Appendix 2: Limitation report

Limitations of "Guidelines for calculating the carbon footprint of food products available on the Danish market"

Advisory report from DCA – Danish Centre for Food and Agriculture

Huayang Zhen, Marie Trydeman Knudsen, Teodora Dorca-Preda, Lisbeth Mogensen

Department of Agroecology, Aarhus University, Blichers Allé 20, P.O. Box 50, DK-8830, Tjele, Denmark

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Data sheet

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Author(s):	Postdoc Huayang Zhen, Senior Researcher Marie Trydeman Knudsen, Postdoc Teodora Dorca-Preda & Lecturer Lisbeth Mogensen Department of Agroecology, AU
Review:	Senior Researcher Anna Woodhouse, NORSUS; Senior Researcher Hayo van der Werf, INRAE; Researcher Hietala Sanna, LUKE and Professor Michael Hauschild, DTU.
Quality assurance, DCA:	Special consultant Susanne Hansen and Special consultant Stine Mangaard Sarraf, DCA Centre Unit, AU
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External comments:	Yes, the report has been into public consultation. Forbrugerrådet TÆNK, Mærkevareleverandørerne (MLDK), Arla, DI Fødevarer (DI), Landbrug og Fødevarer (L&F), Energistyrelsen (ENS), Food & Bio Cluster Denmark and Fødevarestyrelsen (FVST), have made comments on the report. All the comments and AU's handling of the comments can be accessed via this LINK
External contributions:	No.
Comments to the request:	This report is a stand-alone appendix to the report Zhen, H.; Mogensen, L.; Dorca-Preda, T. & Knudsen, M.T. 2023. Guidelines for calculating the carbon footprint of food products available on the Danish market. This delivery replaces the partial delivery from 26.01.2024 consisting of the two appendices: Zhen, H.; Knudsen, M.T. & Mogensen, L. 2023. Appendix 1: Comparison report - Comparison between Product Environmental Footprint, Agribalyse methodologies, and 'Guidelines for calculating the carbon footprint of food products available on the Danish market' & Zhen, H.; Mogensen, L.; Dorca-Preda, T. & Knudsen, M.T. 2023. Appendix 2: Limitation report of which this is appendix 2 and Guidelines of calculating the carbon footprint of food products available on the Danish market.
Comments to the answer:	A data follow-up group (datafølgegruppe) is connected to the Research project. The data follow-up group included members from the Danish Food and Veterinary Agency, The Danish Agricultural Agency, The Danish Energy Agency and the Ministry for Food, Agriculture and Fisheries. The data follow-up group has not been

involved during the process. Members of the group have had the opportunity to submit their comments individually during the public consultation period. The group has been invited to an inquiry meeting after the public consultation period.

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Contents

1. Introduction

In an era marked by increasing environmental consciousness, evaluating a product's environmental impact has taken center stage. Life Cycle Assessment (LCA) has emerged as a sophisticated tool for assessing the carbon footprint of various products/services, including food products. LCA provides a holistic approach to understanding the environmental consequences of a product throughout the studied lifecycle. To quantify the carbon footprint of food products sold on the Danish market, an accounting guideline has been developed based on LCA. However, as with any analytical framework, LCA has some inherent and man-made (due to choices and assumptions) limitations. This report describes the limitations of the carbon footprint accounting guideline.

This report sheds light on the challenges and constraints that influence the accuracy and comprehensiveness of accounting for the carbon footprint of food products with LCA. While LCA has made substantial strides in fostering sustainable practices and informed decision-making, it is imperative to recognize the boundaries and uncertainties that can impact the outcomes and effectiveness of these assessments.

By critically examining these limitations, we try to enhance the understanding of stakeholders who rely on the outcomes of the guideline to guide their sustainable choices and strategies. From system boundaries and data availability to methodological assumptions and simplifications, this report will investigate the limitations that shape LCA results' reliability in quantifying food products' carbon footprint. Through this exploration, we aim to contribute to a more transparent and balanced interpretation of LCA outcomes.

