

# Life cycle assessment report - Chocolate, dark (65% cocoa), 2026-01

## Goal and scope of the study

### Goal

This study was carried out to assess the impact on climate change arising from producing Chocolate, dark (65% cocoa). The global food production system is responsible for 34% of all greenhouse gas emissions, thus understanding the impact of food products is highly relevant in combating global warming. The intended application of this report is thus to provide a climate footprint to an interested supplier who might be influenced by its magnitude of climate impact, or to a decision maker within the food supply chain to influence parameters of that product that can have an impact on its climate footprint.

### Scope

The product under study is a food product, consisting of the following ingredients: Cocoa Mass, Cocoa Butter, Sugar, Emulsifier (Lecithin).

The functional unit of the product system is 1 kg of Chocolate, dark (65% cocoa) provided to the supplier. The system boundaries include all life cycle stages from the agricultural production up until the processors gate.

The geographic scope is valid for products manufactured globally and sold in Europe.

The life cycle stages and their included activities are the following:

- LCS: Agriculture
  - For crops:
    - Fertilizers: Production of inorganic fertilizers (N, P<sub>2</sub>O<sub>5</sub>, K<sub>2</sub>O)
    - Field emissions: nitrogen compound emissions arising from applying both inorganic and organic fertilizers, CO<sub>2</sub> emissions from urea application, CH<sub>4</sub> emissions from flooding rice fields, Pesticides: Production of pesticides
    - On-farm energy: pumping and applying irrigation water (electricity use and/or production and combustion of diesel), production and combustion of diesel in agricultural machinery (e.g. hoeing, tillage, harvesting, etc.)
    - Land use change (LUC): emissions from clearing forests or transformation from perennial to annual cropland
  - For livestock:
    - Feed production (same activities as for the crops), and additionally processing the crops into feed
    - CH<sub>4</sub> emissions from enteric fermentation in ruminants
    - CH<sub>4</sub> and N<sub>2</sub>O emissions from manure management

- N<sub>2</sub>O emissions from manure deposition on pasture
  - electricity and fuel use in animal husbandry
  - Land use change from pasture expansion
- For fish and seafood from aquaculture:
  - Aquatic N<sub>2</sub>O
  - On-farm energy use (electricity, diesel)
  - Feed production (same activities as for the crops), and additionally processing the crops into feed
- For wild-caught fish and seafood:
  - Diesel use in fishing vessels
  - Production and end-of-life of fishing nets
  - Production, maintenance and end-of-life of vessel
- Other/non-agricultural raw products:
  - Generally, acquisition of raw materials
  - Energy use and waste treatment of production scrap in processing
- LCS: Processing - Processing of agricultural raw products into ingredients; production of final products from ingredients
  - Electrical and thermal energy
  - Tap water
  - Cleaning agents
  - Waste treatment of production scrap
- LCS: Transport
  - Production and combustion of diesel in lorries, ships and trains
  - Production, maintenance and end-of-life of transport vehicles and roads
  - Included the following transport step: Product from supplier to processing

### **Land use change, carbon storage and removals**

The calculation of LUC follows the PAS2050 standard. Emissions from LUC are only calculated if there was a net increase between the reference time period and 20 years prior. Both emissions and removals are considered but emissions from LUC are set to zero if the result is computed as a negative value. Carbon storage of food products or bio-based packaging is considered as temporary and is therefore excluded.

### **Data and data quality requirements**

Agricultural production inputs are based on the latest available crop-/country-specific data, with yields averaged across the three most recent years. For other products, data from the most recent scientific publications are used. Inoqo only sources data from peer-reviewed scientific articles, or official governmental bodies (e.g. FAO, IPCC).

The assessment should be valid until 2029.

### **Allocation procedures**

Following ISO 14040 and 14067, allocation is avoided wherever possible by subdivision. Else, the chosen allocation principle follows the hierarchy based on their underlying physical relationship. If no physical relationship between co-products can be established, allocation is based on market prices.

Consequently, allocation procedures for products are as follows:

- Livestock
  - Bio-physical allocation (using PEF default values) between liveweight and raw milk/eggs
  - Economic allocation between slaughterhouse products (using PEF defaults)
- Wild-caught fish and seafood
  - Mass allocation between landed species
- Dairy products
  - Milk solids allocation between products at a dairy plant, based on PEFCR for dairy products

For most other raw products and processed ingredients, economic allocation is applied, using, if available, a multi-year average of market prices.

