Global Metrics for Sustainable Feed

GFLI methodology and project guidelines

Version 3.0, January 2026

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Reading guide

What are you looking for in this document?

- I am a LCA consultant or researcher looking to understand the GFLI methodological approaches. > Read chapters 2 and 3 for the LCA approach and modelling standards GFLI upholds.
- I am an association, a consortium of companies, or a company interested in understanding what I need to prepare to do a data project > Read chapter 5 for the procedures how to conduct a data project and what is required to proceed in a 'GFLI Data-in project'.
- I am of a company and interested in getting my product environmental footprint validated by GFLI > Read chapter 4 for the requirements specific for branded data. Note that chapters 2 and 3 are to be understood by the LCA practitioners in order to fulfil the requirements laid out in chapter 4.

Definitions

Relevant abbreviations for this document

Acronym	Full name
ALCA	Attributional Life Cycle Assessment
DQR	Data Quality Rating
EU	European Union
EEA	European Environment Agency
EMEP	European Monitoring and Evaluation Programme
FAO	Food and Agriculture Organization of the United Nations
GFLI	Global Feed LCA Institute
GR	Geographical Representativeness (used within the Data Quality Rating)
IPCC	Intergovernmental Panel on Climate Change
LCA	Life cycle assessment
LCI	Life cycle inventory
LCIA	Life cycle impact assessment
LEAP	Livestock Environmental Assessment Programme
LUC	Land Use Change
NIR	National Inventory Reports
P	Precision (used within the Data Quality Rating)

PEF	Product Environmental Footprint
PEFCR	Product Environmental Footprint Category Rules
SAC	Scientific Advisory Council
TeR	Technology Representativeness (used within the Data Quality Rating)
TMC	Technical Management Committee (consisting of GFLI members' technical experts, who hold regular meetings)
TiR	Time Representativeness (used within the Data Quality Rating)

Descriptions of relevant terms

Term	**Description**
Activity data	Data on the level of an activity that affects emissions, resource extractions, and land use. Sometimes referred to as foreground system.
Adapted Secondary data	Secondary data considered of higher representative value than the default secondary data. This could be presented in ways of regionalized (& publicized) databases, improving default data by updated and/or more representative data input, a market mix of inputs better representing the trade data of the data provider, or secondary datasets supplemented by primary data.
Aggregated dataset	An LCI of multiple unit processes or life cycle stages, but for which the inputs and outputs are provided only at the aggregated level. Aggregated datasets may also be referred to as LCI results, cumulative inventory or system processes.
Background data	Generic and existing data used to link activity data with emissions from specific processes, often from LCI databases, such as GFLI, Agri-footprint, Ecoinvent, Agribalyse, and GaBi/Sphera.
Background system	The activities for which generic and existing data are used, which are often from LCI databases, such as GFLI, Agri-footprint, Ecoinvent, Agribalyse, and GaBi/Sphera.
Branded data	LCI/LCIA data for a feed ingredient marketed under a certain brand and owned by an entity, such as a company that produces it or a standardization body.
Calculation	Combination of data point, assumptions, calculation rules to derive a value which is input for further LCA calculations.
Chain of Custody (CoC)	A means by which inputs, outputs, and associated attributes are transferred, monitored and controlled as they move forward through each step in the supply chain (adapted from ISO 22095:2020), as indicated by iSEAL (see references chapter).
Company-specific data	Directly measured or collected data from one (site specific data) or multiple facilities that are representative of the activities of the company. It is synonymous with primary data'. To determine the level of representativeness a sampling procedure can be applied.
Cradle to gate	A partial product supply chain, from the extraction of raw materials (cradle) up to the producer's 'gate'. The distribution, storage, use stage and end of life stages of the supply chain are omitted.

Data point	Unique value derived from invoice, a measurement of primary data that is untouched from the source of proof.
Data provider	Individual producers, associations, NGOs, as well as by collaborations (without a legal entity) that provide data for the GFLI database.
Data quality	Characteristics of data that relate to their ability to satisfy stated requirements (ISO 14040:2006). Data quality covers various aspects, such as technological, geographical and time-related representativeness, as well as completeness and precision of the inventory data.
Data-in project	A project in which an LCA is executed and undergoes the GFLI reviewing process for integration in the GFLI database.
Disaggregated data	An LCI of unit processes or life cycle stages for which the inputs and outputs are provided on the most detailed level available (unit process level).
External reviewer	An LCA expert who works independently or at research institutes, consultancies, or certifying organisations, doing a critical review on compliance with the GFLI rules for integration of the data. GFLI provides a list of external reviewers, to be contracted by the data provider, External reviewers shall be independent from the executed LCA.
Feed ingredient	A component part or constituent of any combination or mixture making up a feed, whether or not it has a nutritional value in the animal's diet, including feed additives. Ingredients are of plant, animal or aquatic origin, or other organic or inorganic substances (FAO/WHO, 2008).
Functional unit	A quantifiable function of a product. It is the reference basis for system modelling in environmental assessment.
GFLI database	A collection of all available datasets calculated through the GFLI methodology and externally reviewed. It may refer to any format of the database (LCIA, LCI/system process, unit process).
Internal reviewer	An LCA expert contracted by GFLI that does a review on basic checks for compliance with the GFLI rules for integration of data from data providers.
LCA executor	The LCA expert contracted by the data provider for executing the LCA.
LCA expert	A professional with adequate experience in executing LCAs
LCI dataset	A document or file with life cycle information of a specified product or other reference (e.g., site, process), covering descriptive metadata and quantitative life cycle inventory. An LCI dataset could be a unit process dataset, partially aggregated or an aggregated dataset.
Lifecycle Impact Assessment (LCIA)	Lifecycle impact assessment database, the overview of datasets after the inventory has been assessed through the EF and ReCiPe impact assessment. This is the most commonly used format of the database and details the output of the LCA of emissions per ton (1000 kg) of feed ingredient, as produced.
Life cycle inventory	The combined set of exchanges of elementary, waste and product flows in a LCI dataset. This may contain all unit processes or is aggregated to system process level.
Normalization	After the characterization step, the next step is in which the life cycle impact assessment results are multiplied by normalization factors that represent the

	overall inventory of a reference unit (e.g. a whole country or an average citizen). Normalized life cycle impact assessment results express the relative shares of the impacts of the analyzed system in terms of the total contributions to each impact category per reference unit. When displaying the normalized life cycle impact assessment results of the different impact topics next to each other, it becomes evident which impact categories are affected most and least by the analyzed system. Normalized life cycle impact assessment results reflect only the contribution of the analyzed system to the total impact potential, not the severity/relevance of the respective total impact. Normalized results are dimensionless, but not additive.
Meta data	Meta data are relevant information in regard to the activities or product properties in scope of the datasets, for example nutritional values like N&P content, electricity grid used, farm (management) practices. It should provide a clear qualification of the feed ingredient for database users. Within the LCI, meta data is communicated. In the LCIA, part or all of this information is included in the process description.
Primary data	This term refers to data from specific processes within the supply-chain of the producer applying the study. Such data may take the form of activity data, or foreground elementary flows. Primary data are site-specific, company-specific (if multiple sites for the same product) or supply-chain-specific. Primary data may be obtained through meter readings, purchase records, utility bills, engineering models, direct monitoring, material/product balances, stoichiometry, or other methods for obtaining data from specific processes in the value chain of the data provider. In this Guidance, primary data is synonym of 'company-specific data' or 'supply-chain specific data'.
Regional data	LCI/LCIA data representative for a certain region collected from secondary data
Secondary data	Data from generic processes within the supply chain of the data provider. It is not directly collected, measured, or estimated by the producer, but sourced from a third-party life-cycle-inventory database or other sources. They include supply-chain-average data (e.g., from published production data, government statistics, and professional associations), literature studies, engineering studies and patents, and can also be based on financial data, and contain proxy data, and other generic data.
Sectoral data	LCI/LCIA data of feed ingredients representative for a certain sector. They are developed mainly using primary data collected from a representative sample of producers of that sector.
System boundary	Definition of aspects included or excluded from the study. For example, for a 'cradle-to-grave' EF analysis, the system boundary includes all activities from the extraction of raw materials through the processing, distribution, storage, use, and disposal or recycling stages.
System processes	Aggregated LCI dataset, where the elementary exchanges are visible.

Technology	Technology in LCA generally refers to a specific method of producing or processing that can be distinguished from other technologies and results in different sets of inputs and outputs and therefore different environmental impact.
Tier modelling	A tier represents a level of methodological complexity. Usually, three tiers are provided. Tier 1 is the basic method, Tier 2 intermediate and Tier 3 the most demanding in terms of complexity and data requirements. Tiers 2 and 3 are sometimes referred to as higher tier methods and are generally considered to be more accurate on condition that adequate data are available to develop, evaluate and apply a higher tier method (IPCC, 2019)
Unit process	Smallest element considered in the life cycle inventory analysis for which input and output data are quantified (ISO 14040:2006). In LCA practice, both physically not further separable processes (such as unit operations in production plants, then called 'unit process single operation') and also whole production sites are covered under 'unit process', then called 'unit process, black box' (ILCD Handbook).
Weighting	Weighting is a step that supports the interpretation and communication of the results of the analysis. LCIA results are multiplied by a set of weighting factors, which reflect the perceived relative importance of the impact categories considered. Weighted LCIA results may be directly compared across impact categories and also summed across impact categories to obtain a single overall score.

1. Introduction & the Global Feed LCA Institute

1.1 Context

This guidance document provides a way of generating or updating data according to the Global Feed LCA Institute (GFLI) methodology. It can be used for developing regional, sectoral, or branded datasets or to improve existing datasets and/or methodology.

The GFLI methodology is built on several international standards on product environmental footprinting and follows the latest IPCC methodology for calculation of GHG emissions by countries in their National Inventory Reports. GFLI Methodology and Project Guidelines Version 3.0 is an update of the Methodology and Project Guidelines version 2.0 published July 2024. The document is updated to reflect the updated methodological approaches, applied on the latest major datasets updated.

This is a living document that is intended to be updated regularly.

1.2 Projects

The GFLI database relies on data-in projects facilitated by stakeholders in the sector and/or the GFLI itself (when budget allows) to provide new datasets and/or improve the quality of existing datasets. Data-in projects are coordinated by data providers. A data-in project usually includes an LCA executor (consultant/researcher or in-house expert) to advise the involved parties on which data needs to be acquired, apply the GFLI methodology and deal with methodological issues that might occur. A simplified process of this procedures is visualized in Figure 1.

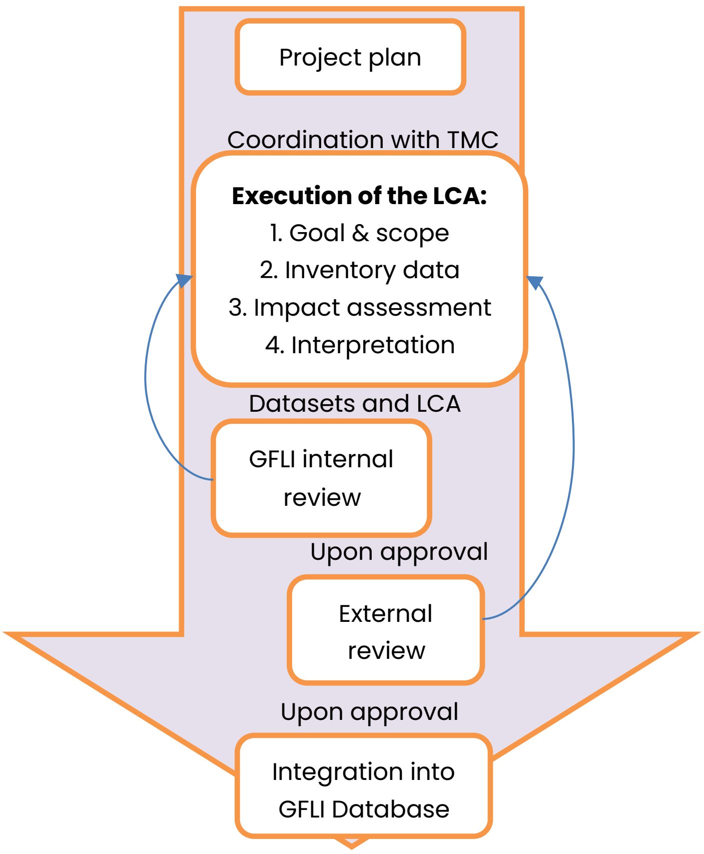

Figure 1 simplified process of a data-in project

Three types of "data-in" projects can be distinguished:

1. Regional: covering feed ingredients within a geographical area
2. Sectoral: covering a specific type of feed ingredients (e.g. wheat and its by-products)
3. Branded: providing data for a specific company's feed ingredient

The focus of a "data-in" project can be:

- First development of LCI datasets not yet available in the GFLI database

- Updating of existing LCI datasets for an improved representativeness (i.e. newer data, different technologies and/or inputs).
- Improvement or updating of modelling to extend the current method of evaluating environmental impacts such as additional impact indicators or new methods of measuring emissions.

Database development projects may involve a first development of LCI datasets or an update of existing LCI datasets.

In chapter 5 Procedures for a data-in project, guidance is given on how to initiate and organize projects. The GFLI database uses the attributional lifecycle assessment approach (ALCA), and therefore does not accept or include offsets and consequential metrics (e.g., comparison of emissions for 'waste' products valorized into feed ingredients versus ending up in landfill) associated with a consequential lifecycle assessment (CLCA).

1.3 Goal of the Global Feed LCA Institute

The Global Feed LCA Institute (GFLI) is an independent animal nutrition and food industry institute with the purpose of developing a Feed Ingredients **Attributional Life Cycle Assessment (ALCA)** database to support meaningful environmental assessment of animal nutrition products and stimulate continuous improvement of the environmental performance in the animal nutrition, animal production and food industry.

- Providing a globally accessible, evolving animal feed ingredient Life Cycle Analysis (LCA) database;
- Supporting compliant, credible, and transparent environmental assessment of animal feed ingredients and their role in the environmental footprint of animal derived products; and
- Fostering continuous improvement of the environmental performance of animal derived products.

The need for high-quality and representative data is growing as LCA and environmental footprinting reporting becomes mandated (EU) or driven by the global market. GFLI ambitions to support the animal feed sector with a methodology and a database. Primary data is key towards representative data, allowing for company-specific environmental footprints, as well as more accurate and representative sector data.

1.4 Governance mechanism

The executive body of the GFLI is the Board of Directors, composed of representatives of the GFLI members and the (non-voting) Technical Management Committee (TMC) Chair. The GFLI Board of Directors oversees all activities of the database development projects and is supported by the TMC. The TMC advises the Board on multiple technical and methodological aspects. The TMC is made up of experts nominated by GFLI Members. The mandate of the TMC is to act as the gatekeeper of the GFLI Methodology and Procedures guidance documents and to guide the expansion and improvement of the database.

To improve objectivity and to strengthen its connection with value chain partners, a Scientific Advisory Council (SAC) was established in 2021. GFLI's Scientific Advisory Council is an external expert panel incorporated to help the GFLI Board of Directors and Technical Management Committee (TMC) address critical questions regarding the quality, safeguarding, and improvement of the database, and to provide feedback about how to improve the methodology and procedures that govern the maintenance and continual improvement of the database. The Council is made up of experts in life cycle assessment methodologies and environmental and animal nutrition fields, each possessing a range of regional and sectoral experience.

1.5 Methodology

This guidance document describes the methodology for deriving LCI data. The methodology is based on the results of several years of development within different frameworks, such as:

1. the FAO/LEAP (Livestock Environmental Assessment and Performance) guidelines, developed in a multi-stakeholder initiative that seeks to improve the environmental sustainability of the livestock sector through harmonized methods, metrics, and data.
2. The PEFCR development of the European Commission and several sector associations (FEFAC, 2024)
3. The IPCC guidelines for national greenhouse gas inventories (IPCC, 2019) with updates remodeling to the newest assessment reports (currently AR6) for the GFLI database inventory.

The methodological requirements and guidance from documents developed in these frameworks are brought together so that the GFLI guidance can be used as a stand-alone reference document, where the user can find all necessary guidance on how to develop and maintain GFLI-compliant datasets. This document and the GFLI database will be modified once updates in the above-mentioned documents are judged relevant.

1.6 Data vision and developments

GFLI works continuously on developing its methodology and database. This also includes forming a framework and system to simplify data projects and populate the database more rapidly. This is being achieved by collaborations and efforts from the GFLI Technical Management Committee. Examples are the methodological discussions for higher tier modelling, the publication of the GFLI cultivation emission model, and the soon to be published Data-in Generator tool for marine ingredients (Sirnes, 2025)

If you are interested to contribute to the future developments within GFLI, or want to stay up-to-date with the latest information, become a member: https://globalfeedlca.org/gfli-members/become-a-member/ and become involved with the Technical Management Committee.

1.7 Set-up of the document

Chapter 1 shares an overall introduction of the Global Feed LCA Institute, its foundation and the form of data projects available.

This Guidance document combines the methodology and guidelines with the procedures for a data in project. Chapter 2 and 3 describes the methodology and guidelines and is relevant for the data-in provider and the LCA-consultant.

Chapter 2 describes the reference documents the GFLI methodology is based on, as well as the requirements for inclusion such as the system boundary, modelling framework, and data sampling.

Which inventory data should be gathered, specified in the different types of feed ingredients in scope, are explained in chapter 3.

The procedures for a Data-in Project is described in chapter 4 and details how to proceed with such a project. Chapter 4 should be read carefully by the data-in provider.

References and annexes are attached in addition to chapter 5 about the default modelling for agriculture and processing, and background data.

1.8 Version and validity

With each major GFLI database, the version of the methodology is updated to reflect the same numbering convention. Therefore, this current document reflects the latest GFLI database version 3.0 (publication January, 2026).

Version no:	3.0
Publication:	January 2026
Valid until:	Next update

2 Reference documents and requirements

2.1 Reference documents

The reference documents are the underlying standards the GFLI follows and/or aligns with. A full overview of the reference documents can be found in the GFLI External Review Guidance document.

2.1.1. ISO standards

GFLI datasets must be compliant with the standards:

- ISO14040:2006 (framework) (ISO, 2006a),
- ISO14044:2006 (methodology) (ISO, 2006b) and
- ISO14071:2024 (external review process) (ISO, 2024)
- ISO14064-3:2019 (verification and validation of greenhouse gas statements) (ISO, 2019)

External reviewers must verify the dataset comply with the requirements of the latter and follow the procedures.

2.1.2. Environmental Footprint standards

The GFLI methodology seeks a high level of alignment with the EU-PEF methodology, following the PEF Guide and underlying latest version of PEFCRs:

- PEF Guide (Fazio S., 2020)
- PEFCR Feed for Food Producing Animals (FEFAC, 2024)
- PEFCR Marine Fish for Human Consumption (Marine Fish PEFCR, 2025)
- PEFCR Dairy (EDA, 2025)

2.2 Feed ingredients and reference units

The GFLI database provides LCI datasets for feed ingredients that can be used in the formulation of compound feed or directly used at the farm (Figure 2). The full lifecycle of production of feed ingredients that can be used in compound feed is in scope (colored boxes). All data in the GFLI database relate to a reference unit of **1000 kg of product (one metric ton).**

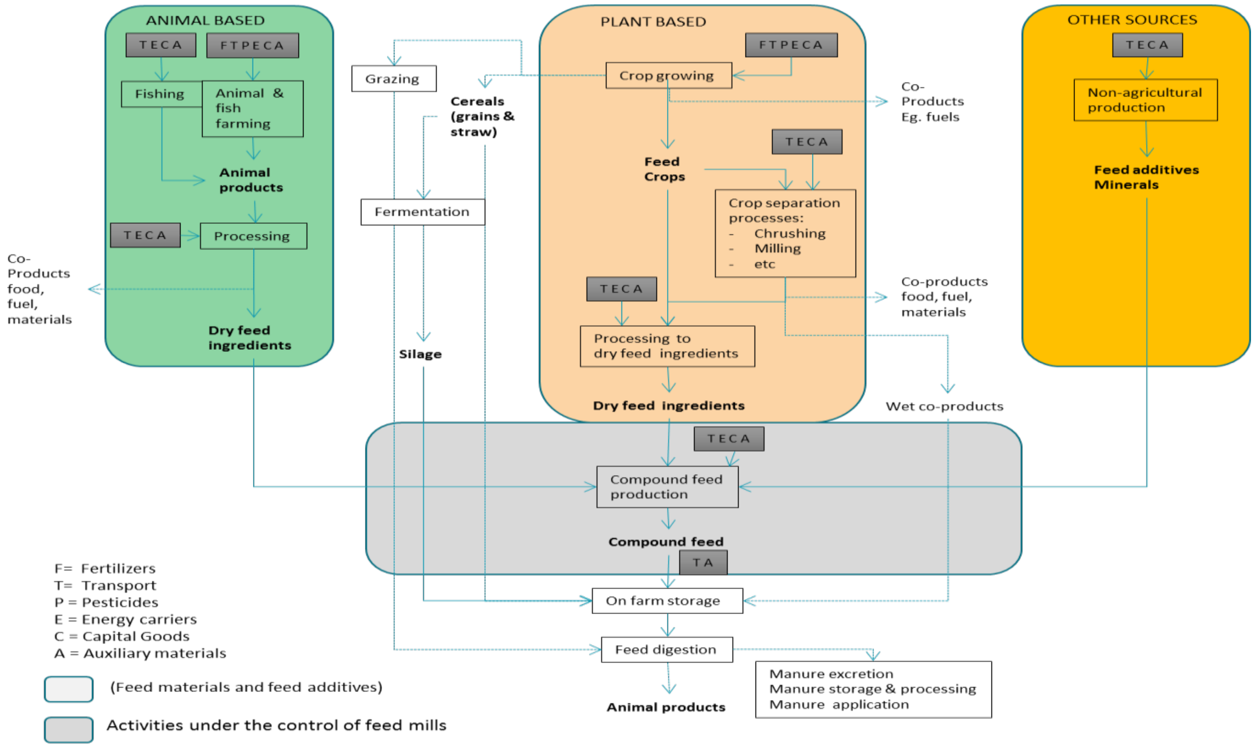

Figure 2. Overview of the production chain of compound feed and other feed flows entering the farm

2.3 System boundaries

The LCA datasets collected and implemented in the GFLI database are data that refer to **primary production (agriculture and fisheries), processing, and transport processes related to producing feed ingredients**. Activities that are not directly related to the physical production operation, such as marketing, business travelling, commuter travelling, living at a farm, etc. are excluded. Additional, a cumulative cut-off threshold of 1% is applied, meaning that processes and elementary flows may be excluded up to 1% (cumulative) based on material and energy flows within a product environmental assessment and the level of environmental significance (single overall score).
The impact of the use of certain feed ingredients on animal performance at farm level (e.g., related to the use of feed additives) is also excluded. However, it is important to capture the positive impact of the use of those feed ingredients (e.g., by improving animal performance, by increasing digestibility of nutrients, or by maintaining animal in good health), when completing LCA for livestock production. See the FAO/LEAP guidelines on feed additives (FAO-LEAP, 2020) for more details to support feed additive LCA calculations.

(Inbound) transport is included to the end-of-production gate. Inbound transport from the feed mill to further processing facilities nor the outbound transport towards farm or other locations are included. The user of the database is responsible to comply with the market regulations and supply chain requests about how data and the figures should be shared.

Per ingredient the system boundary as specified is:

- Products "at farm": the environmental impact of cultivated feed products until farm gate. Environmental impacts include inputs for cultivation (e.g., energy, fertilizer, lime, pesticides, etc.) and emissions on the farm (e.g., fertilizer use, pesticides, etc.).
- Products ''at storage'': the environmental impact of cultivated feed products, dried, until storage gate. Environmental impacts include inputs for cultivation, and possibly drying technologies and emissions.
- Marine products "at vessel": the environmental impact of captured marine products until landing (e.g., energy, gear, refrigerants) and emissions at sea (e.g., guts).
- Products "at processing": the environmental impact of processed feed materials until processing gate. Environmental impact of processed products includes the impact of cultivation of raw materials, sourcing from different countries, energy and auxiliary material use at processing and waste.
- Products ''production mix'': a production mix is used when there is limited availability of where the ingredient is produced or processed, usually indicating it is an average for a region (usually region of Europe or Global). These datasets **exclude** any transportation as they do not include a specified location of origin.

Depreciation of capital goods and machinery and use of consumables are included for farming. They are excluded however, based on the cut-off criterium, (see above) for processing of plants and animal products. The leading principle for data collection is that datasets should be as complete as possible and include all data points that are defined as required. The inclusion and exclusion of data points is further explained in sections 3.10 and 3.12.

The PEF guidance on end-of-life products for recycling and energy recovery, usually concerning packaging, are considered when relevant (>1% of total impact of ingredient production). This usually applies for petfood and small batch ingredients as opposed to bulk animal feed. Defaults may be used.

2.4 Allocation

The allocation procedure in a multiproduct process (i.e. multifunctional process) is one of the most critical issues in LCA. "Allocation", also called "partitioning", solves the multi-functionality problem by splitting up the amounts of the individual inputs and outputs between the co-functions according to some allocation criteria, being a property of the co-functions (e.g., element content, energy content, mass, market price, etc.) (JRC-IES, 2010).

Avoiding allocation by system expansion and inclusion of avoided production shall be applied for energy carriers when the avoided product can be unambiguously determined. For example, when at processing of plant or animal-based products certain co-products are used for excess heat or electricity from combined heat and power production.

Three types of allocation are supported by the GFLI database, in accordance with the Feed PEFCR:

- Economic allocation: economic allocation measures the economic value of the main product produced and the by-products that are less economically valuable, for example soy is used to produce soy oil (main economic activity) with its by-product being soybean hulls and soybean meal.
- Mass allocation: mass allocation is the method to quantify masses entering and leaving a chemical or physical process. The mass-based allocation is done on the basis of the total, dry matter sum of the outputs.
- Energy allocation: energy content-based allocation is based on a caloric value in MJ per kg.

The allocation shall be representative for the region in scope and shall dictate the value ratio between different products with average prices for a 3-year average of the collected data. This is applicable for all feed ingredients in scope, for both co- and by-products from cultivated ingredients, as it is for processing where one raw material may separate towards multiple products. The market price for the main product and (intermediary) co-product(s) can be upheld. All (monetarily) relevant output on-farm should be included in the allocation. Taxes, transport, and insurance costs should not be included in the price. Take notice that the absolute prices are not relevant but the relative price difference between co-products. Caloric values and dry matter yields should be based on recent measurements, accountant reports, or statistics and surveys that are based on accountable validated data. It is important to use complete and consistent data for the range of co-products. Incomplete information of data from separate sources may lead to incorrect results.
Default allocation fractions for some ingredients are available in [cross reference allocation factors]

Within economic allocation, some co- and/or by-product ingredients may fall under such a low economic value, that any emission calculation may be deemed unnecessary. At processing, economic allocation is specified according to the LEAP feed guidelines (FAO-LEAP, 2015) which mandate the following steps:

Determine if your feed ingredient can be considered as a zero-economic allocation product. This is the case when two conditions are met:

a) the product is sold as it is at the point of production (i.e. prior to drying or other modifications) and has a very low (<1%) contribution to the turnover of the entire basket of co-products of the same process sold by the company;
b) the (co-)production and upstream process is not deliberately modified for generating the co-products.

Examples of zero-economic allocation products are wet materials from the food consumer products industry that are sold ‘wet’ to animal farms, such as leftovers from fruit, vegetables and potato processing industry; wet materials from the agricultural commodity industry, such as citrus pulp; and dry materials from the food consumer products industry, such as chocolate, dry bakery and biscuit products, bread from bakers (FAO-LEAP, 2015).

The allocation on mass or energy should be calculated in any case, as the environmental impacts is linked to the process and should be allocated to each of the co-product. For example for co-products such as potato co-products, sugar beet pulp, spent brewer's grain could be considered zero-(economic) allocation if the collected data indicated a low turnover contribution, but a mass or energy allocation would need to be calculated as they are co-products.

2.5 Supported impact categories

LCI impact results are available in Excel format. They are also available in .csv which provides the aggregated inventory results of all datasets for all three allocation methods according to the ReCiPe Midpoint Hierarchy method and the Environmental Footprint (EF) methodology of the European Commission (Fazio S., 2020) impact assessments.

