Communication of environmental product information: characterization and harmonization of ecolabels

vorgelegt von

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Summary

Environmental labels and declarations (or ecolabels) are instruments to communicate the environmental performance of products. The relevance of environmental communication has been highlighted in Europe as far back in the 2000s when the Integrated Product Policy has been settled. Nowadays, environmental labelling is among the policy tools supported by the European Commission (EC) in the improvement of sustainable production and consumption practices. However, ecolabels around the world have developed in many varieties and forms, due to the different communication purposes, target groups and aims they have. The ecolabels existing on the market barely can fit under any existing classification, including the one from the International Organization for Standardization (ISO). ISO manages the 14020-suite of standards designated to provide a framework for ecolabels development. The current ISO classification consists of three types: Type I ecolabels, Type II self-declared claims and Type III environmental product declarations.

The lack of operational classification and systematic approach for characterization of ecolabels is confusing for many users, as well as hinders the research work towards the improvement of their reliability and credibility. In this regard, credible ecolabels are considered those that are based on transparent operation and on scientifically-sound methodology for criteria development and assessment. A method worth exploring in ecolabelling is Life Cycle Assessment (LCA). Already proven and popular in business-to-business (B2B) setting (e.g., in Type III declarations), it is still criticised and not fully explored whether it is applicable in business-to-consumer (B2C) communication.

The objective of this work is to enhance the communication of environmental product information through improved characterization and harmonization of ecolabels. Two research questions are defined and answered to meet this objective, depicting two focus areas of the thesis: firstly, the area of characterization and classification of ecolabels and secondly, the application of LCA for harmonization in ecolabelling. This thesis is based on four peer-reviewed journal publications.

Improvements in the characterization of ecolabels are achieved by the development of a characterization scheme. It is a result of the investigation of a sample of 45 ecolabels and a literature review of existing publications on ecolabel classification and characterization. Based on the gained information, gaps of the ISO classification are highlighted. The application and performance of the scheme is further tested in a case study by characterizing the Cradle to Cradle Certified™ Products Program (C2C Certified for short) as a tool for external environmental communication.

Due to the formerly missing operational way to characterize ecolabels, some questions related to their overall harmonization and particularly to the application of LCA in ecolabels were still open. Thus, the work further focuses on LCA-based ecolabels (such as Type III declarations) and the existing approaches for harmonization of product category rules (PCR). By a desktop research, Type III-like programmes are identified, classified, and evaluated. Trends in their development along the years are observed. Regarding the overview of existing harmonization attempts, 16 initiatives categorized as guidelines, standards and technical specifications, collaborative platforms and other activities related to mutual recognition between parties are examined.

Focus is given on the Guidelines for Product Category Rule Development (GPCRD) and the EC's Product Environmental Footprint initiative (PEF). A road test to align a draft PCR with the requirements of the GPCRD is conducted to evaluate the ability of the Guidelines to facilitate this process in a consistent manner. PEF is analysed from the perspective of an LCA-based instrument for environmental communication. It is compared with a typical Type I ecolabel – the European Ecolabel (EUF) – by conducting three case studies on detergents, paints, and t-shirts to show the interfaces between the two approaches. With the information obtained by the reciprocal analysis, three different perspectives for mutual integration and co-existence are examined.

The first version of the ecolabel characterization scheme contains 18 attributes, classified in four groups. Each attribute comprises two to five options to select among. For example, the attribute "End-user focus" consists of three options: "B2C", "B2B" or "both". The characterization of the ecolabels from the sample by employing the scheme shows that ecolabels apply different awarding formats and criteria in combinations and forms that are not recognized and described by ISO. Only around 40% of the ecolabels from the sample can be assigned to Type I and Type III. None of them declares to be Type II. As a result,

a list of recommendations for improvement to ISO on seven different topics is derived. As an outcome of the case study on C2C Certified, an upgraded ecolabel characterization scheme is issued, consisting of five groups with 22 refined attributes. Proposals for improvement of C2C Certified as a communication tool are also determined.

As regards the harmonization of ecolabels and LCA application in ecolabelling, 48 Type-III-like programmes are listed. The results reveal that e.g., 56% of them operate in Europe, against 28% in North America. The majority cover the building and construction sector. The practical test of GPCRD concludes that the PCR alignment process is an attainable task and that GPCRD is a good complementary tool for Type III operators to strengthen their programme instructions. Several aspects for improvement and necessary common agreements between operators are listed to assure consistent PCR alignment.

As regards the comparison of PEF with EUF, few similarities and many divergences between the two approaches are noted. PEF is a relative approach and provides information on the potential life cycle environmental impacts, whereas the Type I ecolabel criteria are issue-specific and do not necessarily cover the complete life cycle of the product. Further, three perspectives are examined: PEF, EUF and Joint. The first two explore scenarios for mutual integration and co-existence between PEF and EUF. The joint perspective proposes a concept for an LCA-based hybrid ecolabel, building upon the synergies between a classic Type I and a Type III. The Type IV ecolabel, as called, allows for an overall harmonized and improved communication both on B2B and B2C level.

This thesis contributes to the scientific work on the enhancement of ecolabels characterization and harmonization. Its significance and actuality are justified by the current developments in standardization of ecolabels and communication of environmental information on both international and European level. The developed ecolabel characterization scheme is applicable for variety of cases and users; it is also considered as a foundation for improved ecolabels classification. As regards harmonization, the proposed Type IV hybrid ecolabel is an example of an action for reducing the proliferation of ecolabels.

Keywords: environmental communication, ecolabel, characterization, harmonization, Life Cycle Assessment, hybrid approach, Type IV

List of abbreviations

B2B	Business-to-Business
B2C	Business-to-Consumer
C2C	Cradle to Cradle
CAF	Conformity Assessment Form
EC	European Commission
EPD	Environmental Product Declaration
EU	European Union
EUF	European Flower (the European Ecolabel)
GPCRD	Guidance for Product Category Rules Development
GPI	General Programme Instructions
GPP	Green Public Procurement
ISO	International Organization for Standardization
LCA	Life Cycle Assessment
PCR	Product Category Rules
PEF	Product Environmental Footprint
PEFCR	Product Environmental Footprint Category Rules
SDG	Sustainable Development Goal
SIP	Sustainable Industrial Policy
SPC	Sustainable Production and Consumption
TS	Technical Specification

List of publications

The peer-reviewed journal publications used as a foundation of the present thesis are listed in the following. They are not chronologically ordered, but follow the sequence of their use in the thesis.

Publication 1 **(Minkov et al. 2019a):**

> Minkov N, Lehmann A, Winter L, Finkbeiner M (2019) **Characterization of environmental labels beyond the criteria of ISO 14020 series.** Int J LCA 22 8:1744. https://doi.org/10.1007/s11367-019-01596-9

Publication 2 **(Minkov et al. 2018):**

> Minkov N, Bach V, Finkbeiner M (2018) **Characterization of the Cradle to Cradle Certified™ Products Program in the Context of Eco-labels and Environmental Declarations.** Sustainability 10 3:738. https://doi.org/10.3390/su10030738

Publication 3 **(Minkov et al. 2015):**

> Minkov N, Schneider L, Lehmann A, Finkbeiner M (2015) **Type III Environmental Declaration Programmes and harmonization of product category rules: status quo and practical challenges.** J Clean Prod 94:235–246. https://doi.org/10.1016/j.jclepro.2015.02.012

Publication 4 **(Minkov et al. 2019b):**

> Minkov N, Lehmann A, Finkbeiner M (2019) **The Product Environmental Footprint communication at the crossroad: integration into or co-existence with the European Ecolabel?** Int J LCA 10 8:2898 https://doi.org/10.1007/s11367-019-01715-6

Contents

1 Introduction

The environmental qualities that a product holds are credence attributes of the product – such that cannot be seen or experienced by the user (Darby and Karni 1973). This environmental information is usually available, but only known by the producer, which leads to asymmetry between the demand side and the provision side (Roe et al. 2014). In order to cope with this, consumers and purchasers need external support that they can trust (Clift et al. 2005, Rubik and Frankl 2005). This is intended by product environmental labelling – a key instrument for making sustainable purchasing decisions (ISO 2019a).

1.1 Background and motivation

In the recent decades, the overall environmental importance of products has grown. The constantly increasing amount and varieties of products in the world marketplace are leading to an increasing share of the product-related environmental impacts. Moreover, due to the continually developing complexity of the supply chains of products, emissions tend to have non-point sources, in comparison to the past (Rubik and Frankl 2005). In this regard, in 2003, the European Commission (EC) adopted the Integrated Product Policy (IPP) of the European Union (EU) (EC 2003). It lays on the belief that environmental degradation is caused by a product no matter if the degradation comes from the production, use or disposal (Rubik and Frankl 2005). IPP's intention is to minimize the negative impacts by taking an integrated life cycle approach, applying market-based and voluntary instruments and involving a variety of supply chain actors and stakeholders (Ernst&Young 1998, EC 2003). This naturally led to increased consideration and interest in the overall environmental life cycles of products (Rubik and Frankl 2005).

In 2008, the EC presented a strategy to support the integrated approach of the EU, and internationally, to further sustainable consumption and production, called Sustainable Consumption and Production and Sustainable Industrial Policy (SCP/SIP) Action Plan (EC 2008). It builds upon the IPP and proposes a dynamic framework based on a combination of mandatory "push" and voluntary "pull" instruments (Cordella et al. 2019). Among the voluntary actions, the improvement of the communication of environmental

information of products to the consumers through product labelling is comprised; thus, stimulating each actor along the supply chain to improve their environmental performance.

On a broader scale, the communication of environmental information through labelling is among the instruments that are an integral part of the EU's international commitments to work towards the achievement of the 2030 Agenda for Sustainable Development and the 17 Sustainable Development Goals (SDGs) (UN 2015). A particularly relevant goal is SDG 12 on "Responsible Consumption and Production". It focuses on SCP and aims at integration of sustainability information into the reporting cycles of companies (SDG 12.6). It should also ensure that people "have the relevant information and awareness for sustainable development and lifestyles in harmony with nature" (SDG 12.8) (UN 2019).

Environmental labels and declarations (called "ecolabels" for short, see Box 1) are voluntary or mandatory instruments that provide information related to the environmental performance of products, be that goods or services (Bratt et al. 2011, Rubik and Frankl 2005). Ecolabels are especially useful when developed in conjunction with certain policy initiatives (UN 2005). The concept of ecolabelling suggests reduced negative environmental impacts achieved through enhanced sustainable consumption by substituting less environmental-friendly consumption practices with such that are less harmful (Horne 2009, Lavalle and Plouffe 2004). Their role in this process is to be a medium for provision of transparent and robust information and proof of compliance, since ecolabels say little about consumption themselves.

Reliability, trust and credibility of an ecolabel are of fundamental importance when conveying information between producers, retailers and consumers (Rubik and Frankl 2005). Therefore, it is crucial to have the methodologies to set up and operate an ecolabel laid down as rules in e.g., standards. The topic of standardization often comes up when ecolabelling is concerned. Standardization can overall be defined as a form of regulation that aims to impose certain voluntary technical specifications to harmonize different existing international practices for production and exchange of products (Lavalle and Plouffe 2004). Being a form of a non-state authority, the International Organization for Standardization (ISO) for example, has spread their expertise over many fields, including environmental management and in particular – communication of environmental product information. Already since the end of the 90's, ISO is supporting a typology classification

on voluntary ecolabelling based on the ISO 14020-series of standards. ISO 14020 (2000) sets the general principles on environmental labels and declarations. Three particular typologies are then defined in three individual standards: ISO 14024 (2018) on Type I ecolabels, ISO 14021 (2016) of Type II self-declared environmental claims and ISO 14025 (2006a) on Type III environmental product declarations. The latter are designated more for professional purchasers (business-to-business, B2B), whereas Type I ecolabels target at end-consumers (business-to-consumer, B2C). Both Type I and III shall undergo third-party verification, while for Type II self-declared claims this is not mandatory.

Box 1. Adopted definitions for "environmental product information"

A general definition of ISO 14020 states that an **environmental label** or **environmental declaration** is a "claim which indicates the environmental aspects of a product or service" (ISO 2000).

In this work, a mutual term **ecolabel** is adopted to indicate all varieties of environmental claims, environmental labels, environmental declarations or other environmental product information used for communication to both B2B or B2C. When a more detailed specification of the definition is needed, it is indicated in the text and a reference to the respective standard is given, if relevant. For example, in this work:

- a **Type I ecolabel** is a term specifically used for an ecolabel that is conformant with ISO 14024, i.e. "a label which identifies overall environmental preference of a product (i.e. good or service) within a product category based on life cycle considerations" (GEN 2004)
- a **Type III environmental declaration** or an **Environmental Product Declaration (EPD)** are terms used for an LCA-based declaration conformant with ISO 14025, i.e. a declaration that provides "quantified environmental data using predetermined parameters and, where relevant, additional environmental information"(ISO 2006a)
- a **Type III-like declaration** or **LCA-based declaration** are terms used for any LCA-based, Type III-like communication document, other than conformant with ISO 14025

As already discussed, the consideration of the life cycle in product policies is of increasing interest in the recent years. Same applies when it is discussed in the context of communication of environmental product information and ecolabelling. For example, a bottom-line principle in the elaboration of awarding criteria of Type I ecolabels for new product groups is the consideration of the whole life cycle (Spengler et al. 2019). EC's Ecolabel Directive (EC 2010) that governs the European Ecolabel (or EU Flower, EUF) – the European Type I ecolabel – goes a step further and already prescribes that ecolabel criteria shall be based on new or existing Life Cycle Assessment (LCA) studies, in order to assure that all relevant environmental hotspots are identified. LCA is a proven method for the assessment of the potential environmental impacts of products or services along their complete life cycle and it is constituted by the standards ISO 14040 (2006b) and ISO 14044 (2006c). As far back in 2003, LCA has been acknowledged by EC's IPP as "the best framework for assessing the potential environmental impacts of products" (EC 2003) –a common agreement nowadays worldwide (Finkbeiner et al. 2014).

Type III declarations go beyond the requirements for Type I and require the evaluation of each product to be based on an LCA study, which is conducted according to pre-defined Product Category Rules (PCR). Type III declarations are acknowledged as a successful LCA-based tool for communication of the environmental performance of products. Their application and the interest of stakeholders, respectively, are constantly on a rise in the last years (Hunsager et al. 2014, Ibáñez-Forés et al. 2016, Del Borghi et al. 2019).

Despite the common understanding among scientific peers that transparency and credibility of ecolabels require a life cycle perspective of their awarding criteria (see e.g., Laballe and Plouffe (2004), Bratt et al. (2011), Jungbluth et al. (2012), Lasvaux et al. (2014), Del Borghi et al. (2019)), an application expansion of LCA into other ecolabels than Type III is barely observed. In this regard, the Product Environmental Footprint (PEF) initiative of the EC is under testing and development since 2010. It is an action undertaken in realization of the SCP/SIP Action Plan to create an LCA-based method to measure and communicate the life cycle environmental performance of products and organisations (EC 2013a). How exactly PEF will be operationalized is still unclear (Bach et al. 2018); nevertheless, the EC considers PEF as a possible methodological basis for determination of life cycle impacts in creation of awarding criteria for the EUF (Galatola 2019, Spengler et al. 2019). Communication to external stakeholders (both in B2B and B2C) is listed

among the potential options in the latest version of the PEF method (Zampori and Pant 2019). On a EU Member States level, Italy is an example of a country that recommended in the development of their national action plan on green public procurement (GPP) to use ecolabels that are compliant with PEF (Del Borghi et al. 2019).

1.2 Gaps and challenges

In the previous chapter, the means for and the usefulness of communicating environmental product information through ecolabels is given, including the rationale to apply life cycle considerations and LCA in ecolabelling. Nevertheless, in today's reality the number and variety of ecolabels are enormous, as they serve particular needs and operate in particular market environments (Dendler 2014). It is a (sad) reality that often ecolabels are used by organizations for greenwashing to promote their products, aims or policies as environmental-friendly (Shahrin et al. 2017). This leads to "[eco]-label fatigue" (Williams 2004). Due to the profusion of the many ecolabels that are tangibly increasing since the beginning of the 2000's (Bratt et al. 2011), consumers are often confused and/or suspicious towards the credibility of ecolabels they see (Brécard 2014). Vague requirements on the disclosure of product environmental information is seen as a potential thread on trade (UN 2005).

However, the scientific and commercial attempts for ecolabel characterization[1] and classification[2] and the respective existing literature are very limited. There is only one official ecolabel classification – the one provided by ISO 14020 series (discussed in Chapter 1.1). Nevertheless, the level of adoption and its appropriateness for the existing market conditions nowadays are in question, because not all variants of ecolabels can be classified under the existing ISO typologies (Galarraga Gallastegui 2002). According to United Nations Environment Programme (UN Environment) (2005) the three ISO typologies are too broad to be used for an objective evaluation of the environmental and trade effects of ecolabels. Back in 2005, they called for a new and more comprehensive methodology for differentiating among the multiple characteristics of ecolabels (UN 2005).

[1] In the context of this work, the term "characterization" stands for the description of the distinctive attributes of an ecolabel; this meaning is different than the one implied in LCA.
[2] In the context of this work, the term "classification" denotes the process of classifying ecolabels into distinct types according to certain attributes.

Apart from ISO, it was the United States Environmental Protection Agency (EPA 1998), Rubik and Frankl (2005) and Horne (2009) that worked on theoretical ecolabel classifications. These studies built upon each other, by mainly dividing ecolabels based on their compulsoriness and operational scope. Gruère (2013) came up with an initial list of criteria to characterize ecolabels in the context of an international overview of environmental labelling. Nevertheless, none of these works has aimed at providing recommendations to ISO on how to improve their existing typologies given the market conditions at the time.

Besides their inadequate classification, the insufficient implementation of life cycle considerations is another critical point of ecolabels (Spengler et al. 2019). Mono-criteria and non-verifiable practices that do not consider any life cycle perspective are widely used in ecolabelling. What makes them so attractive is that they are less resource-demanding for the producer and often easier to understand by the consumer. The multiplicity of self-declared claims (such as e.g., Type II) compromises the development of LCA-based initiatives (Lavalle and Plouffe 2004). Furthermore, it is reported by some authors that the lack of standardized use of LCA in the awarding criteria development of certain ecolabels leads to irregularities (see e.g., Horne (2009) or Bratt et al. (2011)).

Existing and standardized LCA-based communication initiatives, such as Type III declarations are of high demand, especially in the construction sector (Passer et al. 2015). The increased stakeholder interest and market saturation of Type III operators has led to the issuing of many Type III declarations. However, often declarations for similar products cannot be compared, as they are based on different PCRs (Del Borghi et al. 2008). This sore fact has led to the establishment of initiatives for cooperation between operators, harmonization, and development of common and additional requirements for performing LCAs for Type III declarations. The Guidance for PCR Development (GPCRD) (PCR Guidance Development Initiative 2013) is one of those documents that had a large outreach at the time of its publication, but barely any practical attempts for implementation or scientifically justified criticism have been made ever since.

To a certain extent, PEF has a similar fate. Despite the involvement of tens of stakeholders in each working group and the completion of a pilot phase after over five years, the development of over 20 Product Environmental Footprint Category Rules (PEFCR) for different sectors was not accompanied by a serious scientific debate on how PEF can be

applied in practice. This is especially relevant regarding the missing scientific contributions on PEF as a tool for communication of product environmental information with certain exceptions, e.g., Finkbeiner (2014), Lehmann et al. (2014), Bach et al. (2018) and Del Borghi et al. (2019). Rather, three projects, i.e., EC (2013b), NEF Group (2017) and Lupiáñez-Villanueva et al. (2018) were commissioned by the EC along the years aiming at investigating potential communication options of PEF.

The above shows that in the recent years the existing standardized approaches for communication of environmental product information have not undergone any substantial changes or enhancement, despite the dynamic developments in the market of Type III declarations and the expansion of other "undefined" ecolabels worldwide. Initiatives for handling the proliferation of ecolabels in general seems to be on hold since several years.

Hitherto Chapter 1.1 presented the general background and motivation, followed by the main gaps and challenges related to ecolabel (Chapter 1.2). Next, in Chapter 1.3 the overall structure of the thesis is described.

1.3 Structure of the thesis

This thesis consists of five main chapters (see Figure 1). Chapter 1 "Introduction" presents an exploration in the field and the motivation for this work, including also gaps and challenges in the existing scientific research. In Chapter 2 "Research approach", the overall goal of the thesis, as well as the research questions and related targets are defined. Further, the link between the four grounding publications of the thesis and the research questions and targets is explained. All four publications are presented in Chapter 3 "Results" with an introductory overview of their key results. Chapter 4 "Discussion" summarizes the key findings of the thesis and subsequently discusses the newly defined or remaining methodological or practical challenges. Chapter 5 "Conclusions and outlook" scrutinizes the added value of the thesis findings and suggests paths for future research.

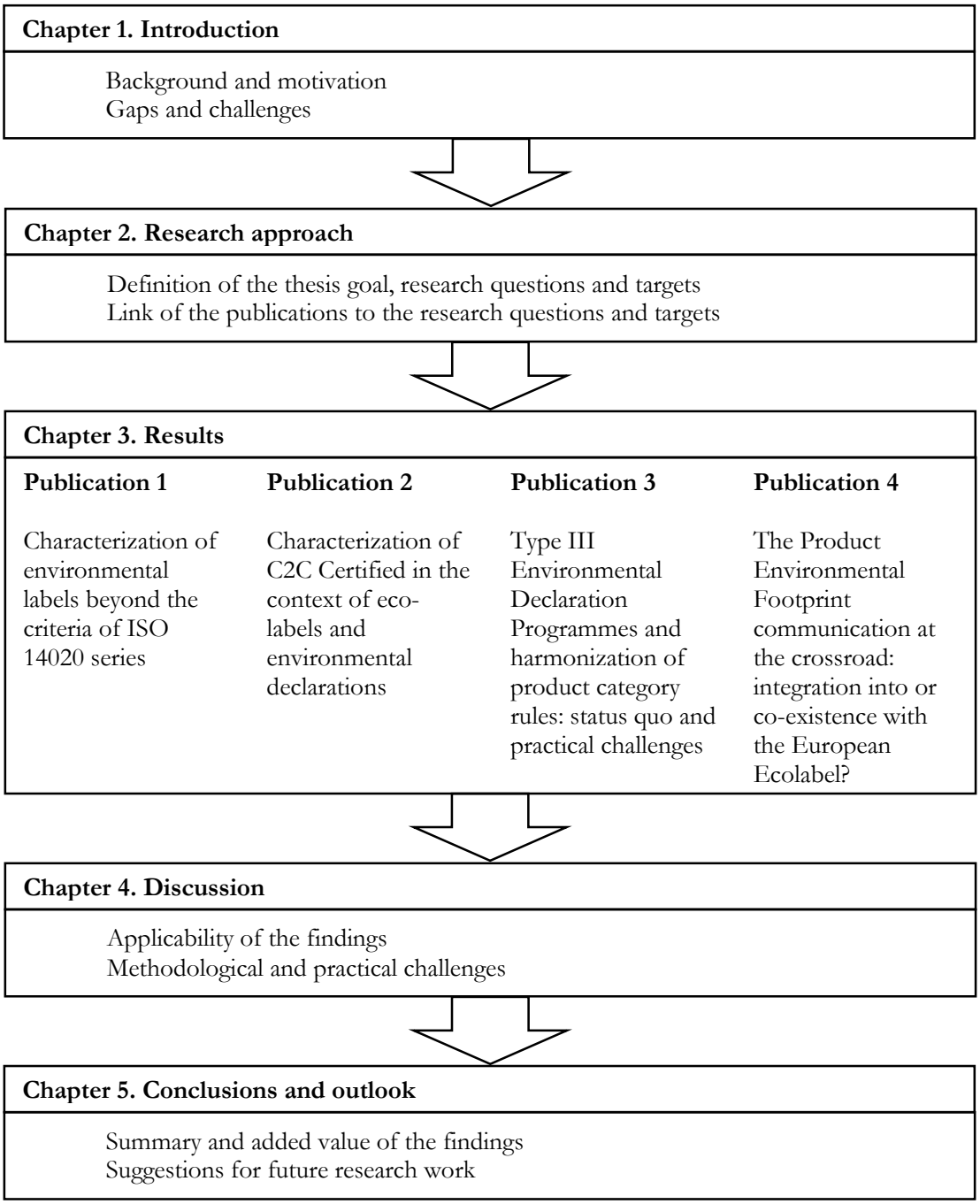

Figure 1. Structure of the thesis

2 Research approach

In this chapter, the overall goal of the thesis is presented, followed by the definition of the specific research questions and respective targets. Further, a link between the defined research questions and targets with the core publications of the thesis is given.

2.1 Goal, research questions and targets

The overall goal of this thesis is to enhance the communication of environmental information of products through improved characterization and harmonization of ecolabels. Two research questions are defined depicting two focus areas, in which research is conducted to reach the overall goal of this thesis. The first one is the area of characterization and classification of ecolabels; the second one is the application of life cycle perspective and LCA for harmonization of ecolabelling. The research questions (RQs) are defined as follows:

RQ1: How to mitigate the gaps in the existing characterization and classification practices for ecolabels?

As addressed in Chapter 1, existing characterization and classification approaches for ecolabels fail to completely cover the many different voluntary ecolabels. Thus, within this thesis, after gaps of the current approaches are identified, a scheme for the characterization of ecolabels is developed and applied in a case study. The learnings from this process are further used for the establishment of a set of recommendations to ISO for the improvement of their currently existing ecolabel classification.

RQ2: How is LCA applied to ecolabels and how can LCA-based approaches contribute to the overall improvement of B2B/B2C communication and harmonization of ecolabels?

As addressed in Chapter 1, the advantages of using environmental claims and ecolabels that apply a life cycle perspective are indisputable. Nevertheless, questions related particularly to the application of LCA in ecolabels are still partly open, also due to the formerly missing operational way to characterize ecolabels. Hence, this thesis sheds light

on how LCA is generally employed in ecolabels and on the trends in the uptake and application of existing LCA-based, Type III-like declarations and the practices for their harmonization. Further, a concept for an LCA-based hybrid ecolabelling approach is proposed, allowing for a harmonized and improved overall communication both to B2B and B2C.

The two research questions are further detailed by the definition of 10 research targets, allocated to each research question, as follows:

RQ1: How to mitigate the gaps in the existing characterization and classification practices for ecolabels?

1.1 Development of an ecolabel characterization scheme for ecolabels based on distinctive attributes

1.2 Recommendations to ISO for enhancement of their existing ecolabel classification

1.3 Characterization of C2C Certified in a case study as a tool for external communication by applying the characterization scheme

1.4 Optimisation and improvement of the characterization scheme based on the case study

RQ2: How is LCA applied to ecolabels and how can LCA-based approaches contribute to the overall improvement of B2B/B2C communication and harmonization of ecolabels?