2. Materials and methodologies

This report analyzes the limitations of the *Guidelines for calculating the carbon footprint of food products available on the Danish market*. Therefore, this report follows the guideline's outline sequence to better match this document to the carbon footprint guideline and the comparison report. Firstly, the choice/decision made in the guideline is pointed out together with justifications for doing so. Then, we describe the limitations of the choice/decision as well as the disadvantages when applying this guideline. Lastly, development needs are provided for future work to improve the guideline. However, development needs might not be visible for every limitation by now. The examined limitations are numbered in a sequence throughout the report.

3. Results

3.1 Goal and scope

3.1.1 Goal definition

No limitations are examined here.

3.1.2 Scope definition

3.1.2.1 Functional unit (FU) and reference flow

No.	Choice/decision	Justification	Limitation	Disadvantages in application	Development needs
1	Reference flow: 1 kg of food product	Generally, food products are sold per mass. Calculating the carbon footprint at a reference flow of 1 kg food product is a comprehensive point of departure which afterwards can be communicated in different ways to consumers.	Nutritional information varies among food products and therefore 1 kg food product can have very different nutritional content. This is not reflected in the carbon footprint when expressed per kg food product.	Consumers cannot compare the CF per nutritional value of products.	Research is on-going on developing a functional unit that reflects nutritional quality and needs of human beings. However, this is very challenging, and no scientific consensus has been reached.
2			Products with varying water content can lead to misleading results when using per unit mass as the functional unit. e.g., chicken with or without added water. However, this has partly been	The impact per kg dry matter is not directly visible. (But can be calculated based on the CF values	Adjusting the CF values and provide information to consumers based on a standard water content.

No.	Choice/decision	Justification	Limitation	Disadvantages in application	Development needs
			accounted for by following AGB A.2.1.4, where some functional units are corrected to standard water content (or sugar, protein) content	and the dry matter content of the product.)	
3	The life time of the product: "how long". This is not considered in the present guideline (does not include the storage in supermarket and use phase).	Having the system boundary from cradle to retail store will provide lower uncertainty and more reliable data, since food item can be stored/cooked/processed differently and the waste rate of using and transporting also vary significantly.	The duration of the product is not included in the present guideline.	Products with longer shelf time (e.g. due to additives) does not get benefits from this.	The life cycle stage could be expanded to consider the reduced food waste due to a longer shelf time. However, the fate of the products are very uncertain and this would imply more uncertainty and extra costs.
4	Focus on only carbon footprint and a reference flow of 1 kg food product		It might support intensive production systems compared to extensive production systems that might have higher yields and higher environmental impacts in other environmental impact categories.	Organic products might have a disadvantage when other impact categories are not included.	Providing the other environmental impact also aiming for a sustainability label.

3.1.2.2 System boundaries

No.		Choice/decision	Justification	Limitation	Disadvantages in application	Development needs
5		The system boundary is from the cradle to the retail store. However, the EoL is considered for packaging materials.	Consumers buy food products mainly from retail stores. Unlike other products, each food item could be cooked/processed differently and the waste rate of using and transporting also vary significantly. This would enhance the uncertainty of the CF values. Having the system boundary from cradle to retail store will provide lower uncertainty and more reliable data. Furthermore, the cultivation phase contributed the most when evaluating the CF of a food product from cradle to the grave.	The system boundary does not include storage in supermarket and use phase (preparation and cooking at home). However, end-of-life is included for packaging materials.	Carbon footprint of food products in the supermarket are not directly comparable since the degree of preparation can vary, e.g. dried beans compared to canned cooked beans.	The system boundary could be expanded to include use phase, e.g. 1 kg food ready to eat, but different food items can be cooked/processed differently and the waste rate of using and transporting also vary significantly.

