Discussion paper

# The Role of the Product Environmental Footprints Classes of Performance in the Ecodesign for Sustainable Products Regulation

Nordic Environmental Footprint Group

---



**Nordic Environmental Footprint Group**
JULY 2023

---

# 1. Foreword

With the present paper, the NEF-group would like to contribute to a discussion on the role of the Product Environmental Footprint within the proposed Ecodesign for Sustainable Products Regulation with a specific focus on its ability to support the classes of performance and the circular aspects. This also includes a discussion of which circular aspects need additional assessment methods.

This discussion paper was outlined in the period from December 2022 until June 2023 and is financed by the Nordic Environmental Footprint Group under the Nordic Council of Ministers.

The discussion paper has been drafted by the authors Sofie Nygaard Rønnov Olesen, Anja Marie Bundgaard, and Arne Remmen, Department of Planning, Aalborg University.

The viewpoints expressed in the document are not necessarily shared by the members of the NEF Group. However, the authors would like to thank the NEF working group for their valuable insights and comments throughout the realization of the discussion paper.

The NEF Group hopes the discussion paper may contribute to a dialogue among European stakeholders.

# Contents

# 2. Summary

A well-functioning green market entails the presence of mechanisms that create a market pull after products with a good environmental performance combined with a regulatory push to ensure that the worst performing products are excluded from the market. The EU energy label in combination with the Ecodesign Directive has successfully managed to provide such mechanisms (energy labelling and minimum performance requirements).

In 2022, the European Commission introduced a proposal for establishing a framework for setting ecodesign requirements for sustainable products, which will repeal the Ecodesign Directive. The aim of the proposed Ecodesign for Sustainable Product Regulation (ESPR) is to improve the environmental sustainability of products and ensure the free movement of products on the European Market. Several means are combined such as minimum ecodesign requirements, information requirements, a digital product passport, a framework for green public procurement and a framework to prevent the destruction of unsold goods. The information requirements can if appropriate be accompanied with information on the performance of the product according to several product parameters established in annex I of the ESPR. Furthermore, when considered appropriate, this can be supplemented with classes of performance, and it is resembling the set-up with the Energy Labelling and the Ecodesign Directive.

Communication of product' environmental performance is a core element in striving for environmentally friendly products and promote the purchase of such products. Life cycle assessments are becoming increasingly used and this increases the complexity of the environmental information and indicates the need for a methodology and communication vehicle that can encompass this complexity in an appropriate manner. To establish a more standardised methodology to life cycle assessment and improve comparability of LCA results, the European Commission has developed the Product Environmental Footprint method. In annex I of the 2021 communication on the PEF method, an example of a method for establishing classes of performance for product in a five-level scale from A to E is presented.

The aim of this discussion paper is to examine how the PEF-method can support the classes of performance within the ESPR, and which circular aspects need additional assessment methods. This includes discussion of the opportunities for using the PEF method to establish classes of performance as well as the limitations that influence the relevance and applicability of the PEF method within the ESPR.

This paper concludes that the PEF method only to a limited extent provide the needed framework to support the classes of performance in the ESPR, and only if PEFCRs are in place for the product group under consideration. PEF is an environmental assessment method with a core focus on environmental emissions and resource consumption. The PEF method can therefore only cover the product parameters related to the environmental impacts of a product. However, the ESPR aims also at making ecodesign requirements to improve the environmental performance of products related to parameters that amongst other are core to circularity such as durability, reparability, and reusability. These product parameters are however either not covered or they are covered indirectly in the assessment, but not communicated or visible to the consumer. Therefore, the PEF method cannot stand alone as the methodological framework for the classes of performance in the ESPR.

The PEF method exemplifies a methodology for establishing classes of performance in a scale from A to E. The 16 impact categories of PEF are relevant for some product parameters in the ESPR, especially the parameters on environmental footprint and carbon footprint. The impact categories on particulate matter, ionizing radiation, photochemical ozone formation, acidification, eutrophication, and ecotoxicity freshwater can potentially provide part of the framework to support the product parameters on emissions to air, water, and soil. Finally, the PEF impact categories on resource use (minerals and metals), resource use (fossil), land use and water could potentially provide the framework for the product parameters on consumption of water, energy, and other resources. The PEF method's impact categories are expected to be extended to also cover other aspects, such as biodiversity.

However, differences exist between the classes of performance suggested in the ESPR and the performance classes suggested in the PEF method. The PEF method suggests the use of an aggregated single score using weighting factors based on all impact categories. Whereas the ESPR is more open to identify one or more relevant impact categories depending on the product in question.

The scale for the performance classes in the PEF method is established based on the theoretical best product, theoretical worst product, the representative product, and a score of a specific product. This will require a PEFCR and a PEF-study. A prerequisite for this is access to industry data to establish the scale. Another method for developing the scale could be to take outset in market data. Here, the ESPR could potentially play a role by setting information requirements on environmental performance data such as environmental footprint or selected impact categories collected in the digital product passport.

In this way, a method for a stepwise implementation could be:

1. Information requirements are set in delegated acts making the producers or importers obligated to provide information on the environmental performance of the product.
2. After data has been collected for a suitable period, an A-E scale can be developed based on the actual environmental performance data of the products.
3. Information requirements step into force in the delegated acts on labelling of the products in compliance with the classes of performance on an A-E scale.
4. Finally, minimum performance requirements step into force in the delegated acts phasing-out the worst performing products on the market based on the A-E scale.

One of the limitations of the PEF-based performance classes is that it entails normalisation and weighting of the results to reach an aggregated result. These types of results should be interpreted with caution as weighting inherently involves value choices depending on policy, culture and other preferences and comes with the risk of burden shifting. Consequently, the weighting factors used in the context of the ESPR should also be in line with the policy aim of the regulation.

Information on products environmental performance is complex, and studies show that consumers prefer single indicators in the communication of a product's performance to make it easier to understand. However, the use of weighting factors into aggregated results poses a challenge, as it influences the consumers ability to understand the relative performance across the broad range of product parameters introduced in the ESPR. In the duration of this project, it has not been possible to identify studies addressing the use of weighted results in environmental communication and consumers ability to understand and behave based on the information. There is a need for further studies within this field and especially on the use of the A-E scale in PEF, if this is intended to be applied within the ESPR.

The applicability of the A-E scale as a communication vehicle thus causes an imbalance between the need for simple environmental information to reduce the complexity as well as the need to provide consumers with concrete and meaningful information. This paper introduces two alternative types of communication vehicles targeting some of the concerns raised, I) Aggregated single score results with the A-E scale and the most relevant impact categories, and II) The most relevant impact categories each displayed using the A-E scale. Both options increase the complexity of the environmental information but increase transparency of the results and the second alternative leaves out weighting.

The paper conclude that the PEF method is insufficient in covering several product parameters in the ESPR that are core to a circular economy, these are: durability, reparability, maintenance, upgrade, reuse, repair, refurbishment, and remanufacture. This is a challenge as the ESPR is assigned a prominent role in the transition towards a circular economy, and this highlights the need for additional assessment methods, which partly has been developed in the French reparability and durability indexes.

Besides, several assessment methods exist on products performance related to circular strategies. This study emphasises the EN 4555X series of standards as well as the Joint Research Centre’s (JRC) scoring framework for repairability and upgradability of products. The EN 45552 on repairability of a product and the JRC scoring framework both provide a method for assessing the repair of products by introducing technical product related elements that should be assessed.

A major challenge in the future product regulation in the EU and in establishing the product performance classes is, how to balance between product impact categories on the one side, and the product properties such as durability and reparability on the other side.

# 3. Introduction

The market plays a vital role in the product-oriented initiatives launched by the European Commission to promote a circular economy and sustainability, such as the Circular Economy action plans from 2015 (European Commission, 2015a) and 2020 (European Commission, 2020a). The reasoning is that if the market rewards the products with the best environmental performance, then the manufacturers of environmentally poor performing products will be pressured out of the market. However, this requires well-functioning green markets. Again, the basis for a well-functioning green market is that the market stakeholders provide trustworthy information about the products environmental performance that is accessible and enables benchmarking.

Understanding all the environmental impacts of a product is a complex process, and it is not anticipated that the ordinary consumer can directly understand or apply the environmental information related to the environmental impact of a product. Most consumers today can resonate with the concept of climate footprints and the official eco-labels. However, it may be difficult to understand other types of environmental impacts classified through for instance lifecycle assessments. Consequently, there is a need to develop models to communicate the environmental performance of products.

The EU Energy Labelling Regulation in combination with the Ecodesign Directive has successfully introduced a benchmark model for energy-related products. The EU Energy Labelling Regulation outlines a performance scale in a simple communication form based on A-E labelling covering energy efficiency of the product during use along with other relevant performance features. Here, the consumers are provided with the necessary information to purchase the most energy efficient product on the market. The Ecodesign Directive then sets minimum requirements for the environmental performance (including energy efficiency) of the product to be allowed access to the European Market. This combination of cutting out the worst performing products from the market and informing the consumers about more energy-efficient products has shown to be a successful strategy. It is estimated that the Ecodesign Directive and the EU Energy Labelling Regulative will result in energy savings of approximately 230 million tonnes of oil equivalent (Mtoe) by 2030 (European Commission, 2023b).

In 2022, a proposal for a regulation on establishing a framework for setting ecodesign requirements for sustainable products (2022/0096 (COD)) was published (European Commission, 2022f). The intention is that the Ecodesign for Sustainable Product Regulation (referred to as the ESPR) shall repeal the Ecodesign Directive after a transition phase (European Commission, 2022f). The proposal for the ESPR also aims to build on the successful synergy between minimum performance requirements and information requirements that can drive the consumer towards more sustainable products (European Commission, 2022f). The information requirements should cover the product parameters specified in annex I of the regulation, covering parameters such as: durability, environmental footprint and waste generated to name a few. The ESPR further specifies that when appropriate the information can be provided in classes of performance possibly ranging from A to G (European Commission, 2022f).

The ESPR specifies that science-based assessment tools such as the EU's Product Environmental Footprint method should be considered when setting ecodesign requirements (European Commission, 2022f). Furthermore, the European Commission recommendation on the use of the environmental footprint method (EU COM 2021/2279) makes it possible to determine the environmental footprint from a product with or without a category rule (PEFCR). When a PEFCR is outlined for a given product category, it will include considerations on benchmarking, which can be used in comparisons in external communication. The PEF method also specifies a procedure for developing classes of performance in the A-E scale.

The purpose of this discussion paper is therefore to discuss how the PEF method can support the classes of performance suggested in the ESPR. The ESPR has a strong focus on material efficiency, but lifecycle assessment methods can have difficulties in modelling certain material efficiency aspects (durability, repair, refurbishment, and upgradability). Consequently, there might be a need for additional assessment methods to support the product parameters outlined in annex I of the ESPR. This discussion paper therefore strives to unfold the following research question:

- *How can the PEF-method support the classes of performance within the ESPR, and which circular aspects need additional assessment methods?*

Investigating this research question, this paper will emphasize and discuss the following:

1. How can PEF support the classes of performance?
2. What are the limitations and opportunities for unfolding the PEF-based performance classes?
3. How and which circular strategies are covered by the PEF-method and what implications does this have on the need for additional methods to support the circular aspects highlighted in the ESPR?

# 4. The two Policy Instruments

The two policy instruments covered by this discussion paper, the EU's Product Environmental Footprint method and the proposal for the Ecodesign for Sustainable Products Regulation, are introduced in this section. Furthermore, an introduction to the predecessor of the ESPR the Ecodesign Directive is provided along with its synergies to other policy instruments.

## 4.1. Introduction to the Product Environmental Footprint

The product Environmental Footprint (PEF) is a lifecycle assessment (LCA) based method for quantitative assessment (measuring and communication) of the potential lifecycle environmental impact from products. The general PEF method is complemented with product specific calculation rules, which enable comparison of environmental performance between similar products (European Commission, 2023d). One of the main ambitions behind the development of PEF was to provide a common methodology that reduces flexibility and subsequently increases the comparability between products within the same product group (Bach et al., 2018). Another objective of the PEF methodology was to ensure better understanding of consumer behaviour and better information on products environmental footprint, to avoid misleading claims and improve the ecolabelling schemes (European Commission, 2011). The PEF method provides less flexibility in the methodological choices compared to the ISO 14040/44, and the flexibility is further reduced for the product groups where Product Environmental Footprint Category Rules (PEFCRs) are developed (Bach et al., 2018).

PEFCRs are product specific life cycle-based rules and requirements that provide methodological guidance for PEF studies on specific product category level. The guidance can be found in the PEF methods Annex II (Part) A and covers both how to develop PEFCRs as well as how to perform PEF studies in compliance with existing PEFCRs (European Commission, 2021a). Development of a PEFCR starts with designation of a Technical Secretariat who develops a model for the representative product PEF-RP used in the first draft PEFCR, which is adjusted through a consultation process and panel review leading to the final draft PEFCR. PEFCRs outline the scope, product classification, description of RP and how it has been derived, functional unit, reference flow, system boundary, list of EF impact categories, additional information, and limitations. All PEF studies shall be conducted in compliance with a PEFCR, if a PEFCR is available.

PEF was initiated in 2008 by the European Council who invited the Commission to *"develop a common methodology on the quantitative assessment of environmental impacts of products, throughout their life cycle, in order to support the assessment and labelling of products"* (Council of the European Union, 2010, 4). The PEF method was developed from 2011 to 2013, which culminated when the European Commission published the first PEF recommendation *"on the use of common methods to measure and communicate the life cycle environmental performances of products and organizations"* (European Commission, 2013a) as well as the communication "*building the single market for green products"* (European Commission, 2013b).

The recommendation emphasizes PEFs usage to a broad range of societal actors as well as outline the method in annexes I and II. Annex I outline the intended application of PEF and its results, and these are summarized in the bullets below (European Commission, 2013a).

- Optimization of processes in a product life cycle
- Support designs that can minimize the environmental impact of products in a life cycle perspective
- Communication of the environmental performance of a product in a lifecycle perspective through voluntary schemes or individual companies
- Enable robustness and completeness of environmental claims
- Identification of the significant environmental impact when determining ecolabel criteria
- Provide incentive based on a life cycle performance

The PEF methodology was tested during the pilot phase from 2013 to 2018, which included different verification and communication approaches. Furthermore, PEFCRs were developed for 24 product categories (European Commission, 2021e). In the following transition phase, the implementation of the finalized PEFCRs was monitored and new PEFCRs are under development for product categories ranging from marine fish, apparel, cut flowers and potted plants, synthetic turf, and flexible packaging (European Commission, 2021f). As the transition phase was finalized in 2021, the PEF method has entered a new phase, in which its role in policy is to be defined.

On the 16th of December 2021, the European Commission published the second environmental footprint recommendation revising the first recommendation. The latest recommendation aims to incentivize manufacturing of more environmentally friendly products by helping companies calculate their environmental performance based on reliable, verifiable, and comparable information and to ensure access to such information for other relevant actors in society (European Commission, 2021b). Additionally, the second recommendation integrates new technical developments, regarding the PEFCRs, and updates on the application and use of PEF, specified through Annexes I and II (European Commission, 2021b). The latest recommendation further establishes three specific uses of the PEF methods in the context of different EU policies and legislations, namely the Taxonomy Regulation (European Commission, 2020c), the Sustainable Batteries Initiative (European Commission, 2020b) and the Green Consumption Pledge (European Commission, 2021g). The potential role of PEF in the proposed ESPR regulation, especially regarding the classes of performance introduced in Annex II, will be outlined in chapter 5, and discussed in chapter 6.

## 4.2. Ecodesign Legislation in European Context

Ecodesign legislation in a European context was introduced in 2005 with the adoption of the Ecodesign Directive, and in 2022 ecodesign legislation took a jump forward with the publication of the ESPR. The following section will provide a short introduction to the Ecodesign Directive and its synergies to the other product policies along with an introduction to the ESPR.

### 4.2.1. The Ecodesign Directive as a Steppingstone for the ESPR

The ESPR can be seen as a continuation of the work done under the Ecodesign Directive during the last 18 years. The aim of the Ecodesign Directive is to continuously improve the environmental performance of energy-using products from 2005 and then energy-related products with the 2008 revision. This is done by setting minimum performance and information requirements in product-specific implementing measures or in voluntary agreements.