Regarding end-of-life allocation, the cut-off approach is used for allocating impacts from treatment of processing waste, as well as packaging and food waste.

#### **Cut-off criteria**

No deliberate cut-off is applied.

#### **Life Cycle Inventory**

##### **Data collection**

Data for the product under study was constructed as a generic industry-reference composition rather than sourced from a specific producer. Where product-specific data was not available, values were instead drawn from published literature and industry statistics. The data points collected and used in the calculation were as follows:

| Type of data                                                                          | Type of data point            | Provided by retailer/producer |
|---------------------------------------------------------------------------------------|-------------------------------|-------------------------------|
|                                                                                       | Product name                  | no                            |
|                                                                                       | Product category              | no                            |
|                                                                                       | Storage temperature           | no                            |
|                                                                                       | Package dimensions            | no                            |
|                                                                                       | Net volume                    | no                            |
|                                                                                       | Net weight                    | yes                           |
|                                                                                       | Gross weight                  | no                            |
| <b>Public data points (on-pack information or publicly accessible by other means)</b> | Product country of farming    | no                            |
|                                                                                       | Product country of processing | no                            |

|                                                                 |                               |    |
|-----------------------------------------------------------------|-------------------------------|----|
|                                                                 | Ingredients on label          | no |
|                                                                 | Nutritional values on label   | no |
|                                                                 | Product labels                | no |
|                                                                 | Product image                 | no |
|                                                                 | Product description           | no |
|                                                                 | Ingredient list               | no |
|                                                                 | Product composition           | no |
|                                                                 | Ingredient country of farming | no |
| <b>Primary data points (information not publicly available)</b> |                               |    |
|                                                                 | Country of farming share(s)   | no |
|                                                                 | Primary packaging             | no |
|                                                                 | Secondary packaging           | no |

Production of the most common agricultural raw materials is modelled following methodology provided in <https://www.inoqo.com/research-methodology>. The most relevant sources for statistics and other data related to the creation of those datasets were extracted from the following sources:

- Crops
  - Yields of primary crops and production areas:
    - <https://www.fao.org/faostat/en/#data>
  - Fertilizer application rates per crop and country:
    - Ludemann, Cameron; Gruere, Armelle; Heffer, Patrick; Dobermann, Achim (2022). Global data on fertilizer use by crop and by country [Dataset]. Dryad. <https://doi.org/10.5061/dryad.2rbnzs7qh>
    - Ludemann, Wanner, Chivenge et al. (2024). A global FAOSTAT reference database of cropland nutrient budgets and nutrient use efficiency (1961-2020): nitrogen, phosphorus and potassium. Earth System Science Data. <https://doi.org/10.5194/essd-16-525-2024>
  - Irrigation water requirements per crop and country, energy consumption of irrigation:
    - Mialyk, O., Schyns, J.F., Booij, M.J. et al. Water footprints and crop water use of 175 individual crops for 1990-2019 simulated with a global crop model. Sci Data 11, 206 (2024). <https://doi.org/10.1038/s41597-024-03051-3>
    - Qin, J., Duan, W., Zou, S. et al. Global energy use and carbon emissions from irrigated agriculture. Nat Commun 15, 3084 (2024). <https://doi.org/10.1038/s41467-024-47383-5>
  - Methane emissions from rice cultivation:
    - Nikolaisen M., Cornulier T., Hillier J., Smith P., Albanito F., Nayak D.: Methane emissions from rice paddies globally: A quantitative statistical review of controlling variables and modelling of emission factors, Journal of Cleaner Production 409, 137245 (2023). <https://doi.org/10.1016/j.jclepro.2023.137245>
  - Feed rations, energy consumption, and direct emissions from livestock:

