

Planet FWD Database Methodology

Table of Contents

Process LCI Database.....	3
General Methodology.....	3
Scope and Boundaries.....	3
Model Development.....	4
Allocation Methods.....	4
LCIA Methodology.....	5
Underlying Models and Data.....	6
Energy and Upstream Transportation.....	6
Refrigeration.....	7
Waste Treatment and End of Life.....	7
Waste Management Pathways.....	8
Default Waste Production Rates.....	8
Default Waste Management Pathway Rates.....	9
Recycled Content Method.....	9
Carbon Storage.....	9
Agricultural Models.....	10
Inputs.....	10
Outputs.....	10
Data Sources.....	11
Land Use.....	11
Land Use Change.....	12
SBTi FLAG.....	12
Land Management Emissions.....	12
Carbon Removals.....	13
FLAG Emissions with Spend Data.....	13
Product Source Location.....	14
Processed Foods/Finished Goods Models.....	14
Environmentally Extended Input-Output LCI.....	16
Methodology.....	16
Data Sources for EEIO.....	16
Advantages and Limitations.....	17

Planet FWD Database Methodology

The PlanetFWD methodology is built upon two core databases, a process LCI database, and an Environmentally Extended Input-Output LCI database, which consists of spend-based accounting of emissions factors.

The Process LCI Database consists of processes and flows that can be used to compile full LCAs and Corporate inventories. All materials in the Process LCI Database are cradle-to-gate unit processes, and there are additional system process modules that enable compilation of materials and other unit processes into full LCAs.

The EEIO database is based on the USEPA EEIO data which directly builds on USBEA data to estimate the environmental impact of spend in various economic sectors.

Process LCI Database

We provide here a description and outline of the methodology and key data sources used to compile our process life cycle inventory (PLCI) database. Our database contains models of the following physical commodities:

- Underlying models and data for energy sources (i.e. fuel combustion, grid electricity, etc), transport modes, processing steps, waste treatment.
- Agricultural products
- Finished/processed food products, materials, chemicals, and fuels

Greenhouse gas emissions (or embodied carbon) is the primary impact category available in our database, though other impact categories (embodied energy, agricultural land use, embodied water and FLAG emissions) are available by request.

General Methodology

Scope and Boundaries

Activity data characterize the life cycle of a product/process by accounting for all material and energy inputs consumed, material and energy outputs generated, transport, storage, and waste outputs generated throughout the life cycle.

The system boundary for materials in our database is "cradle to farm gate" for agricultural models and "cradle to factory gate" for models of processed ingredients and materials. Therefore all activity data for models in our database include only inputs and outputs within these boundaries. All upstream and direct emissions are included, with the exception of those related to the production of capital goods and infrastructure, which are currently excluded, as is a common practice in product LCAs, as they are usually not major contributors to total environmental footprint. Additionally, while models for packaging materials are available in our database, primary and secondary packaging are not included as inputs to models in our database. Packaging can vary significantly depending on size of product and purchase quantity, so is added during the creation of LCAs and Corporate Inventories separately, and not included by default for raw materials.

Model Development

When developing models in our database, data on these inputs and outputs is compiled by our team of scientists and engineers using a variety of sources including primary data, peer reviewed literature, government and NGO published data, production patents, and product manufacturing guides in combination with industry experience to model complex production systems. All data must meet our data quality requirements, which means the data must be from within a reasonable timeframe, be from peer-reviewed sources or government, academic publications, or trusted industry sources, and be in line with our methodology

After the activity data for a given model is compiled and verified by our scientists, the input and output data are modeled in our LCA-engine software to produce LCA results and can be used in customer LCAs and corporate inventories. These models are built using methodologies aligned with Greenhouse Gas Protocol and ISO 14040/44. Emission factors from IPCC AR6 (100 yr GWP) are then used to translate this process activity data into GHG emissions, covering both energy-related and non-energy-related GHG emissions (CO₂, as well as other significant non-CO₂ greenhouse gas emissions). After a model is developed in our LCA software, it undergoes a multi-stage internal review process facilitated by other scientists on our team before being published to our database.

Models in our database are as reflective of standard industry processes and geographic regions as possible, dependent on the availability literature for those processes.

