

# Klimato

# Klimato Database Methodology



Input	Origin & production method	kg CO2e / kg of food
Knorr Garlic Puree	UK, Conventional	0.70
Salt Cooking	Global average, Conventional	0.75
Plumtree Pork sausage 8's British 65% Meat	UK, Conventional	5.68
Mozzarella & Cheddar Grated	UK, Conventional	6.61
Lasagne non pre-cook	Global average, Conventional	15.96
Ardo Ginger Diced	Global average, Conventional	0.83
Brakes Black Pepper Cracked	Global average, Conventional	9.61
Milk Semi Skimmed	Global average, Conventional	2.14
Onions Diced 10mm	UK, Conventional	0.45
Onions Diced	UK, Conventional	0.45
Chopped Tomatoes Italian, in tomato juice	Global average, Conventional	0.76
Vegetable Oil Extended Life	UK, Conventional	3.49
Spiced Fruit Teacake Info MK5, sliced	Global average, Conventional	0.86
Blue Dragon Teriyaki Sauce	Global average, Conventional	1.08
Tomato Paste Italian	Global average, Conventional	1.03
Chopped Garlic in oil	UK, Conventional	0.70
Hake 140-170g (5-6oz) Fillet	Global average, Conventional	10.11
Brakes Chopped Tomatoes In Juice	Global average, Conventional	0.76
Vegetable Oil	UK, Conventional	3.49
Basil	Global average, Conventional	1.56
Oregano	Global average, Conventional	4.23
Spinach Pousse Epinard	UK, Conventional	0.32
Diced Chuck Red Tractor Halal	Global average, Conventional	46.80
Mixed Spice ground	Global average, Conventional	9.61
Chillies Red	UK, Conventional	2.20
Blue Dragon Coconut Milk	Global average, Conventional	0.76
Sweet Potatoes Diced	UK, Conventional	0.74
1kg Sliced Onions 6mm X 1kg Bag(1 x 1Kg)	Global average, Conventional	0.81



# Klimato

## Table of Contents

<b>Executive summary</b>	<b>3</b>
Why this methodology matters	3
Data sources and inclusion criteria	3
System boundaries and functional unit	4
Dealing with data gaps	4
SBTi and the FLAG emissions split	4
Additional environmental indicators and nutrition	5
Governance and quality assurance	5
<b>1. Database methodology</b>	<b>6</b>
1.1 Study Inclusion Criteria	6
1.1.1 Preference hierarchy	8
1.2 Functional unit	9
1.3 System boundaries and life cycle stage definition	9
1.3.1 Agriculture & Land Use Change	10
1.3.2 Processing	11
1.3.3 Packaging	11
1.3.4 Distribution	11
1.3.5 Food losses	12
1.4 Allocation	15
1.5 Dealing with data gaps	15
1.5.1 Proxy data	15
1.5.2 Models	16
1.5.3 Global values	17
1.6 FLAG split as per SBTi	17
1.7 Environmental impacts	18
1.7.1 Nutrient pollution	18
1.7.2 Land use	19
1.7.3 Water use	19
1.8 Nutritional values	20
1.9 Internal data handling and governance	20
1.9.1 Version Control and Naming Convention	21
<b>References</b>	<b>22</b>
<b>Appendix 1 - Land Use Change</b>	<b>25</b>
<b>Appendix 2 - Domestic Distribution</b>	<b>26</b>
European countries	26
US and Canada	27
United Arab Emirates (UAE)	27
Hong Kong	27

# Klimato

## Executive summary

### Why this methodology matters

By combining rigorous LCA data selection, comprehensive system boundaries, transparent fallback logic, and alignment with SBTi FLAG guidance, Klimato's database enables food businesses to quantify and reduce their climate impact. The inclusion of additional indicators and nutritional values provides a holistic view of sustainability, and the menu-label system translates complex science into clear guidance for diners and operators.

The Klimato Database powers key tools in Klimato's offer to food businesses, including:

- **Klimato Food Emissions**, enabling Scope 3 Category 1 reporting
- **Klimato Carbon Accounting**, enabling businesses to quantify corporate emissions with a focus on food.
- **Klimato Product Carbon Footprint**, which calculates product-level carbon footprints for packaged food and ingredient suppliers.
- **Klimato Carbon Labeling** features a Recipe Calculator to help users design low-carbon meals and generate carbon labels for consumers.

The Klimato database provides region-specific emission factors for more than 4,000 food ingredients and 20,000 variations. The database has been reviewed by the **World Resources Institute** (Coolfood) and IVL.

### Data sources and inclusion criteria

Klimato's data are derived primarily from attributional life-cycle assessment (LCA) studies published between 2009 and 2025. To be included, a study must:

- Follow ISO 14040/44/67 standards and clearly describe its assumptions and system boundaries.
- Use a functional unit convertible to kilograms of edible product; for meat, values are converted to bone-free meat using published factors.
- Cover material acquisition and pre-processing, production, and packaging stages; missing stages are estimated via Klimato modelling.



# Klimato

When multiple studies exist for the same ingredient and country, Klimato selects the one that best reflects national production systems and is the most recent and transparent. University theses, conference papers, and Environmental Product Declarations (EPDs) are used if their methodologies are robust.

