the big CLIMATE DATABASE

Version 1.1

BACKGROUND REPORT

CONCITO

DENMARK'S GREEN THINK TANK

The Big Climate Database, version 1.1
Background report

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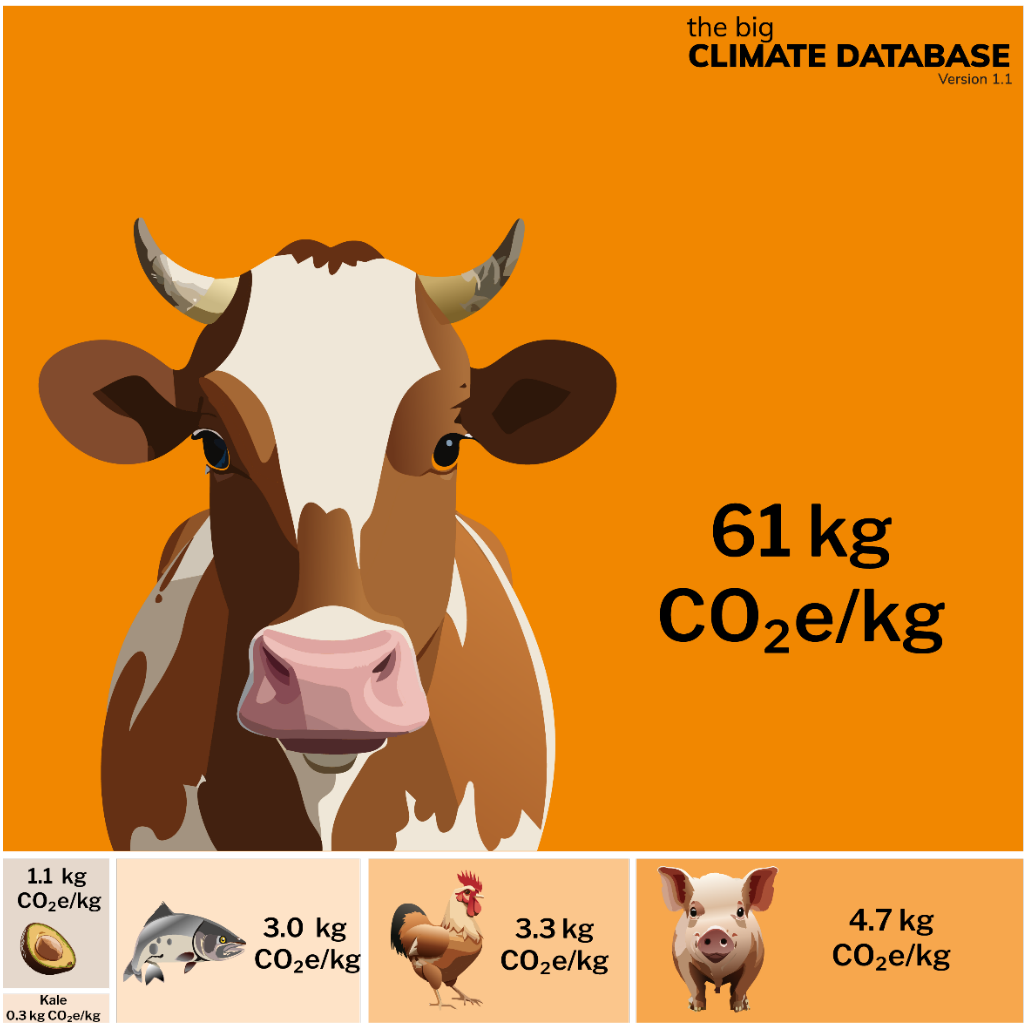
Summary

What we eat and drink has a significant impact on the climate, and more plant-based diets, less beef and less food waste are some of the most important elements in reducing the climate impact of the world's food system.

Consumers as well as professional actors in the retail and food service sectors are increasingly seeking information about the climate impact of the products they buy and trade. With the Big Climate Database, CONCITO gives companies, authorities, and citizens free access to life cycle assessments of the climate impact of 503 of the most common foods on the Danish market via the website denstoreklimadatatabase.dk/en.

The Big Climate Database is a unique tool that highlights the climate impact of changes in food consumption and can thereby help promote more climate-friendly food habits. The database is published by CONCITO in collaboration with 2.-0 LCA consultants, who have calculated the climate impact of the food products.

The first version was launched in February 2021 with support from the Salling Foundations. The updated version 1.1 is funded with prize money from the Nordic Council Environment Prize, which the project was awarded in November 2021.



The climate impact of beef, pork, chicken, salmon, avocado and green kale in The Big Climate Database version 1.1 and illustration of the proportions between them.

In addition to updates and corrections to the results for the original 500 food types, version 1.1 includes results for average beef, pork, and chicken meat, as requested by many users in the food service sector etc. Further, product names and product categories have been adjusted to make it easier to search and navigate the database.

Simultaneously with the launch of version 1.1 for the Danish market, the database is launched in a version for the British market. The GB version can be downloaded from denstoreklimadatabase.dk/international and can be used for non-commercial purposes until 2024. After that, it can be used freely with proper reference.

The database is the first publicly available database in the world with consistent, detailed, and transparent calculations of the average climate impact of such a wide variety of food products. For all products, emissions are broken down into agriculture, indirect land use change (ILUC), processing, packaging, transport, and retail.

The climate database is ideal to use as a basis for climate-calculated recipes and meals, climate calculations of food purchases in companies and households, teaching materials for school students, training of kitchen staff, information campaigns, and much more.

Widespread use of the climate database and government database on the way

The Big Climate Database was launched in February 2021, and since then it has been used in various contexts. In the first two years, the website has had more than 180,000 visits and 650,000 page views, and the download version of the database has been downloaded more than 6,000 times. CONCITO was also awarded the 2021 Nordic Council Environment Prize for the project's great potential for supporting behavioral change.

Following the launch of The Big Climate Database and subsequent testing of a climate labeling scheme in the grocery chain Netto, as well as numerous other uses of the tool, there was a renewed political focus on improved communication and possible climate labeling of food products.

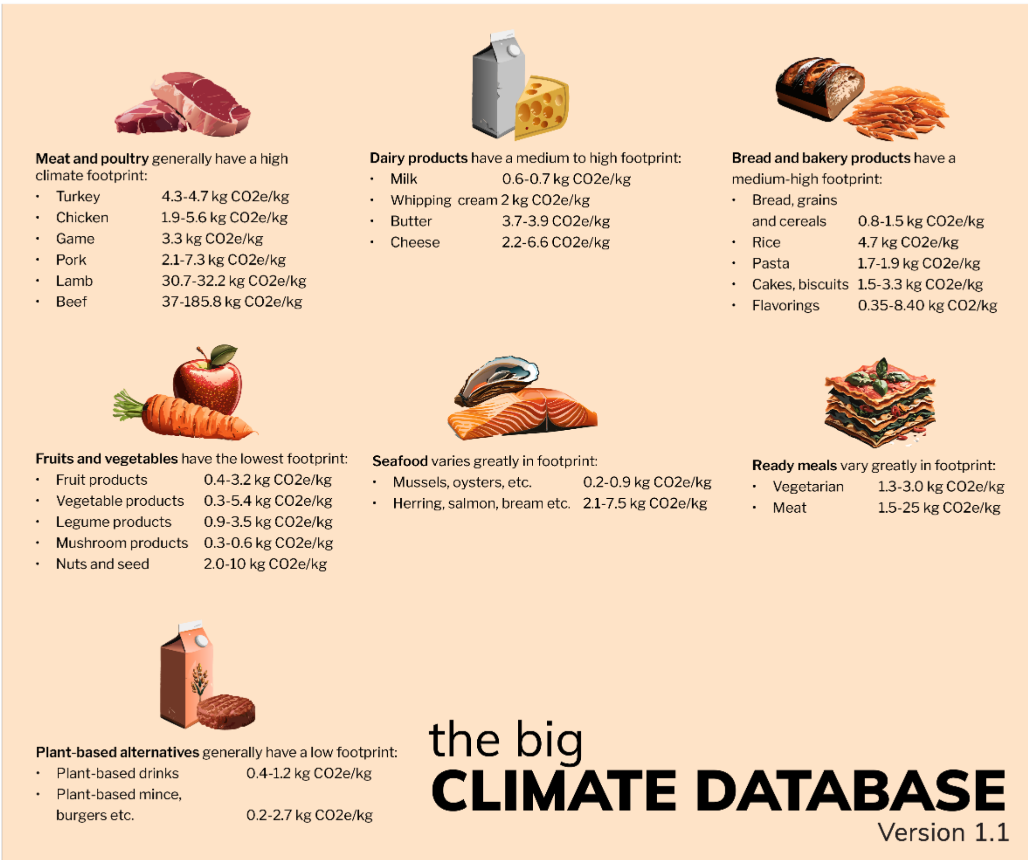
In April 2022, it was decided that Denmark will have a state-controlled climate label. The climate label is intended to help consumers make green choices when shopping, while steering food production in a greener direction. To develop the climate label, a working group was set up consisting of the Danish Veterinary and Food Administration and representatives from the retail industry, the food industry and consumer organizations. In April 2023, the climate label working group presented their recommendations for the future climate label to the Minister for Food, Agriculture and Fisheries.

The final specification of a climate label requires further work, including the development of a method for calculating the climate impact, the development of an official national database for the generic climate impact of foods, specification of the labeling model, etc. The label is not expected to be applicable before 2025 at the earliest.

Climate database methodology and results

In the Big Climate Database, the average climate impact of food products is calculated on the basis of a consequential LCA based on hybrid input-output analysis. This is a combination of a bottom-up analysis, starting from the bottom and moving up the supply chain, and a top-down analysis, beginning with the overall emissions from agriculture, and then moving down the chain to determine the amount of the total emissions associated with a specific production.

The climate impact of the 503 foods is stated in kg CO_2 equivalents (CO_2e) per kg of product (net weight) and expresses the future global climate impact of consuming the different food types. CO_2e includes the climate impact from emissions of CO_2 and other greenhouse gases such as methane and nitrous oxide, as well as the indirect land use change caused by food production.



The results for the different food types in the Big Climate Database version 1.1 are summarized in the following overview.

The information in the Big Climate Database is intended for general information and education purposes only. Despite these reservations, the Big Climate Database represents the most detailed, precise, and accurate data basis for the climate impact of food on the Danish market. It can be used for applications such as:

- Climate calculation of recipes, meal plans, etc.
- Climate calculation of food purchases in companies and households.
- Ranking of food types for simplified climate labeling.
- General information and education about the climate impact of food.

While the potential applications are many, the Big Climate Database will not in itself be suitable for:

- Climate labeling, marketing, or taxation of specific foods: The average climate impacts in the climate database do not reflect the large variation that can exist within each product type. The results in themselves are thus not an accurate or sufficient basis for labeling, promotion, or taxation of specific products.
- Sustainability assessment: The Climate Database calculations do not account for other environmental, social, or economic sustainability parameters.
- Dietary guidance: Dietary choices focused on minimizing the carbon impact of food alone will not necessarily ensure a healthy and nutritious diet.