Allocation Methods

Allocation of resource use and emissions between co-products is performed by dividing a process into distinct sub-processes, or by using mass-weighted economic allocation. We avoid system expansion because of the inherent difficulties and uncertainties involved in identifying and characterizing appropriate marginal product systems. Mass-weighted economic value has proven to be the most reliable method of allocation in many real-world scenarios, particularly for product systems that produce highly dissimilar co-products. Low-value (and often high-volume) waste outputs that may be useful elsewhere, such as recyclable material waste or manure from animal systems, are handled as part of the waste processing algorithm described above

Special Cases:

Dairy Product Production:

Due to the inherent difficulty in placing a stable value on dairy products and coproducts, several exceptions to the standard allocation are made in favor of the allocation procedure outlined in the International Dairy Federation Carbon Footprinting Standard ([IDF, 2015](#)).

Meat production from culled dairy animals:

Allocation between meat and milk is based on a biophysical methodology based on the feed net energy requirements of the cow for growth and for milk production.

Allocation of Raw Milk Burdens in Dairy Products:

Allocation between dairy products and coproducts at the processing facility are made on a mass basis using milk solids as the base unit. Milk solids outflows which are not the main product can fall into three other categories (examples):

1. Coproduct (Whey Permeate processed into Lactose Concentrate)
 - a. Allocated emissions based on mass of milk solids
2. Residual Product (Acid Whey hauled off for animal feed)
 - a. Cut-off process, no emissions added for the main product
3. Waste (Diluted Whey sent to wastewater treatment)
 - a. Emissions from transport and treatment assessed to main product

Co-production of Fuels:

Elementary flows for solid, liquid, and gaseous fuels (eg. coal, diesel, LPG, natural gas) are imported directly from the [US life cycle Inventory Database](#) via LCACOMMONS. In processes that have co-production (eg. petroleum refining producing diesel, gasoline, kerosene, and more) allocation factors are directly imported from USLCI and not manipulated.

Scope 3 emissions for stationary engine fuels are computed from upstream contributions of the appropriate models from USLCI. This scope 3 calculation accounts for various coproducts and allocations throughout the fuel supply chain.

LCIA Methodology

Impacts that can be measured by our tool and their life cycle impact assessment methods are:

- Global warming potentials for greenhouse gasses are based on the IPCC Fifth Assessment Report (AR6) [Global Warming Potential Values](#) and are reported in kg CO₂e.

- This can be further broken down into Non-FLAG Emissions, FLAG Land Management (CO₂ and non-CO₂) and Carbon Removals
- Energy consumption in MJ, or Non Renewable Energy Use (NREU) (also MJ) which is total fossil or nuclear energy
- Agricultural Land Use in m³/yr or ha/yr
- FLAG Emissions Breakdown including Land Use Change, Land Management, and Carbon Removals in kg CO₂e
 - see sections on SBTi FLAG below
- Water Use in m³, which consists of Blue + Grey Water use, and excludes Green water.
- Land Use Change impacts in kg CO₂e
- Biodiversity Impact, which is unitless

Underlying Models and Data

Energy and Upstream Transportation

Primary energy use and GHG emissions per unit of electricity supplied through the grid are calculated using activity data -- consisting of fuel and power plant mixes for various grid regions (both US and international), as well as transmission losses and other details -- from [EPA eGRID2023 Database](#) for US Grids, and [Ember Climate for International Grids](#).

Emission factors for extraction of primary fuels are derived from the [US life cycle Inventory Database](#) and the [IPCC Guidelines for National Greenhouse Gas Inventories](#). Emission factors for combustion of primary fuels are from the [EPA GHG Emission Factors Hub](#).

Transportation emissions factors are well-to-wheel, including upstream well-to-tank emissions as well as direct combustion emissions from vehicle operations. For air transport, a [radiative forcing factor of 2.7](#) is typically used to account for the higher global warming potential from emissions released at higher altitudes. Primary energy use and GHG emissions per tonne-km of freight transport for all transport modes (road, rail, ocean, and air) are calculated using activity data from these sources:

- [Greenhouse Gas Protocol](#)
- [DOE Transportation Energy Data Book](#)
- [Argonne National Laboratory GREET model](#)
- [DOE Bureau of Transportation Statistics Truck Profile](#)
- [DOE Alternative Fuels Data Center](#)
- [Fourth IMO Greenhouse Gas Study](#)

Our models use standard assumptions for transport distances and modes. These assumptions are averaged values specific to product groups (rather than products themselves) based on SCTG commodity codes. These average values are derived from the U.S. Census Bureau Commodity Flow Survey.