## System boundaries and functional unit

Carbon footprints are shown as **kg CO<sub>2</sub>e per kg of edible product**. The system boundary runs from **agricultural production** (including land-use change), through **processing, packaging, and distribution** to a regional center, and includes **post-harvest food losses**.

## Dealing with data gaps

If Klimato cannot find suitable literature for a specific country or ingredient, it uses a structured fallback process. First, it seeks proxy data from similar countries, food categories, or production methods with comparable climate, soil, and energy mix. If proxy data are insufficient, Klimato then applies proprietary estimation models built from peer-reviewed parameters to estimate the missing life-cycle stages. If neither method is suitable, Klimato uses global weighted averages based on FAOSTAT production volumes.

- 1) **Proxy data:** When region-specific data are unavailable, Klimato selects values from countries, categories, or production methods that closely match in climate, soil, and energy mix.
- 2) **Estimation models:** If proxy data are insufficient, proprietary models built from peer-reviewed parameters estimate missing life-cycle stages. For example, the carbon footprint of beef sausage in Finland is derived from the base beef footprint, the meat content of sausages and the energy intensity of processing.
- 3) **Global weighted averages:** If neither proxy data nor estimation models provide suitable information, Klimato applies global averages weighted by FAOSTAT production volumes.

## SBTi and the FLAG emissions split

The **Science Based Targets initiative (SBTi)** urges companies to set emission-reduction targets that support the Paris Agreement. SBTi's **FLAG** framework (Forest, Land and Agriculture) requires companies to report emissions distinguished between **land-use change** and **land-management emissions**. Reporting FLAG emissions helps companies meet SBTi validation requirements for sectors with large land-based emissions, like the food sector.

Klimato calculates and reports carbon footprints with this split:

- Land-management emissions come directly from the selected LCA studies

# Klimato

- Land-use change emissions are estimated using a tiered model based on PAS 2050-1 and spread over 20 years as recommended by the Land Sector and Removal Guidance (GHG Protocol).

## Additional environmental indicators and nutrition

To provide a broader sustainability perspective, the database also reports:



**Nutrient pollution:** eutrophication potential measured in grams of phosphate equivalent per kilogram of product.



**Land use:** m<sup>2</sup>·year/kg of land occupied, based on region-specific data from Poore & Nemecek (2018).



**Water use:** measured in cubic metres per kilogram, broken down into green, blue, and grey water. This follows the Water Footprint Network and research by Mekonnen & Hoekstra.

Klimato adds nutritional values by linking each ingredient to national food composition datasets. These datasets include those from the UK (CoFID), Sweden (Livsmedelsverket), France (ANSES-CIQUAL), and the United States (USDA FoodData Central).

## Governance and quality assurance

The database is maintained by Klimato's science team. Updates are typically released annually; interim updates occur when significant new data emerge. Each new dataset is screened for quality, harmonised to the internal structure, and documented with metadata on source, publication year, and assumptions. A versioning convention and changelog ensure transparency and traceability.

# Klimato

## Extensive Methodology

### 1. Database methodology

#### 1.1 Study Inclusion Criteria

Peer-reviewed studies are evaluated against a comprehensive set of criteria to determine their suitability for inclusion in the database. **Table 1** outlines these requirements along with the actions taken if criteria are not met, ensuring a transparent and consistent selection process.

**Table 1:** Evaluation Criteria for Inclusion

Criterion	Requirement	Action if Not Met
<b>LCA Type</b>	Must be attributional. The study should follow ISO 14040, 14044, and 14067 standards.	Exclude study.
<b>Publication Type &amp; Credibility</b>	The database primarily includes peer-reviewed journal articles by authors with strong credentials and affiliations. Citation count and journal reputation are considered indicators of reliability. University theses, conference papers, Environmental Product Declarations (EPDs), and certified LCA databases (e.g., Agribalyse) are also included when their methodologies are transparent and robust. Studies with unclear or inconsistent assumptions are flagged or excluded.	Gray literature (e.g., blogs, newspaper articles, social media posts) is generally avoided unless it directly links to a scientific source or a peer-reviewed reference.
<b>Assumptions Transparency</b>	Clear documentation of methodology, emission factors (EF), and assumptions is required.	The study is rejected or flagged if assumptions are unclear or inconsistent.
<b>Functional Unit (FU)</b>	The FU shall be expressed per kg of edible product or be convertible to it.	Converted to the correct functional unit using appropriate factors (e.g., from carcass to bone-free meat).
<b>System Boundaries (SB)</b>	The SB should cover Material acquisition and pre-processing, Production, and Packaging.	Missing stages' emissions are estimated using Klimato modelling or Clune et al. data <sup>1</sup> .
<b>Stage Breakdown</b>	Emissions should be broken down per life cycle stage.	Emissions from stages not reported separately are estimated using Klimato's modelling or data from Clune et al.