2.1 Overview of the distribution and trends in development of programmes for LCA-based declarations worldwide

2.2 Revision of the available approaches for PCR harmonization for LCA-based declarations

2.3 Road-testing guidelines for PCR harmonization

2.4 Investigation of the synergies and gaps between the LCA-based PEF and a typical Type I ecolabel – the EUF

2.5 Analysis of scenarios for co-existence and mutual integration of PEF and EUF

2.6 Proposal for a hybrid ecolabel – Type IV – based on the interfaces between PEF and EUF

2.2 Link of the publications to the research questions and targets

The foundation of this cumulative doctoral thesis are four peer-reviewed journal publications (see List of publications). Each of the research targets listed in the previous chapter is addressed by at least one of the four publications. In Table 1, the publications are mapped to the research questions and targets.

Table 1. Link between the publications and the research questions and targets

Research question	Research target	Publication			
		1	2	3	4
RQ1: How to mitigate the gaps in the existing characterization and classification practices for ecolabels?	1.1 Development of a characterization scheme for ecolabels based on distinctive attributes	X			
	1.2 Recommendations to ISO for enhancement of their existing ecolabel classification	X			
	1.3 Characterization of C2C Certified in a case study as a tool for external communication by applying the characterization scheme		X		
	1.4 Optimisation and improvement of the characterization scheme based on the case study		X		
RQ2: How is LCA applied to ecolabels and how can LCA-based approaches contribute to the overall improvement of B2B/B2C communication and harmonization of ecolabels?	2.1 Overview of the distribution and trends in development of programmes for LCA-based declarations worldwide	X		X	
	2.2 Revision of the available approaches for PCR harmonization for LCA-based declarations			X	
	2.3 Road-testing guidelines for PCR harmonization			X	X
	2.4 Investigation of the synergies and gaps between the LCA-based PEF and a typical Type I ecolabel – the EUF				X
	2.5 Analysis of scenarios for co-existence and mutual integration of PEF and EUF				X
	2.6 Proposal for a hybrid ecolabel – Type IV – based on the interfaces between PEF and EUF				X

Below, an introduction to the research approaches of each of the four publications is given. Their methodological steps are described and a linkage to the respective research questions and targets of the thesis is given.

The first publication **(Minkov et al. 2019a)** contributes to answering the first research question, by meeting Targets 1.1 and 1.2, and also supporting Target 2.1 of the second research question. As an initial step, a literature review regarding characterization and classification approaches for ecolabels is conducted, in order to identify the status quo and existing gaps. In parallel, a representative ecolabel sample is established, using forest and paper products as a common product category to shortlist among the many existing ecolabels. Awarding criteria and content analysis of the sampled ecolabels and identification of attributes that characterize them is further conducted. This is done by using the collected literature, such as guiding rules and awarding criteria of the shortlisted ecolabels, as well as other scientific and commercial publications. The identified ecolabel attributes and their options are further summarized in an initial list. Through an iterative process they are then used to characterize each shortlisted ecolabel from the sample. As a result, the attributes and their options are refined and classified in a scheme for ecolabels characterization based on thematic similarities. This contribution meets Target 1.1 of the thesis. With the gained knowledge from the literature review on the existing classification and characterization of ecolabels and with the characterization of each ecolabel from the sample with the help of the characterization scheme, flaws in the existing classification typologies of ISO are identified and a list of recommendations for their enhancement is elaborated, meeting Target 1.2. The obtained information from the characterization of the sampled ecolabels also supports the achievement of Target 2.1.

The second publication **(Minkov et al. 2018)** addresses the first research question by meeting Targets 1.3 and 1.4. Overall, it supports the outcomes of the first publication by testing and providing an updated version of the ecolabel characterization scheme. As a first step, an appropriate case study example is selected to test the applicability of the scheme. Through an additional analysis of the ecolabel sample from the first publication and by additional literature research, the Cradle to Cradle Certified™ Products Program (C2C Certified for short) is selected. Arguments in favour of this selection are the controversial opinions of stakeholders regarding the performance of C2C Certified as a tool for communication of environmental information. By using the initial version of the

characterization scheme, C2C Certified is first analysed against the established Type I and Type III ecolabel typologies by ISO. Further, the same process is repeated, but with concrete examples of Type I and Type III ecolabels within a specific sector, obtaining a complete overview of the performance of C2C Certified as a tool for external communication of environmental product information (Target 1.3). The selection of the Type I and Type III ecolabel examples is done based on shortlisting criteria, explicitly created for this purpose. This way, the more explicit analysis of the three initiatives based on the characterization scheme allows for identifying additional characterization attributes and optimizing others. This upgrade of the characterization scheme meets Target 1.4 of the thesis.

The third publication **(Minkov et al. 2015)** fulfils the first three of the research targets set to answer the second research question (namely Targets 2.1, 2.2 and 2.3). In contrast to the first publication, where a sample of all types of ecolabels is established, here a literature review is conducted, focused on identifying only the existing LCA-based initiatives for Type III-like environmental declarations on a global scale. To meet Target 2.1 of the thesis, criteria based on the bottom-line provisions of ISO 14025 on the establishment of Type III environmental declaration programmes are used to evaluate all identified initiatives by analysing their year of foundation, scope of operation and current activity. As an additional step, again based on the conducted literature review, published literature and existing approaches regarding harmonization of PCR are examined and described, meeting Target 2.2, and depicting an overall picture of the dynamics on the market related to Type III-like initiatives. Out of these, three approaches are shortlisted and additionally examined. GPCRD is tested by aligning a draft PCR with their requirements and evaluating the usefulness of the Guidance to facilitate the development of aligned PCR in a consistent manner. The Guidance's supplementary Conformity Assessment Form (CAF) is used to track the PCR conformity in the alignment process. This successful road test of the GPCRD contributes to meeting Target 2.3.

The fourth publication **(Minkov et al. 2019b)** is a further research step, based on the findings of the third publication. It contributes to achieving the last three targets of the second research question (namely, Targets 2.4, 2.5 and 2.6) and it also partially contribute to Target 2.3. One of the most commented LCA-based initiatives nowadays is PEF. Although it is not considered a participative harmonization initiative, it is assumed

important to analyse its potential for PCR harmonization purposes (Target 2.3). Thus, its interfaces with a typical Type I ecolabel – the EUF – are investigated. A procedure for evaluation of the interface between the two selected initiatives is established and applied to three pre-selected product groups, for which both PEFCR and EUF ecolabel awarding criteria exist. The reciprocal analysis of the complements, resemblances, and differences of PEF and EUF is conducted based on five topics with several guiding questions per topic. The EUF awarding criteria for each product group are assigned to each life cycle stage, as defined by the respective PEFCR, established for the particular product group. The most relevant life cycle stages, process and life cycle impacts defined in the PEFCR are indicated and compared with the ecolabel criteria. This procedure serves to fulfil Target 2.4 of the thesis. With the information obtained by the reciprocal analysis, as a next step, three different perspectives are examined: PEF-, EUF- and Joint perspectives. Each explores scenarios for mutual integration and/or co-existence between the two approaches, thus meeting Target 2.5. Whereas the first two perspectives describe scenarios on how one initiative could benefit from adopting (parts of) the other, the third – joint perspective – conceptualizes a novel approach that intends to use the advantages of both the PEF and EUF in creating a hybrid ecolabel, called Type IV. It allows for a simultaneous evaluation, communication and awarding the product's environmental performance for both B2B and B2C use (Target 2.6).

3 Results

This chapter presents the main results of the thesis, i.e. the four publications. Each sub-chapter begins with a summary of the results of each publication.

3.1 Characterization of environmental labels beyond the criteria of ISO 14020 series

This chapter contains the following publication **(Minkov et al. 2019a):**

> Minkov N, Lehmann A, Winter L, Finkbeiner M (2019) **Characterization of environmental labels beyond the criteria of ISO 14020 series.** Int J LCA 22 8:1744. https://doi.org/10.1007/s11367-019-01596-9

In this publication, a representative ecolabel sample is established, consisting of 45 ecolabel initiatives from 27 countries and the EU, having time representativeness from 1978 to 2013. The ecolabels in the sample are shortlisted from a public database that consists of over 460 ecolabels worldwide by narrowing the scope to such that cover forest and paper products. The sample is not limited to any particular typology of ecolabel, but the opposite – it strives for variety. Further, by an iterative process of working with the ecolabel sample and the relevant literature sources, an ecolabel characterization scheme is established. This first version consists of 18 attributes, each one having between two and five options to select between. For example, the attribute "End-user focus" consists of three options: "B2C", "B2B" or "both". The attributes are grouped in four categories, namely Communication characteristics, Standard characteristics, Life cycle characteristics and Conclusive characteristics. The ecolabel characterization scheme is fine-tuned and upgraded at a later stage as a result of a case study, presented in the second publication (Chapter 3.2).

The analysis of the ecolabel sample against the proposed characterization scheme reveals that nowadays the existing typology classification provided by the ISO 14020 series does not properly serve as a classification and differentiation medium for ecolabels anymore. Regarding ecolabels Type I or Type III, ISO is explicit and their requirements (including

how to apply LCA) are well respected. However, ecolabels that can be assigned to typical Type I and Type III are in practice very few as a share of the whole ecolabel population. Moreover, apart from Type III, 40% of the other initiatives that on first sight indicate to apply LCA in their awarding criteria development or product assessment, transpires to be wrong. This raises the question of the potential misuse of the term "LCA" by ecolabel operators for attempting to derive benefits on its account. Furthermore, approximately 60% of the explored ecolabels in the sample do not declare any ISO typology, whereas none assigns to Type II classification. These "undefined" ecolabels, as referred to as, apply different awarding formats and criteria in combinations and forms that are not recognized and described by ISO or any other known classification approach.

Ultimately, a list of recommendations to ISO for the enhancement of their existing typology classification for ecolabels is elaborated on seven different topics, namely Awarding format, Aspects diversity, Operation scope, Verification, Reconsideration of the usability of ISO 14021, New ISO classification and Improved transparency as an indirect outcome of a stricter ISO classification.

The supplementary material to this publication is presented in Appendix A.1. It contains the ecolabel sample – the list of ecolabels, related information (e.g. country of origin, year of foundation, etc.) and how they are characterized, based on the first version of the characterization scheme with 18 attributes. Further, an excerpt of the sample is provided on how the sampled ecolabels respond to each attribute and their options.

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THE FUTURE OF ECOLABELS

Characterization of environmental labels beyond the criteria of ISO 14020 series

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Abstract

Purpose ISO 14020 series of standards provide guidance for establishing ecolabels and a classification based on three label types, I, II, and III. They also determine the consideration of product's life cycle and application of the life cycle assessment (LCA) in ecolabeling. Still, the large number and variety of existing ecolabels has led to consumer confusion in the recent years. The objective of this paper is to propose a characterization scheme for ecolabels and to provide recommendations for the enhancement of existing ecolabel classification, questioning the current sufficiency of ISO.

Methods To reach the objective, we first create a sample of ecolabels covering forest and paper products as an example, to narrow down the enormous number of existing ecolabels (over 460 as of August 2018). Second, we analyze their content, purpose, and awarding criteria through a desk research. In parallel, scientific publication, reports, and standards are also analyzed. Third, based on the obtained information, we define a list of ecolabel characterization attributes and their options and observe tendencies in ecolabel development. Ultimately, based on the outcomes of the proposed characterization scheme, we give recommendations for enhancement.

Results and discussion Ultimately, we compare a sample of 45 ecolabels against 18 attributes of the proposed characterization scheme, including, among others, their ISO typology, life cycle perspective, awarding format, covered environmental aspects, and scope. Regarding type I or type III label, ISO seems to be explicit and their requirements are well respected, including how LCA is to be applied. However, approximately 60% of the explored ecolabels in our sample did not declare any ISO typology, whereas none assigned a type II classification. These "undefined" ecolabels, as we call them, apply different awarding formats and criteria in combination and hybrid forms that are not recognized and described by ISO or any other observed classification approach. Misuse of the term "LCA" is also perceived in such "undefined" initiatives.

Conclusions We conclude that the current ISO standards on ecolabels belittle the consequences that the increased number of undefined ecolabels brings. We provide a list of recommendations for the enhancement of the current ISO classification in seven topics, namely, awarding format, aspects diversity, operation scope, verification, reconsideration of the usability of ISO 14021, new ISO classification, and transparency. Limitations of the study and outlook conclude the work.

Keywords Characterization · Ecolabel · Environmental labeling · Forest and paper products · ISO

1 Introduction

The labeling of products is recognized as an action of an organization to communicate product-specific information to customers and end-users (Roe et al. 2014). In this context, many consider environmental labels (or ecolabels) a suitable tool to improve production and consumer decision-making, as ecolabels provide valuable information when considering the environmental qualities of a product (Bratt et al. 2011). Environmental qualities are often credence characteristics of products, i.e., the user cannot determine them by simple inspection or experience or they are expensive to judge even

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after purchase (Darby and Karni 1973; Bougherara et al. 2005).

However, as shown further in this paper, nowadays, ecolabels are often developed on an individual and independent basis. They serve particular needs, markets, and credence products and have different awarding approaches and criteria. Thus, different ecolabels exist worldwide. This profusion can lead, on one hand, to consumer confusion given the multiplicity of information formats (OECD 1997; Dendler 2014; Janßen and Langen 2017; Brécard 2014), and, on the other hand, to overlap and antagonize between environmental labels and label types (Allison and Carter 2000; Banerjee and Solomon 2003; Engels et al. 2010; Goossens et al. 2017; Horne 2009).

1.1 Environmental labels and the role of ISO

As ecolabels serve different communication purposes and consist of different formats, the International Organization for Standardization (ISO) provides general definitions and principles for the establishment of voluntary ecolabels through the standard ISO 14020 (ISO 2000). Furthermore, three broad types of voluntary labels have been defined through the following standards, which are as follows:

1) ISO 14024 (ISO 2018) on type I environmental labels or ecolabels—these are multi-criteria-based, third-party-verified labels awarded to products that fulfill certain product environmental criteria based on life cycle considerations;
2) ISO 14021 (ISO 2016) on type II environmental labels, known as self-declared environmental claims, issued in the form of a claim, stamp, label, or declaration; and
3) ISO 14025 (ISO 2006a) on type III environmental declarations, known also as Environmental Product Declarations (EPD). These are third-party verified, quantitative declarations based on a Life Cycle Assessment (LCA) of the product, according to ISO 14040 (ISO 2006b) and apply Product Category Rules (PCR) that are designed specifically for the particular product group in focus.

Being internationally recognized and accepted, these three types have existed for almost 20 years now without being substantially modified (despite the updates of ISO 14021 and ISO 14024 in 2016 and 2018, respectively, when only minor revisions were undertaken). By revising the existing literature, a question has arisen whether the current ISO typology is sufficiently covering all varieties of existing ecolabels and their multiple characteristics. Galarraga Gallastegui (2002) identified weaknesses in the current type I labeling schemes, among which the lack of sufficient categories for the classification of the different types has been pointed out. The United Nations Environmental Program (UNEP) called upon an improved classification framework for ecolabels beyond the existing "superficial" ISO levels to catalyze their better understanding (UNEP 2005). Cobut et al. (2012) gave the example of the Forest Stewardship Council (FSC) label, which was considered as a type I label in their study, although they stressed that it is not a multi-aspect label (a core principle of type I labels, according to ISO 14024), but certifications undergo a third party review and cover key environmental issues. Similar to their outcomes, a publication by the Organization for Economic Co-operation and Development (OECD) concluded that the current ISO typology fails to represent the full diversity of ecolabels nowadays and that all further efforts of ISO on looking at additional standards to cover all types of environmental labels have been concluded (Gruère 2013). The study concluded that the diversity and unequal growth in the increase of ecolabels were driven by the combination of "traditional" labels (e.g., type I) and "more recent" types.

1.2 Other classification approaches

Prior to the publication of the first versions of ISO 14020 series, a study by the United States Environmental Protection Agency (US EPA) (see EPA 1998) provided a classification according to a number of attributes, e.g., operation scope, verification, and compulsoriness (we further describe these in Section 3.1.6, Section 3.1.10, and Section 3.1.11, respectively). In 2005, Rubik and Frankl (2005) proposed a classification based on the compulsoriness of ecolabels. Building on their findings, a study conducted by Horne (2009) also proposed a classification founded on the compulsoriness of the labels, but with focus on product sustainability and routes to sustainable consumption. Additionally, the OECD (Gruère 2013) provided characterization criteria in the context of an international overview of environmental labeling. The study at hand builds upon their findings. Nevertheless, none of these classification approaches have aimed at or have achieved the substitution of ISO typologies as a classification system applied in practice.

1.3 Objectives of the study

Given the extensive literature on the profusion of ecolabels and consumer confusion, there is still a sparse scientific contribution on improving the characterization and classification of ecolabels. Therefore, this work aims at proposing a characterization scheme for ecolabels and at providing recommendations for the enhancement of ecolabel classification. This is based on a list of attributes for the description of ecolabels and builds on the classification approaches listed in Section 1.2. In this paper, we use the term "attribute," defined by the Oxford Dictionaries (2018) as "a quality or feature regarded as a

characteristic or inherent part of something," i.e., of an ecolabel. An attribute in this work is considered as a synonym of a characteristic.

The two-fold objective of this paper aims to contribute to both the science and practice by developing a scientifically sound approach for ecolabel characterization and by proposing improvements in the classification used by stakeholders. We reach the objective by fulfilling the following research tasks:

1) Development of a representative ecolabel sample;
2) Content and criteria analyses of the sampled ecolabels and attribute identification;
3) Characterization scheme setting and recommendations for the enhancement of ecolabel classification.

Section 2 describes the method undertaken to achieve the research tasks. Section 3 shows the results, overviews the proposed characterization scheme, and ultimately provides recommendations for the enhancement of ecolabel classification based on the identified challenges. Section 4 provides the conclusions and outlook.

2 Methods

This paper represents an analytical study based on an online desk research. The following sub-sections describe the steps undertaken to reach the proposed research tasks.

2.1 Development of a representative ecolabel sample

As a first step, we created a list of 91 ecolabels, shortlisted out of the online Ecolabel Index database (Big Room Inc. 2018), being the largest free ecolabel directory that contains over 460 entries (as of August 2018). We narrowed down the many environmental labels by focusing only on the ones that assert to certify products under the category "Forest products/Paper." The category was predefined by the database, and we used it as a search term. We selected paper and forest products (used for paper products) as an exemplary product group that consists of a complex supply chain, several manufacturing steps, and intermediate and final products. Consequently, the stakeholder spectrum was recognized to be very broad, suggesting that many different ecolabels could be found along the supply chain.

We assumed that by limiting the excerpt to a certain product group, we would risk missing out on covering ecolabels with important qualities for completing the list of attributes for ecolabel characterization. Thus, being aware that this could be a biased choice, as a second step, we added five complementary labels in our analysis, which would normally not fit under this product category (e.g., EU Energy label). The additional labels considered were either new initiatives with the potential to become relevant for the market (e.g., The European Product Environmental Footprint, PEF[1]) or they held certain attributes that were important to be discussed herewith, but not those possessed by any of the preselected labels (e.g., WindMade).

Ultimately, due to the lack of access to information (e.g., published documentation or operational webpages), English or German translation, general inactivity of the program, or duplication, i.e., same ecolabel multiplied in different countries, the final list was reduced to 45, including the five complementary ones. The complete ecolabel sample that we worked with and the information on the data collection can be found in the Electronic Supplementary Material, sheet "Database." The sample contains initiatives introduced between 1978 and 2013, covering 27 countries and the European Union and grouped in four categories.

Three ecolabels of the sample were dedicated only to paper products, while another four were related to forest management (including chain of custody certification). The rest were categorized as multi-sectorial labels (see Section 3.1.5), also covering forest and paper products. This list included four type III programs. In addition, PEF was included with the pilot study on "Intermediate paper product". PEF and one type III program (i.e., FP Innovations) were taken from Minkov et al. (2015), since they were not listed in the Ecolabel Index database.

2.2 Content and criteria analyses of the sampled ecolabels and attribute identification

To identify the attributes for ecolabel characterization, three steps were undertaken. First, through an online desk research, we reviewed 90 documents—mostly scientific publications, but also reports and standards—to study the development of and challenges related to ecolabels and to compare existing classification and characterization approaches. This includes the ISO criteria and principles regarding environmental labels. The obtained information was used to support the motivation, formulate the research objectives, and back the final recommendations. Nevertheless, only four of the identified documents related to ecolabel characterization and classification (listed in Section 1.2).

Scientific literature was collected through the scientific citation indexing service "Web of Science[2]" by using the predefined search terms "ecolabel," "environmental label," "environmental claims," "labeling scheme," and "ecolabel

[1] According to Bach et al. (2018), the PEF initiative is currently in transition phase until 2021 and it is not yet decided what the outcome would be used for, e.g., an ecolabel or something else. However, it aims at the development of a harmonized environmental footprint methodology, including the communication of environmental performance based on relevant criteria (EC 2013; Lehmann et al. 2016)

[2] https://webofknowledge.com/

classification." Other documents like standards, guidelines, or reports were also identified by internet searches with identical keywords. Program documentation and guidelines for the overall administration and operation of the shortlisted 45 ecolabels were obtained by an online search through their webpages. No publication time restrictions were applied to the overall desk research.

Second, we analyzed the selected ecolabels by exploring the content of their program guiding rules and awarding criteria, looking for distinctive attributes and their options. Based on these outcomes and the findings of the identified studies from the past that relate to ecolabel characterization and classification, we elaborated an initial list of attributes, from which ecolabels could be characterized. For multi-sectorial labeling programs (e.g., Blue Angel), we reviewed the awarding criteria that related only to forest and paper products.

Third, once an initial list of attributes was created, we further refined them by, e.g., excluding or merging certain attributes or certain options of an attribute. This was an iterative process of additional desk research and working individually on each considered ecolabel in a greater detail. Lastly, we defined categories, based on thematic similarities to classify the attributes, thereby to improve their presentation.

All attributes and their respective options are individually discussed in Section 3.1 supported with data for the distribution of ecolabels from the sample.

2.3 Characterization scheme setting and recommendations for enhancement of ecolabel classification

Subsequently, we summarized the identified attributes and their options together in a form of a characterization scheme. The scheme was, then, applied to the ecolabel sample and juxtaposed with the existing ISO typology (see Section 3.2). A detailed description of each ecolabel according to the defined attributes and the characterization scheme is given in the Electronic Supplementary Material, sheet "Database." Based on the information gained, we, then, identified gaps and challenges and gave recommendations for the enhancement of ecolabel classification (see Section 3.3).

Figure 1 gives a schematic overview of the steps undertaken to achieve the objectives of the paper.

3 Results and discussion

The following sections describe and discuss the results of the study. First, we overview the list of attributes, and, then, we analyze the findings related to each defined attribute individually and their respective options using statistical data from the ecolabel sample. Lastly, we overview the characterization scheme and conclude the section by also identifying the potential gaps and challenges and our recommendations for enhancement.

3.1 Identified attributes for ecolabel characterization

Following the described method in Section 2.2, we established a list of 18 ecolabel characterization attributes, grouped in four categories (see Table 1). Each attribute is individually described in Section 3.1.1 to Section 3.1.18, and, where relevant, the distribution of the respective attribute options per attribute in the ecolabel sample is given. A note has to be made, however, that the distribution shares are influenced by and valid only for the product group we examined.

3.1.1 ISO typology

ISO defines three broad types to classify voluntary labels (see Section 1.1). We, first, observed how these three types were distributed among the examined ecolabels. About a third of the ecolabels were classified as type I, whereas about 10% were type III. Almost 60% did not characterize with any ISO typology. Moreover, no ecolabel was explicitly declared to be type II. This is shown in Fig. 2.

It was not a straightforward decision as to how to determine these undefined ecolabels and whether any of them were typical self-declared environmental claims (i.e., type II) or if they were any others that were different from the three ISO types. On the one hand, as the requirements of ISO 14021 are broad, ecolabels cannot automatically be assigned as type II. On the other hand, some of the ecolabels go beyond the standard's requirements. For example, approximately half of them declare undergoing an independent third-party certification, which according to the standard is not mandatory and already a step further from a regular self-declared claim.

In this regard, certain cases of undefined ecolabels have been addressed by some authors (e.g., Horne 2009; Leire and Thidell 2005; Panainte et al. 2014), by calling them "type I-like" labels, as they bear certain type I qualities, but address only a single environmental aspect or a single product group (see Section 3.1.6 and Section 3.1.8). Similarly, others can be considered as declaration type of statements, but to cover only a single phase of the product's life cycle, thus not qualifying as type III. Nevertheless, we refrained from categorizing them under a specific typology, as there could be many combinations, but we generally called them "undefined" ecolabels and describe their differentiating attributes further in this work.

3.1.2 Awarding format

The awarding format of an ecolabel has an effect on the level of information that the consumers receive and on the way they are likely to interpret this information (EPA 1998; Weinrich and

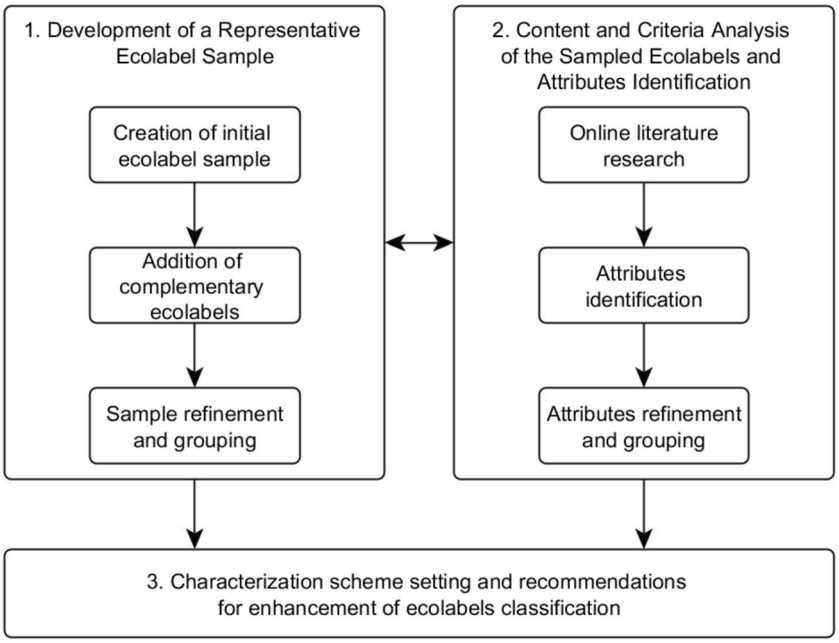

Fig. 1 Description of the method flow

Spiller 2016). Keeping the ISO classification aside, we distinguished three main awarding types and four sub-types out of our examination (described in Table 2 and quantified in Fig. 3).

According to Wu et al. (2014), seal-type ecolabels can be seen as a benchmark, awarding a product that meets the predefined performance criteria. Rating type ecolabels are considered as a newer initiative, implementing different levels of benchmarks (i.e., grades or ranks). These are seen as more comprehensible and provide the most information among other alternatives, such as seal-type ecolabels (Emberger-Klein and Menrad 2018). Weinrich and Spiller (2016) considered rating-type ecolabels as an important tool to promote product differentiation, thus, justifying the eventual increased interest in them by policymakers. Policy regulation or strong retailer commitment would also be needed if rating ecolabels are used to indicate not only the superiority but also the inferiority of products (e.g., a traffic light classification also indicating bad performance) (Thøgersen and Nielsen 2016).