Processing Library

When data for processing energy consumption for a given model is not available, models from our Processing Library are utilized. Our Processing Library contains models which calculate fuel and electricity consumption for general processing steps and/or processing equipment based on parameters specific to that process or equipment (ie throughput rate, particle size of throughput, heat capacity of throughput, etc). Processing models are developed by our team of scientists. These models are developed using the same data quality and validation requirements, and undergo the same internal review process as or material models.

Refrigeration

Primary energy use and GHG emissions for refrigerated storage in warehouses are calculated using activity data from Burek, & Nutter, D. W. (2020). Environmental implications of perishables storage and retailing. Renewable & Sustainable Energy Reviews, 133, 11007. Time in cold storage at warehouse/distribution center, if not provided for specific ingredients or foods, is estimated based on regulations and shelf-life. Energy use and GHG emissions for retail is estimated using activity data from EPA Energy Star. Leakage of refrigerants are accounted for in refrigerated transport and retail storage. Refrigerant leakage is assumed to be negligible in the warehouse and distribution stage as well as industrialized production, as ammonia is the most prevalently used refrigerant in these systems and not a greenhouse gas. For refrigerated transport and retail, however, HFCs are still the most predominantly used refrigerant and average leakage rates are calculated for cold storage volume and a default HFC GWP is applied.

Waste Treatment and End of Life

Waste management is modeled via specific material types diverted to various waste management pathways depending on consumer behavior and national averages.

Types of Waste

End of Life (EoL) and waste production including solid waste and wastewater streams are modeled in detail based on methodologies and parameters adapted from IPCC¹ (2006) and the EPA's Emission Factors for Greenhouse Gas Inventories². We classify waste materials into specific categories to ensure accurate estimations of their environmental impact. These categories include, but are not limited to: Metals, Plastics, Paper Products, Organic Materials, Electronics, Food/Beverage, Concrete, Other.

Waste Management Pathways

Waste materials are managed using a combination of the following strategies: Recycling, Landfilling, Combustion, Composting, Dry Anaerobic Digestion, Wet Anaerobic Digestion

The End-of-Life (EoL) model we use comprehensively estimates emissions from key stages of waste management, encompassing production, storage in warehouses, and consumer use. It notably excludes farm-based waste. This model is meticulous in considering energy consumption across various activities, such as material sorting and processing, tailored to the specific management pathway involved.

Our models replace the default 20-mile transport by a diesel-powered short-haul truck assumption used in EPA's Emission Factors for Greenhouse Gas Inventories and update with a diesel-powered refuse truck with US average load and enable the users to input the specific data (if available) for the distance between landfilling, composting, recycling, and anaerobic digestion facilities.

For certain materials or treatment methods not covered by the EPA Emission Factors for Greenhouse Gas Inventories model, we reference the IPCC's guidelines on waste management (IPCC, 2006) or may use location/country specific data. Wastewater modeling includes aerobic and anaerobic treatments. Industry standard constants & calculations were used from IPCC 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Volume 5 (Waste), Chapter 6 (Wastewater treatment and discharge). Constants were also pulled from the 2006 Guidelines when appropriate. Sludge removal and methane recovery are used based on information from the EPA.