- The EF method includes the following impact categories: Acidification, climate change (distinguishing climate change fossil, climate change biogenic and climate change land use and land use change (LUC)), ecotoxicity freshwater (inorganics and organics), particulate matter, eutrophication marine water, eutrophication freshwater, eutrophication terrestrial, human toxicity cancer (inorganics and organics), human toxicity non-cancer (inorganics and organics), ionising radiation, land use, ozone depletion, photochemical ozone formation, resource use fossils, resource use minerals and metals, and water use.
- ReCiPe includes the following impact categories: global warming (incl. and excl. LUC), stratospheric ozone depletion, ionizing radiation, ozone formation (human health), fine particulate matter formation, ozone formation (terrestrial ecosystems), terrestrial acidification, freshwater eutrophication, marine eutrophication, terrestrial ecotoxicity, freshwater ecotoxicity, marine ecotoxicity, human carcinogenic toxicity, human non-carcinogenic toxicity, land use, mineral resource scarcity, fossil resource scarcity and water consumption.

2.6 Modelling framework (tier approach)

Many emissions, especially at primary production are not measured but calculated flows where farm input activity data are connected to emission models. For example, the NH_3 emission at cultivation is calculated from the inputs of synthetic and organic N-fertilizers considering the type of fertilizer and the technique of application.

There are two levels of modelling possible in the GFLI database:

- Default emission modelling for agricultural products according to the rules of the PEF guidance document (JRC-IES, 2010)A publicly available version of the GFLI emission model is available.

- Regional specific modelling when data providers want to model their inventory data using a more detailed (higher TIER level) modelling approach.

2.6.1 Default GFLI modelling

The default GFLI modelling is described in Annex 4.3 Default emission modelling for GFLI. Created emission models following this methodology and using the licensed default background data (see Annex 5 Default background data) can be used for the modelling of GFLI datasets. The available models have been validated, based on comparisons with existing datasets:

- GFLI cultivation emission model: https://globalfeedlca.org/gfli-emission-models/
- Mérieux NutriSciences | Blonk (through consultancy work)

2.6.2 Higher tier and alternative modelling

Higher tier approaches of the IPCC and National Inventory Reports (NIR) for regionalized approaches are acceptable. Substantiating evidence for the higher tier approach should be reflected in the data collection report, with a comparison between the default modelling results versus the higher tier modelling approach. If a comparison between the default approach of GFLI and the higher tier approach leads few variability of the data output, the higher tier modelled data will be published. If the comparison leads to a significant variability of the data output (over 25% difference), the GFLI will, if the methodological soundness of the alternative model is approved, accept two datasets of the same ingredient and region combination using both the default approach and the higher tier. In principle, GFLI considers multiple identical ingredients in the database undesirable as it may confuse users, therefore the flagging of the higher tier datasets is relevant.

Alternative modelling approaches beyond the IPCC tiered system and NIR should be substantiated with scientific articles or reports (and if in any other language than English, a copy with translations in English). The approach will be evaluated before implementation by the Technical Management Committee (TMC) and the Scientific Advisory Council (SAC) to ensure the quality. If the higher tier modelling approach can be considered as an improved default emission model, the model will be applied in the development of regional datasets.

A data-in provider may wish to use alternative methodological approaches that better represent their region and/or sector, for example more detailed emission modelling. The proposed methodological approach will the revised by the TMC and may be used for continuously improving its methodology and database.

Examples of the types of methodological development:

1. *Detailing existing methodology* for modelling emissions and resource use: this could be, for instance, more accurate emissions modelling for LUC or emissions of nutrients and pesticides.

2. *Alternative methodology* for modelling emissions and resource use: this is a methodology that does not fit into the baseline approach but that does generate meaningful emissions or resource use estimates.

3. *New methodology* for modelling emissions and resource use: this is a methodology on environmental interventions or environmental impacts that is not included in the GFLI methodology (and underlying framework). It involves, for instance, a new methodology for measuring carbon sequestration, soil depletion (loss) or biodiversity loss.

4. *Improved background data* as baseline data such as newer or higher quality, or representing regional areas more.

5. *(re)Alignment with acknowledged methodologies* such as recommendations from FAO/LEAP guidelines or EU-PEFCR Feed, or other new regulating systems such as SBTi, stating alternative measurements or methods of calculations.

The GFLI considers methodology development when there is evidence the suggested development may be a better baseline consideration for the GFLI methodology. The GFLI can uptake suggestions for an internal process, or interested party(ies) may show its interest in methodology development. With complex matters such as alignment with acknowledged methodologies or streamlining a new method for all data, a working group can be considered. Interest in such participation can be shared with the GFLI Secretariat or a request for participation can be sent to all GFLI members and associates (Scientific Advisory Council and relevant contacts in the GFLI network). Reference documents may also be discussed upon methodological changes of which the GFLI standards are based on (2.1 Reference documents).

Substantial evidence of an improvement must be delivered to consider methodology development. This may be verified by (published) scientific articles and/or scientific-based reports. The alternative should be compared to the current methodology and this should be documented to indicate the differences in steps and in outcome. When the development considers more detailed emission modelling, applicability on a broader geographical or sectoral scope should be taken into account. For example, additional emission modelling requires more data on a variety of factors, which may not be obtainable for other countries besides the region it was based on.

Any developmental options will go through the GFLI Technical Management Committee (TMC) for consideration. The TMC may decide upon discussing the matter with GFLI's external panel of experts on the Scientific Advisory Council (SAC). The final decision is made by the TMC and adopted formally with the GFLI Board of Directors.

The pillars for methodology development are:

a) Verified sources and/or acknowledged methodologies
b) Usability by the feed industry
c) Feasibility on global scale, or otherwise large geographical region

d) Alignment with governmental and sectoral regulations where possible

2.7 Distinction in data quality

The GFLI methodology distinguishes three types of data, with the distinction of primary and secondary data coming from the terminology in the FAO-LEAP guidelines (FAO-LEAP, 2016):

- **Primary data:** refers to data sourced directly from the farming/fisheries or manufacturing process (on-farm or on-facility data), which are directly and completely under the control of the applying company.
- **Secondary data:** refers to default data coming from global or regional sources on which the GFLI database relies for its regional datasets, e.g., FAOstat, Eurostat; or may be data collected through default models (e.g. LUC, fertilizer inputs).
- **Adapted secondary data:** refers to not-primary sourced data but would be considered of higher representative value than the default secondary data (requirement to meet a DQR of equal or lower than (≤) 2.0). At minimum, the applying company must know where the material is produced and with which technology in order to select the most representative dataset. This could be presented in ways of regionalized (& publicized) databases, improving default data by updated and/or more representative data input, a market mix of processed ingredients better representing the trade data of the company, or secondary datasets supplemented by primary data.

Updating existing datasets for ingredients require higher data quality than the original data, either through adapted secondary data or primary data. The basic principle is to use as much primary data as possible and needed for deriving accurate results. Therefore, the minimal requirements for primary data depend also on the contribution of the data points to the single score (overall impact) and their accessibility.

The emphasis of primary data collection should be placed on the most contributing activity data, with the possibility to fill data gaps with (adapted) secondary data. The default approach for the database is aligned with the Agri-Footprint database, basing the activity data on FAOstat data for the yield (for version 3.0 for the GFLI database, a 5-year average between 2018 and 2022 is used) (Blonk et al., 2025).

Regional projects should collect at least adapted secondary data for the most contributing activity data points at cultivation:

- Yields of main and co-products,
- Prices of main and co-products,
- Fertilizer,
- Organic fertilizer,
- Energy,
- Irrigation water use.

2.7.1 Examples adapted secondary data

Concrete examples of what is considered adapted secondary data:

- The available information from the supplier should allow for a selection of country-specific secondary data relevant to the actual origin of imported ingredients, instead of a regional market mix. Additional data gathering is necessary to create a representative figure.
- The energy source of the supplier is known. The secondary datasets may be adapted to reflect this.
- A limited amount of primary data can be collected from the tier 1 supplier, but not enough to adhere to the threshold of primary data required (see chapter 2.7.1 in combination with regionalized or secondary data the primary data may be used to create a more representative adapted secondary dataset.

2.8 Chain of Custody principles

The chain of custody identifies models in which each stakeholder is considered and participating within the production of an ingredient, as described in ISO 22095:2020.

The different models can be categorized in multiple models with various properties, including but not limited to:

- Identity preservation
- Segregation
- Controlled blending
- Controlled mass balance
- Mass balance, divided into batch level, site level, and group level
- Book and claim

(Isealalliance.org, 2025)

Each model qualifies for a level of (physical) traceability of the feed ingredient. Feed ingredients can be part of any chain of custody model, though commodity feed ingredients are commonly still purchased and shipped on a mass balance principle.

Data-in projects require a representative figure for the environmental footprints in which this principle can be helpful. GFLI does not require certification or proof of such a model being used, but will inquire about it for communication of the environmental footprints. This also means that claims for (physical) traceability cannot be made based solely on a GFLI (branded) dataset. If such certification is met, it can be added to the GFLI data-in project so it may be clarified in the process description.

2.9 Data sampling at primary data collection

Data sampling may be applied for the collection of primary data in case multiple production sites are involved in the production of the same product (e.g., in case the same feed ingredient comes from multiple production sites or in case the same process is outsourced to more than one subcontractor/supplier). Stratified data sampling is often needed to deal with variation in (performance) of technologies.

The procedure to select a representative sample as a stratified sample is as follows:
1) define the population of operation
2) define if there is variability in (performance) of technologies homogenous sub-populations (stratification)
3) define the sub-samples at sub-population level
4) define the sample for the population starting from the definition of sub-samples at sub-population level.

The baseline approach for defining the sample size is to use **the square root of the number of operations in the sub-population**, e.g., farm operation (field and harvest management), farm size (hectares), yield, processing operation (drying, processing management), and geography are considered. The sample size for each type of operation, soil and land use properties, and each type of geography should be determined. For animal-based products, the technology should be determined e.g., free range hens or beef finished in a feedlot. For processed products (e.g., chemicals, minerals, and other manufactured products) sub-population sampling requirements should be designed according to the technologies and factors influencing the plant's production and/or emissions (i.e. older machinery that may run less efficient. This indicates variability per feed ingredient type Rounding up to a full number might be applicable, as approached in the PEFCR feed (<0.5 would be rounding down, ≥0.5 would be rounding up).

2.9.1 Example of square root sampling

A simple example of determining sampling size: There are 100 farms providing soybeans as an input. 25 farms are in the US, 25 farms are in Brazil, 25 farms are in France and 25 farms are in Argentina. In this simplified case, the geography is consistent by country of origin. Of the farms in Brazil, 9 of them are organic and 16 are conventional. Of the farms in Argentina, 5 farms have 80 hectares of land. 5 farms have 5 hectares. The other 15 have 40 hectares of land.

Sampling size calculation:

- *Square root of each country farms gives required 5 farms for each country or 20 farms total.*
- *Additionally, for Brazil, 3 of the organic farms (sq root of 9) and 4 conventional (sq root 16) are required for a total of 7 farms in Brazil instead of 5.*
- *The same method applies when a large variability in farm sizes is present. For Argentina, 2 farms of 80 hectares, 2 farms of 5 hectares, and 4 farms of 40 hectares should be included. Total farms to provide primary data of 22 based on above divisions by country and farm operation type.*

Cultivated products need crop (management) data averaging over 3 years, aligned with the regional data-in projects, to consider the fluctuations of yield, irrigation, and other processes. This may not be necessary for processing due to a stable situation but will need the newest data available to provide an accurate current situation.

2.9.2 Sample sizing by weighted average

When using a sample size with farms/facilities from different regions or with different technologies and management, making a weighted average may apply. Assuming post-production does not differentiate their product by facility for production, the weighted average of total population should be considered as opposed to the weighted average of the sample. This decreases the biases with random selections, creates a more accurate share of all emissions from the different facilities under the company, and aligns with the overall methodology.

$$\sum n(countries) \frac{production\ quantity\ country}{Total\ production} \cdot impact\ country$$

Example:

The case: Company X produces product A at 9 sites in 4 different European countries. The sites per country are taken as sub-population and per sub-population the sample is based on the square root.

Table 1 Example of making a weighted average in figures

Country	# sites	Production (kton)	Share total production	Impact in CO_2-eq per kton	Impact * share of production
DE	2 sites	250 kton	50%	100 CO_2-eq	50 CO_2-eq
NL	4 sites	100 kton	20%	200 CO_2-eq	40 CO_2-eq
BE	1 site	90 kton	18%	250 CO_2-eq	45 CO_2-eq
UK	2 sites	60 kton	12%	150 CO_2-eq	18 CO_2-eq
Total	**9 sites**	**500 kton**	**100%**	**700 CO_2-eq**	**153 CO_2-eq**

Calculating the relative impact per country against the share of total production, the weighted average of impact is 153 kg CO_2-eq (Table 1). With the above formula, the numbers per country are indicated in the last column. In this example a country equals a sub-population and the impact per country is based on the impact calculated per sub-population.

2.9.3 Sampling primary data from (tier 1) suppliers: additional guidance

In order to have the most representative LCA results, ideally primary data of each life cycle stage should be collected. GFLI recognizes that obtaining a complete primary data inventory may not be feasible for certain feed ingredients or suppliers, therefore the possibility to combine an amount of primary data to show a representative figure is feasible under the following conditions:

- Sampling primary data from the (tier 1) suppliers is possible if the representative sample size from suppliers covers at least 70% of the material's volume, in which case the primary data would not need to be supplemented with adapted secondary data. If this sampling percentage cannot be obtained, the remaining material's volume (i.e. at least over 30%) must be covered with adapted secondary data. This percentage must also be indicated in the data collection report.

Example

The 70% threshold refers to the use of raw materials, so for instance for processing sugar beet pulp, the raw material is sugar beets. If in this example for 72% (< 70%) of the sugar beet supply, primary data could have been obtained, then solely these primary data may be used as data concerning sugar beet cultivation (the 72% is extrapolated to the 100% supply) . In the case for only 65% of the sugar beet supply, primary data could have been obtained, then the remaining 35% should be based on improves secondary data.

- In case of limited secondary data availability, such as if only a global secondary dataset available for the material which insufficiently represents the material, the company must improve the data through supply-chain-specific information in order to achieve a data quality rating of ≤2. In case this poses an impossible task, the applying company may share their case to discuss within the Technical Management Committee on how to proceed.

If the primary data collected misses datapoints in which the inventory would remain incomplete, these datapoints may be completed through (adapted) secondary data as long as they do not hold a significant impact on the product's emissions and would not be subject to scrutiny due to sensitivities (e.g. relying on secondary data for deforestation-free ingredients). The GFLI methodology for branded data upholds the Data Quality Rating (DQR) to achieve high-quality branded data, thus tier 1 supplier data should always achieve this quality and representativeness requirement.

2.10 Data quality rating (DQR)

Data quality measurement is conducted based on the data quality matrix, developed in the EC feed database project. The overview of the full Data Quality Rating (DQR) matrix is portrayed in Annex 1. This information is gathered during the data collection process, and includes 4 Data Quality Indices (DQI) which are:

- Precision
- Time representativeness
- Technological representativeness
- Geographical representativeness

To evaluate the DQR, a division is made in type of data and how they are interrelated. A Data quality evaluation shall consider the contribution of the data points to the overall environmental impact. The DQR evaluation includes activity data and the background data they relate with, being production of goods such as transport, electricity, and combustion of fuels or other chemical conversion during processing. This gives the following set of evaluation points (Table 2).

Table 2. DQR criteria used in connection to activity data and background data for production and combustion/conversion.

Data type	DQR criterion
Activity data	Precision: P
	Time Representativeness: TiR
	Technology Representativeness: TeR
	Geographical Representativeness: GeR
Background data	Time Representativeness: TiR
	Technology Representativeness: TeR

2.10.1 Weight factors

The weighting of each activity datapoint for the DQR is dependent on the calculation of the TeR, TiR, GR and P criteria with the weighted average of each criterion of the most relevant processes and direct elementary flows. The DQR is determined by the data points multiplied by the default weight factors in Table 3. Alternative weight factors may be considered for the specified (cultivation, processing) categories based on the high-impact assessment of the collected primary data. Other ingredients with deviating relevant processes, e.g. feed specialty ingredients, novel ingredients with alternative processes, or animal farming and fisheries, shall calculate weight factors based on their own high-impact assessment.

Table 3 Default weight factors for processing and cultivation, according to the PEFCR Feed (FEFAC, 2024)

Processing	
Activity data	**Weight Factor**
Mass balance	2.5%
Allocation data	10.0%
Input mix	5.0%
Transport modalities mix	2.5%
Production of crops	61.9%
Transport	3.6%
Fuel use	3.7%
Electricity use	7.9%
Water use	0.1%
Other raw materials use	1.0%
Waste water	1.7%
Total	**100%**

Cultivation	
Activity data	**Weight Factor**
Yield (average)	13%
Allocation (economic properties only)	3%
Fuel use	11%
Electricity	7%
NPK	44%
Organic fertilizer	9%
Lime use	3%
Seed use	1%
Pesticide use	4%
Water use for irrigation	2%
Capital goods	5%
Total	**100%**

2.10.2 Updating of datasets through DQR

When the DQR of a product becomes too high, therefore being insufficiently representative in the market, the product/dataset should be updated. GFLI follows the EC PEFCR guidelines, where accordingly a total DQR ***≤3.0*** for relevant processes in secondary data is desirable, with other processes needing a total DQR of ***≤4.0*** (Fazio S., 2020). The DQR in the GFLI database will be updated every two years based on the TiR, with the current trajectory a dataset will lose relevancy in DQR measurements after four to six years.

The procedures for the GFLI database currently do not dictate an expiration data for the product environmental footprint, but aims to maintain a representative DQR through updating of datasets.

3 Sectoral data projects: deriving inventory data per type of ingredient

The GFLI feed database contains different types of ingredients. They can be categorized as follows:

- Cultivated ingredient
- Roughages, forages, & silage
- Processed (wild) fish-based ingredient
- Processed farmed animal-based ingredient
- Processed plant-based ingredient
- Former foodstuffs and (wet) low-impact by-products
- Feed additives (e.g. amino acids), minerals, & vitamins
- Novel feed (algae-based, insect-based, single cell-based, etc.)

These types also correspond with the type of feed ingredient stated in the LCIA format of the database. The following sub-chapters detail the modelling of these different types of ingredients, some of which are detailed together.

3.1 Modelling of cultivated products

The LCI elementary flows of cultivation are not measured but calculated by combining activity data and models (Figure 1). The GFLI has its own emission model freely available, see Default GFLI modelling.

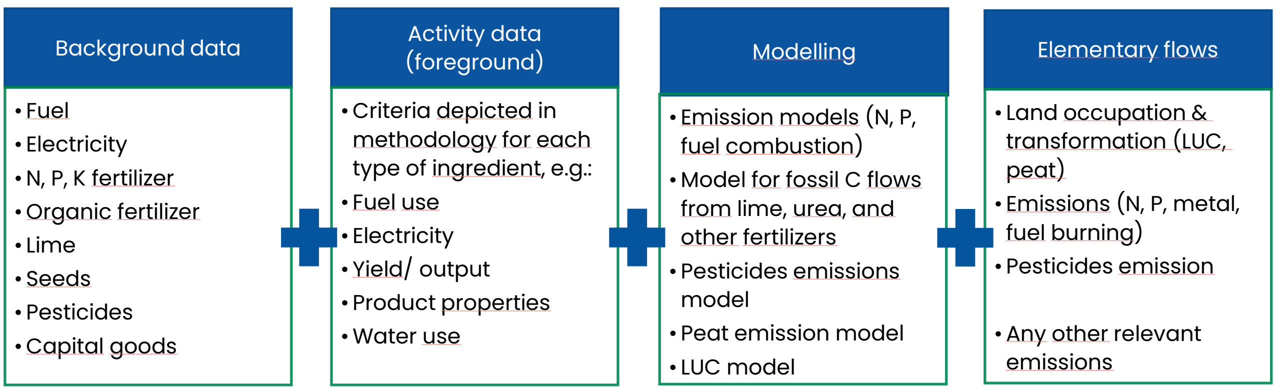

Figure 3. Schematic overview of how elementary flow are modelled at cultivated products.

Depending on the type of emission model (TIER level) and way of allocation, additional information need to be collected on:

- Plant products, co-product and plant residue properties (energy content, or price when applying energy or economic allocation or N- content of plant residues for N emission modelling);
- Crop rotation relationships (assigning activities that are not targeted to one crop but to maintain fields such as manure management, drainage);

- Management practices (soil management in relation to N_2O and CO_2 emissions such as tillage/no tillage);
- Environmental conditions (e.g., ground water level, soil type, water balance).

In the following sections the GFLI method for collecting and modelling cultivation data will be further explained.

3.1.1 System boundary: included activity data

Table 4 shows the activity data that needs to be included at cultivation.

Table 4. Included and excluded activities and elementary flow in cultivation, processing of crops and other production (for italic included default background data may be used).

Included	Excluded
• Fuel use • Electricity use (incl. energy generation on farm related to the cultivation of the product) • N, P, K Fertilizer use • Organic fertilizer (manure and others) use • Lime use • Use of organic fertilizers or soil improvers • Use of Pesticides on the field and at storage • Use of irrigation water • *Seed use* • *Depreciation of capital goods for machinery and storage* • *Packaging of fertilizers and pesticides.*	• Other consumables used during cultivation, except when they have an anticipated material contribution to the activity data. • Activities related to living at or on the farm • Activities related to other business (e.g. producing wind energy)

Other consumables may be excluded at cultivation. These involve mostly negligible quantities in terms of environmental contributions. Activities related to living at the farm (for instance fuel and electricity use) are considered as out of scope but are sometimes hard to distinguish from cultivation related activities.

Activities related to energy production at the farm that are not related to the mass flows being generated due to cultivation or animal farming (e.g. wind or solar power) are only accounted for, when used at that farm again.

Some activity data are more important than others. The italicized data points in Table 4 may be collected. However, if these data cannot be collected in practice, default background data may be used from the GFLI default background datasets, which can be found in the subsequent subchapters or the Annexes.. The approach for manure is confined to the (live) animal farming, resulting in no environmental burden or benefit attributed to manure production, but it will be accounting for its application on-field.

3.1.2 Average situation (steady state)

Cultivation data are collected over a period sufficient to provide an average assessment of the life cycle inventory associated with the inputs and outputs of cultivation that will offset fluctuations due to seasonal differences. Table 5 gives an overview how the EC tender requirements are applied in the data collection process of the main data sources.

Table 5. Implementation of the (steady state) average requirement in the source databases used for the GFLI database.

Requirement
1. For **annual crops**, an assessment period of at least three years shall be used (to level out differences in crop yields related to fluctuations in growing conditions over the years such as climate, pests, and diseases). Where data covering a 3-year period is not available i.e. due to starting up a new production system (e.g. new greenhouse, newly cleared land, shift to other crop), the assessment may be conducted over a shorter period, but shall be not less than 1 year. Crops/plants grown in greenhouses shall be considered as annual crops/plants unless the cultivation cycle is significantly shorter than a year and another crop is cultivated consecutively within that year.
2. For **perennial plants** (including entire plants and edible portions of perennial plants) a steady state situation (i.e. where all development stages are proportionally represented in the studied time period) shall be assumed and a 3-year period shall be used to estimate the inputs and outputs. Where the different stages in the cultivation cycle are known to be disproportional, a correction shall be made by adjusting the crop areas allocated to different development stages in proportion to the crop areas expected in a theoretical steady state. The application of such correction shall be justified and recorded.
3. For crops that are grown and harvested in **less than one year** (e.g. lettuce produced in 2 to 4 months) data shall be gathered in relation to the specific time period for production of a single crop, from at least three recent consecutive cycles.

3.1.3 Assigning inputs and outputs to crops and allocation of crop coproducts

Assigning in-and outputs for crops is relevant when in arable farming crop rotation is maintained, or multiple processes are present on the same farm. To assign the different activities and inputs to specific crops and co-products the LEAP feed guidelines (FAO-LEAP, 2015) are followed, also documented in chapter Allocation. This is also relevant for the allocation of emissions towards the multiple co-products produced by harvested plants (such as seeds and straw). Default allocation factors are included in

3.2 Collection of activity data

3.2.1 Yield of the main product

Yield is defined as the net weight of a product harvested per surface area of farm fields. Crop yield data should comply to the requirements on steady state, time frame and allocation.

Primary data: are data based on recent farm records (available in e.g. farm data management systems or accountancy systems) or recent surveys that and are based on reliable validated data and represent the cultivation in scope, averaged over 3 years.

Secondary GFLI default data: for crop yields are collected from FAOstat yield statistics can be used (FAOstat, 2025). A 3- or 5-year yield average shall be used. In case a specific crop is not reported in FAOstat, a crop similar to the crop in scope might be used as a proxy. This should be documented in the meta data and accounted for in the data quality rating.

Adapted secondary data: are based on well-established data sources representative for the region in scope by statistical institutions, governmental or research bodies and of better quality than FAO stat data to be explained in the meta data.

3.2.2 Yield of the co-product

To quantify the yield of co-products is usually more challenging because yields of co-products are not always available in records or statistics.

Primary data: are based on recent farm records (available in e.g. farm data management systems or accountancy systems) or surveys that collect farm data and are based on reliable validated data and represent the cultivation in scope.

Secondary GFLI default data are based on the fraction of "Above ground dry matter" (AGDM) or crop residues that can be harvested. The default harvesting factors for crop (groups) are based on "sustainable removal rates" or "practically removable fractions". These defaults are included:

- 33.5% for all cereals, except maize (15%), based on a "sustainable removal fraction" of two-thirds for cereals and 30% for maize (Searle, 2017)
- 10% for all pulses and soybeans, based on the "practically removable fraction" of pulses (McDonald, 2010)
- 30% for linseed and rapeseed, based on "typically recoverable fractions" (Copeland, 2008)

Adapted secondary data: can be based on measurements, statistics, reports, or any other reliable information from which the yield of co-products can be derived. Contrary to main products, there is usually little information on the yield of co-products in statistics and reports. The following can be considered as adapted secondary data collection approach: derive yield of co-products from information on fractions of harvested above ground biomass or use straw-to-grain ratios. The data quality should be improved compared to the GFLI default data and must be clarified in the meta data.

3.2.3 Product properties

Product properties concern chemical or physical aspects of feed ingredients which are relevant for calculating the overall feed nutritional data, and for allocation purposes and/or heavy metal calculations . Table 6 shows the data that need to be collected for crops and co-products. There are three categories of data points distinguished:

- Shall, without this property data the dataset cannot be implemented in the GFLI database.
- Should, data should preferably be provided, if not available the defaults are used from a relevant feed ingredients nutritional table or the Feedipedia from FAO.
- May, data should preferably be provided, if not available GFLI defaults are used.

Table 6. Data to be collected for crop (co)- products.

	Unit	Primary data	Adapted secondary data
Price	Money unit/weight unit	Shall	Should
Dry matter content	%	Shall	Should
Caloric value	MJ HHV/kg	Shall	Should
N-content	weight % on as is basis	Shall	Shall
P-content	weight % on as is basis	Shall	Shall
C-content	weight % on as is basis	May	May
Cd-content	weight % on as is basis	May	May
Cr-content	weight % on as is basis	May	May
Cu-content	weight % on as is basis	May	May
Hg-content	weight % on as is basis	May	May
Ni-content	weight % on as is basis	May	May
Pb-content	weight % on as is basis	May	May
Zn-content	weight % on as is basis	May	May

Differentiation of feed ingredients through nutritional values (e.g., crude protein, crude fiber) is currently not present in the database. Exceptions may occur where this data is relevant to mention, for example a high crude protein soybean (48%) or a low crude protein soybean (44%), barley/wheat with high or low specific weight, or if it is a raw ingredient that has been treated or protected to increase its nutritional profile. These may be added to the name of the product for data users.

3.2.4 N in crop residues

The quantification of nitrogen in crop residues is needed for the calculation of nitrous oxide and nitrate emissions.

Primary data and adapted secondary data: Actual measurements of N in crop residues is a constraint approach and usually lacking, in this case adapted secondary data may be used. The amount of nitrogen from crop residues can be calculated using national or regional farm guidelines or publications. Also, the methodology developed for drafting the National Inventory Reports for IPCC climate impact monitoring is reliable source. In any case, the data quality should be improved compared to the GFLI default data and must be clarified in the meta data.

Secondary GFLI default data: nitrogen from crop residues is calculated using IPCC estimations of N added to soils from crop residues per crop(type) (IPCC, 2019). From this the amount of "Above ground dry matter" (AGDM) and "Below ground dry matter" (BGDM) are calculated. AGDM and BGDM together form the total amount of crop residues, from which the amount of nitrogen from crop residues can be quantified.

3.2.5 Energy use

Energy use involves all on-farm energy use related to the production and storage of the crop. This energy use is broken down into two different activities: energy use related to field operations and energy use related to the storage and possible drying of the crop. Drying and storage can take place at farm or at another location. For both activities, data can be gathered in multiple ways. Energy use at farming also includes the usage of fossil fuels as lubricant oils for tractors and machinery.