3.1.3 Environmental impact categories

No.	Choice/decision	Justification	Limitation	Disadvantages in application	Development needs
6	Only climate change is included	The point of departure of this guideline was carbon footprint of food products. It is one of the most commonly assessed/addressed environmental impact categories and the modeling method of climate change is well-developed.	Ignoring other impacts like toxicity, biodiversity loss, eutrophication, water use and animal welfare can result in an incomplete understanding of the overall sustainability of a food product. Trade-offs between difference impacts can occur, where e.g. products with lower CF might have higher impacts on other impacts.	Consumers will not be informed about the other impacts of producing the food item. There is a risk that the climate optimization in the production system will happen using some measures that will introduce negative impacts in other impact categories.	Including more environmental impact categories in future labelling.

3.1.4 Limitations/assumptions

No limitations are examined here.

3.2 Life cycle inventory

3.2.1 Screening step

No limitations are examined here.

3.2.2 Life cycle stages

3.2.2.1 Raw material acquisition and pre-processing

No limitations are examined here.

3.2.2.2 Food production

No limitations are examined here.

3.2.2.3 Distribution

No limitations are examined here.

3.2.3 Nomenclature for the life cycle inventory

No limitations are examined here.

3.2.4 Modeling requirements

3.2.4.1 Agricultural production

3.2.4.1.1 Handling multi-functional processes

No limitations are examined here.

3.2.4.1.2 Crop type-specific and country, region, or climate-specific data

No.	Choice/decision	Justification	Limitation	Disadvantages in application	Development needs
7	Crop type-specific and country/region/climate-specific data for yield, water and land use, land use change, fertilizer (artificial and organic) amount (N, P amount), and pesticide	This is in line with the PEF guideline, which could reduce the data uncertainties.	It might lack data availability for generic products.	Difficulties in collecting the data for generic products.	Recommend some statistical databases that can be used for generic products.

No.	Choice/decision	Justification	Limitation	Disadvantages in application	Development needs
	amount (per active ingredient), per hectare per year, shall be used.				
8	Literature data or experts' opinions may be used if statistical data are not available.	This is in line with the Agribalyse methodology. Data availability is a challenge when doing LCA. Compared to stop calculating, using data with higher uncertainty is a better option as long as it is transparently done. The data quality will also be shown in the data quality assessment.	Uncertainties exist in the Literature data or experts' opinions.	Over- or underestimation of the results might occur.	Update the datasets of generic products when statistical data are available.

3.2.4.1.3 Averaging data

No limitations are examined here.

3.2.4.1.4 Direct emissions

No.	Choice/decision	Justification	Limitation	Disadvantages in application	Development needs
9	Emission factors are generally referred to IPCC 2019 methodology.	This is in line with the PEF guideline, which keeps the compatibility among the other studies.	Uncertainties exist in the emission factors in IPCC 2019.	Over- or underestimation of the results might occur.	

3.2.4.2 Electricity use

No limitations are examined here.

3.2.4.3 Transport and logistics

No.	Choice/decision	Justification	Limitation	Disadvantages in application	Development needs
10	For generic products, the modelling of transportation may refer to sections 3.5 and 3.6 of the Agribalyse methodology report for food products	This is in line with the Agribalyse methodology.	The default scenarios of transportation are based on the French situation.	The results might be biased.	Use Danish default scenarios when they are available.

3.2.4.4 Capital goods

No limitations are examined here.

3.2.4.5 Storage at distribution center or retail

No limitations are examined here.

3.2.4.6 Sampling procedure

No.	Choice/decision	Justification	Limitation	Disadvantages in application	Development needs
11	A sampling procedure may be applied to limit the data collection to only a representative sample of plants, farms, etc.	This is in line with the PEF guideline. It can improve the data representativeness.	It is challenging to classify the subpopulations.	The results might be uncertain due to the unreasonable classification of the subpopulations.	Developing some standard procedures in classifying subpopulations.