<sup>1</sup> Clune, S., Crossin, E. and Verghese, K., 2017. Systematic review of greenhouse gas emissions for different fresh food categories. *Journal of Cleaner Production*, 140, pp.766-783

<b>Land Use Change (LUC)</b>	<p>Studies should include direct or statistical LUC but exclude indirect LUC. If indirect LUC is included, it must be reported separately.</p>	<p>If direct or statistical LUC is provided and reported separately in the study, the source value is used.</p> <p>If direct or statistical LUC is included or mentioned but not reported separately, the LUC model is used to estimate the LUC emissions.</p> <p>If LUC is not mentioned, it is assumed that no direct or statistical LUC is involved.</p> <p>If indirect LUC is included and reported separately, the emissions from it are excluded from the final value used in the database.</p> <p>If indirect LUC is included but not reported separately, the study is excluded.</p>
<b>Carbon Sequestration</b>	<p>If included in the study, it must be clearly reported as a separate value.</p>	<p>Carbon sequestration emissions are removed when they can be separated; if not separable, the study is excluded.</p>
<b>Allocation Method</b>	<p>Studies applying physical and economic allocation are preferred, as the Klimato database only accepts attributional LCA studies and system expansion can bring in consequential thinking.</p>	<p>If a study uses system expansion, and it is the only available data source that otherwise meets the attributional LCA requirement, it is accepted for inclusion. In all cases, regardless of the allocation method applied in the study, the allocation method is mentioned in the metadata of the Klimato database.</p>
<b>GHG Scope</b>	<p>Must include all Kyoto Protocol (CO<sub>2</sub>, CH<sub>4</sub>, N<sub>2</sub>O, HFCs, PFCs, SF<sub>6</sub>, NF<sub>3</sub>) gases.</p>	<p>Excluded if the data cannot be corrected or supplemented to include all Kyoto Protocol gases.</p>
<b>Consistency with Literature</b>	<p>The study's results should generally align with the findings of similar LCAs in scientific literature.</p>	<p>If the study's emission values deviate significantly from similar LCAs in scientific literature, this deviation must be acknowledged and well-justified within the study itself. If such justification is absent or deemed insufficient, the study will be excluded.</p>
<b>Date of Publication</b>	<p>Data sources should be published between 2009 and 2025. More recent studies (≤ 6 years) are preferred for dynamic or fast-evolving sectors (e.g., alternative proteins), while older data may be accepted for stable and consolidated processes (e.g., conventional dairy, cereal crops).</p>	<p>Studies published outside this temporal range are excluded unless no alternative data exist and the available study meets the representativeness criteria.</p>

# Klimato

<b>Representativeness</b>	The study should reflect the dominant or typical production systems used in the region or country, such as national or regional averages. Studies focusing on experimental, pilot-scale, or highly innovative systems that are not yet widely adopted should be deprioritised unless no other data exists.	Flagged for potential lack of generalizability.
<b>Comparative Studies</b>	All else being equal, studies that compare conventional and organic systems under the same methodological conditions are preferred.	If no suitable comparative study exists, separate studies that individually meet Klimato's criteria are used. If no organic-specific data is available, it is assumed that emissions for organic are equal to conventional, and the assumption is clearly documented in the database.
<b>Review or Harmonized Studies</b>	All else being equal, review studies or comprehensive datasets that provide harmonized emissions data across ingredient categories using consistent methods are preferred.	/

In cases where data sources for a specific ingredient are limited and do not fully meet all inclusion criteria, the available source may still be included if it satisfies the minimum requirements of being attributional, transparent, and reasonably recent. Such entries will include:

- Clear documentation of assumptions and limitations, and
- A flag in the Klimato database indicating limited representativeness or data uncertainty.

All fallback decisions are subject to internal cross-validation to ensure methodological consistency and uphold the quality of the assessment in cases of limited data availability.

## 1.1.1 Preference hierarchy when multiple studies are available for the same ingredient in a given country or region

When multiple data sources are available for the same ingredient in a given country or region (e.g., several studies on milk production in Sweden), and all meet the core quality criteria, the following hierarchy is used to select the most appropriate source:

- 1) Representativeness** of the system for the country/region: most representative of national or regionally dominant production systems. For example, if one study covers intensive beef production and another covers extensive farming, but the majority of beef consumed in the country is produced through intensive systems, the study on intensive production is preferred. If no information is available on the dominant production system in the country or region, studies are compared based on other criteria in this hierarchy.

# Klimato

- 2) **Recency:** Most recent (up-to-date) study. Data must reflect current practices.
- 3) **Methodological transparency:** Highest level of methodological transparency and data clarity to ensure results can be trusted and understood.
- 4) **Granularity:** Most detailed breakdown of life cycle stages.

Potential conflicts between selection criteria are resolved by prioritizing the criterion of higher importance in the established hierarchy.

Sometimes, a selected study includes multiple production methods. In such cases, if one method clearly dominates national production (e.g., most of the meat consumed is produced intensively), we use the value corresponding to that method. If no information is available on the dominant method and production volumes are similar (i.e., within 25% of each other), we use an average. If production volumes differ significantly, we use the value corresponding to the method with the higher production share. This approach is consistently applied across all products with multiple production methods, including meat, vegetables, and fruits.

## 1.2 Functional unit



The functional unit is the reference unit used to quantify and compare environmental impacts. It defines what is being assessed and how much of it.

The functional unit is the reference unit used to quantify and compare environmental impacts. It defines what is being assessed and how much of it.