Energy use during field operations

Primary data: data come from recent farm records (available in e.g. farm data management systems or accountancy systems) or surveys that collect farm data and are based on reliable validated data and represent the cultivation in scope. Another potential source could be using measured data for activities from for instance the machinery and equipment monitoring (can be a service of equipment suppliers).

Secondary GFLI default data: are based on an energy model for cultivation that has been developed in a cooperative project between Blonk Consultants and Wageningen University. The model calculates the (direct and indirect) energy use related to the cultivation of a specific crop in a specific country. The included activities are tillage, seedbed preparation, sowing, irrigation, manure application, fertilizer application, pesticide & weed application, harvesting and post harvesting operations. The model uses specific parameters for different crops and countries, which results in a specific energy input for each crop country combination (See Annex 4).

Adapted secondary data: are based on well-established data sources representative for the region in scope by statistical institutions, governmental or research bodies (representation to be explained in the meta data) estimating energy use based on frequency of activities related to energy use.

Energy use during storage

Primary data: data regarding storage needs to be collected specifically and separately for the feed ingredient. Similarly, as for cultivation, energy use related to storage can be collected from bookkeeping information or be measured.

Secondary GFLI default data: Energy use for storage is calculated using Eurostat data on humidity, safe storage conditions described in FAO and energy of 0.15 kWh electricity and 4.5 MJ natural gas per kg of water evaporated.

Table 7Percentage of humidity of dried crops for storage (Blonk, 2025)

Ingredients	Humidity storage
Wheat and spelt	12%
Rye	12%
Barley	12%
Oats	12%
Triticale	12%
Sorghum	12%
Rice	12%
Other cereals and cereal products	12%
(Field) peas	10%
Broad and field beans	10%
Sweet lupins	10%
Other dry pulses and protein crops	10%
Rape and turnip rape seeds	8%
Sunflower seed	8%
Soya	8%
Linseed (oilflax)	8%
Other oilseed crops n.e.c.	8%

Adapted secondary data: are based on well-established data sources representative for the region in scope by statistical institutions, governmental or research bodies (representation to be explained in the meta data). A potential allowed method is to calculate the energy inputs of water evaporation, where the dry matter content of the feed ingredient at harvest and at storage should be determined. In case the dry matter content of the feed ingredient after storage exceeds that of the harvested feed ingredient, the feed ingredient is assumed to be dried. The amount of water that was evaporated is calculated from the dry matter content at harvest and storage. Using a default energy input per kg of water evaporated, the total amount of energy use for storage can be determined. The energy default for the semi-specific approach is 1 kWh electricity and 7 MJ fuel oil per kg water evaporated (Kool, 2012)

The following tables (Table 8 and Table 9) give an overview of the different energy sources used during field operations and storage for which data need to be collected.

Table 8 Energy use for cultivation at the farm. For lubricant oils defaults may be used.

Energy use	Unit
Electricity	kwh/hectare*yr crop under study and if a specific mix is bought (green electricity), the mix can be reported.
Diesel	Liters or kg/hectare*yr crop under study and caloric value (HHV/Liters or kg)
Fuel oil	Liters or kg/hectare*yr crop under study and caloric value (HHV/Liters or kg)
Lubricant oil	Liters or kg/hectare*yr crop under study and caloric value (HHV/Liters or kg)

Other oils	Liters or kg of specified oil/hectare*yr crop under study and caloric value (HHV/Liters or kg)
Natural gas	m^3/hectare*yr and caloric value (HHV/m^3)
Other gas types (eg propene)	m^3 of specified gas/hectare*yr crop under study and caloric value (HHV/m^3)
Biofuels solids	Specify per case type of biofuel, unit, and caloric values
Biofuels fluid	Specify per case type of biofuel, unit, and caloric values
Biofuel/fossil fuel mixes	Specify per case unit and caloric values

Table 9 Energy use for storage.

Energy use	Unit
Electricity use	kwh / ton product*
Fuel	(Liters or kg)** / ton stored product*
Other oils	(Liters or kg)** / ton stored product*
Natural gas	m^3** / ton stored product*
Other gas types (eg. propene)	m^3** / ton stored product*
Biofuels solids***	(Liters or kg)** / ton stored product*
Biofuels fluid***	(Liters or kg)** / ton stored product*

** after storage dry matter content as used or sold and including losses*

*** define caloric value per weight or volume unit*

**** specify type of biofuel*

Activities related to living at the farm (for instance fuel and electricity use) are considered as out of scope.

3.2.6 Fertilizer use (N, P, K)

Application of synthetic fertilizers to crops is crop specific and taking the application of organic fertilizers into account. The amounts of N, P, K uses needs to be translated to specific fertilizer types (Table 10) this can be done in multiple ways:

Primary data: fertilizer use include the quantities of N, P, K and the chemical compound as used and are based on recent farm records (available in e.g. farm data management systems or accountancy systems) or recent surveys that and are based on reliable validated data and represent the cultivation in scope. Ideally, the specific types of synthetic fertilizer are similar as those shown in Table 10. In case other types of fertilizer are used, the content of N, P (in P_2O_5-eq) and K (in K_2O-eq) needs to be specified. These inventoried fertilizers shall then be mapped to the fertilizers by the GFLI database manager to ensure a sound linkage to background data. If required, corrections will be performed to match the nutrient quantity in the inventories to the quantity in the background data.

Secondary GFLI default data: The majority of these fertilizer application rates, in terms of NPK per crop country combination were derived from the Blonk "NPK model" (Blonk, 2025). The model is based on national statistics available on NPK land application per country

(IFA, 2021), production and harvested area of country-crop combinations (FAOstat, 2025) and estimates of fertilizer use by crop category per country.

Adapted secondary data: can be collected in several ways, by using representative national or (sub)regional surveys or by combining crop agronomic reference documents in combination with regional statistics on the type of fertilizers sold within that specific region or country. For this approach it is mandatory to provide crop-specific NPK information. The specific fractions of fertilizer for N, P and K, in combination with the NPK totals, could then be used to quantify the amounts of specific type of fertilizers. The inventoried NPK data needs to be matched to the fertilizers shown in the Table 11. For any method of data collection, the improved data quality compared to the GFLI default data needs to be substantiated in the meta data.

Table 10. Available fertilizers in the GFLI database.

Fertilizer name	Unit
N from artificial fertilizer	Kg N/ha
P from artificial fertilizer	Kg P_2O_5-eq/ha
K from artificial fertilizer	Kg K_2O-eq/ha
Ammonia, as 100% NH3 (NPK 82-0-0), market mix	Kg product/ha
Ammonium nitrate, as 100% $(NH_4)(NO_3)$ (NPK 35-0-0), market mix	Kg product/ha
Ammonium sulphate, as 100% $(NH_4)2SO_4$ (NPK 21-0-0), market mix	Kg product/ha
Calcium ammonium nitrate (CAN), (NPK 26.5-0-0), market mix	Kg product/ha
Di ammonium phosphate, as 100% $(NH_3)2HPO_4$ (NPK 22-57-0)	Kg product/ha
Liquid urea-ammonium nitrate solution (NPK 30-0-0), market mix	Kg product/ha
NPK compound (NPK 15-15-15), market mix	Kg product/ha
Phosphate rock (32% P_2O_5, 50% CaO) (NPK 0-32-0)	Kg product/ha
PK compound (NPK 0-22-22)	Kg product/ha
Potassium chloride (NPK 0-0-60)	Kg product/ha
Potassium sulphate (NPK 0-0-50)	Kg product/ha
Single superphosphate, as 35% $Ca(H_2PO_4)_2$ (NPK 0-21-0)	Kg product/ha
Triple superphosphate, as 80% $Ca(H_2PO_4)_2$ (NPK 0-48-0)	Kg product/ha
Urea, as 100% $CO(NH_2)_2$ (NPK 46.6-0-0), market mix	Kg product/ha
Lime Fertilizer	Kg $CaCO_3$/ha
Dolomite	Kg $CaMg(CO_3)_2$/ha

3.2.7 Organic fertilizer application

Organic fertilizers (manure and other sources such as animal meals or compost) are applied to maintain soil fertility on the farm. Emissions from manure production and storage on animal farm are cut-off and allocated to animal farm emissions, thus are not included in this application stage. Manure and organic fertilizers may be applied according to a crop rotation scheme. The annual application is then often concentrated to a share of the plots which is changing over the years so that every plot gets its addition of organic matter through the years. For the crop rotation situation allocation rules should be applied as explained below.

Primary data: the use of organic fertilizer is based on recent measurements, farm records, accountant reports, or statistics and surveys that are based on validated data and represent the crop and farms in scope. Data should be collected for every organic fertilizer type. Additionally, data needs to be collected on the nitrogen and phosphorus content. Heavy metal content of the different types of manure may be collected but this is not mandatory.

If organic fertilizer is applied in a crop rotation scheme the nutrient application is divided over all crops in the crop rotation scheme based on the share in area, except for the mineral N fraction which is allocated solely to the crop of application.

The following calculation rules apply for fertilization of N (BSI, 2012)

Formula 1 (Calculating N application to a crop as part of a crop rotation scheme)

$\textit{Total N from Organic Fertilizer}_{\textit{applied to the plot where crop A stands}} = NmOA + NcrA + aA/aT \times NoO$

- NmOA = Mineral nitrogen from organic fertilizer applied to crop A (kg N/ area unit)
- NcrA = Nitrogen from crop residues of crop A (kg N/ area unit)
- aA = area of crop A (area unit)
- aT = total area of crop rotation system (area unit)
- NoO = Organic nitrogen from organic fertilizer applied on all area (kg N/ area unit)

All other fertilizing elements supplied using organic fertilizers, including green manure, are calculated by:

Formula 2 (Calculating Fertilizer application to a crop as part of a crop rotation scheme)

$F_{\text{applied to crop}} A = aA/aT \times FO$

Where

- aA = area of crop A (area unit)
- aT = total area of crop rotation system (area unit)
- FO = Organic fertilizer applied on all area (kg FO/area unit)

Secondary GFLI default data: uses the methodology described in the report of Feedprint (Vellinga T. V., 2013). It relies on statistical information of manure (FAOstat, 2025).

Adapted secondary data: are more representative for the region or country in scope than FAO data. This involves for instance data that are collected by a public or industry body that monitors manure application in a certain country/region combined with crop area. This data can consecutively be attributed to crops based on the same allocation rules as in the specific approach. If information on the composition of the manure is lacking, then default compositions are used (Table 11). For any method of data collection, the improved data quality compared to the GFLI default data needs to be substantiated in the meta data.

The amount of manure in combination with the default nitrogen, phosphorus and heavy metal contents of manure are used to determine the emissions associated to manure use. The total amount of manure and total N and P content used for this method is specific for poultry and porcine manure (Wageningen University & Research, 2017).

Table 11 Overview of data requirements for organic fertilizer application for the different approaches

	Specific	Semi-specific
Amount of poultry manure (kg/hectare)	Shall	May
N-P content (N/P / kg poultry manure)	Shall	Shall
Heavy metals (mg / kg poultry manure)	Should	May
Amount of porcine manure (kg/hectare)	Shall	May
N-P content (N/P / kg porcine manure)	Shall	Shall
Heavy metals (mg / kg porcine manure)	Should	May
Amount other organic fertilizer (kg/hectare)	Shall	May
N-P content (N/P / kg organic fertilizer)	Shall	May
Heavy metals (mg / kg other organic fertilizer)	Should	May

3.2.8 Lime and dolomite use

Lime and dolomite (or other $CaCO_3$ containing fertilizers) are used for managing acidity of the soil. The application depends on soil type and type of crop.

Primary data: on application of $CaCO_3$ fertilizers is quantified based on farm specific use statistics or derived from agronomic surveys or guidance documentation representative for the region in scope of the study.

Secondary GFLI default data: a default $CaCO_3$ use of 400 kg/hectare is applied for all agricultural crops. This is based on lime application rates described in Feedprint, which uses an uniform distribution between 0 and 800 kg lime for every crop country combination (van Zeist, 2012).

Adapted secondary data: can be collected in several ways. Allowed as adapted secondary data is using statistics on lime and/or dolomite use within a specific region on arable crops divided by the amount of arable area within that specific area.

3.2.9 Water use for irrigation and other water use

Like all other activity data that can be collected, water use for irrigation and other water use can be determined in three different ways:

Primary data: are farm and crop specific on the quantity of irrigation water applied to fields This data can be based on measurements, statistics, reports, or any other reliable information. Other blue water use related to the cultivation of the crop might be included as well.

Secondary GFLI default data: are based on the amount of irrigation water as defined in the 'blue water footprint' assessment data (Mekonnen, 2010). The blue water footprint refers to the volume of surface and groundwater consumed resulting from the production of a crop. The model uses grid-based dynamic water balances, daily soil water balances, crop water requirements, actual water use and actual yields. The water footprint of crops have been published per country in m^3/ton of product (Mekonnen, 2010). Combined with 5-year average FAO yields the blue water footprint is calculated in m^3/ha.
Not all of the applied irrigated water is actually consumed during cultivation of the crop. In GFLI, water requirement ratios are implemented to determine the actual water consumption of irrigation water. These ratios are county specific and originate from the ReCiPe Characterization report (Huijbregts, 2016)..

Adapted secondary data: the amount of irrigation water applied to the fields can be based on region specific data. This could be based on the total amount of water used for irrigation divided by the amount of arable area within the specific region. For any method of data collection, the improved data quality compared to the GFL default data needs to be substantiated in the meta data

3.1.4.11 Seed use

Seed use refers to the amount of start material required for the cultivation. Data for this can be collected in different ways:

Primary data: region and crop specific farm data on the seed use can be based on measurements, statistics, reports, or any other reliable information.

Secondary GFLI default data: this approach uses crop specific global average seed input based on data from FAOstat (FAOstat, 2025). Although country specific can be used as well, analysis showed that there are huge variations between seed input for countries for the same cultivation.

Adapted secondary data can be collected from various reliable information sources on country or regional level. The data should be at least crop specific. For any method of data collection, the improved data quality compared to the GFLI default data needs to be substantiated in the meta data.

3.2.10 Pesticides use

Pesticides data are often hard to collect, due to insufficient farm records and lack of detailed surveys or statistics. Since pesticides use is strongly influenced by legislation and regional plague risks, which can vary year by year, it is necessary to collect farm and/or country crop specific information.

Primary data: collect crop and region-specific farm data for pesticide use. The total amount of active ingredient of the pesticide(s) applied per hectare of cultivation should be provided, as well as the CAS-number of the active ingredient.

Secondary GFLI data: pesticide applications per crop and country of cultivation (kg a.i./ha) are modelled for insecticides, herbicides and fungicides (based on 5-year average data from 2018 till 2022) (FAOstat, 2025). More information about the default calculations are found in Annex 3.2.

Adapted secondary data: collect pesticide data from regional country crop specific representative sources. In many situations, expert judgement of agricultural advisory organizations is needed to complete statistics and surveys. In general, pesticides use information becomes of better quality when different data sources are combined. For example, combining expert judgement with national statistics on pesticides sales for agriculture and usage surveys. For any method of data collection, the improved data quality compared to the GFLI default data needs to be substantiated in the meta data.

3.2.11 Depreciation of capital goods

Capital goods include all farm buildings, floorings, roads at the farm and machinery that is needed for practicing cultivation and storage activities. Collection of capital goods data is not mandatory. If no data is collected GFLI defaults shall be used.

3.3 Modelling of emissions of N, P, metals, and pesticides

The default method for emission modelling of N, P, metals, and pesticides is described in Annex 4. If a project wants to propose an alternative way of modelling, the method should be described in detail and provided in a well-documented excel sheet. Data can be published in the GFLI database in a regional database.

3.3.1 Modelling of land use change/land transformation (emissions)

Primary Data: impacts related to land use change can be estimated by collecting data on the previous land use of the cultivated area 20 years ago and including specific carbon stock changes for the area in scope. The calculation of carbon emissions should follow the

PAS 2050-1 methodology (as adopted in the PEF methodology). Land use change impacts should be reported in kg CO_2, CH_4 and N_2O per annual hectare cultivation.

Secondary GFLI default data: Land use change is estimated using the "Direct Land Use Change Assessment Tool version 2021" that is developed by Blonk Sustainability to conduct PAS 2050-1 (BSI, 2012) and PEF compliant LUC calculations. This tool provides a predefined way of calculating greenhouse gas (GHG) emissions from land use change when previous land use is known or unknown and based on FAO statistics and IPCC calculation rules, following the PAS 2050-1 methodology. Crop silages may be interchanged with a similar crop if the ingredient in scope is not available in the tool (e.g., a whole barely silage may be interchanged with barley).

Adapted secondary data: for land use change data involves the use of data sources that are more accurate than the default national conversion areas and carbon stocks. The tool: https://orbae.adastra.eco/ may be used to gather juridistical direct land use change (jdLUC). If a subnational level of data is provided, this shall be noted in the product naming convention and process description. The improved data quality compared to the GFLI default data needs to be substantiated in the meta data.

3.3.2 Emissions from drained peat soils

National or regional topographies for peat lands to represent the specific region the cultivated ingredient is sourced from may be presented to the GFLI Technical Management Committee (TMC) for a more accurate depiction of peat emissions of that ingredient.

Primary data: are farm specific data on soil peat content combined with relevant country/regional emission modelling of CO_2 and N_2O preferably compliant with National Inventory Reporting methodology. The emission factors should be crop and country specific and reported in kg CO_2, CH_4 and N_2O per annual hectare cultivation.

Secondary GFLI default data: uses CO_2, CH_4 and N_2O emission factors from the specific country National Inventory Report (NIR) 2019 submission (average of 2012-2017 data) combined with national data of specific crops. Details on this approach can be found in Annex 4.3.

Adapted secondary data: involves the use of data sources that are more accurate than the default GFLI data used for peat oxidation for crop/country combinations. In any case the improved data quality compared to the GFLI default data needs to be substantiated in the meta data.

3.3.3 Choice of background data for production of farm inputs

The provided LCI data on farm inputs (fertilizers, manure, energy, pesticides, water, seeds) will be linked to the background data that are available in the GFLI database. A project can provide suggestions on using alternative background data or can develop additional background data if specific fertilizers, manure, energy, pesticides, water or seeds are used that were not available in the GFLI background database.

Annex 5 gives an overview of background datasets.

3.4 Roughages and forages

Roughages and silages are considered (fresh) grass (grazed or cut and fed), pasture of (a multitude of) fodder plants or legumes, and silages based on either or all of the aforementioned ingredients.
Roughages and silages contain the majority of properties from the previous subchapters, such as yield, product properties, energy use, organic or artificial fertilizer use, water use, seed use, and pesticides use. With a lack of default statistical source (such as the FAOstat), there is more reliance on primary or adapted secondary data in order to facilitate a complete inventory.

3.4.1 Aggregated averages for region or country-level assessments

For non-standardized ingredients such as (fresh) grass and silages, the datasets are averaged for seasonal or annual figures standardized from an average of 3 years, relevant for e.g. screening and hotspot analyses. These may be refined into categories relevant for product indication (i.e. season of harvest, average crude ash, protein, or fiber content, maturity of the grass, or time of silage harvest).

Primary data: farm and roughage specific yield, nutritional values, and fertilizer use based on recent measurements, farm records, accountant reports, or statistics and surveys to indicate the forage management that are based on validated data and represent the crop and farms in scope.

For the following activity data there is no default information available to execute the "Secondary GFLI default data" approach, this means that data needs to be collection either via the "Primary data" or "adapted secondary data" approach:

- Water use for irrigation and other water use
- Manure application
- Fertilizer application
- Pesticides
- Pasture renewal (for example the "FracRenew(T)" in equation 11.6 in IPCC 2019, v.4, Chapter 11))
- Energy use during field activities
- Energy use during storage
- Land transformations and land use change emissions
- Peat soil oxidation
- Waste management for i.e. plastic wrapping and covers

Secondary GFLI default data: there is no secondary GFLI default data available from the activity data stated above, please refer to the adapted secondary or primary data approach. Default emission modelling for roughages are described in annex 4.5, including the start material, accounting for crop residues. Heavy metal emissions defaults can be found in the Annex.

Adapted secondary data: are more representative for the region or country in scope than FAO data. This involves for instance data that are collected by a public or industry body that monitors roughages production in a certain country/region. For any method of data collection, the improved data quality compared to the GFLI default data needs to be substantiated in the meta data.

Land use change and land transformation should also be taken into account, as described in 3.3.1. For silages, when the respective cereal does not have a default method, a similar cereal figure may be used, or alternatively must be calculated through the adapted secondary approach.

3.4.2 Accounting for the physiology of grass

The above method is aligned with the default or higher primary data to receive an aggregated average for a region or country-specific LCA. For targeted improvement/ design of mitigation strategies of animal productions systems, an alternative approach 'per cut/harvest of grass' can be considered. This results in better representativeness on-farm emissions for (fresh) grass production and consumption. Activity data is to be adapted per cut considering the target and harvested/consumed yield, due to a) the significant impact of the feedstuff and its nutritional characteristics, b) the level of control the farmer has on the variables, and c) the use of materials, i.e. fertilizer, will therefore also differ. All three impacts ultimately impact enteric methane emissions to a major extent.

Adapting activity data 'per cut' includes the farmer's decision of target yield and nutritional composition, relevant to targeted on-farm emission reduction related to forage management and animal feed production on-farm. It will be necessary to appropriately assign annual emissions to each cut on a harvested yield or 'consumption through grazing' basis.

Impact of the nutritional composition of the (fresh) grass and silages in the animal or on its enteric methane production are beyond the scope of the GFLI methodology.

To derive 'per cut' LCAs, primary data should be collected inline with the previous subchapter, but specified per cut and communicated as such. Further details of calculations 'per cut' can be found in the 2012 report (Vellinga T. D., 2012). Due to the structure of the GFLI database, 'per cut' figures cannot be integrated into the GFLI database, but an aggregated averaged form for a seasonal ingredient normalized against a 3 year average can be included.

3.5 Marine fish for feed ingredients

This section describes the modelling rules for fish-based ingredients as feed ingredient, derived of the Marine Fish PEFCR (Marine Fish PEFCR, 2025) & compliant with the PEFCR Feed for Food Producing Animals as cross-referenced in both documentation. Feed for (farm) fisheries is included in the overarching PEFCR Feed and GFLI methodology.

The publication of a Marine fish PEFCR-compliant tool, as well as GFLI compliance, for marine-based ingredients will become available in the first half of 2026 to be utilized by anyone interested in creating a PEF or GFLI compliant fish-based ingredient or product (for sectoral and branded projects)(Sirnes, 2025).

3.5.1 Data collection

Fisheries consists of all activities related to catching, landing, and sorting of the fish species for further processing as a feed ingredient. This may be (by-)products from wild-caught fish or farmed fish. Table 12 gives an overview of the inputs and outputs to be included or excluded.

Table 12. System boundaries for fisheries.

Included for wild-caught fish	Included for farmed fish	Excluded
• Fishing and landing • Preparations and processing (onboard or on land) • Fuel use • Refrigerants from fishing vessel • Capital goods: fishing vessels and gear • Auxiliary materials (anti foulings, baits)	• Feed production & processing for farmed fish • Fuel use (growing, fishing, compound feed processing, packaging) • Animal production (hatchery & growth of fish) • Capital goods: infrastructure and equipment • Auxiliary materials (anti foulings, baits)	• Other auxiliary materials adding up to less than 1% of mass contribution • Depreciation of vessel

The data for fisheries should be collected for a specific zone (FAO for Major Marine Fishing Areas[1])and fishing technology (fishing gear classification). The ingredients should be representative for a 3 year-period (averaging out yearly variations in catches) For seasonally bound fish catching, this may also be reflected (e.g., summer caught fish representative for the summers in 2020, 2021, and 2022). If a three-year period is not achieved, this should be stated in the process description.

[1] https://www.fao.org/fishery/en/area/search

3.6 Animal-based ingredients for feed

This section describes the modelling rules for animal farm products that are processed to feed ingredients. This may be rendered products (by-products from the slaughter houses), or processed animal-based ingredients like whey and egg-based by-products, or insects for feed.

The modelling rules are derived from FAO/LEAP guidelines (FAO-LEAP, 2015) (FAO-LEAP, 2016) (FAO-LEAP, 2020) and the PEFCR for dairy (EDA, 2025) and the PEFCR for Red Meat (TS Red meat pilot, 2016). These guidelines can be consulted for more detailed modeling of animal products.

Insect-based ingredients do not have a formal methodological approach as of the 2022 GFLI methodology. With insects, the animal system should be included, such as system boundaries, which emissions come out of the system, what outputs do they have (frass). Modelling should include the insect breed and nutritional composition as a result of the feed composition fed to the insect. Ideally, this requires an average of 3 years of composition and processing but may also be an average of 1 year if proven representative. For decentralized/not-integrated insect systems, outsourced productions e.g., breeding, rearing, processing, may be (adapted) secondary data.

3.6.1 Data collection

Animal farming consists of all activities related to the production and reproduction phase of animal farming. Per unit of animal product coming from a farm the pre-stages should be proportionally represented. Table 13 gives an overview of the inputs and outputs to be included or excluded.

Table 13. System boundaries for animal husbandry.

Included	Excluded
• Input: Output mass balance of animal (co-) products (incl. dry matter contents) • Allocation data • Feed ingredients production lifecycle • Daily ration of compound feed, additives and roughage • Enteric fermentation • Mortality rate • Fuels use • Heat/ Electricity use • Manure management	• Other auxiliary materials adding up to less than 1% of mass contribution • Depreciation of housing system

The data for animal husbandry should be collected for a specific region and the animal products are used as input for processing. There are several approaches possible, for the collection of farm data:

Primary data: consists of representative farm data including all activity data points as mentioned in Table 13.

Secondary GFLI default data: default data for animal husbandry (bovine, porcine, broilers, layers) can be used from the Agri-Footprint (chapter 7 of AFP methodology version 7.0 (Blonk, 2025).

Adapted secondary data: is only needed for branded data. For sector- and region-specific products use of default farm data available in background databases is allowed.

The implemented approach shall be specified in the meta data. The more specific the approach the better the data quality rating.

3.7 Modelling of processing

Plant crops and animal farm products can be processed into feed ingredients. Most of the processed feed ingredients are made of plant-based crops, split into different co-products in a processing facility. Examples of such food processing are the wet and dry milling of grains, the pressing and crushing of oil seeds and beans, or the sugar production. A limited set of the feed ingredients also concern (co-)products from further processing steps, such as oil refining, flaking, or heat treatment.

Processed animal-based products are also used as feed ingredients. There are several fat and protein products used as feed ingredient.

Processing to feed ingredients is mostly happening in large scale processing facilities where besides energy use there is limited input of other raw materials. In several cases processing aids are used such as hexane at crushing or, acids at wet milling or calcium carbonate at sugar production. Processing aids are often used in small quantities. This makes the energy inputs the predominant activity data during processing.

3.7.1 Data collection

The processing stage consists of all steps from the provision of the crops, the processing of the crops and finally the storage of the feed ingredients before delivery to the client.

Table 14 gives an overview of the inputs and outputs to be included or excluded.

Table 14. System boundaries for processing of crops.

Included	Excluded
• Input: Output Mass balance (incl. dry matter content) • Price of (co-)products • Cultivation data • Crop input mix of originating countries • Transport (distance per transport means) • Fuel use • Heat/Electricity use • Water use • Wastewater treatment only for wet processes • Organic waste & losses • Auxiliary materials (processing aids)	• Auxiliary materials adding up to less than 1% of mass contribution • Consumables used at the plant not used as a raw material or auxiliary material • Packaging if occurring

An overview of the currently available processing techniques are available (and sourced from EcoInvent), for other ingredients the EcoInvent or other databases may be considered to include relevant auxiliary materials.

Table 15. Overview of different processing techniques and auxiliary materials available in the GFLI database (Blonk, 2025)

Auxiliary material/Other ingredients	Process
Sodium chloride, powder {GLO}| market for sodium chloride, powder | Cut-off, S	Cheese production
Sulfur {GLO}| market for sulfur | Cut-off, S	Cassava, sugar beet and sugar cane processing
Limestone, unprocessed {RoW}| market for limestone, unprocessed | Cut-off, S	Sugar beet processing
Base oil {GLO}| market for base oil | Cut-off, S	Soybean crushing
Nitrogen, liquid {RoW}| market for nitrogen, liquid | Cut-off, S	Various oil refining

For collecting data in sector, regional and branded product "projects" the following approaches are possible:

Primary data: data collection to be applied for branded product projects and sectoral projects which require primary data for all inputs:

- Mass balance and prices
- Cultivation data
- Crop mix of originating countries
- Transport (distance per transport means)
- Fuel use
- Electricity use
- Water use

- Wastewater treatment only for wet processes
- Organic waste & losses
- Auxiliary materials (processing aids)

In certain cases, where it can be substantiated (e.g. by previous LCA study results) and documented, some of the inputs are not significant to the impact of the process. These data points may then be considered not relevant and not collected. This should be reported in the meta data.

