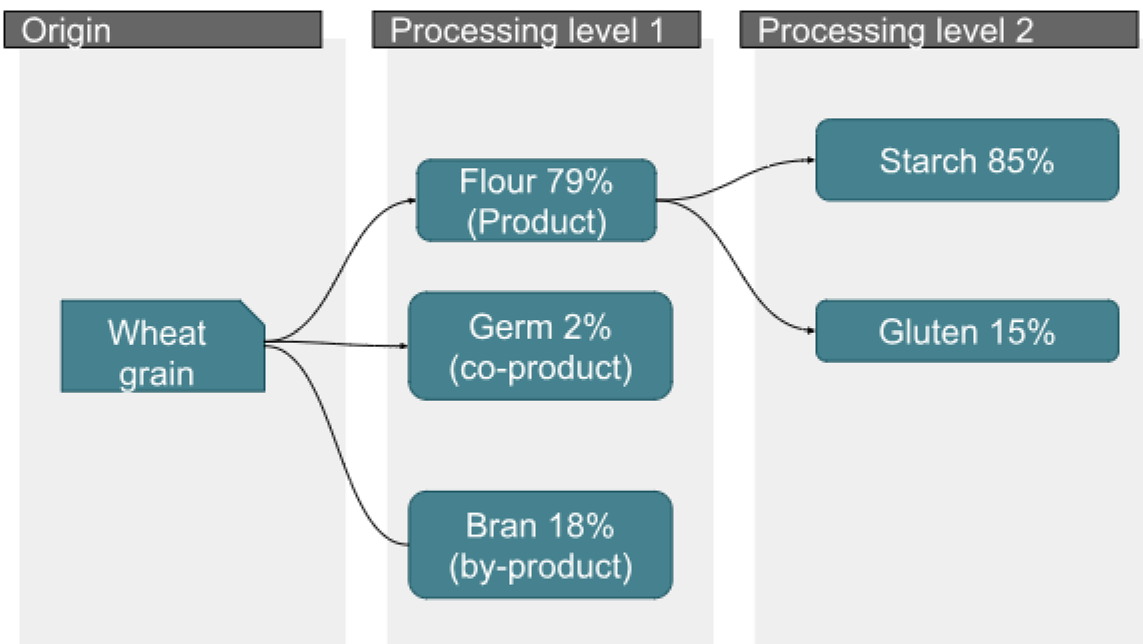
HowGood's allocation procedure accounts for the impact associated with the origin, or raw material, that is transferred to an ingredient. Our allocation procedure is determined through a process using commodity trees.

A.1. Commodity tree definitions

A **commodity tree** is a symbolic representation of the flow from a primary commodity to various processed products derived from it, together with the conversion factors from one commodity to another including all outputs (products, co-products, by-products and waste).

The classification of the by-products is based on the use and fate of the product according to the commercial value as stated in the product classification. An example of a commodity tree is displayed in Figure 3.

Figure A.1. Commodity tree example



A.2. Commodity tree components:

1. **Origin (raw material):** The origin represents the raw material or agricultural product at the beginning of the supply chain, typically defined at the farm gate. This is the point from which GHG emissions are allocated across all downstream products. It is important to confirm that the functional unit used for the origin (e.g., 1 kg of harvested crop) is consistent with the unit used throughout the mass distribution in the commodity tree.

2. **Processing lines (branches).** In a commodity tree there are multiple processing lines and each processing can have multiple co-products.

3. **Levels of processing**. Level 1 usually refers to the initial processing of the raw material coming from the farm. Further processing (level 2, level 3,..., level n) indicates each co-product is processed into a different material resulting in a subsystem with the same structure as the first level.

4. **Outputs (products).** These refer to the multiple outputs from the same processing line, it is important to note that in a single commodity there are multiple processing lines with multiple outputs and we should avoid confusion between outputs (products) from the same processing to be classified as co-products and outputs coming from a different processing line.