When using the results of the database, reference should be made to:
"CONCITO (2024): The Big Climate Database, version 1.1"

1. Background

1.1 The impact of food consumption on the climate

What we eat and drink has a huge impact on the climate. Global food production accounts for almost 30 percent of the world's greenhouse gas emissions (IPCC, 2020) and the consumption of food and beverages accounts for 20 percent of Denmark's global consumption based emissions (CONCITO, 2023a).

According to the global think tank World Resources Institute (WRI, Creating a Sustainable Food Future, 2019) less food waste and more plant-rich diets are the two single most important elements in transforming the world's food system. And in Project Drawdown's ranking of climate solutions, 11 of the solutions in the top 20 are related to the food sector and land use, with reduced food waste and plant-rich diets as some of the biggest reduction potentials (Project Drawdown, 2020). Shifting to sustainable and healthy diets is also highlighted as one of the biggest reduction potentials in the food sector in the IPCC's Sixth Assessment Report (IPCC, 2023).

According to the technical background report for the new official dietary guidelines, which were launched in January 2021, the climate impact from the average Danish food consumption can be reduced by up to 25 percent by choosing the least climate-impacting foods within each food type and by up to 35 percent if, furthermore, some of the meat and dairy products are replaced by plant-based alternatives. If animal-based foods can be completely eliminated, the reduction potential is estimated to be up to 50 percent compared to the current Danish average diet (Lassen, Christensen, Fagt, & Trolle, 2020).

DTU's assessment of the potential of changing dietary habits is based on life cycle analyses from the literature, including the "Table of foods' climate impact" prepared by Mogensen et al. (2016). The carbon impact includes primary production, processing, transportation, storage, preparation, and waste at all stages. The climate impact from the land use change caused by the food consumption is not included.

The Danish Council on Climate Change's analysis on Climate-friendly food and consumer behavior (The Danish Council on Climate Change, 2021) shows that Danes aged 6-64 years, based on the results from the Big Climate Database, could reduce the climate impact of their diet by up to 45 percent by following the official dietary guidelines. This corresponds to a reduction of Denmark's global consumption emissions by almost 4 million tons.

Whether the climate impact from land use change is included or not, it is clear that there are considerable climate potentials associated with changing the Danes' dietary habits.

1.2 Need for consistent, accurate and fair data

Consumers as well as professional actors in the grocery and foodservice sector have long sought information about the climate impact of the goods they buy and trade. Over the years, CONCITO has seen a great demand for information about the climate impact of various products and services, and our food consumption in particular, has come into focus as an area with great potential for change.

In academia, there are many different figures on the climate impact of different foods. This is due to different calculation methods, and not least because it differs how many climate-impacting factors the individual calculations have included in the analysis and how, for example, the emissions from a dairy cow are distributed between the milk and the meat from the cow. The emissions may also depend on the time of the analysis, as, for example, the greenhouse effect from methane emissions has previously been severely underestimated.

Some calculations also emphasize how a changing demand can change a given production and land use, and that this change constitutes a very significant part of a given food's climate impact. This means that emissions from, for example, beef in the various calculations can vary from less than 20 kg to well over 50 kg CO_2e per kg (CONCITO, 2019a).

The Big Climate Database

In the CONCITO report on "Climate-friendly food habits" (CONCITO, 2019a) as well as the blog "A crash course in the climate impact of food" (CONCITO, 2019b) we explained different calculation methods and the need for and usefulness of a tool like The Big Climate Database with average climate impacts for several hundred foods calculated in a consistent, accurate and fair way.

An accurate inventory of a food's climate impact should include all the climate impacts associated with a given consumption, including the positive or negative side effects of the product. In addition, it should be based on the most recent data and consistent use of the data used in the calculations. However, such consistent and publicly available inventories with many food categories are not widely available. This has been the motivation behind the development of The Big Climate Database**.**

What makes The Big Climate Database unique is that it is:

- Detailed – more than 500 products based on Danish consumption patterns
- Consistent - same calculation method, system delimitation, etc. on all products
- Comprehensive - includes all climate impact factors, including climate impact from indirect land use change (ILUC)
- Open - free and freely available in multiple formats in English and Danish
- Transparent - professional background reports and detailed background data for specialists and interested parties.

Other food lists and databases

There are a number of other Danish and international food lists and databases that collect climate impacts for foods from various studies, including:

- Mogensen et al. (2016): Table on foods' climate impact
- Röös (2014): Mat-Klimat-listan (The Food-Climate List)
- Unilever's CO_2 calculator (Unilever Food Solutions): Covers approx. 100 products based on calculations from WSP based on various LCA studies and reports
- Mindful FOOD Solutions (Henrik Saxe): Data collection sold under license to UCPH, University College Copenhagen, calculation of Coop's food pyramid, etc.

- RISE klimatdatabas (climate database) (RISE Research Institutes of Sweden): Swedish database with 750 food products. Requires a license.
- Poore & Nemecek (2018): Article on environmental data for food published in Science
- Moberg et al. (2019): Collection of LCA studies on approx. 100 products.
- Agribalyse (ADEME, 2019): Database of environmental indicators for 2,500 food products produced and consumed in France.
- WRI Cool Food Calculator (2022): Calculator for approx. 50 product types based on Poore et al. including a so-called "Carbon Opportunity Cost" factor.

For an overview of several different climate databases and their characteristics, see Mogensen, et al. (2021)

1.3. Climate data on the political agenda

The issue of improved data and communication on the climate impact of food and other products has been on the political agenda in various contexts for several years.

Back in 2018, the VLAK government, in its Climate and Air Proposal, suggested the introduction of climate labeling of various products. On that occasion, the Minister for Climate had invited the food industry to a debate on the climate labeling of food in March 2019, and the message at the time was clear: It would be difficult and very complicated to create a climate label that would actually guide the consumer. In addition, it was emphasized that any potential climate label should be European and include a nutritional aspect. Subsequently, the government announced that it would focus on advice and guidelines on climate-friendly diets rather than an actual climate label.

Climate data on the agenda in the government's climate partnerships

The idea of climate labeling resurfaced in November 2019, when Salling Group announced an ambition to launch a common climate label based on research and common standards for climate impact. This could for example enable ranking of different product categories, allowing consumers to make a more informed choice.

Subsequently, climate labeling of foods, etc. became a subject of discussion within the government's climate partnerships. In the recommendation report from the climate partnership for trade, it is stated that there is currently not enough data and knowledge to introduce a specific climate label on food. However, the partnership is positive about exploring the possibilities. It was also emphasized that it is desirable to agree on a standard for measuring climate impact at EU level.

One of the recommendations from the climate partnership for trade was to improve data on the climate impact of products: "The government should actively promote publicly available data on the climate impact of the most common food and non-food products. It must be compiled in a uniform, fair and credible way. The industry would very much like to contribute, but in the long run, an independent and evidence-based inventory is best left to the authorities." (Government Climate Partnerships, 2020).

The climate partnership for food, on the other hand, recommended against the introduction of a climate label on food: "Climate labeling - if it is to be implemented - should be a governmental task and should be carried out as a harmonized solution at EU level. The need for European standards, and not Danish standards, is necessary. The starting point must be that consumers are informed on a well-researched and scientifically basis based on PEF assessments." (Government Climate Partnerships, 2020).

State-controlled climate label and climate database under development

Following the launch of The Big Climate Database and subsequent testing of a climate label scheme in two Netto stores, as well as numerous other uses of the tool in the foodservice sector and public kitchens, there was a renewed focus on improved communication and possible climate labeling of food products' climate impact.

In April 2022, it was decided that Denmark will have a state-controlled climate label. The climate label is intended to help consumers make green choices when shopping and, at the same time, push food production in a greener direction. To develop the climate label, a working group was set up consisting of the Danish Veterinary and Food Administration and representatives from the retail industry, the food industry and consumer organizations. In April 2023, the climate label working group presented their recommendations for the future climate label to the Minister for Food, Agriculture and Fisheries.

The working group recommended the establishment of a climate label based on a scale model across all foods, and that foods can be labeled either with the climate label based on generic climate impacts or based on product-specific climate impacts, where a calculation for the specific product has been made. In addition, the working group recommended the use of an A-LCA approach to calculate the climate impact of food products and to establish a national database of the climate impact of food products.

The final specification of a climate label requires further work, including the development of a method for calculating the climate impact, the development of an official national database for the generic climate impact of foods, specification of the labeling model, etc. The label is not expected to be applicable before 2025 at the earliest.

In the meantime, it is important that the good work on the use of climate data in the grocery sector, food service, public kitchens, education, etc. is not put on hold, but rather encouraged and promoted further. Actors in the food sector and public institutions should continue to gain insights and experience with climate accounting of purchases and meals based on currently available and preferred databases, including The Big Climate Database.

The upcoming official national climate database should include both A-LCA and C-LCA results as far as possible. This will enable manufacturers to make product-specific comparisons against the A-LCA result compatible with the EU Product Environmental Footprint (PEF) standards and at the same time provide buyers and consumers with information on the generic climate impact of the product type through the C-LCA result, which fully takes the global impact of a consumption change including the indirect land use change into account.

Pros and cons of the Product Environmental Footprint (PEF)

PEF stands for "Product Environmental Footprint" and is the EU's standard for calculating climate impacts. The overall benefit of this standard is that a common European system for calculating and communicating climate impacts will make it much more manageable and transparent for food companies and consumers to exchange, communicate and use climate data across national borders.

The overall disadvantage is that the standard is based on a negotiated rather than a purely scientific method for calculating climate impacts, and one of the major shortcomings is that it does not include the climate impact of indirect land use change (ILUC). This is emphasized by Wenzel (2019) who points out that ILUC, regardless of the model, varies from being very important for the climate impact to being even more important.

Another disadvantage is that under the PEF standard there are specific product category rules (PCR) for different product groups. These PCRs are in several cases contradictory; for example, using the PCR for animal feed will result in a significantly different footprint for the use of residues from the beverage industry for feed use, than using the PCR for the beverage industry for the same type of feed product.

In addition, PEF standards have not yet been developed for all food types. It will likely take several years before this system for calculating and communicating climate data is sufficiently developed to provide accurate data for the large number of food types included in The Big Climate Database. Finally, the PEF standard is unnecessarily complex and contains unnecessarily extensive documentation requirements, which makes ecolabels many times more expensive and means that the requirements are not feasible in practice (Weidema & Eliassen, 2023).

In the European Commission's 2020 'Farm to Fork' strategy, it was envisaged that the Commission would present a proposal for sustainability labeling of food in 2024. However, the framework legislation, which was supposed to include a sustainability labeling initiative, has since been removed from the Commission's work program and can, at best, be considered postponed until after the European Parliament election in 2024. At present, the Danish Veterinary and Food Administration estimates that a potential EU sustainability label could be a reality from 2030 at the earliest (Danish Veterinary and Food Administration, 2023).