Secondary default GFLI data: are collected as follows:
Mass balance and prices are derived from literature (see Table 15).

- The market mix of crops is formulated based on the FAO trade statistics. The market mix for each raw material is based on domestic production and trade statistics per country. Sourcing countries in the market mix for which no background data is available are removed and the mix is configured accordingly to avoid data gaps. The final inventoried countries cover at least 50% of the market mix.
- For the impact of transporting the raw materials from field to processing facility, default data on transportation distances and transportation modes are used (see Annex 6).
- Use of fuels, electricity, water, and auxiliary materials are derived from literature and connected to country-specific production data when available, otherwise global average datasets are used.

The implemented approach shall be specified in the meta data. The data quality rating will improve with the specificity of the approach.

Adapted secondary data: This approach can be used for sector- or region-specific data, which requires primary data collection for:

- Mass balance and prices
- Fuel use
- Electricity use
- Water use
- Wastewater treatment only for wet processes
- Organic waste & losses
- Auxiliary materials (processing aids)

3.8 Feed additives

(FAO-LEAP, 2020) have published their guidelines on feed additives, including production processes. This publication shall be used for generating feed additives datasets. However, the following deviations shall also be considered for the introduction of feed additive datasets in the GFLI database.

3.8.1 Boundaries

As for any feed ingredient introduced in the GFLI database, the impact assessment of a feed additive is limited to the cradle to feed additive manufacturing site exit gate.

3.8.2 Functional Unit

The Functional Unit relates to the feed additives, as placed on the market, and is expressed as the weight or volume (for liquid feed additives) of the additive, as placed on the market.

Information indicating the concentration of active substance(s) in the feed additive shall be provided, if the quantity of feed additive, as placed on the market, incorporated in the feed or premix will depend on this concentration, to allow the evaluation of the impact of the feed additive during its use phase. As appropriate, representative information shall be included in the GFLI metadata.

3.8.3 Packaging

Considering the high variability of packages used for feed additives (from small bags to bulk) and the potential for different packaging proposed for a same feed additive by its supplier(s), the data sets, for inclusion in the GFLI database, shall omit the packaging phase of the additive. Information to calculate the impact of packaging will be considered in the future, in order to enable the user of the GFLI datasets to calculate the impact of the packaging when calculating the environmental footprint of its premix or compound feed.

4 Branded data – company-specific products

The following methodology is the result of the evaluation during the GFLI Branded Data Pilot that ran from February 2022 to March 2023, and the subsequent experiences gathered during branded data processes from May 2023 onwards. Any company interested in branded data through the Global Feed LCA Institute (GFLI) shall comply with the following methodology.

This chapter is indicative of the level of primary data required specifically for company-specific environmental footprints. Additional information about the data points to be collected and how can be found in chapter 3 in the respective chapter of the ingredient(s) in scope.

Please note that the GFLI database is a 'lifecycle assessment' based database, all environmental categories as described in the previous chapters are mandatory to participate for *branded data*.

4.1 Data quality measurement

Data quality rating (DQR) shall be conducted based on the quality matrix, being developed in the EC feed database project (see Annex 1). The DQR information needs to be gathered during the data collection process. Where primary data are required according to these methods, data must be rated DQR 1. Where adapted secondary data are allowed according to these methods, the DQR must be at least a 2. Within the GFLI branded data methodology, data provided from the supplier(s) of the different materials/carriers/ processing aids, from which the data-in provider is purchasing (chain of custody), should have a DQR of 2 or lower. The score of criterion Precision (P) may not be higher than 3 while the score for Time Representative (TiR), Technical Representative (TeR), and Geographical Representative (GR) cannot be higher than 2 (the overall DQR score shall be ≤1.6) as aligned with the PEFCR Feed, chapter 9.4.1 Company specific datasets (FEFAC, 2024).

The following DQR table is aligned with the PEFCR Feed table, but further clarified to with the scope of the GFLI branded data.

Table 16 DQR interpretation specified towards GFLI branded data

DQR	Precision	Time Representative*	Technology Representative	Geographical Representative[2]
1	Measured/ calculated and verified through third party	Data (at collection) is maximum 2 years older than	Technology of source data is the same as described in the title	Geography of source data is the same as geography stated in the "location"

[2] the definition of geography to determine geographical representative: climate zones/ecozones, with similar climate and soil characteristics.

	verification or through the internal or external review process	the end of the running year	and meta data of the GFLI dataset.	indicated in the meta data of the GFLI dataset
2	Measured/calculated/literature and plausibility checked by reviewer	Data (at collection date) is maximum 4 years older than the end of the running year	Technology of source data is very similar as to what is described in the title and meta data (use of generic technology data instead of modelling all the single plants)	Geography of source data is representative for the geography stated in the "location" indicated in the meta data
3	Measured/ calculated/ literature and plausibility not checked by reviewer, or Qualified estimate based on calculations plausibility checked by reviewer	Data (at collection date) can be maximum 6 years older than the end of the running year	Technology of source data is similar to what is described in the title and meta data but merits improvements. Some of the relevant processes are not modelled with specific data but using proxies.	Geography of source data is sufficiently representative for the geography stated in the "location" indicated in the meta data. E.g., the represented country differs but has a very similar electricity grid mix profile.

There might be an issue regarding the geographical representation if data is collected from a very specific location. At that stage it is very important that the geographical representation can be covered within the sampling method used.

To evaluate the DQR, a division needs to be made on the type of data and how they are interrelated. Data quality evaluation shall consider the contribution of the data points to the overall environmental impact. The DQR evaluation includes activity data and the background data they relate with (e.g., production of goods such as transport and electricity and combustion of fuels or other chemical conversion during processing).

4.2 Background data

The GFLI database uses default background data from Agri-footprint and EcoInvent (see Annex 5). If more granular background data for the product in scope is available from these databases, they may be used but must be indicated in the data collection report. Alternative background data sources are up to discuss with GFLI.

The use of primary data (e.g., fertilizer application and transport and such). The time representativeness (TiR) of background data can be indicated by the validity of the dataset in the database (as published in Ecoinvent). E.g., if the validity is until 2020, you may use 2020 as reference year for the TiR.

The applying company is responsible for the licensing of the background data. Any deviations must go through the GFLI Technical Management Committee for approval.

4.3 Criteria for each ingredient

To create a full inventory that aligns with the branded data methodology, criteria is set up for the amount of primary data necessary. For tier 1 suppliers, adapted secondary data or better (primary) data must be collected. For tier 2 suppliers, secondary data or better (adapted secondary or primary) data must be collected. It's desirable to have higher quality/more representative data than the secondary data to obtain a better Data Quality Rating (DQR).

Activity data should be representative of the processes in scope, with at least a one year average for processed ingredients if this does not include fluctuations in processes created by external factors, and an aimed three-year average for cultivated ingredients to accommodate external factors like climatical fluctuations, droughts, natural disasters, etc.. If a three-year average cannot be obtained, the data collection report shall include an explanation on why the collected activity data is representative for the ingredient(s) in scope.

Prices for the economic allocation should include at least the relative pricing of the main and co/by-products of a three year average, with preference that this accommodates the year(s) of activity data collection.

Each ingredient should include nutritional data regarding the caloric value, dry matter content, crude energy content, nitrogen, and phosphorus content. If primary data is not available, defaults may be used from relevant feed ingredients nutritional tables or the Feedipedia from FAO (this data must be sourced by the applying company).

4.3.1 Example of tier 1 and tier 2 suppliers

The following figure 2 shows the interpretation of tier 1 and 2 suppliers for feed additive manufacturing and processing. In the figure, the following terms are defined as follows:

- **Materials:** substances, including raw materials and other inputs (excluding processing aids and carriers) used for the manufacturing process (definition extracted from the ICCF). This definition would cover a chemical used in the chemical synthesis, thyme plant to produce thyme extract, thymol, or oregano essential oil in a mixture of flavouring, extracted material from mining (for trace elements), ingredient entering in the fermentation broth composition.
- **Processing aids:** any substance, not including apparatus or utensils, and not consumed as a feed ingredient by itself, intentionally used in the processing of materials, feed or feed ingredient, to fulfil a certain technological purpose during treatment or processing and which may result in the non-intentional but unavoidable presence of residues or derivatives in the feed ingredient or its ingredient market formulation, provided that these residues and derivatives do not

have an adverse effect on animal health, human health or the environment (same source as above). This definition cover for example solvents for extraction /extraction step in the manufacturing process.

- **Carriers:** A feed ingredient or water used to physically facilitate handling of the feed ingredient under assessment and its incorporation into ingredient market formulations, premixtures, feeds or water. The use of a carrier does not alter the feed ingredient's intended effect and purpose (same source as above). This definition would cover wheat middling used in a mixture of additive coated agents, potentially antioxidants or emulsifiers.

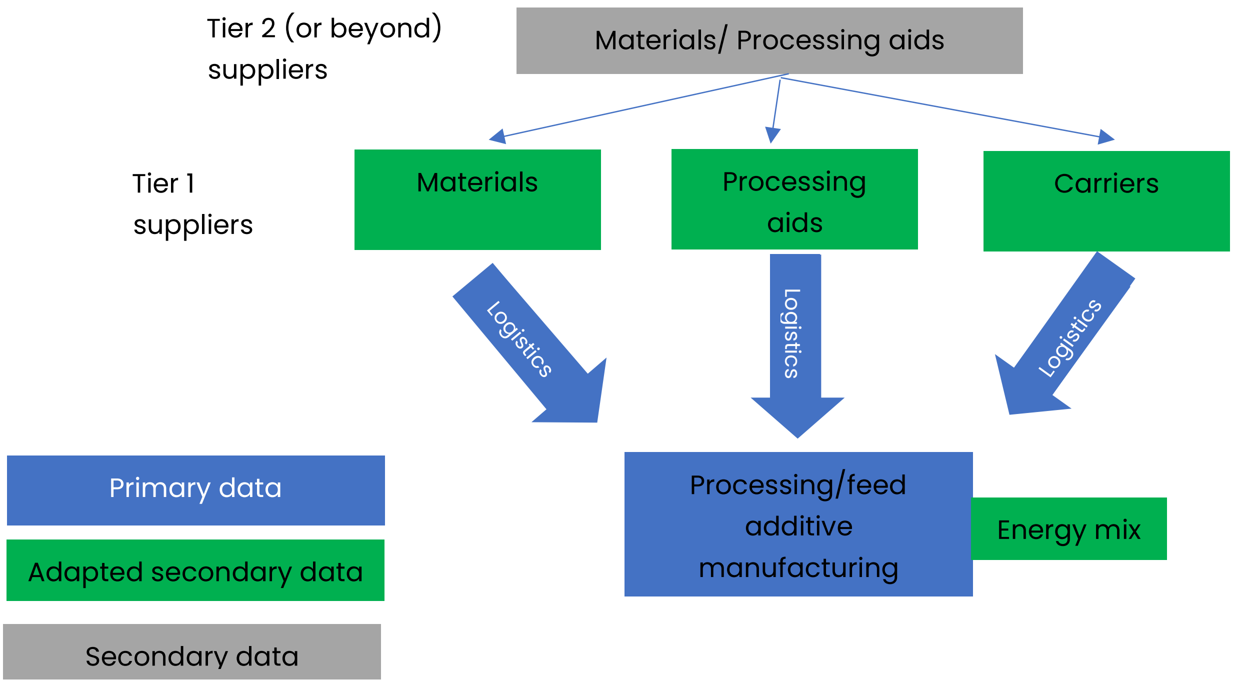

Figure 2. Interpretation of tier 1 and 2 suppliers for feed additives

4.3.2 Cultivated feed ingredients

Cultivated ingredients are all products from crops produced on land or in a greenhouse, and are the main feed sources, such as soy and maize.

Table 17 Criteria for cultivated ingredients

	Data provider (Cultivation)	**Tier 1 supplier (inputs)**	**Tier 2 supplier**
Required	Primary data (3-year average) available on: - Yield (kg/ha) - Fuels use - Electricity use - N, P, K Fertilizer use - Synthetic fertilizer use	Secondary or better data on: - Packaging of fertilizers and pesticides - Chemical input	

	- Organic fertilizer (manure and others) use - Lime use - Use of organic fertilizers or soil improvers - Use of Pesticides on the field and at storage - Use of irrigation water Secondary or better data on: - Depreciation of capital goods for machinery and storage - Seed use - Land use (change) & peat emissions		
Example of actor	Soybean grower	Tier 1 supplier is seeds company, organic/chemical fertilizer provider, pesticides provider	

4.3.3 Processed plant-based products

Processed plant-based products are all from cultivation originated ingredients processed in some form or another to get the final product. This may be drying, milling, crushing, flaking, heating, or other processes.

Table 18 Criteria for processed plant-based products

	Data provider (processer)	**Tier 1 supplier**	**Tier 2 (cultivation farm)**
Required	Primary data (≥1-year average) available on: - Fuels use - Electricity use - Water use - Wastewater treatment only for wet processes - Organic waste and losses - Auxiliary materials (processing aids) Adapted secondary data on: - Process mass balance	Secondary or better data on cultivation (3-year average): - Fuels use - Electricity use - N, P, K Fertilizer use - Organic fertilizer (manure and others) use - Lime use - Use of organic fertilizers or soil improvers - Use of Pesticides on the field and at storage - Use of irrigation water	-

	- Raw material market mix - prices of output products - Inbound transport (distance per transport means)		
Example of actor	Soybean meal producer	Tier 1 supplier can be the soybean producer, the crusher facility, another processor, or a trader.	Tier 2 supplier can be the soybean producer, processor if tier 1 supplier is a trader; however, in both cases a adapted secondary or primary data should be pursued
Example of actor	Mixer/processor of former foodstuffs	The tier 1 supplier are food processing facilities, bakeries, or others, where the former foodstuffs are sourced from, or the tier 1 supplier can be a trader	If tier 1 supplier is a trader, the tier 2 would be the food processing facilities, bakeries, or others

4.3.4 Processed animal-based products

This are all animal co-products becoming available during the slaughter and rendering, such as animal fat, processed animal protein and fish meal. The rendering and processing should contain primary data.

Table 19 Criteria for processed animal-based products

	Data provider (processer/ renderer)	**Tier 1 supplier (slaughterhouses)**	**Tier 2 supplier (livestock farmer)**
Required	Primary data (≥1-year average) available on: - Animal species (bovine, porcine, poultry, fish) and characteristics - Input: output mass balance of animal (co) products - Allocation data (3-year average for prices in case relevant) - Fuels use - Heat/Electricity use - Auxiliary materials (for fish e.g., anti fouling, baits)	Adapted secondary or better data available on: - Heat/electricity use - Fuels use - Mass balance input - outputs	If tier 1 supplier is a processor Secondary or better data on: - Data input of live animal

	- Other inputs relevant (i.e. refrigerants for caught fish). Adapted secondary data on: - Process mass balance - Raw material market mix - prices of output products - Inbound transport (distance per transport means)		
Example of actor	Feather meal processor	Tier 1 supplier is the slaughterhouse	Tier 2 supplier is the livestock farmer
Example of actor	Fish meal processors	Tier 1 supplier are the fishermen and/or landing companies	

Secondary data may be used for data input of the live animal. Adapted secondary data on slaughterhouses, such as based-on-industry-data GFLI data (upon approval of the intellectual property owner), may be used. The data for fisheries should be collected for a specific zone (FAO catch zone and subdivisions) and being representative for a 3 year-period (averaging out yearly variations in catches) and fishing technology.

4.3.5 Feed additives

Feed additives are any manufactured products through natural or chemical processes for the enhancement of animal health, productivity, or environment. Please note that the scope of the GFLI database and methodology is until processing gate, thus the impact a feed additive may have on the environmental output, animal performance, or otherwise, is not taken into account. This may be considered in the future, but at this point of time is not feasible.

Table 20 Criteria for feed additives

	Data provider (feed additives company)	**Tier 1 supplier (Processor)**	**Tier 2 supplier (start material/processor)**
Required	Primary data (≥1-year average) available on: - Logistics - Feed additive manufacturing which involves mass balance, fuels use, electricity Auxiliary materials etc. please use same	Adapted secondary or better data on: - Materials - Carriers - Processing aids - Auxiliary materials - Heat/electricity use - Fuels use	Secondary or better data on: - Originating ingredient cultivation/production values - Materials - Carriers

	structure as for processing plant and animal based products - Natural or chemical processes: biomass extraction, mining, fermentation Adapted secondary data on: - Process mass balance - Raw material market mix - prices of output products - Inbound transport (distance per transport means)		
Example of actor	DL-methionine producer	Tier 1 suppliers are those where the ingredients are sourced from for the manufacturing of the amino acid, either through direct purchase or after processing	Tier 2 suppliers are those where the ingredients are sourced from the tier 1 supplier for either direct purchase or after processing.

4.3.6 Novel feed

Novel feed are not yet commercially available alternative feedstock, such as insects and algae.

Table 21 Criteria for novel feed

	Data provider (Insect processor/integrated farm)	**Tier 1 supplier (substrate provider/feed)**	**Tier 2 supplier (breeder)**
Required	Primary data (≥1-year average) available on: - Logistics - Fuels use - Electricity use - Auxiliary materials In case of animal farming (insects), primary data available on: - Insect breed and nutritional composition of the insect - Substrates - Feed composition for the	Adapted secondary or better data on: - Feed/substrate production - Heat/electricity use - Fuels use	Secondary or better data on: - Data input on animal

	insect (consistent feed or otherwise averaged over 1 year) Adapted secondary data on: - Process mass balance - Raw material market mix - prices of output products - Inbound transport (distance per transport means)		
Example of actor	Insect meal processor	Tier 1 supplier may be the substrate/feed provider. Not-integrated systems may also have tier 1 suppliers be breeders or rearing facilities.	

5 Procedures for a data-in project

All data going into the GFLI database are subject to the following procedures in order to ensure compliance through a GFLI internal review as well as an external review. Table 22 displays the steps for all data projects. A checklist (see Annex 7) provides guidance for the data-in provider during the process of a data-in project.

Table 22 Activities involved in a GFLI data-in project

	Step 1: Defining a data-in project using the project proposal (§ 5.1)
1	Define scope: goal and approach, which feed ingredients, which country or region, data sources, which method, which granularity
2	Define data use conditions
3	Define project proposal (planning, execution team, steering committee, budget, etc.)
4	If alternative decisions and/or tier modelling is opted, this will be discussed in the Technical Management Committee for approval of the alternative usage in the GFLI database
5	Optional: Present the project plan in the Technical Management Committee (only applicable to sectoral data-in projects)
	Step 2: Data collection and modelling (§ 5.2)
6	Execute activities defined in the project plan
7	Collect data from defined sources (databases, primary data from producers), template available through GFLI Secretariat
8	Modelling the data
9	If alternative modelling is used (and previously approved by GFLI's TMC), provide a document with evidence of which alternative methods are used and the explanation on why it provides higher quality and/or representativeness than the baseline approach
10	Write a report on the data collection, which activities were collected and a clarification of approaches used, and LCA report of how the data is modelled and calculated
	Step 3: Review and integration (§ 5.3)
11	GFLI internal review executed by the GFLI LCA consultant
12	External review by a shortlisted external reviewer: see GFLI-website
13	Integration of dataset(s) into database

5.1. Step 1: Defining a data-in project

The first step of a GFLI data-in project is an adequate project outline. This chapter defines what should be included in the project for the creation of new datasets and updating old datasets. It is required to fill in the project proposal form (see Annex 8). For help or feedback regarding the project proposal, you're welcome to reach out to the GFLI Secretariat (info@globalfeedlca.org).

The project proposal should contain the below mentioned details for a successive data-in project. A project proposal should be written for both new projects as well updated project or modelling of subprojects.

5.1.1 Define goal and scope

The first step for every GFLI data-in project is about defining the goal and scope. In the goal of the project it should become clear what type of project is aimed for. Table 3 shows some examples of projects and which typology would apply. A data-in project has a regional, sectoral, or branded focus:

- Regional focus: data or methodology represents (sub)states, (a) country (ies) and/ or region(s).
- Sectoral focus: any selection of feed ingredients or technology represented by a sector. Full market coverage is not a criterion, but it should be made clear which fraction of the market is covered by the data and how these data are better in terms of data quality than the data in existing GFLI datasets.
- Branded focus: the technology and environmental performance of the supply chain specific for a certain brand (company specific product or scheme).

It should also become clear whether it is a first development or an update of data and/ or an extension of modelling.

The scope includes the selection of feed ingredients and/ or technologies the GFLI data-in project aims to gather, as well as a description of the data sources which will be used for the database development.

The selection and definition of methodologies are part of the scope as well. A GFLI project can use GFLI methodology, but alternative methodology regarding background data and emission modelling can also be used for regional and sectoral database developments, if more appropriate. Deviations of the GFLI methodology, indicated as higher tier or alternative modelling processes (2.6.2 Higher tier and alternative modelling) are subject to approval by the GFLI Technical Management Committee. Choices regarding data sources and methodology should be explained and motivated in the proposal and/or data collection report.

Table 23 Examples of types of GFLI projects

		Phase of data-in project		
		First development	**Update**	**Modelling subproject**
Type of data-in project	**Regional**	The European feed sector aims to add feed ingredients commonly fed in Europe to the GFLI-database	Brazil provides better data on the cultivation of soy	Implementing new characterization factors developed for water depletion in the North American region
	Sectoral	The fish sector aims to include a selection of fish feed ingredients in the GFLI-database	The crushing industry provides better data for crushing of oil seeds	The fish sector aims to include an impact category for marine resource depletion for fish feed ingredients

	Branded	Company/organization X produces feed ingredient Y and aims to align their company specific data in compliance with the GFLI branded data methodology	Company X wants to update its existing data on feed ingredient Y to maintain representativeness and/or realign after methodological changes	N/A

Review of existing data (data update)

If the data-in project is focused on updating of existing datasets in the GFLI database, it is relevant to assess the improvement updated datasets would bring. This will likely be applicable for datasets that have been sourced a time ago, but may also have better representative data on improved technologies or have more granularity. This step should make clear which data sources will be used, what life cycle stages, processes or background data will be improved and why the aimed data sources will lead to an improvement of the GFLI database. Statistically, this could be shown with a lower Data Quality Rating (DQR). In decisions, this would translate to amount of primary industry data used, (more) regionalized secondary data sources (databases, scientific literature), use of higher than baseline methodological approaches (as read as specific and semi-specific approaches in the GFLI methodology).

Based on the outcome of this review a plan can be made that defines which data should be collected and which data should be updated for the life cycle stages (farming, processing, logistics) and background data (energy, transport and auxiliary materials).

5.1.2 Data collection procedure

The data collection procedure is to understand who is collecting which data and which approach is used. This forms the baseline for the data collection report to be created which will be subjected to review. More detailed information about the data collection report is available in paragraph 5.2.3.

5.1.3 Methodological aspects

After review of the methodology, a data-in provider might face issues with the methodology for their data alignment. Any data-in project that use higher tier modelling and/or alternative methodological approaches that are deemed to be of higher quality than the baseline GFLI methodology, are to be discussed in the Technical Management Committee for approval of variability of the data. Ideally, this would lead to continuous improvement of the GFLI methodology and allow for the local differences in LCAs (relevant of certain factors like land use conversion, climate, soil, etc.). If this alternative method is potentially robust enough to become the baseline methodology applicable for all data-in projects (global), methodology development will be considered.

5.1.4 Work plan, planning and budget

Work plan with concrete activities, deliverables and relevant participants/parties are optional as part of a smooth-running data project. It is not required for GFLI to have insights on these, but it is recommended as a time estimation for any LCA project is highly dependent on the availability of data, the number of participants, and the level of communications between all relevant parties. As the estimated time necessary will be reliant on successive data collection, a generous timeslot should be accounted for. This also includes any data review.

5.1.5 Coordination with the TMC

During the creation of the project plan for regional or sectoral data-in projects, the data-in provider may request guidance, feedback, or recommendations, from the GFLI Technical Management Committee (TMC). The TMC meets monthly and is prepared to tackle discussion points relevant for the process. After finalization of the project plan, the data-in provider is requested to present their project plan or share the executive summary with the TMC for preemptive discussion on new datasets and how to proceed with older datasets (when relevant) or new methodological approaches, which improves the structure in which GFLI acts as a knowledge center as well as provide the data-in provider with a panel of experts to express their thoughts with.

The TMC Chair presents the data-in project to the Board of Directors (in a Board meeting or through e-mail). If the new data-in project would be debated due to its quality (lower than already existing data), scope, or otherwise, the Board of Directors may decide to decline the data-in project on evidential basis.

Companies applying for branded data are welcome to start such discussions or request feedback as well, but may need to consider confidentiality issues. In such case, they can discuss how to anonymize their (technical) question with the GFLI Secretariat. Before presenting to the TMC, the GFLI Secretariat will provide the TMC feedback to the requestor.

5.2 Step 2: Data collection and modelling

After a robust project plan is set, the next step is its execution through the various activities stated. Data collection and modelling of activity data is reliant on timely data collection through communication with relevant partners. The choice of tools used in this process affects the technical execution of the integration into the GFLI database.

Table 24 Activities for data collection and modelling

Activities for data collection and modelling
Execute activities defined in the project plan
Collect data from defined sources (databases, primary data from producers), template available through GFLI Secretariat
Modelling the data
If alternative modelling is used (and previously approved by GFLI's TMC), provide a document with evidence of which alternative methods are used and the explanation on why it provides higher quality and/or representativeness than the baseline approach
Write a report on the data collection, which activities were collected and a clarification of approaches used, and LCA report of how the data is modelled and calculated

5.2.1 Execute data collection

For data collection, the newest version of the Methodology document is used. If you are already working on a data collection when a newer version is published, it is necessary to re-align the data and methodology with this newest version. GFLI strives to inform running data-in projects on upcoming updates and the possible impact the changes might have on the data collection

A data collection template is available for crop cultivation and processing. The template is a leading document but for the collection additional data might be required depending on the product (e.g., peat oxidation of peatlands for cultivation of crops or product specific data like fleet vessels for fishing). Please contact the GFLI secretariat for access to the template(s).

Already collected data

Existing LCA datasets that have not been formulated by the GFLI methodology may be introduced through a data-in project. Such data-in projects usually will require some modelling and a more thorough internal review, depending on which methodology followed and how the sources have been documented. EU PEF-compliant studies, for example, would be more easily integrated than other LCA studies based on other methodological approaches. Data alignment to the GFLI methodology can be executed by an LCA expert with experience in the GFLI methodology. If you have any available data relevant for the GFLI database, please reach out to the GFLI Secretariat to discuss the options.

5.2.2 Execute data modelling

Data collected, through the collection template or otherwise, is then molded into an LCA model formulated in a software tool. Multiple models may be necessary depending on the complexity of the ingredient and its processing. During this process it is essential to analyze the data for completeness and representativeness. In some cases, additional data may be necessary to complete the full scope when the data is being modelled.

For data modelling, access to the GFLI background data is necessary. This could also be adjusted during the internal review, but that may require additional costs for alignment. The relevant background data in scope can be licensed by GFLI through the 'unit process' level data, a separate background data license, or indirectly through a Simapro license (library: Agri-footprint 7.0) or within OpenLCA.

Alternative modelling

During the data collection and/or modelling phase, alternative modelling may be considered to increase the representativeness of the data. See chapter 2.6.1 higher tier modelling on how to proceed.

5.2.3 Report for internal review submission

Reporting on which data is collected, which sources, and which approaches, are crucial for the next step. For the review it must be clear where data is sourced from and which methodological approaches are taken to result in the lifecycle inventory and impact assessment data.

The report is usually written by the LCA-consultant or by the data-in provider and should at least the following information:

- Goal, scope, system boundaries and functional unit
- Allocation
- Data collection: use of primary, improved secondary and secondary data and data quality ranking
- Emissions modelling (if relevant)
- Background data used
- Impact assessment

5.3 Review and integration

After data collection and alignment to the GFLI methodology, all datasets will go through a process of review. The internal review is executed by the GFLI LCA team, and followed by an external review by a reviewer shortlisted on the GFLI website. Table 25 shows the different steps required for review and integration of the dataset(s).

Table 25 Activities for review and integration

Steps
Fill in application form
Sign GFLI Data-in contract (License agreement)
Share required data-in project documents with the GFLI
Internal review
External review
Integration of dataset(s) into database
Updating the datasets

5.3.1 Application form

Before starting the internal review process, the application form should be filled in. The application form is available on the GFLI-website. The application form requires a brief overview of the organization or company's information, the type and number of products in scope for this project and preferences for database integration. When filling in the form, please pay extra attention to the following:

- Fill in the proposed name of each feed ingredient, the naming should preferably be consistent with the GFLI guidelines. More information about correct naming can be found in paragraph 5.3.3.