Carbon footprint (CF) values in the database are expressed in kilograms of CO<sub>2</sub>-equivalent per kilogram of food product (kg CO<sub>2</sub>e/kg food) as the functional unit. For meat and fish products, values are reported per kilogram of bone-free meat (BFM), with conversion factors from live weight or carcass weight to BFM based on Clune et al. (2017).

## 1.3 System boundaries and life cycle stage definition



System boundaries define which stages of a product's life cycle are included when assessing environmental impacts.

The CF values in the Klimato database encompass emissions from multiple stages of the food product's life cycle, including the agricultural stage, processing, packaging, and distribution to the regional distribution center. Emissions associated with food losses are also taken into account.

# Klimato

The definitions of each stage, along with a detailed breakdown of what is included, are provided in the following sections.

## 1.3.1 Agriculture & Land Use Change

This component accounts for the share of the carbon footprint resulting from the agricultural stage, including emissions from land use change (LUC).

### Agriculture

This value can be sourced directly from literature (including calculations derived from published data), estimated through Klimato's internal models, or approximated using proxy data. For more details on how proxy data and models are applied, please refer to [Section 1.5.1](#) and [Section 1.5.2](#), respectively.

### Land Use Change



LUC refers to the transformation of natural landscapes into agricultural or industrial areas, leading to carbon stock changes and greenhouse gas emissions. LUC emissions primarily stem from deforestation, peatland drainage, and land conversion for agriculture. These emissions contribute significantly to the CF of food products, particularly for crops cultivated in regions with active deforestation.

LUC impacts are accounted for using a tiered approach, prioritising data sources by their accuracy. Methodologies are applied in the following order of preference (from most to least accurate) with Step 1 being the most accurate. Less specific approaches are used only when higher-quality data are not available.

The assessment follows these three steps:

- 1) Literature-derived LUC values:** When primary data are not available, LUC emissions are sourced directly from peer-reviewed studies that provide either statistical or direct land use change data.
- 2) Klimato's LUC estimation model:** For cases where literature does not provide explicit LUC values, a proprietary model is used to estimate emissions based on historical land conversion data and global land use trends.
- 3) Proxy data:** If neither literature nor modeling data is available, LUC values are approximated based on similar crops or assumed negligible if data supports a low risk of land conversion.

# Klimato

Klimato's LUC model is developed in accordance with the PAS 2050-1 methodology by the BSI (2012), using factors and parameters from IPCC and statistical data from FAO. It follows a linear amortization approach over a 20-year period, in line with GHG Protocol Land Sector Guidance.

The selection of the linear amortization approach ensures that recent land use changes are weighted more heavily, aligning with the Science-Based Targets initiative (SBTi) recommendations.

Further details about Klimato's LUC emissions model are provided in [Appendix 1](#).

## 1.3.2 Processing

This stage represents the share of the carbon footprint attributed to the processing of the ingredient, if any. This value can be sourced from the literature, derived from a model, or estimated. When a specific model is not available or considered unnecessary, default parameters based on the ingredient type are applied. These default values are taken from Clune et al. (2017).

## 1.3.3 Packaging

The packaging stage represents the share of the carbon footprint attributed to the packaging of the ingredient, if any. The value can either come from the literature paper, or be estimated. In this case we use a default parameter depending on the type of ingredient and packaging, based on the data provided by Clune et al. (2017).

## 1.3.4 Distribution

Distribution emissions from the country of food production to the country of consumption are included. Moreover, Klimato includes emissions from domestic transport when the country of production and consumption is the same.

### International distribution

In case of international distribution, transport distances are calculated using the Haversine formula based on latitude and longitude coordinates for the origin and destination.

Klimato estimates food transport modes (i.e., truck, ship, train, or plane) based on common practices in international logistics. These assumptions are informed by a combination of academic literature, government data, and trade publications. Key sources include Gleave et al. (2015), national freight statistics (e.g., BTS Freight in America), industry reports (e.g., Kan-Haul's U.S. Food Transportation Infographic), and international trade snapshots (e.g., UAE Food and Agriculture Snapshot, 2022; Li et al., 2022 on global food miles).

# Klimato

Emissions from transport are calculated in kg CO<sub>2</sub>e for 1kg of any food product transported for a certain distance in km. Klimato uses emission factors from Sacchi & Bauer (2023) and DEFRA (2025)

## Domestic distribution

To estimate the carbon footprint associated with domestic food transport, Klimato applies a region-specific methodology. The approach focuses on identifying the dominant transport modes, estimating average transport distances, and applying appropriate emission factors to calculate transport-related emissions. The methodology varies by region depending on data availability, infrastructure, and transport practices. More detailed information can be found in Appendix 2.

### 1.3.5 Food losses



At Klimato, we follow the definition of food losses and food waste provided by FAO (2011). According to this definition, food losses and waste refer to the quantities of edible food intended for human consumption that are lost or discarded along the food supply chain. This excludes food used for animal feed or inedible parts of food products. The key distinction between the two lies in where they occur: food losses occur during production (including harvest and pre-harvest operations), post-harvest handling, and processing, while food waste takes place at the end of the food chain (retail and final consumption), mainly due to retailers' and consumers' behavior.