The Ecodesign Directive takes a lifecycle perspective and strives to target those environmental aspects with a significant environmental impact or a significant environmental improvement potential. As energy-using products was targeted in the beginning this implied that most minimum performance requirements focused on energy consumption in the use stage. The background studies (the preparatory studies) also showed that the significant environmental impact was caused by the consumption of energy in the use phase. However, as the products became more energy efficient and combined with the transition towards a cleaner energy mix, the focus began to shift towards material efficiency requirements. This shift was also supported by the first circular economy action plan from 2015, which emphasised the

Ecodesign Directive as an important policy instrument to drive the circular transition. In 2019, several material efficiency requirements were adopted in either revised implementing measures or newly adopted implementing measures. These material efficiency requirements covered aspects such as: spare parts availability, reparability, upgradability, data deletion, design for recycling and hazardous substances. This represented a significant shift in the focus of the ecodesign directive from energy efficiency towards circularity (Bundgaard et al., 2017).

The Ecodesign Directive has not stood alone in the transformation of the market towards more environmentally friendlier products. It has worked in synergy with other European Policy mandatory and voluntary policy instruments such as the RoHS Directive, the EU Energy label, the EU Ecolabel, and the Green Public Procurement (see figure 1).

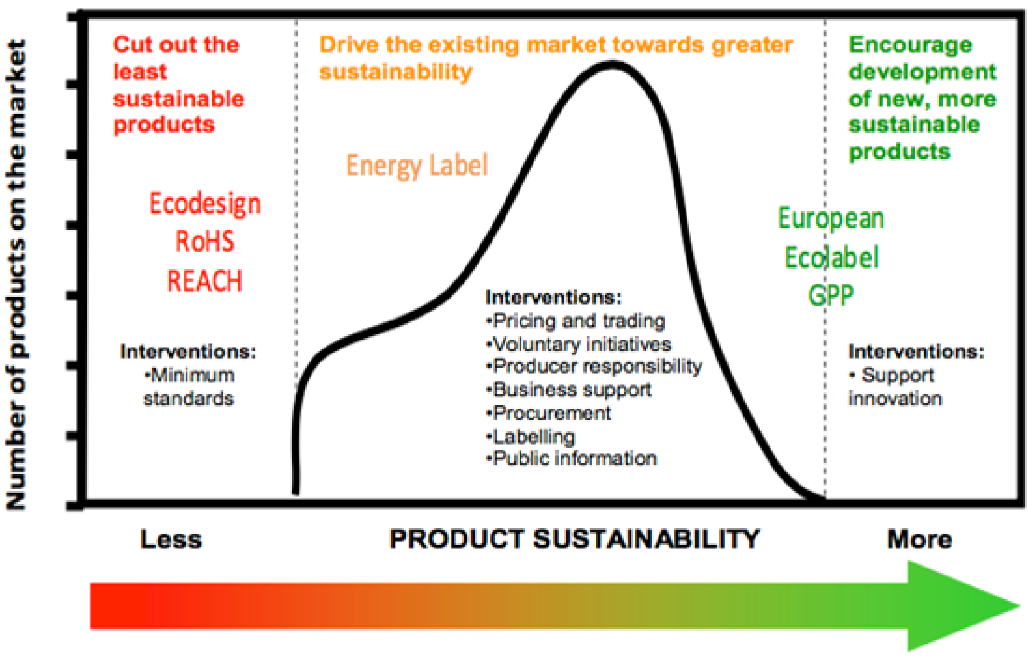


*Figure 1: The intended aim and scope of the different European Product-based Policy Instruments*

The intended synergies between the policy instruments are that the mandatory instruments, such as the minimum performance requirements in the Ecodesign Directive and the restriction of hazardous substances in the RoHS Directive, cut off the environmentally worst performing products from the European internal market. The EU Energy Label provides the consumers with the mandatory information about the product, which has driven the existing market towards more energy efficient products. Finally, the EU Ecolabels (and national ecolabels) and Green Public Procurement guidelines provide the consumers (both private and public) with information to select the environmentally friendlier products. Thereby, this combination of policy instruments has driven the European market towards cleaner products.

Especially, the synergies between minimum performance requirements in the Ecodesign Directive and information towards the consumers in the EU Energy Labelling has proven to be effective means to transform the market towards more environmentally friendlier products. Consequently, initiatives have been taken to improve the synergies between the two instruments such as alignment of the product group definitions as well as on the scopes and temporal aspects.

### 4.2.2. Introduction to the Ecodesign for Sustainable Products Regulation

The scope of the ESPR is to establish a framework which can improve the environmental sustainability of products and ensure the free movement of products on the internal European market by setting ecodesign requirements that products shall fulfil (European Commission, 2022f). Therefore, the scope of the ESPR is in line with the old Ecodesign Directive. The ESPR further specify which aspects the ecodesign requirements should cover such as (European Commission, 2022f):

- Product durability and reliability
- Product reusability
- Product upgradability, reparability, maintenance, and refurbishment
- The presence of substances of concern in products
- Product remanufacturing and recycling
- Products' carbon and environmental footprint
- Products expected generation of waste materials

The product specific ecodesign requirements are to be set in delegated acts (European Commission, 2022f). In addition to the ecodesign requirements, the ESPR also establish a digital product passport, provides the framework for setting mandatory green public procurements criteria and creates a framework to prevent the destruction of unsold consumer products (European Commission, 2022f).

The ESPR extends the product scope compared to the Ecodesign Directive, as it covers all products except for food, feed, medicinal products, veterinary medicinal products, living plants, animals and micro-organisms and products of human origin (European Commission, 2022f).

The ecodesign requirements should cover both performance requirements as established in Article 6 and information requirements as established in Article 7 (European Commission, 2022f). The performance requirements should take outset in the aspects listed in Annex I of the ESPR (European Commission, 2022f). The performance requirements should when relevant include minimum or maximum levels or non-quantitative requirements in relation to the specified aspects. Finally, the performance requirements can also cover requirements to the functional performance of the product (European Commission, 2022f)

The information covers as a minimum the information requirements set out in the product passport and the information requirements in relation to substances of concerns (European Commission, 2022f). These minimum information requirements can if appropriate be accompanied with information on the performance of the product in relation to the parameters listed in annex I of the ESPR (European Commission, 2022f). The proposed regulation further specifies that when establishing information on the performance of the product, classes of performance shall be determined when appropriate (European Commission, 2022f).

The classes of performance shall correspond to the statistically signification improvement in the performance levels (European Commission, 2022f). Information on handling the product in the use phase to ensure optimum durability and the handling of the product to ensure proper end-of-life treatment shall be included in the information requirements when appropriate (European Commission, 2022f). Further specification on the intended use of classes of performance outlined by the ESPR will be discussed in chapter 5.
Thereby, the ESPR is a combination of several policy means which potentially can help transform the market towards more environmentally friendlier products as illustrated in figure 2. The minimum performance requirements can help cut out the worst performing products from the market.

The information requirements potentially in the format of classes of performance and the digital product passport can provide information on the environmental performance of the products and thereby drive the market towards more environmentally friendlier products. Finally, the Green Public Procurement framework can encourage the development of new more environmentally friendlier products. This idea of embedding the different policy means in the same regulation is also in line with the idea of the integrated Product Policy introduced by the European Commission in 2003. However, the realisation and effect of these potential synergies will depend on the development of the product-specific delegated acts.

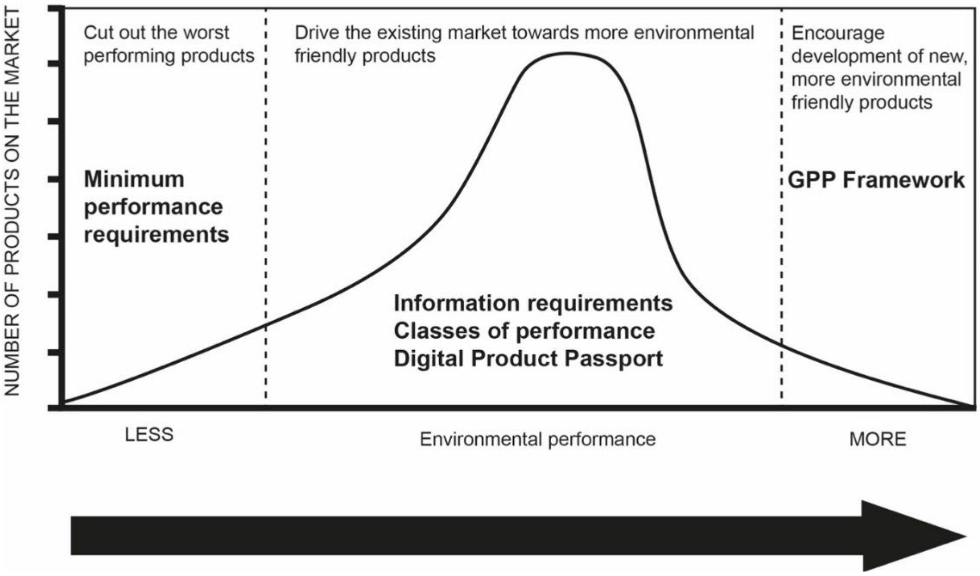


*Figure 2: Potential synergies between the policy means introduced in the ESPR*

# 5. Opportunities for using the PEF-based classes of performance in the ESPR

The first recommendation on the use of PEF from 2013 did not consider the Ecodesign Directive as a possible application of the PEF method or its results (see bullets in section 4.1). Still, elements from the PEF method are under implementation in the 2020 revision of the Methodology for Ecodesign of Energy-Related Products (MEErP) such as a simplified version of the Circular Footprint Formular, the 16 impact categories and the EF datasets from PEF (Bundgaard et al., 2022; Caldas et al., 2021). Furthermore, specific reference is made to the PEF method in the ESPR.

This section aims to outline the opportunities for using the PEF method in the ESPR by presenting PEF results as seen in Annex II of the PEF method, including both benchmark (A.5.1) and classes of performance (A.5.2), compared to the role of performance classes in the ESPR.

## 5.1. Classes of performance in PEF

The PEF method establishes that identification of classes of performance is optional, and the technical secretariats can define a method for identifying classes of performance as they find relevant (European Commission, 2021a). However, a method for establishing performance classes is exemplified in A.5.2 in annex 1, in the form of five-levels (European Commission, 2021a). Thus, it is emphasised in the PEF method that the procedure described is only an example of how the scale could be established (European Commission, 2021a). The classes of performance in PEF range from category A as the best in class with lowest environmental impact to category E which subsequently represents the worst class for products with the highest environmental impact (European Commission, 2021a).

The classes of performance in the PEF method can be seen as one type of communication vehicle for PEF results and is referred to as a five-level benchmark A-E (Nordic Environmental Footprint Group, 2018). Different reports have been published throughout the years comparing and testing different communication vehicles for the environmental footprints of products. The reports provide valuable insights into the effect and implications of applying the A-E scale compared to other alternatives and other established types of communications like the Nordic Swan Label, this is unfolded in section 5.4.

The classes of performance in PEF are identified through a single overall score, which is the sum of the weighted environmental footprint results of all 16 impact categories (European Commission, 2021a). The PEF method establishes the limits between the classes of performance by the indexation as presented in table 1.

| Category | Class of performance boundaries |
|---|---|
| A | OS < BP + (BM-BP) * 0.30 |
| B | BP + (BM-BP) * 0.30 ≤ OS < BP + (BM-BP) * 0.85 |
| C | BP + (BM-BP) * 0.85 ≤ OS < WP + (BM-WP) * 0.85 |
| D | WP + (BM-WP) * 0.85 ≤ OS < WP + (BM-WP) * 0.30 |
| E | OS ≥ WP + (BM-WP) * 0.30 |

*Table 1 Overview limits of the performance classes exemplified in the PEF method* (European Commission, 2021a)

- **BP:** the single overall score of the best product

- **WP:** the single overall score of the worst product
- **BM:** the single score of the Representative Product (benchmark value),
- **OS:** a single overall score of a specific product calculated in a PEF study in compliance with a PEFCR (European Commission, 2021a).

The limits of the five-level A-E scale is defined in relation to single scores and rely on identification of the midpoint of class C and the two extremes of class A and E. Once these are identified the limits of the other classes are identified according to table 1 (European Commission, 2021a). The single overall score of the representative product (BM) outlines the midpoint of class C and is calculated using the second PEF Representative Product (PEF-RP) (European Commission, 2021a). The upper and lower limits of the category A and category E are identified using a sensitivity analysis on the model of the PEF-RP, in cases where there are more than one PEF-RP then an analysis is performed on all PEF-RPs (European Commission, 2021a). A prerequisite for doing the sensitivity analysis is that the industry data provided by the technical secretariat members, and once the parameters can be identified, then the theoretical best product and theoretical worst product can be found by assigning either the best technically feasible value or the worst technically value for the parameters (European Commission, 2021a). This thus defines the upper limit of category A (OS-BP) and the lower limit of category E (OS-WP) (European Commission, 2021a).

The PEF method summaries the PEF classes of performance in a visual representation as the one shown in figure 3:

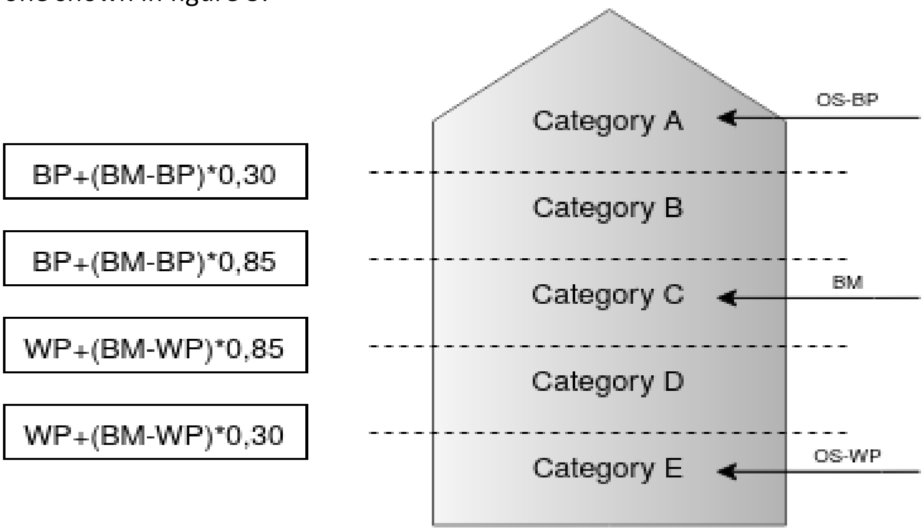


*Figure 3 Visual representation of how to establish the limits of the PEF classes of performance. Adapted from Annex II, Figure M-3* (European Commission, 2021a: 143)

## 5.2. Performance Classes In the ESPR

As a starting point on how the PEF performance classes could play a role in the ESPR, the definitions and terminology applied in the proposed ESPR is interesting: Article 2 includes a definition of PEF and defines environmental footprint as *“a quantification of a product environmental impacts, whether in relation to a single environmental impact category or an aggregated set of impact categories based on the Product Environmental Footprint method”* (European Commission, 2022f, article 2). From this definition, for determining a product's environmental footprint, the PEF method is seen as the main reference. The ESPR defines ‘class of performance’ as *“a range of performance levels in relation to one or more product* *parameters referred to in Annex I, ordered into successive steps to allow for product differentiation"* (European Commission, 2022f, 44).

The product parameters presented in Annex I are listed in table 3. The ESPR further emphasis in Article 14, that the layout and the layouts content, including classes of performance, must be specified in the delegated acts (European Commission, 2022f). Furthermore, it is specified that for energy-related products the energy label is the primary instrument for giving information to the consumers and that classes of performance should be incorporated into the EU Energy Label as supplementary information when appropriate (European Commission, 2022f). Indicating that at least for energy-related products the classes of performance could resemble the energy labelling scale. Thus, it will be based on a product group to product group evaluation as defined in the delegated acts.

## 5.3. The use of PEF performance classes in the ESPR

The PEF method does not provide a general definition of how classes of performance should be understood. Nonetheless, PEF still provides an example of a five-level A-E scale, as introduced above, which could be used on a product specific level. This A-E scale suggested in PEF correlates with the definition and the intention of classes of performance in the ESPR as it presents a range of performance levels ordered in successive steps ranging from best class (category A) and to worst class (category E). This thus outline both a performance range and logical order which resonate with consumers due to the similarities to the EU Energy Labelling. A detailed discussion on the use of the A-E scale as a communication vehicle is unfolded later in this chapter. The PEF method is based on 16 impact categories and their ability to cover the product parameters in Annex I, especially in terms of the notion of "one or more product parameters" in the ESPR definition of class of performance will be discussed in chapter 6.