When juxtaposing the ISO types with the complete range of awarding formats that we identified, the classic type I labels conform to the "seal" ones, whereas the type III ones conform to the "non-sealed" declarations. However, what is more interesting, the existent ISO typology approach seems insufficient and fails to cover the many different awarding types that exist and operate on the market nowadays.

3.1.3 Aspects diversity

This attribute examines whether ecolabels covered additional aspects aside from the environment. We counted that around 30% of the ecolabels also considered social aspects. However,

Table 1 List of identified characterization attributes divided into four categories

• Communication characteristics	• Life cycle characteristics
1. ISO typology	5. Life cycle perspective
2. Awarding format	6. Multiplicity of covered aspects
3. Aspects diversity	7. Operation scope
4. End-user focus	
• Standard characteristics	• Conclusive characteristics
8. Sector scope	16. Transparency
9. Geographic scope	17. Comparability
10. Verification	18. Environmental excellence
11. Compulsoriness	
12. Governance	
13. Financing	
14. Purpose	
15. Longevity	

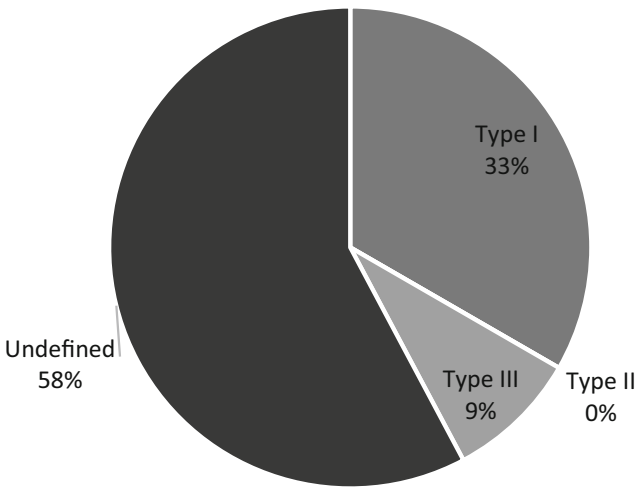

Fig. 2 Distribution by ISO typology of ecolabels from the sample

Table 2 Identification and description of the existing awarding formats

Type	Description
1. Seal[a]	• These ecolabels provide simple binary pass–fail information (UNEP 2005) • Products either comply with the criteria of the ecolabel program or fail to be awarded (Thøgersen and Nielsen 2016) (e.g., EU Ecolabel and all type I labels) • Products awarded in the same product category cannot be compared (Cobut et al. 2012) • Type II claims, such as, e.g., "compostable," are also included under this category
2. Rating	• These ecolabels demonstrate a level of superiority between products by ranking them on a predefined scale (e.g., Gold, Silver, Bronze)
2.1. Rating (non-sealed)	• Products are ranked based on their performance without minimum criteria to be covered or a seal to be awarded (e.g., EU Energy label)
2.2. Rating (sealed)	• Prior to the ranking, the ecolabel is awarded to a product with a seal after complying with certain minimum performance criteria (e.g., Cradle to Cradle Certified™ Products Program)
3. Declaration	• These ecolabels consist of declarations of quantifiable results based on pre-set list of categories
3.1. Declaration (non-sealed)[b]	• These ecolabels provide quantified environmental data using predetermined parameters • ISO type III labels (e.g., Earthsure) fall under this category, for which comparative assertions are not allowed (ISO 2006a)
3.2. Declaration (sealed)	• The product obtains a seal for covering minimum criteria in addition to the declaration of pre-defined categories of results (e.g., WindMade)

[a] Entitled also as "seals-of-approval" by EPA (1998) and Horne (2009)

[b] Several declaration-based ecolabels did not conform fully to ISO 14025 and, therefore, could not be classified as type III declarations but still served similar purposes; thus, they were accounted for in this study

our analysis showed that often the criteria were only qualitative and, in most cases, focus on social issues within local communities, health and safety issues related to employees, labor and wages, facilities and workplace, etc. Moreover, social criteria did not evidently relate to the product under evaluation, but rather to the organization (see Section 3.1.7). However, only around 20% of the organization-awarding ecolabels in our sample declared covering social aspects. Furthermore, a clear trend could not be observed where newer ecolabels considered social criteria more often than the older ones. Nevertheless, an expert survey among academic researchers and practitioners conducted by Shao et al. (2017) showed that health, safety, and labor issues ranked in the top 10 among other environmental aspects in the subject of sustainable consumption.

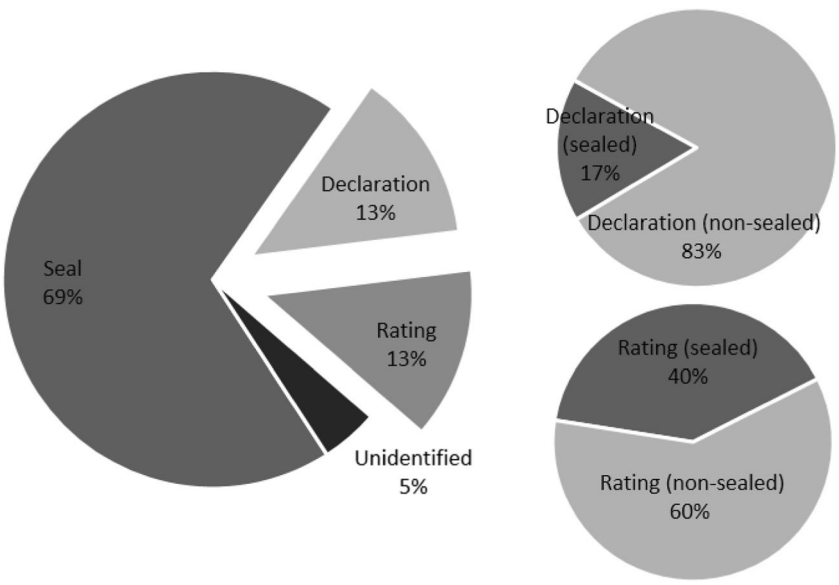

Fig. 3 Distribution by awarding format of ecolabels from the sample

3.1.4 End-user focus

The most common differentiation of the end-user communication focus of ecolabels is between the end consumer (business-to-consumer, B2C) and businesses (business-to-business, B2B). In their publication, Gruère (2013) distinguished two more types of communication channels, i.e., business-to-government (B2G) and government-to-consumer (G2C), of which we did not have examples in our sample.

Seal- and rating-type ecolabels are usually better understood by consumers than declaration-type ecolabels. The former are less demanding in terms of the technical knowledge of the users, although they sometimes may be oversimplified and judgmental (Banerjee and Solomon 2003; Horne 2009). Moreover, they are considered a useful tool for consumers, due to their benchmarking properties (see Section 3.1.2). In contrast, the declaration type of labeling (e.g., type III labels) is a common way of B2B communication where technical knowledge in processing complex sets of results is ensured on both the producer and consumer sides. In our sample, we observed almost even distribution of ecolabels that focused on B2B, B2C, and those covering both.

3.1.5 Life cycle perspective

Principle 5 of ISO 14020 postulates that the development of ecolabels shall take into consideration all relevant aspects of the product's life cycle (LC) (ISO 2000). Life cycle thinking (LCT) and the application of LC-based evaluation tools (like LCA) in product certification are important, since it assures that burdens are not shifted between the different LC stages.

Through the online desk research, it was difficult and uncertain to track how ecolabels considered an LCT perspective and how they eventually applied LCA at the stage of criteria development. However, what we could observe with higher precision was to what extent these were addressed in their awarding criteria. In our analysis, we distinguished three variations of ecolabels according to the LC perspective and the application of LCA:

- Non-LC based—these can be product-based ecolabels that only consider a single stage or attribute of the product in their awarding criteria. Accounting of the complete LC at the stage of criteria development is not necessary, neither an LCA study is performed at any point (e.g., Chlorine-Free Products Association).
- LC-based—these ecolabels require only a qualitative LC screening of a product under consideration at the point of criteria development, whereas the awarding criteria could only focus on particular LC stages. A full LCA study is not necessarily performed. The classic ISO type I ecolabels fall under this category.
- LCA-based—such ecolabels consider all relevant environmental aspects of a product throughout its entire LC (cradle-to-grave), and full conformance with ISO 14040 (2006b) is required. ISO type III labels fall under this category.

Figure 4 shows the profile of the observed ecolabels regarding their LC perspective. About a third of them declared a non-LC perspective. Another third accounted themselves as LC-based, whereas the last third declared that their criteria were based on full LCA. Regarding the latter finding, 29% of these were type III labeling programs (for which, an ISO-conformant LCA study is anyhow mandatory). Another almost a third were other ecolabels that require LCA studies to be conducted. Strikingly, for over 40%, we could not prove through our research that they required a complete LCA for a product to meet certain criteria. This finding raises the question regarding the potential misuse of the term "LCA" in the subject of ecolabeling.

Almost 70% of the undefined ecolabels did not require a full LCA. Ecolabels were mostly based on specific environmental concerns within a particular product sector and on a particular LC stage of the product, rather than on a complete LCA. No clear tendency was observed toward an increased adoption of LCA by newer ecolabels.

3.1.6 Multiplicity of covered aspects

Ecolabels can be characterized based on the types and number of environmental aspects that they consider in their assessment criteria and the results profile they disclose, respectively. Herewith, we distinguished them only as single- and multi-aspect. Single-aspect ecolabels cover and report only one environmental aspect (e.g., CO_2-eq. emissions or recycled content), whereas the multi-aspect ones cover more than one. When it comes to LCA-based ecolabels, the communication of LCA results by a single or incomplete set of impact aspects shall be considered carefully due to the risk of burden-shifting between impact categories.

The majority (over 70%) of the ecolabels examined in this study were multi-aspect labels, to which the classic type I and III labels belong. Of the rest—the single-aspect ones, which did not follow within any ISO typology—approximately 65% were carbon footprint labels (e.g., based on single-impact category LCA studies or other accounting methods), and the rest were awarded as single aspects, such as energy consumption, share of renewable energy sources, or content/lack of certain substances (e.g., chlorine-free products).

3.1.7 Operation scope

The operation scope defines whether an ecolabel characterizes a property of the product, a production process, or an

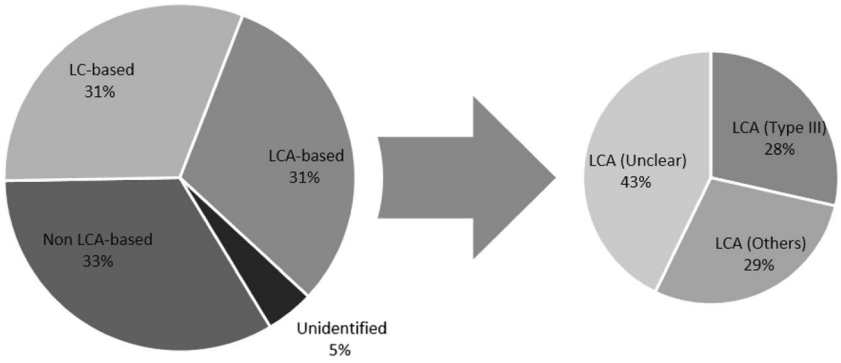

Fig. 4 Distribution of ecolabels from the sample by life cycle (LC) perspective

achievement of an organization. The former is usually what ecolabels refer to. However, as seen in our analysis, some can also address production processes or organizations (ISEAL 2015; Roe et al. 2014) (see, also, Section 3.1.3). Therefore, the operation scope can be distinguished between the following:

- The performance of a product—the ecolabel characterizes a property of the product or an ingredient of the product (e.g., the Biodegradable Products Institute Label awards a level of biodegradability) or the product use (energy efficiency);
- The performance of a production process—awarding criteria are developed regarding a step of or the whole production process or method (e.g., FSC, awarding sustainable forest management);
- The performance of an organization—in this case, an ecolabel awards certain achievement of an organization (e.g., LowCO_2 Certification, certifying the relative decrease of an organization's carbon footprint). The certification of an organization can be further related to a specific site (physical location) or to the overall performance or commitment of a company.

In the ecolabel sample, we observed all three types of operation scope; over three quarters of all characterize the performance of a product. The other two categories were equally distributed—approximately 10% each. Only undefined ecolabels certified the performance of organizations. The majority of LCA-based ecolabels certified the performance of products; nevertheless, beyond ecolabeling, LCA can be applied also to production processes and organizations (e.g., see Martínez-Blanco et al. 2015).

3.1.8 Sector scope

Regarding their production sector scope, ecolabels can be either sector-specific or multi-sectorial. In the first case, only one sector is covered and ecolabels are usually tailor-made for a specific problem at hand (de Boer 2003), e.g., Ancient Forest Friendly™. Multi-sectorial ecolabels cover products from different sectors; certification criteria are usually developed for each product group individually (e.g., Blue Angel). Such ecolabels are usually well suited to product sectors where the criteria are relatively easy to define and where "no controversial political conflicts exist" (Truffer et al. 2001).

Among the observed ecolabels, a quarter are sector-specific, and these are all undefined by ISO. All type I and type III labels are multi-sectorial, except for FP Innovations, an ISO type III operator serving the wood industry.

3.1.9 Geographic scope

Ecolabels can have a national, regional, or international perspective and scope. Regional ones are rare. Among the examined ecolabels, we considered the European-based initiatives like the EU Ecolabel, EU Energy label, and PEF (being around 7% of all) as regional. National and international ecolabels had an almost equal share of the rest (approximately 36 and 42%, respectively). Over 16% of the ecolabels could not be defined. It was noticeable that type I and type III labels were usually national-based initiatives, whereas most of the others declared an international scope (almost 60%).

3.1.10 Verification

Verification refers to the confirmation, through the provision of objective evidence, that all criteria and requirements of an ecolabel are met (ISO 2018). This confirmation is considered critical in strengthening the reliability of an ecolabel (Nikolaou and Kazantzidis 2016). We distinguished three types in our work. Since the ISO 14020 series do not use a harmonized terminology on this matter, we had to adjust the definitions, by using as a starting point the definitions by ISO 17000 on vocabulary and general principles for conformity assessment (ISO 2004):

- First-party verification—performed by the organization that applies for the ecolabel itself.

- Second-party verification—performed by an independent verification body that can be internal to the labeling program.[3]
- Third-party verification—performed by an independent third-party verification body that is external to the labeling program.

No verification is certainly an option, too. In our sample, only one ecolabel stated that verification was not required; two ecolabels performed a first-party verification. A total of 60% relied on a third-party (here, including all type III labels) and twice less used a second-party. Each of the listed verification forms could be observed in the undefined ecolabels.

3.1.11 Compulsoriness

Labels can be either voluntary or mandatory. The latter are relatively rare; examples according to the EPA (1998) and Rubik and Frankl (2005) can be, e.g., hazards or danger labels (e.g., a pesticide content label) or related to information disclosure (e.g., an energy label), i.e., they apply to only a specific set of goods and characteristics, and aim to reach standardized information disclosure (Gruère 2013). In this regard, ISO discourages any mandatory characteristic for environmental labeling programs individually, "including those developed or operated by government-sponsored agencies" (ISO 2016). Nevertheless, in practice, an ecolabel can become pseudo-mandatory in cases when major market players adopt it and further insist that their suppliers conform to it or when a producer is "forced" to use a certain label, because all its competitors do so. The only mandatory label in our sample is the EU Energy label, which is driven by EU legislation.

3.1.12 Governance

The mode of governance is critical to understand the incentives behind an ecolabel (Gruère 2013; Li and van't Veld 2015). One can divide ecolabels mainly by governmental or private ones. Furthermore, we defined an additional category for governmental initiatives that were managed by private companies, i.e., quasi-governmental. Private ecolabels can be managed by private for profits (PFP), private for non-profits (NPO), or non-governmental organizations (NGO). Usually, the market influence and penetration of programs run by governments is much higher when compared to the private ones (Banerjee and Solomon 2003).

Figure 5 represents the establishment of ecolabels from 1978 to 2015, showing a tendency of governmentally owned and operated ecolabels giving in to private initiatives. There have been no newly established governmental ecolabels since 2003, and almost all of them were established in the early 90s. An exception is PEF, counted separately here as a governmental initiative but is currently in the transition phase (Bach et al. 2018).

In our ecolabel sample, governmentally managed ecolabels had a share of approximately 25%. The rest were divided into PFPs, NPOs, and NGOs. We further observed that type I labels were typically governmentally (or quasi-governmentally) managed, whereas the rest (apart from the EU Energy label and PEF being governmental but not type I) were privately managed initiatives.

3.1.13 Financing

Ecolabel program holders apply a variety of combinations of funding sources, such as private or governmental financing, fees and/or member dues, donations, or industry funding, and hardly any rely on only one source. We obtained an average profile of the funding sources using data available for 34 ecolabels in our sample (see Fig. 6).

Apart from ecolabel fees, which is a source of financing applied by all ecolabels, the results showed that type I labels also rely on governmental subsidies. On the contrary, type III labels in the sample were financed only via license registrations and/or annual fees and member dues. Donations and industry funding were shown to be important funding sources for many of the undefined ecolabels. A small share came from conference revenues or investment incomes (indicated as "others" in Fig. 6).

Specific classification based on pricing could not be observed, as data were scarce and very heterogeneous. Financing was used as an additional sub-category under the attribute Transparency (see Section 3.1.16).

3.1.14 Purpose

Regarding their purpose, certain ecolabels can serve as a benchmark of achieving certain ideals or excellence (e.g., EU Ecolabel). We call these ideals-centric.[4] Others serve at the bottom line to show the avoidance of certain adversities, e.g., "chlorine free paper" ecolabels like the Chlorine-Free Products Association. Likewise, are the social labels or ecolabels that contain social criteria, claiming that their products have been created at least in a socially acceptable manner (e.g., Climatop). We call these adversity-centric. This categorization is applicable only for the seal and rating labels and is

[3] In contrast to this adapted definition, ISO 17000 determines a second-party as an activity that is performed by a body that has a user interest in the object (e.g., purchasers or users of an ecolabel), which cannot be the case in ecolabelling.

[4] According to de Boer (2003), ideals-centric labels are seriously criticized because they do not provide methodology to clearly distinguish individual products across an entire product category.

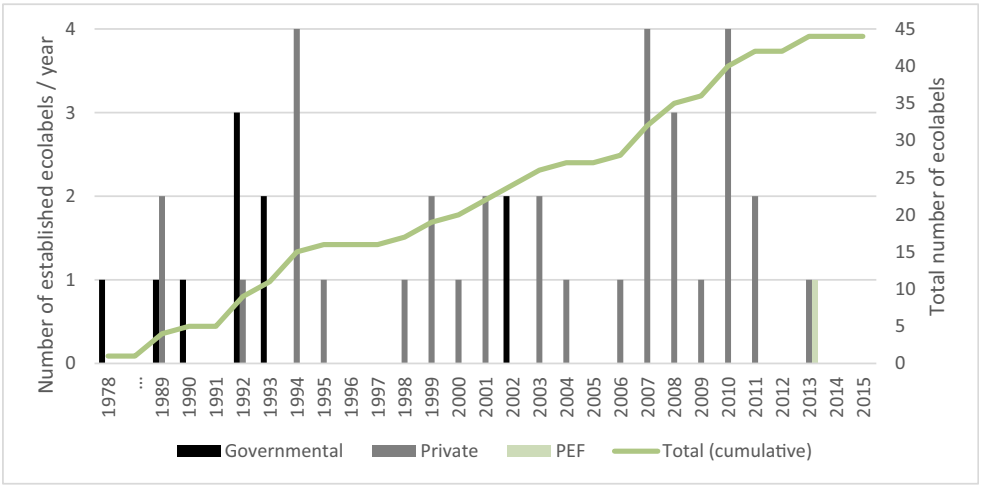

Fig. 5 Establishment of ecolabels (governmental vs. voluntary) and accumulation along the years (1987–2015)

based on the work of de Boer (2003). We categorized declaration types of ecolabels as "neutral" under this category.

In our analysis, all type I labels were logically defined as ideals-centric, whereas type III labels were neutral. For the rest, a mixture between ideals- and adversity-centric ecolabels was observed, whereas the latter were very few in number (below 10%).

3.1.15 Longevity

This attribute defines the fate of an ecolabel after expiration. An ecolabel can be either issued once and never be a subject of further verification again, or it can be updated (e.g., after expiration). The former we called "single-issued" ecolabels. In cases when an update is foreseen, an assessment and verification are required after a certain period or after the ecolabel criteria are revised (e.g., for type I labels). Significant changes in system elements (e.g., raw materials, suppliers) can be a driving force for, e.g., type III declarations to be updated. We named such ecolabels as "renewable."

Moreover, an ecolabel can also imply improvement requirements, i.e., the product must demonstrate an improved performance on a regular basis (e.g., a reduction of CO_2 emissions during the use phase by 10% every two years). We called this type "improvement-based ecolabels" or "reduction claims."

Regarding this attribute, our examination showed that all type I and type III were classified as "renewable," whereas for the rest, the information was controversial. "Single-issued" were usually the type II self-declared labels and, in our sample, many of the undefined ones, among which we also detected "improvement-based" approaches.

3.1.16 Transparency

Transparency is an indication of credibility and trust in an ecolabel, and it is undeniably worth observing. It should be assured through all stages of the ecolabel's development and operation (ISO 2018). In this relation, Principle 4 of ISO 14020 states that "information concerning the procedure,

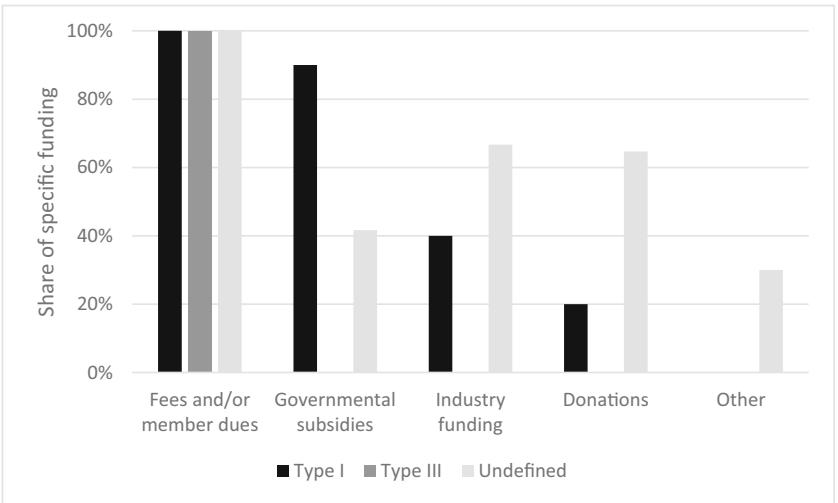

Fig. 6 Share of specific funding sources divided by ISO type

methodology, and any criteria used […] shall be available and provided upon request […]". Furthermore, Principle 9 develops on the necessity of relevant information on the environmental aspects of labeled products l to be accessible by purchasers (ISO 2000).

Gruère (2013) examined the transparency of ecolabels based on the following two factors: (1) the available information on the ecolabel setting process and (2) the available information on the publication of awardees. In addition to this, we included another sub-attribute, (3) access to information on financing.

In the final sample, we included only ecolabels for which information on the ecolabel setting process was assured; however, information on the awardees was available for two thirds of the cases. Data were mostly missing for the undefined ecolabels and type I labels. Regarding access to information on funding, information on the funding profile was obtained for 75% of the ecolabels (see Section 3.1.13), but only a third provided quantitative data on pricing.

3.1.17 Comparability

Comparability is an important attribute of an ecolabel when evaluating or promoting products (Marin and Tobler 2003). However, as the estimation of how an ecolabel ensures comparability between awarded products is subjective, we did not provide quantitative results of the observed ecolabels, but we base our estimation on the ISO requirements. As set by ISO 14025, type III should assure the user with the most objective level of comparability[5] among the three ISO types as long as the compared EPDs are based on the same PCR (Minkov et al. 2015). Type I ecolabels were counted at a level below, since a comparison is not possible between the products awarded the same ecolabel if a binary awarding is applied. Type II labels are very diverse in their criteria setting process, thus a level of comparability could not be adjudged. Nevertheless, ISO 14021 devotes a substantial part of the standard on defining rules for comparative claims.

3.1.18 Environmental excellence

This attribute determines whether an ecolabel assures conditions that allow for the demonstration of excellence by the labeled products among other products. Type I ecolabels promote environmental excellence by delivering credible information to consumers regarding the most environmentally friendly products on the market, also assuring in the criteria setting process that a certification is awarded only to the best performing products of a product category. In contrast, type III labels do not inform the end-user about environmental excellence, as they only provide the buyer with the environmental profile of the certified product and every product can theoretically obtain a declaration. Regarding type II and all the other undefined ecolabels, environmental excellence could be promoted, depending on the awarding criteria and ecolabel's objectives. Due to the subjective character of this attribute, quantitative results are not provided.

[5] "Comparability" shall not be confused with "comparative assertion" which is explicitly forbidden by ISO 14025.

3.2 Characterization scheme setting

In this sub-section, we overview the proposed attributes and their options in a characterization scheme, grouped under four topics. In addition, we provide a map of those attributes with the existing ISO and undefined types of ecolabels (see Table 3). As an outcome, recommendations for the enhancement of the current ecolabels characterization are proposed.

It is important to mention that, as no ecolabels were classified as type II in our sample, in the conclusive attributes (numbers 17 and 18 in Table 3), we evaluated the responses for type II based on the prescription of ISO 14021, but not on the results of the ecolabel sample. Moreover, the results in Table 3 are given in relative scores and are based on a mean value for the representative set (calculation formula is provided in the Electronic Supplementary material, sheet "Scheme"). Results are valid only for the examined ecolabel sample in this study.

3.3 Recommendations for the enhancement of ecolabel classification

The outcomes and findings of the analyzed ecolabels and the proposed characterization scheme in the preceding sections represent scientifically justified evidence that underline the need for improvements in the current existing classification of ecolabels.

By comparing the existing ISO typology against the proposed characterization scheme (summarized in Table 3), two main conclusions could be drawn, which are as follows: on the one hand, the standards on types I and III (ISO 14024 and 14025, respectively) are strict, clear, and demanding by their nature. Ecolabels declaring an affiliation to types I or III are well defined and much latitude is not allowed. However, these were about less than half of the ecolabels that we worked with. Furthermore, we observed a standstill in the development of new type I programs for several years, whereas type III have also seemed to have reached their peak (Arvizu-Piña and Cuchí Burgos 2017). On the other hand, about 60% of the observed ecolabels could not be assigned to any ISO type, whereas the added value to declare type II was not accounted by any ecolabel. These undefined ecolabels were characterized by each existing attribute option (see Table 3).

