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a systematic review

Pedersen, Emil; Remmen, Arne

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Challenges with Product Environmental Footprint – a systematic review

Emil Pedersen [a*], Arne Remmen [b]

[a*] *Corresponding author, email address: emilp@plan.aau.dk*
Department of Planning, Aalborg University, Rendsburggade 14 9000, Aalborg, Denmark

[b] *Department of Planning, Aalborg University, A.C. Meyers Vænge 12 2450 København SV, Denmark*

Abstract

Purpose: This paper aims to review the current literature on PEF to answer the following questions: 1) What methodological issues have been dominant in the discussion of PEF, and how do the suggested updates address them? 2) What are the challenges of using PEF in policies and how can these be resolved?

Method: The research questions were answered through a structured literature review of publications on the PEF method. The search was conducted in three databases: Scopus, ProQuest, and ScienceDirect using the search words: "Product Environmental Footprint," "Product Environmental Footprint Category Rules," and PEFCR.

Results and discussion: The methodological issues in the PEF method have caused ongoing discussions. Some of the identified issues have been addressed by a subsequent update of the PEF guidance, but there are still some open questions. These are: The defined functional units in the PEFCR are inadequate to ensure a fair comparison of products, impact categories for biodiversity and indirect land-use change are still being developed, secondary data is not available in an easy-to-use format, the existing and new PEFCR need to adopt a benchmarking method, uncertainty exists about how the costs of making an LCA study are affected by PEF, and it is unclear how the results of a PEF study should be communicated.

Conclusion: The PEF method could play an essential role in developing a market for green products, but it has met substantial critique from academia. Some of the issues identified in the critique are addressed by the updated PEF method, but there are still open questions that should be addressed to improve the PEF method.

Keywords: Product environmental footprint, PEF, Product Environmental Footprint Category Rules, PEFCR, LCA, Policy, Barriers

1 Introduction

As part of the European Commission's communication *Roadmap to a Resource Efficient Europe*, the Commission would establish *a common methodological approach* that would enable the Member States and the private sector *to assess, display and benchmark the environmental performance of products, companies, and services based on an assessment of the environmental impacts during its life cycle* (European Commission, 2011, p. 7). This initiative aimed to promote sustainable consumption and production by providing accurate information to help guide consumption decisions. Many methods and standards for assessing the environmental impacts already existed, but an analysis of the existing methodologies for environmental assessments concluded that these methods did not provide an adequate basis for comparative assertions (Chomkhamsri & Pelletier, 2011). The proliferation of methods for assessing environmental impacts made it too complicated and expensive for companies to make environmental claims about products. Therefore, the Commission argued that there was a need to provide a new solution built on existing methods by combining suitable approaches and further development (Galatola & Pant, 2014). This resulted in the development of the Product Environmental Footprint (PEF), a life cycle assessment (LCA) method to assess the environmental impacts of products.

In 2013, the Commission began the development and testing of the method during a pilot phase. Two hundred eighty organizations and approximately 3.000 stakeholders participated in the process (Partl et al., 2019). By April 2018, 20 Product Environmental Footprint Category Rules (PEFCR) had been developed, of which eight were within the food and agriculture industry. A PEFCR is a consistent and specific set of rules for calculating the relevant environmental information of products belonging to the product category in scope (Zampori & Pant, 2019). The primary objectives of PEFCR are to determine a consistent set of rules to calculate the environmental information of products within the same category and to enable comparisons and comparative assertions in all cases, where it is considered feasible, relevant, and appropriate (European Commission, 2017). Since 2018, PEF has been in a transition phase planned to run until the end of 2021. There are three aims of this period 1) monitoring the implementation of existing PEFCR, 2) develop new PEFCR 3) advancing methodological developments. There is no available description of how the implementation of existing PEFCR is conducted and progressing. A report called *Suggestions for updating the Product Environmental Footprint (PEF) method* (Zampori & Pant, 2019) was published during the transition phase. It contains changes to the PEF method that has already been implemented.