- FAO Global Livestock Environmental Assessment Model (v2.0, v3.0).  
<https://www.fao.org/gleam/en/>
- Feed rations, energy consumption and direct emissions from aquaculture:
  - MacLeod, M.J., Hasan, M.R., Robb, D.H.F. et al. Quantifying greenhouse gas emissions from global aquaculture. *Sci Rep* 10, 11679 (2020).  
<https://doi.org/10.1038/s41598-020-68231-8>
  - Tacon, Hasan, Metian (2011). Demand and supply of feed ingredients for farmed fish and crustaceans: trends and prospects. *FAO Fisheries and Aquaculture Technical Papers* 564.  
<https://openknowledge.fao.org/handle/20.500.14283/ba0002e>
- Fuel and fishing efficiency for wild-caught seafood
  - Newton R., Maiolo S., Malcorps W., Little D.C.: Life Cycle Inventories of marine ingredients. *Aquaculture*, 739096 (2023).  
<https://doi.org/10.1016/j.aquaculture.2022.739096>
  - Parker, R.W.R. and Tyedmers, P.H. (2015), Fuel consumption of global fishing fleets: current understanding and knowledge gaps. *Fish Fish*, 16: 684-696.  
<https://doi.org/10.1111/faf.12087>
- Honey production
  - Pignagnoli, A.; Pignedoli, S.; Carpana, E.; Costa, C.; Dal Pra, A. Greenhouse Gas (GHG) Emissions from Honey Production: Two-Year Survey in Italian Beekeeping Farms. *Animals* 2023, 13, 766. <https://doi.org/10.3390/ani13040766>
  - Guo W, Dong S, Qian J, Wang K, Zhao Z. Estimation of Carbon Footprint of Honey Production: A Case from China. *Polish Journal of Environmental Studies*. 2024. doi: 10.15244/pjoes/187114.

All data used for the creation of the life cycle inventories was manually reviewed and validated using mass and energy balance checks.

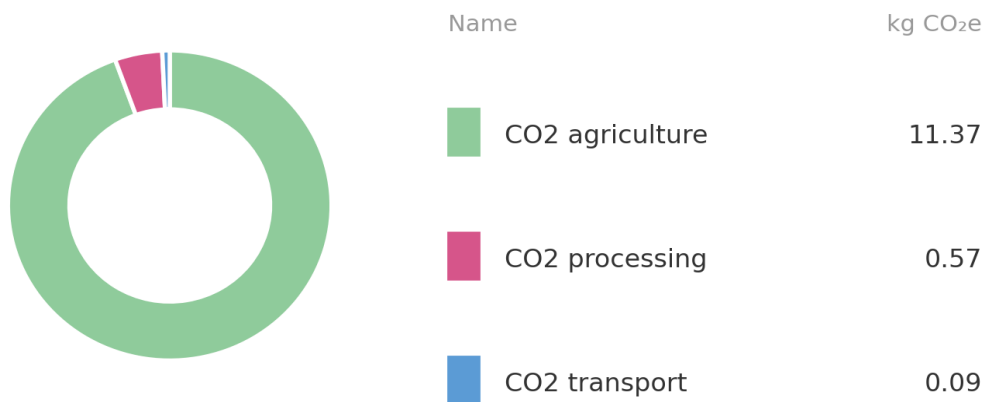
## Life Cycle Impact Assessment

### Results

For the impact assessment, the impact category 'Climate change - total', with the impact indicator Global Warming Potential over 100 years (GWP100) and the Bern characterisation model ("IPCC 2021"), expressed in kg CO<sub>2</sub> eq., is taken from the EF 3.1 impact assessment method. Its characterisation factors for the most relevant greenhouse gasses (non-exhaustive list) are 1 for carbon dioxide (for carbon dioxide from fossil sources or from land transformation), 273 for dinitrogen monoxide, 27 for biogenic and 29.8 for fossil methane, 25200 for sulfur hexafluoride.

The total climate footprint of Chocolate, dark (65% cocoa) is 12.03 kg CO<sub>2</sub> eq per functional unit. A contribution analysis per life cycle stage was performed, which can be seen in Figure 1.

Figure 1: Breakdown per lifecycle stage



Cocoa derivatives are typically the dominant contributor to the footprint of dark chocolate, consistent with published chocolate LCA literature; the most contributing life cycle stage is CO2 agriculture.

*Note: this product is a generic industry-reference (benchmark) composition, publicly documented chocolate-industry formulation patterns for products of this type. It does not represent a named, real-world supplier's product.*