Given the above-mentioned findings and assuming that the ISO typology is the classification scheme used the most in

Table 3 Overview of the proposed characterization scheme and semi-qualitative comparison between the three ISO types and undefined ones; indication in the table is based on relative scores from 0 to 15: [XXX], always (15); [XX], frequently (8–14); [X], rarely (1–7); [ ], never (0)

No	Attribute	Type I	Undefined (type II)	Type III
Communication characteristics				
1	ISO typology	XXX		XXX
2	Awarding format			
	Seal	XXX	XX	
	Rating (non-sealed)		X	
	Rating (sealed)		X	
	Declaration (non-sealed)		X	XXX
	Declaration (sealed)		X	
3	Aspects diversity			
	Environmental (only)	XX	XX	XXX
	Social/health	X	X	
4	End-user focus			
	B2C	XX	X	
	B2B	X	X	XX
	Both	X	X	XX
Life cycle characteristics				
5	Life cycle perspective			
	Non-LC-based	X	XX	
	LC-based[b]	XX	X	
	LCA-based[c]	X	X	XXX
6	Multiplicity of covered aspects			
	Single aspect		X	
	Multi-aspect	XXX	XX	XXX
7	Operation scope[a]			
	Product	XX	XX	XX
	Production process/method	X	X	
	Organization		X	X
Standard characteristics				
8	Sector scope			
	Sector-specific	X	X	X
	Multi-sectorial	XX	XX	XX
9	Geographic scope			
	National	XX	X	XX
	Regional	X	X	X
	International	X	XX	X
10	Verification[d]			
	First party		X	
	Second party	X	X	
	Third party	XX	X	XXX
11	Compulsoriness			
	Voluntary	XXX	XX	XXX
	Mandatory		X	
12	Governance			
	Governmental	X	X	X
	Quasi-governmental	X		
	Private (PFP, NPO, NGO)	X	XX	XX
13	Financing[e]			
	Fees and/or member dues	XXX	XXX	XXX
	Governmental subsidies	XX	X	
	Industry funding	X	XX	
	Donations	X	XX	
	Other		X	
14	Purpose			
	Ideals-centric	XXX	XX	
	Adversity-centric		X	
	Neutral		X	XXX
15	Longevity			
	Single-issued		X	
	Renewable	XXX	X	XXX
	Reduction-based		X	
Conclusive characteristics				
16	Transparency[e]			
	Label-setting process	XX	XX	XXX
	Awardees	XX	XX	XXX
	Funding	XX	XX	XX
17	Comparability[f]			
	Low		? (undefined)	
	Medium	XXX	XXX (type II)	
	High		? (undefined)	XXX
18	Environmental excellence[f]			
	Intended	XXX	? (undefined)	
	Not intended		? (undefined)	XXX
	Possible		XXX (type II)	

[a] For undefined ecolabels, the total amount of occurrences exceeded the real amount of revised ecolabels, as several have claimed to support both, e.g., product and organization certification

[b] Optional for type I, according to ISO

[c] Requirement for type III, according to ISO

[d] Third-party verification is a mandatory requirement for types I and III, according to ISO

[e] Scoring is given to ecolabels that answer "yes." The sub-categories were evaluated independently from each other

[f] ISO perspective

practice (see Section 1.2), we call for a revision and upgrade of the currently existing ISO typologies and their respective standards. Herewith, we provide several specific recommendations for improvement.

3.3.1 Awarding format

We identified five different types of awarding formats (see Table 2), whereas currently only two have been

standardized—the seal and declaration. Emerging new types (e.g., the "rating (non-sealed)" type) may become largely adopted practice in the future. It is evident not only in practice, but also in the literature, that such new types have been tested (see, e.g., Thøgersen and Nielsen (2016) or (Weinrich and Spiller (2016)). Special attention should be given to these types of rating schemes as they could be misused by setting the reduction target or the benchmark in an accommodating way. Therefore, standardization could be especially useful. ISO should observe such developments and recognize, adopt, and classify them in an existing or new typology.

3.3.2 Aspects diversity

When ISO standards on environmental labeling were first developed, the communication of topics, such as social impacts, health and safety issues, or chain of custody certification, was still emerging and not the focus of ecolabeling. To date, none of the discussed ISO standards regulate social aspects. Nevertheless, the increasing importance of social issues is noticeable, due to the increased amount of initiatives working on this topic (Rubik 2015). We have also observed that in the last few years these aspects have appeared more often in ecolabels. Studies (e.g., Dendler 2014 and Nikolaou and Kazantzidis 2016) have suggested the use of overarching schemes that should provide more information on the social aspects together with environmental dimensions.

For future standardization activities, we recommend that ISO keep the currently existing ecolabeling standards from defining rules regarding criteria that are different from the environmental. Social and socio-economic aspects should be aggregated in (an) additional norm(s), where the specifics of such evaluations are addressed, referring also to existing guidelines for social assessment. As a result, there would be no need to define new typologies to only include social aspects. Instead, these could be counted as a sub-typology of a regular environmental type (e.g., a type I ecolabel).

In addition, given the increasing scientific literature on sustainability labeling (not being in the focus of this study), a logical next step would be the consolidation of guidelines on environmental with socio-economic aspects and the establishment of a future sustainability label typology, along with the existing types. This may require the development of a new standard. Currently, ISO 14021 explicitly prohibits self-declared claims "of achieving sustainability" (ISO 2016) and accepts the use of qualified claims of "sustainability" only by third-party verified schemes. These, however, are not in the scope of ISO 14021 and have never been discussed by ISO 14024 or by ISO 14025.

3.3.3 Operation scope

Considering the operation scope of ecolabels, the inclusion of the performance of organizations is seen as an emerging tendency, especially with regard to socio-economic aspects. The "classic" ISO types of ecolabels, however, are not intended to certify organizations, but products only, since product specificity is sought in their awarding criteria. Here, we recommend a similar approach as that for the socio-economic aspects, i.e., an eventual additional norm that defines the requirements on the scoping of organizations.

Nevertheless, further exploration is needed to determine whether there is a proven market or scientifically sound reason for the existence of such a new typology of product-specific ecolabel, covering organizational specifications. In any case, it should be noted that voluntary environmental management instruments for organizational assessment, such as the European Eco-Management and Audit Scheme (EMAS) (EC 2009) or the international ISO 14001 (ISO 2015), and guiding documents as the "Guidance on Organizational LCA" (Martínez-Blanco et al. 2015) already exist and as such should be attentively considered.

3.3.4 Verification

Independent third-party verification is necessary to avoid unfair practices by companies that use the imperfect consumer knowledge to increase economic benefits through self-claimed labels (Brécard 2014). Studies have assumed that self-declared claims cannot lead to improved environmental quality due to the lack of regulation of the ecolabel's awarding criteria and inconsistent evaluation systems (Shao et al. 2017; Brécard 2014). Nevertheless, a study by Yenipazarli (2015) suggested that ecolabels often did not apply external third-party verification due to the increased costs and the increased end price of the certified product, respectively.

Assuming the need for more information to be in a position to give a specific recommendation on this aspect, we provide only two perspectives for future consideration by ISO. One possibility is the delimitation of ISO from standardizing self-declared and non-third party-verified claims. An alternative is to allow for the standardization of non-third party-verified claims, but only when a certain level of transparency of the evaluation system behind the ecolabel is assured.

3.3.5 Reconsideration of the usability of ISO 14021

With their standard on type II labels, ISO seeks to harmonize the basic principles and requirements for self-declared claims. However, according to the current setting of the standard and its broad requirements, almost every environmental label or a claim that does not undergo third-party verification falls under the definition of a type II label. As seen in practice, an affiliation to it does not seem beneficial for ecolabel program holders. Thus, type II currently cannot be considered as a distinctive ecolabel type, but rather as a recommendation of following certain broad principles for self-declared claims. If a

description of an ecolabel is sought, we recommend that ISO reconsider the usefulness and usability of ISO 14021 and its extremely wide scope of application by being more specific in their criteria. Otherwise, we recommend the term "type II" to be made available for the description of a specific ecolabel typology as the current types I and III.

3.3.6 New ISO classification

In 2005, UNEP identified a need for the development of scientifically sound methods for the evaluation of the real environmental effects of ecolabels (UNEP 2005). Among several reasons for the absence of such methods, the lack of proper classification of ecolabels was listed. To date, improvements in this direction are not known. In this sense, the characterization scheme presented in this paper could be used by ISO as a basis for the further proposal of a new, improved, and more detailed classification. This should incorporate the interlinkages between the attributes defined in this work and classify the many more types that exist beyond the ones of today. Ultimately, the creation of a new classification should also consider the market and consumer behavior perspectives—aspects not dealt within this work and are subjects for additional research.

3.3.7 Improved transparency as an indirect outcome of a stricter ISO classification

Overall, transparency and access to information are decisive to reliability and trust. Our examination of the existing ecolabels revealed that often information was hard to obtain, thus bringing doubts about the ecolabels' aims and the plausibility of their awarding criteria. For example, an attribute influenced by the transparency of awarding criteria is the LC perspective, where we observed that vague and inaccurate information led to the misuse of terms such as "LCT" and "LCA."

Additionally, the program function, the financing mechanisms, or the governance of ecolabel schemes are important aspects for which information should be accessible. ISO set explicit requirements on transparency, but, being voluntary, these standards are not binding. If incentives for a better acceptability of the ISO classification are in place (e.g., the ones we suggest previously), the adoption of ISO among ecolabel program holders would increase, thus improving the transparency of the respective ecolabels that they manage.

4 Conclusions and outlook

This paper contributes to the scarce availability of scientific work related to the classification of environmental labels. We provide a set of scientifically derived attributes in the form of a characterization scheme for ecolabels which fills the gap in characterizing the currently existing types of ecolabels. From a practical perspective, our contribution is considered as an initial step toward a consistent methodological framework to provide clarity within the plethora of ecolabels on the market and to guide an improved classification of ecolabels.

The analysis of the elaborated representative ecolabel sample against the proposed characterization scheme revealed that nowadays, the existing typology provided by ISO does not serve properly as a classification and differentiation medium for ecolabels anymore. Although a general approach of ISO is to develop standards when there is a clear market requirement, we currently observed a great variety of ecolabels that were not covered by the current existing ISO guidance and, thus, were classified as "undefined."

In this work, we recommended that ISO refine the current classification and criteria for ecolabel development. We expect this to lead to improvement in the standards' robustness and credibility by being up-to-date with the latest developments in the ecolabeling world. An improved classification would, on one hand, incite ecolabel programs to rely more on ISO and to actually apply their guidance. This would result in the improved transparency of the ecolabeling setting processes and, thus, in better market positioning. On the other hand, this should facilitate companies that intend to certify their products in the selection of the most appropriate type of ecolabels for their products. This is expected to ultimately have an impact on the end-users by facilitating their choices when purchasing products.

On a more general level besides the recommendations to ISO, the proposed characterization scheme can be of use for a variety of stakeholders. Ecolabel program holders can apply it to juxtapose their existing or prototyped schemes with the ISO typology or to compare them with other ecolabels. Companies looking for appropriate ecolabels for their products can support their informed choices by analyzing different schemes based on the attributes they are interested in. This was successfully tested in previous study by Minkov et al. (2018), where an initial version of the scheme was applied to compare three different ecolabels.

The scope of this work was limited by covering ecolabels only for one specific sector "forest and paper products" (with the inclusion of a few others). This limitation bears the risk of missing certain attributes or an option of an attribute that is held by an ecolabel that was not covered in this study; nevertheless, we assume that no substantial additional attributes are missing for a general application of the scheme. Further expansion of the ecolabel sample to include other product groups is considered useful to improve the statistical representativeness of the results, to observe whether significant changes would occur, and maybe, also, to fine tune certain attributes.

Besides, during the course of this work, we identified issues that were not tackled within this paper but deserve

appropriate research in the future. First, LCA is a well-developed and recognized method for assessing the potential impacts of products and reducing the risk of one-sided environmental characteristics (Gruère 2013; Finkbeiner et al. 2014). Its use in ecolabeling is justified by the need to cover wider types of impacts (see Section 3.1.5). However, it still seems controversial, and some questions worth exploring include (1) whether it is the high cost, complexity, or verifiability as to the reasons why the application of LCA in ecolabeling has not increased lately, (2) whether LCA is a solution for each case and ecolabel, and (3) whether its potential has been fully realized. In this sense, forest management labels, like FSC, call upon all who apply or use LCA to recognize its limitations (FSC 2016).

Second, ecolabels are often criticized regarding their vagueness about environmental themes and "[…] their failure to assure the buyer about the product's ecological impact [...]" (van Amstel et al. 2008). Ultimately, the overall goal of ecolabels is "to encourage the demand for and supply of those products and services that cause less stress on the environment" (ISO 2000). Thus, operational and widely accepted methods for evaluating the real environmental effects of the use of ecolabels should be in the scope of further research.

Third, as indicated in Section 3.3, the development of a new and improved ecolabel classification would benefit the most from future research that incorporates the outcomes of this work together with studies orientated to consumer behavior and market analysis.

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3.2 Characterization of C2C Certified in the context of eco-labels and environmental declarations

This chapter contains the following publication **(Minkov et al. 2018):**

> Minkov N, Bach V, Finkbeiner M (2018) **Characterization of the Cradle to Cradle Certified™ Products Program in the Context of Eco-labels and Environmental Declarations.** Sustainability 10 3:738. https://doi.org/10.3390/su10030738

In this publication, the first version of the ecolabel characterization scheme is applied to characterize the C2C Certified in the context of ecolabels and environmental declarations. The selected initiative is compared with Type I and Type III ecolabels and further illustrated by an example from the construction sector with two typical representatives of the two ecolabel typologies – the Blue Angel and the Institut Bauen und Umwelt e.V.

This case study delivers results in two directions. First, it systematically analyses the C2C Certified and helps stakeholders to understand how such a controversial certification initiative characterizes as an instrument for external communication and ecolabelling. Strengths and weaknesses are described and justified. For example, from an ecolabelling perspective, the downsides of the initiative are: the generic, but not product-specific focus of the awarding criteria, the lack of a life cycle perspective, and the incompletely transparent stakeholder involvement procedure. On the other hand, for certain attributes like the awarding format, C2C Certified provides practical solutions and goes beyond a Type I ecolabel. Substantial similarities between Type III declarations and C2C Certified are not identified. Recommendations for improvement of C2C Certified as an environmental communication tool are also derived.

Secondly, this work tests the ecolabel characterization scheme and identifies measures to improve it. From the insights gained by the case study of C2C Certified, the initial 18 characterization attributes in four categories are extended to 22 attributes in five categories. The updated scheme consists of the following new attributes: Awarding criteria revision, Awarding criteria scope, Materiality principle and Stakeholder involvement. Certain options of particular characterization attributes are also refined.

The supplementary material to this publication is presented in Appendix A.2. It contains the updated ecolabel characterization schemes and a description of each attribute.

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Characterization of the Cradle to Cradle Certified™ Products Program in the Context of Eco-labels and Environmental Declarations

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Abstract: (1) Background: The Cradle to Cradle Certified™ Products Program (C2C Certified for short) is a scheme for the certification of products that meet the criteria and principles of the Cradle to Cradle® design approach. The objective of this paper is to characterize C2C Certified as an instrument for external communication in the context of environmental labeling and declarations. (2) Method: An eco-label characterization scheme consisting of 22 attributes was used to analyze C2C Certified. In addition, it was compared with the established standardization labeling typologies, namely Type I and Type III. This was further illustrated in an example within the building and construction sector. (3) Results: C2C Certified can be classified neither as a Type I, nor a Type III label. The main weaknesses of C2C Certified from a labeling perspective are: the generic, but not product-specific focus of the awarding criteria, the lack of a life cycle perspective, and the incompletely transparent stakeholder involvement procedure. Nevertheless, for certain attributes (e.g., the awarding format), C2C Certified provides practical solutions and goes beyond a Type I eco-label. Substantial similarities between Type III declarations and C2C Certified cannot be identified. (4) Conclusions: The main advantages and shortcomings of C2C Certified from a labeling perspective are pointed out. The approach shows similarities to a Type I eco-label, and efforts toward conformance with the International Organization for Standardization (ISO) labelling standards would result in improving its comparability, recognition, and robustness.

Keywords: cradle to cradle; environmental labeling; eco-label; EPD; characterization; criteria; ISO

1. Introduction

The environmental performance of products (including goods or services) is a credence attribute that cannot be determined by the user, even after purchase and consumption [1]. In this sense, environmental labels and declarations (referred to further in this paper as labels or eco-labels) are considered a useful tool for conveying such environmental product information from the producer to the final user [2].

Nowadays, there are many different types and varieties of environmental labels and certification approaches that deliver information on the environmental performance of products [3]. Among these, the Cradle to Cradle Certified™ Products Program certification system (C2C Certified for short) has gained a certain relevance. However, this system is not officially assigned to any of the three typologies that were established by the International Organization for Standardization (ISO), and it is therefore challenging to evaluate its performance characteristics as a tool for external communication.

A review of the scientific literature shows that there are only a few publications that analyze C2C Certified as a certification system. In 2011, a position paper by the Dutch Ministry of Economic Affairs, Agriculture, and Innovation [4] described C2C Certified from a communication perspective,

focusing on how users approach certification and on how and whether life cycle assessment (LCA) can be incorporated. Similarly, Bakker et al. [5] focused more on the C2C concept from a business perspective in product development, and additionally on how LCA can complement C2C. Bjørn and Hauschild [6] compared the C2C approach with eco-efficiency and LCA. They briefly addressed C2C Certified by using certified products as examples, and they compared their performance from an LCA perspective. De Pauw et al. [7] briefly juxtaposed C2C Certified with LCA to show two fundamentally different approaches in assessing the effects of products on the environment, i.e., the benefits versus the burdens. Niero et al. [8] compared the environmental impact associated with different levels of two C2C certification requirements by using LCA. Nevertheless, a comprehensive analysis of C2C Certified from a labeling perspective was missing. Recently in a book chapter, Bjørn and Hauschild [9] explored C2C Certified, and briefly compared it with ISO Type I labeling, concluding that the program in focus has many similarities to classic Type I eco-labels, such as the Nordic Swan. Nevertheless, a systematic attributes-based comparison of C2C Certified and (common) environmental labeling schemes (based on ISO) is still missing.

To address this gap, the objective of this paper is to characterize the C2C Certified program as an instrument for external communication in the context of environmental labels and declarations, by applying a comprehensive set of attributes.

The present work is structured as follows: Section 2 provides introductory information on environmental labeling and ISO, followed with an explanation of C2C Certified. Section 3 describes the materials and methods needed to achieve the given objective. Section 4 provides the results, while the discussion and conclusions are given in Sections 5 and 6, respectively.

2. Background

In this section, background information on environmental labeling and the ISO standards for environmental communication is provided. Further, details regarding C2C Certified and the certification process are explained afterwards.

2.1. Environmental Labelling and ISO

ISO defines three types of environmental labels and declarations, which will be described later. An overarching standard that is common for the three is ISO 14020 [10]. It provides nine common guiding principles for the development and use of environmental labels and declarations.

Type I environmental labels are defined by ISO 14024 [11] as voluntary, multi-criteria based third-party programs (managed by a respective eco-labeling body) that award licenses for the use of environmental labels on products. Type I eco-labels are based on the concept of eco-efficiency [9], which proclaims that the development of new products or the improvement of existing products should be done with an intention to reduce their damage on the ecological systems (i.e., doing more with less). To achieve the certification, a product should fulfill certain product environmental criteria that are also based on life cycle considerations. "Product environmental criteria" is the official term as per ISO 14024. However, in this paper, the terms "awarding criteria" and "certification criteria" (as per C2C Certified) are also used and accounted as synonyms. Type I eco-labels usually facilitate business-to-consumer (B2C) communication, and the awarded label indicates overall environmental preferences within a certain product category. Typical examples include the German Blue Angel (BA) [12], the European Eco-label [13], and the Scandinavian Nordic Swan [14].

Type II labels are self-declared environmental claims that are either issued in the form of a claim, a stamp, a label, a declaration, or a more complex rating system. It is not mandatory for such claims to undergo third-party certification. Although ISO 14021 [15] seeks to harmonize the basic principles and requirements of such self-declared claims, nowadays, their availability and variability on the market is large, making it almost impossible to categorize average properties and characteristics. Thus, Type II claims are not further considered in this work (a further explanation for this is given in Section 3).

Type III environmental declarations (known also as environmental product declarations, or EPDs) present third-party verified and quantified environmental information on the life cycle of a product. They are governed by ISO 14025 [16], and are based on an LCA study that was conducted according to specific product category rules (PCR). EPDs are intended for business-to-business (B2B) communication, although B2C application is not precluded [16]. Typical Type III programs (managed by a legal body called a program operator) include the Swedish International EPD® System [17] and the German Institut Bauen und Umwelt e.V. (IBU) [18].

2.2. C2C Certified

This subsection introduces C2C Certified. Firstly, the Cradle to Cradle® design approach that is the underlying method focused on during certification is described. Secondly, the certification program and its functioning are introduced.

2.2.1. Cradle to Cradle® Design

Cradle to Cradle® (C2C) is defined as a continuous improvement design approach that was developed by William McDonough and Michael Braungart, and detailed in their 2002 book *Cradle to Cradle: Remaking the Way We Make Things* [19]. Cradle to Cradle® is a registered trademark that is owned and licensed by McDonough Braungart Design Chemistry, LLC (MBDC). The approach integrates multiple attributes such as safe materials, the continuous reclamation and reuse of materials, clean water, renewable energy, and social fairness. Instead of aiming at reducing the negative environmental impacts of products (e.g., by optimizing already existing systems, such as the concept of eco-efficiency), C2C aims at leaving "a beneficial footprint for human society and the environment" through product design [20] (p. 2). C2C proponents believe that this design approach can be achieved by fulfilling three principles [9,20]:

- Waste equals food, i.e., eliminate the concept of waste: all materials are seen as potential nutrients in either the technical or the biological cycles; products should be designed with materials that are safe for human health and the environment, and they can be reused everlastingly;
- Use current solar income, i.e., use renewable energy: renewable energy sources are paramount to effective design, and their use should be maximized;
- Celebrate diversity: it is believed that technological diversity is key for innovation, and local specifics should be considered, i.e., avoiding "one-size-fits-all designs"; operations should be done with social fairness and stakeholder considerations.

2.2.2. Introduction to and Functioning of the Certification Program

C2C Certified was launched in 2005 by MBDC. A license to manage the program was granted to the Cradle to Cradle Products Innovation Institute (C2CPII), a not-for-profit organization, in 2010 [20]. The certification program strives for full integrity of the three C2C principles mentioned above [21]; its rules and certification standard are therefore directed toward achieving these principles [20].

Products seeking certification under C2C Certified are evaluated against criteria and divided into five "quality categories", namely: Material and Health, Material Reutilization, Renewable Energy and Carbon Management, Water Stewardship, and Social Fairness [21].

According to the C2C Certified Products Standard v3.1 [20] (i.e., the guiding document that determines the program's operation), the certification applies to materials, subassemblies, and finished products. The scope is generic, and is neither specific to a product group or industry sector, nor geographically limited. Nevertheless, it specifically excludes e.g., food, beverages, pharmaceuticals, or fuels, as well as buildings (but not building and construction-related materials). Products with ethical issues or safety concerns from rare or endangered species, etc., are excluded.

C2C Certified incorporates a rating system of five levels (Basic, Bronze, Silver, Gold, and Platinum). An achievement level is assigned to each of the five quality categories. The product's overall mark is

determined by the lowest achieved level assigned to one of the five quality categories. As of September 2017, there were 499 products certified (0.2% Platinum, 18% Gold, 37% Silver, 43% Bronze, and 2% Basic), most of which were in the categories Building Supply & Materials and Interior Design & Furniture (183 and 170 certificates, respectively) [22]. A trend for the program's growth since its establishment cannot be depicted, due to unsuccessful attempts to obtain historical data. Nevertheless, according to unofficial information, it is estimated to be around 10–20% per year since 2014.

The process for certification of a product first begins with the determination of whether the product is appropriate for certification, i.e., whether it falls within the scope of the program and conforms with the Banned Chemicals List developed by C2C Certified. Further, the product should be evaluated for whether it conforms to the program standard. As a next step, the applicant selects an assessment body from a list of accredited assessment bodies that work with C2C Certified. It is common practice that the applicant works with the assessor during the process of supply chain data collection or data evaluation, and during the process of optimization strategy development. Usually the assessor supports the applicant until the end of the certification process. Further, the applicant pays an associated certification fee, and the C2CPII performs a review that is based on the Assessment Summary Report. The review concludes whether the information is complete and accurate, and a certification decision by C2CPII follows [21].

3. Materials and Methods

The following section describes the method and steps applied to reach the objective of this paper. This study is based on desk research, i.e., a review of scientific publications and an examination of published documents related to the programs in focus. Expert interviews have not been carried out.

3.1. Characterization of C2C Certified Regarding ISO Typology

As a first step, this paper characterizes C2C Certified and compares it with the established Type I and Type III rules given by the respective ISO standards. Type I and Type III are two very different approaches in regard to providing environmental product information, serving different purposes, and operating in different manners. The comparison enables an understanding of how C2C Certified is characterized, and how it is positioned on the market compared with other established approaches. Type II were excluded from this analysis, because (as explained in Section 2.1), self-declared claims can vary enormously in their awarding type, purpose, and other characteristics; they are therefore difficult to characterize under a common denominator.

For the characterization of the three approaches, this work adapts Minkov et al.'s characterization scheme for environmental labels and declarations [3]. The scheme originally provided a list of 18 characterization attributes, with their respective features divided into four categories. Additionally, four new attributes were identified, namely: "Awarding criteria scope", "Materiality principle", "Awarding criteria revision", and "Stakeholders involvement". The attribute "Transparency" was moved under the category "Conclusive". A new category, "Governance characteristics", was established, maintaining four of the attributes that were originally under the category "Standard characteristics". These modifications assured a more complete and better structured characterization scheme, which in turn led to a better delimitation between the three compared approaches. The final characterization scheme applied in this work is presented in Table 1. A description of each attribute and its respective features is provided in the supplementary material to this article.

Table 1. Adapted eco-label characterization scheme applied in the present study, based on Minkov et al. [3].