- Ensure that the number of datasets matches the number of proposed names: when applying for three datasets, please check whether the application form also contains a proposed name for each dataset (ingredient).
- Indicate the publication preferences. It is necessary to share this information with GFLI before starting the procedure, as the data-in providers' deliverables to GFLI may vary depending on the publication preferences. Detailed information about the publication preferences and the corresponding deliverables can be found in paragraph 5.3.8.
- Data collection from years. The year of data collection is used to determine the reference year for each dataset. When data is collected over multiple years, all years should be indicated in the application form. When using data over multiple years,
- The application form also contains the invoice information. Please make sure to fill in the information correct, as GFLI will not proceed with the internal review before the invoice has been paid.
- Note that once the application form is approved, the ingredients in the document are the only ingredients considered for the project. Expansion of the projects (in particular for branded data) may be discussed for price indications of the GFLI internal review.

Please return the application form to the GFLI secretariat. After confirmation, the next steps are followed.

5.3.2 GFLI data-in contract (License agreement)

In order for GFLI to review the data and (optionally for branded data) integrate it into the GFLI database, a contract must be signed. This can be requested at the GFLI secretariat at info@globalfeedlca.org. An Non-Disclosure Agreement (NDA) for the review and handling of the data can be requested.

Within the contract, the data use conditions are shared. These are the following categories in which the data may be made available within the GFLI database as indicated by the licensee (data-in providers).

The GFLI data-in provider may consider in which format the data is made available in the database. This can be categorized and made accessible through the below-mentioned options. The description of the types of data and level of sharing can be found in the glossary.

1) Aggregated data (environmental impact data (LCIA) and inventory data (LCI)) will be freely accessible to the public;
2) Aggregated data may be licensed for use in tooling (i.e. commercially sold LCA calculation tools)
3) The disaggregated Feed/Food LCA Dataset(s) (unit process inventory data) of the Client presented in accordance with the GFLI methods and procedures; these data will only be made available to parties which procure a license for the use of the Global Feed LCA Database. In this option only the outcome of the calculation will be shared;
4) The disaggregated Feed/Food LCA Dataset(s) (unit process inventory data) of the Client presented in accordance with the GFLI methods and procedures and the

calculations made in accordance with the GFLI methods and procedures; these data will only be made available to parties which procure a license for the use of the Global Feed LCA Database. In this option both the outcome and calculation will be shared.

5) Disaggregated data may be licensed for use in tooling (i.e. commercially sold LCA calculation tools).

For sectoral and regional data-in projects, at least one of the beforementioned options should be considered. For branded data-in projects, it is not mandatory from GFLI to publish the data, but it may be requested by industry or regulatory demands. Branded data-in providers that prefer to not publish their data are not required to choose one of the options and may leave the boxes blank.

Intellectual properties

The datasets that make-up the GFLI Database remain the intellectual property of the data provider, where usage is granted through the license agreement. Data providers have no intellectual property rights over any of the outcomes of processed data that are part of the GFLI database (downstream products calculated (in part) with data of the data provider, LCA calculated products based on data from the database, etc.). The data provider has the right to withdraw their data from the GFLI database at any time.

There is an option to relent ownership of the provided data by marking a clause in the contract. The data provider understands and agrees that the datasets will be presented to the GFLI Secretariat for integration into the GFLI database with no retention of ownership by the data provider for any of the activity data (i.e. collected primary or secondary data such as yield, fuel use, energy use in processing steps, etc.). By orphaning the data, no ownership of the datasets can be claimed by the signing party, which will allow GFLI to take full custody of the activity data to be modelled and licensed within the GFLI database according to GFLI standard. This would mean updating the datasets and any alterations to improve the datasets may be executed by GFLI.

For the preparation of the next step, please make sure the data contains a data quality rating, is available as lifecycle inventory, and has a lifecycle impact assessment (LCIA) format with the newest EF and ReCiPe methods.

For sectoral data-in projects, the completed form should be approved by the GFLI Technical Management Committee. Branded data-in project do not require approval of the GFLI Technical Management Committee.

5.3.3 Required information for review process

After filling in the application form, return it to the GFLI Secretariat, signing the license agreement and payment of the invoice, it is possible to start the review process. For the review process, the GFLI Secretariat would like to receive the following documents:

1. Data collection report (see paragraph 5.2.3)
2. LCIA results (xls.file)

3. LCI data

LCIA results

The LCIA results must be included in the GFLI-LCIA template. Please contact the GFLI secretariat to receive this template. To ensure smooth integration (if desired) into the GFLI-database and prevent any delay, please do not adjust the allocation tabs, naming of the impact categories or change orders of provided columns. The data-in provider or LCA-consultant should only fill in the required information in the cells designated for the particular information. GFLI provides guidelines for the following columns:

Products (Naming of the ingredients)

The GFLI database aims for consistent naming of ingredients to make comparisons easier. It is recommended to check the GFLI Excel database and/or datasets overview to consider a name aligned with similar ingredients. The naming follows, depending on the type of data, the category:

- Sectoral/regional datasets:
  [Product name], [product general or chemical name], [property or concentration], [system boundary (at farm/processing/storage/plant)], [ISO code for country/region], [allocation type (Economic/Energy/Mass)]
- Branded datasets:
  [Product name], [product general or chemical name], [property/concentration], [company name], [system boundary (at farm/processing/storage/plant)], [ISO code for country/region], [allocation type (Economic/Energy/Mass)]

Examples for naming can be found in Table 20.

Table 26 Examples of naming ingredients for the different types of datasets.

Product name	Type of data
Coconuts, dehusked, at processing/ID Economic	Sectoral/regional
Safflower seed hull (solvent), at processing/MX Energy	Sectoral/regional
Fat from animals, poultry, company name, at processing/NL Energy	Branded

For questions about the naming of the ingredient, please reach out to info@globalfeedlca.org. Note that the naming should be compatible for integration in LCA software tools.

Source

- Sectoral/regional datasets: The source details either an overall name related to the datasets or the research institute, organisation or consortium, or association name.
- Branded datasets: Naming of the source should be “Branded data”.

Year of publication

Year of publication refers to the year in which the dataset is published by GFLI.

<u>Nutritional values and DQR</u>
Both nutritional values (paragraph 3.2) and the DQR (see paragraph 2.10 and Annex 1) should be available. GFLI cannot proceed with the review process if nutritional values and DQR's are not available.

<u>Data on the impact categories</u>
Data for all three allocation methods (economic, energy, mass) for both EF3.1 and ReCiPe should be available.

<u>Process description</u>
The process description provides detailed information for the database-users, summarizing the most important features of the process behind the dataset. Goal of the process description is to clarify choices that have been made within a process, noteworthy choices due to remarkable circumstances and, if applicable, include the source (accessible for the database-users) substantiating a choice made during data collection. A maximum of 100 words is suggested for the process description. The following information should be included in the process description:

- For branded datasets: Specify the type and purpose of the ingredient.
- System boundaries;
- Reference year of the data, if data is collected over multiple years, please specify the complete reference time frame;
- Overall DQR;
- Short description of process(es) behind the dataset: argument why a process is included or purposely not included in the LCA.

Table 27 Examples of a correct process description.

Type of dataset	Process description
Sectoral/regional	Data was collected between 2023 and 2024. System boundary: cradle to farmgate. Overall DQR: 1.9. [Product name] is crushed to increase digestibility. No data about N-content was available, data from [source] was used.
Branded	[Product name] is a feed additive, developed to improve gut health of poultry. The system boundaries are from cradle to gate and the reference year of all primary data was 2024, for electricity data from 2025 was used. Overall DQR: 1.2. For […] 80% of data is derived from primary data, primary data for […] was unavailable, therefore adapted secondary data (20%) from [source] was used.

LCI data

The LCI data should be shared with the GFLI to ensure all process are correct included in the LCA. The GFLI does not have strict guidelines for data-in providers about sharing the LCI data. Possible options for sharing the LCI data are via a csv.file suitable for SimaPro users, a word document or an Excel file. The data-in provider will be notified by the GFLI internal reviewer in case essential parts of the LCI data is missing, the data-in provider has the opportunity to gather the information and reshare it with the GFLI.

5.3.4 GFLI Internal review

Upon completion of the data collection, the prepared documentation and data should be sent to the GFLI Secretariat for the internal review. The datasets in its final impact assessment form (LCIA template), the lifecycle inventory (LCI data), and supporting documents such as the data collection report and, if relevant, (part of) the project plan are reviewed.

The data is reviewed for:

- Consistency with GFLI methodology
- Completeness of numerical data (including DQR) & alignment with methods
- Completeness and clarity of qualitative descriptions in meta data
- Safeguarding methodological choices and emission models used

Feedback will be provided by the data provider, in which if the data is not consistent or complete, will be requested to adjust. When the data is aligned, the GFLI internal reviewer will provide a review statement in order for the data provider to proceed with the external review.

Before the external review, a basic check is done by an expert at GFLI (referred to as internal review). This check includes only high level principles of the GFLI database. To start with, the internal reviewer checks if data are complete for incorporation in GFLI and for external review. The internal reviewer will also check if the modelling at different tier levels is adequate enough. The following is a list of specific focus points for the internal review.

- Are the report and data available for review:
  - Is there a detailed LCA report including all required sections?
  - Are all required LCIA results reported (EF 3.1 and ReCiPe 2016 Midpoint H; Economic, Energy and Mass allocation)
  - Are the LCI data available?
- Are the main methodological requirements in the report in line with GFLI?
  - Is the LCA system boundary from cradle to gate?
  - Are all relevant processes included?
  - Are the secondary data sources in line with GFLI?
  - Is the use of primary, adapted secondary and secondary data in processes of the foreground system (including Tier 1 and Tier 2 suppliers) in line with the GFLI requirements?
  - Is the data sampling method in line with the GFLI requirements?
  - Are cultivation data based on 3-year average?
  - If emission modelling is relevant, what level is applied: default modelling (Tier 1) or higher Tier? Are the equations correct?
  - Is the data quality rating method applied in line with GFLI requirements (criteria, score per criterium, weighting factor, total score)?

So, if any of these requirements are not met, the applicant (data provider/LCA consultant) will be asked to adapt the LCA and/or provide additional data. This can take several rounds until the data and report are ready for external review. The external review checklist below partly overlaps the above "internal review" checklist to make sure the external review is complete.

After completion of the internal review, the data-in provider receives a 'GFLI Internal Review Statement'.

5.3.5 External review

The external review is a critical third-party review of the data collection process, the methodological choices made, and the documentation provided by the data provider, in order to verify the quality of the data as suggested in the documents and the end result (LCI, LCIA). The GFLI website (www.globalfeedlca.org) shortlists the current available external reviewers familiar with the GFLI methodology. The data provider may choose the reviewer and reach out individually, or in communications with the GFLI Secretariat. The list includes the expertise and location of the reviewer to allow for matching the expertise with the type of datasets to be reviewed. Relevant reviewing information can be found in the External Review Guidance document on the GFLI webpage: https://globalfeedlca.org/data-critically-reviewed/. The external review may also include suggestions for potential future improvements of the data, collection process, or data-in project.

The review is completed with a positive review statement of GFLI-compliancy in the data collection, modelling, and alignment. Any changes to the data based on the external review statement must be corresponded in a final review report, to be shared with the data manager for data integration. Please share after completion of the external review, the external review statement with the GFLI.

The external reviewer should be a proven LCA expert and have sufficient background knowledge of the feed ingredients in scope and meet the following requirements:

- performed at least 3 reviews of LCA/LCI datasets in the past 5 years;
- have at least 5 years of experience with LCA methodology and practice;
- have at least 3 years of experience in the private or public sector related to the feed ingredients or technologies.

The last two requirements may be met within an organisation in one or more persons.

5.3.6 Letter of confirmation (applicable for branded data-in providers)

After successfully completing the internal and external review for branded data, GFLI prepares a letter of confirmation which states the products that are fully aligned with the GFLI Branded Data methodology and can be used for communication with external parties.

Data-in providers for sectoral and regional datasets will not receive a letter of confirmation.

5.3.7 Integration into the GFLI database

The options for publication preferences are stated in the license agreement. Documents which should be shared with the GFLI for data integration vary among the desired preferences. In Table 28, the options for publication preferences for the type of data-in projects are provided. Multiple options are possible in case the data-in providers would like to share the data with both database-users as well as tool-developers.

Table 28 Different options for data integration into the GFLI database.

Publication preferences	Applicable for type of data	Files to be shared with GFLI
1) No publication - Data is not available in GFLI as LCIA format (xls.file), system or unit process level. - Product and DQR is mentioned on the GFLI website.	Branded	None
2) Share aggregated data with users - Data is available for all licensees as LCIA format (xls.file) in the GFLI database. - Data is shared on system process level (csv.file) and can be uploaded in SimaPro by LCI-licensees	Sectoral, regional and branded	LCIA (xls.file); LCI data on system process level (csv.file)
3) Share aggregated data for tooling - Data is available for all licensees as LCIA format (xls.file) in the GFLI database. - Data is shared on system process level (csv.file) and can be uploaded in SimaPro by developer-licensees, using the data for software development/tooling.	Sectoral, regional and branded	LCIA (xls.file); LCI data on system process level (csv.file)
4) Share disaggregated data with users - Data is available for all licensees as LCIA format (xls.file) in the GFLI database. - Data is shared on unit process level (csv.file) and can be uploaded in SimaPro by LCI-licensees	Sectoral, regional and branded	LCIA (xls.file); LCI data on unit process level (csv.file)
5) Share disaggregated data for tooling - Data is available for all licensees as LCIA format (xls.file) in the GFLI database. - Data is shared on unit process level (csv.file) and can be uploaded in SimaPro by developer-licensees, using the data for software development/tooling.	Sectoral, regional and branded	LCIA (xls.file); LCI data on unit process level (csv.file)

Sectoral and regional datasets

For sectoral and regional datasets, additional costs may apply and may range dependent on the data formatting. When the datasets are finalized and ready for integration, sectoral and regional datasets will be published separately onto the GFLI website until they are integrated into the database.

Branded datasets

After finalizing the data-in project and share the files necessary for database-integration, the data-in provider and corresponding naming of datasets and DQR will be mentioned on the GFLI website. Note that this also applies to data-in providers that prefer not to publish their data in the GFLI database.

Database updates

Integration of new datasets in the GFLI database is set to happen approximately twice a year, or earlier. The data provider will be informed when the datasets are available in the database.

5.3.8 Updating of data

All data in the GFLI database is subject to updates to upkeep the representativeness of the datasets and allow for improvements to show in the figures by the industry efforts of sustainable production.

Data updates are relevant due to the changing of activity data such as crop yield, fertilizer use, climatical and geographical changes, as well as innovations in technologies and processing. Within the GFLI database, this is measured through the Data Quality Rating (DQR). This measures the quality of the data based on four pillars: technological, geographical, and time representativeness, and precision (level of uncertainty of data derivation) in a rating from 1.0 to 5.0. When the DQR of a product becomes too high, therefore being insufficiently representative in the market, the product/dataset should be updated. GFLI follows the EC PEFCR guidelines, where accordingly a total DQR ***≤3.0*** for relevant processes in secondary data is desirable, with other processes needing a total DQR of ***≤4.0***. The DQR in the GFLI database will be updated every two years based on the time representativeness, with the current trajectory a dataset will lose relevancy in DQR measurements after four to six years.

The main contacts from the data-in projects will be contacted when their data is subject for an update. An estimated time for update may be included in the data collection report which may be referred for the update. Datasets not updated timely might be subject to a transition period, in which the data provider receives additional time to update the datasets in favour of not having them removed from the database. A data-in provider may decide to not update the data. In this case, the Technical Management Committee (TMC) may consider the continued existence of the datasets in the database beyond its 'end-date' when the datasets thusly remain relevant for database users. However, the data-in provider is within its rights to request removal of the datasets at any point in the future.

Any updated datasets are subject to the temporary publication on the GFLI website until a database update, meaning two of the same datasets may exist as GFLI-compliant.

Updating branded datasets

Branded data is moreover based on primary data and requires a faster turnover of new data to maintain its representativeness. Branded data should ideally be updated every two years. If the data-in provider does not manage to update the data within two years, the dataset(s) remain available in the GFLI-database but it's DQR will be increased due to a less favorable Time Representativeness.

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Annex 1 DQR method

1.1 Data quality system and indicators

The DQR for feed ingredients is measured based on 4 aspects:

- Precision
- Time representativeness
- Technological representativeness
- Geographical representativeness

To evaluate the DQR a division needs to be made in type of data and how they are interrelated. Moreover, the data quality shall be determined on a cradle to gate process considering the contribution of data points to the overall environmental impact.

The DQR evaluation includes activity data and the background data they relate with, being production of goods such as transport and electricity and combustion of fuels or other chemical conversion during processing. This gives the following set of evaluation points.

Table 1-1. DQR criteria used in connection to activity data and background data for production and combustion/conversion.

Data type	DQR criterion
Activity data	Precision: P
	Time Representativeness: TiR
	Technology Representativeness: TeR
	Geographical Representativeness: GeR
Background data*	Time Representativeness: TiR
	Technology Representativeness: TeR

*For background data usage, the validity as indicated in the database may be upheld (for example, in EcoInvent if it states a validity until 2020, that means 2020 may be used as reference year for this data point).

The scoring of the DQR is determined based on a rating system derived from the DQR system applied in the PEF. Tabel 1-2 gives an overview of the criteria for the rating.

Table 29. DQR criteria matrix

	Activity data				Production of goods		Combustion/Con version of goods	
	P	**TiR**	**TeR**	**GeR**	**Tir**	**Ter**	**Tir**	**Ter**
1	Measured/ calculated and verified	Data (at collection) is maximum 2 years older than the "reference year" of the GFLI database version	Technology of source data is the same as described in the title and meta data of the GFLI dataset.	Geography of source data is the same as geography stated in the "location" indicated in the meta data of the GFLI dataset	Reference year of the source data is maximum 2 year older than the reference year of the GFLI database version	Technology of source data is the same as described in the title and meta data of the GFLI dataset.	Reference year of source data is maximum 2 year older than the reference year of the GFLI database version	Technology of source data is the same as described in the title and meta data of the GFLI dataset.
2	Measured/ calculated/ literature and plausibility checked by reviewer	Data (at collection date) is maximum 4 years older than the "reference year" of the GFLI database version.	Technology of source data is very similar as to what is described in the title and meta data. (use of generic technology data instead of modelling all the single plants.)	Geography of source data is representative for the geography stated in the "location" indicated in the meta data	Reference year of source data is maximum 4 years older than the reference year of the GFLI database version	Technology of source data is very similar to what is described in the title and meta data. (use of generic technology data instead of modelling all the single plants.)	Reference year of the used dataset is maximum 4 years older than the reference year of the GFLI database version	Technology of source data is very similar to what is described in the title and meta data (use of generic technologies' data instead of modelling all the single plants).
3	Measured/ calculated/ literature and plausibility not checked by reviewer OR Qualified estimate based on calculations plausibility checked by reviewer	Data (at collection date) can be maximum 6 years older than the "reference year" of the GFLI database version.	Technology of source data is similar to what is described in the title and meta data but merits improvements. Some of the relevant processes are not modelled with specific data but using proxies.	Geography of source data is sufficiently representative for the geography stated in the "location" indicated in the meta data. E.g. the represented country differs but has a very similar electricity grid mix profile.	Reference year of the source data is maximum 6 years older than the reference year of the GFLI database version	Technology of source data is similar to what is described in the title and meta data but merits improvements. Some of the relevant processes are not modelled with specific data but using proxies.	Reference year of the source data is maximum 6 years older than the reference year of the GFLI database version	Technology of source data is similar to what is described in the title and meta data but merits improvements. Some of the relevant processes are not modelled with specific data but using proxies.

	Activity data				Production of goods		Combustion/Con version of goods	
	P	TiR	TeR	GeR	Tir	Ter	Tir	Ter
4	Qualified estimate based on calculations. plausibility not checked by reviewer	Data (at collection date) can be maximum 8 years older than the "reference year" of the GFLI database version.	Technology of source data is different from what is described in the title and meta data. Requires major improvements.	The included dataset is only partly representative for the geography stated in the "location" indicated in the meta data. E.g. the represented country differs and has a substantially different electricity grid mix profile	Reference year of the source data is maximum 8 years older than the reference year of the GFLI database version	Technology aspects are different from what is described in the title and meta data. Requires major improvements.	Reference year of the source data is maximum 8 years older than the reference year of the GFLI database version	Technology aspects are different from what is described in the title and meta data. Requires major improvements.
5	Rough estimate with known deficits	Data (at collection date) can be maximum 10 years older than the "reference year" of the GFLI database version.	Technology aspects are completely different from what is described in the title and meta data. Substantial improvement is necessary	The processes included in the dataset are not representative for the geography stated in the ""location" indicated in the meta data.	Reference year of the source data is maximum 10 years older than the reference year of the GFLI database version	Technology aspects are completely different from what is described in the title and meta data. Substantial improvement is necessary	Reference year of the source data is maximum 10 years older than the reference year of the GFLI database version	Technology aspects are completely different from what is described in the title and meta data. Substantial improvement is necessary

1.2 Data quality of agricultural processes

The approach for agriculture is closely related to how LCI data are generated for cultivation. The DQR of cultivation as a cradle to gate process can be defined as a function of the DQR of background data (production of goods & combustion of fuels) activity data and modelling elementary flows. We only consider the DQR of the activity data in combination with its background data and not the quality of modelling.

Activity data for agriculture can be split into:

Data that determine the quantity of elementary flows per baseline production unit (hectare)

- Data that are used for the scaling of the baseline production unit to the feed ingredient (yield and allocation)

Tabel 1-3 gives an overview of activity data and how the DQR is calculated.

Table 30. Activity data mentioned in the Formula and how they relate to environmental impact and DQR.

Abbr	Name	Environmental impact	DQR
Fu	Fuel use [kg/l per ha]	Quantity in combination with production and combustion determines total impact. Production data come from EC T&E dataset. Combustion in agricultural machinery comes from AFP and Agribalyse datasets.	Mathematical average of: 1. Production (Ter, Tir) 2. Use quantity (Ter.Tir. Gr. P) 3. Combustion data (Ter. Tir)
Eu	Electricity use [kwh/ha]	Quantity times production data (country specific)	Mathematical average of: 1. Production (Ter, Tir) 2. Use quantity (Ter.Tir. Gr. P)
F	Fertilizer use [kg product/ha]	Quantity times production data (AFP data sets and Ecoinvent datasets)	Mathematical average of: 1. Production (Ter.Tir) 2. Use quantity (Ter.Tir. Gr. P)
Fo	Organic fertilizer use [kg product/ha]	Quantity times production data (AFP data set)	Mathematical average of: 1. Production (Ter.Tir) 2. Use quantity (Ter.Tir. Gr. P)
L	Lime use [kg $CaCO_3$/ha]	Quantity times production data (Ecoinvent data set)	Mathematical average of: 1. Production (Ter.Tir) 2. Use quantity (Ter, TiR, GR, P)
Su	Seed use	Quantity times production data (AFP)	Mathematical average of: 1. Production (Ter.Tir) 2. Use quantity (Ter.Tir. Gr. P)
Pu	Pesticides use	Quantity times production data (AFP)	Mathematical average of: 1. Production (Ter.Tir)

			2. Use quantity (Ter.Tir. Gr. P)
Wu	Water use	Quantity	1. Use quantity
CG	Capital Goods depreciation	Quantity times production data (AFP)	Mathematical average of: 1. Production (Ter.Tir) 2. Use quantity (Ter.Tir. Gr. P)
Yield	Yield [kg/ha]	Quantity	Quantity
Allocation data	Mass* value Crop rotation	Allocation fractions derived from several data (see annex 4)	Quantity

To determine the relevance of the activity data amongst each other and relative to yield and allocation a contribution analysis has been conducted for four main crops with datasets that we know are relatively complete: wheat UK; Soy BR. Maize FR and Rapeseed DE. The impact of allocation has been set on default on 2.5% (allocation involves co-product allocation and crop rotation allocation). The impact of yield is set equal to land occupation plus the impact of crop residues and is on average 12.5%.

The average contribution of activity data of these four crops shall be applied for all crops as an average weight factor for DQR contribution. These results provide an accurate estimate of the relevant importance of the lifecycle impact related to the activity data in this case.

1.3 Data quality of processing agricultural products

The environmental impact of processing a crop is determined by 9 activity data of which 4 data points can be seen as scaling or context data such as the mass balance, allocation data, crop mix and transport modalities mix. The other activity data, such as use of crops, energy, water, and other raw materials are directly related to the type of crop extraction/splitting technology.

Table 1-4. Activity data of crop processing.

Activity data	Relation to elementary flows and impact
Mass balance	Scales and divides over co-products
Allocation data	Divides over co-products
Crop mix	Determines which crops and their impacts are considered and scales the relative impact of contribution of crops
Transport modalities mix	Determines the environmental intensity of transport
Production of crops	Quantity and Connection to background data
Transport	Quantity and Connection to background data
Fuel use	Quantity and Connection to background data
Electricity use	Quantity and Connection to background data
Water use	Quantity and Connection to background data
Other raw materials use	Quantity and Connection to background data

Mass balance data of crop processing can vary due to the composition of the raw materials and technology parameters. For instance, the mass balance of dry milling is dependent on the grain constitution and the average amount of grinding runs. Both the composition of the grain and the amount of grinding runs can vary over time. The composition of grains relates to climate conditions and the number of runs relates to market conditions. The information on mass balances is often collected as a specific data point and separately maintained from other data points such as energy use.

Allocation data points are prices or energy values by which the masses of co-products are multiplied. Energy content values can vary in relation to the composition of the incoming crops and the technology parameters. Prices vary on top of that in relation to market conditions. Prices of coproducts are also dependent on the location of production. The bigger the distance to international harbors and export markets the lower the price for the co-product at location of production. Allocation prices are therefore standardized and reflect an average situation relevant for the EU market. Prices for economic allocation need to be updated regularly.

Both the mass balance and the price determine the amount of elementary flows assigned to a certain co-product.

Crop mixes and transport modality mixes are also not technology-dependent but defined by the location of processing and the market of supply of crops. Some processing facilities are located quite nearby to the crop. This is mostly the case when the crop is voluminous or contains considerable water amounts so that transport is expensive. Examples are sugar beets, cane and potatoes, while other crops such as seeds, beans and grains can be transported long distances for processing. The data on origin of crops are important due to the variability in the environmental impacts of crops. These data are derived by analysis of production, import and export statistics. This also holds for the scenarios of transport distances and transport modalities. The baseline approach is a statistical analysis. For several processes, more accurate data can be collected from country statistics, literature, or business information.

1.4 Data quality of other processes

The DQR of the production of animal-based products is based on the same methodology as for processed crops, where the following activity data and its production processes are evaluated.

Table 1-5. Activity data of animal processing.