3.2.4.7 Modelling requirements for the use stage

No limitations are examined here.

3.2.4.8 Recycled content and end of life modeling

No limitations are examined here.

3.2.4.9 Extended product lifetime

No limitations are examined here.

3.2.4.10 GHG emissions and removals

3.2.4.10.1 Climate change-fossil

No limitations are examined here.

3.2.4.10.2 Climate change-biogenic

No limitations are examined here.

3.2.4.10.3 Climate change-land use and land use change

No.	Choice/decision	Justification	Limitation	Disadvantages in application	Development needs
12	Soil carbon sequestration is not included.	This is in line with the PEF guideline.	This aspect might demotivate the farmers to apply carbon sequestration practices.	Farmers who take carbon-sequestration practices (including grassland cultivation and biochar application) might stop using these practices, which could have negative impact on climate.	Include carbon sequestration.

3.2.4.11 Offsets

No limitations are examined here.

3.2.4.12 Food processing

3.2.4.12.1 Cross-cutting aspects

No limitations are examined here.

3.2.4.12.2 Raw material origin

No.	Choice/decision	Justification	Limitation	Disadvantages in application	Development needs
13	The data of detailed origin of each raw material by country shall not be lower than 70%.	This is in line with the Agribalyse methodology. If more origins are considered, the cost will be	The rest origins of the raw material might have significant CF, e.g., the raw material is produced in the deforested area.	The results might underestimate the total impact.	Be aware of the products that have a high possibility of being produced in

No.	Choice/decision	Justification	Limitation	Disadvantages in application	Development needs
		increased while the marginal benefit is decreasing. Besides, data availability is another issue.			deforested areas, e.g., coffee, cocoa, soybean, palm oil, etc.

3.2.4.12.3 Processing processes (food industry)

No limitations are examined here.

3.2.4.12.4 Recipes

No limitations are examined here.

3.2.4.12.5 Packaging

No limitations are examined here.

3.2.5 Handling multi-functional processes

3.2.5.1 Allocation in animal husbandry

No.	Choice/decision	Justification	Limitation	Disadvantages in application	Development needs
14	The prices used in the economic allocation shall be replaced with the Danish market prices (use the average values in the past 5 years)	This guideline is a national guideline that shall be based on the national price.	It is different from the requirements of the PEF guideline. The product prices are different between countries.	The results might be different if CFs of products from other countries with other price relations between co-products.	

3.2.5.2 Allocation in crop production

No limitations are examined here.

3.2.6 Data collection requirements and quality requirements

3.2.6.1 Generic product data

No.	Choice/decision	Justification	Limitation	Disadvantages in application	Development needs
15	A generic product shall be a virtual (non-existing) product that is calculated based on average Danish market sales-weighted characteristics (based on mass (a ton of material)) for all existing technologies/materials covered by the sub-category.	These are the products that can be found in the supermarket that the consumers can choose to buy.	Production systems or technologies update frequently, which also influences the market share.	The defined generic product might not represent the product in the following years.	The generic products shall be reviewed regularly.
16			If there is only one CF per product category (e.g. for pork) the same CF will be applied to imported and pork produced in Denmark. This might be misleading if there is a big difference in the CF of the imported versus the Danish pork		Take into account the possible differences between CF from imported or Danish products when choosing the product categories.

No.	Choice/decision	Justification	Limitation	Disadvantages in application	Development needs
17	Classification of products by activity (CPA) is recommended.	This product classification system is used by PEF guidelines and some PEFCRs. It is popular at the EU level, e.g., the EUROSTAT is based on this system.	It is a broad classification system that cannot classify products with special technologies. For example, CPA only included liquid milk, instead of skimmed, semi-skimmed, and whole milk, which are common on the Danish market.	By using CPA, subcategories need to be defined. However, it can be subjective. The representative product is highly dependent on the subcategories. The generic CF is also based on the representative product.	Experts need to be enquired to develop reliable representative subcategories.