Attributes and Features		
Communication Characteristics		
1 ISO Typology Type I Type II Type III Undefined	2 Awarding format Seal Rating (non-sealed) Rating (sealed) Declaration (non-sealed) Declaration (sealed)	3 Multiplicity of covered aspects Single-aspect Multi-aspect
4 Aspects diversity Environmental Social Health	5 End-user focus Business-to-consumer (B2C) Business-to-business (B2B) Both	
Scope		
6 Sector scope Sector-specific Multi-sectorial	7 Operation scope Product Production process/method Organization	8 Geographic scope National Regional International
9 Awarding criteria scope Product-specific Generic	10 Materiality principle Yes Neutral No	11 Life cycle (LC) perspective Non-LC based LC based LCA based
Standard Characteristics		
12 Compulsoriness Voluntary Mandatory	13 Financing [1] Fees and/or member dues Governmental subsidies Industry funding Donations Other	14 Purpose Ideals-centric Adversity-centric Neutral
15 Longevity Single-issued Renewable Improvement-based		
Governance Characteristics		
16 Governance Governmental Quasi-governmental Private (PFP, NPO, NGO)	17 Verification First party Second party Third party	18 Awarding criteria revision Yes, regularly Yes, randomly No
19 Stakeholder involvement Low Medium High		
Conclusive Characteristics		
20 Transparency [2] Label-setting process Awardees Funding Verification report	21 Comparability Low Medium High	22 Environmental excellence Intended Not intended Possible

[1] The evaluation of this attribute could result from the sum of two or more features. [2] The features of this attribute are evaluated individually. ISO: International Organization for Standardization, NGO: or non-governmental organizations, NPO: private for non-profits, PFP: private for profits.

3.2. Sector-Specific Example

A comparison of a particular approach as C2C Certified with the generic ISO requirements on Type I and Type III labels must unavoidably remain on a generic level. To make the analysis more explicit and concrete, a second step involved the assessment of C2C Certified against concrete examples of Type I and Tape III labels within a specific sector.

The C2C Certified categories of certified products were reviewed in order to define a relevant industry sector for the example. The ones that dominated with the most certified products were Building Supply & Materials, and Interior Design & Furniture (183 and 170 certificates respectively, as of September 2017) [22]. Consequently, these products were hereafter assigned to one common sector, "Construction and construction services" (as classified by the Central Product Classification v2.1 of the United Nations Statistics Division [23]), which was selected as the subject of the example.

The selected exemplary sector is also relevant for the other labeling approaches that were observed. In the last few years, there has been a high interest in the assessment and certification of construction-related materials through EPDs [24–26]. Moreover, green-building certification schemes (GBCS) such as the ones of the German Sustainable Building Council (DGNB) [27], the British Sustainability Assessment Method for Buildings (BREEAM) [28] or the United States (US) Leadership in Energy and Environmental Design (LEED®) v4 [29], recognize the use of EPDs for the disclosing of the environmental information of construction products. Type I eco-labels do not necessarily find application in GBCS; nevertheless, many programs certify end-consumer products applicable in the "Construction and construction services" sector for both B2C or B2B relations and are used in Green Public Procurement (GPP).

Further, two exemplary approaches (in that they are typical representatives for Type I and Type III labels) were selected and compared with each other, and with C2C Certified. They were chosen based on literature research and a predefined criteria set that is described in Table 2.

Table 2. Criteria for shortlisting programs to be compared with Cradle to Cradle Certified™ Products Program certification system (C2C Certified).

Criterion	Description
ISO typology	The selected program shall be a typical representative of the respective ISO typology (i.e., Type I or Type III);
Operation within the selected product sector	The selected program shall certify products applicable in the selected industry sector;
Market recognition	The selected program shall be well established and recognized on the market with proven traditions along the years.
Geographic coverage	The selected program shall operate in the same countries where C2C Certified operates.

As a typical Type I eco-label, BA was selected. Established in 1978, the eco-label is the first and oldest eco-label worldwide [30], and the one that has the highest number of certified products and the largest market share [31]. From over 100 product categories covered by BA, 16 are classified under "Construction" products [12]. The eco-label was established in Germany, but BA certified products can be found beyond it, in almost all of the European countries, as well as worldwide. BA is a member of the Global Eco-label Network (GEN), an organization that is leading Type I eco-labels worldwide [32].

Founded in 2004, IBU is one of the most prominent Type III program operators nowadays, and was therefore selected as an example in this work. IBU is the biggest Type III operator in Germany, and only operates within the scope of construction products and components [18]. EPDs issued by IBU can be found on products all over Europe and beyond. The program operator is a founding member of the ECO Platform, a cooperation of program operators and LCA practitioners working on the

development of a coherent framework for the EPDs of construction products [33]. IBU also works in close cooperation with other single operators beyond Europe on the basis of mutual recognitions and agreements [25].

Figure 1 displays the steps undertaken to achieve the objectives of the paper.

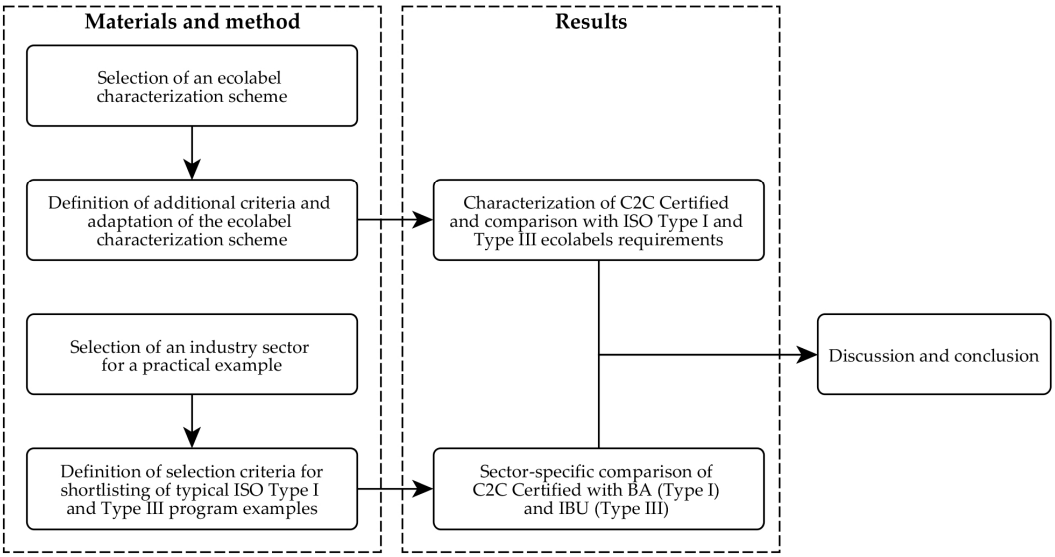

Figure 1. Description of the method flow of the paper at hand.

4. Results

This section provides the results of the study, initially by presenting the general characterization of C2C Certified (Section 4.1), and further by providing a sector-specific example and comparison (Section 4.2).

4.1. Characterization of C2C Certified Regarding ISO Typology

This section presents the analysis of the C2C Certified approach by comparing it with Type I and Type III, as postulated by ISO 14024 and ISO 14025, respectively. The results of the attribute-based assessment are given in Table 3. Following this, the section gives an overview of the results, and highlights several of the most critical and relevant characterization attributes for C2C Certified.

In the following section, some key aspects of the above-listed attributes assessment are described in more detail, with a focus on the C2C Certified performance in comparison with Type I and Type III environmental labels. The section follows the structure of the characterization scheme (Table 3), based on the five main categories.

Table 3. Characterization of C2C Certified and comparison with Type I and Type III environmental labels, based on a characterization scheme adapted from Minkov et al. [3]. EPD: Environmental product declarations, LCA: life cycle assessment, PCR: product category rules.

Attribute	Type I Eco-Label	Type III EPD	C2C Certified
Communication Characteristics			
ISO typology	Type I (ISO 14024)	Type III (ISO 14025)	Does not fully conform with Type I or Type III label requirements of ISO
Awarding format	Seal (binary pass–fail information; products either conform or not)	Declaration (non-sealed; quantified environmental data using predetermined parameters)	Rating (sealed; ranked on a predefined scale after complying with minimum performance criteria)

Table 3. *Cont.*

Attribute	Type I Eco-Label	Type III EPD	C2C Certified
Multiplicity of covered aspects	Multi-aspect	Multi-aspect	Multi-aspect
Aspects diversity	Environmental only (few programs cover also social/health aspects)	Environmental only	Both environmental and social/health
End-user focus	B2C (mostly)	B2B (mostly)	B2B (mostly)
Scope			
Sector scope	Multi-sectorial	Multi-sectorial	Multi-sectorial
Operation scope	Product (social criteria often related to the organization)	Product	Product (certain criteria in three of five quality categories relate to the organization)
Geographic scope	National (mostly), regional, or international	National (mostly) and international	International
Awarding criteria scope	Product-specific (product-specific awarding criteria)	Product-specific (product-specific LCA category rules)	Generic (equal criteria for all products)
Materiality principle	Yes (key environmental performance characteristics of the products are identified for the definition of awarding criteria)	Neutral (the EPD intends to declare a comprehensive set of impacts without prioritizing them)	No (all products are assessed against the same set of criteria, independent from their individual materiality)
Life cycle (LC) perspective	LC based	LCA based	Non-LC based
Standard Characteristics			
Compulsoriness	Voluntary	Voluntary	Voluntary
Financing	Fees and/or member dues (mostly); governmental subsidies (seldom)	Fees and/or member dues	Fees and/or member dues; donations
Purpose	Ideals-centric (a benchmark of achieving excellence within the respective product group)	Neutral (declarations cannot be categorized under this category)	Ideals-centric (a benchmark of achieving conformance with the C2C principles)
Longevity	Renewable (the license can be renewed after expiration or when the awarding criteria are revised)	Renewable (the EPD can be renewed after expiration or if significant changes in the system elements occur)	Improvement-based (in case of re-certification, intentions for improvement must be reported)
Governance Characteristics			
Governance	Governmental (mostly, but not an ISO 14024 requirement)	Private (mostly)	Private
Verification	Third party (mandatory by independent, external body)	Third party (independent body, not mandatory to be external, if not explicitly for B2C application)	Third party (mandatory by independent, internal certification body; however, independence of the conformance assessment body not assured)
Awarding criteria revision	Yes, regularly (revised based on a predefined period that is usually dependent on the product group specifics and market conditions)	Yes, regularly (PCR usually expire in 3–5 years, when it is further revised or, if not used, when it is discarded)	Yes, regularly (revision of the Product Standard to be done every three years)
Stakeholders involvement [1]	High (product category selection and awarding criteria development should be the result of a consultation process with stakeholders)	High (mandatory open consultation during development or update of EPD program instructions and PCRs)	Medium (during the product standard revision process, two public comment periods are at disposal for comments by stakeholders; not yet carried out in practice)

Table 3. *Cont.*

Attribute	Type I Eco-Label	Type III EPD	C2C Certified
Conclusive Characteristics			
Transparency	Program-specific; usually information on the program-setting process, awardees, funding, and pricing is accessible; verification report shall be available for the eco-labeling program, but not mandatory for the public	Program-specific; usually information on the program rules and PCRs is accessible, but information on funding and pricing is more seldom accessible; verification report shall be available to any person upon request	Information on the certification process, awardees, funding, and pricing is accessible; verification report exists, but it is not publicly available
Comparability	Medium (comparison and comparative assertions are not possible between products awarded the same label; awarded products can claim superiority to non-awarded products)	High (the EPD allows for objective comparison between products if the same PCR is used; comparative assertions not allowed)	Low (comparison between products is difficult due to the five quality categories; comparative assertions are not possible; comparability is not strived for by the program)
Environmental excellence	Intended (frontrunner principle applied)	Not intended (all products can get a declaration)	Intended (however, frontrunner principle not applied)

[1] In this category, interested parties (e.g., industry or trade unions, consumers, media, science, environmental groups, etc.) are envisaged as stakeholders external to the program.

4.1.1. Communication Characteristics

The "Communication" category consists of criteria related to the awarding format of an eco-label, the type and multiplicity of covered aspects (environmental and other), as well as the end-user focus. Ultimately, an eco-label affiliation to any of the three ISO typologies is evaluated. In the case of C2C Certified, the program does not fully conform to Type I (ISO 14024) or Type III (ISO 14025), although many similarities to Type I are pointed out hereafter when presenting the results of the characterization analysis.

C2C Certified applies a rating awarding approach consisting of five levels, from Basic to Platinum. This is considered advantageous in comparison to a binary pass–fail approach, since the label allows for the differentiation and ranking of the performance of the different certified products (the aspects of comparability in this relation are further described in Section 4.1.5). However, it is important to highlight that although a ban of the use of certain toxic substances and materials is ensured, only a rudimental material and energy inventory of the product is made at the first level of certification (i.e., Basic). This level is intended to show that the company has started out "on the path to certification" [20] (p. 11). The Basic certification is provisional, and the product must undergo further higher certification no later than two years after the Basic achievement, as it would otherwise be delisted from the program. Basic-level certification cannot be used as a mark on the product, but only in marketing materials [22]. This change in the latest version of the Product Standard v3.1 [20] reduces the risk of accusations of greenwashing.

In contrast, Type I eco-labels are usually awarded for real product performance. This is assured by ISO 14024's requirement for market analysis, as part of the feasibility study on the development of criteria for a new product group (discussed further in Section 4.1.2). Type III declarations, on the other hand, assure the robust communication of products' LCA profiles. Nevertheless, these products can be completely imaginary, and are either still in the research and development (R&D) phase or configured to answer certain application needs, without having been put into application.

C2C Certified is a multi-attribute system that covers both environmental and social performance aspects in their certification criteria. The intended end-user focus of C2C Certified is not explicitly stated. According to Bjørn and Hauschild [9], certification applies to both B2B and B2C, depending on the nature of the certified products. In practice, mostly B2B applications have lately been observed;

such as for example, the application of C2C Certified into the green-building rating and certification systems, which is discussed further in Section 4.2.

To conform with the respective ISO standards on Type I eco-labels and Type III declarations, programs shall cover and communicate multiple environmental aspects. Aspects beyond those that are environmental are not prohibited, but are also not explicitly defined and governed by the observed ISO standards.

Due to their binary awarding format and the ease with which final consumers can understand them, Type I eco-labels are mostly used for B2C, although this is not a requirement of ISO 14024. Type I eco-labels are also used in B2B in e.g., public procurement procedures (described further in Section 4.2).

According to ISO 14025, Type III EPDs are intended for B2B communication. Nevertheless, B2C applications are not prohibited by the standard. Additionally, additional rules for verification apply in the case of B2C (see Section 4.1.3).

4.1.2. Scope

The scope of an eco-label has several dimensions. It consists of the type of sector and geographical coverage, the operational scope of the label, what the awarding criteria cover, and whether materiality and product life cycle perspectives are considered behind the criteria.

C2C Certified is a multi-sectorial approach that is practically not limited by geographic boundaries. Although it is intended for the certification of products, some criteria are company-focused instead of product-focused; thus, they also focus on gate-to-gate processes only (discussed further in this section). Renewable Energy & Carbon Management, Water Stewardship, and Social Fairness are three of the five quality categories that require information on certain criteria that are related to the organization, without being related to the product that is the focus of the certification.

C2C Certified is a certification system whose certification criteria are not product-specific, but rather general for all products. The program does not require any product-specific feasibility and materiality assessment study for the establishment of new product categories or product-specific certification criteria, while Type I eco-labels do, as requested by e.g., ISO 14024. The advantage of having common rules for all products is that these are easy to understand by the consumer. However, two disadvantages occur: on the one hand, the criteria become too generic; thus, in theory, all sorts of product categories could qualify for the certificate. On the other hand, in the specific case of C2C Certified, it is easier to certify products from product groups that are homogenous or simpler from a material perspective (while it is difficult to do this for products from other product groups that are not so homogenous or that consist of more complex materials) [9]. This limits those product categories that, in practice, can undergo certification.

Applying identical criteria to all of the products also implies that the certification focus would not always necessarily be on those aspects and parameters that are the most relevant in completely determining the (environmental) performance characteristics of the product. This determination of products' relevant characteristics is known as the 'materiality principle', i.e., "focusing where it really matters" [34] (p. 113). If the materiality principle is not observed, certain certification criteria could be found to be irrelevant for a certain product, though they would still need to be covered and reported in order for the product to obtain the certificate.

Furthermore, the application of common awarding criteria, but not product-specific ones, implies that a specific evaluation of a product's life cycle is not performed, but rather considered as common for all products. In addition (and partly because of the lack of product specificity), many criteria in C2C Certified focus only on a particular life cycle stage, e.g., mostly on the final manufacturing (gate-to-gate), without conducting a specific evaluation of the life cycle of the given product under certification, and without providing a proper argumentation for the exclusion of any life cycle stage.

Conversely, when setting the awarding criteria, ISO 14024 requires Type I eco-labels to conduct feasibility and materiality assessment studies on the potential product categories, including on the specifics of the market (e.g., under 30% of the products from a given product category could obtain

the label). The standard here demands that product-specific environmental criteria be elaborated, respecting the materiality principle. This helps to differentiate environmentally sound products from others, based on "a measurable difference in environmental impact" [11] (p. 5). Furthermore, ISO 14024 postulates that the criteria for awarding Type I eco-labels shall not lead to the transfer of impacts from one life cycle stage to another, or "from one medium to another without a net gain of environmental benefit" [11] (p. 9). Thus, the product's life cycle shall be taken into account when awarding criteria are developed. This should ensure that, although final awarding criteria do not necessarily cover all of the life cycle stages of a product, the risk of burden shifting is minimized.

For the development of ISO 14025-conformant Type III EPDs, the LCA rules are based on PCR, which are considered to be a particular set of awarding criteria. PCR assure that the rules are specific to the product group in focus, and that future LCA studies based on the PCR focus on the most relevant aspects and parameters. All of the life cycle stages from cradle to grave are usually covered. In the case of the omission of a certain stage, this shall be justified properly. Nevertheless, from an impact assessment perspective, the materiality principle is not always observed in practice, because Type III operators often do not allow for the selection of impact categories that are specific to the product group, but rather keep them general for all PCR.

4.1.3. Standard Characteristics

The standard characteristics of an eco-label are defined by the type of compulsoriness of the label, its financing, the definition of the purpose, and longevity. C2C Certified is a voluntary program that is funded by certification fees and donations. Its purpose is to certify the level of products' conformance with the five C2C quality categories.

C2C certificates expire after two years. In case of re-certification, intentions for improvement must be reported in the form of optimization strategies (e.g., an intention for the eventual phase-out of a problematic substance) and a progress report against the original action plan [20]. This characteristic of C2C Certified can be considered as a step beyond the classic Type I eco-labels and Type III declarations, where, after expiration, an eco-label license or an EPD can also be renewed, but a binding requirement for improvement in the case of re-certification does not exist. Technically, in the case of Type I eco-labels, an improvement of the environmental performance of the product can be aimed at if the updated awarding criteria demand it. Nevertheless, ISO 14024 does not demand for a continuous improvement strategy to be set as part of the label or the criteria update.

4.1.4. Governance Characteristics

The governance characteristics relate to the type of governance, the verification process (including the conformance assessment and final certification), the regulations regarding the awarding criteria revision, and the process of stakeholders' involvement.

C2C Certified is managed by the non-for-profit organization C2CPII (see Section 2.2.2). Regarding the verification process, an assessment body that is trained and accredited by C2CPII performs the testing, analysis, and evaluation of the applicant. When an evaluation is finalized, the assessment body provides an Assessment Summary Report to C2CPII, and the latter takes the final certification decision [21]. However, the assessment body, i.e., the body that "conducts [the] conformance assessment" of the applicant [35] (p. 7) and "makes a certification recommendation" [35] (p. 15), can also act as a consultant. According to C2CPII, this double role of the assessment body is in the "best interest of the client by providing guidance to achieve certification" [35] (p. 7). This is in conflict with the verification requirements of ISO 14024 and ISO 14025; thus, the conformity assessment does not qualify as independent. As the Assessment Summary Report is the main information for a certification decision, this is a significant issue.

In comparison, Type I eco-labeling programs shall conform to ISO 14024 by undergoing mandatory, independent, external third-party verification, performed by a body that is independent to the program holder and the applicant [11]. In the case of Type III EPDs, the process is similar, but verifications can

be either internal or external. According to ISO 14025, independent external third-party verification is mandatory only when the declaration is intended for B2C communication [16]. Nevertheless, in practice, it is performed by most of the operators.

The C2C Certified Product Standard shall be revised no later than three years from the date of the current version [36]. As of November 2017, v3.1 of the standard is under its first revision, which started in June 2014 and is expected to finish by the end of 2018 [37]. A revision of the certification criteria is not explicitly set as part of the process, and this is considered as a flaw in the program's documentation. However, an improved version of the standard is sought in practice, assuming that certification criteria would be revised and eventually improved. In contrast, ISO 14024 clearly states that the awarding criteria for Type I eco-labels shall be reviewed within a predefined period. Similarly, PCR for the elaboration of Type III declarations have a predefined expiration period that is set by the respective program operator, after which the PCR shall be revised or discarded.

According to the program's policy for the revision of the standard [38], the revision process should consist of two public comment periods (60 days each), during which external stakeholders may provide inputs. Five advisory groups (one for each quality category) consisting of over 70 experts are responsible for providing expert guidance on the new standard. All of these activities give the impression of substantial stakeholder involvement. Nevertheless, according to personal communication with the C2C Certified support personnel, by the time the present article was submitted, no public comment period had been held, though this is expected to happen in 2018 [39]. The authors do not know of any additional publicly accessible information on any stakeholder involvement process (e.g., protocols of collected and processed comments).

Regarding Type I and Type III labels, the respective standards governing their development are both established on Principle 8 of ISO 14020, stating that an open consultation with interested parties should be included in the process of developing eco-labels and declarations. For Type I eco-labels, the product category selection and awarding criteria are a result of a consultation process between the program and the interested parties. Similarly, Type III EPDs are issued based on PCR developed after stakeholder consultations. Furthermore, for the update of the instructions for the operation of the Type III program, the program operator seeks stakeholders' opinions via an open period for comments.

4.1.5. Conclusive Characteristics

Transparency, comparability, and the intention to achieve environmental excellence are the three attributes that form the last category of the characterization scheme.

Concerning transparency, information on the certification process, awardees, funding sources, and pricing is accessible for C2C Certified. The Assessment Summary Report is submitted by the assessment body to C2CPII, but this document is usually not publicly available.

This is considered to be in line with ISO 14024, according to which information on the program-setting process and rules of the specific program shall be accessible; a verification report on the certified product shall be available to the eco-labeling body, but it is not mandatory that it be open to the public [11]. Similarly, ISO 14025 allows open access to the program-setting process; a verification report of the EPD shall be available upon request [16]. Further evaluation cannot be made here, since the level of transparency of the operation of a given Type I eco-label or of a given Type III EPD program is program-specific.

Comparability is not a topic in C2C Certified. The Product Standard v3.1 [20] does not mention comparability or comparative assertions regarding the superiority between certified products. Nevertheless, stakeholders tend to use C2C certificates in order to compare products in reality [40]. At first glance, this seems possible, because the rating format of awarding gives the user a notion of superiority between products, and the idea that a comparison is possible. However, in practice, obtaining an objective conclusion by comparing two C2C certified products is challenging and scientifically unjustified. The reason for this is that a product obtains a respective level of certification as the minimal performance level achieved in one of the five quality categories, regardless of which

one. Thus, a product is awarded e.g., an overall rating of Silver, because it may obtain a minimum score for Silver in e.g., the Material Health category. However, this does not imply that it has the same performance characteristics as another product that also has achieved an overall rating of Silver, but achieved its minimum score in e.g., Social Fairness. As a result, if the user does not get introduced with the background documentation (e.g., the certification scorecard) along with the certificate, misleading conclusions are conceivable.

A careful comparison of the scorecards of two products could give the user a perspective on which product scores better in each category. Nevertheless, C2C Certified does not oblige, but rather only encourages, certification holders to publish the scorecards on their marketing materials [20]. Furthermore, the awarding criteria setting procedure does not consider the so-called 'frontrunner' principle, i.e., a certification awarded only to the best performing products of a product category for a certain market. Thus, overall comparative assertions should not be allowed.

With regard to Type I eco-labels, comparative assertions between two products that have the same label are not possible, and neither are statements regarding the level of environmental superiority between the same. This is due to the binary awarding format, through which both products have covered the same criteria, but nothing more. However, Type I eco-labels in their essence are used to indicate an overall environmental superiority over products that do not hold the label. Environmental excellence is aimed for, and only the best performing products within a product category on the market can obtain the label.

By their nature, Type III declarations allow the user to compare products under the condition that the EPDs are based on the same PCR (e.g., identical product category definition, system boundaries, and functional unit). EPDs are designed to present transparent and quantitative information, thus allowing the user to fully understand eventual limitations while making a comparison. Depending on the granularity of the product group definition, rules for the execution of the LCA could vary to different extremes, going from being very specific to very generic; this could be an impediment for EPD comparisons, despite being based on the same PCR. The product performance improvements can be measured based on the disclosed LCA profile that lists potential environmental impacts in the form of impact categories. However, Type III EPDs are not intended to suggest the environmental excellence of the declared product, given that theoretically, all products can obtain a declaration. Comparative assertions are not allowed.

The eco-efficiency approach (used as a basis by Type I eco-labels) and the C2C approach differ in their fundamental principles aimed toward sustainable production, as do the respective labeling and certification schemes that are derived from them. C2C Certified can be considered neither a Type I nor a Type III label, although similarities to Type I can be identified. However, the main discrepancies relate to the generic (but not product-specific) awarding criteria focus, the lack of product life cycle perspective, and the non-explicit requirement for criteria revision, despite the requirement for regular revision of the standard. Type III conformance is not achievable. An obvious reason, among others, is that for example, C2C Certified does not apply LCA.

4.2. Sector-Specific Example

In the following section, a sector-specific example is provided: C2C Certified is compared against the performance characteristics of two existing labels, namely the Type I BA and the Type III IBU. The same set of characterization attributes as in Section 4.1 is used, but in Table 4, the results are presented only for those that show specifics of the analyzed approaches and are important for the comparison. Few of them are discussed hereafter. Following this, the performance of the three approaches from the perspective of overall acceptance within the "Construction and construction services" sector and GBCS is presented.

Table 4. Characterization of C2C Certified and comparison with Blue Angel (BA) and Institut Bauen und Umwelt e.V. (IBU) in the context of construction products.