¹ Bogner, J., M. Abdelrafie Ahmed, C. Diaz, A. Faaij, Q. Gao, S. Hashimoto, K. Mareckova, R. Pipatti, T. Zhang, Waste Management, In Climate Change 2007: Mitigation. Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [B. Metz, O.R. Davidson, P.R. Bosch, R. Dave, L.A. Meyer (eds)], Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA. Accessed 10/31/2023:
<https://www.ipcc.ch/site/assets/uploads/2018/02/ar4-wg3-chapter10-1.pdf>

² https://www.epa.gov/system/files/documents/2023-03/ghg_emission_factors_hub.pdf

Default Waste Production Rates

When model-specific data on waste production and/or management pathways is not available, we defer to our default waste assumptions. These assumptions are based on the type of product being modeled. Our default waste rates and waste management pathways are derived from sources including but not limited to ReFed Insights Engine Food Waste Monitor, FAO Food Loss and Waste Database, Global food losses and food waste – Extent, causes and prevention (FAO, 2011) and EPA's 2019 Waste Food Report. Data from these sources has been compiled, reconstructed by our team of researchers to ensure an apples-to-apples comparison across sources, and used to produce regional averages specific to different commodity categories

*Default Waste Management Pathway Rates**Recycled Content Method*

Recycling, upcycling, and reuse are modeled using the "recycled content" method which defines how environmental burden is allocated in a system where a material may have multiple lives. The system boundaries are drawn such that the system that produces the recyclable waste is responsible up to the point of delivering the waste to a recycling facility, and then any subsequent transport, processing and use of that material is included in the second system(s) that uses the would-be-waste material in some form.

Other types of waste material that may be useful elsewhere, such as manure from animal systems, are handled in a similar manner: The product systems that use the material, such as organic crop systems that use manure as a substitute for fertilizers, get credit for avoiding the resource use and emissions associated with fertilizer manufacture; and these systems also bear the burden of actually applying the manure and the subsequent nitrous oxide emissions from the soil

Carbon Storage

Carbon stored via biomass growth and soil sequestration are not accounted for in our agricultural models by default. Carbon storage can only be accounted for if primary data is provided in addition to the other requirements outlined in the GHGP Land Sector Guidance Draft.

Agricultural Models

The production of agricultural commodities are modeled uniformly based on a detailed inventory of inputs and outputs as indicated below. These inputs include those required during crop establishment periods and those related to planting and maintaining cover crops. The activity data required for agricultural models is highly dependent on the type of agricultural product being produced. The following is a non-exhaustive summary of items that may be included in agricultural activity data

Inputs

- Fertilizer application (both synthetic and organic)
- Pesticide application
- Soil amendments and oil micronutrients
- Animal feed
- Water
 - Irrigation -- including district-supplied water
 - Pumped ground water,
 - surface water from natural sources such as rivers
- Energy: Electricity and fuel use

Outputs

- Emissions and Sequestration:
 - CO₂ from lime and urea application, Direct/indirect N₂O emissions from soils and water due to nitrogen fertilizer application (both synthetic and organic)
 - Direct/indirect N₂O emissions from soils due to crop residues and biological nitrogen fixation
 - CH₄ from flooded rice fields
 - CH₄ from enteric fermentation in ruminant animals
 - CH₄ and N₂O emissions from manure management
 - Changes in the carbon content of soils (emissions/sequestration) due to land management methods -- for general scenarios such as changing from conventional to organic crop production, or for specific changes related to tillage, application of organic amendments, etc.⁴
 - Direct GHG emissions from on-site waste treatment
 - Direct GHG emissions from fuel combustion

- Solid and Liquid Waste streams (management pathways and treatment methods discussed in [Waste Treatment and End of Life](#))
- Co-products
- Product being modeled (note: product carbon storage not included, see [Carbon Storage](#))

Data Sources

Data for development of agricultural models is collected from a variety of sources that meet our data requirements (as outlined in the Model Development section above), but some key sources that are used throughout are:

- Data for fertilizer production are based on [IFA](#) publications, pesticide data are derived from the [Encyclopedia of Pest Management](#), and water/wastewater treatment data are from [ACEEE](#) and [IPCC](#).
- Emission factors for GHG emissions inherent agricultural processes -- are consistently derived and calculated using the following two sources:
 - [US life cycle Inventory Database](#)
 - [IPCC Guidelines for National Greenhouse Gas Inventories](#)
- GHG emissions, primary energy use, and water use for agricultural products and processes are calculated using activity and other data from numerous credible sources, including university agricultural extensions, agro-economics departments, government agencies and peer-reviewed research publications. Representative data sources include but are not limited to [University of California, Davis - Agricultural Cost and Return Studies](#), [British Columbia Ministry of Agriculture, Food and Fisheries](#), and [Journal of Cleaner Production](#)