Accurate climate communication on food

The issue of climate data is also central in the report on "Accurate climate communication on food" (Holmbech, Minter, Sall, & Winther, 2020), to which CONCITO has contributed. It provides a comprehensive proposal for guidelines, principles and strengthened industry collaboration to counteract misleading green marketing. It suggests that foods with a generally low climate impact may only be advertised with the climate claim "Low climate impact" if the impact is significantly below the normal climate impact in the product group, and there is evidence of this in databases such as The Big Climate Database or other studies on the climate impact of foods. It is also recommended that the public authorities establish a threshold for what can be marketed as having a low climate impact.

1.4 Development and use of The Big Climate Database

The work on The Big Climate Database began in December 2019. In order to design the tool in the best possible way and ensure broad recognition and acceptance, a virtual dialogue meeting was held on March 12, 2020, with almost 60 participants from CONCITO's members and other invited stakeholders from companies, organizations, authorities, and research institutions. During the meeting, the project's background, purpose, and possible applications as well as the calculation method were presented and discussed. The presentations and the participants' questions and views on the database were subsequently published in a brief (CONCITO, 2020).

During the development of version 1, we experienced great interest from many different companies, organizations, and public institutions, who approached us with questions, requests, and ideas for the design of the database or potential applications. In September 2020, a dialog meeting was held for CONCITO's members to give an update on the project and discuss possible uses and dissemination of the database. Finally, shortly before the release of the climate database, a preliminary briefing was given to CONCITO's members as well as selected research institutions and authorities to improve the background information and communication of the climate database.

In December 2023, a webinar was held for CONCITO's members, presenting and discussing the results of The Big Climate Database version 1.1. Additionally, opportunities for the further development and dissemination of the database through the global Carbon Footprint Calculator, developed by Aalborg University as part of the 70i30 initiative, were explained. According to the plan, the initiative is to be launched in 2025 (Aalborg University, 2023).

Extensive use and coverage of The Big Climate Database

The Big Climate Database was launched in February 2021, and since then it has been used in many places. During the first two years, the website has had over 180,000 visits and 650,000 page views, and the download version of the database has been downloaded more than 6,000 times. CONCITO was further awarded the 2021 Nordic Council Environment Prize for the project's great potential for behavioral change.

Box 1: Examples of applications and a selection of the actors who have used or referred to the results from The Big Climate Database in their strategy work, customer service, communication, teaching, etc.

Several public institutions have also focused on reducing the climate impact of public meals, and in recent years, several initiatives have been taken to support climate-friendly eating habits. Prior to the launch of version 1.1 of The Big Climate Database, CONCITO published a study in May 2023 on the extent to which municipalities, regions, and the state calculate the climate impact of food purchases and meals and to what extent this is based on the results in The Big Climate Database (CONCITO, 2023b).

Based on information collected from approximately 80% of the municipalities, regions, and the state, the survey results can be summarized in the following points:

- 9 out of 13 public institutions that responded that they calculate the climate impact of their food purchases, directly or indirectly use the results from The Big Climate Database.
- Three regions have central procurement calculations and reduction targets.
- Four municipalities have specific reduction targets, and 42 municipalities plan to introduce climate calculations within the next few years.
- Climate calculations are a requirement in the government's tender documents. Currently, climate data is only calculated for food purchases in ministries and agencies in Copenhagen.
- Six municipalities and two regions use The Big Climate Database.
- Aalborg University Hospital uses The Big Climate Database in the project More2Eat goes green.
- The Big Climate Database is used in regions and municipalities as an information base when kitchen staff and citizens are educated about the climate impact of food.
- Regions and municipalities call for consistent and officially recognized data to use in their climate calculations in order to enable comparisons.
- Performing climate calculations is very administrative and resource-intensive for many municipalities, prompting a demand for a free, user-friendly tool.

1.5 Significant changes in version 1.1

Version 1 of The Big Climate Database was the first of its kind in the world to process very large amounts of data and calculations. Since its release, 2.-0 LCA consultants have been working to further improve the data, weed out errors discovered after the release, and refine the algorithms behind the calculations.

In general, most of the results in version 1 were as expected, but there were a few surprises that required further explanation, such as a higher emission for fish than typically seen in other food climate impact databases.

In version 1.1, several of these results have been examined in more detail, and some have been retained while others have been changed, including a significantly lower emission for fish compared to version 1 based on new references for energy consumption in aquaculture production, etc. The most significant changes are listed below and described in more detail in the technical background report from 2.-0 LCA consultants.

This has led to a number of changes in version 1.1, the most significant of which are:

1. Addition: In response to requests, particularly from foodservice actors, three new products have been added to version 1.1: Average beef, pork, and chicken.
2. Adjustment: General corrections and improvements to the calculation basis, such as updating to more recent data from the IPCC (IPCC, 2019).
3. Adjustment: Significant changes have been made to the data basis for the production of farmed fish, including energy consumption, and the climate impact of the energy used and the feed composition. This results in significant reductions in emissions from fish compared to the first version, generally about a halving. Thus, in version 1.1, the emission from fish approaches the emissions from chicken and pork.
4. Adjustment: Improved calculation of animal manure management, including better data for displacement of synthetic fertilizer and field emissions.
5. Adjustment: Improved modeling of feed, e.g. soybean oil is a by-product of soy protein that displaces palm oil on the global market, which means that soy protein has a lower climate impact than previously calculated.
6. Adjustment: Improved calculation of grain transportation.
7. Adjustment: Improved calculation of canned seafood, including more representative materials in packaging and fillings, as well as ensuring that the raw material is fillets and not whole fish.
8. Adjustment: The climate impact of almond drink has been significantly reduced in version 1.1 due to more representative recipes with significantly fewer almonds per liter of almond milk.
9. Adjustment: The climate impact of coffee and cocoa has increased due to the update of nitrous-oxide emissions from cultivation.
10. Correction: The vegan block (vegetable butter) was missing palm oil input in the first version. Vegan block does not contain palm oil, but rapeseed oil and coconut oil. However, the coconut oil content is modeled as palm oil because coconut production is not affected by changes in coconut oil demand.
11. Correction: Error in the modeling of energy consumption for dried basil has been corrected.
12. Correction: In the first version, the emissions from fennel were mistakenly modeled as fennel seeds.

13. Correction: Error in the modeling of raw onions.
14. Correction: The yield for blueberries was set too low in version 1.
15. Correction: The climate impact from supermarket storage facilities has been reduced as it was included in several places in the first version.
16. Correction: Emissions from rice are significantly higher in version 1.1 due to an error in the modeling of methane emissions from rice production.
17. Correction: Emissions from eggs are regulated, as version 1 did not account for the fact that chicken meat is a by-product of egg production.

Read more about the changes in version 1.1 methodology report from 2.-0 LCA consultants and the comparison table in the download version at denstoreklimadatabase.dk/download.

The following table shows a selection of items where the carbon impact has changed more than 50 percent from version 1 to version 1.1. See explanation of the reasons behind the changes in the download version's tab comparing the results of the different versions.

Food & Beverage	**Version 1** Kg CO_2e/kg	**Version 1.1** Kg CO_2e/kg	**Main reason for change**
Atlantic salmon, farmed	9.1	3.0	New reference on energy consumption
Herring	9.3	3.1	
Cod fillet, breaded	6.6	2.8	
Rice, parboiled	1.3	4.7	Correction of CH_4 emissions when growing rice
Rice noodles	1.4	4.6	
Fennel	4.5	0.33	Correction of classification for statistics and new data collection
Onion	0.90	0.25	Correction of classification according to statistics
Almond drink	3.5	0.37	New recipe
Cocoa powder	5.0	12.4	Update on N_2O emissions from cocoa bean cultivation
Coffee beans, roasted ground	3.2	5.4	Update on N_2O emissions from coffee bean cultivation

Table 1: Overview of a selection of major changes to the results in version 1.1.

2. Basic information about the climate impact of food

There are many different assessments (LCA calculations) of the climate impact of individual foods, and there are many different figures for the same products. This is often not due to errors in the assessments, but because different methods, different assumptions and different time periods have been used. These factors are rarely reflected when the figures are presented in tables or in different statements, meaning that the figures, even if they are presented as such, often not are comparable.

There can also be a significant difference in the climate impact of the same product depending on the production site, production methods, varieties, etc. For example:

- Greenhouse versus open field tomatoes
- Highly extensive productions versus highly intensive productions
- Productions with highly efficient nutrient utilization versus productions with high nutrient losses
- Goods with short transportation distances versus goods with very long transportation distances.

The climate impact of the 503 foods in The Big Climate Database is stated in kg CO_2 equivalents (CO_2e) per kg of product and expresses the future global climate impact of consuming the different food types. CO_2e includes the climate impact from emissions of CO_2 and other greenhouse gases such as methane and nitrous oxide, as well as the indirect land use change caused by the food production.

The results show the average climate impact of the food, which is relevant for food professionals and consumers in order to see which food types typically have high and low emissions.

In tomato production, for example, there will be some cultivation methods that emit significantly more than others. However, it is initially not within the scope of the climate database to distinguish the individual cultivation methods from each other. Therefore, no distinction is made between greenhouse and open field or between organic and conventional cultivation. The climate impact is only based on the average of products on the Danish market.

There are a number of fundamental things to be aware of when considering the climate impact of food. These are broadly outlined in the following.

2.1 The functional unit

The functional unit is, as the word suggests, the unit you calculate on. It is important to define the unit clearly, as major misunderstandings otherwise can happen.

In The Big Climate Database, the functional unit is 1 kg of product delivered from the supermarket. Here, for example, 1 kg of pork is defined as it appears in the refrigerated counter, including the production and disposal of packaging and handling in the supermarket, while 1 kg of pork in other studies may be defined as 1 kg of carcass at the slaughterhouse, or 1 kg of live pig at the farmer. The numbers for these three different units will be very different and not directly comparable, even though they can all be referred to as 1 kg of pork.

Attention must be paid to the interpretation and application of the functional unit in practice when it is defined here as 1 kg net weight, which is typically indicated on the product declaration. The functional unit of 1 kg net weight does not take the substitutability of foods into account.

For example, it is almost meaningless to compare 1 kg of wheat flour with 1 kg of cayenne pepper, as 1 kg of cayenne pepper will probably last a lifetime. So, with the functional unit chosen in The Big Climate Database, one must pay close attention to the actual consumption of the product when interpreting the results. This also applies when comparing beverages, vegetables, and meat products, for example.

2.2 The system boundary

In LCA calculations, it is necessary to define the subset of the world included in the calculation. This is called the system boundary.

A traditional system boundary for pork, where the functional unit is 1 kg pork carcass ex slaughterhouse, would be to include the farmer's emissions, including feed production, feed imports, energy consumption, etc. as well as transportation to the slaughterhouse and the slaughterhouse's energy consumption, etc. Anything outside the system boundaries is not included.