5. **Mass balance (%).** It quantifies the proportion of each output derived from the origin material and is important for calculating allocation ratios. Example: origin: Banana, 100%; outputs: banana puree, 70%; banana peel, 30%.

A.3. Identify & filling commodity tree gaps

Some of the commodity trees available in the sources are incomplete, particularly in terms of co-product representation and missing mass distribution data. To address these gaps, we conduct targeted, independent research to supplement the existing structures. This process will involve identifying missing co-products, estimating or validating mass percentages, and ensuring that the overall mass balance is consistent and aligned with the functional unit. By doing so, we can improve the completeness, accuracy, and reliability of the commodity trees for downstream modeling and analysis.

A.4. Sources for commodity trees and allocation ratios

The commodity trees of the HowGood origins and the allocation ratio values are collected from recognized sources such as the FAO technical conversion factors for agricultural commodities. This document contains technical conversion factors and information currently used by the Statistics Division of FAO to compile commodity balances and flows of the processed products derived from a primary commodity.

https://www.fao.org/fileadmin/templates/ess/documents/methodology/tcf.pdf

Other sources of information are organizations such as scientific peer reviewed publications, and/or reputable industry reports where allocation factors are sourced such as those listed in Section 2.3.3. Some additional examples include:

https://doi.org/10.1016/j.jclepro.2019.118241 https://www.osti.gov/biblio/816536

https://iopscience.iop.org/article/10.1088/1755-1315/195/1/012043/pdf

A.5. Updating schedule

HowGood follows a quarterly update schedule for allocation ratios driven by strategic priorities when new research becomes available and by customer needs such as new ingredient requests that didn't previously exist in our database.

A.6. Quality Assessment

The quality assessment of the sources follows the similar rules provided for other data collection such as GHG emissions, processing energy consumption, manufacturing, etc. The assessment considers the following criteria:

- As noted in Section 2.3.3, preference is given to industry standard reports detailing allocation factors.
- Type of data (measured or estimated)
- Granularity: source should display the mass balances of all products, mass weight of products, by-products. Any additional information about the use or product intention and value.
- System boundaries: related to the specific processing or manufacturing
- Functional unit: units of product weight are preferred in kg or tonnes, but mass percentage is also considered.

Appendix B: Data Ingestion into Latis

Purpose:

Data Ingestion into Latis is a key process handled by Research data team members. Data team members receive or extract customer data files, transform and at times enrich customer data to accurately match it to data fields in our database to load customer products and materials into Latis delivering impacts such as PCFs.

Who:

Any data team member on the Research Delivery team.

What:

Please see documentation below for an introduction to the varying ways to ingest data, and how we quality control (QC) on data ingested.

B.1. Data Ingestion - Uploading Customer Data

This document details the ways the Research data team uploads data into the HowGood database. The method of upload depends on the format of the customer data and the fields included.

Data Formats

a. HowGood Data Templates

The Research team has developed several data templates intended for use by our small and medium sized customers to provide activity data and supporting data such as vendor and vendor ID. When correctly filled out, these templates make uploading data via our API more streamlined and removes as much human intervention as possible to free up the Research team's time for other tasks. Data templates are often filled in with errors in structure or format that the data team fixes, when possible, during a series of data transformation steps before uploading customer data and matching to fields in our database.

b. Data Files

Larger customers, including enterprise accounts, often have more complex data systems and it's easier for both sides to agree upon required data fields during data integration to accept outputs from their ERP or other systems. These customer-specific file formats can also be uploaded via our API, but will use different functions in the API script(s). Such data requires data transformation prior to upload, and this work performed by our data team is akin to a data implementation often done by a third party system implementation partners for many software companies.