An important aspect to highlight is, that the ESPR does not entail binding requirements on the establishment and use of classes of performance, but rather state that classes of performance shall be defined *"as appropriate"* (European Commission, 2022f article 7), which influence the extent to which it is possible to be certain of the future role of classes of performances in ESPR.

In the Impact Assessment accompanying the proposal ESPR (SWD(2022) 82 final) PART 1/4 establishing classes of performance is suggested as a measure under two different options for how to ensure better access to sustainability information along the value chain. The two options are *"sustainability information to consumers"* and B2B and to *"reward more sustainable products through incentives"* and both are included in the preferred combination of policy options throughout the impact assessment documents (European Commission, 2022b). The Impact Assessment accompanying the proposal ESPR (SWD(2022) 82 final) PART 2/4 presents results from an open public consultation. These results indicate that various stakeholders support and acknowledge the need for classes of performance. The EU citizens and consumer organisations strongly support the options on enhanced incentives measures as 75 % indicated support or strong support for identifying classes of product performance. Furthermore, 53 % of business associations and companies and 83 % of EU public authorities supported or strongly supported the idea of identifying classes of performance (European Commission, 2022c).

Article 14 in the ESPR on Labels, further specifies that when information requirements include a label for the class of performance of a product according to Article 7(4), then the layout of the label shall make it easy for consumers to compare product performance in relation to the relevant product parameter and thus choose the better performing product (European Commission, 2022f). Here, it is further seen that for energy-related products where information on a relevant product parameter cannot be included into the energy label, then it will be possible for the commission to require development of a label in accordance with the ESPR regulation (European Commission, 2022f).

The ESPR proposal is broad by intention. This entails, that the ESPR does not specify the requirements in much detail, as these are to be defined in the delegated acts adopted according to Article 4 (European Commission, 2022f). In the ESPR, it is emphasized, that the delegated acts can determine classes of performance for one or more relevant product parameters, as part of the information requirements, to enable comparison of products based on the corresponding product parameters to drive the market towards more sustainable products (European Commission, 2022f).

The Impact Assessment of the proposal ESPR (SWD(2022) 82 final) PART 4/4 exemplifies the impact and implication for the different SPI related policy options based on a case study on the product group *jeans*. An interesting finding is that a prerequisite for doing the case study have been the assumption that a PEFCR is available used in combination with other tools and sources of information (European Commission, 2022d, p. 483). THE PEFCR hotspot analysis is highlighted as a means for identifying environmental criteria and a PEF study is suggested for the requirement on minimising the environmental footprint of a product. The case study quite interestingly further state, that PEFCRs allows for establishing classes of performance on sustainability based on the 16 PEF impact categories either as a total score or based on one of the impact categories. Three different alternatives are presented on how to potentially establish environmental footprint classes of performance of a product, these are (European Commission, 2022d):

- Classes of performance on total environmental impact of a product (scale in points)
- Classes of performance on one impact category e.g., climate change (scale in kg $CO_2$-eq)
- Classes of performance on specific processes e.g., water use (scale in $m^3$)

Classes of performance can enable differentiation of products based on their relative sustainability and of relevance both to consumers and public authorities. The classes of performance in PEF can have some methodological relevance in the ESPR. As illustrated above the impact assessment of the proposal of the ESPR (SWD(2022) 82 final) PART 4/4 introduce PEF as a methodology for establishing a scale for environmental footprint classes of performance. The case study further exemplifies circularity requirements for durability and recyclability highlighting different test methods and information requirements on a visible label, however, with far less detail than the EF requirements (European Commission, 2022e, pp. 485–486). Thus, uncertainty remain about the circularity requirements in the ESPR on durability, reliability, repair etc. are to be documented and communicated using classes of performance.

## 5.4. Choosing communication vehicle – benefits and barriers of the A-E scale

The development and testing of different communication vehicles for PEF have been an iterative process based on support and feedback during the pilot phase from various stakeholders and involvement of the public to do actual testing on possible communication vehicles. This process and the benefits and barriers of the A-E scale are relevant to understand when discussing its potential relevance in the ESPR.

The European Commission published in 2016 "*Background Document for testing of Communication Vehicles in the Environmental Footprint Pilot Phase 2013-2016"* in which some general principles are laid down to specify what the test on communication vehicles needed to consider, including an annex listing some of the communication vehicle that could be tested (European Commission, 2016).

In the final report *Assessment of different communication vehicles for providing Environmental Footprint Information* by the European Commission, it was concluded that the A-E scale PEF label is the most effective type of communication vehicle for PEF results using an average product score (Lupiáñez-Villanueva et al., 2018). The report draws on studies on both consumers and B2B preferences supporting the use of an A-E scale. Additionally, communication tests with consumers showed that the impact categories of PEF are too complex to understand and that there is a need to translate this complex information into simple information. The consumers prefer graphics, bars and scales and the report concluded that the label should be supported by QR codes, bar codes, links, and websites etc., where further information can be displayed for those interested (Lupiáñez-Villanueva et al., 2018).

It is important to understand how the communication vehicle acts as a choice architecture, that ultimately influences whether a green purchase decision is made by the consumer or company (Nordic Environmental Footprint Group, 2018). The PEF label communication (scoring system for A-E scale and benchmark) is understood as one type of choice architecture. Other eco-labels use other choice architectures, e.g., the Nordic Swan and EU Ecolabel provide the consumer with the possibility to take an easy and fast choice based on the presence or absence of a label. Contrarily, the EU Energy label provides more information to the consumer and involves choosing a specific preference between the levels A-E (Nordic Environmental Footprint Group, 2018), as also suggested in the PEF method.

When talking about how to communicate the environmental performance of products using the PEF method, it is relevant how other policy areas are considering the potential synergies with the PEF method. The report *Product Environmental Information and Product Policies – How Product Environmental Footprint (PEF) changes the situation?* from 2019 examines how PEF and Type 1 eco-labels, especially the Nordic Swan can benefit from each other (Nissinen et al., 2019). The report concludes, amongst others, that it is crucial to obtain a synergy between the PEF communication and type 1 eco-labels in terms of the message they disclose to the consumer regarding what the "greenest product" is, and it advocates for further examination of how such an alignment can be obtained. This is supported in another report, which further specifies that the product categories between PEF and the Nordic Swan differs, making it difficult to compare across the two schemes and causing different results in terms of the best product (Suikkanen et al., 2019). Another study recommends using PEF and the EU Ecolabel in combination as well (Minkov et al., 2020).

The potential benefits of using the A-E scale in the ESPR is its resemblance to the EU energy label scale and that it communicates clearly in terms of the PEF results. However, a potential barrier is related to its choice architecture properties as it enables consumer interpretation of the scale, where the consumer can assign value to a score from A to E based on their subjective understanding. Another weakness is that the consumers might be satisfied with the average levels, which will hinder one of the expected benefits of the PEF communication, namely a *"pull from the market"* as well as a *"push at the back"* for the worst performing products (Nordic Environmental Footprint Group, 2018). Contrarily, the A-E scale does enable differentiation between the products compared to "*best in class*" used in other ecolabels like the Nordic Swan, the EU ecolabel, and the Blue Angel (Nordic Environmental Footprint Group, 2018).

To summarize this section, the A-E scale has some benefits in terms of communication of results, which supports the role of PEF in the ESPR. However, several major risks emerge when communicating such complex product parameters as those outlined in the ESPR. These risks relate to the consumers perception and behaviour as weighting and aggregation of results causes a low transparency. This is elaborated in chapter 7.

## 5.5. Establishing the Representative Product

When examining the opportunities of unfolding the PEF method in the ESPR in terms of defining a scale for the classes of performance, it becomes evident that a prerequisite is information feedback from the industry, allowing the worst- and best performing product as well as the representative product (RP) to be defined. It is therefore relevant to see how benchmarking can be done within the scope of the ESPR including considerations as to how the representative product can be identified, taking point of departure in the PEF methodology. Consideration will also be given to how the MEErP similarly puts up a framework for benchmarking based on the concept "base case(s)", which to some extent corresponds to the RP used in the PEF method.

In the PEF method Annex II, it is stated, that a benchmark should be provided in a PEFCR for each RP and correspond to the PEF profile of the second PEF-RP modelled in the PEF study (European Commission, 2021a). The results of the benchmark must be provided for each RP in both characterized, normalized, and weighted results for all EF impact categories and as a single overall score based on a set of weighting factors. It further specifies that results should cover I) the total life cycle, and II) the total life cycle excluding the use stage (European Commission, 2021a). The Technical Secretariat develops a "model" for the representative product in relation to the product category within the scope of the PEFCR (European Commission, 2021a). When establishing the RP, the data used shall match realistic market averages and be recent (European Commission, 2021a). Moreover, the RPs must reflect the current situation at the time the PEFCR is developed, thus future scenarios for technologies, transport etc. are to be excluded (European Commission, 2021a).

The definition of the RP in the PEF method states that the RP can be a real or a virtual (non-existing) product, especially if the market is made up of different technologies (European Commission, 2021a). The virtual product should be calculated using the average European market sales-weighted characteristics for all existing technologies/materials related to a product category or sub-category (European Commission, 2021a). However, the PEF method also allows for other weighting sets to be used if justifiable, an example being the weighted average of mass (ton of material) (European Commission, 2021a).

Determining the RP is part of the process of developing the PEFCRs. First, the RP is defined by the technical secretariat, and then the first PEF study on the representative product is performed, here no cut-offs are allowed on processes, emissions to the environment or the resources from the environment. All stages and processes should be covered. The output of this study is a PEF-RP report. Then based on information from consultations and supporting studies, a second PEF-RP is modelled, as the PEF study on a RP is an iterative process. The second PEF-RP study shall, amongst others, identify the values for the benchmark (European Commission, 2021a). The environmental performance of an RP represents the benchmark. The RP can thus be seen as a reference point. Benchmarking against an RP cannot be done without a PEFCR. For each RP at least three PEF supporting studies shall be carried out (European Commission, 2021d).

In 2023, there are not yet developed a method for defining a representative product in the proposal for the ESPR. However, it is stated in annex II of the ESPR that: *product or products in question on the market and identify the technical options for improving the product performance"* (European Commission, 2022c, 3). More specifically, the technical, environmental, and economic analysis shall pick several representative models of products on the market and identify potential improvements (European Commission, 2022a).

The Ecodesign Directive identify in MEErP, like the PEF method, a benchmark called the base case. The base case is identified in task 4 of the MEErP along with an analysis of the technologies and then an environmental and economic analysis is made in task 5 and 6 (Kemna, 2011). In the following, we will investigate how the base case is defined within the framework of the Ecodesign Directive.

In MEErP, the notion base case is used to similarly define the average EU product. In MEErP, the base case(s) are defined as: *"The Base Case may or may not be a real product that one can buy on the market. Especially when the market is made up of different technologies, the Base Case will be a virtual (non-existing) product with the average sales-weighted characteristics of all technologies around"* (Kemna, 2011, 17).

The definitions of RP and base case indicate that they are methodological compatible and serve the same function in terms of how they determine the respective point of reference for benchmark. Nonetheless, to better understand how they are both applied in practice an example is included to compare the base cases used in the MEErP for Photovoltaic (PV) Modules and the finalized PEFCR for PV Modules, see table 2.

| **PEFCR for Photovoltaic Modules (PEFCR pages 18-22)** | |
|---|---|
| Product categories:<br><br>The product analysed is a "photovoltaic module" used as a general term for panels (framed modules) and laminates (unframed modules).<br>Mounting is part of the product. Inverters and the AC cabling is not part of the product analysed. | Representative products:<br><br>The average photovoltaic module is a virtual product. The PEFCR include five subcategories covering the following technologies:<br><br>- Cadmium-Telluride photovoltaic modules (CdTe)<br>- Copper-Indium-Gallium-Selenide photovoltaic modules (CIS / CIGS)<br>- Micromorphous Silicon photovoltaic modules (micro-Si)<br>- Multicrystalline Silicon photovoltaic modules (multi-Si)<br>- Monocrystalline Silicon photovoltaic modules (mono-Si)<br><br>The rated power of the module should not be lower than 100 Watt and the size not below 0.5 $m^2$. The RP specifies the technology mix (using global production volumes of PV technologies) and the bill of material (listed per square meter of module and relative to total mass of input material for unframed laminate. It is based on weight of materials from LCI of different technologies). |
| **MEErP for Photovoltaic Modules (PS for PV pages 269-325)** | |
| Product categories:<br><br>The product categories are defined in task 5 as three base cases:<br>**BS1:** Residential multi crystalline Si BSF<br>**BS2**: Commercial multi crystalline Si BSF<br>**BS3**: Utility scale multi crystalline Si BSF<br>Both mounting and inverters are part of the products analysed. | Base cases:<br><br>The three base cases are further specified by:<br>**BS1:** Residential multi crystalline Si BSF - Multi crystalline Si Cell, String Inverter 2500 W, Roof Mounting<br>**BS2:** Commercial multi crystalline Si BSF - Multi crystalline Si Cell, String Inverter 20 kW, Roof Mounting<br>**BS3:** Utility scale multi crystalline Si BSF - Multi crystalline Si Cell, Central Inverter 1500 kW, Ground Mounting |

*Table 2 Example on product category and base case / representative products for Photovoltaic Modules from Wesnæs* (2019)

Based on table 2 there are some differences between MEErP and PEF in terms of how the product categories are defined, where PEFCR includes different technologies, then the Ecodesign preparatory study only covers Multi Si panels. Another difference is that the inverter for PV modules is included in the Ecodesign preparatory study but not in the PEFCR. There are some discrepancies in the actual implementation of the methods in MEErP and PEF, but their methodological framing is somewhat similar. Hence, to ensure that the PEF method can be used in the ESPR, when establishing the performance classes, it is important the representative product or base case, which it is called in the context of the Ecodesign Directive, is aligned.

## 5.6. Sub-conclusion: A stepwise implementation strategy and duality of opportunities

Both the ESPR and the PEF method covers the idea of providing the consumers with information on the performance of the product in the form of performance classes. The PEF method suggests using an A to E scale based on the weighted LCA results and provides an example on how to establish the scale. The ESPR, on the other hand, leaves the layout and content of the scale to be defined in the delegated acts. Therefore, it is possible that there will be different type of scales or scales with different indicators across the different product categories. This will remain unsure until the delegated acts are established.

For energy-related products the classes of performance should be incorporated into the energy label unless there are good reasons not to do so. The EU Energy Label has a similar scale as the one proposed in the PEF method but ranges from A to G (European Commission, 2017). It is possible that the performance classes defined in the PEF method can be used as the outset for future classes for performance in the delegated acts under the ESPR - if a PEFCR is in place for the product under consideration. This is supported by its similarity to the scale of the EU Energy Labelling. However, it will require new studies to examine the application in this new context and testing on actual product groups.

The PEF method also provides an example of a procedure for how to establish the specific scale based on the performance of the theoretical best product, the theoretical worst product, the representative product, and a score of a specific product. Obtaining this information requires that a PEFCR is developed for the product group, but also that the industry provides the necessary data.

However, instead of establishing the scale based on the PEF methodology using the theoretical best product, the theoretical worst product, the representative product, and a score of a specific product outset could be taken in data on the environmental footprint or impact of product on the market. This data could be obtained by setting information requirements in the ESPR making the producers obligated to provide the data on the environmental performance of their products. Within the framework of the Ecodesign Directive, it has previously been practised to first set information requirements to a specific ecodesign parameter and then subsequently set minimum requirements after a few years. The same method could be applied here. Hence, when establishing the specific scale, the stepwise implementation could be suggested:

1. Firstly, information requirements are set in delegated acts making the producers or importers obligated to provide information on the environmental performance of the product such as environmental footprint, environmental impact of the product or other specific product parameter relevant for that product category.
2. Secondly, when data has been collected for a suitable period a A-E scale can be established based on environmental performance data of the products on the market provided by the producers or importers.
3. Thirdly, information requirements steps into force in the delegated acts on labelling of the products in compliance with the classes of performance on a scale from A-E which is based on the market data.