Activity data	Relation to elementary flows and impact
Mass balance	Scales and divides over co-products
Allocation data	Divides over co-product
Origin mix of animal raw materials	Defines relative impact of animal production/ fishing
Transport modalities mix	Determines the environmental intensity of transport

Production of animal products (fishing included)	Quantity and Connection to background data
Transport	Quantity and Connection to background data
Fuel use	Quantity and Connection to background data
Electricity use	Quantity and Connection to background data
Water use (if relevant)	Quantity and Connection to background data
Other raw materials use (if relevant)	Quantity and Connection to background data

Annex 2 Default allocation factors

Table 2-1. Default economic allocation factors based on value per ton of product. Those indicated with a [1] are based on FAOstat (FAOstat, 2025) (Blonk, 2025)

Process	Processing method	Outputs	Value/ton	Default
Palm fruit bunch crushing		Palm oil	960[1]	81.5%
		Palm kernel	790[1]	18.5%
Groundnut crushing	solvent	Crude peanut oil	1351[1]	79.4%
		Groundnut meal	333[1]	20.6%
Linseed crushing	solvent	Crude linseed oil	1210[1]	51.8%
		Linseed meal	616[1]	48.2%
Linseed crushing	pressing	Crude linseed oil	1210[1]	42.6%
		Linseed expeller	616[1]	57.4%
Maize wet milling, germ oil production	pressing	Crude maize germ oil	1091[1]	66.4%
		Maize germ meal expeller	278[1]	33.6%
Maize wet milling, germ oil production	solvent	Crude maize germ oil	1091[1]	75.3%
		Maize germ meal extracted	278[1]	24.7%
Palm kernel crushing		Crude palm kernel oil	1090[1]	89.3%
		Palm kernel expeller	116[1]	10.7%
Rapeseed crushing	pressing	Crude rapeseed oil	897[1]	59.8%
		Rapeseed expeller	275[1]	40.2%
Rapeseed crushing (EU)	solvent	Crude rapeseed oil	897[1]	70.1%
		Rapeseed meal	275[1]	29.9%
Rapeseed crushing (nonEU)	Solvent	Crude rapeseed oil	897[1]	73.0%
		Rapeseed meal	275[1]	27.0%
Rice bran oil production		Crude rice bran oil	1564[1]	34.6%
		Rice bran meal	480[1]	65.4%
Soybean crushing	pressing	Crude soybean oil	776[1]	24.7%
		Soybean expeller	400[1]	75.3%
	solvent, with	Crude soybean oil	776[1]	11.3%

Soybean crushing	protein-concentrate			
		Soybean hull	125	0.7%
		Soybean molasses	35	0.8%
		Soybean protein-concentrate	2000	87.2%
Soybean crushing (EU)	solvent	Crude soybean oil	776[1]	32.2%
		Soybean meal	4001	67.8%
Soybean crushing (nonEU)	solvent	Crude soybean oil	7761	33.6%
		Soybean meal	4001	64.3%
		Soybean hull	125	2.1%
Sunflower seed crushing	pressing	Crude sunflower oil	8661	68.8%
		Sunflower seed expelled dehulled	2091	31.2%
		Sunflower hull	0	0.0%
Sunflower seed crushing	solvent	Crude sunflower oil	8661	77.2%
		Sunflower seed meal	2091	22.8%
		Sunflower hull	0	0.0%
Maize dry milling		Maize flour	4121	75.1%
		Maize middlings	200	24.9%

Annex 3 Default modelling of agriculture

3.1 'Cradle' start material

Start material is the starting input, such as seeds. In case the amount of 'cradle' material is not reported, crop specific defaults will be used to include the amount of start material and its impact. The amount of this material is derived from FAO statistics based on 3 or 5 year-average of seed use globally divided by the 3 or 5 year-average of agricultural area of that specific crop. An overview of the quantified average seed use for the most common feed crops is shown the Table 25 below.

Table 3.1. Global average seed input for common feed crops.

Crop	Start material (kg/ha)
Barley	172.3
Broad bean	88.3
Groundnuts	73.1
Linseed	36.9
Lupins	62.8
Oats	265.9
Peas	139.7
Rye	235.1
Soybeans	65.4
Sunflower seed	27.1
Wheat	152.8

3.2 Pesticides

The default Pesticides application rates are following the Agri-footprint 7.0 methodological approach (Blonk, 2025). The following is a copy from Appendix I pesticides model:

The model database (1) is based on national statistics available on NPK land application per country (IFA, 2025), production and harvested area of country-crop combinations (FAO, 2025a) and estimates of fertilizer use by crop category per country (IFA, 2022). In particular, the last cited study allowed to derive from the overall NPK use in a specific country (IFA, 2022), average 2028-2022), how much was used for cultivation of crops (4) (wheat, rice, maize, soybean and oil palm) and crop groups (2) (other cereal, other oil seed, fibre crops, sugar crops, roots & tuber, fruits and vegetables). For the fertilizer use by crop group in a specific country a model was developed (3). For each country/crop group combination three (for N, P2O5 and K2O) parameter R (kg/kg) requirement are calculated:

$$RNPK = \frac{kgNPK}{\sum(kg_{prod,c} * DM_c)}$$

where kg_{NPK} is the kg of N, P2O5 or K2O used for a certain country/crop group combination,
$kgprod.c$ is the production in kg of the specific crop c and DMc is the dry matter content (kg/kg) of the specific crop c. The dry matter content was retrieved from (USDA, 2019), (RIVM, 2016) and in the few cases from literature.
The parameter R represent how much NPK is required to have 1 kg of solids as output. It is then multiplied by the dry matter yield (FAOSTAT data * DM content) to calculate the NPK application per hectare (5). For the one-crop groups was possible derive the NPK application directly (5), by dividing the fertilizer use by crop in a specific country by the production area reported by FAOstat for the specific country-crop combination (average 2013-2017).
The chosen option avoids allocating NPK to a crop just because contain high water contents, this is relevant for oilseed (specifically coconuts and olives) and for fruit and vegetables, that show a large variability in water content. Another discarded option was calculating NPK use per kg of specific nutrient (NPK). Calculating the NPK application based on the NPK extraction from field is a common agricultural practice. The option of further considering NPK content was discarded due to the high uncertainty and variability in NPK content, even between the same crop in different countries or cultivation practices.
The source IFA provides data for specific crops and for crop groups, making the accuracy on the statistical results more complex for fruits and vegetables, due to the high variation of NPK doses between crops of the same crop-group.
Since the estimation are based on global statistics from two different source, we considered the possibility of inconsistent or unrealistic estimates. This is more relevant for low produced crops (inconsistency between IFA percentages per crop and FAO harvested areas), rare for largely produced crop. Cut off criteria were therefore selected based on previous literature search performed by Blonk Consultants (6).
Example:
*-Synthetic fertilizer use is: **12.13** kg N, 11.26 kg P205 and **2.02** kg K2O equivalents, based on NPK model.*
*-Synthetic fertilizer use is: **270.00** kg N, 0.00 kg P205 and **160.00** kg K2O equivalents, based on KWIN 2015 table 6.3.7.*

Other countries excluded from the scope of the model are the one included by (IFA, 2022) in Rest of the World. Pulses, tree nuts, coffee, cocoa and tea are included in the group "residual" in the cited report, together with other non-agricultural uses. It was therefore not possible to disaggregate these fertilizer uses. Even though grass is a disaggregated NPK use in the cited report, FAO surface data on how much grass surface is naturally growing, and how much is cultivated are incomplete. Pulses, tree nuts, coffee, cocoa, tea and grass are therefore out of the scope of the model. NPK application for out of scope country-crop combinations are based on literature (Pallière, 2011; Rosas, 2011).
Another limitation of the model is related to legumes. Three crops included in the vegetable crop group are indeed legumes (green peas and green beans). But since the N application is based on solids extraction from field, it does not account for the fact that nitrogen is fixated by the plants. This usually results in lower N application on field. The

option of including a N fixation rate of the specific legume was investigated but discarded due to low data reliability.

To match these total N, P and K application rates (7), to specific fertilizer types (e.g. Urea, NPK compounds, super triple phosphate etc.), data on regional fertilizer consumption rates from (IFA, 2025) were used (8).

Some fertilizers supply multiple nutrient types (for example ammonium phosphate application supplies both N and P to agricultural soil). In IFA statistics (IFA, 2025), the share of ammonium phosphate is given as part of total N and also as part of total P supplied in a region. To avoid double counting, this dual function was taken into account. Therefore, the following calculation approach was taken:

1. A fertilizer type is considered in isolation (e.g. only Potassium supplying fertilizers, or only Nitrogen). The relative shares of the specific fertilizers were calculated for a crop (e.g. if a crop A in Belgium requires 10 kg K/ha, 35% is supplied from NPK, 52% from Potassium Chloride and 11% from Potassium Sulfate). However, some fertilizers supply nutrients of different types (e.g. both N and P or N, P and K). The amounts of other nutrients supplied are subtracted from the total nutrient requirements.
2. Next, the share of the second fertilizer type is calculated, taking into account the amount of nutrient supplied by multi-nutrient fertilizers from the previous step. Again, other nutrients supplied are subtracted from the requirements for the last fertilizer type.
3. For the remaining nutrient, the single nutrient supplying fertilizers are used (as NPK and ammonium phosphate etc. are already considered during previous calculation steps).

In this approach, there are 6 different calculation routes (K then P then N, K then N then P and so forth). For most cases, these routes all yield similar answers. However, in some extreme cases (e.g. no K supplied, and high amount of N supplied), there is a risk of calculation negative application rates when the calculation starts with the nutrient with the highest quantity supplied (i.e. for most crops this would be N). For example, if an overall crop requirement is 100 kg N, 10 kg P and 0 kg K and the calculation is started with calculation the specific shares of N fertilizers first, the calculation results in a certain amount of NPK fertilizer being applied. However, as K requirement is zero, this cannot be true. However, if one starts with the smallest nutrient type being applied (in this case 0 kg K), no NPK will be applied, and the other nutrient requirements can be supplied by pure N and P or NP fertilizers.

For consistency, the approach used for Agri-footprint is therefore to determine the order of N, P and K from smallest to largest for each specific crop/country combination and use that order for the calculation (9). E.g. for a crop requiring N:60 kg, P:20 kg, K: 30 kg, the calculation starts with calculating the shares of specific fertilizers for P then K and finally N.

3.3 Default emission modelling for GFLI

The default emission modelling GFLI follows is from Agri-Footprint. The following information comes directly from the methodology (Blonk, 2025). Table 3-2 gives an overview of what emissions are considered and which methods are used to quantify the emission flow. Besides this, not all emissions are considered for the most important aspects. For instance, laughing gas emissions are quantified for fertilizer inputs, manure inputs and crop residues, but is "not applicable" for lime inputs. Please note that ammonia emissions from manure is based on the tier 1 IPCC methods, whereas for fertilizer use ammonia emissions are based on the more detailed method described in EMEP/EEA.

Table 3-2 Overview of modelled emissions, literature source and which aspects are included for the calculations.

Emission	Level	Method	Fertilizer	Manure	Crop residues	Lime
(In)direct laughing gas emissions	Tier 1	IPCC (IPCC, 2019)	Yes	Yes	Yes	-
Ammonia emissions	Tier 1		No	Yes	No	-
Nitrate emissions	Tier 1		Yes	Yes	Yes	-
Carbon dioxide emissions	Tier 1		Yes	-	-	Yes
Nitrogen monoxide emissions	Tier 1	EMEP/EEA (European Environment Agency, 2016)	Yes	Yes	No	-
Ammonia emissions	Tier 2		Yes	No	No	-
Phosphorus emissions		ReCiPe (Huijbregts, 2016)	Yes	Yes	No	-
Heavy metal emissions		Nemecek & Schnetzer (Nemecek and Schnetzer 2011)	Yes	Yes	Yes	Yes

Some emissions are specifically for a certain crop or item, these include:

- Methane emissions for rice cultivation

3.4 Nitrous oxide (N_2O) emissions

There are a number of pathways that result in nitrous oxide emissions, which can be divided into direct emissions (release of N_2O directly from N inputs) and indirect emissions (N_2O emissions through a more intricate mechanism). Beside nitrous emissions due to N additions, there are other activities that can result in direct nitrous oxide emissions, such as the drainage of organic soils, changes in mineral soil management, and emissions from urine and dung inputs to grazed soils. These latter two categories are not taken into account in the crop cultivation models, as it is assumed that crops are cultivated on cropland remaining cropland and the organic matter contents of the soils does not substantially change, and that cropland is not grazed. The emissions from grazing of pastureland are however included in the animal system models. The following equations and definitions are derived from IPCC methodologies on N_2O emissions from managed soils;

$$N_2O - N_{direct} = N_2O - N_{Ninputs} + N_2O - N_{OS} + N_2O - N_{PRP}$$

Where,
$N_2O{-}N_{Direct}$ = annual direct $N_2O{-}N$ emissions produced from managed soils, [kg $N_2O{-}N$]
$N_2O{-}N_{N\ inputs}$ = annual direct $N_2O{-}N$ emissions from N inputs to managed soils, [kg $N_2O{-}N$]
$N_2O{-}N_{OS}$ = annual direct $N_2O{-}N$ emissions from managed organic soils, [kg $N_2O{-}N$]
$N_2O{-}N_{PRP}$ = annual direct $N_2O{-}N$ emissions from urine and dung inputs to grazed soils, [kg $N_2O{-}N$]

Note that the unit kg N_2O-N should be interpreted as kg nitrous oxide measured as kg nitrogen. In essence, Equation to Equation 5 describe nitrogen balances. To obtain [kg N_2O], [kg N_2O-N] needs to be multiplied by $\left(\frac{44}{28}\right)$, to account for the mass of nitrogen (2*N, atomic mass 14) within the mass of a nitrous oxide molecule (2*N+1*O, atomic mass 16). See Table 28 for a list of emissions factors and constants.

The N_2O emissions from inputs are driven by four different parameters; the application rate of synthetic fertilizer, application of organic fertilizer (e.g. manure), amount of crop residue left after harvest, and annual release of N in soil organic matter due to land use change. The latter was incorporated in the aggregated emissions from land use change.

In addition to the direct emissions, there are also indirect emission pathways, in which nitrogen in fertilizer is first converted to an intermediate compound before it is converted to N_2O (e.g. volatilization of NH_3 and NO_x which is later partly converted to N_2O). The different mechanisms are shown schematically in Figure 5.

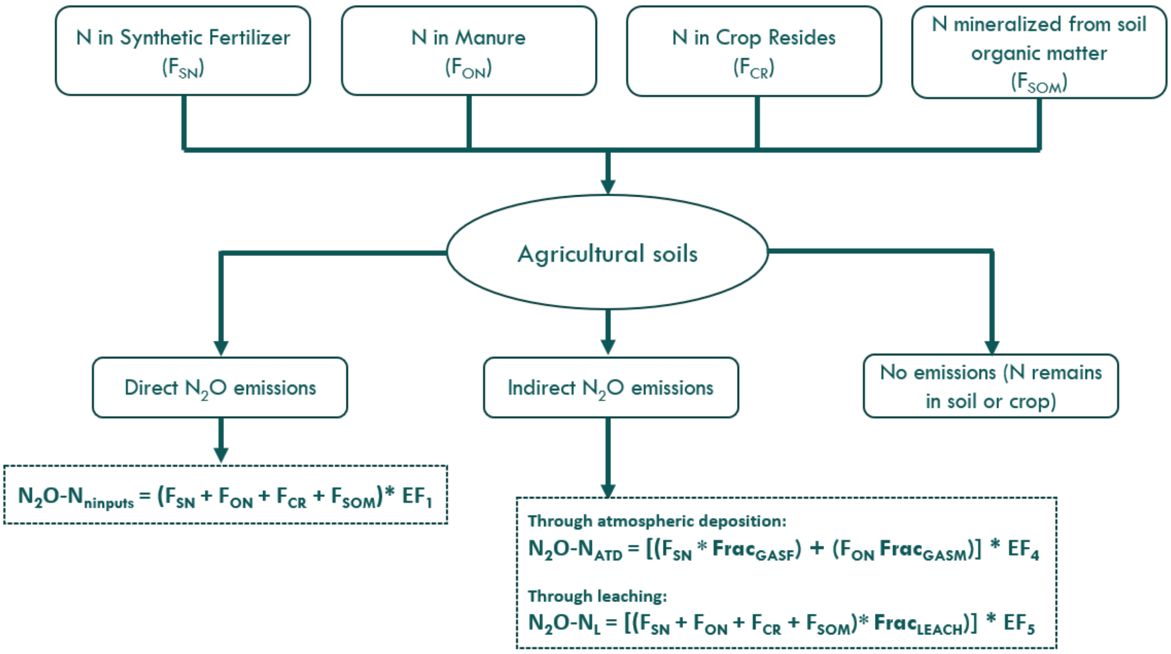

Figure 3-3. Nitrous oxide emission (direct and indirect) due to different N inputs (IPCC, 2019)

The equations listed in Figure 3-5 will be discussed in more detail below. First, the major contribution from direct emissions of N_2O is from N inputs:

$$N_2O - N_{Ninputs} = (F_{SN} + F_{ON} + F_{CR} + F_{SOM}) * EF_1$$

Where,
F_{SN} = the amount of synthetic fertilizer N applied to soils, [kg N]
F_{ON} = the amount of animal manure, compost, sewage sludge and other organic N additions applied to soils, [kg N]
F_{CR} = the amount of N in crop residues (above-ground and below-ground), including N-fixing crops (leguminous), and from forage/pasture renewal, returned to soils, [kg N]
F_{SOM} = the amount of N in mineral soils that is mineralized, in association with loss of soil C from soil organic matter as a result of changes to land use or management, [kg N]
EF_1 = emission factor for N_2O emissions from N inputs, $[\frac{kg\ N_2O-N}{kg\ N\ input}]$

As mentioned before, the contribution of F_{SOM} is incorporated in the emissions from land use change. F_{CR} is dependent on the type of crop and yield and is determined separately. The IPCC Guidelines for National Greenhouse Gas Inventories (IPCC, 2019) provides guidance on how to do this using an empirical formula and data for a limited number of crops and crop types. The emission factor EF_1 in Equation 1 has a default value of 0.01 (i.e. 1% of mass of N from fertilizer and crop residue will be converted to N_2O).

In GFLI the direct N_2O emissions are modelled according to the IPCC Tier 1 approach. The uncertainty range of the EF_1 emission factor is very high (0.003 – 0.03) because climatic conditions, soil conditions and agricultural soil management activities (e.g. irrigation, drainage, tillage practices) affect direct emissions.

F_{SN} has been determined using mainly data from Pallière (2011). The contribution of F_{ON} has been determined on a country basis, as described in the methodology report of the Feedprint study (Vellinga T. V., 2013), which formed the basis of the crop cultivation models in this study.
There are two other, indirect, mechanisms that also contribute to the total N_2O emissions:

$$N_2O - N_{indirect} = N_2O_{(ATD)} - N + N_2O_{(L)} - N$$

Where,
$N_2O_{(ATD)}-N$ = amount of N_2O-N produced from atmospheric deposition of N volatilized from managed soils, [kg N_2O-N]
$N_2O_{(L)}-N$ = annual amount of N_2O-N produced from leaching and runoff of N additions to managed soils in regions where leaching/runoff occurs, [kg N_2O-N]

The amount of N_2O that is emitted through atmospheric deposition depends on the fraction of applied N that volatizes as NH_3 and NO_x, and the amount of volatized N that is converted to N_2O:

$$\mathrm{N_2O - N_{ATD}} = [(\mathrm{F_{SN}} * \mathrm{Frac_{GASF}}) + ((\mathrm{Fon} + \mathrm{Fprp}) * \mathrm{FracGASM})] * \mathrm{EF_4}$$

Where,
F_{SN} = annual amount of synthetic fertilizer N applied to soils, [kg N]
F_{ON} = annual amount of animal manure, compost, sewage sludge and other organic N additions applied to soils, [kg N]
$Frac_{GASF}$ = fraction of synthetic fertilizer N that volatilizes as NH_3 and NO_x, $\left[\frac{kg\ N\ volatilized}{kg\ N\ applied}\right]$
$Frac_{GASM}$ = fraction of applied organic N fertilizer materials (F_{ON}) and of urine and dung N deposited by grazing animals (F_{PRP}) that volatilizes as NH_3 and NO_x, $\left[\frac{kg\ N\ volatilized}{kg\ N\ applied\ or\ deposited}\right]$
EF_4 = emission factor for N_2O emissions from atmospheric deposition of N on soils and water surfaces, $\left[\frac{kg\ N_2O-N}{kg\ NH_3-N + NO_x-N\ volatilized}\right]$
F_{PRP} = annual amount of urine and dung N deposited by grazing animals on pasture, range and paddock, [kg N]

No mixed enterprise farming systems are considered. Therefore, in the crop cultivation models, F_{PRP} was set to 0 (no urine and dung from grazing animals). However, emissions from grazing were taken into account in the animal systems, where appropriate. The default emission factor EF_4 and the default fractions are listed in Table 28. The equation below shows the calculation procedure for determining N_2O emission from leaching of applied N from fertilizer (SN and ON), crop residue (CR), grazing animals (PRP) and soil organic matter (SOM).

$$N_2O - N_L = \left[(F_{SN} + F_{ON} + F_{PRP} + F_{CR} + F_{SOM}) * Frac_{LEACH-(H)}\right] * EF_5$$

$Frac_{LEACH-(H)}$ = fraction of all N added to/mineralized in managed soils in regions where leaching/runoff occurs that is lost through leaching and runoff, $\left[\frac{kg\ N}{kg\ of\ N\ additions}\right]$
EF_5= emission factor for N_2O emissions from N leaching and runoff, $\left[\frac{kg\ N_2O-N}{kg\ N\ leached\ and\ runoff}\right]$

3.5 Ammonia (NH_3) and nitrate (NO_{3-}) emissions – tier 1

Again, the IPCC calculation rules (IPCC, 2019) were applied to determine the ammonia and nitrate emissions. This approach of modelling ammonia volatilization was used only for emissions from manure; the ammonia volatilization from inorganic fertilizer was indeed modelled following EMEP/EEA guidelines. It was assumed that all nitrogen that volatizes converts to ammonia, and that all nitrogen that leaches is emitted as nitrate. In essence, Equation 4 & Equation 5 are the same as the aforementioned equations for nitrous emissions from atmospheric deposition and leaching (Equation 2 & Equation 3) but without the secondary conversion to nitrous oxide.
Ammonia (NH_3) emissions:

$$NH_3 - N = (F_{SN} * Frac_{GASF}) + ((F_{ON} + F_{PRP}) * Frac_{GASM})$$

Equation 1

Where,
NH_3-N = ammonia produced from atmospheric deposition of N volatilized from managed soils, [kg NH_3–N]

Nitrate (NO_3^-) emissions to water:

$$NO_3^- - N = (F_{SN} + F_{ON} + F_{PRP} + F_{CR} + F_{SOM}) * Frac_{LEACH-(H)} * Frac_{wet}$$

Equation 2

Where,

NO_3^--N = nitrate produced from leaching of N from managed soils, [kg NO_3^--N]

The IPCC includes a note "that in the Tier 1 method, for wet climates or dry climate regions where irrigation (other than drip irrigation) is used, the default $Frac_{leach}$ is 0.24. For dry climates, the default $Frac_{leach}$ is zero." Now including a $Frac_{wet}$ to better quantify the nitrate emissions that are taken place in agricultural systems. The $Frac_{wet}$ represents the share of wet climate within a country, data is taken from the land use change tool (Blonk Consultants, 2021).

3.6 Carbon dioxide (CO_2) emissions

Carbon dioxide emissions from lime, dolomite and urea containing compounds are included in the inventory. Both lime and dolomite are resources of fossil origin. Carbon dioxide emissions from urea containing compounds are included as well since: "CO_2 removal from the atmosphere during urea manufacturing is estimated in the Industrial Processes and Product Use Sector (IPPU Sector)" (IPCC, 2019). In GFLI, two urea containing compounds are present: urea (which is 100% urea) and liquid urea ammonium nitrate solution (which contains 36.6% urea).

CO_2 emissions from limestone, dolomite and urea containing compounds:

$$CO_2 - C_{em} = (M_{Limestone} * EF_{Limestone}) + (M_{Dolomite} * EF_{Dolomite}) + (M_{Urea} * EF_{Urea})$$

Equation 3

Where,

CO_2–C_{em} = C emissions from lime, dolomite and urea application, [kg C]

$M_{limestone}$, $M_{dolomite}$, M_{urea} = amount of calcic limestone ($CaCO_3$), dolomite ($CaMg(CO_3)_2$) or urea respectively, in [kg]

$EF_{limestone}$, $EF_{dolomite}$, EF_{urea} = emission factor, $\left[\frac{kg\ C}{kg\ of\ limestone, dolomite\ or\ urea}\right]$

Default emission factors are reported in Table 3-6.

3.7 IPCC tier 1 emissions factors and constants

Table 3-4. IPCC Tier 1 emission factors and constants.

IPCC Tier 1 Emission factors and constants [and units]	Value [IPCC 2006]	Value [IPCC 2019]
$EF_1 \left[\frac{kg\ N_2O - N}{kg\ N_{applied}}\right]$	0.01	0.01
$EF_4 \left[\frac{kg\ N_2O - N}{kg\ N_{volatized}}\right]$	0.01	0.01
$EF_5 \left[\frac{kg\ N_2O - N}{kg\ N_{leached}}\right]$	0.0075	0.011
$EF_{Dolomite} \left[\frac{kg\ CO_2 - C}{kg\ Dolomite}\right]$	0.13	0.13
$EF_{Lime} \left[\frac{kg\ CO_2 - C}{kg\ lime}\right]$	0.12	0.12
$EF_{Urea} \left[\frac{kg\ CO_2 - C}{kg\ Urea}\right]$	0.2	0.2
$Frac_{GASM} \left[\frac{kg\ NH_3 - N}{kg\ N_{in\ manure\ applied}}\right]$	0.2	0.21
$Frac_{GASF} \left[\frac{kg\ NH_3 - N}{kg\ N_{in\ fertilizer\ applied}}\right]$	0.1	0.11
$Frac_{LEACH} \left[\frac{kg\ NO_3^- - N}{kg\ N_{applied}}\right]$	0.3	0.24
Conversion from kg CO2-C to kg CO2	$\left(\frac{44}{12}\right)$	$\left(\frac{44}{12}\right)$
Conversion from kg N2O-N to kg N2O	$\left(\frac{44}{28}\right)$	$\left(\frac{44}{28}\right)$
Conversion from kg NH3-N to kg NH3	$\left(\frac{17}{14}\right)$	$\left(\frac{17}{14}\right)$
Conversion from kg NO3--N to kg NO3-	$\left(\frac{62}{14}\right)$	$\left(\frac{62}{14}\right)$

3.8 Nitric Oxide (NO) emissions

In GFLI, nitric oxide emissions from fertilizer use are considered. Although nitric oxide is produced as an intermediate product of the nitrification and denitrification processes, no methodology has been developed in the IPCC guidelines of 2006 to quantify its emission. A default value of 0.04 kg NO_2 per kg of N fertilizer and kg N from manure applied is used for GFLI (European Environment Agency, 2016).

3.9 Ammonia (NH_3) emissions – tier 2

For ammonia emissions from inorganic fertilizers a more detailed tier 2 approach is used based on emission factors for specific type of fertilizers described by EMEP/EEA (European Environment Agency, 2016). All inventoried nitrogen-containing fertilizers have their own specific emission factor described in Table 3-7.

Table 3-5. Emission factors for ammonia emissions from fertilizers (g NH_3/kg N applied) (European Environment Agency, 2016).

	Climate					
	Cool		Temperate		Warm	
	normal pH ([a])	high pH ([b])	normal pH ([a])	high pH ([b])	normal pH ([a])	high pH ([b])
Anhydrous ammonia (AH)	19	35	20	36	25	46
AN	15	32	16	33	20	41
Ammonium phosphate (AP) ([c])	50	91	51	94	64	117
AS	90	165	92	170	115	212
CAN	8	17	8	17	10	21
NK mixtures ([d])	15	32	22	33	20	41
NPK mixtures ([d])	50	91	67	94	64	117
NP mixtures ([d])	50	91	67	94	64	117
N solutions ([e])	98	95	100	97	126	122
Other straight N compounds ([f])	10	19	14	20	13	25
Urea[g]	155	164	159	168	198	210

([a]) A 'normal' pH is a pH of 7.0 or below.
([b]) A 'high' pH is a pH of more than 7.0 (usually calcareous soils).
([c]) AP is the sum of ammonium monophosphate (MAP) and diammonium phosphate (DAP).
([d]) NK mixtures are equivalent to AN, NPK and NP mixtures, which are 50 % MAP plus 50 % DAP.
([e]) N solutions are equivalent to urea AN.
([f]) Other straight N compounds and equivalent to calcium nitrate.
(g) Urea is an organic compound with the chemical formula $CO(NH_2)_2$.

Due to the lack of data on the pH of soils, it is assumed that all soils around the world are "normal". Using the climate zone criteria described in the reference and average temperatures of countries around the world, each country is classified as "cool", "temperate" or "warm".

3.10 Phosphorus emissions

The phosphorous content of synthetic fertilizers and manure is emitted to the soil. An emission factor of 0.1 per kg of phosphorus for manure and synthetic fertilizer based on default modelling of ReCiPe (Huijbregts, 2016) is applied.

3.11 Heavy metal emissions

The emissions of heavy metals was based on a methodology described in Nemecek & Schnetzer (2012). The emissions are the result of inputs of heavy metals to the soil due to the application of fertilizers and manure, and deposition and outputs of heavy metals due to leaching and removal of biomass. The heavy metal content of fertilizers and manure was based on literature as stated in Table 3-6 and Table 3-7, respectively. The deposition of heavy metals is stated in Table 3-8.

Table 3-6. Heavy metal content of fertilizers.