The carbon footprints of food products in Klimato's database include the impact of food losses, but exclude food waste. Following Poore and Nemecek (2018), we account for losses from postharvest handling and storage as well as processing, packaging and transport. However, losses occurring before and during harvest are excluded. This approach aligns with FAO's methodologies for developing food balances (FAO, 2023) and monitoring the SDG Target 12.3.1 Global Food Loss Index (FAO, 2018).

To include food losses into Klimato's carbon footprints, we used weight percentages of food losses for different food categories to estimate the additional quantity of food required to deliver one kg of food (Table 2). The loss percentages were primarily derived using data from FAO (2011; Annex 4 p.26-27). For certain food categories not covered by FAO (e.g., coffee and spices), we used data from Waite et al. (2019). Since the reported losses in FAO (2011) are for different regions worldwide, we used regional domestic supply data from FAO's food balances (FAO, 2021) to calculate global weighted averages for each category.

Based on estimated loss percentages, we calculated the carbon footprints by factoring in the additional GHG emissions associated with producing surplus food to compensate for losses. Equation 1 estimates the absolute emissions from food losses during the agricultural,

# Klimato

processing, and packaging stages (L1), while Equation 2 accounts for emissions from losses during the transport stages (L2).

$$L1 = CF_{agriculture} + CF_{processing} + CF_{packaging}) * L1(\%) \quad (1)$$

$$L2 = CF_{agriculture} + CF_{processing} + CF_{packaging} + CF_{transport}) * L2(\%) \quad (2) \quad (1)$$

Where:

- **CF<sub>agriculture</sub>** = Carbon footprint of the agricultural stage (including post-harvest and handling), in kg CO<sub>2</sub>e/kg
- **CF<sub>processing</sub>** = Carbon footprint of the processing stage, in kg CO<sub>2</sub>e/kg
- **CF<sub>packaging</sub>** = Carbon footprint of the packaging stage, in kg CO<sub>2</sub>e/kg
- **CF<sub>transport</sub>** = Carbon footprint of the transport stage, in kg CO<sub>2</sub>e/kg
- **L1(%)** = Estimated percentage increase in emissions due to food losses across agriculture, processing, and packaging stages.
- **L2(%)** = Estimated percentage increase in emissions due to food losses across transport stages.

**Table 2:** Percentage increase in carbon footprint due to food losses at agricultural, processing and packaging stages across various food categories.

<b>Category</b>	<b>L1(%)</b> <i>Increase in carbon footprint due to losses across the agriculture, processing, and packaging stages (%)</i>	<b>L2(%)</b> <i>Increase in carbon footprint due to losses during transport (%)</i>
Juices	0.0%	0.0%
Water	0.0%	0.0%
Alcoholic beverages	7.9%	1.0%
Soft drinks	8.0%	0.3%
Fats & Oil	11.3%	1.8%
Fish & shellfish	11.1%	0.3%
Fruits & berries	19.8%	4.4%
Vegetables	14.3%	4.4%
Root vegetables	30.5%	4.4%
Mushrooms	1.6%	0.8%
Legumes	15.4%	1.0%
Beef	5.6%	0.4%

# Klimato

Pork	5.6%	0.4%
Chicken	5.6%	0.4%
Lamb	5.6%	0.4%
Other meat types	5.6%	0.4%
Meat substitutes	0.0%	0.0%
Dairy	5.2%	0.4%
Dairy substitutes	0.0%	0.0%
Milk substitutes	13.7%	1.8%
Nuts, seeds & kernels	10.2%	1.8%
Sugars and sweeteners	6.3%	2.0%
Flours and bread	0.0%	0.0%
Rice	9.1%	1.0%
Cereals and pasta	9.1%	1.0%
Egg	0.5%	0.4%
Other ingredients	0.0%	0.0%
Herbs and spices	26.3%	0.3%
Vegetarian recipes and sauces	0.0%	0.0%
Vegan recipes and sauces	0.0%	0.0%
Meat and fish recipes and sauces	0.0%	0.0%
Coffee, tea, and chocolate	26.3%	0.3%

Some categories in **Table 2** show a 0.0% increase due to losses. This is because these categories typically represent processed products or prepared dishes. For these items, the food losses are primarily captured and accounted for at the raw ingredient level. Including an additional loss percentage for the final product or recipe would result in **double-counting** the impact of losses, thus overstating their carbon footprint.

## 1.4 Allocation

During the literature review process to assess the CF values for ingredients in the Klimato database, the allocation method used in each study was stored as metadata. This ensures the final CF values can be properly explained and justified.

When possible, priority was given to papers that used the same allocation method for foods within the same category. However, there were instances where this was not feasible due to insufficient literature sources. In such cases, the allocation method reported in the available study was used.

## 1.5 Dealing with data gaps

In cases where specific literature values are absent, Klimato resorts to **proxy data** or **internal models**. Proxy data involves attributing the carbon footprint of a similar food product based on shared characteristics like food category, cultivation methods, and country similarities (climate, soil, energy mix). Internal models are proprietary estimation models applied for data gaps or when existing sources do not cover all life cycle stages, built using data from peer-reviewed sources (e.g., for Land Use Change, Processing, and Packaging).