B.2. Data Ingestion QC Process

The Research team follows data quality steps during and after uploading customer data. The process is designed to catch errors made in the upload process when the data was uploaded via API. Errors made by the customer when sending the data, such as misspelling a product name or including wrong ingredients can only be identified by the customer during the data review period following their data upload, are not included in this QC process. Errors may arise through customer-provided data as a result of miscategorizations or mistranslations that customers may report to their Customer Success Manager and/or through the in-app chatbot. Customers may provide feedback and/or report model bugs during the data review process either through the in-app chatbot and/or to their Customer Success Manager.

a. **Checks during data uploads**

We have automatic functions built into our process to check for the following types of errors:

1. **Ingredients that are missing specific metrics**
   When an ingredient's metric is grayed out in the heatmap section of a product in Latis, the Research content team needs to complete or save research for new crop-location combinations.
2. **Products with weights that don't sum to 100**
   For certain products, like cheeses, ingredients must sum to greater than 100% to reflect allocation guidelines (in this case the industry standard moisture content guidance for types of cheese as defined by the EU Product Environmental Footprint, or PEF). Most products will sum to 100%, and products summed to <100% is usually the result of how the data was provided from the customer but could signal a mistake in the transformation or upload steps and requires investigation by the data team.
3. **Duplicate product names**
   Some products may be intended by the customer to be duplicated, for example products with the same name but manufactured at different facilities and made with ingredients from different locations. This context should be conveyed to the data team member performing the upload. In cases when duplication is unexpected, the team checks for it and investigates, working with Customer Success if needed.
4. **Products with duplicate ingredients**
   This may be normal for ingredients with nested products or variety packs but is another way to check for data processing or parsing errors.
5. **PCF outliers, based on customer provided categories**
   Customers provide some level or taxonomy or organizing structure for their products that is visible in the platform. Products are reviewed using the context of

the categories and product naming to ensure that unexpectedly PCFs are not due to mistakes generated in the upload.

6. **Standards**
   We check that the standards and certifications (i.e., USDA Organic) specified by the customer have been correctly applied.

b. Quality control checks after data uploads

We have automatic functions built into data team process to check for the following types of errors:

1. Check all relevant products from customer provided files exist in Latis.
2. Find empty PCFs and patch with missing values if any are found.
3. Find and delete duplicate products if any slipped through step 3.
4. Check fields exist as per the provided file(s): UPCs or other product identification codes, product standards and certifications, vendor names and IDs, etc.
5. Check origin locations associated with ingredients are all published. If any are unpublished or missing, check with the content team that those origin locations are in the research queue.
6. Check and adjust ingredient weights for any with rules for greater than 100% formula inclusion (water in beer, milk for cheese, etc.) or rules for less than 1% formula inclusion (vitamins, flavors, colors, etc.)
7. Evaluate results of manual QC performed by content team and reupload products, if needed.
8. Check PCF values in Latis by sorting the appropriate carbon field by highest to lowest, reviewing both high and low values for outliers.

c. Manual QC checks

Depending on the level of activity data provided, we perform additional checks once the products have been uploaded.

1. **Higher levels of activity data**
   When customers provide activity data for a larger number of fields specified in Section 3.2, an additional check is performed in Latis to check products for expected PCF values, such as reviewing those with the highest and lowest PCFs. Keyword searches are included specific to the customer's product portfolio. Because more activity data was provided, any mistakes are more likely to have been caught by the standardized data team process above, or be caused by customer data.

2. **Lower or limited levels of activity data**

When customers provide limited activity data, or fewer activity data fields, as specified in Section 3.2, more extensive manual QC checks are performed. For smaller product portfolios (<1,000) checks are performed in Latis sorting data from high to low and checking products with the highest and lowest PCF values for relevance and accuracy, followed by keyword searches. For medium and larger product portfolios (1,000 to >100,000) where machine algorithm matching on limited activity data is more likely to result in mismatches, the Research data team prepares QC files for the Research content team of SMEs to review. The Project Manager prepares the file by conducting a quick analysis by a level of data organization such as sales volume and/or sales category, for the content team to focus attention on the most likely errors. Once the team has identified errors and corrections, the data team member responsible for the upload adjusts any flagged products. An additional final step is performed in Latis similar to the step outlined above for smaller product portfolios.