Land Use

Land use modeling is based on methodologies and parameters adapted from [IPCC](#) tier 1/2, and includes two specific scenarios: unchanged land use and changes in land use. Unchanged land use is a measure of area needed to produce a specific quantity of crop (i.e. ha/kg), while land use change is a measure of the change in land-based carbon pools as a result of conversion from one land use type to another. All common land use categories are included (Forest, Cropland, Grassland, Wetlands, and Settlements). Land-based carbon pools included in land use change calculations are above-ground and below-ground biomass, dead organic matter, such as litter and dead wood, and soil carbon -- during land use change as well as over time.

Land Use Change

Land use change (LUC) is calculated as the emissions due to recent land conversion within a landscape or jurisdiction. Direct LUC is calculated based on land conversion directly on the area of land that a company owns/controls or on specific lands in the company's value chain. In cases where such detailed information is lacking, statistical LUC calculations are employed, taking into account the extent of physical traceability to the source location of the products. Statistical LUC data is derived from FAOSTAT land use and land cover information. Both direct and statistical LUC emissions calculations are grounded in GHGP and IPCC data pertaining to biomass carbon, soil carbon, and litter carbon. LUC emissions are specific to production location and reported separately from direct emissions.

SBTi FLAG

The above methodology and documentation related to agricultural models and carbon storage is in direct alignment with SBTi's FLAG emission accounting and reporting requirements. Accounting requirements include land management emissions, carbon removals, and land use change. Additional guidance on PlanetFWD's methodology FLAG emissions reporting and for customer intake data and sourcing location are included below.

Land Management Emissions

Emissions from land management are separated into two reporting categories, CO₂ and non-CO₂. Land management emissions from CO₂ include the following sources:

- CO₂ emission from machinery used on-farm
- CO₂ emission from transport of biomass
- CO₂ emission from soil input production, including fertilizers, pesticides, irrigation, and soil amendments and micronutrients

Land management emissions from non-CO₂ (CH₄ and N₂O) include the following sources:

- CH₄ emission from manure management
- Enteric CH₄ emissions
- CH₄ emissions from flooded soils
- Direct and indirect N₂O emissions from manure management and fertilizer application
- N₂O emissions from crop residue

- CH₄ and N₂O emissions from agricultural waste burning
- N₂O from fertilizer production

Carbon Removals

Land removal and storage include those from enhanced soil organic carbon and agroforestry. Enhanced soil organic carbon includes one or multiple shifts in management practices, such as erosion control, use of larger root plants, reduced tillage, cover cropping, restoration of degraded soils and biochar amendments. Carbon storage from agroforestry includes carbon sequestered in perennial tree crop woody biomass.

Carbon sequestered from these sources will remain as part of PlanetFWD's product emission factors until the release of the final version of the Greenhouse Gas Protocol (expected 2025). Aligning with the GHGP draft, carbon removals can only be included in a product carbon footprint if the following criteria are met:

- **Ongoing storage monitoring** is documented in a land management plan or monitoring plan and implemented to ensure carbon remains stored on the landscape and they can detect losses of stored carbon in relevant land-based carbon pools
- **Traceability** to the land management units where the carbon is stored
- Net carbon stock changes are accounted for using **primary data** specific to the land carbon pools where the carbon is stored in the reporting company's operation or value chain
- Net land carbon stock increase is statistically significant based on quantitative **uncertainty** estimates
- Report net land carbon stock losses of previously reported removals in the year the losses occur (**reversal accounting**).

FLAG Emissions with Spend Data

Customers may provide their purchase data either in total purchase mass or total spend. Total purchase mass is preferred over the latter. With PlanetFWD's database of mass-based emissions factors, matching of customer purchases and database models allows for the most accurate results. With this mass-based method, FLAG emission breakdown is easily propagated through to the final processed model.