Mineral fertilizers	Unit	Cd	Cr	Cu	Hg	Ni	Pb	Zn

Urea	mg/kg	2.796	36.301	12.116	0.047	9.739	25.583	94.598
Nitrogen solutions	mg/kg	1.800	23.370	7.800	0.030	6.270	16.470	60.900
NPK compound	mg/kg	6.840	94.005	18.195	0.060	16.755	18.405	157.230
Anhydrous ammonia	mg/kg	4.920	63.878	21.320	0.082	17.138	45.018	166.460
Ammonium nitrate	mg/kg	2.100	27.265	9.100	0.035	7.315	19.215	71.050
Calcium ammonium nitrate	mg/kg	1.658	22.656	8.883	0.036	6.975	15.877	62.940
Ammonium phosphate	mg/kg	23.835	326.648	57.305	0.193	54.929	50.268	522.890
Ammonium sulfate	mg/kg	1.260	16.359	5.460	0.021	4.389	11.529	42.630
Triple superphosphate	mg/kg	18.960	260.640	43.440	0.144	42.384	32.160	402.720
Single superphosphate	mg/kg	8.295	114.030	19.005	0.063	18.543	14.070	176.190
PK compound	mg/kg	8.712	120.736	20.966	0.066	19.976	14.916	185.944
Ground rock	mg/kg	12.640	173.760	28.960	0.096	28.256	21.440	268.480
Potassium chloride	mg/kg	0.060	3.480	2.880	0.000	1.500	0.480	3.720
Potassium sulphate	mg/kg	0.050	2.900	2.400	0.000	1.250	0.400	3.100
Lime	mg/kg	0.280	8.249	8.169	0.040	5.886	5.446	37.481

Table 3-7. Heavy metal content of manure.

Manure	Unit	Cd mg/kg Fertilizer	Cr mg/kg Fertilizer	Cu mg/kg Fertilizer	Hg mg/kg Fertilizer	Ni mg/kg Fertilizer	Pb mg/kg Fertilizer	Zn mg/kg Fertilizer
Cattle	mg/kg	0.038	1.755	4.378	0.017	1.594	1.211	18.254
Pigs	mg/kg	0.060	1.230	42.059	0.007	1.621	1.260	94.674
Poultry	mg/kg	0.952	5.446	61.974	0.053	11.925	10.141	293.594

The above European values are also used for other continents because data is not available, incomplete or it is not stated if the values are 'per kg dry matter' or 'per kg manure as is'. Please note that ranges in heavy metal contents of animal manure are large. Please note that the amount of copper (Cu) and zinc (Zn) in pig slurry and manure is high because additional copper and zinc is added to the feed by pig farmers for animal health reasons. It is assumed that only pig and poultry manure is applied in cultivation of arable crops[3] because cattle systems are often closed-loop systems. The ratio pig / poultry manure is based on FAO data on the amount of available nitrogen per type of animal manure.

[3] Please note that cattle manure is applied on those crops which are cultivated on dairy farms for feed (e.g. maize silage) due to the closed system.

Table 31. Deposition of heavy metals (Nemecek and Schnetzer 2012).

		Cd	Cu	Zn	Pb	Ni	Cr	Hg
Deposition	mg/ha/yr	700	2,400	90,400	18,700	5,475	3,650	50

Heavy metals are removed from the soil via removal of biomass and via leaching. The heavy metal content of biomass of crops is shown in Table 3-9. Leaching of heavy metals to ground water is mentioned in Table 3-10.

Table 3-9 Heavy metals in biomass expressed in fresh weight except for grass fresh and hay (Delahaye et al. 2003)

Crop	Cd (mg/kg DM)	Cr (mg/kg DM)	Cu (mg/kg DM)	Hg (mg/kg DM)	Ni (mg/kg DM)	Pb (mg/kg DM)	Zn (mg/kg DM)
Fodder beets, rapes, carrots	0.04	0.22	1.08	0.0011	0.094	0.154	6.2
Chicory roots	0.04	0.22	1.66	0.0011	0.094	0.154	2.6
Wheat	0.013	2.28	4.1	0.00862	0.86	0.1	24.8
Rye	0.013	0.93	3.11	0.00862	0.86	0.3	28.8
Barley	0.013	2.28	3.9	0.00862	0.19	1	24
Oat	0.013	2.28	3.6	0.00862	0.86	0.05	24.7
Maize	0.52	0.24	1.58	0.01	0.86	1.3	21.6
Triticale	0.013	2.28	4.7	0.00862	0.86	0.14	34
Other cereals	0.013	2.28	4.1	0.00862	0.86	0.1	24.8
Pulses/Lupine	0.02	1.4	8.03	0.013	0.86	0.4	33.7
Oilseeds	0.1	0.5	12.62	0.00862	0.86	1	49.6
Cassava	0.009	2.28	2.92	0.01	0.86	0.9	13
Sweet potato	0.009	2.28	5.7	0.0088	0.86	0.31	5.6
Rapeseed	0.02	1.4	4.4	0.013	1	0.4	46.5
Potatoes	0.03	0.4	1.1	0.003	0.25	0.03	2.9
Sugar beet	0.04	0.22	1.1	0.0011	0.094	0.154	6.2
Chicory	0.03	0.4	2.1	0.003	0.25	0.03	12.5
Onions	0.012	0.4	0.4	0.002	0.04	0.021	1.6
Maize silage	0.1	0.24	3.6	0.01	0.861	0.1	36
Fodder beet	0.2	1.32	8.3	0.0188	3.9	2.25	43
Grass fresh (DM)	0.2	0.6	8.3	0.0188	3.9	2.25	44
Fodder potatoes	0.03	0.395	1.13	0.003	0.25	0.03	2.9
Corn cob silage	0.04	0.22	1.34	0.0011	0.094	0.154	16
Other green fodder crops	0.04	0.22	1.08	0.0011	0.094	0.154	6.2
Hay (DM)	0.2	1.32	8.3	0.0188	3.9	2.25	43
Vegetables & fruit	0.03	0.5	0.5	0.002	0.14	0.54	4

*Not referred to in (Delahaye et al. 2003) but average of other crops.

Table 32. Heavy metal leaching to groundwater (Nemecek and Schnetzer 2012).

		Cd	Cu	Zn	Pb	Ni	Cr	Hg
Leaching	mg/ha/yr	50	3,600	33,000	600	n.a.	21,200	1,3

An allocation factor is required because not all heavy metal accumulation is caused by agricultural production. Heavy metals are also caused by deposition from other activities in the surrounding area. The allocation factor is calculated as follows:

$$A_i = M_{agro\ i} / (M_{agro\ i} + M_{deposition\ i})$$

Equation 4

A_i = allocation factor for the share of agricultural inputs in the total inputs for heavy metal i

$M_{agro\ i}$ = input due to agricultural activities (fertilizer and manure application) for heavy metal i

$M_{deposition\ i}$ = input due to deposition for heavy metal i

Heavy metal emissions into the ground and surface water are calculated with constant leaching rates as:

$$M_{leach\ i} = m_{leach\ i} * A_i$$

Equation 5

Where,

$M_{leach\ i}$ = leaching of heavy metal i to the ground and surface water

$m_{leach\ i}$ = average amount of heavy metal emission

A_i = allocation factor for the share of agricultural inputs in the total inputs for heavy metal i

Heavy metals emissions to the soil are calculated as follows:

$$M_{soil\ i} = (\Sigma inputs_i - \Sigma outputs_i) * A_i$$

Equation 6

Where,

$M_{soil\ i}$ = accumulation in the soil of heavy metal i

A_i = *allocation factor for the share of agricultural inputs in the total inputs for heavy metal i*

$$\Sigma inputs_i = A * A_{content\ i} + B * B_{content\ i} + C$$

Equation 7

Where,

A = fertilizer application (kg/ha/yr)

$A_{content\ i}$ = heavy metal content i for fertilizer applied

B = manure application (kg DM/ha/yr)

$B_{content\ i}$ = heavy metal content i for manure applied
C = deposition

$$\Sigma outputs_i = M_{leach\ i} + D * D_{content\ i}$$

Equation 8

Where,
D = yield (kg DM/ha/yr)
$D_{content\ i}$ = heavy metal content i for crop

When more heavy metals are removed from the soil via leaching and biomass than is added to the soil via fertilizers, manure and deposition, the balance can result in a negative emission.

3.12 Emissions from drained peat soils

In previous versions of GFLI, peat emissions from drained soils were only considered for a limited number of crops. Now this is included for all crops. For all GHG emissions estimations of drained peat soils, the calculation is based on the factor $A_{crop,\ country}$, which for each crop-country combination is defined by

$$A_{crop,\ country} = \frac{harvested\ area\ of\ crop\ in\ country\ on\ drained\ peat\ soils}{total\ harvested\ area\ of\ crop\ in\ country}$$

Once $A_{crop,\ country}$ is determined, CO_2 emission factors are extrapolated from the specific country National Inventory Report (NIR) 2019 submission (average of 2012-2017 data). In case the country does not submit a NIR, and for N2O emissions factors, IPCC (2013) supplement is used (IPCC Guidelines on Wetlands, 2006[4]). To calculate the GHG emissions from peat oxidation per ha crop in each country, the emission factors are multiplied by the $A_{crop,\ country}$. CO_2 emissions from the extraction of peat and peat burning due to fires are not considered, and only the on-site peat emissions from drained organic soil are considered. The emission factors are dependent on type of land occupation (orchard, palm, cropland, paddy rice and grassland) and climate (tropical, temperate and boreal). We assumed that each country has one dominant climate.

$A_{crop,\ country}$ is determined in two steps

1. **Calculation of country-level average values:** Estimation of a country-specific value$A_{country}$, i.e. not on a crop-specific level. Data on the parameter $A_{country}$ was collected from National Inventory Reports (2012-2017 average)[5]. When not available, $A_{country}$ is extrapolated with data from FAOSTAT.

In the GFLI methodology and database version 2, a correction factor was applied as indicated below. In the GFLI methodology and database version 3, this correction factor is removed.

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[4] https://www.ipcc-nggip.iges.or.jp/public/wetlands/index.html
[5] https://unfccc.int/process-and-meetings/transparency-and-reporting/reporting-and-review-under-the-convention/greenhouse-gas-inventories-annex-i-parties/national-inventory-submissions-2019

In this way, we take into account crop-specific variations of drained organic peat soils. Although some crops, in particular tubers, seem to be cultivated more frequently on peat-rich soils, it should be noted that the variability of $A_{crop,\ country}^{geo}$ is typically less than 20%, i.e. the crop type has a much smaller influence on the GHG emissions from peat oxidation than the country.

For Indonesia and Malaysia, the area of drained organic soil cultivated with palm oil is well documented in literature (Schrier-Uijl et al. 2013). Therefore, specific values of A for palm are used, and the country average is adjusted based on the crop specific harvested areas derived from FAOSTAT.

Since the impact of drained peat oxidation can be large on climate change, and given its intrinsic uncertainty, it was decided to give the possibility to show the impact of peat separately (similar as LUC). For this, one existing and two additional substances are used:

- Carbon dioxide, peat oxidation
- Methane, peat oxidation
- Dinitrogen monoxide, peat oxidation

3.13 Regionalized emissions and resources

In previous versions of GFLI only water use was regionalized. With that we mean that within the LCI itself, the region is specified. For example, water use in the Netherlands would have the have the substance name of “Water, unspecified natural origin, NL”. In recent SimaPro updates more regionalized substances have been added some of them are also relevant for GFLI. The names of certain emissions or resources have been changes to enable regionalization of certain. The following substances are now also regionalized in GFLI LCIs.

Table 33. Update and regionalized substances in GFLI, with Netherlands as an example.

Substance name GFLI v1	Substance name GFLI v2
Occupation, annual crop	Occupation, annual crop, NL
Occupation, permanent crop	Occupation, permanent crop, NL
Occupation, grassland/pasture/meadow	Occupation, grassland/pasture/meadow, NL
Transformation, from annual crop	Transformation, from annual crop, NL
Transformation, from forest, unspecified	Transformation, from forest, extensive, NL
Transformation, from grassland	Transformation, from grassland/pasture/meadow, NL
Transformation, from permanent crop	Transformation, from permanent crop, NL
Transformation, to annual crop	Transformation, to annual crop, NL
Transformation, to grassland	Transformation, to grassland/pasture/meadow, NL
Transformation, to permanent crop	Transformation, to permanent crop, NL
Ammonia	Ammonia, NL
Nitrogen monoxide	Nitrogen monoxide, NL
Nitrate	Nitrate, NL
Phosphorus	Phosphorus, NL
Water, unspecified natural origin, NL	Water, unspecified natural origin, NL

Whether regionalized flows lead to different environmental impacts due to (potentially) different emissions factors depends on the method that has been used.

3.12 Specific Emissions: Methane emissions in rice cultivations

Methane emissions that are a result of rice cultivation have been inventoried for rice cultivations in GFLI. In this GFLI database the emission factors for rice cultivation are based on information from a single public source. FAOstat reports on the "implied emissions factor for CH_4" for rice cultivation for 120+ countries (FAOSTAT, 2019). This factor is converted from gram methane/harvested square meter to kg biogenic methane per harvested hectare in the LCIs for rice cultivation.

3.14 Default energy use for activities

The following activities are considered in determining the total energy requirements for cultivation in the default approach

Table 34.

Activity	Equipment	Diesel use (l/ha)	Comment
Tillage	Ploughing; reversible plough 1.6 m	27.5	Specify equipment and frequency tillage. Multiple equipment can be used for this task. By default, this is specified per crop and country tillage statistics.
	Disc harrow, double, 3 m	6.6	
	Rotating harrow, 3 m	11.2	
Sowing	Seeder, cam wheel seed drill 3 m	5.2	Specify equipment used for sowing. By default, one type of equipment is use per crop (type).
	Planting machine, direct from dumper 3 m;	13.4	
	Seeder, distance 50 cm; precision 6 m	4.8	
	Large scale dumper, 37 m^3, 8500kg	7.3	
Irrigation	Furrow		By default, only applied for rice cultivation (0.3 MJ/m3)
	Hose reel		By default, only applied for "small" farms (1.2 MJ/m3)
	Centre pivot		By default, only applied for "large" farms (0.6 MJ/m3)
Manure	Manure injection (40 m^3)	31.5	Specify type of equipment used for manure spreading. By default, injectors are used for pig manure and much spreader for poultry manure.
	Manure injector, vacuum tank 20 m^3	43.27	
	Manure muck spreader, 6 t/10 tons application	15.3	
Fertilizer	Centrifugal spreader> 18 m 1500 l	2.9	Specify frequency of activity. Defaults are per crop type (1-6 applications).

Lime	Centrifugal spreader> 18 m 1500 l	2.9	Specify frequency of activity. Default = 0.25
Pesticide application	Field sprayer of 2000/24 m	3.0	Specify frequency of activity. Defaults are per crop type (0.1 – 16).
Weeding	Field sprayer of 2000/24 m	3.0	Specify frequency of activity. Defaults are per crop type (1-6)
Harvesting	Combine harvester, self-propelled, 6 m	31.4	Specify which harvesting equipment is used. Possibly multiple equipment is used to do the task. By default, this is specified for each crop (type).
	Haulm topper, 3 m	19.1	
	Self-propelled harvester, 3m (sugar beet)	40	
	Forage Harvester, self-propelled, 3 m	9.2	
	Maize MKS; 6-row self-driving	25	
	Groundnut windrowing, lifter (harvesting A groundnuts)	10	
	Grassland Topper	3.8	
	Grassland cutting eq, 3M	15	
	Self-propelled bunker harvester, 1.5 m (potatoes)	57.3	
	Groundnut thresher and picker (harvesting B groundnuts)	100	
	Large baler; straw/silage presses (excluding drain)	13.4	
Transport to storage	Medium scale dumper, 19 m^3, 6500kg	7.3	Specify equipment used for transporting the product to storage. By default, one type of equipment is specified per crop (type).

Annex 4 Default emission modelling for roughages

For the default emission modelling of roughages, the following defaults with residues and heavy metals can be used (Table 4-1). For other compositions of the grasslands or other details, it is requested to provide primary or adapted secondary data to account for such changes (e.g., white or red clover, mixtures, or (semi)-natural pastures with other plant species).

Table 4-1

Roughage	Start material (kg/ha)	Crop residue calc Slope & Intercept (IPCC 2019)	Crop residue calc N content in AGR and BGR, and ratio between BGR and AGR(IPCC 2019)	Heavy metals
Grass	6	Perennial grasses	Perennial grasses	Grass fresh (16% DM)
Grass-clover	6	Grass-clover mixtures	Grass-clover mixtures	Grass fresh (16% DM)
Lucerne	6	Alfalfa	Alfalfa	Other green fodder crops
Maize forage	37.74	Non-N-fixing forages	Maize	Corn cob silage
Rye forage	235.13	Non-N-fixing forages	Rye	Rye
Barley forage	172	Non-N-fixing forages	Barley	Barley
Sorghum forage	19.55	Non-N-fixing forages	Sorghum	Other green fodder crops
Fodder beet	4	Potatoes and tubers	Potatoes and tubers	Fodder beets, rapes, carrots
Fodder potatoes	1711.15	Potatoes and tubers	Potatoes and tubers	Fodder potatoes
Hay	6	N-fixing forages	N-fixing forages	Hay (80% DM)
Hay (non N-fixing)	6	Non-legume hay	N-fixing forages	Hay (80% DM)
Other forage (N-fixing)	6	N-fixing forages	N-fixing forages	Other green fodder crops
Other forage (non-N-fixing)	150	Non-N-fixing forages	N-fixing forages	Other green fodder crops

IPCC 2019 has default values for crop residues calculations related to crop cultivation[6], which is also the default method for crop residue calculations in GFLI. In the absence of

[6] https://www.ipcc-nggip.iges.or.jp/public/2019rf/pdf/4_Volume4/19R_V4_Ch11_Soils_N2O_CO2.pdf

more accurate data, cereal roughages are assumed to resemble their cereal equivalent with regards to the N content in aboveground residues (AGR) and belowground residues (BGR), and the ratio between BGR and AGR. In a similar way, fodder beets and fodder potatoes are assumed to resemble “potatoes and tubers”.

Annex 5 Default background data

Table 5-1.. Default background data from Agri-footprint 7.0 and Ecoinvent version 3.10.

Source	Background datasets
Rail	Transport, freight train, electricity, bulk, 80%LF, flat terrain, default/GLO Economic
Rail	Transport, freight train, electricity, bulk, 80%LF, hilly terrain, default/GLO Economic
Rail	Transport, freight train, electricity, bulk, 80%LF, mountainous terrain, default/GLO Economic
Rail	Transport, freight train, diesel, bulk, 80%LF, flat terrain, default/GLO Economic
Rail	Transport, freight train, diesel, bulk, 80%LF, hilly terrain, default/GLO Economic
Rail	Transport, freight train, diesel, bulk, 80%LF, mountainous terrain, default/GLO Economic
Ocean	Transport, sea ship, 50000 DWT, 80%LF, short, default/GLO Economic
Ocean	Transport, sea ship, 50000 DWT, 80%LF, middle, default/GLO Economic
Ocean	Transport, sea ship, 50000 DWT, 80%LF, long, default/GLO Economic
Ocean	Transport, sea ship, 60000 DWT, 100%LF, short, default/GLO Economic
Ocean	Transport, sea ship, 60000 DWT, 100%LF, middle, default/GLO Economic
Ocean	Transport, sea ship, 60000 DWT, 100%LF, long, default/GLO Economic
Ocean	Transport, sea ship, 80000 DWT, 80%LF, short, default/GLO Economic
Ocean	Transport, sea ship, 80000 DWT, 80%LF, middle, default/GLO Economic
Ocean	Transport, sea ship, 80000 DWT, 80%LF, long, default/GLO Economic
Barge	Transport, barge ship, bulk, 1350t, 80%LF, empty return/GLO Economic
Barge	Transport, barge ship, bulk, 5500t, 80%LF, empty return/GLO Economic
Barge	Transport, barge ship, bulk, 12000t, 80%LF, empty return/GLO Economic
Truck	Transport, truck >20t, EURO2, 50%LF, default/GLO Economic
Truck	Transport, truck >20t, EURO3, 50%LF, default/GLO Economic
Truck	Transport, truck >20t, EURO4, 50%LF, default/GLO Economic
Truck	Transport, truck >20t, EURO5, 50%LF, default/GLO Economic

Source	Background datasets
Energy	Energy, from diesel burned in machinery/RER Economic
Capital goods	Basic infrastructure, at farm/GLO Economic
Capital goods	Silo, for grain storage, at farm/GLO Economic
Capital goods	Tractor, 4-wheel, agricultural {GLO}| market for | Cut-off, S - Copied from ecoinvent
Fertilizer production	Ammonia, as 100% NH3 (NPK 82-0-0), market mix, at regional storage/FSU Economic
Fertilizer production	Ammonia, as 100% NH3 (NPK 82-0-0), market mix, at regional storage/OCE Economic
Fertilizer production	Ammonia, as 100% NH3 (NPK 82-0-0), market mix, at regional storage/RAF Economic
Fertilizer production	Ammonia, as 100% NH3 (NPK 82-0-0), market mix, at regional storage/RER Economic
Fertilizer production	Ammonia, as 100% NH3 (NPK 82-0-0), market mix, at regional storage/RLA Economic
Fertilizer production	Ammonia, as 100% NH3 (NPK 82-0-0), market mix, at regional storage/RME Economic
Fertilizer production	Ammonia, as 100% NH3 (NPK 82-0-0), market mix, at regional storage/RNA Economic
Fertilizer production	Ammonia, as 100% NH3 (NPK 82-0-0), market mix, at regional storage/SAS Economic
Fertilizer production	Ammonia, as 100% NH3 (NPK 82-0-0), market mix, at regional storage/UN-EASIA Economic
Fertilizer production	Ammonium nitrate, as 100% (NH4)(NO3) (NPK 35-0-0), market mix, at regional storage/FSU Economic
Fertilizer production	Ammonium nitrate, as 100% (NH4)(NO3) (NPK 35-0-0), market mix, at regional storage/OCE Economic
Fertilizer production	Ammonium nitrate, as 100% (NH4)(NO3) (NPK 35-0-0), market mix, at regional storage/RAF Economic
Fertilizer production	Ammonium nitrate, as 100% (NH4)(NO3) (NPK 35-0-0), market mix, at regional storage/RER Economic
Fertilizer production	Ammonium nitrate, as 100% (NH4)(NO3) (NPK 35-0-0), market mix, at regional storage/RLA Economic
Fertilizer production	Ammonium nitrate, as 100% (NH4)(NO3) (NPK 35-0-0), market mix, at regional storage/RME Economic
Fertilizer production	Ammonium nitrate, as 100% (NH4)(NO3) (NPK 35-0-0), market mix, at regional storage/RNA Economic
Fertilizer production	Ammonium nitrate, as 100% (NH4)(NO3) (NPK 35-0-0), market mix, at regional storage/SAS Economic
Fertilizer production	Ammonium nitrate, as 100% (NH4)(NO3) (NPK 35-0-0), market mix, at regional storage/UN-EASIA Economic
Fertilizer production	Ammonium sulfate, as 100% (NH4)2SO4 (NPK 21-0-0), market mix, at regional storage/FSU Economic
Fertilizer production	Ammonium sulfate, as 100% (NH4)2SO4 (NPK 21-0-0), market mix, at regional storage/OCE Economic
Fertilizer production	Ammonium sulfate, as 100% (NH4)2SO4 (NPK 21-0-0), market mix, at regional storage/RAF Economic

Fertilizer production	Ammonium sulfate, as 100% (NH4)2SO4 (NPK 21-0-0), market mix, at regional storage/RER Economic
Fertilizer production	Ammonium sulfate, as 100% (NH4)2SO4 (NPK 21-0-0), market mix, at regional storage/RLA Economic
Fertilizer production	Ammonium sulfate, as 100% (NH4)2SO4 (NPK 21-0-0), market mix, at regional storage/RME Economic
Fertilizer production	Ammonium sulfate, as 100% (NH4)2SO4 (NPK 21-0-0), market mix, at regional storage/RNA Economic
Fertilizer production	Ammonium sulfate, as 100% (NH4)2SO4 (NPK 21-0-0), market mix, at regional storage/SAS Economic
Fertilizer production	Ammonium sulfate, as 100% (NH4)2SO4 (NPK 21-0-0), market mix, at regional storage/UN-EASIA Economic
Fertilizer production	Calcium ammonium nitrate (CAN), (NPK 26.5-0-0), market mix, at regional storage/FSU Economic
Fertilizer production	Calcium ammonium nitrate (CAN), (NPK 26.5-0-0), market mix, at regional storage/OCE Economic
Fertilizer production	Calcium ammonium nitrate (CAN), (NPK 26.5-0-0), market mix, at regional storage/RAF Economic
Fertilizer production	Calcium ammonium nitrate (CAN), (NPK 26.5-0-0), market mix, at regional storage/RER Economic
Fertilizer production	Calcium ammonium nitrate (CAN), (NPK 26.5-0-0), market mix, at regional storage/RLA Economic
Fertilizer production	Calcium ammonium nitrate (CAN), (NPK 26.5-0-0), market mix, at regional storage/RME Economic
Fertilizer production	Calcium ammonium nitrate (CAN), (NPK 26.5-0-0), market mix, at regional storage/RNA Economic
Fertilizer production	Calcium ammonium nitrate (CAN), (NPK 26.5-0-0), market mix, at regional storage/SAS Economic
Fertilizer production	Calcium ammonium nitrate (CAN), (NPK 26.5-0-0), market mix, at regional storage/UN-EASIA Economic
Fertilizer production	Di ammonium phosphate, as 100% (NH3)2HPO4 (NPK 22-57-0), market mix, at regional storage/FSU Economic
Fertilizer production	Di ammonium phosphate, as 100% (NH3)2HPO4 (NPK 22-57-0), market mix, at regional storage/OCE Economic
Fertilizer production	Di ammonium phosphate, as 100% (NH3)2HPO4 (NPK 22-57-0), market mix, at regional storage/RAF Economic
Fertilizer production	Di ammonium phosphate, as 100% (NH3)2HPO4 (NPK 22-57-0), market mix, at regional storage/RER Economic
Fertilizer production	Di ammonium phosphate, as 100% (NH3)2HPO4 (NPK 22-57-0), market mix, at regional storage/RLA Economic
Fertilizer production	Di ammonium phosphate, as 100% (NH3)2HPO4 (NPK 22-57-0), market mix, at regional storage/RME Economic
Fertilizer production	Di ammonium phosphate, as 100% (NH3)2HPO4 (NPK 22-57-0), market mix, at regional storage/RNA Economic
Fertilizer production	Di ammonium phosphate, as 100% (NH3)2HPO4 (NPK 22-57-0), market mix, at regional storage/SAS Economic
Fertilizer production	Di ammonium phosphate, as 100% (NH3)2HPO4 (NPK 22-57-0), market mix, at regional storage/UN-EASIA Economic
Fertilizer production	Liquid urea-ammonium nitrate solution (NPK 30-0-0), market mix, at regional storage/FSU Economic
Fertilizer production	Liquid urea-ammonium nitrate solution (NPK 30-0-0), market mix, at regional storage/OCE Economic
Fertilizer production	Liquid urea-ammonium nitrate solution (NPK 30-0-0), market mix, at regional storage/RAF Economic

Fertilizer production	Liquid urea-ammonium nitrate solution (NPK 30-0-0), market mix, at regional storage/RER Economic
Fertilizer production	Liquid urea-ammonium nitrate solution (NPK 30-0-0), market mix, at regional storage/RLA Economic
Fertilizer production	Liquid urea-ammonium nitrate solution (NPK 30-0-0), market mix, at regional storage/RME Economic
Fertilizer production	Liquid urea-ammonium nitrate solution (NPK 30-0-0), market mix, at regional storage/RNA Economic
Fertilizer production	Liquid urea-ammonium nitrate solution (NPK 30-0-0), market mix, at regional storage/SAS Economic
Fertilizer production	Liquid urea-ammonium nitrate solution (NPK 30-0-0), market mix, at regional storage/UN-EASIA Economic
Fertilizer production	Nitric acid, in water (60% HNO3) (NPK 13.2-0-0), market mix, at regional storage/FSU Economic
Fertilizer production	Nitric acid, in water (60% HNO3) (NPK 13.2-0-0), market mix, at regional storage/OCE Economic
Fertilizer production	Nitric acid, in water (60% HNO3) (NPK 13.2-0-0), market mix, at regional storage/RAF Economic
Fertilizer production	Nitric acid, in water (60% HNO3) (NPK 13.2-0-0), market mix, at regional storage/RER Economic
Fertilizer production	Nitric acid, in water (60% HNO3) (NPK 13.2-0-0), market mix, at regional storage/RLA Economic
Fertilizer production	Nitric acid, in water (60% HNO3) (NPK 13.2-0-0), market mix, at regional storage/RME Economic
Fertilizer production	Nitric acid, in water (60% HNO3) (NPK 13.2-0-0), market mix, at regional storage/RNA Economic
Fertilizer production	Nitric acid, in water (60% HNO3) (NPK 13.2-0-0), market mix, at regional storage/SAS Economic
Fertilizer production	Nitric acid, in water (60% HNO3) (NPK 13.2-0-0), market mix, at regional storage/UN-EASIA Economic
Fertilizer production	NPK compound (NPK 15-15-15), market mix, at regional storage/FSU Economic
Fertilizer production	NPK compound (NPK 15-15-15), market mix, at regional storage/OCE Economic
Fertilizer production	NPK compound (NPK 15-15-15), market mix, at regional storage/RAF Economic
Fertilizer production	NPK compound (NPK 15-15-15), market mix, at regional storage/RER Economic
Fertilizer production	NPK compound (NPK 15-15-15), market mix, at regional storage/RLA Economic
Fertilizer production	NPK compound (NPK 15-15-15), market mix, at regional storage/RME Economic
Fertilizer production	NPK compound (NPK 15-15-15), market mix, at regional storage/RNA Economic
Fertilizer production	NPK compound (NPK 15-15-15), market mix, at regional storage/SAS Economic
Fertilizer production	NPK compound (NPK 15-15-15), market mix, at regional storage/UN-EASIA Economic
Fertilizer production	Phosphate rock (32% P2O5, 50% CaO) (NPK 0-32-0), at mine/RER Economic
Fertilizer production	Phosphoric acid, merchant grade (75% H3PO4) (NPK 0-54-0), at plant/RER Economic
Fertilizer production	PK compound (NPK 0-22-22), at plant/RER Economic