The European Green Deal is The European Union's new agenda for sustainable growth. As part of this agenda, the Circular Economy action plan has been presented, with PEF mentioned explicitly: *(…) the review of the Ecodesign Directive as well as further work on specific product groups under the Ecodesign framework or in the context of other instruments, will build, where appropriate, on criteria and rules established under the EU Ecolabel Regulation, the Product Environmental Footprint approach and the EU GPP criteria* (European Commission, 2020b, p. 4). As part of the Circular Economy Action Plan, the Commission also proposed that: *(…) companies substantiate their environmental claims using Product and Organization Environmental Footprint methods* (European Commission, 2020b, p. 5). The Commission will also *(…) test the integration of these methods in the EU Ecolabel* (European Commission, 2020b, p. 5). In the Farm to Fork Strategy, the Commission refers to a method for calculating environmental footprints: *(…) the Commission will promote schemes (including an EU Sustainable food Labelling framework) and lead the work on international sustainability standards and environmental footprint calculation methods in multilateral fora to promote a higher uptake of sustainability standards* (European Commission, 2020a, p. 18). It is unclear which method will be used in a coming EU Sustainable food labeling framework or which environmental footprint calculations the strategy refers to. PEF has previously been mentioned in the context of a new type of sustainability labeling where the European Commission tested different communication vehicles for providing environmental footprint information (Lupiáñez-Villanueva et al., 2018). From these plans three possible policy application areas for the use of PEF are identified. 1) The PEF method will be used for background studies in existing policies, e.g., the Ecodesign Directive. 2) The PEF method will be used for business-to-consumer communication and in the EU Ecolabel. 3) The PEF method will be used by companies that wish to make environmental claims for their products.

From the scientific community there has been some resistance and critique towards the PEF method during the development and testing of the method. The critique stems from disagreements on the method itself as it prescribes a way of making LCA that not everyone agree with. An overview of the subjects which has been discussed in academic literature is given in Table 1. The PEF method is a moving target as it is continuously updated with new guidelines which complicate the discussion of the method. The latest update of the PEF method was made available with the publication of the *Suggestions for updating the Product Environmental Footprint method* (Zampori & Pant, 2019). The aim of this paper is to identify the issues that are still relevant

and based on those result analyze what are the challenges of using the PEF method in the identified policy application areas and how those challenges can be solved. This paper answers the following research questions:

- What have been the methodological issues in the discussion of PEF, and how do the suggested updates address them?
- What are the challenges of using PEF in policies and how can these be resolved?

2 Method

The first research question is answered through an extensive literature review conducted on PEF. Literature review was chosen as the method in order to summarize the knowledge about PEF since it was initiated in 2012. The search was conducted as a systematic review as described by (Jesson et al., 2011). The screening of the literature began in August 2020 and ended in November 2020. The publications fitting the scope of this study were published in the period 2014 to 2020. The systematic search was undertaken in the databases ProQuest, ScienceDirect, and Scopus and was limited to articles in English. The search words were 'Product Environmental Footprint,' 'Product Environmental Footprint Category Rules,' and PEFCR, which were searched using a single search string: TITLE-ABS-KEY ("product environmental footprint" OR "product environmental footprint category rules" OR pefcr). The abbreviation PEF was excluded as a search word because this abbreviation is used in many other fields of research as well. The initial search identified 234 publications, and after the removal of duplicates, there were 140 publications. Each abstract was screened for any results, discussion, or conclusions addressing methodological issues of PEF or any challenges of using PEF. The final number of publications matching the scope of this paper was 68, covering the subjects shown in Table 1. Each subject is addressed in the result section. The second research question is answered through an analysis of the challenges for each of the three policy application areas. The challenges are identified by analyzing how the issues that are still relevant could affect the policy application area.

3 Results from the literature review

This chapter presents the systematic review results and identifies also the issues addressed by the newest version of the PEF guidance. The chapter is structured around the two research questions, which will be addressed in each section. Section 3.1 presents the methodological issues identified in the papers on PEF. Section 3.2 focuses

on the challenges of using PEF while conducting LCA studies. Section 3.3 give an overview of which issues are still open and which are solved with the updates to the PEF method.

3.1 The methodological issues of PEF

This first section focuses on highlighting the most relevant discussions regarding the methodology used in PEF. The *Suggestions for updating the Product Environmental Footprint method* (Zampori & Pant, 2019) has addressed some of the issues identified in the literature, and their continued relevance will therefore be discussed. The structure follows the PEF method beginning with the definition of scope and ending with benchmarking.