4. Fourthly, minimum performance requirements steps into force in the delegated acts phasing-out the worst performing products on the market based on the A-E scale and the market data provided.

There are indications that this could be a possible road forward as information requirements on LCA results are suggested in the preparatory study for photovoltaics modules, inverters, and systems and the proposal for regulation concerning batteries and waste batteries. Another aspect to consider is using indexes as the French Durability index as an informative instrument used to guide both industry and consumers. The French durability index is introduced in section 8.2 and described as a potential additional assessment method.

Defining the scale of performance classes is a data driven task that requires the industries involvement and support, which in the past have shown to be difficult on a voluntary basis. It also requires extensive insights into the market. Contrarily, regulation on the matter is an efficient way for ensuring that the industry is prioritizing data on their products. The ESPR could therefore provide the needed regulatory frames especially as it also introduces a European digital product passport. This is supported in a discussion paper by the Nordic Environmental Footprint Groups (2018) in which a long-term vision is presented for the PEF communication. The paper suggests that the EU Commission and national authorities must ensure appropriate legislation and amendments of existing regulations, including the Ecodesign Directive, to cover new requirements related to the PEF communication. Another precondition is that the EU Commission establish and support a data register for data applied in verified PEFs, which would enable the Commission to update the product benchmark and performance classes regularly.

A difference between the PEF methodology and what is suggested within the ESPR relates to how the environmental performance of a product should be communicated in relation to the classes of performance. The PEF method suggests the use of an aggregated single score based on all impact categories, whereas the ESPR are open to identify one or more relevant impact categories depending on the product in question.

In general, a premise of ensuring a relation between PEF and the ESPR is an alignment of the product categories, however this has yet to happen. An example is the product definition of PV modules in the PEFCR and in the implementing measures for PV models, which are not aligned. However, recent efforts are made for both PV modules and batteries to further align the methods. Wesnaes Skov Hansen and Gydesen (2019) also concludes that it is possible to align the product categories between the PEFCR and Implementing Measures. The differences between the two schemes are considered minor and therefore the study emphasizes that it is possible to define the same product category and base cases in both schemes, and that such an alignment can be done without compromising either method.

The broad scope of the ESPR product parameters covers product properties like durability, reliability, maintenance, reuse, and refurbishment etc., which will not be covered by simply aligning the impact categories. The PEF methods ability to cover the circular product parameters of the ESPR is unfolded in the following chapter.

# 6. The Product Parameters from the ESPR and the PEF Impact Categories – the challenges of Circularity

The ESPR annex I specify several product parameters to consider when setting specific and information requirements on product performance in the product specific delegated acts. The extent to which the PEF impact categories and thereby the PEF classes of performance will be able to cover these product parameters varies. Table 3 provides an overview of the product parameters, and to which extent these parameters are covered by the impact categories included in the PEF method or if the products parameters are included in the calculation of the PEF results.

This section does to some extent support the findings of chapter 5 on the opportunities of using PEF in the ESPR. As the table below indicates, then some of the impact categories in PEF can be used to cover the product parameters introduced in the ESPR.

However, the ability of the impact categories to cover the product parameters varies and becomes insufficient on the circular parameters that are linked to prolonging the lifetime of the products. This is elaborated after the table, where red indicates that they are NOT covered by the PEF impact categories. Yellow indicates that they are partly covered by the PEF method, but not directly communicated to the customer or consumer as a specific product parameter. Green indicates that they are covered by the PEF impact categories.

| Product parameters | Covered by the PEF method |
|---|---|
| Durability and reliability | Indirectly covered in the functional unit but is not provided as a specific result. |
| Ease of repair and maintenance | Not covered |
| Ease of upgrading, reuse, remanufacturing, and refurbishment | Not covered |
| Ease and quality of recycling | Indirectly covered in the Circular Footprint Formular but is not provided as a specific result. |
| Avoidance of technical solutions detrimental to re-use, upgrading, repair, maintenance, refurbishment, remanufacturing and recycling of products and components. | Not covered |
| Use of substances, on their own, as constituents of substances or in mixtures, during the production process of products, or leading to their presence in products, including once these products become waste; | Included in the life cycle inventory depending on the cut-off criteria.<br>Limitedly covered by ecotoxicity and human toxicity but these impact category methods are not mature enough to be applied in external communication. |
| Consumption of energy, water, and other resources in one or more life cycle stages of the product, | Partly covered by the impact categories resource use (minerals and metals), resource use (fossil), water use and land use. |
| including the effect of physical factors or software and firmware updates on product efficiency, | Not covered by the PEF method |
| including the impact on deforestation; | Included as direct land use change |
| Use or content of recycled materials | Use of recycled materials is included in the Circular Footprint Formular but is not provided as a specific result. |

| | |
|---|---|
| Weight and volume of the product and its packaging and the product-to-packaging ratio | Weight and volume of the product is included in the calculation of the PEF calculation depending on the system boundary and/ or the functional unit the packaging material may also be included in the PEF calculation. However, it is not provided as a specific result. |
| Incorporation of used components | Not covered by the PEF method |
| Quantity, characteristics, and availability of consumables needed for proper use and maintenance. | Not covered by the PEF method |
| The environmental footprint of the product, expressed as a quantification, of a product's life cycle environmental impact, whether in relation to one or more environmental impact categories or and aggregated set of impact categories | Covered |
| The carbon footprint of the product | Covered |
| Microplastic release | Not coved by the PEF method. |
| Emission to air, water, or soil in one or more life cycle stage of the product | Partly covered by the impact categories: particulate matter, ionizing radiation, photochemical ozone formation, acidification, eutrophication (terrestrial, freshwater, marine), ecotoxicity freshwater. |
| Amounts of waste generated | Waste is included when calculating the PEF results and as part of the circular footprint formular. However, a specific result on waste generated is not provided. |
| Conditions for use | Not covered by the PEF method. |

*Table 3: Overview of the product parameters from the ESPR and if they are covered by PEF impact categories or the PEF methods.*

## 6.1. The environmental and Carbon Footprint of a Product

The application of the PEF methods suggested classes of performances may play a key role related to two product parameters from the ESPR, - namely the performance or information requirements on *environmental footprint of the product* and the *carbon footprint* of the product. Here, there is an obvious link between the PEF impact categories and the ESPR product parameters.

Within the scope of the old Ecodesign Directive, these types of requirements have already emerged in the preparatory study for photovoltaics modules, inverters, and systems (Dodd et al., 2020), but also in the preparatory study for rechargeable batteries (Van Tichelen et al., 2019) and the proposal for regulation concerning batteries and waste batteries (European Commission, 2020b).

For photovoltaics modules, inverters, and systems an information requirement is suggested on Gross Energy Requirements (GER) and Global Warming Potential (GWP) and for batteries carbon footprint is suggested (Bundgaard et al., 2022). For both product groups, the PEFCRs for rechargeable batteries and photovoltaic electricity production respectively are suggested as possible methodological basis for the requirements (Bundgaard et al., 2022). In both cases, the information requirements concern specific impact categories and not an aggregated value in the form of classes of performance. Instead, specific impact categories have been selected based on the significant environmental impacts that the regulation should target based on the lifecycle impact assessed in the preparatory study.

## 6.2. Emissions to air, water, or soil in one or mor elife cycle stages of a product

The PEF method covers several impact categories in relation to *emission to air, water, and soil* such as particulate matter, ionizing radiation, photochemical ozone formation, acidification, eutrophication, ecotoxicity freshwater (European Commission, 2021a). This section elaborates on the impact categories in the PEF method and its ability to cover the product parameters related to emissions to air, water, or soil.

**Particulate matter** is included as an environmental footprint impact category. The indicator is the impact on human health with a unit of disease incidences (European Commission, 2021a). The characterization models cover both outdoor and indoor exposure to particular matter and the effect on human health (Fantke et al., 2016). The characterization model is based on Fantke et al (2016). This impact category covers the product parameter related to emissions to air (Fantke et al., 2016).

**Ionizing radiation** is included as an impact category in the PEF method. This impact category is *Ionized radiation, human health* and it covers the human health damages related to the man-made routine releases of radioactive material to the environment (European Commission, 2021a). The impact category indicator is human exposure to efficiency relative to $U^{235}$ with the unit kBq $U235_{eq}$. The characterization model is based on Frischknecht (2000).

**Photochemical ozone formation** is also an impact category in the PEF method. The impact category covers emissions to the air and the indicator is tropospheric ozone concentration increase with the unit kg $NMVOC_{eq}$ (European Commission, 2021a). The characterization model applied is a human health effect model LOTUR EUROS on ozone formation at ground level in the troposphere caused by photochemical oxidation of Volatile Organic Compounds and carbon monoxide in the presence of NOx and sunlight (European Commission, 2021h). The model is by Van Zelm et al. (2008) as applied in ReCiPe 2008.

**Acidification** is also included in the PEF impact categories and uses the indicator accumulated exceedance (AE) in the unit mol $H^+$ eq (European Commission, 2021a). The indicator AE is used to characterize change in the critical load exceedance of sensitive terrestrial and main freshwater ecosystems where substances that can acidify are deposited (European Commission, 2023c). The characterization model is on accumulated exceedance made by Seppälä et al. (2006) and Posch et al. (2008).

There are three impact categories in the PEF method for **eutrophication** covering terrestrial, freshwater and marine. The impact category for terrestrial eutrophication uses the indicator accumulated exceedance where the unit is MOL $N_{eq}$, as terrestrial ecosystems mainly become eutrophied by nitrogen emissions to air (European Environment Agency 2021). The characterization model applied is, like acidification, accumulated exceedance by Posch et al. (2008) and Seppälä et al. (2006) . For freshwater eutrophication the indicator is the fraction of nutrients reaching freshwater end compartment (p) in the unit kg P-eq (European Commission, 2021a). For marine eutrophication the indicator is the fraction of nutrients reaching marine end compartment (N) in the unit Kg N-eq (Cosme et al., 2016; European Commission, 2021a). The different impact categories have, as indicated by the units different characterized substances. Both categories use the EUTREND model by Struijs et al. (2009) as applied in ReCiPe.

**Ecotoxicity freshwater** is the last relevant impact category in the PEF method for these product parameters. This category covers emissions caused by use of various substances, such as chemicals and heavy metals, that cause ecotoxic impact on freshwater damaging the ecosystem quality (BRE Group, 2023). The indicator is the comparative toxic unit for ecosystems in the unit CTUe. The characterization model is based on the USEtox2.1 model Fantke (2016), adapted as in Saouter et al. (2018).

It will to a high extend depend on the product category under consideration, if these impact categories cover the most important emissions to air, water and soil related to the life cycle of the product. Therefore, a product-by-product evaluation may be needed, to evaluate if all impact categories are relevant or if other impact categories are needed, as also done in the supporting studies of the PEFCRs.

## 6.3. Use of Substances

The appendix to the ESPR also contains a product parameter targeting the use of substances more specifically it states: "*use of substances, on their own, as constituents of substances or in mixtures, during the production process of products, or leading to their presence in products, including once these products become waste*" (European Commission, 2022a). Substances used in the life cycle of the product will of course be part of the lifecycle inventory, unless they are allowed to be excluded based on the cut-off-criteria.

However, the PEF method also covers an impact category on ecotoxicity for fresh water and two on human toxicity, which could potentially be relevant for this product parameter, if also targeting substances of concern. As explained in section 6.2, **ecotoxicity freshwater** covers substances, that cause ecotoxic impact on freshwater damaging the ecosystem quality. Thereby, the substances covered primarily are those which have an impact on the quality of freshwater ecosystems. For **human toxicity, (cancer and non-cancer)** the indicator is comparative toxic unit for humans ($CTU_h$) and is based on the USEtox2.1 model (European Commission, 2021a). Where $CTU_h$ expresses the estimated increase in morbidity in the total human population per unit mass of chemical emitted.

Hence, these impact categories provide information on the impact on humans and freshwater ecosystems by certain chemicals and heavy metals. Thereby, they do not provide information on the use of substances during the production process, the presence of substances in the product or in the resulting waste fraction. Furthermore, human toxicity, (cancer and non-cancer) and ecotoxicity for freshwater are not considered sufficiently robust to be included in external communication (Sala et al., 2018). This implies that there is limited possibility for the PEF methods to cover the product parameter "use of substances" in the ESPR.

## 6.4. Consumption of Water, Energy, and other Resources

The PEF methods also includes several impact categories that covers the *consumption of energy, water, and other resources*, such as resource use (mineral and metals), resource use (fossil), water use and land use, where the latter also covers the product parameter in the ESPR related to deforestation.

**Resource use (minerals and metals**) is an impact category that covers depletion of non-living resources, which amongst others, are caused by mining of minerals and metals used to sustain industrial development and overconsumption. The indicator is abiotic resource depletion (ADP ultimate reserves) in unit kg Sb-eq which can be used to measure the decrease in the natural configuration of the resources in the environment.  The characterization model on ADP is from (van Oers et al., 2002) as in CML 2002 method, v.4.8.

**Resource use (fossil**) have some similarities to the previously mentioned, but the indicator is abiotic resource depletion – fossil fuels (ADP-fossil) with the unit being MJ to measure the loss of fossil energy availability (van Oers et al., 2002). The characterization model on the ADP is also from (van Oers et al., 2002) as in CML 2002 method, v.4.8.

**Land use** refers to occupation and transformation of land. The indicator is soil quality index (a result of an aggregation by JRC) the unit is dimensionless and expressed as points (Pt). Pressure on land resources due to intensification and expansion of human activities causes soil quality degradation (De Laurentiis et al., 2019). The characterization model is the index which is based on the LANCA model by De Laurentiis et al. 2019 and the LANCA CF version 2.5 by Horn and Maier, 2018, to assess the impact of land use activities on soil properties.  The land use impact category also covers the product parameter on deforestation.

**Water use** is the last impact category of relevance to this product parameter. The indicator is user deprivation potential (deprivation weighted water consumption in the unit $m^3$ water eq of deprived water). This is measured using the characterization model Available Water Remaining (AWARE) (Boulay et al., 2018). The model assesses the potential amount of available water remaining per area in a watershed after having met the need of aquatic ecosystems and humans, as the less water that remains the more likely another user is to be deprived (Boulay et al., 2018).

## 6.5. Durability and Reliability

Durability and reliability are also covered by the product parameters in the ESPR. There are different definitions of *durability and reliability*, but in connection with the development of the EN4555X series of standards the following definitions were established:

1. Durability is defined as the "*ability to function as required, under defined conditions of use, maintenance and repair, until a limiting state is reached*" (CEN and CENELEC, 2020: 5). Durability can be expressed as calendar time, operating cycles or similar (CEN and CENELEC, 2020).
2. Reliability is defined as the "*probability that a product functions as required under given conditions, including maintenance for a given duration without limiting events"* (CEN and CENELEC, 2020: 6).

Thereby, durability and reliability should be indirectly covered in the PEF methods, if the functional unit takes into consideration the lifespan of the product.

The PEF method specify four aspects the functional unit in the PEF study should define (European Commission, 2021a):

1. The function(s)/ service(s) provided "what"
2. The extent of the function or service "how much"
3. The expected level of quality "how well"
4. The duration/ lifetime of the product "how long"

Hence, if the functional unit includes the lifetime of the product, then durability and reliability is included as a parameter in the LCA calculations. Thus, it is not possible to use the PEF results to communicate information on the product's durability and reliability to the end-users. It can only be used to communication on the impact of the lifetime on the environmental performance. Furthermore, several studies have documented that not all the PEFCRs developed defines the four aspects in their functional unit (Lehmann, Bach, and Finkbeiner 2016; Bach et al. 2018a; Pedersen and Remmen 2022a). Especially, the question of "how well" and "how long" is not always covered in the functional units developed in the PEFCRs (Pedersen and Remmen 2022a; Bach et al. 2018a). This indicates that durability and reliability may not always be included in the PEF studies.

## 6.6. Recycling amounts of waste generated, ease and quality of recycling and use or content of recycled materials

*Recycling, the amounts of waste generated, and the use or content of recycled materials* is included in the PEF as the burdens and benefits from the end-of-life stage are covered. However, the PEF method does not allow for a specific result on the amount of waste generated, the use or content of recycling materials, or the recyclability or quality of recycling which can be communicated to the end-users. During the years, different methods has been included in the PEF method to calculate the end-of-life stage.