### 1.5.1 Proxy data

During a literature review, it is possible to encounter a lack of data regarding certain food types or production countries, resulting in unknown food carbon footprint (CF) values. In these cases, Klimato makes some assumptions.

Klimato attributes to a food product the same CF of another when:

- Two countries have similar climate, soil, food production methods, and energy mix (e.g., the known value for potatoes produced in Sweden is assigned to potatoes produced in Norway, whose CF is unknown),
- The food belongs to the same food category (e.g., equivalent to fruit must be another fruit), and
- The food has the same cultivation and/or production methods (e.g., equivalent to a vegetable grown in a greenhouse must be another vegetable also grown in a greenhouse).

### 1.5.2 Models

In the absence of specific carbon footprint data for certain ingredients, or when available sources do not cover all life cycle stages within Klimato's system boundaries, estimation models may be applied as a secondary option. These models are built using data from peer-reviewed sources, including conversion ratios, processing yields, energy consumption figures, or other relevant parameters, depending on the type of ingredient. Their purpose is to derive reasonable estimates for the Agriculture and/or Processing stages of ingredients not directly covered in the literature.

These models currently support a range of ingredients and food categories, such as:

- Meat conversions (e.g., *live weight to boneless meat*)
- Processed meat and fish products
- Beef to veal ratio
- Bakery products (e.g., *bread, flour, bran*)

# Klimato

- Pulses and legumes
- Dairy products
- Brewed beverages (e.g., *tea, coffee*)
- Chocolate and cocoa derivatives
- Fried and dried products (e.g., *chips, crisps, vegetables*)
- Cooked and canned goods
- Cakes and baked goods
- Egg components (e.g., *yolk, white*)



## Example: **Beef Sausage Produced in Finland**

Here, it is reported how Klimato calculates the climate impact of beef sausage produced in Finland as an example of our models. Klimato uses the baseline value from the Klimato database for unprocessed products (i.e., beef produced in Finland). The value is extracted from Hietala et al., 2021.

Model development: According to Scholz (2013), most sausages have an average meat content of 60%, and the non-meat portion has a negligible influence on the total CF of the product. The same study also provides information on the energy required to process beef meat into sausages. Using this data, Klimato estimates the CF of the production stage by applying the reported energy consumption (in kWh), the country-specific energy emission factor for Finland, and the 60% meat content assumption.

The country-specific emission factors are sourced from OurWorldinData (2022) and represent the production mix (i.e., the average carbon intensity of electricity produced in each country). Klimato uses the production mix rather than the residual mix because the database is designed to reflect average food products, not specific supply chains or producers, an approach more appropriate for generalized LCA modelling.

## 1.5.3 Global values

The database also contains global average values, which are weighted averages by production volumes from FAOSTAT and focused on top-producing countries for representativeness.

Global averages are selected by users when:

- Specific country data is missing for an ingredient.
- Ingredient origin is unknown or varies.
- Users operate in regions lacking country-specific data.
- Users prefer a global assessment across multiple countries.

# Klimato

## 1.6 FLAG split as per SBTi

The [Science Based Targets initiative \(SBTi\)](#) helps companies set emissions reduction targets in line with climate science — specifically, with the goals of the Paris Agreement.


Many businesses already set SBTi-aligned climate targets. But the SBTi has now introduced a dedicated framework for land-based emissions, called **FLAG**.

**FLAG** stands for **Forest, Land, and Agriculture**. It covers greenhouse gas emissions and removals that are tied to how land is used and managed.

FLAG emissions include:

- **Land use change (LUC)** — for example, converting forests to farmland
- **Land management emissions** — such as emissions from livestock, soils, and fertilizers

To help companies prepare for their [SBTi Service Portal submission](#), Klimato provides carbon emissions in line with the FLAG split requirements.

Environmental impact	Total	Unit
 <b>Carbon footprint</b>	<b>535</b>	<b>kg CO<sub>2</sub>e</b>
of which FLAG* emissions	332.6	kg CO <sub>2</sub> e
of which agriculture (land management)	332.4	kg CO <sub>2</sub> e
of which land use change	240	g CO <sub>2</sub> e

Land Management emissions are sourced from the same literature Klimato utilizes to build the database. Disaggregation between CO<sub>2</sub> and non-CO<sub>2</sub> is not possible in all cases, as original sources often report only aggregated values. All land management emissions are reported under the land management non-CO<sub>2</sub> (this is accepted by SBTi).

Land Use Change (LUC) emissions are estimated using the tiered approach explained in section 2.3.1, prioritising direct values from the literature where available. In other cases, the model developed by Klimato and based on statistical LUC is applied (Appendix 1). This model follows the PAS 2050-1 methodology (BSI, 2012), uses IPCC and FAO data and parameters, and amortises LUC emissions over a 20-year linear period, in line with the GHG Protocol Land Sector and Removals Guidance.

## 1.7 Environmental impacts

In addition to CF, the Klimato database includes three additional Environmental Impact (EI) indicators:

- **Nutrient Pollution** (Eutrophication)
- **Land Use**

## → Water Use

These are based on recognized scientific methodologies and sourced from leading research in the field.