3.1.1 Definition of scope and functional unit

The functional unit (FU) is the quantified performance of a product system for use as a reference unit. In the PEF method, it is required that the FU is defined based on the four elements "what," "how much," "how well," and "how long" (Zampori & Pant, 2019). However, some of the FUs defined in the PEFCR do not address the requirements set in the PEF method on including performance and quality of products in the definition of the FU (Bach et al., 2018). Therefore, the FU is unsuitable for making meaningful comparisons, as the products' relevant performance and quality aspects are neglected as a parameter in the assessment (Lehmann et al., 2016). Without these aspects, it will not be possible to make a fair comparison of products. An example of a PEFCR that does not fulfil the requirements for the FU is the PEFCR for dry pasta. The FU of the PEFCR for dry pasta is *1 kg of dry pasta ready to be cooked at home or at restaurant*. This FU does not include any quality aspects as the only parameter included is the weight of the pasta. The main function of pasta is to make a person satiated and provide nutrients, and this should be reflected in the FU to allow for fair comparison. The FU could be: Prepared pasta (what) to keep one person (how much) satiated (how well) for four hours (how long). This is an essential critique of the developed PEFCR as one of the objectives of developing the PEF method was to compare products. However, not all the developed PEFCR has this problem. For example, the PEFCR for paint fulfills all criteria, as it answers the four questions: What? *"Provide decoration and protection of a substrate,"* how much? "*Coverage of 1 m² of substrate,"* how well? "*with a minimum 98% opacity,"* how long? *"for 50 years*" (Technical secretariat decorative paints, 2018). The issue seems most significant for the product categories where it is difficult to answer the four questions, e.g., in the PEFCR for food products. There are several functions of food products, e.g., satisfy hunger, taste, nutrition. In the example with pasta satiety was

used as the function, but there is not a consensus on the function of food products in LCA studies. In our view there is a need for further research on developing a method for assessing the function of food.

3.1.2 Data requirements

The PEF method requires that company-specific data is used for all known inputs and outputs from the processes, e.g., energy, water, land, products, co-products, or waste. Previously no cut-off criteria were allowed, which meant a considerable workload for gathering data related to processes with minimal influence on the results. With the updated PEF guidance, a cut-off is allowed on the processes that account for less than 3% of the total material and energy flow.

The need for reliability in a PEF study requires strict attention to data quality (Galatola & Pant, 2014). Therefore, the PEF method includes data quality requirements, which could contribute to the comparability and reliability of PEF studies (Ojala et al., 2016). However, too many requirements for primary data could become a barrier for using the PEF method, as access to primary data is limited for some product groups, e.g., packaging materials and chemicals (Golsteijn et al., 2018). Besides, book-keeping data is not directly usable as life cycle inventory data as it needs to be processed, transformed, or completed using literature data or calculation models (Six et al., 2017), which also makes the use of primary data costly (Russo et al., 2016). The costs of collecting primary data are mainly an issue for SMEs, and therefore the future use of PEF depends on the assurance that it will be as easy for SMEs as for larger companies to use PEF to make LCA (Russo et al., 2016). In our view, the development of PEFCR that specify which data should be collected and where the cut-off is could reduce the cost of collecting primary data.

In the PEF method, secondary data is allowed for processes outside the company's control. The problem with using secondary data is that there is uncertainty within the secondary data (Raffn et al., 2019). Using secondary data for background processes also risks decreasing the fair comparability of products as one product's potentially higher environmental impacts are omitted when secondary data is used (Bach et al., 2018; Corradini et al., 2019). This issue has been partly solved by the development of EF-compliant datasets and implementation of the Data Needs Matrix. However, the use of secondary data will reduce the resources required to make a PEF study, and it could also increase the reproducibility of studies (Lehmann et al., 2016). The limits set in the PEF method towards when secondary data is allowed should limit the drawbacks of using secondary data.

3.1.3 End-of-Life

When the PEF method was first published, the end-of-life method was based on an adapted version of the 50/50 method from the French environmental footprint (BPX 30-323). Half the benefit of recycling material is assigned to the company, which sends the material to recycling, and the other half is accounted to the company using the recycled material. The choice of this method met some critique. Firstly, the method neglects that some materials are recycled multiple times (Allacker et al., 2017; Hohenthal et al., 2019; Lehmann et al., 2016). Secondly, incineration was favored over reuse or recycling, as the benefit of incinerating a product at the end of life was set to 100%, while the benefit of recycling a product was only set at 50% (Lehmann et al., 2016). Thirdly, the method required more data than other end-of-life methods, as it requires a more considerable amount of material coefficients (Mengarelli et al., 2017). Fourthly, the practical application of the method was a challenge because of its many different variables and terms (Wade et al., 2018). Finally, the method implied that the consumption of recycled material and the production of recycled material had an environmental benefit (Schrijvers et al., 2016). Overall, the end-of-life method used in the first versions of PEF risked reducing fair comparability because it removed the flexibility from the modeling (Lehmann et al., 2016) and lead to misleading conclusions, as it did not take all the aspects mentioned above into account (Hohenthal et al., 2019).