The most recent method is the Circular Footprint Formular (CFF). The CFF establishes the rules for how the environmental burdens and benefits associated with the end-of-life stage should be allocated. It covers recycling (parts/ product reuse), recycled content, energy recovery and disposal. The CFF also covers the quality degradation in connection with the recycling process. Thereby, the product parameter for *ease and quality of the recycling* is indirectly covered, this does however solely refer to the quality aspect of the parameter and not the ease of recycling which is not covered by the CFF. Critiques have been raised that the default data provided in the PEF method is not accurately enough to really reflect the differences in the materials recyclability (Pedersen and Remmen 2022a). Other points of criticism of the CFF are that it does not take into consideration that materials can be recycled multiple times, and that it only allows for an 80% credit of the recycled material (Pedersen and Remmen 2022).

## 6.7. Circularity: Repair, Reuse, Upgrade, Remanufacturing and Refurbishment

However, a number of these product parameters are not well covered by the impact categories in the PEF method or in the specific PEF calculations. This especially concerns the product parameters such as repair, reuse, upgrade, remanufacturing, and refurbishment. These parameters are also often referred to as circular strategies relevant for the inner circles of technical cycle in the circular economy (Ellen Macarthur Foundation, 2015).

The circular strategies covered by the ESPR product parameters that are not covered by the PEF method are:

- Ease of repair and maintenance
- Ease of upgrading, reuse, remanufacturing, and refurbishment
- Remanufacturing and refurbishment of products and components
- Avoidance of technical solutions detrimental to re-use, upgrading, repair, maintenance, refurbishment, remanufacturing and recycling of products and components.
- The effect of physical factors or software and firmware updates on product efficiency
- Incorporation of used components
- Quantity, characteristics, and availability of consumables needed for proper use and maintenance
- Conditions for use

Here, it will be necessary to identify additional assessment methods to evaluate these parameters. In chapter 8, different assessment methods are proposed, which could be relevant in relation to these material efficiency aspects. In the recent proposal for a "Directive on Green Claims" (European Commission, 2023a) this limitation of PEF and the focus on impact categories is recognised: "*In addition, many environmental claims are also made on environmental aspects (e.g., durability, reusability, reparability, recyclability, recycled content, use of natural content) for which the environmental footprint methods are not suited to serve as the only method for substantiation. Addressing the very wide and fast changing area of environmental claims by means of a single method has its limitations*" (European Commission, 2023a, p. 14).

## 6.8. Sub-conclusion: The Ability of PEF to Cover Circularity

The main opportunity for using the PEF method in relation to the product parameters in the ESPR is the environmental footprint and the carbon footprint of the product. Information requirement on the carbon footprint and the Gross Energy Requirements (GER) is already under consideration for PV panels within the framework of the current Ecodesign Directive and the Regulation for Batteries and Waste Batteries. However, other PEF impact categories may also provide inputs to the product parameters in the ESPR such as particulate matter, ionizing radiation, photochemical ozone formation, acidification, eutrophication and ecotoxicity freshwater, which cover emissions to air, water, or soil. However, whether these impact categories will cover the most important emissions to air, water or soil will depend on the product or product group under consideration. Therefore, the impact categories from the PEF method may not be sufficient. The impact categories resource use (minerals and metals), resource use (fossil), land use and water use may likewise provide inputs to the product parameters in the ESPR covering consumption of water, energy, and other resources.

Several product parameters from the ESPR are included in the PEF method and the calculations, but without providing the opportunity to display it as a specific result. This covers aspects such as durability and reliability, which should be covered in the functional unit, and aspects related to recycling and use of recycled materials which is covered by the CFF. However, an important consideration here is the lack of communication of these results. Despite the functional unit being somewhat covered in PEF then the results are not communicated to the consumers despite it containing crucial information on the circularity of a product. This has negative implication on the PEF methods ability to support the communication needs of the ESPR to enable a sustainable purchasing behaviour.

There are also several product parameters from the ESPR which are not covered by the PEF method. Many product parameters related to the inner circles of the circular economy such as maintenance, upgrade, reuse, repair, refurbishment, and remanufacturing. This provides a challenge as the ESPR is assigned an important role in the transition towards a circular economy. It is therefore decisive that the classes of performance in the ESPR can also cover these aspects. Consequently, additional assessment methods are needed, see chapter 8.

# 7. Limitations for Using the PEF method in the ESPR

Based on chapter 5, it is evident that there are some opportunities for unfolding the PEF-based classes of performance within the ESPR if PEFCRs are in place for the product category under consideration. However, as illustrated in chapter 6 there are also some limitations when it comes to the PEF methods ability to model and communicate aspects of relevance in a circular economy. This chapter will further outline both methodological limitations (normalisation, weighting, and impact categories) as well as limitations on the use of the communication vehicle (A-E scale) suggested in PEF method.

## 7.1. Impact Assessment: Normalisation and Weighting

The PEF impact assessment includes four steps: classification, characterisation, normalisation, and weighting (European Commission, 2021a). The PEF method further specifies that results of a PEF study shall be calculate and reported as both characterised, normalised, and weighted results along with a single overall score (European Commission, 2021a). It is the normalisation and weighting steps, which makes it possible to calculate a single overall score. Hence, if the aggregated values from the PEF method (A-E scale) are used as the basis for calculating the classes of performance in the ESPR, normalisation and weighting of the PEF results for the 16 impact categories are introduced. This is one of the places, where the PEF method differ from the ISO 14040/44 standards, as normalisation and weighting is optional in the ISO 14040/44 standards (Thrane & Jannick H., 2017). However, there are some challenges when it comes to both normalisation and weighting and the results should be interpreted with caution (Thrane & Jannick H., 2017).

First and foremost, these challenges relate not to their function as part of the PEF impact assessment but to only using normalised and/or weighted results in the communication of PEF results.

**Normalisation** is used to make comparison of results easier and make the results more relatable. The normalisation factor applied in the PEF method is global impact per person (European Commission, 2021b). However, studies have indicated that the normalisation factor is not sufficiently matured and is a relative approach (Pedersen and Remmen 2022a). By normalising to global impact per person, there is a risk that if the emissions are relatively low in a local area compared to the global emissions, then the impact is less relevant after normalisation which may not always be true (Pedersen & Remmen, 2022).

During the **weighting** step, an evaluation is made of the relative seriousness or importance of each impact category (Thrane & Jannick H., 2017). Weighting is a much-debated concept in the LCA field, as it is considered a political issues and not scientific issue (Pedersen & Remmen, 2022). Previously, there was a global consensus that weighting should not be used when making publicly available comparative declarations (Finkbeiner, 2014). Weighting of results also comes with the risk of burden shifting, due to the focus on the impact categories with the highest weighting factors (Pedersen and Remmen 2022a).

Weighting in the PEF method should be done based on the normalised results, where the normalised results are multiplied by the weighing factors presented in table 4 (European Commission, 2021a). The weighting factors developed for the PEF methods reflect the relative importance of the impact categories and takes into consideration the robustness of the indicators (Sala et al., 2018). The process of the developing the weighting factors started in

2015 and consisted of several steps including: a workshop, a literature review and an identification, evaluation, and development phase (Sala et al., 2018).

| Impact category | Weighting factors (incl.) robustness | Weighting factors (incl.) robustness excluding toxicity-related impact categories |
|---|---|---|
| | *Scale to 100* | |
| Climate change | 21.06 | 22.19 |
| Ozone depletion | 6.31 | 6.75 |
| Human toxicity, cancer effects | 2.13 | *excluded* |
| Human toxicity, non-cancer effects | 1.84 | *excluded* |
| Particulate matter | 8.96 | 9.54 |
| Ionizing radiation, human health | 5.01 | 5.37 |
| Photochemical ozone formation, human health | 4.78 | 5.10 |
| Acidification | 6.20 | 6.64 |
| Eutrophication, terrestrial | 3.71 | 3.91 |
| Eutrophication, freshwater | 2.80 | 2.95 |
| Eutrophication, marine | 2.96 | 3.12 |
| Ecotoxicity freshwater | 1.92 | *excluded* |
| Land use | 7.94 | 8.42 |
| Water use | 8.51 | 9.03 |
| Resource use - minerals and metals | 7.55 | 8.08 |
| Resource use, fossils | 8.32 | 8.92 |

*Table 4 The 16 impact categories and the final weighting factors used in PEF* (Sala et al., 2018).

Another challenge is that the varying maturity of the impact assessment methods used in the PEF method is not sufficiently considered (Pedersen & Remmen, 2022). Thereby, the inclusion of impact assessment methods with a high uncertainty can result in misleading results (Pedersen & Remmen, 2022). To compensate robustness is as mentioned earlier included in the weighting factors. Furthermore, two sets of weighting factors are developed one including and one excluding human toxicity (cancer), human toxicity (non-cancer) and ecotoxicity as the maturity levels of the impact assessments methods for these impact categories are not considered to be sufficiently robust to use in external communication (Sala et al., 2018). These are however expected to be included once their robustness is improved.

As weighting is not mainly based on natural science but inherently involved several value choices depending on policy, culture, and other preferences (Sala et al., 2018). It is important that a new study is initiated ensuring that the weighting factors are in line with the scope of the ESPR and ensuring that the weighting factors supports the goal of the Regulative. Furthermore, it should be further examined if it is the best option to develop classes of performance based on normalised and weighted results. Or if it could be based on the results of the individual impact categories or supplemented by results from the impact categories to create transparency of potential trade-offs between impact categories.

## 7.2. Communicating complex environmental footprint results to consumers

This chapter outline some of the main challenges when communicating complex environmental footprint results to consumers based on the A-E scale as suggested in chapter 5. This entails consideration on the implications of using aggregated results to communicate complex environmental information as well as possible alternatives ways of communicating such results in relation to the consumers perception and corresponding behaviour. The alternatives presented are to support the aggregated result with sub-score for the three most relevant impact categories or by only communicating on the environmental footprint results based on the most relevant parameters subjective to the given product category.

Based on section 5.4 it can be said that the A-E scale functions as a communication vehicle for environmental information to consumers. This is supported by section 6.1, where the PEF methods can have relevance in relation to especially two product parameters in the ESPR: the environmental footprint of products and the carbon footprint of products (see table 3). It can thus be argued that the A-E scale potentially can play a role here. However, there are some major challenges to be addressed in relation to the communication of aggregated environmental footprint results which relates to the partly subjective evaluation (value choices depend on policy, culture, and value systems etc.) when introducing weighted results (as mentioned in the previous section) and the consumers ability to understand the complexity of the environmental footprint results and change behaviour based on the results.

There is logic behind studies stating that consumers prefer simple and single score indicators to communicate EF information of a product (Galatola & Pant, 2014). In a way, it is easily accessible, especially in areas where the information displayed is somewhat simplistic and relates to the consumers everyday life. However, when the EF information covers the 16 impact categories in PEF method, the complexity increases which decreases the consumers ability to comprehend the information (Cimini & Moresi, 2018). The complexity is then further increased by introducing aggregated results based on weighting. So, where the A-E scale introduces simple information for the consumers to interpret and understand, then the underlying impact categories and weighting factors becomes harder to relate to for the consumers. The environmental footprint information must be meaningful for the consumer to support the intended purchasing behaviour (Elsen et al., 2019). It can therefore be argued that the A-E scale causes an imbalance between the intention to reduce the complexity of the environmental information and at the same time provide the consumer with concrete information that support purchasing of more environmentally friendly products.
As mentioned in section 4.2.1, the Ecodesign Directive and the Energy Efficiency Label has jointly transformed the market towards more energy efficient products by providing the consumers with information on the energy efficiency of the products on the market and by cutting out the worst performing products on the market. Here, the A-G scale has been successful. However, energy efficiency in the use phase is also less complex to understand than the environmental footprint of a products. Furthermore, buying an energy-efficient product can provide a financial return for the consumer in the long run.

Klik eller tryk her for at skrive tekst.Using aggregated results in an A-E scale results in a low transparency of the environmental footprint results. Communicating the EF information, using aggregated results, also makes it impossible to see if and which underlaying trade-offs that influence different products EF. These trade-offs take place between the different impact categories, where a decrease in one category can cause an increase in another category. This can be undesirable, as the latter might have “higher priority” to the general society which is somewhat reflected in the different weighting factors applied. This could also simply be in relation to the individual preference of the consumer.

Borin et al. (2011) also found that the impact of environmental information is greater for consumable products, which supports that consumers pay more attention when they are directly influenced in their everyday life by the environmental information displayed. This is another challenge of communicating environmental footprint results using the A-E scale for different product groups, as some of these are more distanced from the consumer. Hence, it is important to distinguish between business-to-business products and business-to-consumer products when communicating environmental information.

Based on the discussions above it can be argued that there are challenges using aggregated results in communicating complex environmental information to consumers. This is supported by Finkbeiner (2014), who have stated that there has been a global consensus for years supporting the subjective weighting should not be used for comparative purposes disclosed for the public. It has not been possible to find studies that explore the consumers ability to understand the meaning of aggregated results and weighting based on complex environmental impact categories for environmental communication purposes. This is interesting, and it is recommended to further explore consumers ability to understand the meaning of aggregated results as well as its ability to influence consumers behaviour towards purchasing of greener products.

The purpose of communicating and displaying environmental footprint information is to promote purchasing of more environmentally friendly products (Elsen et al., 2019). However, there are still a need to examine if the A-E scale based on aggregated LCA results incorporating weighting factors actually change consumer behaviour. Efforts should be made to develop and foster the use of communication vehicles that are more transparent. This could also provide the consumer with more detailed information on for instance the most relevant impact categories that contributes to the environmental footprint of the product.

In the EC study from 2019 *Consumer testing of alternatives for communicating the Environmental Footprint profile of products - Final report*, it was concluded that the best solution to promote environmentally friendly choices, was that the overall PEF performance should be complimented with information on either the life cycle stages or most relevant impact categories of the product (Elsen et al., 2019). Where the latter was found more efficient by the consumers (Elsen et al., 2019). One alternative type of communication vehicle is thus to use information about the most relevant impact categories as a supplement to the aggregated results in the communication.

There are pros and cons when considering this type of communication vehicle. On one side, the complexity of the environmental information displayed increases (Elsen et al., 2019). It can hinder the effect of the information as it becomes more difficult to comprehend for consumers (Elsen et al., 2019), and risks confusing the consumers (Finkbeiner, 2014).

The PEF method includes 16 impact categories that varies across a broad number of environmental categories, some are more easily understood than others. The impact category climate change relates directly to the main environmental concern of European citizens whereas the impact categories for eutrophication and acidification are less known and understandable for consumers (Elsen et al., 2019). On the other side, it can be argued, that more concrete information on the products impacts makes the overall performance information more meaningful for the consumer and potentially better guide the consumer behaviour (Elsen et al., 2019).

This option of supplementing the aggregated results with impact categories can be exemplified using the French food labelling Planet-score, which is assigns a product an overall score across an A to E scale supplemented with three sub-scores for pesticides, biodiversity, and climate. The label builds on top of the Nutri-score scheme[1] and was initiated to add transparency on the environmental impact of a product (ITAB et al., 2021). The Planet-score label is illustrated in figure 4 and 5 for products with or without animal matter.


*Figure 4: The Planet score label for products containing animal matter* (Sabine Bonnot, 2023)

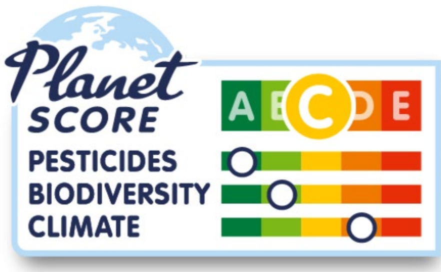


*Figure 5: The Planet-score label for products without animal matter*(Sabine Bonnot, 2023)

The Planet-score labels content and layout is based on a behavioural study which led to a focus on making a label in a semi aggregated format supported by three different visual parameters as shown in figure 4 and 5. These are:

1. The scoring (aggregated score that summarize environmental impact of the product)
2. The graduation (three sub-scores)
3. The method of production for animal products score as in figure 4 (colour-based logo for animal welfare for livestock products) (ITAB et al., 2021).

The score from A to E is based on a scale from 0 to 100, which is calculated using weighting of different sustainability sub-indicators (human health, biodiversity, climate, and resources).