### 1.7.1 Nutrient pollution

Nutrient pollution refers to the accumulation of nitrogen and phosphorus in ecosystems, which can cause excessive growth of plants such as algae in freshwater and marine environments. This process, known as eutrophication, negatively affects water quality and biodiversity. Nutrient pollution is primarily driven by the production and application of fertilizers.

Global nutrient pollution data are sourced from Poore and Nemecek (2018). The impact is measured in grams of phosphate equivalent (g PO<sub>4</sub><sup>3-</sup>-eq) per kilogram of product.

The assessment follows the CML 2 baseline Life Cycle Assessment method, developed by the Centre of Environmental Science at Leiden University. This evaluation encompasses the agricultural stage, as well as processing, packaging, food losses, and distribution.

### 1.7.2 Land use

Land use measures the area of land utilised for food production over time. It accounts for the land lost as a resource. It is seen as an indicator of the environmental impact\* on biodiversity. The data used for this category are region-specific and are derived from Poore and Nemecek (2018). (e.g., Europe, North America, etc.), meaning that a specific ingredient produced within countries of the same region is assigned the same land use impact. This regional approach balances accuracy and practicality, as land use patterns tend to be more similar within geographic regions due to comparable climate, agricultural practices, and land availability. Studies in life cycle assessment often apply regionalized data to capture relevant variability while maintaining methodological consistency.

Land use is measured in m<sup>2</sup>\*year/kg of product and is assessed at the agricultural production level. No distinction is made between organic and conventional farming methods.

### 1.7.3 Water use

Water use represents the volume of freshwater consumed in the production of goods and services. It accounts for three types of water involved in food production:

- **Green water:** Water from precipitation stored in the soil and used by plants.
- **Blue water:** Surface and groundwater that evaporates or is incorporated during production.

# Klimato

- **Grey water:** Freshwater needed to dilute pollutants and maintain water quality standards.

The assessment follows the Water Footprint approach developed by the Water Footprint Network.

Values in the database are specific to each region and reported in cubic meters per kilogram (m<sup>3</sup>/kg).

- For crops, data is sourced from Mekonnen and Hoekstra (2011).
- For animal products, values are based on Mekonnen and Hoekstra (2012).

## 1.8 Nutritional values

The nutritional values rely on a combination of food composition databases developed by governmental bodies and research institutions, which provide detailed data for a wide range of foods:

- United Kingdom: **The Composition of Foods Integrated Dataset** (CoFID)
- Sweden: **Livsmedelsverket** (Swedish Food Agency)
- France: **The ANSES-CIQUAL Food Composition Table** – Published by ANSES
- United States: **USDA FoodData Central**

When direct matches are not available, values are assigned based on similar ingredients using clear and reasonable assumptions, always prioritizing accuracy and consistency. Special care is taken with items that may differ significantly depending on preparation or form, such as cooked, canned, dried, or specific meat cuts.

## 1.9 Internal data handling and governance

Klimato's database is continually updated to account for new studies and scientific knowledge, ensuring that its CF values remain accurate and up-to-date.

The Klimato database is centrally maintained by the Klimato Science Team, with updates managed at the role level rather than individual responsibility to ensure transparency and continuity.

- The primary responsibility for updating, expanding, and maintaining emission factors and underlying methodology lies with the LCA Specialist.
- When adding new values to the database, the review checklist in Table 2 is applied as a standard to select the most representative studies. In case of any potential uncertainties, a second LCA specialist is involved to review the selection process.

# Klimato

- Database updates include the addition of new ingredients, packaging materials, transport modes, and methodology refinements (e.g., allocation rules, food loss application).

## Update process:

- New data is identified and evaluated for quality and source validity (see database quality screening procedure).
- Data is harmonized into Klimato's internal structure, with consideration of region, production method, and functional unit (typically kg of food).
- Each entry is documented with metadata on source, publication year, system boundaries, and any adaptations made.
- Changes are logged in the internal changelog and flagged for peer review.
- Upon successful review, updates are merged into the working version and deployed into the operational database used by the Food Producer Tool and procurement modules.

## Regular update cadence:

- Annual updates (typically Q1).
- Ad-hoc updates may be conducted when critical new datasets become available or if a methodological revision requires immediate implementation.

## 1.9.1 Version Control and Naming Convention

Each database release follows a standardized versioning structure:

Mothership\_v[major].[minor]\_[YYYY-MM-DD]

Example: Mothership\_v2.0\_2025-05-27

- **Major version changes** reflect substantial structural or methodological changes (e.g., shift to new IPCC GWP, introduction of regional allocation systems).
- **Minor versions** reflect incremental but significant improvements or corrections. Each version is accompanied by a changelog describing:
  - ◆ Scope of changes (e.g., ingredient EF updates, packaging corrections).
  - ◆ Source and rationale for changes.
  - ◆ Expected impact on existing CF values.

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## Appendix 1 - Land Use Change

LUC emissions can be categorized into two types:

- **Direct LUC (dLUC):** refer to the emissions directly resulting from land conversion in the specific area where the change occurred.
- **Statistical LUC (sLUC):** refer to emissions that are calculated for a broader area, such as a country or region, using aggregated statistical data (WRI & WBCSD, 2022).