Outside the traditional system boundaries, there may be a climate impact from activities associated with production, such as the construction of the barns, machinery used for construction, computer systems, accountants, consultants, etc. These are typically things that are difficult to measure and relatively small, but there are many of them, and the sum of them can therefore be significant.

To give an example, we can consider the emissions from transportation in a car.

In most calculations, the emissions from car transportation are equal to the emissions from direct fuel consumption, e.g. 100 g CO_2/km, corresponding to a car driving just over 25 km/l.

This is a very narrow system definition, as everything outside of direct fuel consumption is not included. For example, it could emit approx. 10 tons of CO_2 to produce the car, and in addition, the car must be maintained, washed, insured, workshops and infrastructure must be built, etc. All of this means that emissions will increase significantly - perhaps more than twice as much - if the system is defined more broadly than just fuel consumption.

To get the most accurate numbers possible for the climate impact of a product or activity, it is important that the system boundary is as extensive as possible and that everything within the system boundary is included to the greatest extent possible. In practice, this is almost impossible with traditional calculation methods. Therefore, the climate database uses a method where the system boundary includes the entire world for all products. This is done by using so-called environmentally enhanced economic input-output tables. This is described in more detail in chapter 3. This way, the climate database avoids the problem of system boundaries for all products, as all climate impacts from the production by definition are included.

2.3 Land use

Especially for food, it is important that the emissions associated with land use, called Land Use Change (LUC) and Indirect Land Use Change (ILUC), are included. When producing food, some agricultural land is typically needed, and as an alternative, this land could be forests or other natural areas that sequester large amounts of carbon and reduce emissions to the atmosphere.

Direct and indirect land use changes

Land use can be viewed in terms of Land Use Change (LUC) or Indirect Land Use Change (ILUC).

LUC is the direct change in land use that occurs when previously uncultivated land, such as fertile soil under forest, is cleared and cultivated for agricultural production, grazing, etc. For example, increased demand for soy protein and lack of available arable land means that forest in the Amazon is being cleared to make room for soy fields.

ILUC is the indirect change in land use that occurs when production is expanded or changed in a given location by converting land that has previously been cultivated with specific agricultural products. The displaced agricultural products will then be cultivated elsewhere in the world, taking previously uncultivated but fertile land under forests into production. An example could be that increased demand for soy leads to the conversion of grazing fields in South America to soy production. However, due to the continued demand for beef and lack of arable land, forest in the Amazon is cleared to make room for new grazing fields.

Box 1: Explanation of LUC and ILUC

When converting forests and nature into agricultural fields, large amounts of CO_2 are typically emitted, and these emissions must be included in the calculation. According to the UN Intergovernmental Panel on Climate Change, around 12% of global greenhouse gas emissions come from land use change, making it a highly significant factor to include. The more land a particular food occupies, the greater the climate impact from land use will be. Therefore, crops with high yields per hectare will have lower land use emissions than crops with low yields per hectare, and animal products, especially from ruminants, will emit significantly more than products from animals that require less land per kg of food produced, such as chicken and pork.

The calculation of ILUC is relatively complicated, and for a detailed description, please refer to chapter 3.2 of the methodology report (Schmidt, et al., 2023).

2.4 Consequential LCA or attributive/normative LCA

There are two fundamentally different methods for calculating the climate impact of a product: A consequential LCA or a normative LCA (attributional).

Generally speaking, a consequential LCA shows the future global climate impact of the consumption of a given product, while the normative LCA (or market average) shows the historical emissions from the production of a given product. Furthermore, the normative method is, as the name suggests, normative. This means that the calculation method is "negotiated" rather than based on scientific principles of cause-and-effect relationships. For example, the calculation rules in the Product Category Rules (PCR) under the EU PEF standard are negotiated among the companies involved in the given industries.

The difference between consequential LCA and the normative method can be illustrated using fish consumption and milk and beef consumption as examples.

Consequential LCA of fish consumption

Nearly all wild-caught fish are subject to quotas, meaning only a certain number of different fish species is caught to reduce the risk of overfishing. In reality, this means that there are no more wild fish to catch even if the demand were to increase. Therefore, an increased demand for fish can only be met by increasing the production of farmed fish, and about half of all fish for human consumption today comes from aquaculture.

Fish from aquaculture generally emit more than wild-caught fish, mainly due to the energy consumption in aquaculture and the production of feed etc. Roughly speaking, wild-caught fish have relatively low emissions, while farmed fish have relatively high emissions on average.

If the climate impact of buying a wild-caught fish is calculated using the normative method, one would typically use numbers for what the catch of wild fish emits, which could be, for example, 1.5 kg CO_2e/kg.

However, since no more wild fish are produced even if demand increases, you will effectively throw another consumer out of the wild fish market and into the aquaculture market, as this is the only way to meet the increased demand. So, if you buy a wild-caught fish, the real future consequence will be an increase in aquaculture production, and thus the emissions from buying a wild fish are the same as the emissions from buying a farmed fish and thus around 4kg CO_2e per kg of fish. Therefore, the consequence of buying a wild fish is the production of a farmed fish, and it is the emissions from the latter that are used in a consequential LCA.

In consequential LCA, it is therefore not the historical emissions from the product you buy that are calculated, but rather the future emissions from the product it will be replaced by on the market. In some cases, future demand will be met with the same product produced in the same way, and there will be little difference between the two methods. In other cases, such as the fish example, there can be significant differences between the results of a consequential LCA and a normative LCA.

Since consequential LCA looks at the future emissions of the choices made, the climate database is based on this method, as it provides the most accurate picture of the emissions from a given action. Consequential LCA is therefore particularly suitable when the calculation is intended to serve as a tool for decision-making, which is exactly the goal of the climate database.

Consequential LCA of milk and beef consumption

Global cattle production puts pressure on the climate and biodiversity due to emissions of the potent greenhouse gas methane as well as extensive land use for feed.

The purpose of the consequential assessment in The Big Climate Database is to shed light on the future global climate impact of a change in beef consumption. In other words, what will the typical effect of buying minced beef for dinner instead of sausages or falafels be? Here, the applied consequential LCA provides the most useful and accurate result. One of the advantages is that every calculation is always compared to a "zero alternative". For example, the impact of demanding 1 kg of beef compared to not demanding any. This represents the impact of the choices we can make as professionals or ordinary consumers.

In the climate database calculations, dairy products receive a "discount" on their climate impact, as the beef from the retired dairy cow and its calves helps to displace the consumption of more climate-intensive beef cattle on the global market. If this were not the case, the climate impact of dairy products would be significantly higher.

In contrast, the climate impact of beef from dairy cows is considered to be on par with the global average, as the consumption of the meat contributes to increasing the global demand for beef, and the global expansion of beef production typically occurs in inefficient, clean beef cattle productions.

The assumption is that a change in the demand for beef will not affect the number of dairy cows. On a global food market, there is a large climate benefit in reducing beef consumption in Denmark, and if we cannot eat all the beef from Danish dairy cattle ourselves, it can be sold abroad and help displace beef cattle production there.

2.5 Allocation, system expansion and displacement

In the production of many food products, the production process often results in the output of more than one product. For example, milk production involves both milk and meat from calves and the dairy cattle themselves. The milk is further turned into many different products such as butter, cream, skimmed milk, whole milk, etc. The production of soy protein for animal feed produces both a protein product and a soybean oil. This means that the emissions from a cow or a soy plant must be allocated among several different products.

There are many methods and standards for allocating the climate impact from a production process to different products. Here we focus on the methods used in the climate database.

Taking milk as an example, a certain amount of meat will be produced due to the milk production. However, an increased demand for meat will not increase the production of dairy cattle - only an increased demand for dairy products will. An increased demand for beef will therefore increase the production of beef cattle.

For dairy cattle, the primary product is milk, and the by-product is meat. This meat effectively reduces the need for beef cattle (system expansion), as part of the demand for beef can be satisfied by the meat from milk production. Milk production thus reduces the need for dedicated beef cattle production, resulting in emission savings. This saving is subtracted from the emissions from milk, which then becomes lower. However, the meat from dairy cattle will not be considered a by-product with particularly low emissions. The reduction in emissions from a dairy cow cannot be used twice. Therefore, the higher the emissions from beef cattle, the lower the emissions from milk, as the displacement effect becomes more significant.

The same phenomenon is seen with soy protein, for example, which is widely used to feed livestock. The primary reason for growing soy is the demand for the protein (and not the oil), but to get the protein in as pure a form as possible, the oil is extracted from the soybeans as soybean oil. The protein is the primary product, and the soybean oil is the by-product. The soybean oil will displace the consumption of especially palm oil, resulting in less palm oil production when soy protein is in demand. The reduced production of palm oil results in reduced emissions, which are subtracted from the emissions from the soy protein, which are then reduced.

There are some specific cases where there is no alternative production of any of the products from a process. For example, only beef slaughterhouses can produce beef tenderloin and minced beef. In this case, it will be the price of the product that determines how much the slaughterhouse changes its production - a change in demand of 1 DKK results in a change in production of 1 DKK. When 1 kg of beef tenderloin is demanded at, for example, 300 DKK/kg, the slaughterhouse increases its production of beef products by 300 DKK, which means that more than 1 kg of beef products are produced because the average price is lower than 300 DKK/kg. There will then be some shifts among consumers of the different beef products. Ultimately, this modeling leads to the same result as when using economic allocation (Schmidt J. , 2010).

To put it simply, the climate database uses an "economic allocation" of different cuts from slaughterhouses. This means that the total calculated climate impact from beef is distributed based on the economic value of the individual cuts, using average prices. So, the more expensive the cut, the greater the emissions will be. However, the very expensive cuts represent a relatively small proportion of the total slaughtered beef product.

3. The climate database methodology

The climate impact of the food products in The Big Climate Database is calculated by 2.-0 LCA consultants on the basis of a consequential LCA based on hybrid input-output analyses.

As mentioned in chapter 2, the traditional way of conducting LCA assessments is, for example when looking at pork, to start with a farm and then map the emissions associated with the production. If the system boundary of the analysis is pork from the slaughterhouse, the emissions associated with the slaughter process are included. This is a bottom-up analysis, starting from the bottom and moving up the chain.

The advantage of this is that the figures you get are fairly accurate for the specific production. The disadvantage is that there are many climate impacts from the production system that are not included in the analysis. These are, of course, climate impacts outside the system boundaries, but often also figures within the system boundaries, such as the production of the slaughterhouse's buildings and machinery.

3.1 Hybrid LCA based on input-output analyses

Another method is to move from the top down - a top-down analysis. For example, you can start with the emissions of the entire agricultural sector and then move downwards to find out how much of the emissions are associated with pig production. This way, the numbers become less precise for each specific product. On the other hand, more of the actual climate impact of the production system will be captured. The optimal and most accurate result is obtained by combining the two methods in a hybrid LCA, which is the method used in The Big Climate Database.