It is paired with bonuses or penalty entries for each sub-indicator, e.g., forbidden pesticides and deforestation is a penalty which influence the calculation negatively. Three sub-scores are included, these are a pesticide score, biodiversity score and climate score. The Planet-score provides more concrete information and enables comparison of food products based on different product groups and different sub-scores (ITAB et al., 2021). The benefits of using a similar communication vehicle in the ESPR is that the trade-offs between significant impacts becomes transparent to the consumer, as exemplified on figure 5. On figure 5, the overall score is a C, which is caused by a high impact on the climate but a lower impact from the sub-scores pesticides and biodiversity. It could be interesting to investigate the possibilities of a similar approach for the ESPR information requirements as it can be used to overcome some of the previous limitations regarding low transparency and meaningfulness of the score provided by the PEF method.

Another alternative way of communicating the complex environmental footprint information in ESPR is to simply use the most relevant impact categories for the product group under

[1] Created in 2017 by the health authorities in France. It is a scale grounded on five levels A to E, where each have separate colors. The nutrition value is converted using an algorithm (Egnell et al., 2018).

consideration. It became clear in section 5.4 that the A-E scale has potentials as a communication vehicle. However, it could also be used as a single score indication instead of the aggregated result. This alternative is in line with the framework in the proposal ESPR, as the ESPR's definition of classes of performance suggests that it is a range of performance levels on one or more product parameters referred to in Annex 1 (European Commission, 2022f). This type of communication vehicle could possibly lead to more informed decisions, as it increases transparency and concreteness of the information and enable consumers to gain information on the actual impacts potentially increasing the meaningfulness of the information displayed.

It is therefore recommended that additional exploratory studies are performed on the use of impact categories and specific product parameters as a communication vehicle. This should aim to gain an understanding of consumer perceptions of the use of impact categories as well as insights to how these influence consumer behaviour at the point of purchase and whether these are the same for all product groups.

## 7.3. Sub-conclusion: The importance of transparent environmental information

This chapter have discussed implications of three different types of communication vehicles for communicating the complex environmental footprint results as those introduced within the ESPR. The three options for communication are based on:

1) Aggregated single score results with the A-E scale
2) Aggregated single score results with the A-E scale and most relevant impact categories
3) The most relevant impact categories each displayed using the A-E scale

The last two options target some of the concerns raised in this chapter. The second option provides addition information on select impact categories increasing the transparency of the results. It can also potentially clarify possible trade-offs between the impact categories. The third option also leaves out the normalisation and weighting of the impact category results in addition to providing more transparency. On the other hand, both option two and three makes the communication of the environmental footprint more complex. Furthermore, core circular strategies such as reliability and durability will - as product properties - not be visible to the consumers unless a direct communication vehicle is found.

However, before selecting any of these options more studies are needed on how consumers interpret and change their behaviour based on environmental footprint results. During this project, we did not identify any studies addressing the use of weighted results in environmental communications. Therefore, there seems to be a need for further studies within this field. It might also be needed to do product specific or product group specific studies as consumer behaviour may differ depending on the product group in question.

# 8. The need for additional assessment methods to support circularity

As shown in chapter 6, the PEF method abilities to cover certain material efficiency aspects relevant in a circular economy are limited. Especially, when it comes to modelling and communicating on aspects such as durability, repair, remanufacturing, and reuse of components. Therefore, additional assessment methods are needed to assess and communicate on these aspects in the context of the ESPR. During the years, the European Commission has initiated several initiatives to support the development of methods to assess and communication on material efficiency aspects. This section will elaborate on two if these initiatives namely the EN4555X series of standards and Joint Research Centres technical report on a scoring system for repair and upgrade of products (Cordella et al., 2019).
The main resources will be the EN 4555X series of standards (table 4) and the report developed by Joint Research Centre on analysis and development of a scoring system for repair and upgrade of products.

## 8.1. EN45XXX series of standards

In 2015, the European Commission issued a standardisation request M/543 on developing generic material efficiency assessment standards to support the uptake of material efficiency requirements under the Ecodesign Directive (European Commission, 2015b).

The following standardisation work resulted in eight European Standards and one technical report covering aspect such as durability, repair, reuse, upgrade, remanufacturing, reuse of components, recyclability, recoverability, proportion of recycling materials, declaration of critical raw materials and methods for proving information on material (Bundgaard & Huulgaard, 2023).

| Standard | Title | Published |
|---|---|---|
| TR 45550 | Definitions related to material efficiency | 2020-12-04 |
| EN 45552 | General method for the assessment of the durability of energy-related products | 2020-03-11 |
| EN 45553 | General method for the assessment of the ability to remanufacture energy-related products | 2020-07-10 |
| EN 45554 | General methods for the assessment of the ability to repair, reuse and upgrade energy-related products | 2020-02-21 |
| EN 45555 | General methods for assessing the recyclability and recoverability of energy-related products | 2019-11-27 |
| EN 45556 | General method for assessing the proportion of re-used components in energy-related products | 2019-06-07 |
| EN 45557 | General method for assessing the proportion of recycled material content in energy-related products | 2020-04-29 |
| EN 45558 | General method to declare the use of critical raw materials in energy-related products | 2019-03-01 |
| EN 45559 | Methods for providing information relating to material efficiency aspects of energy-related products | 2019-03-01 |

*Table 5: Overview of European standards and technical reports developed under standardization mandate M/543 (Bundgaard & Huulgaard, 2023)*

All standards include general methods for how to assess selected material efficiency aspects for energy-related products. An overview is provided in table 5. The standards are horizontal meaning that product-specific standards need to be developed based on the horizontal ones. The only exception is EN45558 on the declaration of the use of critical raw materials, which can be applied directly (Bundgaard & Huulgaard, 2023). The standards are slowly being brought into play in the Ecodesign process. By 2023, the standards were referenced in the implementing measure covering servers and data storage products, the standardisation mandate M/573 and the preparatory study covering mobile phones, smartphones, and tablets (Bundgaard & Huulgaard, 2023).

### 8.1.1. A scoring system for repair, reuse, and upgrade in EN45554

Especially, annex A in the standard EN 45554 on general methods for the assessment of the ability to repair, reuse and upgrade energy-related products is relevant when discussing classes of performance, as it includes an example of a scoring system also based on an A to C/D/E score (Technical Committee CEN-CENELEC/JTC 10, 2020). The method covers 11 criteria relevant when assessing the ability of an energy-related product to be repaired, reused and/or upgraded (Technical Committee CEN-CENELEC/JTC 10, 2020).

The eleven criteria to be scored are (Technical Committee CEN-CENELEC/JTC 10, 2020):

1. Disassembly depth
2. Fasteners and connectors
3. Tools
4. Working environment
5. Skill level
6. Diagnostic support and interface
7. Availability of spare parts
8. Type and availability of information
9. Return options
10. Data management
11. Password and factory reset for reuse

For each of the 11 criteria a method is provided on how to classify the aspect according to an A to C/D/E score (Technical Committee CEN-CENELEC/JTC 10, 2020). In table 6 and example is provided for fasteners.

| Category description | Class | Explanation |
|---|---|---|
| Reusable | A | An original fastening system that can be completely reused, or any elements of the fastening system that cannot be reused are supplied with the new part for the repair, reuse or upgrade process |
| Removable | B | An original fastening system that is not reusable, but can be removed without causing damage or leaving residue which precludes reassembly (in case of repair or upgrade) or reuse of the removed part (in case of reuse) for repair, reuse or upgrade process |
| Neither removable nor reusable | C | Neither removable nor reusable: An original fastening system that is not removable and not reusable, as designed above, for repair, reuse or upgrade process. |

*Table 6: Classification of fastener types according to EN 45554 (direct quote of the original text)* (Technical Committee CEN-CENELEC/JTC 10, 2020: 15)

In addition to the classification for each of the eleven criteria, annex A also provides a method to calculate an aggregation of the 11 criteria scores (Technical Committee CEN-CENELEC/JTC 10, 2020). In the calculation of the aggregated score each class (from A to C/D/E) is assigned a numeric value. The higher a score the greater is the products ability to be repaired, reused and/or upgraded (Technical Committee CEN-CENELEC/JTC 10, 2020). The score can then after the aggregation be expressed numerical or alphabetical (Technical Committee CEN-CENELEC/JTC 10, 2020).

References have already been made specifically to annex A in EN 45554 in the preparatory study for mobile phones, smart phones, and tablets (Schischke et al., 2021). More specifically, it is suggested that the classification method should be used in relation to the disassembly requirements for batteries and display units, fasteners and connectors, tools, working environment and skill levels (Schischke et al., 2021). Furthermore, reference to annex A in EN 45554 is made in standardisation mandate M/573 covering servers and data storage products (European Commission, 2021c). Here, the classification methods should be used to verify the availability of firmware and security updates (European Commission, 2021c).

Moreover, the mandate specifies the minimum rating of spare part availability and skill level. Here, spare part availability should be rated "B" as minimum and skill level should be rated "C "as a minimum - again according to annex A in EN 45554 (European Commission, 2021c).

Hence, annex A in EN 45554 is already brough into play in the context of current the Ecodesign Directive. Therefore, it may also be assigned a role in the ESPR in the future. Yet, it may be necessary to make new generic standards for the non-energy-related product categories covered by the ESPR (Bundgaard and Huulgaard 2023a).

## 8.2. A scoring system for assessing repairability and upgradability of products

France was the first country to develop and implement a repairability index, which was put into place in January 2019. The reparability index aims to provide the consumers with clear information about reparability of electrical and electronic equipment (Right to Repair, 2021). The French reparability index is applied to five product categories and assesses the following criteria:

1. Documentation
2. Disassembly
3. Availability of spare parts
4. Price of spare parts
5. Product-specific aspects

Each criterion is scored up to 20 points and aggregated across the 100 possible points. The final score is found by dividing with 10 and rounding up to nearest 1 decimal digit and displayed using five colours from red (low reparability) to dark green (high reparability) (Right to Repair, 2021). The French repairability index is increasingly used and have paved the way for increased information on the reparability of products.

The European Commissions has similarly initiated a process of developing a framework for assessing and scoring reparability and upgradability of products. The process resulted in the JRC technical report *"Analysis and development of a scoring system for repair and upgrade of products"* (Cordella et al., 2019).

The JRC report aimed to develop a general method on how to assess the ability of repair and upgrade of energy-related products and to test the feasibility and applicability on different product groups. The development of a framework for assessing repair and upgrade of generic products is, as illustrated in figure 6, based on three pillars: 1) priority parts, 2) key parameters and 3) a scoring framework.

The framework for assessing repairability and upgradability of products must be adapted to the specification of the given product group or type of product, and the framework has been tailored to three product groups in the report to illustrate the possible applicability of the framework (Cordella et al., 2019). The framework suggested in the JRC study is shown in figure 6.

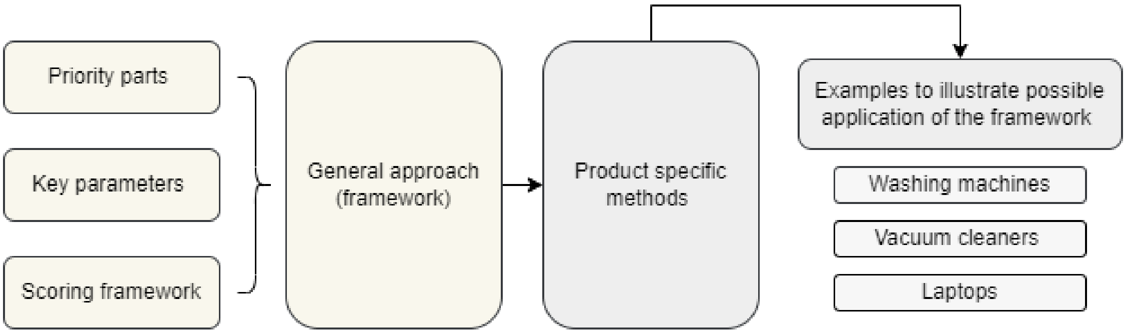


*Figure 6 Elements in the framework for assessing repairability/upgradability of products. From general to product specific* approach (Cordella et al., 2019)

Pillar 1 in the JRC report suggests focussing on **priority parts** to reduce the complexity of the assessment of a products reparability. The priority parts of a product are to be identified at product group level to ensure comparative assessment and is based on frequency of failure/upgrade and the functional importance of a product.

Pillar 2 in the assessment of a products reparability is **key parameters**. The JRC report presents a list of 12 key parameters that potentially can be used in the assessment, depending on the product. The 12 parameters are listed below and outline aspects to potentially consider, and they cover design characteristics related to design for disassembly (#1-4), relevant operational aspects for the repair and upgrade of product (#5-11) and supporting measures (#12) (Cordella et al., 2019):

1. Disassembly depth / sequence
2. Fasteners
3. Tools
4. Disassembly time
5. Diagnosis support and interfaces
6. Type and availability of data
7. Spare parts
8. Software and firmware
9. Safety, skills and working environment
10. Data transfer and deletion
11. Password reset and restoration of factory settings
12. Commercial guarantee

The parameters could also cover economic aspects indirectly by considering how the ease of disassembly influence the duration of repairing a product and hence the cost of it. The selection of parameters, their classification, rating, and weighting in the scoring framework should be as close as possible to the EN 45554 standard as introduced in section 8.1. Furthermore, the parameters should be tailored to the specific product group or type of product and be measurable.

The last pillar 3 of the framework is the suggested **scoring framework** with pass/fail criteria (binary system) that determines whether a product is eligible for a repair/upgrade rating. Furthermore, it includes a scoring framework with a selection of scoring criteria that indicates to which extend a product is repairable. The scoring framework consists of classification and rating criteria for the relevant product-specific parameters, including the pass/fail criteria and support to assessment and verification. The scoring is based on points ranging from 0 to 1 done proportionally to the rating classes for each parameter. 0 indicate that repair is not possible, between 0 and 1 then it is possible and 1 represents the optimal condition. The main components of the scoring framework for a generic product and the parameter "spare part" are shown in table 7.

| Parameter | Pass/fail criteria | Rating classes | Support to assessment (A) and verification (V) |
|---|---|---|---|
| Spare parts | For each priority part:<br><br>**I)** spare parts are declared to be available for X years after placing the last unit on the market<br><br>**II)** spare parts are deliverable within Y working days<br><br>**III)** list of spare parts and recommended retail prices set by manufactures are made publicly available<br><br>NOTES:<br>X and Y are defined at product group level. | **a)** A score is assigned for each priority part based on the period where spare parts are available. <<br>**I)** The spare part is declared to be available for a duration of X years = 1 point<br>**II)** the spare part is declared to be available for a duration of Y years = 0.66 point<br>**III)** The spare part is declared to be available for a duration of Z years = 0.33 point<br><br>**b)** a score is assigned for each priority part based on the target groups:<br>**I)** the spare part is available to all interested parties 1 point<br>**II)** the spare part is available to any self-employed professional and legally established organizations providing repair services = 0.66 point<br>**III)** the spare part is available to service providers authorised by manufacturer to offer repair services = 0.33 point<br><br>**c)** when relevant, a score is assigned to priority parts based on spare part interface:<br>**I)** the part is non-proprietary and has a standard interface = 1 point<br>**II)** the part is either proprietary or does not have a standard interface = 0.5 point.<br><br>**Score (#7) = Score (#7a) x Score (#7b) x Score (#7c)** | **A**: commitment by the manufacturer about the availability of spare parts over time, as well as provision of information about:<br><br>- Delivery time<br>- Recommended retail price of spare parts<br>- Target groups<br>- Interface used<br><br>**V**: Check of actual availability |

*Table 7: Classification and rating criteria for the parameter "spare parts" on a generic product (Cordella, Alfieri, and Sanfelix 2019)*

Based on the pass/fail criteria, the reparability of a product should subsequently be assessed based on a max of 12 parameter scores on N priority parts. The method for aggregating the results is that first, a score is calculated for each parameter (either at product or priority part level) including a weighting based on the parts importance. Then, the 12 parameter scores can be combined into different indices (design for disassembly (#1-4), repair and upgrade process (#5-11) and/or overall repairability and upgradability (#1-11). The combination of scores is made by assigning a weight to each parameter and calculate the weighted average.