Calculating dLUC emissions requires location-specific data on previous land use, which is often unavailable. As a result, a more practical approach is to estimate sLUC emissions based on national and regional land use statistics. To support this, Klimato has developed a global sLUC emissions model that provides country- and region-specific LUC estimates.

Klimato's LUC model is developed in accordance with the PAS 2050-1 methodology by the BSI (2012), using parameters from IPCC and national land use, crop, and yield data from FAO.

The model estimates LUC emissions for both crop and animal-based products. For animal products, it applies a **feed basket approach**, which estimates emissions based on the crop-level LUC emissions of feed ingredients weighted by their contribution to the animal's diet, in line with the SBTi (2022) guidance.

LUC emissions are allocated using a **weighted average method**. This means that emissions are proportionally assigned based on the share of land converted from different previous land categories (e.g., forest, grassland, or cropland) into the expanding crop area. The model starts by assessing the area of crop expansion within a country and determines how much of this expansion replaced each land category.

Besides country-specific LUC emissions, the model calculates global and regional average LUC emission factors for each crop and animal-based product. These values are computed using weighted averages based on crop yields (for crops) and production quantities (for animal products) per country from FAOSTAT data (FAO, 2024), averaged over the three most recent years prior to the assessment year (2022). These global and regional averages serve as default values when country-specific data are unavailable, complementing the detailed country- and crop-specific estimates derived from land use change dynamics.

To account for the temporal distribution of emissions, the model uses a 20-year amortization period and follows a **linear amortization approach**. The amortization approach determines how emissions from a LUC event are accounted for in the years following the event. There are two approaches to amortization:

- **Equal amortization:** assumes that emissions are the same for each year throughout the entire amortization period, starting from the year of the LUC event.
- **Linear amortization:** assumes that emissions gradually decrease over time, with emissions approaching zero by the end of the amortization period. In essence, with the

# Klimato

linear approach emissions from recent years receive more weight compared with earlier years.

The selection of the linear amortization approach in the Klimato database ensures that recent land use changes are weighted more heavily and aligns with both the GHG Protocol Land Sector Guidance and Science-Based Targets initiative (SBTi).

LUC emissions are allocated using a **weighted average method**. This means that emissions are proportionally assigned based on the share of land converted from different previous land categories (e.g., forest, grassland, or cropland) into the expanding crop area. The model starts by assessing the area of crop expansion within a country and determines how much of this expansion replaced each land category.

## Appendix 2 - Domestic Distribution

### European countries

The methodology is based on Valsasina (2016), originally developed for Switzerland in the Ecoinvent database. To estimate domestic transport emission factors for each region, the following steps were used.

The first step was to estimate **weighted average transport distances** for all European countries using Eurostat data from the period 2018–2024. Specifically, two key metrics were extracted for each mode of transport (**road, railway, and inland waterways**) from the relevant Eurostat datasets (Eurostat 2025a; 2025b; 2025c):

- The total quantity of freight transported (in thousand tonnes), and
- The total transport performance (in million tonne-kilometres or tkm).

These data were extracted for the following NST (Nomenclature uniforme des marchandises pour les Statistiques de Transport) 2007 groups:

1. *Products of agriculture, hunting, and forestry; fish and other fishing products*
2. *Food products, beverages, and tobacco*

For each transport mode and NST category, the **average distance** was calculated by dividing the total payload-distance (tkm) by the total freight amount (tonnes). Then, the average distance across the two categories was computed to represent the typical transport distance for food-related goods.

Next, the **modal shares** were calculated as the proportion of goods transported by each mode (road, rail, and inland waterways) in relation to the total, based on mass (tonnes). These modal shares were then combined with the mode-specific average distances to compute a **weighted average transport distance** for food products in each country.

# Klimato

Finally, these weighted average distances were used to estimate the carbon footprint of domestic food transport, using emission factors from **Mobitool 3.0** (Sacchi and Bauer, 2023).

## US and Canada

The methodology to estimate the carbon footprint of domestic transport for the US is the same as the one used for European countries. The datasets used were extracted from Freight Analysis Framework ([National Transportation Research Center](#), 2023) for the US and from the Canadian Freight Analysis Framework (Statistics Canada, 2023).

## United Arab Emirates (UAE)

The carbon footprint of domestic food transport in the UAE is estimated under the assumption that all transport is done by road. This is because the country's recently developed rail network is primarily designed for passengers and industrial goods (e.g., granulated sulfur), rather than food products (Arabian Business, 2023).

To estimate average transport distances, a sample of 14 key farm areas was identified using land use maps from Sherif et al. (2018). The road distances from these farms to the main urban centers (Dubai and Abu Dhabi) were measured using Google Maps, and the average was calculated.

The carbon footprint was then estimated using emission factors from Mobitool 3.0 (Sacchi & Bauer, 2023).

## Hong Kong

The carbon footprint of domestic transport for food products in Hong Kong was calculated assuming that all the transportation is done via road, as the distances from the agricultural areas and fishponds are small (approx. 30 km). The average distance was estimated using the land use map from Wang et al. (2018). The EFs were taken from Mobitool 3.0 (Sacchi and Bauer, 2023).

# Klimato

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