During the PEF pilot phase, the end-of-life method was changed. In v.6.3 of the PEF method, the current end-of-life model was published. An end-of-life scenario shall now use the *Circular Footprint Formula*, a formula developed by the European Commission to assess the environmental impacts of the end-of-life scenario for a final product or intermediary products (Zampori & Pant, 2019). The formula includes the three aspects material recycling, energy recovery, and disposal. As this method for the end-of-life is relatively new, only two peer-reviewed papers published at this time have identified any challenges of using the new method. The papers conclude that the new method does not favor incineration over reuse and recycling anymore. However, some challenges are present. The number of cycles a material is reused is not accounted for (Bach et al., 2018). A material that is only recycled once gets the same "credit" as a material that goes through several cycles. The default data provided for the quality of recycled materials is not adequate to reflect the differences in quality for different materials (Bach et al., 2018). The new method also contradicts ISO 14044, as it only allows for 80% of the credits for recycling a material to go to the product system and not 100%, which is allowed in ISO 14044 (Bach et al., 2018). Another challenge is a lack of compatible databases, making the end-of-life model more time-consuming to use (Mirzaie et al., 2020). On the positive side, the allocation and quality parameters

increase the realism of the results on recycled content and end-of-life impacts as these parameters enable more realistic modeling of the end-of-life scenario.

3.1.4 Impact Assessment

Compared with other methods and standards, the PEF method differs by providing a specific set of impact assessment methods to be used. In the ISO 14044 standard, there are no requirements for which impact assessment methods to use (Lehmann et al., 2015). Some argue that because the ISO 14044 standard does not set a specific requirement for which impact categories to use, the results based on the ISO standard will be inconsistent. Comparative assertions cannot be made based on the results (Manfredi et al., 2015).

In a PEF study, 16 different impact categories shall be considered (Zampori & Pant, 2019). An identified challenge in the literature is that the impact assessment methods applied in PEF are used without proper precautions to the maturity level of the methods (Finkbeiner, 2014). The risk is that including the results from the impact categories with a high uncertainty can lead to misunderstandings (Six et al., 2017). When the PEF method aims to harmonize methods, selecting established methods could have been better than proposing new and unproven methods (Finkbeiner, 2014). The insufficient maturity level of some impact assessment methods is recognized in many of the PEFCR (Lehmann et al., 2016), and half of the impact categories are not considered to be adequate for decision support (Lehmann et al., 2015). The Commission acknowledges that some impact assessment methods could become outdated, but they will continue to be included in the PEF method until a better substitute is identified (Galatola & Pant, 2014). With the publication of the updated PEF guidance, an ongoing process of improving and updating the model is apparent for some impact categories. So far, the characterization model for water use, land use, resource use, particulate matter, human toxicity cancer, human toxicity non-cancer, and ecotoxicity freshwater has been updated. The characterization factors for ozone depletion and climate change have also been updated. Therefore, the issues with the impact assessment models seem to be less critical now than previously because of the continued work with improving the models. However, changing an impact assessment method will require a revision of the PEFCR because the impact categories, which have been identified as the most relevant in the PEFCR, might not be the same when using the updated version of an impact assessment method (Lehmann et al., 2016).

Another challenge with the impact assessment is that the included impact categories only reflect a portion of the environmental impacts of a product, and some impact categories like biodiversity are still not included in the assessment and should be considered qualitatively (Lehmann et al., 2015; Pyay et al., 2019). In the PEF guide (v. 6.3, 2018) it is also argued indirect land-use change shall not be included because the methods and data requirements for calculating indirect land-use change are not fully developed yet. In our view, the indirect land-use change have to be included in the assessment of bio-based products, because the inclusion of indirect land-use change gives an indication of a hotspot related to bio-based products and make the studies of bio-based products more accurate (Muñoz et al., 2014).

3.1.5 Weighting and normalization

Alongside the development of the PEF method, a set of normalization and weighting factors were developed. In other environmental policies and ISO type I labels, the weighting was hidden, which was not considered appropriate (Galatola & Pant, 2014). However, weighting is problematic as it is more a political issue than a scientific, and it should not be part of a scientific assessment method (Bach et al., 2018). Previously, a global consensus was that weighting should not be used to make publicly available comparative assertions (Finkbeiner, 2014). One challenge of the weighting is that identifying the most relevant impact categories for each PEFCR could lead to burden shifting. The reason is that the improvement of a product will be focused on the selected impacts at the expense of the other impact categories (Lehmann et al., 2016). Another challenge is that there is an implicit weighting of the different impact categories, when there is only one impact category for land use but three for eutrophication (Bach et al., 2018).