Appendix C: Proxy application and identification guidelines

C.1. Proxy Application (when to apply proxies)

Whenever a land management GHG value for an origin location is not available both in primary (e.g., LCA study) and secondary (e.g., collection of carbon footprint values) sources, a proxy value is necessary.

More specifically, the application of a proxy crop occurs when:

- Public data or peer reviewed publications are not available, the research has not been carried out or it is a novel or rare crop/animal origin.
- Having available data, the report/publications do not meet the quality assessment criteria. In other words:
    - Information in the source is incomplete or inaccurate
    - The source is too old (2014 and older)
    - Methodology is not specified, and the value is not supported by calculations or models.
    - When the data cannot be extracted, (GHG value) estimated or modeled from the original source using information provided in the same document.
    - Other criteria stated in the data quality assessment document.
- Proxy application follows the steps outlined in HowGood's Proxy Identification Guidelines

The application of the proxy selection is limited to internal use by HowGood Research team members. Customers can submit a request for new ingredient and location combinations.

C.2. Proxy Identification Steps

1. Prioritize:
    - Origin in similar taxonomy (at least family, preferable genus or order);
    - Similar crop type, yield, and agricultural management practices; and
    - in the same location or climatic/ecological region.

2. If an origin in a similar taxonomy, with comparable yield and in the same region cannot be found, look for a similar product (e.g., similar botanical characteristics or same crop category) for the same location (preferable) or same climatic region.

3. Picking the same product from a location belonging to a different region should be kept as the last option. If you pick this option, make sure the original source has high quality data.
4. Finally, when choosing a proxy, double-check that:
    - The System Boundary and life cycle stage are correct: (cradle-to-farm gate and land management)

- The functional unit is $kgCO_2e/kg$. Also, specify if it's fresh or dry weight (whenever this information is known)
- The production system is the conventional/dominant one for the origin location

NOTE: When in doubt about the proxy or the quality of the source used to extract the GHG value, proceed to identify a proxy (and a source) and add a comment in the LCA research spreadsheet to request a second opinion by another researcher.

Appendix D: Data source update schedule

D.1. Land management emissions

The HowGood Research team reviews data sources for land management emissions on two cadences – annually and quarterly. During those reviews, we update sources and their associated values when better sources are available.

D.1.1. Annual updates

We follow an annual cycle reviewing our lowest scoring and oldest land management sources. In the first quarter of each calendar year, HowGood will conduct a review of lowest scoring and oldest sources.

Sources to be reviewed will achieve a Fair data quality rating (DQR), or a DQC above Fair and published prior to the oldest option per criteria per life cycle stage, unless a more recent cutoff year is chosen for any given life cycle stage. Please refer to Section 3 for details.

As a result of the annual review of old sources, if new sources are available and in line with our quality criteria, achieving a higher data quality score than the existing source for the corresponding stage of the carbon life cycle, update the value and record metadata about the source in the appropriate workflow spreadsheet. If no new source is available for an individual emissions factor, record the findings and date in the annual source review document.

D.1.2. Quarterly updates

Each quarter, on a limited and as-needed basis, either as a strategic decision or because of customer inquiry, we schedule audits for specific crops/materials that serve as deep dives across locations to ensure measures of consistency and quality.

An example of a strategic update is stevia. In the past, due to limited sources, we used an industry paper for cradle-to-farm gate emissions. After the publication of a peer reviewed paper this year, and other sources the team found, we modeled the cradle-to-farm gate stevia emissions in a way we think is more robust and defendable than the values in the aforementioned paper. While the modeling of cradle-to-farm gate emissions is an exception for us (in the vast majority of cases, we extract values from peer reviewed papers), we were satisfied with the result after comparing final numbers against the equivalent value in a customer's publicly available LCA.