On a global scale, conducting a top-down analysis would be an impossible exercise, as it would be far too comprehensive and time-consuming. However, within the field of economics, researchers have developed so-called input-output analyses that allow for detailed tracking of cash flows down through the systems. Various environmental parameters have also been linked to these cash flows, including the relevant greenhouse gases. This means that the movement of money can be followed through different industries and countries, and thus the climate impact of a given consumption can be tracked.

For example, if you have data on how much cement production emits globally and you know the price of cement, you also know how much cement emits per DKK. It is then possible to follow the money for cement down through the systems and thereby also follow the emissions and who ultimately pays for the cement - for example, a farmer who has built a pigsty.

In a highly simplified model, you can take all the money spent in the world in a year, measured as GDP (an amount of approx. 530,000 billion DKK) and compare this with the total annual global greenhouse gas emissions (approx. 55 billion tons). Based on this model, approximately 110 grams of CO_2e are emitted for every DKK spent.

In reality, different things do not emit the same amount per DKK, and a concert ticket will emit less per DKK than, for example, the purchase of cement. There will be large geographical differences as well.

If a slightly more advanced two-box model is created, the world can be divided into food and non-food, where food (as a purely illustrative example) emits 200 grams of CO_2e/DKK and non-food emits 90 grams of CO_2e/DKK.

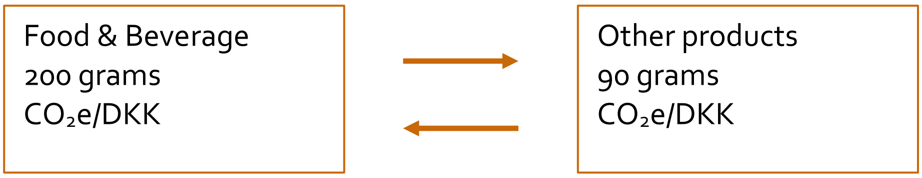


Figure 1: Illustrative simple model for the climate impact of food and other goods per DKK

This allows for a slightly more advanced calculation, where a given consumption is divided into food and non-food items. However, food and non-food items are also interdependent product groups. One cannot produce food without getting energy and materials from the non-food box and vice versa, and thus the emissions per DKK will change in relation to the figures in the box. When calculated, a very simple input-output table with environmental parameters attached has been made.

This is the principle used to calculate emissions in The Big Climate Database. However, the tables used are of course much more extensive, and in the real world there will also be quite large geographical variations in what the same things emit. Therefore, very large tables are used, which are further divided into many countries and regions.

The table that forms the basis of the climate database is called EXIOBASE. It consists of 164 boxes with different product categories distributed across 44 countries, plus 5 regions covering the countries that are not included. All the countries and regions have 164 boxes that are interconnected and dependent on each other. So, there is a huge matrix of numbers and calculations behind the database, and in practice, the calculations are carried out using a specialized software. Additionally, land use for food production is also included in the database, allowing the aforementioned ILUC to be included.

For example, one box is called "Cultivation of vegetables, fruit, nuts". If one wants to know what vegetables, fruits and nuts from Spain emit per ton (the economic figures are as far as possible converted to physical units in this EXIOBASE version), a very accurate figure can be obtained by using the Spanish version, which in turn include data from all the other boxes and in all other countries.

However, it is not particularly useful in relation to The Big Climate Database to know what a mix of vegetables, fruits and nuts emit in Spain, as the items in the climate database are much more specific than that. Therefore, a hybrid version of the database is created, combining the top-down approach of the input-output database with the traditional bottom-up approach.

For example, if you are interested in the climate impact of peppers from Spain, you can find specific data for peppers from the literature and especially FAO's databases, including e.g. what the yield is per hectare, fertilizer usage, energy consumption, auxiliary materials, raw materials, etc. Over 27,000 datasets serve as background material for this calculation.

Next, take the "Cultivation of vegetables, fruit, nuts" box and replace the relevant parameters in it with the correct figures for peppers so that the box will specifically present peppers. This way it presents the average of peppers from Spain, but not a specific pepper from a specific producer, as this is not the target in the climate database.

For peppers on the Danish market, we analyze where peppers in Denmark typically come from and then take a representative average of peppers delivered to the Danish market, which could be an average of 10 countries' production of peppers.

However, this box only covers the primary production of peppers for the Danish market, as it has yet to be processed, packed, transported, and handled in the Danish store. For these calculations, other boxes in the databases are used in a similar way so that the emissions from primary production, ILUC, processing, packaging, transportation, and storage and refrigeration can be shown in The Big Climate Database.

The transport column in the climate database covers the transportation of raw materials for processing and the final transportation to the stores. The rest of the transportation is included in the other production phases.

For packaging, the end use of the packaging is also included, e.g. recycling of bottles or incineration of plastic for cogeneration.

When there is no system boundary and all climate impacts in the production system are accounted for, many of the figures will be higher than what is typically observed. This is particularly evident in the carbon impact from transportation, which for many products in The Big Climate Database, takes up a larger share than usual, especially for heavy foods with low emissions in primary production that are transported over long distances.

This is because, often, only the energy consumption for the actual transportation is considered, whereas in the climate database, emissions from the production of all the prerequisites for transportation are included as well. This encompasses the manufacturing of ships and trucks, port facilities, roads, transshipment facilities, general infrastructure, maintenance, etc. As a result, the emissions from transportation can be more than twice as large as when calculating the climate impact based solely on fuel consumption.

On the other hand, it cannot be immediately concluded that one can entirely save the emissions from transportation by choosing a locally produced product. While it is possible to save emissions from the fuel, emission reductions related to the infrastructure are limited. For a more detailed review of the methodology, please refer to the methodology report (Schmidt, et al., 2023).

3.2 Selecting and categorizing foods in the climate database

In selecting the 500 foods for version 1 of The Big Climate Database, we endeavored to include as many different food types as possible while including foods that are widely used in Danish kitchens and are a common part of the assortment in well-stocked supermarkets. In version 1.1, we have added average climate impacts for beef, pork, and chicken, bringing the total to 503 foods.

The selection of the 503 foods is based on the following criteria:

- The best-selling raw materials and basic products based on sales statistics, etc.
- Best possible coverage across a common product range in a well-stocked supermarket.
- More variants in product groups with a generally high climate impact, e.g. different meat cuts.
- Both unprocessed and processed versions of the same raw material, e.g. raw and pickled cucumber.
- A wide range of plant-based alternatives to meat and dairy products, which have seen strong sales growth in recent years.

The naming of the foods and their content of calories and the macronutrients protein, carbohydrates and fat are based on two main sources. Approximately 380 of the foods are selected from the National Food Institute's database, Frida, which contains information about the nutrients in more than 1500 foods on the Danish market (National Food Institute, 2023). These foods are supplemented with 120 product examples from GS1Trade Sync, which contains master data for thousands of foods on the Danish market, including nutritional information on specific products (GS1, 2020).

Product names and general product categories have been changed to make navigation and searching in the climate database easier. Version 1.1 covers the following 16 general product categories:

1. Beverages (17 items)
2. Bread and bakery products (25 items)
3. Candy and sugar products (11 items)
4. Cereals and cereal products (31 items)
5. Fruits and fruit products (44 items)
6. Legumes and legume products (12 items)
7. Meat and poultry (63 items)
8. Milk, dairy products, and eggs (27 items)
9. Mushrooms and mushroom products (5 items)
10. Nuts and seeds (8 items)
11. Plant products and drinks (31 items)
12. Ready meals (37 items)
13. Seafood (51 items)
14. Seasonings and spices (30 items)
15. Vegetables and vegetable products (96 items)
16. Wine, beer, and spirits (15 items)

4. The climate database's results

The Big Climate Database shows the climate impact of 503 products divided into 16 product categories. In the database, it is possible to read the total climate impact of the products, as well as the specific impact stemming from agriculture, ILUC, processing, transportation, packaging and retail storage, refrigeration, etc. The share of emissions from the different production phases varies from product to product.

4.1 Results for the main product categories

For **fresh vegetables,** emissions generally range from 0.25-1.2 kg CO_2e/kg, and transportation in particular can make a relatively large difference to the climate impact of the products. This is because the emissions covered by transportation in the climate database are far more comprehensive than what is usually seen, including much more than just fuel consumption. No distinction is made between field and greenhouse crops, but as a rule of thumb, the emissions from agricultural production should be multiplied by approximately a factor of 10 to get an approximate climate impact for greenhouse crop production.

For **fresh fruit,** the same picture applies as for vegetables. Here, the range is also from 0.25-1.2 kg CO_2e/kg. However, it is important to consider the amount consumed, as, for example, a melon will usually add more weight to a meal than a meal of spinach. Again, the big variations in the emissions come from transportation.

Nuts and seeds are generally in the range of 2-10 kg CO_2e/kg and here "agriculture" is generally more important than for fruit and vegetables, while transportation is still significant.

Cereals and grains range from 1-5 kg CO_2e/kg, while **spices** range from 0.5-7.5 kg CO_2e/kg. Again, interpretation of the results should consider the actual amounts consumed.

Bread and pastries range from 0.8-3 kg CO_2e/kg with rye bread being the lowest and sweet pastries with a higher fat content being the highest.

Beverages such as beer, wine, juice, and soft drinks generally range from 0.5-2 kg CO_2e/kg with beer at the low end and wine at just under 2 kg (again, remembering the actual quantities consumed). High-alcoholic drinks (e.g. sherry and cognac) range from 2.5-5 kg CO_2e/kg.

Fresh fish and seafood generally range from 0.2-11 kg CO_2e/kg, with mussels being the lowest and crab claws the highest. Fresh fish is typically 2.5-4 kg CO_2e/kg but can span up to 7.5 kg CO_2e/kg. **Processed fish and seafood products** generally have higher emissions, partly because fish packaging significantly increases the climate impact.

The variation for **meat and poultry** is very large, ranging from 1.9 kg-186 kg CO_2e/kg.

The very high values apply to beef and are dependent on the cut as explained in section 3.1. Beef ranges from 37-186 kg CO_2e/kg, with an average for all beef at 61 kg CO_2e/kg. Lamb is just over 30 kg CO_2e/kg.

Pork generally ranges from 2-7.3 kg CO_2e/kg, again depending on the cut, and is less than a tenth of the emissions from beef. The average pork emits 4.7 kg CO_2e/kg.

Chicken and other poultry have the lowest emissions ranging from 1.9-5.6 kg CO_2e/kg, with the average chicken meat at 3.26 kg CO_2e/kg.

Figure 2: Climate impact of average beef, pork, and chicken meat as well as an illustration of the proportions between them.

Dairy products range from 0.6 kg to just over 7 kg CO_2e/kg. The lowest emissions are found for drinking milk (skimmed milk) and the highest for cheese. Again, it is important to interpret the results in light of the quantities consumed.