The normalization factors used in PEF is also a challenge. It assumes that if the emission is relatively low compared to, e.g. the global emissions, then that impact is less relevant, which is not always true (Bach et al., 2018). One publication also found that the normalization factors had an inconsistent geographical scope (Wade et al., 2018). These challenges indicate that the normalization method is not sufficiently mature, which reduces the reliability and comparability of PEF studies (Ojala et al., 2016). In the updated PEF guidance, default normalization factors are provided, and this will resolve the issue of an inconsistent geographical scope. However, it will not solve the assumption that a low emission relative to a global emission is less critical than a high emission relative to the global emissions.

3.1.6 Benchmarking

PEF recommends that each PEFCR develop a benchmark method that can be used to compare products. The benchmarking is based on a single score result given by the weighting and normalization methods. So far, only a few PEFCR have presented ideas for defining environmental performance classes (Lehmann et al., 2016). The lack of benchmarking could be explained by the insufficient guidelines for making a benchmark in the PEF method (Lehmann et al., 2016), but in the updated PEF guide, there is a suggestion for how to establish performance classes. Therefore, the PEFCR under development can be expected to include a benchmark method that companies can use.

A challenge of the benchmarking method is that the product lifetime is included since the consumers' behavior and practices are critical for the product's expected lifetime which make it difficult to include (Gül et al., 2015). In the authors view, it should however be possible to estimate the life time of a product based on an assumption about the average use pattern of the product type. Building the benchmarking on a hot spot analysis also risks ignoring minor critical impacts in the product's life cycle and ignoring impacts related to impact categories not included in the assessment (Gül et al., 2015). For those PEFCR where a benchmark has been developed, there is also a lack of supporting studies, which can confirm the benchmarks set in the PEFCR (Lehmann et al., 2016). Overall, the benchmarking contradicts the ISO standards, which states that life cycle impact assessment should not be used as the sole basis for comparative assertions (Lehmann et al., 2015).

3.2 Challenges of using the PEF method for conducting LCA-studies

In the publications on PEF, two main problems are identified for using the PEF method for making LCA on products: 1) the costs of making LCA in a company could increase if the PEF method becomes mandatory 2) the communication of the results of a PEF study is challenging.

3.2.1 The costs of making a PEF study

The cost of making an LCA is expected from the Commissions side to be reduced by approximately 30-50% compared to the situation before PEF (Galatola & Pant, 2014), while others predict that the costs will be doubled (Finkbeiner, 2014) or around 100.000€ (BDI, 2015). The expected cost increase comes from the requirements for data quality, regionalized inventory data, the verification scheme (Finkbeiner, 2014), and the numerous predefined impact assessment categories (Cimini & Moresi, 2018; Ojala et al., 2016). The requirements are extensive and

require a substantial effort from the companies involved in the assessment (Wade et al., 2018). Some requirements, like the data quality criteria, are also expected to have little real value due to its subjectivity as it is based on subjective quantifications of qualitative parameters (Six et al., 2017). Others argue that the many predefined requirements could decrease the costs of an LCA as only a few definitions and decisions then need to be made by the LCA practitioner (Galatola & Pant, 2014). These estimated costs of a PEF study were published early in the process of developing PEF. In our view there is a need for research on the actual costs of making a PEF study.

3.2.2 Communication of results

Consumers are positive towards green claims as they have a strong interest in knowing more about the environmental impacts of the products that they purchase (Iraldo, 2018). Using environmental labels for communicating environmental impacts is also considered positive by the consumers, especially when designed clearly and simply (Iraldo, 2018). However, some think that LCA for consumer communication risk confusing the consumers (Finkbeiner, 2014) and that a PEF label will only add to the already abundant collection of product labels (Lehmann et al., 2016). Meanwhile, a specific challenge is to communicate the results of all the impact categories to environmentally unconscious consumers (Cimini & Moresi, 2018).