The JRC report argues that quantification and aggregation of the results is the preferred method to provide easy-to-communicate indices and acknowledge that background information must be provided to increase the transparency of the results. This assessment framework will provide scores and indices in numbers between 0 and 1 for the reparability of a product. However, they emphasize that these can be rescaled based on the final application of the scoring system suggested. Some alternative communication vehicles mentioned include differentiation of the reparability based on 5-10 classes or in different levels of reparability ranging from level 1 being a potentially easy and quick disassembly to a level 4, which indicates that a product cannot be repaired (Cordella et al., 2019).

The scoring system proposed should be updated periodically to ensure continuous methodological improvements and to follow changing market conditions. The JRC study emphasizes that the complexity of developing a scoring system is reduced on areas where existing legislative boundaries are set, exemplified with washing machines and the revised Ecodesign Directive. The JRC suggests that the scoring system is used as a technical reference in policy making, amongst others the Ecolabel, Energy Label and Ecodesign Directive, where it can be used to develop and design a new label for products.

## 8.3. Sub-conclusion

The alternative assessment methods presented in this chapter suggests different methods for the assessment of aspects relevant for the inner circles in the circular economy such as durability, repairability, remanufacturing, and reuse. These aspects are not well covered by the PEF method or LCA methods in general.

The 11 criteria in the EN 45554 and the 12 parameters in the JRC scoring system are similar. Some minor differences are that the JRC includes *disassembly time* in standard time units, which potentially could partly substitute or replace disassembly depth, fasteners, and tools. The disassembly time becomes important when economic considerations are given in terms of the operational costs of a service (Cordella et al., 2019). The JRC also includes the parameter *software and firmware* as a dominant parameter for ICT products and the parameter *commercial guarantee* as a supporting measure. The software and firmware are another product parameter in the ESPR, which is not covered by the PEF methods impact categories as introduced in chapter 6. *Return options* is one of the 11 criteria in the EN 45554, whereas return models have been excluded in the JRC scoring framework due to the difficulties in predicting whether it results in an actual repair of a product.

The two methods introduced in this chapter suggest the use of different communication vehicles, where EN 45554 suggests the use of an alphabetic scale as suggested in PEF, the JRC scoring system provides a number between 0 to 1 but acknowledge the possibility of rescaling this. Both assessment methods entail aggregation of the reparability results of a product based on its specifications. Where the previous discussions on the use of aggregations have argued that this makes it more difficult to understand for the consumer, there might be some relevance for the use of an aggregated result on specific circular aspects as the scope is less broad and the criteria or parameter in focus is more self-explanatory.

The French repairability index shows a different assessment method for reparability of products that is more simplistic but that at the same time leaves room for product specific aspects, which could be an interesting methodology to explore as an assessment method. Based on the experience of the French index as well as the pressing need to deal with circularity aspects of products like reliability and durability of products, the French Government have decided to supplement the repairability index with a durability index by January 2024. The durability will thus combine both repairability and reliability aspects of products (Right To Repair, 2021). This development can also be seen at a European level. JRCs have made a draft for a technical report for Ecodesign for sustainable products regulation – preliminary study on new product priorities (G. Faraca et al., 2023a). The JRC report provides a preliminary proposal of the new product groups and horizontal measures that should be prioritized in the ESPR framework. The horizontal measures are presented including the potential provisions and potential product coverage. The horizontal measures cover durability, recyclability, and post-consumer recycled content (G. Faraca et al., 2023b, p. 10).

A preparatory study on the durability index have found that important criteria to include in the assessment of a products durability is reparability, reliability, robustness, and upgradability including weighting between these criteria based on the specific product type or product group (ADAME, 2021). These criteria are thus something that should be covered by the additional methods needed to be able to integrate the circularity elements outlined within the ESPR.

Regardless of the assessment method, an initial evaluation is important of the material efficiency aspects of a product to better understand, which circular strategies that are optimal to adopt (Cordella et al., 2019).

# 9. Conclusion

The PEF method provides some opportunities within the ESPR as a frame for specifying the classes of performance and a method on how a scale with *"successive steps to allow for product differentiation"* can be defined, if PEFCRs are in place. For the product parameters in the ESPR on environmental footprint and carbon footprint the PEF method in combination with PEFCRs can provide the methodological outset. Still, more studies are needed on a product level to ensure compatibility.

Additionally, other impact categories in the PEF method can to some extend constitute a methodological reference point for two ESPR product parameters in Annex I. These are the impact categories on particulate matter, ionizing radiation, photochemical ozone formation, acidification, eutrophication and ecotoxicity freshwater, which can partly support the product parameters from the ESPR on emissions to air, water, or soil. Furthermore, the impact categories on resource use (minerals and metals), resource use (fossil), land use and water use can partly support the product parameters in the ESPR annex I on consumption of water, energy, and other resources. Thus, the impact categories in the PEF method do not fully cover the product parameters from the ESPR. More studies are needed to ensure that the most important impacts from that specific product group is covered by the PEF impact category.

The ESPR proposes that the requirements can be accompanied with information on the performance of the product according to the parameters listed in annex I of the ESPR. Furthermore, when determining the information requirements on the product performance then classes of performances should be established when appropriate. However, the layout and content of the scale are to be defined in the product specific delegated acts. The PEF method from 2021 annex I includes an example of a method for establishing classes of performance of a product in a five-level scale from A to E. The PEF classes of performances are presented using a single score indicator, which is calculated as the sum of the weighted results across all 16 impact categories of PEF method.

The scale of the performance classes is suggested in PEF to be established using the theoretical best product, theoretical worst product, the representative product, and a score of a specific product. Consequently, it requires data provided by the industry to establish the PEF based classes of performance. However, the scale could also be established based on market data taking a more empirical outset. Here, the ESPR could potentially support the development of the performance classes by setting information requirements to the environmental performance of the product such as the environmental footprint information or selected impact categories. The Digital Product Passport will also be a way to collect specific date for this purpose.

1. Information requirements are set in delegated acts making the producers or importers obligated to provide information on the environmental performance of the product.
2. After data has been collected for a suitable period a A-E scale can be develop based on the environmental performance data of the products.
3. Information requirements steps into force in the delegated acts on labelling of the products in compliance with the classes of performance on a A-E scale.
4. Finally minimum performance requirements steps into force in the delegated acts phasing-out the worst performing products on the market based on the A-E scale.

There are some limitations for unfolding the PEF-based performance classes within the context of the ESPR. Firstly, an imbalance exists between the consumers desire for simple and easy-to-understand environmental information and the need for transparent and concrete information on the complex environmental footprint results that are being communicated. Secondly, the PEF-based performance classes entail normalisation and weighting of the results. These types of results should be interpreted with caution, as weighting is considered more a political issue than a scientific issue. Furthermore, weighting also comes with the risk of burden shifting depending on the weighting factors. Thirdly, a challenge is that the PEF performances classes are reducing communication of complex environmental information, and that the uncertainty on the consumers ability to understand and respond to this type of information has not been investigated to a higher degree.

Further studies should be made on the consumers ability to understand and relate to the environmental footprint information and the underlying impact categories. Alternatively, only the most relevant impact categories for the specific product should be communicated using an A to E scale as exemplified with the Planet score from France. The latter could lead to more informed decisions, increase transparency and specificity of the information, and provide the consumers with perhaps more meaningful information, while still being in line with the ESPRs definition of classes of performance. This paper introduces two other types of communication vehicles targeting some of the concerns raised, 1) The aggregated single score results with the A-E scale combined with the most relevant impact categories, and 2) The most relevant impact categories presented using the A-E scale.

The PEF method uses an aggregated single score based on all 16 impact categories which are normalised and weighted. The ESPR definition of classes of performance highlight that they could act as performance levels in relation to one or more of the product parameters outlined in Annex I. ESPR does not specify that the performance of a product must be communicated as an aggregated single score. Furthermore, if the PEF method is to be used within the ESPR more consideration should be given to the current weighting of the impact categories in PEF and whether these correlate with the scope of the ESPR.

The ESPR covers a far-reaching range of product parameters that have different characteristics, some relate to properties of a product and can be used to identify improvement potentials, while others are directly linked to the environmental impact of a product, see figure 7.

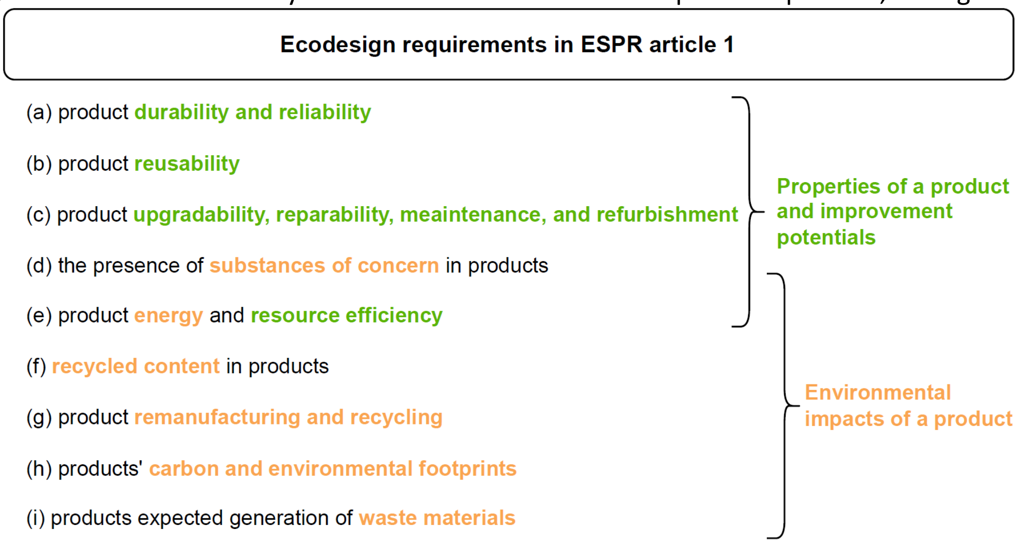


*Figure 7 Different characteristics based on the product parameters outlined in the ESPR article 1 (Own elaboration)*

A major limitation to PEF is its inability to cover all the product parameters introduced as ecodesign requirements in ESPR article 1 (European Commission, 2022f). The product parameters in the ESPR covers various characteristics and based on our knowledge of existing tools, it is found that a combination of tools and assessment methods is required to cover all of these.
PEF is an environmental assessment method with a core focus on environmental emissions and resource consumption – in other words, a quantification of environmental impact of products. The role of the PEF method is therefore limited to the product parameters that relate to the environmental impacts of a product, see figure 7.

However, as highlighted earlier ESPR aims at making ecodesign requirements to improve the environmental performance of products related to parameters that are core to circularity such as durability, reparability and reusability as outlined in ESPR article 1. These product parameters are however either not covered, e.g., point (b) and (c), or they are covered indirectly in the assessment, but then not communicated or visible to the consumer, e.g., point (a) which is somewhat covered via the functional unit. Durability should be included in the functional unit, but this is not always the case. The PEF of a product cannot from a consumer perspective be used to compare products in terms of durability. The benefits of the points (a), (b) and (c) in figure 7 will therefore only be indirectly visible in terms of the lifetime of the product.

The ESPR entail various product parameters with characteristics related to the material efficiency of a product such as durability, reliability, upgrade, repair, reuse, remanufacturing, refurbishment, and recycling. Some of these parameters such as recyclability and recycling content is somewhat included in the PEF method through the CFF, and durability ought to be covered in the functional unit. The PEF method thus only cover these product parameters indirectly and the results of these parameters are not disclosed to the consumer. The ESPR scope is thus broader than the PEF method. This paper finds that many important product parameters for the inner circles of the circular economy and for extending the lifetime of products are not covered in the PEF method. These parameters can be characterised as properties of a product and covers durability, reliability, repair, reuse, upgrade, refurbishment, and remanufacturing. Here, additional assessments methods are needed.

Several initiatives have been initiated by the European Commission on material efficiency aspects that could be used as additional assessment methods. The EN 4555x series of standards and the JRC technical report on a scoring system for repair and upgrade of products show a methodological foundation that is better suited the circular strategies that are prolonging the product lifetime. EN 45554 and the JRC scoring system for repair and upgrade can be used to assess some of these circular strategies as they establish technical product elements needed to do the assessment. Summing up the project has identified the following opportunities and limitations for unfolding the PEF-method within ESPR:

**Opportunities:**

- PEF provides a method for establishing classes of performance using an A to E scale
- The PEF A to E scale provides consumers with a simple and easy to understand information
- The A to E scale based on PEF resembles the EU Energy Label
- ESPR can provide the regulatory frame to ensure that data is provided from industry in PEF

- The PEF method can be used as one of the possible methods to calculate the environmental footprint and carbon footprint, as specified in the ESPR if there is a PEFCRs that can provide the methodological outset

**Limitations:**

- PEF uses weighting of so far 16 impact categories, but the ESPR opens for a focus on more product parameters depending on the product group
- Weighting in PEF comes with the risk of burden shifting and inherently involves value choices depending on policy, culture, and other preferences
- Crucial product information for the consumers such as durability and reparability are not communicated directly to the consumers
- The PEF impact categories only cover a limited number of ESPR product parameters and not those that are core in a circular economy. Therefore, additional assessment methods are needed to support the product parameters not covered by the PEF method
- The PEF A to E scale covers complex information across 16 impact categories which decrease the consumers ability to understand the information (low meaningfulness)
- It is unsure whether consumers understand and give value to aggregated results presented using an A to E scale

# References

ADAME. (2021). *Preparatory study for the introduction of a durability index*.

Bach, V., Lehmann, A., Görmer, M., & Finkbeiner, M. (2018). Product Environmental Footprint (PEF) Pilot Phase - Comparability over Flexibility? *Sustainability*, *10*(2898).

Borin, N., Cerf, D. C., & Krishnan, R. (2011). Consumer effects of environmental impact in product labelling. *Journal of Consumer Marketing*, *28*(1), 76–86. https://doi.org/10.1108/07363761111101976

Boulay, A. M., Bare, J., Benini, L., Berger, M., Lathuillière, M. J., Manzardo, A., Margni, M., Motoshita, M., Núñez, M., Pastor, A. V., Ridoutt, B., Oki, T., Worbe, S., & Pfister, S. (2018). The WULCA consensus characterization model for water scarcity footprints: assessing impacts of water consumption based on available water remaining (AWARE). *International Journal of Life Cycle Assessment*, *23*(2), 368–378. https://doi.org/10.1007/s11367-017-1333-8

BRE Group. (2023). *Ecotoxicity: Ecotoxicity to freshwater and land: kg 1,4 dichlorobenzene (1,4-DB) eq.* https://tools.bregroup.com/greenguide/page.jsp?id=2099

Bundgaard, A. M., & Huulgaard, R. D. (2023). The role of standards in support of material efficiency requirements under the Ecodesign Directive [Article]. *Journal of Cleaner Production*, *385*, 135599. https://doi.org/10.1016/j.jclepro.2022.135599

Bundgaard, A. M., Huulgaard, R. D., & Remmen, A. (2022). *The Integration of the PEF method in the Ecodesign Directive*.

Bundgaard, A. M., Mosgaard, M., & Remmen, A. (2017). From energy efficiency towards resource efficiency within the Ecodesign Directive. *Journal of Cleaner Production*, *144*, 358–374. https://doi.org/10.1016/j.jclepro.2016.12.144

Caldas, M. G., Spiliotopoulos, C., Alfieri, F., Eynard, U., Zampori, L., Blengini, G. A., Mancini, L., Mathieux, F., & Ardente, F. (2021). *JRC Technical Report: Review of the MEErP-Methodology for Ecodesign of Energy-related Products*. https://susproc.jrc.ec.europa.eu/product-bureau//sites/default/files/2021-09/MEErP_revision_draft_report_Task_1-2_24-06-2021.pdf

CEN and CENELEC. (2020). *TR 45550 Definitions related to material efficiency*. CEN and CENELEC.

Cimini, A., & Moresi, M. (2018). Are the present standard methods effectively useful to mitigate the environmental impact of the 99% EU food and drink enterprises? In *Trends in Food Science and Technology* (Vol. 77, pp. 42–53). Elsevier Ltd. https://doi.org/10.1016/j.tifs.2018.05.005

Cordella, M., Alfieri, F., & Sanfelix, J. (2019). *Analysis and development of a scoring system for repair and upgrade of products*. https://doi.org/10.2760/725068

Cosme, N., Verones, F., & Hauschild, M. Z. (2016). 9. Marine eutrophication. In *Global Guidance for Life Cycle Impact Assessment Indicators*.