3.2.6.2 Company-specific data

No.	Choice/decision	Justification	Limitation	Disadvantages in application	Development needs
18	For the CF calculation of a specific product from a company, the core processes (agricultural cultivation, animal husbandry, food process, etc.) shall be modeled with company-specific data.	It is in line with the PEF guideline.	Getting company-specific data can be challenging.	It is time-consuming and costly to collect company-based primary data.	

3.2.6.3 Secondary data

No limitations are examined here.

3.2.6.4 Datasets to be used

No.	Choice/decision	Justification	Limitation	Disadvantages in application	Development needs
19	The secondary datasets may be derived from EF, ILCD-EL or other ISO 14040 compliant datasets	It is in line with the Agribalyse methodology. Since the PEF study is still in the developing stage, there are not enough EF-compliant datasets to be used.	This is different from what is required in the PEF guideline.	The guideline is less comparable to the PEF guideline.	More EF-compliant datasets should be developed.

3.2.6.5 Cut-off

No limitations are examined here.

3.2.6.6 Data quality requirements

No.	Choice/decision	Justification	Limitation	Disadvantages in application	Development needs
20	Data quality requirements are following PEF.	In line with PEF to ensure the same requirements as for PEF studies.		Disadvantages suggested by AAU: "*Not possible to handle uncertainty stemming from low data quality.* *-The aggregation approach is not scientific:* *-To our knowledge no one has yet demonstrated how to apply the data quality requirements referred to here. It would probably require a tailormade software.* *Also, there are nothing in the guideline that describes how to deal with uncertainties."*	One alternative solution is to follow AGB. (AGB (agricultural phase) referred to Ecoinvent (Frischknecht et al, 2007) and ILCD Handbook. AGB (food products)'s data quality rating is in line with the PEF but adapted to their scope.) Another alternative solution suggested by AAU is to use the pedigree matrix approach for uncertainty instead, as it is used in the Ecoinvent database.

3.3 Carbon footprint impact assessment

No limitations are examined here.

3.4 Product carbon footprint reports

No limitations are examined here.

3.5 Verification and validation of carbon footprint studies, reports, and communication vehicles

No.	Choice/decision	Justification	Limitation	Disadvantages in application	Development needs
21	Verification and validation procedure are following PEF.	In line with PEF.	This requirement can be demanding and costly.	Disadvantages suggested by AAU: "*Validation is required to include coverage, precision, completeness, representativeness, consistency, reproducibility, sources, uncertainty, plausibility, quality, and accuracy of the LCA-based data, the correct conversion of measurement units, and quality and accuracy of additional environmental, technical, and supporting information, including parameters and datasets used to model the circular footprint formula. Company-specific data are required to be validated through a visit to the production site. For at least 80% (in number) of the most-relevant processes and for at least 30% (in number) of the remaining processes, the verifier(s) shall check that are*	An alternative solution suggested by AAU is to replace the current requirements with the ISO 14040/44 requirement on third-party critical review.

No.	Choice/decision	Justification	Limitation	Disadvantages in application	Development needs
				correctly identified and all related activity data and the datasets used to model these processes shall be validated, including their correct implementation in the software for at least 50%(in number) of the most-relevant processes and for at least 10% (in number) of the remaining processes. A validation report and validation statement are mandatory, and the latter shall always be provided as an annex to the PEF report. A validation report and validation statement shall refer to one specific PEF study only and is valid for a maximum of 3 years. If during these 3 years, the verifier(s) shall evaluate whether the results of one of the impact categories or the aggregated score have worsened by more than 10% or 5%, respectively, in which case the PEF study and report shall be updated. These validation requirements can at best be described as excessive. On the other hand, validation by mass balance, one of the most simple and	

No.	Choice/decision	Justification	Limitation	Disadvantages in application	Development needs
				solid validation procedures for system completeness, is made impossible by the required mixture of market-based substitutions and economic and physical allocation factors."	