Plant-based alternatives to dairy products generally have lower emissions than cow's milk but range from 0.37 kg CO_2e/kg for almond drink to 1.23 kg CO_2e/kg for rice drink.

One reason for the relatively low emissions of dairy products (as explained in section 3.1) is that the meat from dairy production displaces the production of beef, and the climate effect of this displacement is subtracted from the emissions of milk.

Plant-based alternatives to meat, with emissions ranging from 0.2-2.7 kg CO_2e/kg, are generally well below the products they replace and significantly lower than beef.

Sweets such as chocolate, candy, and marzipan generally range from 1.5-10 kg CO_2e/kg, with chocolate and marzipan-based products at the high end and sugar-based products at the low end.

Vegetable oils range from 3-5 kg CO_2e/kg, with margarine at the lowest and olive oil at the highest.

Finally, there is a wide range of **ready meals and processed products**. These show a significant variation, primarily influenced by the amount of beef they contain, while products without beef have a much narrower emission interval. For instance, a beef lasagna emits over 10 kg CO_2e/kg, while a vegetarian lasagna emits 1.5 kg CO_2e/kg.

4.2 Results for the production phases

For all products, emissions are broken down into agriculture, ILUC, processing, packaging, transport, and retail.

For **agriculture,** the highest values observed are for beef production, followed by nuts, dairy products, pork, chicken, and vegetable oils.

A similar pattern is generally seen for **ILUC,** where nuts, cocoa, coffee, and tea also exhibit high emissions due to relatively low yields.

For **processing,** fish products are particularly high. This is mainly because the entire aquaculture and fish production fall into the processing category. Butter and crisps also have high emissions in processing.

It should also be noted that some processing operations have negative emissions, and this is especially true for slaughterhouses. This is because some of the slaughterhouse waste can be recycled, and especially the part that can be used for protein feed displaces other feed production. This displacement is subtracted from the slaughterhouse's emissions, often resulting in negative net emissions from processing. For slaughterhouse waste used for energy, the reduction will be significantly smaller, as displacing feed has a higher effect than displacing energy production.

For **packaging,** certain fish and seafood, beverages, and spices have particularly high emissions. For all of these, the packaging typically contributes significantly to the overall weight compared to the product.

For **transportation,** the picture is more varied, but (beef) meat, in particular, has high emissions. In general, goods with a refrigeration requirement have relatively higher emissions from transportation than goods without such a need.

Emissions from **retail,** including storage, refrigeration, and freezing, are very low and have limited impact on the overall emissions from the products. In general, emissions range between 10 and 20 grams of CO_2e/kg.

4.3 Summary of results by product types and categories

The results for the different product types in The Big Climate Database version 1.1 are summarized in figure 3-5 and table 2 on the following pages.

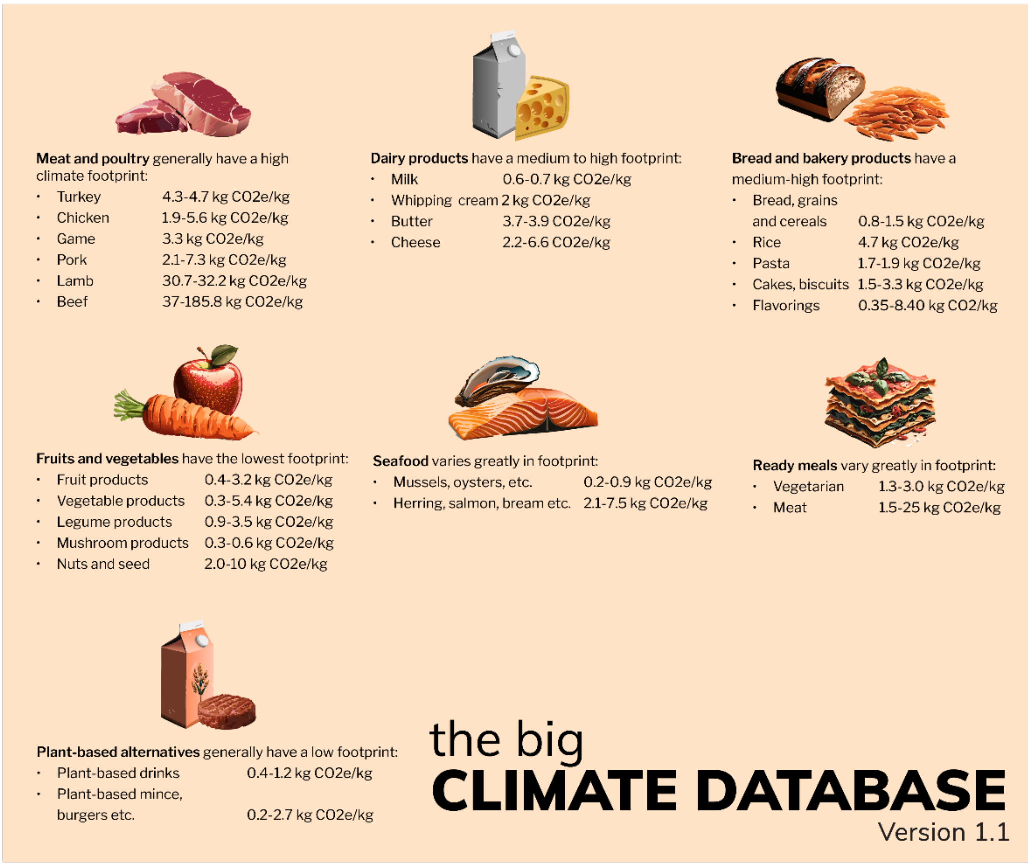


Figure 3: Overview of the variation in climate impact for selected categories and product types (rounded decimals).

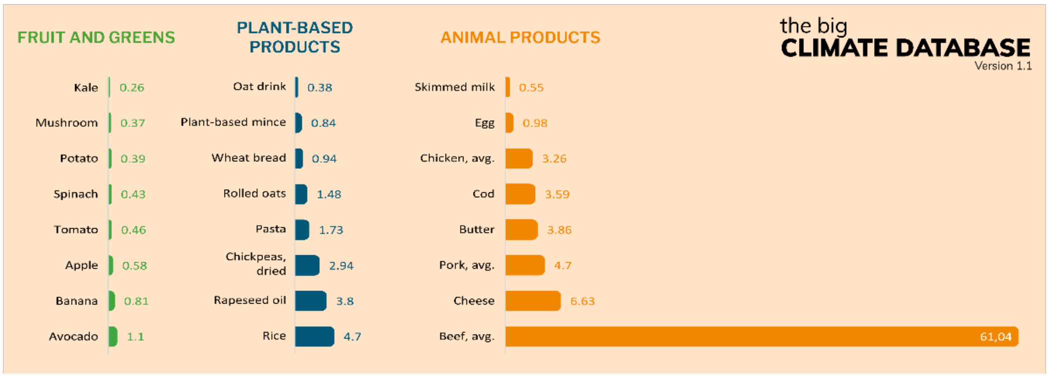


Figure 4: Climate impact of selected products broken down by fruit and vegetables, processed plant-based products, and animal products.

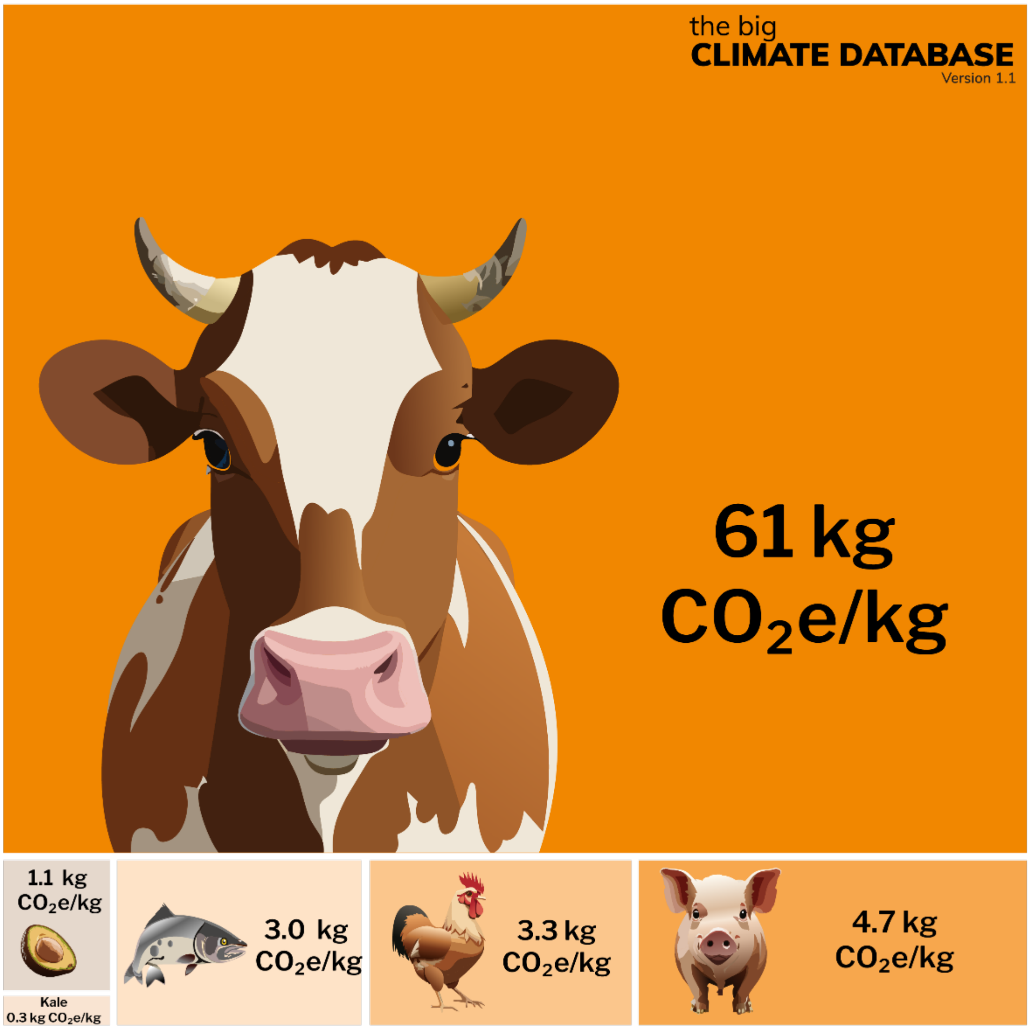


Figure 5: The climate impact of average beef, average pork, average chicken, salmon (farmed), avocado and green kale in The Big Climate Database version 1.1 and illustration of the proportions between them.