Council of the European Union. (2010). *Council conclusions on sustainable materials management and sustainable production and consumption: key contribution to a resource-efficient Europe*.

De Laurentiis, V., Secchi, M., Bos, U., Horn, R., Laurent, A., & Sala, S. (2019). Soil quality index: Exploring options for a comprehensive assessment of land use impacts in LCA. *Journal of Cleaner Production*, *215*, 63–74. https://doi.org/10.1016/j.jclepro.2018.12.238

Dodd, N., Espinosa Martinez, M. D. L. N., Van Tichelen, P., Peeters, K., & Soares, A. (2020). *Preparatory study for solar photovoltaic modules, inverters and systems*. Publications Office of the European Union. https://doi.org/10.2760/852637

Egnell, M., Ducrot, P., Touvier, M., Allès, B., Hercberg, S., Kesse-Guyot, E., & Julia, C. (2018). Objective understanding of Nutri-Score Front-Of-Package nutrition label according to individual characteristics of subjects: Comparisons with other format labels. *PLOS ONE*, *13*(8), e0202095. https://doi.org/10.1371/journal.pone.0202095

Ellen Macarthur Foundation. (2015). *Towards a circular economy: Business rationale for an accelerated transition*.

Elsen, M., van Giesen, R., van den Akker, K., & Dunne, A. (2019). *Consumer testing of alternatives for communicating the Environmental Footprint profile of products Final report*.

European Commission. (2011). *Communication from the European Parliament, The Council, The European Economic and Social Committee of the Regions - Roadmap to a Resource Efficient Europe, COM(2011) 571 final*. https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52011DC0571

European Commission. (2013a). *Commission Recommendation of 9 April 2013 on the use of common methods to measure and communicate the life cycle environmental performance of products and organisations* (2013/179/EU). Official Journal of the European Union. https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32013H0179

European Commission. (2013b). *Communication from the Commission to the European Parliament and the Council: Building the Single Market for Green Products: Facilitating better information on the environmental performance of products and organisations*. Official Journal of the European Union. https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex%3A52013DC0196

European Commission. (2015a). *Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions: Closing the loop - An EU action plan for the Circular Economy: An EU action plan for the circular economy*. https://doi.org/10.1017/CBO9781107415324.004

European Commission. (2015b). *M/543 Commission implementation decision o as regards ecodesign requirements on material efficiency aspects for energy-related products in support of the implementation of Directive 2009/125/EC of the European Parliament and of the Council* (M/543). https://ec.europa.eu/growth/tools-databases/mandates/index.cfm?fuseaction=search.detail&id=564

European Commission. (2016). *Background document for the testing of communication vehicles in the environmental footprint pilot phase 2013-2016*.

European Commission. (2017). *Regulation (EU) 2017/1369 of the European Parliament and of the Council of July 2017 setting a framework for energy labelling and repealing Directive 2010/30/EU*. Official Journal of the European Union.

European Commission. (2020a). *COM(2020) 98 final Communication from the Commission to the European Parliament, the Council, The European Economic and Social Committee and the Committee of the Regions - A new Circular Economy Action Plan For a cleaner and more competitive Europe*. European Commission.

European Commission. (2020b). *Proposal for a REGULATION OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL concerning batteries and waste batteries, repealing Directive 2006/66/EC and amending Regulation (EU) No 2019/1020* (COM(2020) 798 final).

European Commission. (2020c). Regulation (EU) 2020/852 of the European Parliament and of the Council of 18 june 2020 on the establishment of a framework to facilitate sustainable investment and amending Regulation (EU) 2019/2088. In *Official Journal of the European Union*.

European Commission. (2021a). *Annex I and II: Product Environmental Footprint to the Commission Recommendation of 16.12.2021: on the use of the Environmental Footprint* *methods measure and communicate the life cycle environmental performance of products and organisations*.

European Commission. (2021b). Commission Recommendation of 16.12.2021: on the use of the Environmental Footprint methods to measure and communicate the life cycle environmental performance of products and organisations. In *Recommendation*.

European Commission. (2021c). *M/573 Commission Implementing Decision of 12.01.2021 on a standardisation request to the European standardisation organisation in support of Regulation (EU) 2019/424 as regards ecodesign requirements for servers and data storage products*.

European Commission. (2021d). *Understanding Product Environmental Footprint and Organisation Environmental Footprint methods* .

European Commission. (2021e). *Environment: The Environmental Footprint Pilots*. https://ec.europa.eu/environment/eussd/smgp/ef_pilots.htm#pilot

European Commission. (2021f). *Environment: The Environmental Footprint transitional phase*. https://ec.europa.eu/environment/eussd/smgp/ef_transition.htm

European Commission. (2021g, January 25). *European Commission launches Green Consumption Pledge, first companies commit to concrete actions towards greater sustainability*.

European Commission. (2021h, February 12). *Knowledge for Policy: Supporting policy with scientific evidence. Photochemical ozone formation*. https://knowledge4policy.ec.europa.eu/node/9315_el

European Commission. (2022a). *Annexes to the Commission proposal for a Regulation of the European Parliament and of the Council establishing a framework for setting ecodesign requirements for sustainable products and repealing Directive 2009/125/EC*.

European Commission. (2022b). *Impact assessment. Accompanying the document Proposal for a Regulation of the European Parliament and of the Council. Establishing a framework for setting ecodesign requirements for sustainable products and repealing Directive 2009/125/EC. PART 1/4*.

European Commission. (2022c). *Impact assessment. Accompanying the document Proposal for a Regulation of the European Parliament and of the Council. Establishing a framework for setting ecodesign requirements for sustainable products and repealing Directive 2009/125/EC. PART 2/4*.

European Commission. (2022d). *Impact assessment. Accompanying the document Proposal for a Regulation of the European Parliament and of the Council. Establishing a framework for setting ecodesign requirements for sustainable products and repealing Directive 2009/125/EC. PART 4/4*.

European Commission. (2022e). *Impact assessment. Accompanying the document Proposal for a Regulation of the European Parliament and of the Council. Establishing a framework for setting ecodesign requirements for sustainable products and repealing Directive 2009/125/EC. PART 4/4*.

European Commission. (2022f). *Proposal for a REGULATION OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL establishing a framework for setting ecodesign requirements for sustainable products and repealing Directive 2009/125/EC*. https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52022PC0142&qid=1660551451817

European Commission. (2023a). *Proposal for a Directive on green claims*. https://environment.ec.europa.eu/publications/proposal-directive-green-claims_en

European Commission. (2023b). *About the energy label and ecodesign*. https://commission.europa.eu/energy-climate-change-environment/standards-tools-and-labels/products-labelling-rules-and-requirements/energy-label-and-ecodesign/about_en

European Commission. (2023c). *European platform on Life Cycle Assessment: LCIA method data set overview page*. https://eplca.jrc.ec.europa.eu/SDPDB/showLCI-AMethod.xhtml;jsessionid=2AFF86DC8D93D5AC85BC61D6472EBE11?uuid=f6cbd466-253f-4145-a4bb-8dae7d266e89&stock=default

European Commission. (2023d, January 6). *Environment: Environmental footprint methods*. https://environment.ec.europa.eu/news/environmental-footprint-methods-2021-12-16_en

European Environment Agency. (2021). *Eutrophication of terrestrial ecosystems due to air pollution — European Environment Agency*. https://www.eea.europa.eu/airs/2018/natural-capital/eutrophication-of-terrestrial-ecosystems

Fantke, P., Evans, J., Hodas, N., Apte, J., Jantunen, M., Jolliet, O., & McKone, T. E. (2016). 4. Health impacts of fine particulate matter. In *Global Guidance for Life Cycle Impact Assessment Indicators: Vol. Volume 1* (pp. 76–100).

Finkbeiner, M. (2014). Product environmental footprint - Breakthrough or breakdown for policy implementation of life cycle assessment? In *International Journal of Life Cycle Assessment* (Vol. 19, Issue 2, pp. 266–271). https://doi.org/10.1007/s11367-013-0678-x

Frischknecht, R., Braunschweig, A., Hofstetter, P., & Suter, P. (2000). Human health damages due to ionising radiation in life cycle impact assessment [Article]. *Environmental Impact Assessment Review*, *20*(2), 159–189. https://doi.org/10.1016/S0195-9255(99)00042-6

G. Faraca, C. Spiliotopoulos, A. Ranea Palma, M.N. Pérez-Camacho, F. Alfieri, D. Bernad Beltran, A. Lag Brotons, A. Delre, Z. Pérez Arriba, A. Arcipowska, M.G. La Placa, O. Wolf, E. Sanye Mengual, A. Amadei, T. Maury, F. Ardente, & F. Mathieux. (2023a). *DRAFT Ecodesign for Sustainable Products Regulation - preliminary study on new product priorities. Technical report*.

G. Faraca, C. Spiliotopoulos, A. Ranea Palma, M.N. Pérez-Camacho, F. Alfieri, D. Bernad Beltran, A. Lag Brotons, A. Delre, Z. Pérez Arriba, A. Arcipowska, M.G. La Placa, O. Wolf, E. Sanye Mengual, A. Amadei, T. Maury, F. Ardente, & F. Mathieux. (2023b). *DRAFT Ecodesign for Sustainable Products Regulation - preliminary study on new product priorities. Technical report*.

Galatola, M., & Pant, R. (2014). Reply to the editorial "product environmental footprint - breakthrough or breakdown for policy implementation of life cycle assessment?" Written by Prof. Finkbeiner (Int J Life Cycle Assess 19(2):266-271). In *International Journal of Life Cycle Assessment* (Vol. 19, Issue 6, pp. 1356–1360). Springer Verlag. https://doi.org/10.1007/s11367-014-0740-3

ITAB, Sayari, & VGF. (2021). *Affichage environnemental: rapport d'expérimentation Planet-score. Enjeux autour du dispositif d'affichage environnemental, et impacts pour l'éco-conception des produits alimentaires*.

Kemna, R. (2011). *Methodology for ecodesign of energy related products Part 1: Methods* (p. 169). European Commission.

Lehmann, A., Bach, V., & Finkbeiner, M. (2016). EU product environmental footprint-mid-term review of the pilot phase. In *Sustainability (Switzerland)* (Vol. 8, Issue 1, pp. 1–13). https://doi.org/10.3390/su8010092

Lupiáñez-Villanueva, F., Tornese, P., Veltri, G. A., & Gaskell, G. (2018). *Assessment of different communication vehicles for providing Environmental Footprint information Final Report*. http://europa.eu

Minkov, N., Lehmann, A., & Finkbeiner, M. (2020). The product environmental footprint communication at the crossroad: integration into or co-existence with the European Ecolabel? *International Journal of Life Cycle Assessment*, *25*(3), 508–522. https://doi.org/10.1007/s11367-019-01715-6

Nissinen, A., Suikkanen, J., & Salo, H. (2019). Product Environmental Information and Product Policies: How Product Environmental footprint (PEF) changes the Situation? In *TemaNord 2019: 549*. Nordic Council of Ministers.

Nordic Environmental Footprint Group. (2018). *Discussion paper: Future environmental footprint communication*.

Pedersen, E., & Remmen, A. (2022). Challenges with product environmental footprint: a systematic review. *The International Journal of Life Cycle Assessment*. https://doi.org/10.1007/s11367-022-02022-3

Posch, M., Seppälä, J., Hettelingh, J.-P., Johansson, M., Margni, M., & Jolliet, O. (2008). The role of atmospheric dispersion models and ecosystem sensitivity in the determination of characterisation factors for acidifying and eutrophying emissions in LCIA [Article]. *The International Journal of Life Cycle Assessment*, *13*(6), 477–486. https://doi.org/10.1007/s11367-008-0025-9

Right To Repair. (2021, February 3). *The French repair index: challenges and opportunities*.

Rikke Dorothea Huulgaard. (2015). *Ecodesign : A Study of the Ecodesign Directive and Ecodesign Practices at Grundfos, Bang & Olufsen and Danfoss Power Electronics*.

Sabine Bonnot. (2023). *Unpublished material from Planet-Score received in an email correspondance*.

Sala, S., Cerutti, A. K., & Pant, R. (2018). *Development of a weighting approach for the Environmental Footprint*.

Saouter, E., Biganzoli, F., Ceriani, L., Pant, R., Versteeg, D., Crenna, E., & Zampori, L. (2018). *Using REACH and EFSA database to derive input data for the USEtox model*.

Schischke, K., Clemm, C., Berwald, A., Proske, M., Dimitrova, G., Reinhold, J., Prewitz, C., Durand, A., & Beckert, B. (2021). *Ecodesign preparatory study on mobile phones, smartphones and tablets : final report*. European Commission. https://doi.org/doi/10.2873/175802

Seppälä, J., Posch, M., Johansson, M., & Hettelingh, J.-P. (2006). Country-dependent Characterisation Factors for Acidification and Terrestrial Eutrophication Based on Accumulated Exceedance as an Impact Category Indicator (14 pp) [Article]. *The International Journal of Life Cycle Assessment*, *11*(6), 403–416. https://doi.org/10.1065/lca2005.06.215

Struijs, J., Beusen, A., van Jaarveld, H., & Huijbregts, M. A. J. (2009). Aquatic Eutrophication. Section 6. In M. , H. R. , H. M. A. J. , D. S. A. , S. J. , V. Z. R. Goedkoop (Ed.), *ReCiPe 2008 - A life cycle impact assessment method which comprises harmonised category indicators at the midpoint and the endpoint level. Report I: Characterisation factors,* (First).

Suikkanen, J., Nissinen, A., & Wesnæs, M. (2019). Nordic Swan Ecolabel and Product Environmental Footprint: Focus on Product Environmental Information. In *TemaNord 2019:544*. Nordic Council of Ministers.

Technical Committee CEN-CENELEC/JTC 10. (2020). *DS/EN 45554:2020 General methods for the assessment of the ability to repair, reuse and upgrade energy-related products* (p. 30). Danish Standards Association.

Thrane, M., & Jannick H., S. (2017). Life Cycle Assessment. In L. Kørnøv, M. Thrane, A. Remmen, & H. Lund (Eds.), *Tools for Sustainable Development* (First edition, pp. 205–240). Aalborg Universitetsforlag.

van Oers, L., de Koning, A., Guinée, J. B., & Huppes, G. (2002). *Abiotic resource depletion in LCA Improving characterisation factors for abiotic resource depletion as recommended in the new Dutch LCA Handbook*.

Van Tichelen, P., Mulder, G., Durand, A., & Viegand, J. (2019). *Preparatory Study on Ecodesign and Energy Labelling of rechargeable electrochemical batteries with internal storage* *under FWC ENER/C3/2015-619- Lot 1 -TASK 7 Report Policy Scenario Analysis*. https://ecodesignbatteries.eu/

Wesnæs, M., Hansen, P. S., & Gydesen, A. (2019). *Initial analysis of EcoReport Tool: Suggestions for improvement of EcoReport tool, based on practical experience, as well as analysis of the advantages and disadvantages of implementing elements from the Product Environmental Footprint (PEF) method*.

Zelm, R. van, Huijbregts, M. A. J., Hollander, H. A. Den, Jaarsveld, H. A. Van, Sauter, F. J., Struijs, J., Wijnen, H. J. Van, & Meent, D. van de. (2008). European characterization factors for human health damage of PM10 and ozone in life cycle impact assessment [Article]. *Atmospheric Environment (1994)*, *42*(3), 441–453. https://doi.org/10.1016/j.atmosenv.2007.09.072

# NEF - Nordic Environmental Footprint

Nordic Environmental Footprint (NEF) was established in 2015 by the working group for Sustainable Consumption and Production under Nordic Council of Ministers (NMR).
The aim is to coordinate the Nordic countries authority work of common interest regarding Environmental Footprint work, Eco-Design for Sustainable Products Regulation and Green Claims and in common keep an up-to-date overview regarding the development in the EU PEF and OEF of special Nordic interest within these policy areas.
The participants of the group include national representatives and are organized in a Steering Committee and a Technical Advisory Board
The NEF group will initiate debate and analyses of issues of common Nordic interest. Activities of common interest are initiated by NEF who will disseminate knowledge regarding PEF to Nordic stakeholders. Information about the NEF conferences can be found under

https://www.nordic-pef.org/