Attribute	BA	IBU	C2C Certified
Communication Characteristics			
ISO typology	Fully conformant Type I eco-label program according to ISO 14024	Fully conformant Type III program operator according to ISO 14025	Does not fully conform with Type I or Type III label requirements of ISO
Awarding format	Seal	Declaration	Rating (sealed) Five ratings: Basic, Bronze, Silver, Gold, Platinum
Multiplicity of covered aspects	Multi-attribute: Four general protection objectives: Climate, Resources, Environment and Health, and Water (type and number of specific aspects are dependent on the product category)	**Multi-attribute:** **Six environmental impact** categories: Global warming Ozone depletion Acidification for soil and water Eutrophication Photochemical ozone creation Depletion of abiotic resources (elements and fossil fuels) And 10 resource use parameters	Multi-attribute: Five quality categories: Material and Health Material Reutilization Renewable Energy and Carbon Management Water Stewardship Social Fairness
Aspects diversity	Mostly environmental and occupational health and safety, but also social (for certain product categories)	Environmental (optional health)	Both environmental and social/health
Scope			
Sector scope	Multi-sectorial 16 product categories with many subcategories related to the "Construction and construction services" sector	Sector-specific 109 PCRs in three main groups (Basic materials and precursors, Building products, and Building service engineering)	Multi-sectorial two product categories with many subcategories related to the "Construction and construction services" sector
Standard Characteristics			
Longevity	Renewable Label validity: three to five years	Renewable EPD validity: five years	Improvement-based certificate validity: two years
Governance Characteristics			
Verification	Third party (mandatory by independent, external body)	Third party (mandatory by independent, external body; verifiers are approved by the advisory board)	Third party (mandatory by independent, internal certification body; however, independence of the conformance assessment body not assured)
Awarding criteria revision	Yes, regularly; criteria revised after three to five years	Yes, regularly PCR validity: three years	Yes, regularly (revision of the Product Standard is to be done every three years)
Stakeholders involvement	High (open consultations during the development of new or updating existing awarding criteria)	Medium (no procedure for the involvement of external parties in program rules' development or update; internet forum available for public comments during the development of new or updating expired PCR)	Medium (during the Product Standard revision process, two public comment periods are at disposal for comments by stakeholders; not yet carried out in practice)
Conclusive Characteristics			
Transparency	Program rules—yes Awarding criteria—yes Awardees—yes Pricing—yes Verification report—not public	Program rules—yes PCR—yes Awardees—yes Pricing—yes Verification report—available on request	Program rules—yes Certification criteria—yes Awardees—yes Pricing—yes Verification report—not public

BA applies a binary seal type of awarding format. In addition, the label is divided into four different protection objectives: Climate, Resources, Environment and Health, and Water. When a

product is awarded the BA label, a protection objective is assigned and displayed on the seal. The idea is that the consumer is shown the focus of the awarding criteria. The assignment of more than one protection objective to a product group is inadmissible [41].

EN 15804+A1 [42] is a European norm, providing core rules for the product category of construction products in development for EPDs. Together with ISO 14025, EN 15804+A1 is also the core standard behind the ECO Platform initiative (explained in Section 3.2.). The standard is widely accepted, and is a symbol of harmonization work between a large group of stakeholders working in the sector. In this sense, IBU's involvement in this process is a guarantee for a coherent and aligned communication flow in the sector between stakeholders along the supply chain. As an example, IBU's EPDs follow the EN 15804+A1 requirements on impact assessment by declaring the results based on six environmental impact categories and 10 resource use parameters, as set in the standards (listed in Table 4).

Whereas IBU's EPDs cover environmental (and optionally health) aspects, both BA and C2C Certified also include social elements. BA recognizes products that are environmentally friendly in a holistic way, but that also meet high standards for occupational health and safety. "Socially controversial" products are excluded [41] (p. 1). Furthermore, the fundamental principles and rights relating to working conditions, as reflected in the applicable core labor standards of the International Labor Organization (ILO), shall be met both by the licensees and the value chain producers [41].

On the other hand, C2C Certified also account, with their Social Fairness category, for progress made toward sustainable business practices, respecting human rights and labor practices, and assuring worker health and safety. The different certification levels require different levels of commitment, starting from a self-audit and assessing the protection of human rights at the Basic level, to aiming for a third-party audit of the facility that conforms with an internationally recognized social responsibility program (e.g., SA8000) at the Platinum level [20].

C2C Certified is recognized by LEED® v4 for credit "Building product disclosure and optimization—material ingredients", where C2C Certified's rigorous requirement for a complete bill of material is used to achieve one point. An additional point is given if the material ingredient optimization is documented (a requirement for C2C Certified levels above Silver). It is not known whether C2C Certified is recognized in other GBCS or schemes for other sectors. Nevertheless, in 2017, the US Environmental Protection Agency (EPA) recommended C2C Certified in their "Recommendations of standards and eco-labels for federal sustainable purchasing" in seven building and construction product categories [43].

EPDs by IBU and other program operators are also promoted by LEED® v4 to achieve material credits [44]. The scheme awards materials with one point in the category "Building product disclosure and optimization—environmental product declarations". EPDs also find application in GPP, since the declared information is verified, and allows for a comparison of the environmental impact at the level, on the one hand, of technically equivalent construction materials and products, and on the other hand at the level of building elements or even a whole building. An example of the application of EPDs in GPP are the recently developed GPP criteria for office building design, construction, and management by the European Joint Research Centre [45], where the performance of the main building elements can be evaluated based on EN 15804-conformant EPDs. IBU is also recognized by the main GBCS in Europe—DGNB and BREEAM.

Despite BA not being recognized in any GBCS (i.e., it does not bring any credits in any of the described schemes), the label has a strong focus on construction-related materials (a total of 16 product categories), and the label's requirements are often used in GPP practices. Figure 2 shows the application areas and the respective overlaps between the three approaches.

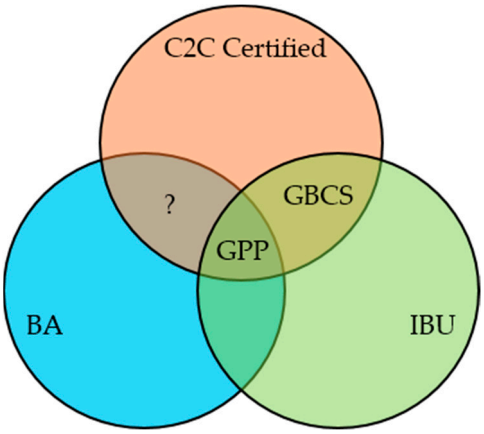

Figure 2. Application areas and overlap between C2C Certified, BA, and IBU.

5. Discussion

C2C is a useful approach in concept development and in designing new products. It is assumed to be effective for a deeper understanding of material composition and design for recycling [5]. Nevertheless, it is also important for designers to understand and track the environmental impacts and benefits of their design actions [7,46]. In this sense, as a tool for providing quantifiable environmental effects and as an instrument for external communication in the context of environmental labels and declarations, C2C Certified still bears certain shortcomings.

On the one hand, a flaw in the relation between the certification holder and the user (e.g., a consumer or designer) could arise when the latter does not completely understand that C2C Certified is a benchmark for achieving the C2C principles, rather than a tool for the quantifiable estimation of environmental impacts. Furthermore, when the C2C certificate is taken as a given without attention into the details (i.e., examining the scorecard), users may use it for direct comparability between certified products or to plead for overall environmental preferability over non-certified products, which, as shown in this paper, is not that straightforward.

On the other hand, C2C Certified is often perceived by the public as a Type I eco-label [47]. As discussed by Bjørn and Hauschild [9], and as also confirmed in the paper at hand, the program shows many similarities to Type I. Nevertheless, when going through the program's documentation, it is significant that ISO 14024 (the standard that defines Type I eco-labels) is never cited under the list of normative references, whereas a reference to ISO 14025 (Type III) occurs many times (see e.g., C2CPII 2015, C2CPII 2016a and C2CPII 2016b [35,48,49]). Therefore, in order to provide clarity for an interested public, this paper answered the question of whether C2C Certified is a Type I or Type III (as defined by the respective ISO norms), and parallel to this, it pointed out the benefits and drawbacks of such (non)conformity.

C2C Certified is a voluntary, multi-aspect program with a multi-sectorial scope. These typical Type I characteristics are backed by assured access to information about the program setting regarding funding and operation, as well as regarding product certification. In certain respects, the program even goes beyond a typical Type I eco-label, e.g., the binary pass–fail awarding format is upgraded by a rating scheme that ranks the products' performances. However, some of its characteristics show clear non-conformance with the requirements of ISO 14024. First and most importantly, the certification criteria of the program are generic without being product-specific. Thus, a specific evaluation of a product's life cycle is not performed. The standard further requires the elaboration of feasibility studies for the establishment of new product categories or product-specific awarding criteria, which is missing in C2C Certified, as it has a generic, but not product-specific, scope. The missing product-specific life cycle perspective in the certification criteria development ensures that the evaluation of a product focuses only on certain life cycle stages without any product specificity. This bears the risk of misbalance

between the different certification criteria [8] by shifting burdens between life cycle stages, which is a situation that shall be avoided, as ISO 14024 explicitly states.

Similarities between C2C Certified and Type III declarations can barely be found. However, together they can be recognized as complementing tools. As shown in the sector-specific example in this paper, both approaches are applicable in LEED® v4, where they complement each other without competing. Thanks to their different application purposes (i.e., a certification of conformance and comprehensive content declaration versus a quantitative list of impacts), they are used to obtain different credits through different conformance paths. Furthermore, when it comes to the evaluation of alternatives and backing up strategic decisions, a quantifiable approach to the estimation of potential environmental impacts is needed; this is not supported by C2C Certified, but rather by EPDs.

On a higher level, this paper raises a discussion of whether C2C Certified is an eco-label or not. Eco-labeling is a voluntary method of environmental performance certification and labeling. An eco-label identifies products that overall are environmentally preferable within a specific product category. In this sense, C2C Certified is awarded to products that have achieved a certain level of conformance to the C2C principles. Thus, the question that has to be answered is whether the adoption of the C2C principles actually leads to the creation of overall environmentally preferable products. This has not been the focus of this article, and it deserves to be unraveled in future research; yet, according to Bjørn and Hauschild [9], C2C certification cannot guarantee better environmental performance for products compared with other products from the same product category.

Moreover, as an additional point for future examination, few articles (e.g., Paul et al. Niero et al, and Bjørn and Hauschild [7–9]) discuss that C2C Certified does not guarantee that a certified product really meets the C2C principles philosophy. De Pauw et al. [7] argue that the certification levels of the program cannot represent the beneficial impact of a design. According to Bjørn and Hauschild [9] (p. 615), "C2C certified products are by no means ideal C2C products". Not even a Platinum level assures a "true" C2C product, i.e., one that fulfills all three principles for all aspects. According to Bühner [47], the full circularity of a product is not assured until one reaches the Silver level.

6. Conclusions

This article provides a characterization and analysis of C2C Certified as an external communication tool in the frame of environmental labels and declarations, and does so by applying an existing, upgraded eco-labels characterization scheme to that developed by Minkov et al. [3]. To the authors' knowledge, such a comprehensive analysis from this perspective has not yet been published, and the results are considered to be of interest to a variety of the programs' stakeholders, e.g., the C2C Certified management, existing and future C2C Certified certification holders, and the general public as potential users of C2C Certified products.

By comparing the approach with the requirements of ISO on environmental labeling, and by additionally comparing it with two existing typical representatives of Type I and Type III labels, the advantages and weaknesses of C2C Certified are exposed. An analogy with Type II self-claims is not conducted, due to the very wide scope of the standard, and the difficulty in characterizing it with any typical example.

As a communication approach, C2C Certified is considered operational; the program's management seems robust; the program's guiding documents are detailed and transparent. Still, its undefined affiliation in the realm of environmental labels gives the user heterogeneous perceptions of the program's objectives. For example, C2C Certified is often perceived by the public as a Type I label, although the program itself never states this. In this context, this work shows that despite the differences, C2C Certified has many similarities to a typical Type I eco-label (and very few to Type III). It is believed that the eventual efforts put toward fulfilling ISO 14024's conformance requirements for eco-labels would help improve C2C Certified's image and its robustness as an eco-label, and would also allow for a more objective comparison with other eco-labels.

Given the achieved objectives and obtained results of this paper, it can be concluded that the established methodological approach can be applied to any other environmental labeling scheme or standard by comparing it with any other scheme, or, as done here, by juxtaposing it with ISO standards for environmental labels in order define conformity to a certain ISO typology. Amongst others, potential users could be program holders and eco-label developers testing and comparing their approaches, as well as companies looking for an appropriate environmental label for their products, or consumer organizations guiding their members through the current variety of existing eco-labels.

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Conflicts of Interest: The authors declare no conflict of interest. M.F. is a member of the BA Jury and a member of the Advisory Board of IBU. These voluntary and unsalaried functions are personal and did not have any influence on the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript, and in the decision to publish the results.

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3.3 Type III Environmental Declaration Programmes and harmonization of product category rules: status quo and practical challenges

This chapter contains the following publication **(Minkov et al. 2015):**

> Minkov N, Schneider L, Lehmann A, Finkbeiner M (2015) **Type III Environmental Declaration Programmes and harmonization of product category rules: status quo and practical challenges.** J Clean Prod 94:235–246. https://doi.org/10.1016/j.jclepro.2015.02.012

In this publication, first a literature review of the existing Type III environmental declaration programmes and the existing initiatives for PCR harmonization is conducted. 39 programmes are identified and listed by country of origin, operation language, geographic and sector scope, year of foundation and date of the last update of their General Programme Instructions (GPI). The gained information allows for the evaluation of the transparency of the observed Type III programmes, the trends of their development and their conformance to ISO 14025. For example, 75% of all are fully conformant to ISO, 10% are partly and 15% are not. 56% of the schemes operate in Europe, against 28% in North America. In terms of geographic scope, over half are international. In terms of sector scope, the building and construction sector is dominating (36%), whereas 44% are generic, i.e. not specific to a certain industry sector; the rest cover also other sectors. The market development since 1998 shows a steady climb of Type III programmes, having only very few to officially ascertain their closure.

As regards the overview of existing harmonization initiatives, the publication discusses five scientific papers that deal with the problem, as well as 16 initiatives categorized as guidelines, standards and technical specifications, collaborative platforms and other activities related to mutual recognition between parties. Focus is given on the GPCRD, PEF and ISO/TS 14027, expecting that they would have significant impacts on policy and market in the near future.

In the analytical part of this publication, the structure and performance of GPCRD are tested as a PCR alignment initiative. The comparison of GPCRD with the PCR development procedures of the analysed operators (according to their GPIs) resulted in a

list of 12 topics in three groups that are somehow approached controversially or sometimes even untouched by programme operators, but are found to be of importance, in order to develop reliable PCRs. After, a draft PCR for "Oil processing services" is used as an example to align with the requirements of the GPCRD. All 66 "shall" requirements of the Guidance to develop an aligned PCR are met. Being a new experience of practical testing of GPCRD for all involved stakeholders, active communication between the PCR drafters, the operator's technical committee and the Guidance authors is initiated. It is ultimately concluded that this particular PCR conformity assessment is perceived challenging, but possible tasks and that GPCRD is a good complementary tool for Type III operators that want to have their GPIs strengthened. The publication lists several aspects for improvement and necessary common agreements between operators, in order to assure consistent PCR alignment, such as, but not limited to: product category classification, fixed and flexible content, stakeholder engagement procedure, "conflict of interests" disclosure, PCR committee requirements, primary data quality assessment, reporting and interpretation of LCA results, etc.

The supplementary material to this publication is presented in Appendix A.3. It contains the background information obtained for the road test of GPCRD, namely: descriptions of the surplus requirements and actions for alignment of the draft PCR with the Guidance as per the PCR template and the GPCRD CAF and also a description of the non-obligatory recommendations and actions for alignment as per the GPCRD CAF.

As the original publication was issued in 2015, additional literature review is presented in Chapter 3.3.1. It embraces existing Type III operators, PCR harmonization initiatives and related scientific papers from 2014 to date that are not identified in this publication.

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Review

Type III Environmental Declaration Programmes and harmonization of product category rules: status quo and practical challenges

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ABSTRACT

A steady growth of the number of existing Type III environmental programmes (schemes) has been noticed in recent years. Consequently, overlapping and duplication of the product category rules supervised by these programmes is increasing, risking the legitimacy of environmental claims. To overcome these difficulties and challenges, different approaches striving for mutual recognition and harmonization of schemes have been launched, e.g. the Guidance for Product Category Rules Development (the Guidance). Since a proper reflection of these current developments is not yet available, this paper reviews existing Type III programmes and their conformance to ISO 14025. Further, an overview of cooperation approaches and global trends for harmonization of rules is provided, including the latest European product environmental footprint initiative. As a case study, the requirements of the Guidance are tested by aligning them to a set of exemplary product category rules under development. Challenges in both review and alignment processes are described. The results show that out of 39 analysed programmes, over 75% are fully ISO-conformant. Nearly half claim to cover all types of products and services, followed by the "building and construction sector" related schemes that currently reach a share of over 35%, after a steady growth in the last 2–3 years. Concerning the origin of schemes, European based ones are dominating (over 55% of all). The cooperation initiatives analysis outlines that mutual recognition of instructions and rules among operators is becoming a valuable approach to reduce time, costs and duplication of documentation. The development of supplementary guidelines is also considered useful in order to assure harmonization among parties. Finally, the draft category rules alignment test is acknowledged as a challenging, but feasible task. Based on this review, more than 10 areas for improvement of the harmonization level of instructions are identified. The paper provides recommendations for the development of the new ISO/DTS 14027, one of which is the adoption of the Guidance as seed document.

1. Introduction

In this paper, the status quo and practical challenges of Type III Environmental Declaration Programmes and the harmonization of Product Category Rules (PCR) are analysed by a literature review. This analysis tackles the questions, how many Type III programmes actually exist, how they developed over time, what the main divergences among them are and how the harmonization between them could be improved.

Type III environmental declarations (better known as environmental product declarations – EPDs) provide quantified and independently verified environmental information over the life cycle of goods or services (ISO, 2006a; Steen et al., 2008; Zackrisson et al., 2008). EPDs are methodologically based on life cycle assessment (LCA), standardized by ISO 14040 (2006b) and ISO 14044 (2006c) and developed according to a set of pre-defined product category rules. The principles and procedures of EPDs are defined by ISO 14025 (ISO, 2006a).

EPDs should enable comparison between products, fulfilling the same function (Fet and Skaar, 2006; Fet et al., 2009). Their development and use is a voluntary act (ISO, 2006a), nevertheless the demand in recent years has increased (Ingwersen and Stevenson, 2012; Strazza et al., 2010). Subsequently, the number of Type III

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programme operators – the bodies supervising and administrating the development of PCRs and verifying EPDs under a Type III Environmental Declaration Programme (also known as EPD programme or EPD scheme) – has increased too, as they are becoming more known and sought (Del Borghi et al., 2008; Strazza et al., 2013). This demand is observed particularly in the building and construction sector (Braune et al., 2011).

In theory, everyone can become a programme operator (Schmincke and Grahl, 2007), to set their own instructions (defined per ISO 14025 as General Programme Instructions – GPI), to develop PCRs and to verify EPDs. Environmental labels in general (and EPDs in particular) can be used to increase the positive market feedbacks by providing transparent environmental information through LCA (Del Borghi et al., 2014). However, the increasing number of EPD schemes can also lead to trade barriers on the market (Bogeskär et al., 2002; Del Borghi, 2013), due to different requirements. Moreover, in the recent years, PCRs published by different programme operators are increasingly overlapping. This has resulted in inconsistencies of PCRs for the same product categories (Ingwersen and Subramanian, 2014; Ingwersen et al., 2012). The absence of a systematic coordination of PCR development on international level (through e.g. a consistent and properly working global PCR library) leads to difficulties in finding newly published documents. Moreover, comparability between the environmental performance of products lacks significance and bears to risk the legitimacy of LCA-based claims on the market (Ingwersen and Subramanian, 2014). "Similar-but-different" methods for calculating environmental impacts are lately introducing additional confusion among consumers, the majority of who do not trust "green" claims (Galatola and Pant, 2014).

PCRs are sometimes set in a way that allows a wide interpretation of the rules, leading to potential incomparability of EPDs based on the same PCRs (Fantin et al., 2012). This lack of detailed instructions and harmonized methodologies can lead to the creation of competitive advantages and misleading results (Dias and Arroja, 2012), e.g. incomparability, due to favoured results of one of the EPDs. In order to assure the practicability of using EPDs to compare products, harmonization of their development among programmes is needed (Schmincke and Grahl, 2007), which further may promote their global consistency (Ingwersen et al., 2012). This could be achieved by the development of general guidelines for scheme management (Del Borghi, 2013). The Guidance for Product Category Rule Development – GPCRD (2013) is such a new approach, providing a step-by-step guidance for PCR development (Ingwersen and Subramanian, 2014), applicable for all types of products (i.e. goods or services).

The European Commission's Product Environmental Footprint (PEF) is also one of the newest initiatives, responding to the request of the Member States to elaborate an approach for measuring and communicating the environmental performance of products that could be used in EU policies (Galatola and Pant, 2014). PEF proposes a multi-criteria measure for the calculation of the environmental footprint of goods or services (EC, 2013a), followed by a regularly updated guidance for the development of PEF category rules, named PEFCR (EC, 2013b).

Another approach published two years ago is EN 15804 (CEN, 2012), but applying only to the construction sector. Nowadays it is already a proved standard developed to ensure harmonization among EPD for all types of building and construction products by providing the so called "Core PCR" (Erlandsson et al., 2013). Other examples of initiatives striving for harmonization and mutual recognition are discussed further in Section 3 of this paper, including an overview of the scientific publications related to the problem.

Considering the increasing interest of EPDs and the increasing number of newly established schemes and overlapping PCRs, it is necessary to research profoundly on the robustness and applicability of new and existing approaches that strive for global consistency. Furthermore, it is considered that primarily there must be a clear understanding of the current state of all EPD-like schemes, their resemblances and differences in terms of methods used and application purposes. Therefore, in order to analyse the current state and practical challenges in the field, the objective of this paper is trifold (graphically presented in Fig. 1). Firstly, by complementing and updating existing studies, a review of existing EPD-like schemes and operators is conducted, including the analysis of their conformance to ISO 14025. Secondly, the available practices for harmonization are examined. For both, a comprehensive and actual overview is provided. Thirdly, by means of a practical example, a PCR under development is used in order to test the alignment possibilities with the requirements of GPCRD. In parallel, GPIs of the analysed operators are compared with the Guidance, thus listing topics of divergences between them. GPCRD is chosen, since it is an initiative developed with the participation of many PCR practitioners and leading Type III operators, thus considered an accepted and promising approach. Another reason is that it is a newly published document, which has not found much reflection in scientific publications yet. Practical examples can be carried out with other initiatives/requirements as well; however, this is out of the paper's scope.

2. Review of EPD-like programmes

EPD schemes and PCRs development has been a very dynamic field in recent years; one can easily lose track on the developments, and overview studies quickly lose their relevance. Moreover, there are not many EPD-related papers in scientific literature. The latest one – a publication of Hunsager et al. (2014), gives an overview of the state of the art of May 2013 by listing 27 EPD programmes.

Considering the dynamics of the market, an updated analysis complementing existing studies is conducted in this section (presented after in Table 1). Beforehand, the method and criteria for evaluation, as well as the scope of the review are discussed.

2.1. Method and scope of the review

GPI is the fundamental and mandatory document for the operation of every EPD scheme. The obligation of the programme operators to develop such programme instructions is defined by clause 6.4 of ISO (2006a), accompanied with 13 mandatory requirements to be part of the GPIs' content, whereas the requirements for PCR development are defined by clause 6.7 of the same standard. In the present analysis, these two ISO clauses are used as the principle criteria to evaluate all EPD schemes that were preliminary identified through a profound online research. Moreover, the requirements for PCR development of clause 6.7 of ISO together with GPCRD are used as a benchmark regarding the development of more specific guides on PCR elaboration. The main findings of the schemes' comparison and analysis are further presented in Section 4.

Carbon footprinting programmes are not included in this study, as firstly, the subject on "quantification and communication of a carbon footprint of products is still under development" (ISO, 2013) and due to the existence of several competing methodologies that also need harmonization (Soode et al., 2013). Secondly, carbon footprint studies address only one impact category – climate change, which may lead to wrong interpretation of the outcomes (Schmidt, 2009).

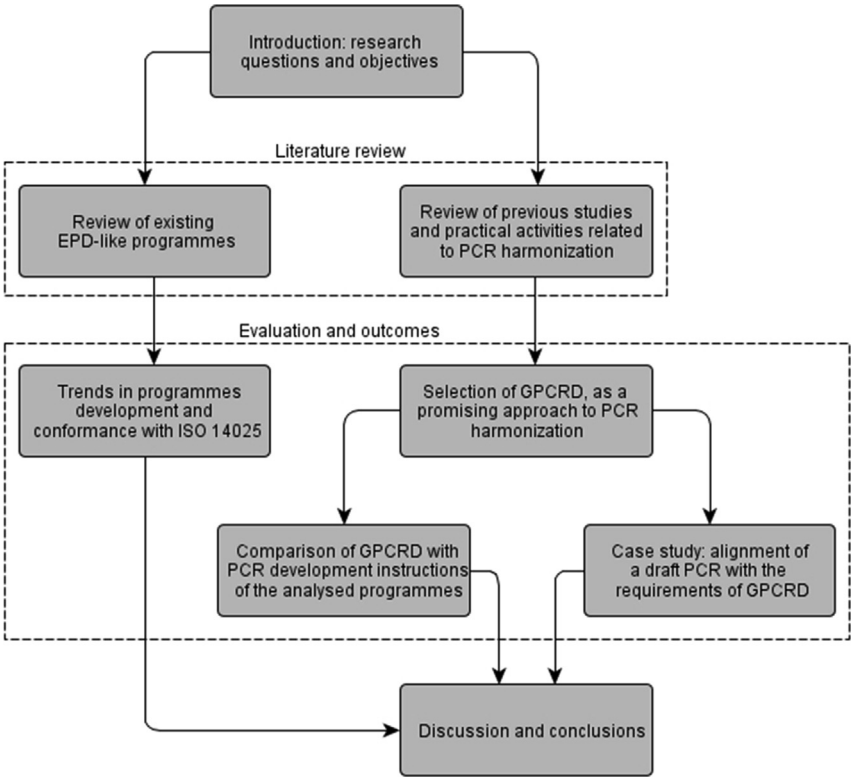

Fig. 1. Graphical representation of the logical flow of the paper.

2.2. Existing EPD-like programmes

Table 1 provides an overview of EPD-like programmes (ordered by year of foundation) that are further discussed in this paper. Thirty-nine programmes are listed, enhancing existing assessments by analysing additional aspects, like scope (geographic and sector), year of foundation and the latest publication of instructions. The last actualization was performed in April 2014.

3. Review of approaches to harmonization

With respect to the large number of existing EPD schemes, stakeholders realise the need to work in direction to harmonization in order to reduce overlapping of documentation, time and costs. The following section aims at describing the previous studies in the context of existing schemes overview and relevance of harmonization for the scientific community (Section 3.1), as well as at outlining practical activities of organisations and companies in the field of Type III labelling (Section 3.2). Furthermore, three of these approaches in focus are described (Section 3.3). The analysis provided here gives an impression of the awareness of the problem and its reflection both from scientific and business perspective. The outcomes are further evaluated in Sections 4, whereas conclusions are presented in Section 5.

3.1. Previous studies

In 2002, a study commissioned by the European Commission (EC) and performed by the Environmental Resource Management (ERM) (Bogeskär et al., 2002) documented and evaluated both national and industry EPD systems and compared their characteristics with each other and to ISO 14025 version from 2000. Furthermore, the possible future directions for EPD schemes in Europe were examined. Although this study was conducted 12 years ago, it had already concluded that EPDs are becoming an accepted communication tool, despite still being in a developmental state. However, even back then, harmonization among EPD schemes was outlined as an aspect for improvement. Moreover, the study suggested a development of general guidelines regarding scheme management and LCA application, which is still a hot topic nowadays.