Using PEF as a supportive method in developing eco-labels has also been investigated in some publications. Compared with PEF, the method used in the EU Ecolabel is more flexible as it includes non-quantifiable information and qualitative expert judgments in the criteria setting (Minkov et al., 2020). The EU Ecolabel sets restrictions and requirements to the product's performance, identify improvement potentials in the design of products, and advises the users on how to handle the product in the best possible way. At the same time, the PEF method only delivers information on the potential environmental impacts (Minkov et al., 2020). A discrepancy also exists between the processes identified as most relevant by the PEFCR and the EU Ecolabel (Minkov et al., 2020). Despite their differences, or maybe because of these, some publications recommend that the methods are used in combination (Minkov et al., 2020; Saotuer et al., 2018). The EU Ecolabel performance criteria could be used to determine the FU in a PEFCR (Minkov et al., 2020). The two different methods used in the EU Ecolabel and the PEF method for assessing the toxicity of a product complement each other by focusing on different parts of the product's life cycle. The method used in the EU Ecolabel answers how toxic the substances in the product are, while the method used by PEF provides a broader and long-term perspective on the toxicity (Saotuer et al., 2018).

Another way to communicate the environmental impacts of products is an Environmental Product Declaration that is applied in business-to-business relations. One of the ways LCA is used in companies today is by applying EPDs for assessing products' environmental impacts. Even though the EPD scheme and the PEF method have the same scope, several publications have highlighted that there are apparent differences in the way the two methods handle cut-off rules, goal and scope definition, life cycle inventory, life cycle impact assessment (both impact categories and characterization methods), data quality requirements, end-of-life allocation, allocation rules and interpretation of results (Del Borghi et al., 2019; Durão et al., 2020; Passer et al., 2015). Furthermore, due to the PEF method's current level of maturity, the absence of scientific agreement, and its European scope, PEF cannot serve as a solution for global harmonization of PCR development rules (Minkov et al., 2015).

3.3 PEF is a moving target

The PEF method is a moving target that has been developed continuously over the past 10 years. Some issues identified in this literature review are now addressed with the updated version of the PEF method. Other issues are still open for clarification and discussion. An overview of open and addressed issues is presented in Table 2.

4 Challenges regarding policy implementation

The second purpose of this article is to identify the challenges that the PEF method is facing in the transition from a development phase to being used by companies and governments across Europe. There are three possible policy application areas for using PEF. 1) as background studies for existing legislation, e.g. the Ecodesign Directive. 2) as for business-to-consumer communication and in the EU Ecolabel. 3) as used by companies to make environmental claims for their products.

1)

The PEF method can be used for background studies in existing policies to assess the environmental impact of products and the effect a policy proposal could have on the environmental impact, e.g., in the Ecodesign Directive. The challenge is that the PEF method only assesses the product's environmental impact while the existing method for the Ecodesign Directive also assess other aspects, e.g., product quality, social issues, and economic effects. These aspects would still need to be assessed using the existing method. Therefore, the added benefit of using the PEF method instead of the existing method is uncertain.

2)

For business-to-consumer communication, PEF faces several challenges. First, communicating PEF results to consumers will require that the results are presented in a straightforward format. The benchmarking results could be used for business-to-consumer communication, but that is still limited until the PEFCR contains a benchmarking method for all products. A second challenge is benchmarking products without adequately assessing the quality of the product (Gül et al., 2015). This could misguide the consumers to buy a product of inadequate quality if the product has a good environmental performance. Excluding these aspects means that it is impossible to choose the best product based solely on the PEF results, which creates a barrier for using PEF to make comparative assertions. A third challenge is that PEF is limited to environmental impacts. Allowing companies to make comparative assertions based solely on environmental parameters could create issues of neglecting other sustainability parameters such as social issues in the value chain or animal welfare for food products.

3)

Making PEF the required method for a company that wants to make a green claim also raises several challenges, including that it is only possible to make green claims for products where a PEFCR is available. Only few enterprises have in-house competencies for making a PEF study. Therefore, the costs of making a PEF study could become too high for SMEs, which could have the unintended consequence that small and medium-sized enterprises would not be able to make these claims. Another challenge is that there are some green claims where using the PEF method to substantiate the claims will not increase the credibility of the claim. A few examples can be listed: The amount of recycled material in a product, extended lifetime of a product, the possibility to repair and maintain a product. Finally, in some cases with greenwashing, companies use words that are too positive with consideration to the environmental impact of their product. This issue will not be solved by making PEF the required method to substantiate green claims, as the challenge also is to define when companies can use certain words to describe their products.

5 Recommendations to tackle the challenges to make PEF adaptable for policy

How the PEF method should tackle the challenges depend on the policy application area. However, a few general recommendations can be made regardless of the policy instrument.