Fertilizer production	Potassium chloride (NPK 0-0-60), at plant/RER Economic
Fertilizer production	Potassium sulfate (NPK 0-0-50) (Mannheim), at plant/RER Economic
Fertilizer production	Single superphosphate, as 35% Ca(H2PO4)2 (NPK 0-21-0), at plant/RER Economic
Fertilizer production	Triple superphosphate, as 80% Ca(H2PO4)2 (NPK 0-48-0), at plant/RER Economic
Fertilizer production	Urea, as 100% CO(NH2)2 (NPK 46.6-0-0), market mix, at regional storage/FSU Economic
Fertilizer production	Urea, as 100% CO(NH2)2 (NPK 46.6-0-0), market mix, at regional storage/OCE Economic
Fertilizer production	Urea, as 100% CO(NH2)2 (NPK 46.6-0-0), market mix, at regional storage/RAF Economic
Fertilizer production	Urea, as 100% CO(NH2)2 (NPK 46.6-0-0), market mix, at regional storage/RER Economic
Fertilizer production	Urea, as 100% CO(NH2)2 (NPK 46.6-0-0), market mix, at regional storage/RLA Economic
Fertilizer production	Urea, as 100% CO(NH2)2 (NPK 46.6-0-0), market mix, at regional storage/RME Economic
Fertilizer production	Urea, as 100% CO(NH2)2 (NPK 46.6-0-0), market mix, at regional storage/RNA Economic
Fertilizer production	Urea, as 100% CO(NH2)2 (NPK 46.6-0-0), market mix, at regional storage/SAS Economic
Fertilizer production	Urea, as 100% CO(NH2)2 (NPK 46.6-0-0), market mix, at regional storage/UN-EASIA Economic
Electricity production	Electricity, low voltage {AR}| market for electricity, low voltage | Cut-off, S - Copied from ecoinvent
Electricity production	Electricity, low voltage {AT}| market for | Cut-off, S - Copied from ecoinvent
Electricity production	Electricity, low voltage {AU}| market for | Cut-off, S - Copied from ecoinvent
Electricity production	Electricity, low voltage {BE}| market for | Cut-off, S - Copied from ecoinvent
Electricity production	Electricity, low voltage {BG}| market for | Cut-off, S - Copied from ecoinvent
Electricity production	Electricity, low voltage {BR}| market group for electricity, low voltage | Cut-off, S - Copied from ecoinvent
Electricity production	Electricity, low voltage {BY}| market for electricity, low voltage | Cut-off, S - Copied from ecoinvent
Electricity production	Electricity, low voltage {CA}| market group for | Cut-off, S - Copied from ecoinvent
Electricity production	Electricity, low voltage {CH}| market for | Cut-off, S - Copied from ecoinvent
Electricity production	Electricity, low voltage {CL}| market for | Cut-off, S - Copied from ecoinvent
Electricity production	Electricity, low voltage {CN}| market group for | Cut-off, S - Copied from ecoinvent
Electricity production	Electricity, low voltage {CO}| market for electricity, low voltage | Cut-off, S - Copied from ecoinvent
Electricity production	Electricity, low voltage {CR}| market for electricity, low voltage | Cut-off, S - Copied from ecoinvent
Electricity production	Electricity, low voltage {CY}| market for | Cut-off, S - Copied from ecoinvent

Electricity production	Electricity, low voltage {CZ}| market for | Cut-off, S - Copied from ecoinvent
Electricity production	Electricity, low voltage {DE}| market for | Cut-off, S - Copied from ecoinvent
Electricity production	Electricity, low voltage {DK}| market for | Cut-off, S - Copied from ecoinvent
Electricity production	Electricity, low voltage {EE}| market for | Cut-off, S - Copied from ecoinvent
Electricity production	Electricity, low voltage {EG}| market for electricity, low voltage | Cut-off, S - Copied from ecoinvent
Electricity production	Electricity, low voltage {ES}| market for | Cut-off, S - Copied from ecoinvent
Electricity production	Electricity, low voltage {ET}| market for electricity, low voltage | Cut-off, S - Copied from ecoinvent
Electricity production	Electricity, low voltage {FI}| market for | Cut-off, S - Copied from ecoinvent
Electricity production	Electricity, low voltage {FR}| market for | Cut-off, S - Copied from ecoinvent
Electricity production	Electricity, low voltage {GB}| market for | Cut-off, S - Copied from ecoinvent
Electricity production	Electricity, low voltage {GR}| market for | Cut-off, S - Copied from ecoinvent
Electricity production	Electricity, low voltage {HU}| market for | Cut-off, S - Copied from ecoinvent
Electricity production	Electricity, low voltage {ID}| market for | Cut-off, S - Copied from ecoinvent
Electricity production	Electricity, low voltage {IE}| market for | Cut-off, S - Copied from ecoinvent
Electricity production	Electricity, low voltage {IN}| market group for electricity, low voltage | Cut-off, S - Copied from ecoinvent
Electricity production	Electricity, low voltage {IT}| market for | Cut-off, S - Copied from ecoinvent
Electricity production	Electricity, low voltage {JP}| market for | Cut-off, S - Copied from ecoinvent
Electricity production	Electricity, low voltage {KH}| market for electricity, low voltage | Cut-off, S - Copied from ecoinvent
Electricity production	Electricity, low voltage {LT}| market for | Cut-off, S - Copied from ecoinvent
Electricity production	Electricity, low voltage {LV}| market for | Cut-off, S - Copied from ecoinvent
Electricity production	Electricity, low voltage {MX}| market for | Cut-off, S - Copied from ecoinvent
Electricity production	Electricity, low voltage {MY}| market for | Cut-off, S - Copied from ecoinvent
Electricity production	Electricity, low voltage {NL}| market for | Cut-off, S - Copied from ecoinvent
Electricity production	Electricity, low voltage {NO}| market for | Cut-off, S - Copied from ecoinvent
Electricity production	Electricity, low voltage {NZ}| market for electricity, low voltage | Cut-off, S - Copied from ecoinvent
Electricity production	Electricity, low voltage {PE}| market for | Cut-off, S - Copied from ecoinvent
Electricity production	Electricity, low voltage {PH}| market for electricity, low voltage | Cut-off, S - Copied from ecoinvent

Electricity production	Electricity, low voltage {PK}| market for electricity, low voltage | Cut-off, S - Copied from ecoinvent
Electricity production	Electricity, low voltage {PL}| market for | Cut-off, S - Copied from ecoinvent
Electricity production	Electricity, low voltage {PT}| market for | Cut-off, S - Copied from ecoinvent
Electricity production	Electricity, low voltage {PY}| market for electricity, low voltage | Cut-off, S - Copied from ecoinvent
Electricity production	Electricity, low voltage {RAF}| market group for | Cut-off, S - Copied from ecoinvent
Electricity production	Electricity, low voltage {RAS}| market group for | Cut-off, S - Copied from ecoinvent
Electricity production	Electricity, low voltage {RER}| market group for | Cut-off, S - Copied from ecoinvent
Electricity production	Electricity, low voltage {RLA}| market group for | Cut-off, S - Copied from ecoinvent
Electricity production	Electricity, low voltage {RME}| market group for | Cut-off, S - Copied from ecoinvent
Electricity production	Electricity, low voltage {RNA}| market group for | Cut-off, S - Copied from ecoinvent
Electricity production	Electricity, low voltage {RO}| market for | Cut-off, S - Copied from ecoinvent
Electricity production	Electricity, low voltage {RU}| market for | Cut-off, S - Copied from ecoinvent
Electricity production	Electricity, low voltage {SD}| market for electricity, low voltage | Cut-off, S - Copied from ecoinvent
Electricity production	Electricity, low voltage {SE}| market for | Cut-off, S - Copied from ecoinvent
Electricity production	Electricity, low voltage {SI}| market for | Cut-off, S - Copied from ecoinvent
Electricity production	Electricity, low voltage {SK}| market for | Cut-off, S - Copied from ecoinvent
Electricity production	Electricity, low voltage {SN}| market for electricity, low voltage | Cut-off, S - Copied from ecoinvent
Electricity production	Electricity, low voltage {TH}| market for | Cut-off, S - Copied from ecoinvent
Electricity production	Electricity, low voltage {TR}| market for | Cut-off, S - Copied from ecoinvent
Electricity production	Electricity, low voltage {UA}| market for | Cut-off, S - Copied from ecoinvent
Electricity production	Electricity, low voltage {US}| market group for | Cut-off, S - Copied from ecoinvent
Electricity production	Electricity, low voltage {UY}| market for electricity, low voltage | Cut-off, S - Copied from ecoinvent
Electricity production	Electricity, low voltage {VE}| market for electricity, low voltage | Cut-off, S - Copied from ecoinvent
Electricity production	Electricity, low voltage {VN}| market for electricity, low voltage | Cut-off, S - Copied from ecoinvent
Electricity production	Electricity, low voltage {ZA}| market for | Cut-off, S - Copied from ecoinvent
Electricity production	Electricity, low voltage {AR}| market for electricity, low voltage | Cut-off, S - Copied from ecoinvent
Heat production	Heat, district or industrial, natural gas {Europe without Switzerland}| heat production, natural gas, at industrial furnace >100kW | Cut-off, S - Copied from ecoinvent

Heat production	Heat, district or industrial, natural gas {RoW}| heat production, natural gas, at industrial furnace >100kW | Cut-off, S - Copied from ecoinvent
Heat production	Heat, district or industrial, other than natural gas {RoW}| heat production, heavy fuel oil, at industrial furnace 1MW | Cut-off, S - Copied from ecoinvent
Heat production	Heat, district or industrial, other than natural gas {RoW}| heat production, light fuel oil, at industrial furnace 1MW | Cut-off, S - Copied from ecoinvent
Pesticide production	Fungicide, at plant/RER Economic
Pesticide production	Herbicide, at plant/RER Economic
Pesticide production	Insecticide, at plant/RER Economic

Annex 6 Transportation distances

Manure, fertilizer and pesticides are transported to the farm. The default transport requirements to the farm are a transportation distance of 30 km for manure and a transportation distance of 50 km for all other inputs like fertilizer and pesticides. Transportation requirements between cultivation and processing are largely based on the methodology applied in Feedprint (Vellinga T. V., 2013). In short, the transport model consists of two parts. First the distance within the country of origin (where the crop is cultivated) is estimated, it is assumed that the crops are transported from cultivation areas to central collection hubs. From there, the crops are subsequently transported to the country of the market mix. The seaship distance is according to default transport of the PEFCR Feed version 4.2 annex 6 (FEFAC, 2024), unless further specified.

Table 35. Transport distances (in km) and transport mode split for crops and processed crop products.

Country A	Country B	Base Product	Transport Moment	Lorry dist	Train dist	InlandShip dist	SeaShip dist
AR	AR	Soybean	Crop_to_Process	205	40	5	0
AR	AR	Sunflower seed	Crop_to_Process	410	80	10	0
AR	NL	Sorghum	Crop_to_Mix	466	82	29	11738
AR	NL	Soybean	Crop_to_Process	410	80	10	11738
AR	NL	Soybean	Crop_to_Mix	466	82	29	11738
AR	NL	Soybean	Process_to_Mix	56	2	19	11738
AR	NL	Sunflower seed	Process_to_Mix	56	2	19	11738
AR	NL	Sunflower seed	Crop_to_Mix	466	82	29	11738
AU	AU	Sugar cane	Crop_to_Process	25	0	0.0	0
AU	NL	Lupine	Crop_to_Mix	456	102	19	17826
AU	NL	Pea	Crop_to_Mix	0	102	19	17826
AU	NL	Sugar cane	Process_to_Mix	456	102	19	21812
BE	BE	Barley	Crop_to_Process	59	7	11	0
BE	BE	Oat	Crop_to_Process	59	7	11	0
BE	NL	Barley	Crop_to_Mix	187	49	135	0

BE	NL	Barley	Process_to_Mix	128	42	123	0
BE	NL	Oat	Crop_to_Mix	187	49	135	0
BE	NL	Oat	Crop_to_Process	131	46	116	0
BE	NL	Oat	Process_to_Mix	128	42	123	0
Country A	**Country B**	**Base Product**	**Transport Moment**	**Lorry dist**	**Train dist**	**InlandShip dist**	**SeaShip dist**
BE	NL	Rapeseed	Process_to_Mix	128	42	123	0
BE	NL	Rye	Process_to_Mix	128	42	123	0
BE	NL	Wheat	Process_to_Mix	128	42	123	0
BR	BR	Soybean	Crop_to_Process	867	477	101	0
BR	BR	Sugar cane	Crop_to_Process	25	0	0.0	0
BR	IE	Soybean	Crop_to_Mix	925	477	101	9300
BR	NL	Citrus	Process_to_Mix	56	2	19	9684
BR	NL	Maize	Crop_to_Mix	923	479	120	9684
BR	NL	Soybean	Crop_to_Process	867	476.85	101.15	9684
BR	NL	Soybean	Crop_to_Mix	923	479	120	9684
BR	NL	Soybean	Process_to_Mix	56	2	19	9684
BR	NL	Sugar cane	Process_to_Mix	923	479	120	9684
CN	CN	Rice	Crop_to_Process	455	1005	136	455
CN	CN	Sunflower seed	Crop_to_Process	455	1005	136	455
CN	NL	Rice	Crop_to_Mix	510	1007	156	19568
CN	NL	Rice	Process_to_Mix	56	2	19	19113
CN	NL	Sunflower seed	Process_to_Mix	56	2	19	19113
CN	NL	Sunflower seed	Crop_to_Mix	510	1007	156	19568
DE	BE	Rapeseed	Crop_to_Process	269	134	181	0
DE	BE	Rye	Crop_to_Process	269	134	181	0
DE	BE	Wheat	Crop_to_Process	269	134	181	0
DE	DE	Barley	Crop_to_Process	84	18	4	0

DE	DE	Maize	Crop_to_Process	84	18	4	0
DE	DE	Rapeseed	Crop_to_Process	84	18	4	0
DE	DE	Rye	Crop_to_Process	84	18	4	0
DE	DE	Starch potato	Crop_to_Process	84	18	4	0
Country A	**Country B**	**Base Product**	**Transport Moment**	**Lorry dist**	**Train dist**	**InlandShip dist**	**SeaShip dist**
DE	DE	Sugar beet	Crop_to_Process	84	18	4	0
DE	DE	Wheat	Crop_to_Process	84	18	4	0
DE	NL	Barley	Crop_to_Mix	301	121	177	0
DE	NL	Barley	Process_to_Mix	216	103	174	0
DE	NL	Lupine	Crop_to_Mix	301	121	177	0
DE	NL	Maize	Crop_to_Mix	301	121	177	0
DE	NL	Maize	Crop_to_Process	245	119	158	0
DE	NL	Maize	Process_to_Mix	216	103	174	0
DE	NL	Pea	Crop_to_Mix	301	121	177	0
DE	NL	Rapeseed	Crop_to_Process	245	119	158	0
DE	NL	Rapeseed	Process_to_Mix	216	103	174	0
DE	NL	Rye	Crop_to_Mix	301	121	177	0
DE	NL	Rye	Crop_to_Process	245	119	158	0
DE	NL	Rye	Process_to_Mix	216	103	174	0
DE	NL	Starch potato	Process_to_Mix	216	103	174	0
DE	NL	Sugar beet	Process_to_Mix	216	103	174	0
DE	NL	Triticale	Crop_to_Mix	301	121	177	0
DE	NL	Wheat	Crop_to_Mix	301	121	177	0
DE	NL	Wheat	Crop_to_Process	245	119	158	0
DE	NL	Wheat	Process_to_Mix	216	103	174	0
FR	BE	Rapeseed	Crop_to_Process	368	139	146	0
FR	BE	Wheat	Crop_to_Process	368	139	146	0

Country A	Country B	Base Product	Transport Moment	Lorry dist	Train dist	InlandShip dist	SeaShip dist
FR	DE	Maize	Crop_to_Process	551	215	252	0
FR	FR	Barley	Crop_to_Process	80	11	2	0
FR	FR	Maize	Crop_to_Process	80	11	2	0
FR	NL	Barley	Crop_to_Mix	274	75	90	498
FR	NL	Barley	Process_to_Mix	194	63	88	498
FR	NL	Maize	Crop_to_Mix	274	75	90	498
FR	NL	Maize	Crop_to_Process	218	73	71	498
FR	NL	Maize	Process_to_Mix	194	63	88	498
FR	NL	Pea	Crop_to_Mix	274	75	90	498
FR	NL	Rapeseed	Crop_to_Process	194	63	88	498
FR	NL	Sunflower seed	Crop_to_Mix	274	75	90	498
FR	NL	Triticale	Crop_to_Mix	274	75	90	498
FR	NL	Wheat	Crop_to_Mix	274	75	90	498
FR	NL	Wheat	Crop_to_Process	218	73	71	498
ID	ID	Coconut	Crop_to_Process	15	0	0.0	0
ID	ID	Oil palm fruit bunch	Crop_to_Process	15	0	0.0	0
ID	NL	Coconut	Process_to_Mix	456	2	19	15794
ID	NL	Oil palm fruit bunch	Process_to_Mix	456	2	19	15794
IE	IE	Barley	Crop_to_Mix	58	1	0.0	0
IE	IE	Barley	Crop_to_Process	58	1	0.0	0
IE	IE	Barley	Process_to_Mix	58	1	0.0	0
IE	IE	Wheat	Crop_to_Mix	58	1	0.0	0
IN	IE	Sugar cane	Process_to_Mix	58	1	0.0	11655
IN	IN	Coconut	Crop_to_Process	15	0	0.0	0
IN	IN	Sugar cane	Crop_to_Process	25	0	0.0	0
IN	NL	Coconut	Process_to_Mix	224	672	19	11655

IN	NL	Sugar cane	Process_to_Mix	224	2	19	11655
MY	MY	Oil palm fruit bunch	Crop_to_Process	15	0	0.0	0
MY	NL	Oil palm fruit bunch	Process_to_Mix	160	107	19	14975
NL	BE	Oat	Crop_to_Process	141	26	128	0
Country A	**Country B**	**Base Product**	**Transport Moment**	**Lorry dist**	**Train dist**	**InlandShip dist**	**SeaShip dist**
NL	BE	Wheat	Crop_to_Process	141	26	128	0
NL	NL	Animal by-product	Process_to_Mix	56	2	19	0
NL	NL	Brewers grains	Process_to_Mix	56	2	19	0
NL	NL	Fodder beet	Crop_to_Mix	56	2	19	0
NL	NL	Fodder beet	Crop_to_Process	56	2	19	0
NL	NL	Fodder beet	Process_to_Mix	56	2	19	0
NL	NL	Maize	Process_to_Mix	56	2	19	0
NL	NL	Milk	Crop_to_Process	93	0	0	0
NL	NL	Milk	Process_to_Mix	56	2	19	0
NL	NL	Oat	Process_to_Mix	56	2	19	0
NL	NL	Oat	Crop_to_Process	56	2	19	0
NL	NL	Oat	Crop_to_Mix	56	2	19	0
NL	NL	Rapeseed	Process_to_Mix	56	2	19	0
NL	NL	Rye	Process_to_Mix	56	2	19	0
NL	NL	Soybean	Process_to_Mix	56	2	19	0
NL	NL	Starch potato	Crop_to_Process	56	2	19	0
NL	NL	Starch potato	Process_to_Mix	56	2	19	0
NL	NL	Sugar beet	Crop_to_Process	56	2	19	0
NL	NL	Sugar beet	Process_to_Mix	56	2	19	0
NL	NL	Sugar beet	Crop_to_Mix	56	2	19	0
NL	NL	Triticale	Crop_to_Mix	56	2	19	0
NL	NL	Wheat	Crop_to_Mix	56	2	19	0

NL	NL	Wheat	Process_to_Mix	56	2	19	0
NL	NL	Wheat	Crop_to_Process	56	2	19	0
PH	NL	Coconut	Process_to_Mix	456	2	19	17811
Country A	**Country B**	**Base Product**	**Transport Moment**	**Lorry dist**	**Train dist**	**InlandShip dist**	**SeaShip dist**
PH	PH	Coconut	Crop_to_Process	15	0	0.0	0
PK	IE	Sugar cane	Process_to_Mix	58	1	0.0	10900
PK	NL	Sugar cane	Process_to_Mix	1075	2	19	11275
PK	PK	Sugar cane	Crop_to_Process	25	0	0.0	0
PL	BE	Rye	Crop_to_Process	697	305	12	230
PL	NL	Rye	Crop_to_Mix	689	280	30	207
PL	NL	Rye	Crop_to_Process	633	278	10	207
SD	NL	Sugar cane	Process_to_Mix	461	2	19	7439
SD	SD	Sugar cane	Crop_to_Process	25	0	0.0	0
TH	NL	Cassava	Process_to_Mix	363	2	19	16787
TH	TH	Cassava	Crop_to_Process	15	0	0.0	0
UA	NL	Sunflower seed	Process_to_Mix	56	2	19	6423
UA	NL	Sunflower seed	Crop_to_Mix	341	2	19	6423
UA	UA	Sunflower seed	Crop_to_Process	285	0	0.0	0
UK	BE	Wheat	Crop_to_Process	134	11	0.09	784
UK	IE	Barley	Crop_to_Mix	170	12	0.1	441
UK	IE	Barley	Process_to_Mix	86	1	0.0	441
UK	IE	Wheat	Crop_to_Mix	170	12	0.1	441
UK	NL	Wheat	Crop_to_Mix	183	14	19	684
UK	NL	Wheat	Crop_to_Process	128	11	0.1	684
UK	UK	Barley	Crop_to_Process	84	11	0.1	0
US	DE	Maize	Crop_to_Process	182	619	1019	7266
US	IE	Maize	Crop_to_Mix	240	619	1019	5700

US	IE	Oat	Crop_to_Mix	240	619	1019	5700
US	IE	Rapeseed	Process_to_Mix	58	1	0.0	5700
US	NL	Citrus	Process_to_Mix	56	2	19	6423
US	NL	Maize	Crop_to_Mix	238	621	1038	6365
US	NL	Maize	Crop_to_Process	182	619	1019	6365
US	NL	Maize	Crop_to_Mix	238	621	1038	6365
US	NL	Maize	Process_to_Mix	56	2	19	6365
US	NL	Sorghum	Crop_to_Mix	238	621	1038	6365
US	NL	Soybean	Crop_to_Process	182	619	1019	6365
US	NL	Soybean	Process_to_Mix	56	2	19	6365
US	NL	Soybean	Crop_to_Mix	238	621	1038	6365
US	NL	Sugar cane	Process_to_Mix	238	2	19	6365
US	US	Maize	Crop_to_Process	182	619	1019	0
US	US	Rapeseed	Crop_to_Process	182	619	1019	0
US	US	Sugar cane	Crop_to_Process	25	0	0.0	0

Annex 7 Checklist for a data-in project

Nr.	Topic	Criteria
1	Goal	Does the goal of the LCA comply with the reporting of the environmental footprint of feed ingredients for publication in the GFLI database?
2	Functional unit	Is the reference unit "1000 kg of feed ingredient as is" (at the indicated gate in the system boundaries section)?
3	Functional unit	Are relevant quality aspects and mandatory feed ingredient properties reported?
4	System boundaries	Is the system boundary gate defined clearly and correctly according to the GFLI guidelines and are all main stages from cradle to this gate included?
5	System boundaries	Are all foreground unit processes described properly?
6	System boundaries	Are all (potentially) relevant inputs and outputs included/considered in each of the foreground system unit processes (for example, land use change and peatland emissions in cultivation processes)?
7	System boundaries	Are processes included that should not be? Can they be removed from the LCA for GFLI application?
8	LCI data	Do the foreground system LCI data look plausible (within the expected range) and is there plausible explanation/proof in case of very high efficiency/purchasing of certified feed ingredients?
9	LCI data	Is the use of background data in line with the GFLI guidelines (and if deviating from default database GFLI/Agri-footprint, is this sufficiently justified)?
10	LCI data	Is a 3-year/steady state average used for cultivation (and if not, is this sufficiently justified)?
11	LCI data	Has the mandatory methodology for calculating land use change/land transformation been followed?
12	LCI data (primary)	Has primary data been collected in a correct way? If based on a sample, is the sample size sufficient to guarantee representativeness (for branded data, including the square root of the number of operations/facilities in the sub-population)?
13	LCI data (primary)	Does the primary data comply to the minimum requirements for primary and adapted secondary data/maximum for secondary data?
14	Emission modelling	Is the emissions modelling (if relevant) compliant to the GFLI?
15	Allocation	Have the allocation procedures been followed correctly in all foreground system unit processes (in 3 different versions, i.e. economic, mass, and energy)?
16	Data quality rating	Is the data quality rating compliant to the GFLI guidelines? And does the overall score meet the requirements, depending on the type of data (branded, sectoral, regional)?
17	Meta data	Have the meta data been reported appropriately?
18	LCIA	Are the data provided in the template with all required indicators (EF3.1 and ReCiPe 2016 Midpoint H + adapted to display GWP separated in peat and LUC) and all allocation alternatives (economic, mass, and energy)?
19	LCIA	Do the datasets represent a likely environmental footprint, is it measurable against other datasets in the same category or feed ingredients?

20	LCIA	If there are large deviations, do the documents provide enough evidence and reason to support the data?
21	LCIA	Is the GFLI LCIA template used?
22	LCIA	Does the process description follow the guidelines by GFLI

Project proposal

for data-in projects

Global Metrics for Sustainable Feed

Annex 8 Project Proposal data-in projects

Company «name of the company»
Date «date»
Form filled in by «first name, last name»

Applying for a data-in project requires filling in this project proposal form. The project proposal provides guidance and an overview for both the applying party as well as GFLI. All light-green fields should be filled in by the applying company. Completed forms can be returned via email to Claudia Meeusen (meeusen@globalfeedlca.org).

For help or feedback regarding the project proposal, you are welcome to reach out to your GFLI contact person or the GFLI Secretariat (info@globalfeedlca.org).

General information

General information ***Please indicate the description in the green fields below***	
Type of data-project	«Branded data or sectoral data»
Phase of data-in project	«New project, update of existing project or modelling subproject»
Used LCA-software modelling program:	«Type here»

Goal and scope

Please fill in the right column in the table below.

Goal and scope ***Please indicate the description in the green fields below***	
Ingredients in scope:	«Type here»
Technologies in scope:	«Type here»
System boundary:	«Type here»
Remarks:	«Type here»

Data collection procedure

Please indicate in the table below a description of the data collection procedure. It should provide insight in who is collecting which data and which approach is used.

Description of data collection procedure ***Please indicate the description of data collection in the green field below***	
General description:	«Type here»

Methodology

Description of methodology ***Please indicate the methodology in the green field below***	
General description:	«Type here»
Is higher/alternative tier modelling used? If yes please specify:	«Type here»

Work plan

The work plan should contain information about all relevant participants included in the project. Furthermore, the activities to be executed and deliverables should be included in the work plan.

Work plan ***Please indicate the work plan in the green field below***	
Participants	«Type here»
Activities that will be executed:	«Type here»
Deliverables:	«Type here»
Remark	«Type here»

Planning

The timeline of a data-in project may vary depending on various factors such as the availability of data and level of communication. Please indicate the estimated time needed before delivering all relevant information to GFLI, specify whether you already found an LCA-consultant and the status of data collection.

Planning ***Please indicate the planning in the green field below***	
Found an LCA-consultant?	«Yes/No»
Data collection status	«Type here»
Estimated timeline for finalizing data collection	«Type here»

gfli

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