Christiansen et al. (2006) studied the main consumer concerns related to the comprehensibility, completeness and comparability of EPDs. Their discussion considered three main topics, i.e. reliability of data, completeness of environmental information and adequate stakeholder involvement (Christiansen et al., 2006), and provided a number of recommendations for improvement.

In a comparison study by Schenck (2011), four operators (IES, IERE, ADEME (BPX 30-323) and ECO-LEAF) were analysed based on their publicly-available GPIs. In summary, it was concluded that despite many similarities among operators, there are “substantial differences relating to transparency of the process”, which create obstacles for partnerships and harmonization (Schenck, 2011).

From PCR development perspective, Ingwersen et al. (2012) concluded that PCRs provide additional guidance on the product level, going beyond the basic guidance applicable to all products and thus, alignment is necessary despite the many potential challenges along the road. Published in 2012, the paper analysed numerous obstacles to reach alignment of PCRs, starting from structure of the PCR system, through product categorization and geographical scope, to different communication uses.

In the same year, Subramanian et al. (2012) developed a PCR comparison template used as a tool for comparison of duplicate PCRs of the same category, but issued by different operators. They concluded that duplicity is a common problem and have proposed that the provision of a PCR guidance document is “the logical path to moving forward” (Subramanian et al., 2012).

Table 1
Overview of programmes providing product category rules.

Scheme name	Scheme abbreviation	Origin	Language	Scope (as per section 6.2 of ISO 14025 (2006a))		Year of foundation	Latest publication of GPIs
				Geographic	Sector		
1. The International EPD® System	IES	SE	English	International	Generic	1998	2013
2. Earthsure – Institute for Environmental Research and Education	IERE	US	English	International	Generic	2000	2012
3. SCSglobal	SCS	US	English	International	Generic	2000	2013
4. ECO-LEAF	ECO-LEAF	JP	English/Japanese	International	Generic	2002	2002[a]
5. Korean Environmental Industry & Technology Institute EDP	KEITI EDP[b]	KR	Korean	International	Generic[c]	2002	2002
6. The Association for Environmental Relevant Product Information	MRPI[b]	NL	Dutch	National	Building and construction	2002	Unclear
7. The Norwegian EPD Foundation	EPDN	NO	English/Norwegian	International	Generic	2002	2014
8. Institut Bauen und Umwelt e.V.	IBU	DE	English/German	International[d]	Building and construction	2004	2013
9. Instytut Techniki Budowlanej	ITB	PL	English/Polish	International[e]	Building and construction	2004	2012
10. European Aluminium Association	EAA	EU	English	Europe	Aluminium	2005	2013
11. Danish Environmental Protection Agency	EPD-DK	DK	English/Danish	International	Generic	2006	2007
12. Environment and Development Foundation	EDF [b, f]	TW	Taiwanese	Unclear	Unclear	2006	Unclear
13. FDES INIES	FDES[g]	FR	French	International	Building and construction	2006	2011
14. PlasticsEurope	PE	EU	English	International	Uncompounded polymer resins, or reactive polymer precursors	2006	2007
15. PEP ecopassport	PEP	FR	English/French	International	Electric, electronic and HVACR products	2007	2011
16. BRE Global Limited	BRE	UK	English	International	Building and construction	2008	2013
17. Sistema Declaraciones Ambientales de Productos por la construcción	DAP[g]	ES	Spanish	National	Building and construction	2008	2013
18. The Green Standard	TGS[h]	US	English	Unclear	Unclear	2008	2011
19. Carbon Leadership Forum	CLF	US	English	International	Building and construction	2009	2012
20. Agence de l'Environnement et de la Maîtrise de l'Energie + AFNOR	ADEME[i]	FR	French/English	International	Generic	2011	2011
21. Confederation of European Paper Industries	CEPI[j]	EU	English	Europe	Paper	2011	No GPI
22. FP Innovations	FP	CA	English	Unclear	Wood products	2011	2013
23. ift Rosenheim	ift[g]	DE	German	National	Building and construction	2011	2013
24. NSF International	NSF	US	English	North America	Generic	2011	2012
25. The Spanish Association for Standardisation and Certification	AENOR GlobalEPD[k]	ES	Spanish	International	Generic	2011	2013
26. UL Environment	UL	US	English	International	Generic	2011	2011[a]
27. Centrum environmentálních prohlášení	CENDEC[l]	CZ	Czech	National	Generic	2012	2012
28. Canadian Standard Association Group	CSA	CA	English	International	Generic	2012	2013
29. Declaración Ambiental de Productos de Construcción	DAPCO	CL	English/Spanish	National	Building and construction	2012	2012
30. Global GreenTag (old name: ecospecifier)	GGT	AU	English	International	Generic[m]	2012[n]	2012
31. ICC Evaluation Service	ICC-ES	US	English	North America	Building and construction	2012	2012[o]
32. ASTM International	ASTM	US	English	North America	Generic	2013	2012
33. National Ready Mixed Concrete Association	NRMCA	US	English	International	Ready mixed concrete	2013	2013
34. Product Environmental Footprint	PEF[p]	EU	English	Europe	Generic	2013	2013
35. Slovenian National Building and Civil Engineering Institute	ZAG EPD[l]	SL	English/Slovenian	National	Building and construction	2013	2013
36. The Austrian EPD Platform	EPD-AT	AT	English/German	Europe	Building and construction	2013	2014
37. The DAPHabitat system	DAPH[g]	PT	Portuguese	National	Building and construction	2013	2013
38. The International EPD® System Türkiye	EPDT[q]	TR	Turkish	National	Generic	2013	2013
39. Australian and New Zealand EPD System	LCANZ/ALCAS EPD	AU/NZ	English	International	Building and construction	2014[r]	2014

[a] Expected update in 2014; terminology used in the current version is not conformant with ISO 14025.
[b] Insufficient information in English/no access to GPI.
[c] Excluding medical equipment, pharmaceutical products, primary agricultural products, livestock, fishery and forestry products.
[d] With focus on German-speaking countries.
[e] With strong focus on the national market.
[f] According to Hunsager et al. (2014), EDF has stopped its PCR development activities; but there is no information when.
[g] Insufficient information in English.
[h] No longer in operation.
[i] Insufficient information in English/not fully conformant to ISO 14025.
[j] Listed by Hunsager et al. (2014), but not considered as real EPD scheme (as per ISO 14025) here.
[k] Insufficient information in English/no official GPI published.
[l] Insuffucient information in English/GPI is under translation.
[m] With focus on building and construction materials, personal and cleaning products, clothing and textiles, paper and packaging.
[n] Although launched in 2012, currently the operator is restoring documentation and plans to be back in operation in 2014.
[o] GPI is accessible only online in html format.
[p] Not fully conformant to ISO 14025; requests PCR development, but no EPD publication.
[q] Insufficient information in English/GPI adopted from IES.
[r] Not officially launched yet (by April 2014).

As discussed in Section 2, a recent study by Hunsager et al. (2014) analysed the harmonization potential by reviewing the existing PCR and EPD documents, including comparison of the existing EPD schemes. The authors marked off several directions for improvement in order to reach harmonization. Additionally, a proposal for a global PCR register is given in order to "guide practitioners in the search for suitable documents" (Hunsager et al., 2014).

As outlined above, the scientific community highlights the need of further steps towards harmonization of PCR development rules. The following subsection examines how the scientific findings are translated into practical models by overviewing what has been done to date.

3.2. Activities in practice

Many activities of programme operators and other stakeholders in the field of Type III labelling have not been properly reflected in the scientific literature yet. In order to distinguish such activities, practically applicable approaches toward PCR alignment and harmonization of instructions can be defined and generally divided as development of 1) guidelines that overview common rules, applicable on international level (Del Borghi, 2013; Subramanian et al., 2012), 2) standards and technical specifications, or 3) collaborative platforms between different bodies working in same area. The latter can be e.g. mutual recognition of documentation and/or memorandums of understanding between parties. By using this division, guidelines, standards, platforms and other initiatives striving for harmonization of PCR development rules are chronologically overviewed below.

- Guidelines:
  - 2013: Sustainable Apparel Coalition (SAC) – sector guidance for PCR development published by an industry group consisting of over 75 parties and aiming to serve as a basis for the development of globally applicable PCRs for apparel and footwear verified under the Earthsure's EPD scheme, named IERE (Schenck, 2013)
  - 2013: Guidance for Product Category Rules Development (GPCRD) – guiding document, an answer to the raising need for the additional instructions on the development of category rules (GPCRD, 2013), developed by an international multi-stakeholder group of parties, called the Product Category Rule Guidance Development Initiative (PCR Initiative)
  - 2013: Product Environmental Footprint (PEF) Initiative – with a pilot phase started in 2013, the European Commission's (EC) initiative aims at the development of common product specific rules for the calculation of the environmental footprint of products (EC, 2013a)
- Standards and technical specifications:
  - 2007: ISO 21930 – one of the first steps on international level towards sectorial specifications supporting harmonization by complementing ISO 14025 for EPDs of products and intended for the building and construction sector (ISO, 2007)
  - 2012: EN 15804 – European standard, horizontally harmonized and developed in accordance with ISO 14025, providing "core product category rules for all construction products and services" (CEN, 2012)
  - 2014: ISO/DTS 14027 – new ISO project, part of the ISO 14020 series of standards, aiming at complementing ISO 14025 by giving more detailed guidance on PCR development (ISO, 2014); the document is still under development
- Collaborative platforms:
  - 1999: GEDnet – an international collaborative initiative of organizations interested in the development of environmental declarations with the objective "to foster co-operation and encourage information exchange among its members and other parties operating or developing Type III environmental declaration programs" (GEDnet, 2010)
  - 2011: ECO Platform – an European platform for EPD program operators to agree on common rules, principles and procedures, leading to mutual recognition of EPDs of construction products across regional borders, signed by 27 parties (11 of which are EPD operators) and aiming at an European-wide accepted Core-EPD, based on EN 15804 and replacing multiple EPD formats (Del Borghi, 2013; ECOPlatform, 2013)
- Other activities related to mutual recognition between parties:
  - 2011: Mutual recognition between IES and IBU – related and restricted to EPDs of construction products (Del Borghi, 2013)
  - 2012: CENDEC – establishment of the Czech's EPD programme based on adopting IES's GPI (IES, 2014a; Jelse, 2014)
  - 2012: PRé North America Inc. – commissioned to identify the programme operators in North America in order to integrate their PCRs in a global PCR database, together with the integration of the PCR databases of Japanese Environmental Management Association for Industry (JEMAI) and IES (Subramanian, 2012)
  - 2013: Mutual recognition between IBU and UL – agreement "amongst others things on the harmonization of the verifying process in order to achieve comparable results, according to the calculation rules of EN 15804" (IBU, 2013)
  - 2013: Memorandum of understanding (MoU) between IERE and JEMAI – another example for collaboration between programme operators in order to share resources and use of PCRs (IERE, 2013)
  - 2013: MoU between AENOR, IBU and IES – to increase the competitiveness of Spanish construction and building products (AENOR, 2013; Jelse, 2014)
  - 2013: EPD Türkiye – establishment of the Turkish EPD programme based on adopting IES's GPI (IES, 2014a; Jelse, 2014)
  - 2013: MoU between ALCAS/LCANZ and IES – to develop an Australasian EPD system based on IES[1] (ALCAS, 2013; Jelse, 2014)

Mutual recognition of PCRs, EPDs and instructions among operators is obviously becoming a valuable approach to reduce time, costs and duplication of documentation. Therefore, it is the role of specific (national, international or sectorial) activities to lay the foundations for more and stricter requirements.

3.3. Approaches in focus

In the following subsection, three approaches are described in more detail.[2] They were selected by the authors, firstly because of their recent introduction and thus yet insufficient recognition in the scientific literature, and secondly, because they are expected to have high effects on policy and market in the near future.

3.3.1. GPCRD

As shortly explained in Section 3.2, GPCRD is an approach to respond to the increasing need of additional instructions for PCR development. A taskforce group examining PCR alignment

[1] By the time of writing this paper, it was still not announced whether the new scheme will publish their own GPI, or if it will adopt the IES one.

[2] Alternatively, EN 15804 is also considered as a valuable input leading to harmonization of EPDs of constructions products (Del Borghi, 2013; Rossi, 2014); however, the document is already well implemented in daily practices, and due to its sector and geographic (yet) scope limitations, it is not further discussed here.

possibilities officially started the process for the decision on such guidance in October 2010 (GPCRD, 2013; Ingwersen and Subramanian, 2014). A year later, led by the American Center for LCA (ACLCA), a decision to start the development of PCR guidance was taken. Nowadays the document is known as the Guidance on Product Category Rule Development. It was published in 2013 as a result of the collaborative work of the "PCR Initiative" that consisted of 40 organizations from 13 countries (Ingwersen and Subramanian, 2014). The main standards, specifications and programmes that serve as a basis for the development of GPCRD are ISO 14025 (2006a), ISO/TS 14067 (2013), PAS 2050 (2011), GHG Protocol (2011), EN 15804 (2012), ISO 21930 (2007), PEF Guide (2013a) and BPX 30-323 (2011), although some of them relate to single-issue declarations (e.g. carbon footprint), not being under the scope of the present paper. The Guidance is considered as an adequate response to the increased users' needs and thus its structure and testing performance are evaluated further in this paper (Section 4.3).

3.3.2. PEF

In parallel to the GPCRD development, another important activity is currently taking place – the PEF Initiative. It endeavours to be a measurement tool, based on existing standards and approaches (Galatola and Pant, 2014), which is applicable for both in-house needs (e.g. identification of environmental hotspots) and external communications (Allacker et al., 2014; EC, 2013b). Currently, a 3-years pilot phase is running, aiming at the development of Product Environmental Footprint Category Rules (PEFCRs). Guidance for PEFCR development (EC, 2013b) has been published by the Commission and regularly updated, based on the findings of the pilot studies.

Despite the development and use of product specific category rules, the PEF Initiative is not a true EPD scheme, as defined by ISO 14025, since there is neither a programme operator assigned, nor a clear decision on how assessments based on PEFCRs will be further used. Moreover, in its current version, the PEF method conflicts with the constitutional ISO standards (i.e. ISO 14040 (2006b) on LCA and ISO 14025 (2006a) on Type III labels) in several areas. For instance, differences in terminology,[3] application and target audience (communication vs. non-communication driven), ban of cut-off rules, allowance of weighting in support of comparative assertions, category rules development procedures, etc. These methodological inconsistencies and the lack of a clear vision how the results should be communicated, may confuse users (Finkbeiner, 2013).

In a study from 2002, Bogeskär et al. (2002) have listed several reasons against EC to establish its own EPD-like scheme including but not limited to that such a voluntary instrument would require flexibility from an institution taking "sometimes politicised" decisions, and also that companies would be reluctant to "give up" existing schemes in favour of the European one (Bogeskär et al., 2002). In addition, more than 10 years later, Finkbeiner (2013) concludes that even if all methodological shortcomings are neglected, PEF may rather turn out as a cost driver for businesses and an obstacle for promoting LCA use. In contrary, Galatola and Pant (2014) describe PEF as an approach that can be used in existing or new EU policies, whereas existing LCA standards do not fully match those policy needs.

Nevertheless, the PEF initiative is politically justified by the need to harmonize environmental information in order to support a single green market in Europe. As such, it can be seen as a top-down harmonization initiative driven by the EC. The PEFCR concept is their artificial wording for a PCR in order to allow comparison between systems. To complement the analysis of the bottom-up approaches like GPCRD, to reflect its relevance in the current debate in Europe and due to its potential influence on policy and market in general, PEF is included in the evaluation of this paper. Although, PEF is not a participative harmonization initiative, it is considered important to analyse whether it could eventually be used for harmonization purposes related to the development of category rules in future.

3.3.3. ISO/DTS 14027

In April 2014, as part of the ISO 14020 series of standards, a new ISO project for the development of a technical specification ISO/DTS 14027 (2014) was approved. Developed under ISO's Environmental labelling technical committee (ISO/TC 207/SC 3), the document aims at complementing ISO 14025 by giving more detailed guidance on PCR development. The justification for the project addresses that practitioners consider ISO 14025-requirements, related to PCR development as insufficient, which can lead to the publication of inconsistent PCRs of different quality.

However, at this point information disclosed to the public is still sparse as the standardization process was just initiated. Consequently, the findings of this paper support the future development of the new ISO project.

4. Evaluation and outcomes

As defined in Section 1, the objectives of this paper are to overview EPD schemes, to examine harmonization practices worldwide and to test a PCR alignment initiative. In order to achieve the first one, a criteria-based analysis is performed. The conformance of EPD schemes with ISO 14025 and the handling of information disclosure are examined in Section 4.1, whereas the EPD schemes development trends are identified in Section 4.2. As a last sub-section, analysis and testing of GPCRD is disclosed (Section 4.3). Topics of divergences are defined and subsequently addressed by acknowledging also the review of EPD schemes (Section 2) and the approaches to harmonization among operators and stakeholders (Section 3).

4.1. Transparency of EPD schemes and ISO conformance

As it comes to evaluation of EPD schemes transparency, clause 5.5 of ISO 14025 (2006a) states that "[…] the programme operator shall be responsible […] to ensure credibility and transparency in the operation of the programme". Moreover, clause 5.9 of the same standard sets additional obligations in order to assure transparency of schemes, including publicly accessible GPI, a list of all published PCR documents under the respective programme, explanatory materials, etc. These principles are considered in the evaluation of existing programmes.

As shown in Table 1, the number of programmes using PCRs is very high (39). However, several are found to be no longer in operation, whereas others are not fully conformant to ISO 14025. Another group are such, which cannot be evaluated, due to lack of information and/or lack of transparency of the disclosed information. In our attempt to access information and evaluate transparency or usability, two major obstacles were faced relating to language and no public access to GPI/guidance documentation. Although English is not the official and obligatory language of ISO, it is internationally accepted and the lack of English version of documentation can sometimes be interpreted as an emphasis of the geographic limitation of a given programme and the specific target

[3] This was already reviewed by the European Commission noting that renaming common terms found limited support by the stakeholders (Galatola and Pant, 2014).

group. Furthermore, such cases are considered also as a holdback for cooperation among parties.

In parallel, no public access to GPI/guidance documentation is rendered as reluctant for transparency and/or inactivity of the operator. In cases when information is insufficient and/or inaccessible (e.g., due to non-accessible English GPI, closed webpage, unclear ecolabel type and/or conformance to ISO 14025, etc.), attempts were made to get in personal communication with representatives of the respective EPD schemes. Four programmes did not respond (thus, considered inactive), whereas with 18 communication was established and requested information (e.g. additional documentation that is not uploaded on their webpages) was received by most.

As a result of the detailed assessment, over 75% of the 39 schemes are considered fully ISO-conformant. About 10% are not or partly conformant, which can be a result of e.g. differences in the used terminology, operation without published GPI, non-observance of the mandatory content for GPI or PCR, etc. For the rest (less than 15%) of the analysed schemes, ISO conformance cannot be proven due to insufficient publicly available information (or information not translated in English). Thus, they are considered as "unclear". However, in this study, as a basis for further comparison of schemes, all of them that provide information regarding scope, year of foundation, first and latest published instructions and use product category rules by any means in order to develop LCA-based claims are acknowledged.

4.2. Trends in EPD schemes development

In order to identify a clear trend in EPD schemes development over the years, appropriate criteria are needed. In addition to Hunsager et al. (2014), who have described and used several attributes with regard to market position, operator type, EPD/PCR ratio, etc., the focus of the evaluation in this paper are origin, scope (geographical and sector), year of foundation and latest published GPI of each scheme (see Table 1). While the cited study describes differences in business models and structure of schemes, the present review aims at complementing it by additionally following through the historical development of the EPD market and trying to foresee future activities in general and specific sectors. Table 2 presents an overview of the distribution of schemes, based on their origin, geographical and sector scope.

Table 2
Distribution of programmes based on origin, geographic and sector scope.

Distribution	Amount	Share
Origin		
Europe	22	56%
North America	11	28%
Asia	3	8%
Australia	2	5%
South America	1	3%
Geographical scope		
International	21	54%
National	8	20%
Europe	4	10%
North America	3	8%
Unclear	3	8%
Sector scope		
Generic	17	44%
Building and construction	14	36%
Other sectors[a]	6	15%
Unclear	2	5%

[a] Three programmes under "Other sectors" can be considered as schemes verifying products directly applicable to the construction sector, but their scope is not defined officially as "building and construction".

Table 2 shows the clear domination of European-based schemes (over 55%) followed by North America (holding over a quarter of all). While on both continents the trend is steady and EPDs have been a well-known tool for some years already, the market is currently expanding in Australia (incl. New Zealand) and descending in Asia (where the focus is shifting towards carbon footprint labels). About two years ago, South America got its first EPD scheme, too.

Regarding the geographical scope of the analysed schemes, a clear tendency of claiming international coverage of most of the schemes is observed, although many are not recognised as international in practice. Examples for such are PEP, EPD-DK, ECO-LEAF, ADEME, etc., which mainly certify products for their local market. In addition to international and national scopes, several schemes declare continental scope, e.g. Europe and North America, which are mostly industrial associations (typically driven by policy), but not single entities (e.g. for Europe – EAA, PE, PEF and for North America – NSF, ICC-ES, ASTM, etc.).

Fig. 2 provides a graphical representation of the EPD-scheme market development over the past years, since the launch of the first scheme in 1998. A steady growth of their number is observed. Over the whole period, only one operator has officially stated its close down – TGS (Dunning, 2012), whereas KEITI has stopped its environmental declaration programme and has continued only its carbon footprint labelling programme (Hong, 2014). According to Hunsager et al. (2014), the Taiwanese EDF has stopped its operation, too, but no further details are available.

As shown in both Table 2 and Fig. 2, due to steady growth observed over the last years, the "building and construction" related schemes hold a large share of the total amount. Obviously, EPDs are becoming useful instrument in the building and construction sector (Braune, 2011; Lasvaux et al., 2014). This is also partly due to the newly introduced requirements for green building certification. For instance, the rating system of the US Green Building Council's LEED v4 standard awards additional points to projects that use products verified with EPDs (LEED, 2014). Furthermore, the European Construction Products Regulation, adopted in 2011, requires implementation of measures for sustainable use of resources, reduction of emissions and use of EPDs for assessing and reporting the environmental impacts of construction products (CPA, 2012). Consequently, the largest expansion of EPD schemes verifying construction products has been observed in Europe.

As described in Section 3.2, Europe is also home for most of the harmonization initiatives among sectors and operators, including the standard EN 15804 giving the core rules for construction EPDs (CEN, 2012). Shortly after its publication, an interesting trend on a global scale was apparent. A large number of newly registered EPD

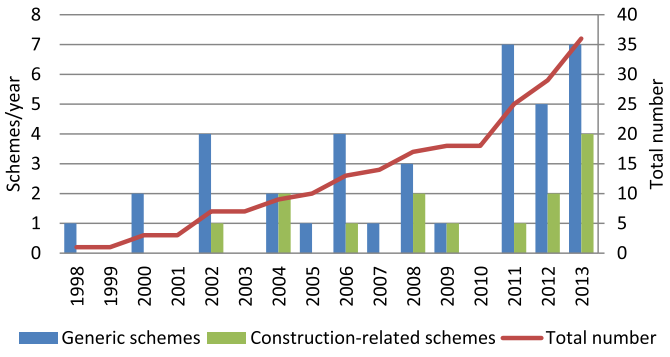

Fig. 2. Overview of newly established programmes and their total number over the years.

schemes (7) and updates of GPIs of older operators (8), including also an increasing number of MoU agreements between parties (6), can be observed.

4.3. Analysis and testing of GPCRD

GPCRD is a guiding document, elaborated because of the increased need for harmonized and more detailed requirements for PCR development. The enhanced interest in this subject is also proven by the large number of stakeholders who participated during the development of the document (see Section 3.3.1). This activity proves its relevance and importance for practitioners. As the Guidance was published only recently, its practical implementation and performance are not proven and have not been investigated yet. Therefore, detailed analysis of the practicality of the document to complement GPIs is provided, followed by a road test.

4.3.1. GPCRD as a complement to GPIs

In this section, an overview of GPCRD's structure is provided and a comparison with GPIs of the analysed EPD schemes is conducted. Shortcomings of these programmes are described together with an evaluation whether the Guidance is capable to complement GPIs and to tackle these drawbacks.

GPCRD consists of seven chapters and four annexes. It provides detailed guidance for elaboration of PCRs from the initiation and preparation phase up to the publication, maintenance and usage of the rules. Best practices for PCR development and management are also given. A PCR development template is proposed in Annex I, while Annex II compares the LCA methodological approaches used by the standards, specifications and programmes that have been used for the development of the Guidance (listed in Section 3.3.1). This comparison aims at pointing out the consistent and contradictory elements between methods, thus raising awareness, "if a program intends to design a PCR that is applicable to more than one standard or program" (GPCRD, 2013). For given aspects GPCRD lists options, among which users can choose (e.g. the review of product classification systems in Annex III), whilst in other cases it provides ready solution to be used without options. Sometimes it demands more details than any other programme instructions (e.g. identification of stakeholders or requirements for PCR committee). Annex IV provides additional criteria for selection of impact methods.

The comparison of GPCRD with the PCR development procedures of the analysed GPIs resulted in a list of topics that are somehow approached controversially or sometimes even untouched by operators, but are found to be of importance in order to develop reliable PCRs. Evident examples of such topics of divergences are listed in Table 3. Their original titles as per GPCRD are kept and followed by examples highlighting how some schemes endeavour the topics:

As an addition to the above-listed topics, obligatory GPI items, as required by ISO 14025 (described in Section 2.1), are often only mentioned in GPIs but detailed specifications are missing. This results in an arbitrary interpretation of the programme instructions and thus sometimes provokes conflicts among stakeholders. Moreover, insufficient instructions hinder mutual recognition between operators and sometimes GPIs even contradict each other. In this context, in the present paper GPCRD is considered as a guiding document eligible for schemes, willing to improve their PCR instructions and to allow harmonization. In theory, GPCRD is appraised as an adequate response to the increased needs of global PCR alignment, which can even be used as a foundation for the development of ISO/DTS 14027. Thus, it is the subject of the following practical testing exercise.

4.3.2. Road testing GPCRD

In order to test the applicability of the Guidance in practice, a PCR for "Oilseed processing services" (IES, 2014b) is used as an example. By the time of GPCRD's publication, the PCR was already under development (thus further referred to "draft PCR"). IES is the operator supervising and owning the PCR; the authors of the paper were part of the PCR committee, developing the document. This involvement in the process and the insight gained was also one practical reason why the authors chose this exemplary PCR to test the GPCRD.

According to the operator's GPI, its general PCR development process is conformant with GPCRD "with some minor exceptions" (IES, 2013), where IES being the only operator claiming such conformance by the time of the paper submission. Thus, a PCR developed under this EPD scheme is chosen here also to verify this proclamation. It is considered that if other PCRs from the same operator, conformant with the latest GPI version, were used for this study, similar results would be obtained. Alternatively, any other PCR from different programme can be used; however, the outcomes of such comparisons cannot be expected here, since GPIs have diverse qualities and requirements. Studies in this direction are thus further suggested.