If PEF is to be used for one or more of the analyzed policy application areas, the first recommendation is to develop more PEFCR as it will enable the use of the PEF method in more sectors. The Commission are working on this with five new PEFCR under development within packaging, flowers, apparel, synthetic turf, and marine fish. When identifying which product categories to develop new PEFCR on the focus should be on the most relevant products from a sustainability perspective, e.g., food products or construction materials. How narrow or wide the scope of the new PEFCR should depend on which products that the companies should be able to benchmark their products against and which products the consumers should be able to compare. If the objective is to encourage companies to make incremental improvements to their products to push the production of products in a more sustainable direction, then the scope of the developed PEFCR should be narrowed in on specific products, e.g. meat from beef, milk from cows, or t-shirts made from cotton. If the objective is to push consumers towards taking more sustainable choices then the scope of the new PEFCR should be wider so the scope includes all products that could fulfill the same function from a consumer point of view, e.g. foods with high protein content like meat, meat substitutes and beans, or dairy products and dairy substitutes, or t-shirts made from different raw materials. The PEFCR's with an inappropriate FU, should also be updated so their FU satisfy the requirements set in the PEF method. This will ensure that relevant quality and durability aspects of the product are included in the assessment. This will ensure fair comparability of products with the same function. The update should also ensure that the system boundaries in the PEFCR are clear. The recommendations for each policy application area are presented below.

1)

In the background studies for the EU Ecolabel and the Ecodesign Directive, the PEF method could be used for identifying the environmental hotspots for new product groups by using the identified hotspots in the PEFCR for identifying the most relevant processes and impact categories.

2)

When the PEF method is used for business-to-consumer communication, the communication should be based on a benchmark procedure that also include performance classes. An example where such a benchmark procedure is used is in the voluntary label scheme called *Made Green in Italy*, which is based on the PEF method (Masoni, 2017). In that scheme companies can communicate their performance for each of the relevant impact categories divided in three classes called A, B, and C. It enables consumers to compare products in a simple way based on PEF results. However, if PEF is to be used for business-to-consumer communication, then the PEF result should not stand alone to guide the choice of consumers. The PEF result should be supported by other parameters such as quality measure, nutrition value, social aspects, or animal welfare to ensure that the consumers have the relevant sustainability parameters presented to them.

3)

Reducing the costs of making a PEF study is especially important if the PEF method becomes mandatory to use for substantiating a green claim about a product or service, as small- and medium sized enterprises should be able to make the same claims about their products as large enterprises can. This can be ensured through a continued delivery of open access secondary data and by reducing the complexity of making a PEF study. In the continued development of the PEF method, it should be a priority and focus point to ensure that the modelling complexity does not become too high. Keeping the requirements for primary data at a minimum could also contribute to reducing the costs of making a PEF study.

Specifying what type of green claims the PEF method should be used to substantiate is necessary as the policy should avoid making it too costly and difficult to make green claims. Some of the green claims where substantiating the claim with the PEF method could increase the credibility could be those using the words CO_2-neutral, climate friendly, environmental friendly, and sustainable. A clear definition of when a company can use the words in their green claims should also be developed. This definition could include thresholds for each impact category in the PEF method that the product should stay within for the company to use a certain word in its claim.

6 Discussion

With this paper we have tried to create an overview of possible policy application scenarios for the PEF method and analyze challenges for each of these applications. The focus has been on issues identified in the academic literature. It limits the conclusions from this review to be exclusively from an academic point of view, which could be a limitation of this study as some of the most critical voices have communicated through other media, e.g., blog posts or letters of opinion. Much of the critique identified in the literature review in this paper come from one institute. The critique presented in this paper should therefore not be interpreted as the general viewpoint in the academic society. The critique is however still valuable.

7 Conclusion

With the European Commission as the facilitator, the PEF method results from an effort by stakeholders across corporations, academia, and public authorities to develop a standard ruleset for how LCA studies should be made for each product group covered by a PEFCR. The PEF method could play an essential role in developing a market for green products. With the aim of identifying which challenges PEF is facing and analyzing the challenges that PEF is facing as it moves closer to policy implementation a literature review of academic papers was conducted. The review made it clear that there still are some open issues that should be dealt with to make PEF more adaptable for policy implementation. If PEF should be used for background studies in existing policies or for business to consumer communication, it is a challenge that PEF only assess environmental impacts and do not include social aspects. A PEF study should therefore not stand alone but be supported by other type of information. Another challenge is that the quality of the products is not considered in some of the PEFCR. This aspect should be part of the FU that is defined in the PEFCR. A third challenge for PEF in business to consumer communication is that a framework for how to communicate the environmental impacts does not exist yet. The initiative called *Made Green in Italy* could be used as an inspiration for the development of a communication framework. If PEF become mandatory for substantiating green claims the first challenge is that the costs of making a PEF study could be too high for SMEs. Keeping the costs of making a PEF study low enough to ensure that it is possible for SMEs to make green claims should therefore be a focus in the continued development of PEF. Another challenge for using PEF to substantiate green claims is that there are some green claims where the use of PEF does not increase the credibility of the claim. PEF should therefore only be