In circumstances where total purchase mass is unavailable, a spend-based approach may be used to calculate a customer's FLAG emissions. The methodology for calculated FLAG emissions from spend data leverages PlanetFWD's database models and EEIO factors to

compute the average FLAG emissions per dollar spent on commodities. The initial step involves aligning the customer's product with our database categories and correlating these to BEA/NAICS codes, which are linked to EEIO LCI data to estimate CO₂e emissions per dollar spent. Using the average FLAG emissions within each of our database categories and BEA/NAICS codes, we calculate the product's FLAG emissions as a percentage of its total carbon footprint. Next, utilize this percentage of FLAG emissions and the EEIO LCI data to compute the percentage of kilograms of CO₂e per dollar spent. Lastly, we can leverage the total spending data on the customer's product to calculate the kilograms of CO₂e specifically attributed to FLAG emissions.

Product Source Location

Location of production for purchased materials is essential for accurate emission measurement and reporting. Sourcing region is used within each FLAG emission calculation, including land management, carbon removals and land use change. For land use change, country specific data is the most specific level of traceability for sourcing region we are able to calculate. When source location is unknown, global sLUC emissions factors are calculated based on product and year.

Processed Foods/Finished Goods Models

The production of processed foods/finished commodities are also modeled uniformly based on a detailed inventory of inputs and outputs. Though production of these goods does not generate direct emissions or sequestration from biomass growth, fertilizer-soil interactions, land use change, land management practices, etc, the input data, can be much more variable from one model to the next than that of agricultural models. The following is a general summary of items that may be included in activity data for producing processed foods or other finished goods:

- Inputs
 - Material inflows (highly variable): any and all materials required to produce a given product including but not limited to water, agricultural products and other finished goods
 - Energy: Electricity and fuel use
- Outputs:
 - Emissions:
 - Direct GHG emissions from fuel combustion
 - Direct GHG emissions resulting from a specific process in production system

- Direct GHG emissions from waste treatment methods
 - Solid and Liquid Waste streams (management pathways and treatment methods discussed in Waste Treatment and End of Life)
 - Co-products
 - Product being modeled (note: product carbon storage not included, see Carbon Storage)

Environmentally Extended Input-Output LCI

Methodology

This section outlines the methodology and key data sources used to compile our environmentally extended input-output life cycle inventory (EEIOLCI) database³. Three life cycle impact categories are included for all the goods and services in the database: greenhouse gas emissions (embodied carbon), primary energy use (embodied energy) and water use (embodied/virtual water).

At the core of the database is the USEEIO dataset which provides input-output life cycle model for 411 goods and services sectors in the US economy based on one 2012 US dollar of producer price as reference. Our implementation enhances this model to cover purchaser price, inflation, and other necessary extensions in order to make it usable for product life cycle assessments and corporate GHG inventory analyses. Our EEIOLCI database uses one US dollar of purchaser price as reference (the reference year will be updated annually). It is the producer price that is mapped to the environmental flows and life cycle impact categories associated with the production of a good or service. The system boundary is cradle-to-gate.

We also have non-US EEIO data from [Exiobase](#) 3.9.5, in order to provide spend based emissions factors for 49 countries and 163 industry sectors. No adjustments are made to Exiobase data, since the underlying data is annualized.

Data Sources for EEIO

US Environmentally-Extended Input-Output Dataset

The USEEIO dataset from the Environmental Protection Agency combines data on economic transactions between 411 industry sectors with environmental data for these sectors covering various resource uses and emissions, to build a life cycle model of US goods and services. The dataset represents the 50 US states. The original model was intended to represent conditions for the base year as closely as possible. Resource uses

³ Yang, Y., Ingwersen, W. W., Hawkins, T. R., Srocka, M., & Meyer, D. E. (2017). USEEIO: A new and transparent United States environmentally-extended input-output model. *Journal of cleaner production*, 158, 308-318. Available from: <https://www.epa.gov/land-research/us-environmentally-extended-input-output-useeio-technical-content>

and emissions reflect the environmental burdens of producing one 2013 US dollar worth of a good or service.

Gross Domestic Purchases Price Index

The gross domestic purchases price index is the featured measure of inflation in the US economy and is produced by the Bureau of Economic Analysis (US Department of Commerce). The index measures the prices of goods and services purchased by US residents, regardless of where the goods and services were produced.

Operating and Net Margins by Sector

This dataset provides the gross, net and operating margins for 94 industry sectors in the US consisting of a total of over 7000 firms. This includes manufacturers, distributors, retailers and service providers.