Category	Lowest climate impact	Highest climate impact
Bread and bakery products	Rye bread (0.81)	Marzipan (9.98)
Legumes and legume products	Wax beans (0.90)	Peanut butter (3.48)
Beverages	Tap water (0.001)	Coffee, instant, powder (14.59)
Seafood	Mussels (0.19)	Crab claws (10.92)
Fruits and fruit products	Watermelon (0.39)	Raisins, stone-free (3.16)
Ready meals	Samosa, vegetarian, frozen (1.27)	Chili con carne (25.05)
Vegetables and vegetable products	Onions (0.25)	Coconut milk (5.44)
Cereals and cereal products	Rye flour and kernels (1.01)	Rice flour (4.74)
Meat and poultry	Chicken, thighs, meat, and skin, raw (1.87)	Beef, tenderloin, trimmed, raw (185.76)
Milk, dairy products, and eggs	Skimmed milk (0.55)	Cream cheese, yellow cheese, parmesan, and mozzarella (6.63)
Nuts and seeds	Chestnut (2.04)	Cashew nuts, dry roasted (9.94)
Plant products and drinks	Vegan bacon (0.24)	Nut paste with cocoa (4.83)
Candy and sugar products	Syrup (1.42)	Dark chocolate (6.27)
Seasonings and spices	Bouillon, chicken, ready to eat (0.35)	Bouillon, beef, concentrated, cube (8.40)
Mushrooms and mushroom products	Portobello mushroom (0.26)	Mushrooms, canned (0.61)
Wine, beer, and spirits	Beer, lager, 4.4% vol. (0.65)	Cognac (5.21)

Table 2: The variation in carbon impact from lowest to highest carbon impact within the 16 product categories.

5. Applications and user guide

The Big Climate Database aims to improve companies' and citizens' access to the climate impact of the most common foods on the Danish market. The aim is to make the calculations as accurate and up-to-date as possible and to reflect the supply of food in Denmark as accurately as possible. However, given the extensive amount of data and complex calculations, errors cannot be ruled out.

Any errors in the database will be corrected in future updates as they are discovered. In addition, the results may change as the data basis is updated, new calculation factors are introduced in international standards, etc.

5.1 Possible applications

The information in The Big Climate Database is intended for general information and education purposes only. Despite these reservations, The Big Climate Database represents the most detailed, precise, and accurate data basis for the climate impact of food on the Danish market. It can be used for applications such as:

- Climate calculation of recipes, meal plans, etc. (see example below)
- Climate calculation of food purchases in companies and households
- Ranking of food types for simplified climate labeling
- General information and education about the climate impact of food.

Under the right conditions, the climate impact of the products in The Big Climate Database can also be used as a benchmark in assessing whether a specific food product's climate impact is significantly above or below the market average. However, this requires methodological rigor and due consideration of the uncertainties in this type of calculation.

Pasta Bolognese on a climate diet

Traditional bolognese with ground beef
Carbon footprint per serving: **5.27** kg CO2e

Ground beef halved and replaced with carrots
Carbon footprint per serving: **2.94** kg CO2e — Approx. 45% reduction in carbon footprint

Ground beef replaced with ground pork
Carbon footprint per serving: **0.85** kg CO2e — Approx. 85% reduction in carbon footprint

Ground beef replaced with carrots and lentils
Carbon footprint per serving: **0.56** kg CO2e — Approx. 90% reduction in carbon footprint

Ground beef replaced with plant-based mince
Carbon footprint per serving: **0.49** kg CO2e — Approx. 90% reduction in carbon footprint

Figure 6: Example of climate-calculated recipes. Different variants of pasta bolognese and reduction in carbon impact compared to the traditional one.

While the potential applications are many, The Big Climate Database will not in itself be suitable for:

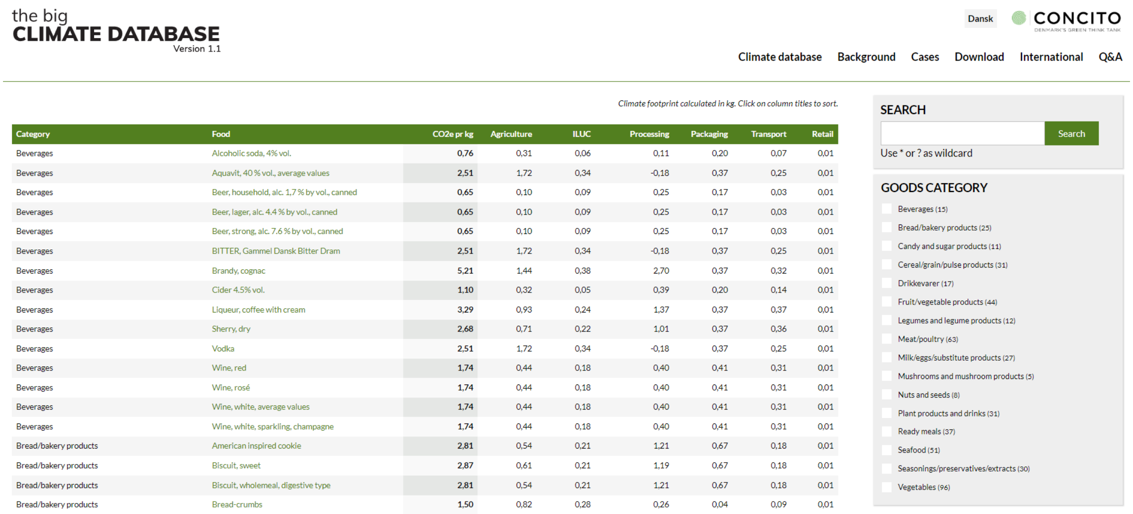
- Climate labeling, marketing, or taxation of specific foods: The average climate impacts in the climate database do not reflect the large variation that can exist within each product type. The results in themselves are thus not an accurate or sufficient basis for labeling, promotion, or taxation of specific products.
- Sustainability assessment: The Big Climate Database provides detailed and accurate information on the average climate impact of foods, but the calculations do not account for other environmental, social, or economic sustainability parameters.
- Dietary guidance: Dietary choices focused on minimizing the carbon impact of food alone will not necessarily ensure a healthy and nutritious diet. A climate-friendly and healthy diet requires attention to both the climate impact and obtaining an appropriate number of calories, carbohydrates, protein, fat, vitamins, minerals, etc.

The following projects and activities can complement or succeed version 1 of The Big Climate Database:

- Extending the database with calculations for more products or other product groups
- Expansion of the database with data and calculations of more environmental and sustainability parameters.

5.2 User guide

The Big Climate Database is freely accessible on the website denstoreklimadatatabase.dk, where tables, detailed background data, methodology report, background report, Q&A, etc., are available. Users can search and navigate the results using product categories and read much more about how the results are calculated. It is also possible to download the overall results for all 503 foods.

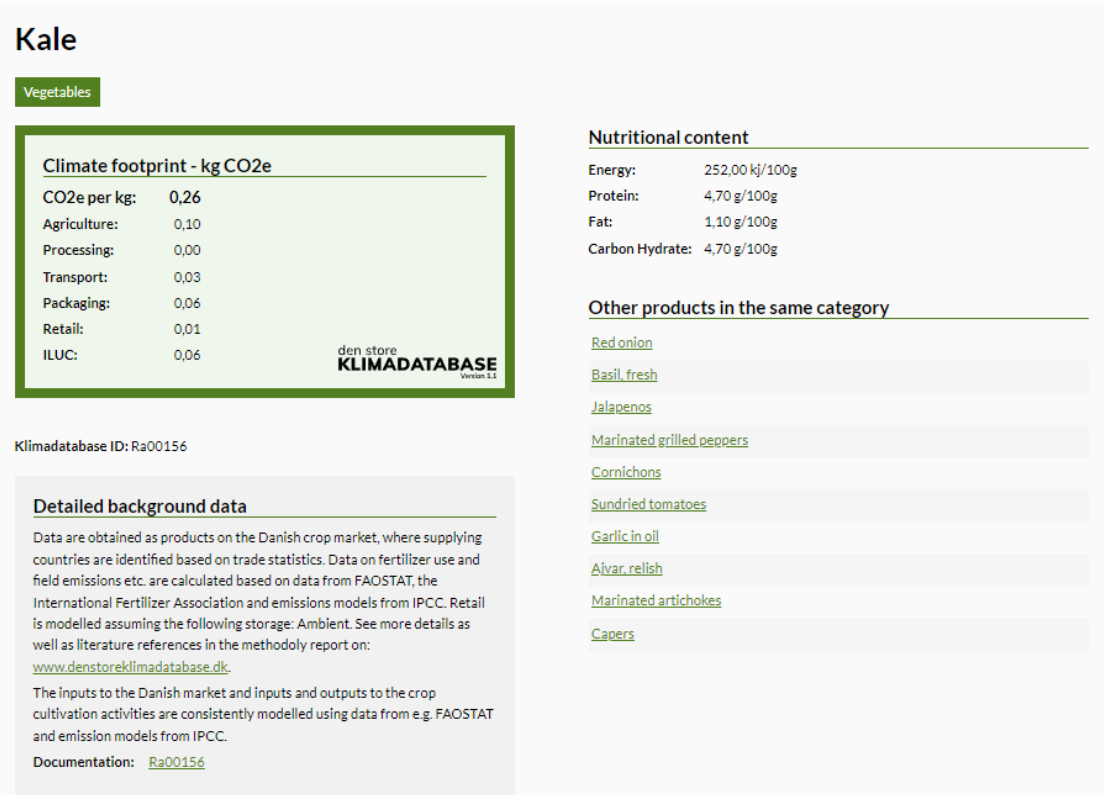


Category	Food	CO2e pr kg	Agriculture	ILUC	Processing	Packaging	Transport	Retail
Beverages	Alcoholic soda, 4% vol.	0,76	0,31	0,06	0,11	0,20	0,07	0,01
Beverages	Aquavit, 40 % vol., average values	2,51	1,72	0,34	-0,18	0,37	0,25	0,01
Beverages	Beer, household, alc. 1,7 % by vol., canned	0,65	0,10	0,09	0,25	0,17	0,03	0,01
Beverages	Beer, lager, alc. 4.4 % by vol., canned	0,65	0,10	0,09	0,25	0,17	0,03	0,01
Beverages	Beer, strong, alc. 7.6 % by vol., canned	0,65	0,10	0,09	0,25	0,17	0,03	0,01
Beverages	BITTER, Gammel Dansk Bitter Dram	2,51	1,72	0,34	-0,18	0,37	0,25	0,01
Beverages	Brandy, cognac	5,21	1,44	0,38	2,70	0,37	0,32	0,01
Beverages	Cider 4.5% vol.	1,10	0,32	0,05	0,39	0,20	0,14	0,01
Beverages	Liqueur, coffee with cream	3,29	0,93	0,24	1,37	0,37	0,37	0,01
Beverages	Sherry, dry	2,68	0,71	0,22	1,01	0,37	0,36	0,01
Beverages	Vodka	2,51	1,72	0,34	-0,18	0,37	0,25	0,01
Beverages	Wine, red	1,74	0,44	0,18	0,40	0,41	0,31	0,01
Beverages	Wine, rosé	1,74	0,44	0,18	0,40	0,41	0,31	0,01
Beverages	Wine, white, average values	1,74	0,44	0,18	0,40	0,41	0,31	0,01
Beverages	Wine, white, sparkling, champagne	1,74	0,44	0,18	0,40	0,41	0,31	0,01
Bread/bakery products	American inspired cookie	2,81	0,54	0,21	1,21	0,67	0,18	0,01
Bread/bakery products	Biscuit, sweet	2,87	0,61	0,21	1,19	0,67	0,18	0,01
Bread/bakery products	Biscuit, wholemeal, digestive type	2,81	0,54	0,21	1,21	0,67	0,18	0,01
Bread/bakery products	Bread-crumbs	1,50	0,82	0,28	0,26	0,04	0,09	0,01

The Big Climate Database is published in Danish and English and can be used freely with the above-mentioned reservations. When using the results of the database, reference should be made to:

"CONCITO (2024): The Big Climate Database, version 1.1"

For each individual product, the climate impact broken down into the different production phases, as well as the nutritional content of the products according to DTU's FRIDA database and other sources, can be seen. Finally, you can see detailed background data in English and, via the documentation link, detailed background tables with the inputs and emission factors used to calculate the climate impact.