An example of a customer inquiry that led to a quarterly audit involved a question of allocation for butter. In addition to reviewing the allocation applied in our allocation procedure for butter, the team audited our dairy cow cradle-to-farm gate emissions values and sources, harmonizing to the PEF standard, including a functional unit reflecting fat- and protein-corrected milk.

These quarterly updates are released on a rolling basis and are posted in HowGood's Research Updates.

D.2. Statistical Land Use Change

Statistical land use change values are updated annually. Sources are evaluated as they become available or improve, based on the extent of crop/commodity and geographic coverage and rigor of the dataset.

D.3. Ingredient Processing Types

Sources for steps and energy types and inputs for ingredient processing and product manufacturing have undergone a complete audit in 2023. The full audit included the separation of fuel types and energy consumed per fuel type added to the database. Energy types included biomass to allow for biogenic calculations. Further updates are made on an as-needed, ongoing basis and after the full audit are typically initiated through a customer's new ingredient request that involves an assessment of how the ingredient is processed. When customers provide primary activity data for upstream processing, we check that the data provided matches the year of the other PCF activity data.

D.4. Manufacturing Types

See the previous section, "Ingredient Processing Types" for more information. Manufacturing types are expanding based on the expansion of our customer base. For example, we built a precision fermentation manufacturing type for a new customer based on data they provided in the HowGood Manufacturing Data template. When customers provide primary activity data for manufacturing, we check that the data provided matches the year of the other PCF activity data.

D.5. Energy Emissions Factors

Grid emissions factors are updated annually.

D.6. Other data points

Other data points are fairly consistent, like transportation EFs, for which we use the GLEC Framework that carries the mark "Built on GHG Protocol". Such EFs are updated after new versions become available.

Appendix E: Updating existing emissions factors in the database

This section is distinct from Section 4.3.1 and refers to individual data point EFs that HowGood has researched.

Customers are notified through the UI when new data is available for their product(s). Customers can then accept the data update on a product to see the update reflected in a live view. Customers and partners receiving data outside of Latis have their data updated as per their contract. Before these updates are made available to the customer, there is an internal review process. First, processes outlined in Section 4.3.2 are completed and then the update to the database follows the procedures below.

For updates to existing emissions factors if the new value is lower than the old value OR the update impacts less than 5,000 products:

- Update the database
- Then update the the #research-updates channel including:
  - The name of what was updated
  - The metrics impacted
  - The before and after values
- The Latis Updates help center article is updated
- A workflow is generated to notify customers using Latis

For updates to existing emissions factors if the new value is higher than the old value and the update impacts more than 5,000 products:

- Write a ticket for a data team member to test the changes running an impact report by customer.
- Post the update to the #research-updates Slack channel asking Customer Success for permission to post without delay or a timeline for them to communicate to any customers with more exposure to the update. The post should include:
  - The name of what was updated
  - The metrics impacted
  - A summary of the before and after values
  - A link to the impact report with customer-specific impacts
- Once update timing is confirmed, update the database
- The Latis Updates help center article is updated

Appendix F: Circular Footprint Formula Parameters

Table F.1. CFF A Factor (per PEF Annex C):

A	Applied when	Materials
0.2	Low offer of recyclable materials and high demand: the formula focuses on recyclability at end of life.	Metals Glass Paper and Cardboard
0.5	Equilibrium between offer and demand: the formula focuses both on recyclability at end of life and recycled content.	Plastics
0.8	High offer of recyclable materials and low demand: the formula focuses on recycled content.	Wood

Table F.2. CFF Qsin/Qp Factor (per PEF Annex C):

Material	Default value (Qsin/Qp)
Glass	1
Steel	1
Aluminium	1
Other metals	1
Paper and cardboard	0.85
Paper and cardboard	1
PET - SSP recycling	1
PET mechanical recycling	0,9
PP	0.9
HDPE	0.9
LDPE film	0.75