mandatory to use for the claims where it adds credibility. There are most likely other challenges before PEF can be used in policies but a key takeaway point from this study is that there are different policy application areas for PEF, but for all of them there are still some challenges. These challenges are not unsolvable, but it will require further development of PEF before the authors of this paper will recommend it for policy implementation. A couple of areas for further research were also identified in the paper. The first is that there is a need for developing a FU for food products that enable a comparison of these products based on something else than their weight. Another area for further research is to make an analysis of the costs of making a PEF study.

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9 Tables

Table 1 Subjects derived from the literature.

	Subjects	Sources

The methodological issues of PEF	Definition of scope	(Bach et al., 2018; Corradini et al., 2019; Egas et al., 2019; Lehmann et al., 2016; Zampori & Pant, 2019)
	Data requirements	(Bach et al., 2018; Corradini et al., 2019; Galatola & Pant, 2014; Golsteijn et al., 2018; Lehmann et al., 2016; Ojala et al., 2016; Raffn et al., 2019; Six et al., 2017; Golsteijn & Vieira, 2019; Poolsawad et al., 2017; Russo et al., 2016; Wade et al., 2018)
	Co-product allocation	(Egas et al., 2019; Manfredi et al., 2015; Schrijvers et al., 2016)
	End-of-life	(Allacker et al., 2017; Bach et al., 2018; Hohenthal et al., 2019; Lehmann et al., 2016; Mengarelli et al., 2017; Mirzaie et al., 2020; Schrijvers et al., 2016; Wade et al., 2018)
	Impact assessment	(Bach et al., 2018; Del Borghi et al., 2020; Finkbeiner, 2014; Galatola & Pant, 2014; Lehmann et al., 2015; Lehmann et al., 2016; Manfredi et al., 2015; Pyay et al., 2019; Saouter et al., 2017; Six et al., 2017)
	Weighting and normalization	(Bach et al., 2018; Finkbeiner, 2014; Galatola & Pant, 2014; Lehmann et al., 2016; Ojala et al., 2016; Wade et al., 2018)
	Benchmarking	(Gül et al., 2015; Lehmann et al., 2015; Lehmann et al., 2016)
Challenges of using the PEF method for conducting LCA-studies	Cost of making a PEF study	(BDI, 2015; Cimini & Moresi, 2018; Finkbeiner, 2014; Galatola & Pant, 2014; Kuo & Lee, 2019; Manfredi et al., 2015; Ojala et al., 2016; Six et al., 2017; Wade et al., 2018)
	Communication	(Cimini & Moresi, 2018; Cristóbal et al., 2016; Del Borghi et al., 2020; Durão et al., 2020; Finkbeiner, 2014; Iraldo, 2018; Lansche et al., 2016; Lehmann et al., 2016; Minkov et al., 2015; Minkov et al., 2020; Passer et al., 2015; Russo et al., 2016; Saotuer et al., 2018; Walker & Rothman, 2020)

Table 2 Addressed and open issues with the PEF method.

Issue	Status
Functional unit	Still open: The issue continues until the FU is updated in all PEFCR containing an incomplete FU in relation to the "what", "how much", "how well", and "how long".
Data requirements	Addressed: Cut-off of processes that account for less than 3% of the material and energy flow has been introduced.
End-of-life model	Addressed: The Circular footprint formula, which includes the three aspects of material recycling, energy recovery, and disposal, has been developed.
Impact assessment models	Addressed: The characterization model has been updated for water use, land use, resource use, particulate matter, human toxicity cancer, human toxicity non-cancer, and ecotoxicity freshwater. The characterization factors have also been updated for ozone depletion and climate change.

Impact categories	Still open: Biodiversity and indirect land-use change are only included as "additional environmental information."
Normalization and weighting	Addressed to some degree: Default normalization factors have been introduced, but there are still underlying issues with the normalization method.
Benchmarking	Still open: The existing and new PEFCR need to adopt a benchmark method.
Costs of making a PEF study	Still open: Primary data collection is expected to be costly especially for SMEs.
Communication of PEF results	Addressed to some degree: There is a risk of misguiding consumers if PEF results are communicated without addressing the social and environmental impacts outside the PEF methods scope.
Availability of data	Still open: Primary data is expected to be costly to collect for especially SMEs.

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