Points to consider when interpreting the results

In addition to the caveats mentioned in section 5.1, attention should be given to the following factors when using and interpreting the results of the climate database:

- **Nutritional content of food**: Consideration should be given to the nutritional content of the food, as it can vary significantly and is an essential aspect of the food as a functional unit. The functionality of a food item is measured not only in kilograms but also in terms of nutrient content, satiety, taste, and enjoyment. Conversely, nutrients may not always be a relevant functional unit, as many Danes receive more nutrients than they need, and reducing some nutrients may be beneficial.
- **Food density**: There is a big difference in how far a kilogram of each product goes, and it would be irrelevant to compare the climate impact of a kilogram of cayenne pepper with a kilogram of flour or a kilogram of cheese.
- **Food cooking shrinkage or growth**: The climate impact is stated per kilogram of purchased product. Some foods will shrink when cooked, due to factors like cooking shrinkage or discarded peels. Other foods will increase in quantity when cooked, such as pasta, rice, dried legumes, or dried mushrooms.
- **Seasonality and production system**: There is no distinction between e.g. open field and greenhouse crops, but as a rule of thumb, the emissions from agricultural production should be multiplied by about a factor of 10 to get an approximate climate impact for greenhouse crop production.

In addition to these general considerations, help can be found in the Q&A section of denstoreklimadatabase.dk. The most frequently asked questions about version 1 and answers to these can be found in Appendix 1 of this report.

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Appendix 1: Q&A for The Big Climate Database, version 1

Below is a reproduction of answers to the most frequently asked questions for version 1 of The Big Climate Database. See future updates of Q&A at denstoreklimadatatabase.dk/en/qa.

1. Why is there a difference in the climate impact of different cuts of meat?

The result for the different cuts is based on the climate impact per DKK of beef, pork or chicken from the slaughterhouse, and then converted to climate impact per kg of the different cuts based on the relative price difference and quantity from the slaughterhouse.

This is calculated per DKK and not per kg because all cuts from a slaughterhouse help determine how much meat the slaughterhouse produces. This means that the slaughterhouse will respond with increased production when there is a demand for more minced meat and tenderloin.

When determining how much a slaughterhouse increases production when demand for a given cut changes, it can be identified by the price of the product being sold. Slaughterhouses set the price of different cuts of meat to ensure they make as much profit as possible and to ensure they sell all their meat. Therefore, it is the price of the meat sold, and not the quantity in kilograms, that determines how much extra production from the slaughterhouse is induced through a change in demand for a given cut.

The average climate impact of beef from the slaughterhouse is 50.2 kg CO_2e per kg, while the average climate impact of pork from the slaughterhouse is 4.3 kg CO_2e per kg.

The distribution of the climate impact for the different cuts of beef ranges from 31 kg CO_2e per kg of ground beef to 152 kg CO_2e per kg of beef tenderloin. For pork, it ranges between 3 kg CO_2e per kg of minced pork and 5.5 kg CO_2e per kg of pork tenderloin.

For example, if the choice is between 1 kg of ground beef and 1 kg of beef tenderloin, the best climate choice would be 1 kg of ground beef. If the choice is between DKK 100 of ground beef and DKK 100 of beef tenderloin, there will be no difference in the climate impact.

The allocation of the climate impact on cuts is described in chapter 8.1 of the methodology report.

LCA theory for determining and dependent products

LCA theory for multiple determinant products.

2. Why is the climate impact stated per kilo of food and not in relation to the nutrient content?

The Big Climate Database provides the climate impact per kg of food, as this is the most relevant and practical measure of the climate impact of food. However, the nutritional content of the food is shown in the description of each product.

Beyond taste and enjoyment, we eat to feel full and get the nutrients we need - not to maximize calories, protein, etc. When it comes to optimizing our diet in relation to climate and health, nutritional content is not the relevant measure. For example, no one shops for calories or proteins, and most Danes today consume too many nutrients.

In addition, recipes and purchases are usually described and recorded in the weight of the different ingredients and items - not in the number of calories, protein, etc. For example, you buy 1 kg of potatoes - not 20 grams of potato protein.

The sole purpose of The Big Climate Database is to shed light on the climate impact of what you have in your shopping cart or in your meal, not to put together your purchase or meal in a nutritionally optimal way. It is a good idea to refer to the official dietary guidelines.

The purpose and applications of the climate database are described in chapter 5 of the background report.

Weidema B P, Stylianou K S (2020). Nutrition in the life cycle assessment of foods - function or impact? The International Journal of Life Cycle Assessment 25-:12101216.

3. Why are the results for fish based on the climate impact of farmed fish?

The purpose of The Big Climate Database is to provide information about the climate impact of our food consumption, and a change in the demand for fish will ultimately affect fish farming - whether the fish is caught in the sea or comes from aquaculture.

The results for fish are based on internationally recognized studies that show that the amount of wild-caught fish does not change. There are plenty of fish in the oceans - we just cannot catch more.

Wild-caught seafood is generally a globally limited resource that cannot be increased, as the carrying capacity of ecosystems is fully utilized in virtually every part of the world. However, this does not apply to marine molluscs such as mussels, oysters, and squid, which are abundant.

Statistics from the FAO show that the amount of wild-caught fish has remained virtually unchanged since the mid-1990s, while aquaculture is growing rapidly and has been responsible for meeting virtually all of the increasing demand for fish.

Good fish management can help to increase fish stocks but given that aquaculture now accounts for almost half of the world's fish production, it is difficult to see how changes in management locally in the EU can significantly change the global fish market.

The assumptions for the calculation of the climate impact for fish are described in chapter 7 of the methodology report.

4. Is the large variation in climate impact within each food type taken into account?

In this first version of The Big Climate Database, we have only calculated the average climate impact of 500 different foods and beverages. However, there can be quite large differences in the climate impact within each food type depending on production location, production methods, varieties, etc. For example:

- Greenhouse vegetables versus outdoor vegetables
- Highly extensive productions versus highly intensive productions
- Productions with highly efficient nutrient utilization versus productions with high nutrient losses
- Goods with short transportation distances versus goods with very long transportation distances.

The climate impact from the different production methods for the food and beverages on the Danish market is included in the average. However, if a distinction is to be made between, for example, Danish-produced vs. foreign-produced, open-air production vs. greenhouse production or extensive production vs. intensive production, this would require separate calculations for each individual country, production method, production system, etc.

The results in The Big Climate Database do not show the climate impact of a specific tomato or a specific cutlet in the store, but the average climate impact of tomatoes and cutlets on the Danish market.

This makes the climate database a relevant tool for food professionals and particularly interested consumers to view and calculate the climate impact of meals and purchases. In addition, it can be a relevant benchmark for food producers who want to investigate or document whether their own production is more or less climate-friendly than the market norm.

5. Is carbon storage accounted for in the climate database results?

No, it is not. Storage and decomposition of carbon in the soil is not included, but a model is being developed for this purpose, which may make it possible to include it in future versions of the climate database. However, emissions from drainage and cultivation of organic soils are included.

6. Does the climate database take other sustainability factors than climate into account?

No, it does not. Other sustainability factors such as biodiversity, aquatic environment, animal welfare, health, social conditions, etc. have not been taken into account, and these factors should of course also be included in the assessment of sustainable food consumption.

On the other hand, the climate database provides new and more accurate knowledge about the climate impact of the different product types, and it is thus a very important supplement to, for example, the eco-label, animal welfare labels, fair trade labels, etc.

7. Why does it say that you do not take responsibility for the data presented and its use?

CONCITO and 2.-0 LCA consultants vouch for the results, but do not exclude the possibility of errors in such a large data material based on many millions of data points. Any errors found in the climate database will be corrected.

In addition, we have no control over what the data material is used for when it is freely available and therefore, we cannot take responsibility for it. Disclaimers like this are standard in many open-source databases and are also used, for example, by the National Food Institute in relation to their frida.fooddata.dk.

8. Are two decimal places on the results indicating high precision and is 0.00 equal to zero climate impact?

All life cycle analyses are associated with a certain degree of uncertainty, and this naturally also applies to the results in The Big Climate Database. The two decimal places in the results should therefore not be interpreted as an expression of high precision in the calculations of the climate impact of food. When we use two decimal places in the large table on the website, it is to show the total climate impact for all products in the range from 0.22 kg CO_2e per kg at the low end (mussels) to 151.95 kg CO_2e per kg at the high end (beef tenderloin).

The carbon impact of tap water is listed as 0.00 in the large table on the website but is actually calculated to have a climate impact of around 0.001 kg CO_2e per kg. This is reflected in the downloadable spreadsheet, where there are even more decimal places in the results.

The uncertainty in the calculations is described in chapter 2.11 of the methodology report.

9. Why is the climate impact of processing certain foods listed as negative?

The negative emissions from the processing of meat and dairy products in particular, as well as a few vegetable products, are due to a displaced climate impact because by-products substitute other production. For example, the utilization of slaughterhouse by-products for meat and bone meal and fat displaces other production of animal feed, fuels, fertilizers, and biodiesel.

LCA theory for determining and dependent products

LCA theory on by-products and waste.

10. Is the climate database based on research and does it meet scientific standards?

The publication and general dissemination of The Big Climate Database is the responsibility of CONCITO. The calculations of the climate database results are based on recognized scientific methods and carried out by experienced experts in the field. The main experts responsible for version 1 are Jannick Schmidt, Stefano Merciai, Ivan Muñoz, Michele De Rosa, and Miguel F Astudillo, all of whom have contributed to several scientific and peer-reviewed publications on life cycle assessments as well as large EU projects in the field.

See a selection of publications from the experts on the 2.-0 LCA consultants website.

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DENMARK'S GREEN THINK TANK

CONCITO is an independent think tank that communicates climate knowledge and solutions to politicians, companies, and citizens.

Our purpose is to contribute to reduced greenhouse gas emissions and limit the damaging effects of global warming.

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