Therefore, with the intention of evaluating GPI's flexibility and likelihood to take upon additional obligations and to road test GPCRD, possibilities to align the draft PCR with the requirements of GPCRD are explored in this Section.

- Adjustment of the alignment procedure

Firstly, the content requirements of the GPCRD and the GPI of IES are compared. The draft PCR is based on the operator's PCR template (IES, 2012). Due to slightly different information disclosure and format requirements between IES's PCR template and the one provided by GPCRD (Annex I of the Guidance (GPCRD, 2013)), additional clarification was needed with regard to which document to be used. Thus, after parallel communication with the authors of GPCRD and representatives of IES, it was agreed that the PCR would keep its current structure and content, as required by the operator, but use the GPCRD's PCR template as a complementary checklist.

Secondly, the Conformity Assessment Form (CAF) (Ingwersen and Subramanian, 2013) – a supplement to the GPCRD – is used to track the PCR's conformity. This form represents an extract of all requirements and recommendations from the Guidance (Ingwersen and Subramanian, 2013) and facilitates the assessment of any PCR striving for conformity to the Guidance. In order to be fully compliant, a PCR shall cover 100% of the 66 requirements as listed in the form. Other 86 non-mandatory recommendations are also listed. Usually, CAF is intended to be used by both the PCR drafters and the reviewers.

GPCRD is not a standard intended for certification purposes and its authors are not a certification body. Moreover, it has not been defined who has the responsibility and who is supposed to declare conformance to the Guidance. For that reason, the PCR conformity assessment was performed based on a common agreement between the drafters of the PCR and the Technical Committee (TC) of the IES. The CAF was filled in by the drafters of the PCR. Next, by using this form, the conformity of the PCR with the GPCRD was verified by the TC in parallel with the obligatory PCR review for GPI conformity.

- Alignment with GPCRD's PCR template

As a first step, the structural requirements of the two PCR templates were compared. Differences and/or additional

Table 3
List of exemplary topics of divergence between GPCRD and analysed GPIs.

Topic	Description
Development process	
Identifying the stakeholders	Stakeholder engagement can be a long and complex process; however, most of the operators do not concentrate on this much, but rather only give basic directions with regard to stakeholder identification; in contrary, GPCRD stresses on this topic by proposing a procedure for stakeholder identification and listing different types of stakeholders that have to be considered
PCR committee	As it comes to the identification of PCR committee members (i.e. the parties developing the draft PCR), several operators speak about "adequate knowledge" (ICC-ES, NRMCA and FP) of the participants, but no one defines clear criteria to assess such; moreover, none of the GPIs raises the question regarding balance and/or domination of single organizations among members; the potential risk of conflict of interests is often neither managed, nor addressed, whereas GPCRD outlines this issue specifically
Public consultation	A topic that in most of the cases is also disregarded; IES and IBU can be outlined as the only operators providing an online platform for stakeholder consultations (also recommended by GPCRD), thus assuring transparency of the process
Definition and classification of the product category	This issue is handled differently by each operator; there are divergences on the decision which classification system to be used; there are schemes like PEF and NRMCA that use only locally applicable systems (i.e. Eurostat's Classification of Products by Activity (CPA) and the North American Industry Classification System (NAICS), respectively); others, as e.g. ECO-LEAF and EPD-DK, do not propose any specific classification system; in the majority of cases GPIs recommend the use of the United Nations Central Product Classification (UNCPC) GPCRD does not propose specific system, but rather overviews several that are the most promising for application on global level;
Taking steps toward alignment of PCRs	Operators are not obliged to work towards harmonization between programme instructions and PCRs, although encouraged by ISO 14025 (Del Borghi et al., 2008); the standard also recommends to consider and to use readily available PCRs when developing PCR, which is translated in the GPIs of several operators (IES, CLF, IERE, PE, EPDN, etc.); however, in the general case operators consider "harmonization" only as a compliance with international standards (e.g. ISO 14025) and no one reaches the GPCRD's detailed level of recommendations yet
LCA-related	
Data requirements	PCRs should state what data is to be collected, together with defining for which process primary data and for which generic data is to be used; this has a direct linkage with the modularity, as a key principle in LCA based claims (Buxmann et al., 2009); the majority of EPD schemes allow the use of information modules, but rarely give specific details on the relation between modules and data requirements; exceptions are IBU, IES and IERE; GPCRD recommends GPIs to specify generic data sources like life cycle inventory databases in order to ensure that result differences are not artefacts of different background data
Data quality requirements	Observed schemes rarely go beyond ISO requirements for data quality or specify any additional data quality assessment procedures; in contrast, GPCRD requires data quality assessment to be performed for primary data collected, including the use of specific data quality assessment methods that have to be described in the PCR and additionally recommends PCRs to suggest the use of a data quality management plan
Impact categories and impact assessment methods	While some operators as BRE and EPDN recommend as a general rule the use of predefined parameters describing environmental impacts and resource use (as per sections 7.2.3 and 7.2.4 of EN 15804), others like SCS, UL or NSF consider this issue to be a specific case for each particular PCR; GPCRD only provides guidance on selecting of the life cycle impact assessment methods, but does not discuss who and how the methods shall be defined
Assumptions and Limitations	Although being an integral part of every LCA study, often assumptions and limitations are not a mandatory part of PCRs content; GPCRD demands the disclosure of such
Uncertainty	Unlike GPCRD, there is no PCR scheme that recommends the use of any method for handling and reporting uncertainties as a requirement of the PCRs; uncertainties are mostly considered as a requirement for the underlying LCA report and EPD verification
Structure and content	
Structure of PCR document	Many schemes do not provide clear and specific structure of the PCR document, but mostly rely on the ISO requirements (e.g. ICC-ES, SCS, CLF, NRMCA, PE); in contrast, GPCRD requires the use of their own PCR template
Fixed and flexible content in PCRs	Fixed elements have to be agreed in order to promote comparison (mainly regarding LCA-related topics); operators consider this issue differently and agreement among them is needed in order to allow alignment of PCRs; GPCRD assures variability within product categories by leaving some PCR elements flexible (such are mostly related to the presentation of the results, where geographic or sector specific characteristics has an influence)

requirements to be fulfilled were identified in 14 of 41 fields. These are namely: product category, language of PCR, reasoning for development of PCR, open consultations, impact indicator selection justification, interpretation, assumptions and limitations, uncertainty, PCR review report, PCR committee member conflicts of interest, sample claim, outstanding methodological issues, additional requirements in standards not covered in PCR, and conformance with the GPCRD.

Modifications for most of the above-listed fields were implemented instantly without needs for discussions between the PCR drafters and the programme operator. For some fields (e.g. impact indicator selection justification, PCR review report, PCR committee member conflicts of interest, etc.) more detailed information disclosure in the PCR was needed to conform to the GPCRD's PCR template. However, no inconsistencies that can restrain the alignment between the two PCR templates were observed.

- Alignment based on CAF

In the context of the conformity assessment, the CAF is the more relevant assessment form compared with the GPCRD's PCR template, since the latter only gives requirements to the structure of the PCR. Hence, as listed in the Electronic Supplementary Material to this paper, with regard to the conducted case study, obstacles and needs for modifications in conforming to the GPCRD requirements through alignment based on CAF's items were defined. As a rule, conformity with GPCRD is claimed only when 100% of the requirements are fulfilled. Out of the 66 mandatory CAF requirements, for 10 actions were undertaken in order to conform with CAF.

The most relevant topics of divergence, which require adaptation are e.g., the conflict of interest of stakeholders and PCR reviewers, domination of single organization in the PCR committee, data quality assessment, primary data verification, reporting and

interpretation of results, PCR update. For each of these, GPCRD provides more detailed guidelines than the GPI. Thus, the draft PCR had to be adapted and additional information to be included, but no cases of conflicts between GPI and the Guidance were registered.

In its second part, CAF continues by listing 86 non-obligatory recommendations to PCR developers, among which in the Electronic Supplementary Material four are highlighted as important for the development of transparent and robust PCRs. In the focus of this were topics as e.g., expertise of PCR committee members, PCR flexibility to regional differences, description of environmental mechanisms for the selected impact categories, etc.

As an overview of the whole process, the attempt to align the draft PCR with the PCR template of GPCRD brought out 14 of 41 fields that needed to be additionally synced in the draft PCR. Regarding the conformity with the 66 requirements of CAF, due to insufficient information required by GPI, shortcomings were identified for 10 of them. Furthermore, as decisions could not be taken by the PCR drafters solely, an additional discussion between the TC and the PCR committee was required for four of these 10 requirements. As part of the official PCR review process, the TC issued an official statement and recommendations for the adoption of additional requirements of the GPCRD, based on which modifications were introduced. Furthermore, recommendations from the second part of CAF were considered useful and over 70 were implemented.

Although the draft PCR had to undergo several modifications, the overall impression is that IES's GPI and GPCRD are complementing each other and that both are heading in the same direction, striving for common objectives. Thus, it is acknowledged that in the specific case the draft PCR alignment with GPCRD was a challenging, but not a troublesome task.

Nonetheless, if the same attempt to align a PCR with GPCRD is duplicated to a random PCR published by any other of the studied schemes, it is assumed that alignment may need to undergo a different procedure, eventually associated with more effort. As each operator has its specific requirements, it is not possible to make a general conclusion. The analysis reveals that IES is one of the EPD schemes providing the most detailed programme rules (thus to some extent being less flexible), whereas other GPIs are less detailed and/or operators do not provide PCR templates. For such, the Guidance is an enhancement to introduce more specifications and to use already developed solutions. However, it is acknowledged that superficial PCR development rules may be ideally an easy task in a sense of absence of conflicting areas with already settled rules. Nevertheless, difficulties can occur due to potential necessity of much deeper involvement of PCR committee, operator and reviewers (i.e. TC). It is another discussion if operators are reluctant in adopting rules that their PCRs closer to international recognition.

5. Discussion and conclusions

The present paper provides a comprehensive analysis of the current market of EPD schemes worldwide, the trends of their development and an overview of the existing approaches to harmonization. As also proven in the current work, the harmonization of rules and instructions is becoming a process that many of the schemes will face. Three leading initiatives are described profoundly, due to the expectation of their impact on the EPD market. The paper presents results of the first road test of the GPCRD Guidance. The test shows the practical challenges in harmonizing the PCR development requirements of GPCRD with a PCR and emphasizes on the major methodological divergences between the GPIs of the analysed schemes that hinder harmonization.

5.1. EPD schemes and harmonization approaches

The increasing demand of disclosing environmental information becomes apparent by the increasing number of EPD schemes worldwide. While there were only seven operators until 2002, by the end of 2013 a fivefold increase has been observed in this study (see Section 2). Nowadays, just less than half of all EPD schemes are managed by the construction sector (see Section 4.2). Due to the presence of varying geographic and product scopes and subsequently, different rules for PCR development, harmonization initiatives are becoming widely recognised in order to increase the significance and comparability of EPDs on a global scale.

The GPIs analysis of 39 schemes shows that differences among rules still exist. Even though ISO 14025 can be considered as a common reference, in its eight years of existence it was experienced that it cannot provide detailed solutions for each case. This is mainly because different sectors require different methodological solutions and information disclosure. In such cases, it is the place for country-, sector-specific or other supplementary guiding documents to provide more explicit guidance.

In this context, as outlined in Section 3.3, three larger initiatives among others have focused one's attention on this matter lately. Two of them are the publication of GPCRD (practically justified in this paper) and the launch of the new ISO project ISO/DTS 14027 (being in too early development phase yet), both resulting from the users' demand for more detailed PCR instructions. It is important to mention here that neither GPCRD, nor ISO/DTS 14027 are the only prerequisite to achieve harmonization between schemes, as both are focused only on the PCR development process.

The third one is a recent activity that has been receiving international attention lately, i.e. the EC's PEF initiative. In comparison with GPCRD and ISO, PEF also provides guidance for development of rules for products fulfilling the same functions (called PEFCR in PEF language). However, it is not fully conformant to ISO 14025. Moreover, in its current state, the scientific community has not yet reached a consensus of the robustness of the proposed new footprinting method. According to Finkbeiner (2013), PEF, being in clear conflict with ISO 14040/44, threatens harmonization of LCA-based claims and rules. On the contrary, Galatola and Pant (2014) justify the methodological issues, rendering into account also that the PEF initiative is currently in pilot phase, expecting a review phase after. Therefore, in this paper, it is acknowledged that due to the current level of maturity, the absence of scientific agreement and its European scope only, PEF cannot serve as a solution for global harmonization of PCR development rules (including adoption by ISO/DTS 14027) at this time.

5.2. PCR alignment in practice

Based on the evaluation of existing EPD schemes and harmonization initiatives, the GPCRD is perceived as a good opportunity for operators to synchronize their GPIs with the latest PCR developments. In order to test the applicability of the GPCRD, an alignment of the rules of the Guidance with an existing draft version of a PCR was performed. After active communication between parties (PCR drafters, operator and TC) and the adoption of several modifications (mostly clarification and additional texts) by the PCR committee, TC proposed complementary clarifications to be included in order to meet fully the requirements of GPCRD. Ultimately, lined with a positive statement by the TC that the PCR is in conformance to all 66 “shall” requirements of the GPCRD, the PCR conformity assessment was perceived as challenging, but possible task.

Several shortcomings in terms of PCR content were observed in this paper, considering that the GPCRD is much more detailed and

demanding in many aspects. However, it complements IES's GPI conveniently, without showing any major divergences or requiring significant enhancements. Although the structure of the content of IES's PCR template is not completely in-line with the requirements of GPCRD template, recommendations for the implementation any major modifications in IES's PCR template are not provided.

On a broader level, no major conflicts and unresolved issues between the GPI of the IES and GPCRD were observed. The attempt to align the draft PCR showed slight differences between IES's instructions and the Guidance, but generally, such alignment is possible without major adjustments. Nevertheless, strengthening the instructions of IES in several aspects may be beneficial to increase the scheme quality (e.g. stakeholder engagement, "conflict of interests" disclosure, PCR committee requirements, primary data quality assessment, reporting and interpretation of LCA results, etc.).

By analysing the GPIs of other active operators, this paper demonstrates that in many aspects GPCRD exceeds the existing concepts and requirements related to PCR development. Many of the requirements and solutions as proposed by GPCRD are acknowledged as very useful and beneficial for use by PCR developers on one hand, and GPI upgrades on the other. Furthermore, in order to align the rules for PCR development on a broader scale and to achieve harmonization, several aspects have to be highlighted, presuming that there is not one solution for all of them at once. The systems for product category classification that are considered in PCRs have to be narrowed down ideally to one, but currently 2–3 that are free, publicly accessible, internationally applicable and mutually compatible is also feasible. Flexible and fixed content of the PCR should be agreed (as proposed per section 7.3 of GPCRD and highlighted in Table 3 of the paper), considering that a PCR can be divided by two parts: the LCA part that should be fixed, while geographic and sector specifics may permit differences (e.g. selection of impact methods and/or reporting and interpretation of LCA results). The validity and requirements for updates (not only after expiration), as well as data quality verification procedures, can also be better aligned. Although operators have almost the same procedures for PCR development, there is still room for improvement in several aspects, in order to assure alignment of processes (e.g. stakeholder identification, requirements for PCR committee members, etc.).

Many of these aspects are addressed in GPCRD by providing specific solutions or recommendations. Moreover, the Guidance is important, as it is a global initiative, built upon existing methods and refraining from introducing and/or imposing new methodological approaches. Providing a PCR template, it is a useful supplement to EPD programme operators and their respective GPIs. Thus, the current analysis considers that the Guidance can serve as a robust basis for the development of the new ISO/DTS 14027 or any other code for PCR development.

A practical test of the GPCRD alignment with only one PCR is considered as a limitation of the paper. Hence, examinations with PCRs from other operators are recommended in order to observe more widely how GPCRD is accepted and how it fits among operators. Furthermore, it will be interesting to observe how GPCRD, the new ISO specification and any other supplementary/harmonization initiative (e.g. EN 15804) will support ISO 14025 in providing more enhanced guidance on PCR development.

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Appendix A. Supplementary data

Supplementary data related to this article can be found at http://dx.doi.org/10.1016/j.jclepro.2015.02.012.

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3.3.1 Literature review: results update

The review in Publication 3 of the existing Type III programme operators and initiatives for PCR harmonization was conducted for the period up to 2014. Additional investigation to fill up the eventual gaps from 2014 to date is necessary and performed in the following. It is used to confirm or to cast aside the already identified trends and to support the discussion and conclusions of the thesis.

Through additional desk research, it is confirmed that the number of Type III operators is still increasing. Nine new initiatives are determined (see Table 2). Interesting to note is that all these new programmes operate in the sector of building and construction products (one also having a general scope and one – very narrow scope of a specific construction product). The majority of them are members of the ECO Platform – a group of programme operators striving for consistent and transparent EPD development in Europe (ECO Platform 2019).

Table 2. List of additionally identified Type III programmes

Scheme name	Origin	Sector scope	Year of foundation
NAPA EPD program	US	Asphalt mixtures	2014
EPD Italy	IT	General	2015
EPD Belge	BE	Building and construction	2016
RTS EPD	FI	Building and construction	2016
EPD India	IN	Building and construction	2017
Ecobility Experts	DE	Building and construction	2017
Tata Steel	UK	Building and construction	2018
EPD Ireland	IR	Building and construction	2018
SÜGB	CH	Building and construction	2019(?)

Within the observed period (2014-2019), additional seven new Memorandums of Understanding between different programme operators worldwide are counted. Again, most of the activities are in the building and construction sector. As a result of mutual recognition agreements between different operators, dual Type III declarations are already a fact in the last years. They carry two registration numbers and two logotypes for increased market recognition. All this is a prove for the continuous work of stakeholders towards mutual recognition and cooperation, based on the unabated interest for Type III declaration in the sector.

In terms of scientific publications, the interest in Type III declarations seems to be constant. Five publications are identified that deal with variety of EPD related issues, such as, for example, the investigation by Strazza et al. on the effects of using data retrievable from EPDs into a non-conventional LCI, thus replacing inventory background data from secondary datasets (Strazza et al. 2016). In two publications, Gelowitz and McArthur discuss EPDs in the frame of their adoption in green building certification schemes, such as the USGBC LEED[3] (Gelowitz and McArthur 2016) or exploring the common errors and omissions in different harmonization documents that result in poor harmonization of PCRs (Gelowitz and McArthur 2017). Recently, Del Borghi et al. published a study on how the discrepancies between the Guidelines for PEF and the GPI of a prominent Type III operator could affect the consistency in the outcomes (Del Borghi et al. 2019). Galindro et al. suggested a framework to use data envelopment analysis to benchmark EPDs (Galindro et al. 2019).

As regards harmonization of PCRs, new commercial initiatives in operation have not been detected. In terms of standardization, however, activities on both international and European level are observed. Certain movements are seen in ISO/TC 207/SC 3 – the sub-committee of ISO that is managing the standards on communication of environmental aspects of products and the ISO 14020 series. The draft technical specification (TS) to ISO 14025, namely ISO/TS 14027 (2017a) that is discussed in the publication, has been officially published in 2017 to become the ISO response to the increasing need for standardized principles, requirements and guidelines for developing quality PCRs (ISO 2017a). As of August 2019, a new ISO project on a TS to ISO 14025 on principles and procedures for mutual recognition between Type III programme operators is under preparation (ISO 2019b). Entitled ISO/NP TS 14029, it is intended to be a guidance on how to assess, evaluate and compare the GPIs of programme operators for defining different levels of cooperation. These ISO norms are further discussed in Chapter 4.1.3.

Regarding construction products in particular, this third publication discusses the standards EN 15804:2012+A1:2013 (2013) and ISO 21930 (2007). By the time of writing this thesis, the European EN 15804:2012+A1:2013 is undergoing an update, approved for

[3] The U.S. Green Building Council (USGBC) Leadership in Energy and Environmental Design (LEED) is a green certification programme for building design, construction, operations and maintenance (source: https://new.usgbc.org/leed)

publication by mid-October 2019 (CEN 2019). The document is the EPD standard for sustainability of construction works and services that provides an overarching PCR for EPDs of construction products. The new version, referred to as EN 15804:2012+A2:2019, is supposed, among others, to be aligned with PEF in different aspects e.g., the use of a broader set of environmental indicators that PEF recommends (Gaasbeek 2019).

The analogous standard to EN 15804:2012+A1:2013 on core rules in sustainability in construction works on international level – ISO 21930 – has been updated in 2017 (ISO 2017b). The update was intended to make the ISO standard more aligned to the European norm and thus, to expect improved cross-recognition of EPDs across e.g. North America and Europe. Since the new EN 15804:2012+A2:2019 is already approved, its ISO equivalent would still have to catch up with the latest European developments.

In addition to the new EN 15804:2012+A2:2019, again in 2019, EC has given a mandate to the European Committee for Standardization (CEN) to start a new working item on a standard that should allow the application of product benchmarking in EPDs. This is believed to potentially enable EPDs to be used on B2C level and to allow for comparative assertions between EPDs (Gaasbeek 2019).

3.4 The Product Environmental Footprint communication at the crossroad: integration into or co-existence with the European Ecolabel?

This chapter contains the following publication **(Minkov et al. 2019b)**:

> Minkov N, Lehmann A, Finkbeiner M (2019) **The Product Environmental Footprint communication at the crossroad: integration into or co-existence with the European Ecolabel?** Int J LCA 10 8:2898. https://doi.org/10.1007/s11367-019-01715-6

The object of the analysis in the fourth publication is PEF. It is a product evaluation method, based on LCA that sets up procedures for development of category rules; thus, it is also in focus of the previous publication among other harmonization initiatives. Here, in a first step, PEF is analysed from the perspective of a tool for communication of LCA information and compared with EUF based on three case studies, i.e. three different product groups: detergents, paints, and t-shirts. Overall, few similarities and many divergences between the two approaches are noted, given that PEF is a relative approach and provides information on the potential life cycle environmental impacts, whereas the Type I ecolabel criteria are issue-specific and do not necessarily cover the complete life cycle of the product. PEFCRs set rules for an LCA study, whereas ecolabel criteria are restrictive and set emission limits, product performance requirements and recommendations to users.

As a second step, the PEF-, EUF- and Joint perspectives for mutual integration and/or co-existence of PEF and EUF are developed. Each of the first two perspectives (PEF perspective and EUF perspective) explores three scenarios on how one initiative could benefit from using elements of the other (and vice versa) and serving different communication needs (B2B or B2C). In any of the scenarios it is assumed that PEF and EUF exist in parallel. In the Joint perspective, only one scenario is examined. It conceptualizes a hybrid ecolabel typology. This Type IV, as called, combines a life cycle perspective that is imperative for any LCA-based declaration (such as a PEF profile) with the product- and issue-specific nature of the awarding criteria of a Type I ecolabel (e.g. EUF). It is assumed that such a hybrid ecolabelling system could potentially be an instrument against the constant proliferation of ecolabels by merging both PEF and EUF

and providing a Type I ecolabel awarding based on a B2B-oriented environmental declaration (Type III). This way, one ecolabel operator could simultaneously issue both: an LCA-based declaration (Type III) for B2B and a pass-fail Type I ecolabel for B2C.

The supplementary material to this publication is presented in Appendix A.4. It contains the following information for each of the three case studies:

- General background information, as a comparative summary of the specifications of the PEFCRs and the respective EUF criteria;
- EUF awarding criteria and the PEFCR most relevant processes and impact categories based on the PEFCR system boundaries;
- Classification of the EUF criteria;

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LCA COMMUNICATION AND LCA FOR ISO LABELS

The product environmental footprint communication at the crossroad: integration into or co-existence with the European Ecolabel?

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Abstract

Purpose Since 2013, the European Commission (EC) is developing and testing the Product Environmental Footprint (PEF)—a product evaluation method, based on life cycle assessment (LCA). How and if PEF would be applied in communication and ecolabelling is still unclear; likewise, the scientific work on this matter is incomplete. This study aims to investigate the interface between PEF and the European Flower (EUF)—the European type I ecolabel—and to particularly examine scenarios for their co-existence and mutual supplement.

Methods The aim of this work is achieved by conducting an analysis of three case studies on three different product groups for which both Product Environmental Footprint Category Rules (PEFCR) and European Ecolabel awarding criteria exist, namely, detergents, paints, and T-shirts. This includes a topic-based assessment and comparison of which life cycle stages, processes, and environmental aspects they cover. Based on this inquiry, a reciprocal analysis of synergies, gaps, and potential conflicts of the PEFCR and the ecolabel is performed. Finally, concepts for achieving mutual benefits for both approaches are provided and proposals for a consistent integration of PEF results in business-to-business (B2B) and business-to-consumer (B2C) communication are developed.

Results and discussion The results of the three case studies point out similarities and gaps between PEF and EUF, as well as methodological shortcomings of both approaches. Based on this, three perspectives (namely, PEF, EUF, and Joint perspectives) are explored. They represent possible combinations and co-existence between PEF and EUF and serve different communication needs (B2B, B2C, or both). Whereas the first two perspectives examine scenarios for integration of one approach into the other and their parallel co-existence, the Joint perspective proposes a hybrid approach (called ecolabel type IV). It is a combination of elements of type I and type III environmental labels that allows for two different, but simultaneous product certifications depending on the end-user focus.

Conclusions In order to improve the current approaches for ecolabelling, the use of criteria that cover the complete life cycle is imperative. Still, tools that go beyond the calculation of an LCA profile and cover product-specific aspects are needed. The proposed hybrid ecolabel covers both aspects by combining PEF and EUF. It is believed to be a solution for the EC to operationalize PEF in communication and in parallel, to avoid further proliferation of ecolabels.

Keywords Co-existence · Communication · Environmental labelling · European Ecolabel · Product environmental footprint

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1 Introduction

1.1 Motivation and objectives

Life cycle assessment (LCA) is a tool that allows for a holistic understanding of all potential environmental impacts of a product along their complete life cycle—from the cradle to the grave (ISO 2006a). LCA reduces the risk of misinformation due to one-sided environmental characteristics (Finkbeiner et al. 2014; Gruère 2013), or burden shifting

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between life cycle (LC) stages (ISO 2018; Minkov et al. 2018). The communication of LCA results to stakeholders is a relevant topic for businesses that work on improving their products and organization's footprint and image. To support this, environmental declarations and labels (or "ecolabels" for short) are a voluntary tool for transmitting information of the environmental performance of products between stakeholders.

Since 2010, Directorate-General for Environment (DG ENV) of the European Commission (EC) in cooperation with the Joint Research Center (JRC) are developing and testing the Product Environmental Footprint (PEF). It is an action undertaken in realization of the EC's "Recommendation on the use of common methods to measure and communicate the life cycle environmental performance of products and organisations" (EC 2013c) that followed the EC's Sustainable Consumption and Production and Sustainable Industrial Policy (SCP/SIP) Action Plan (EC 2008a). PEF aims at developing a harmonized European methodology for assessment studies based on the life cycle approach (EC 2013a; Manfredi et al. 2015). In 2013, the pilot phase started: PEF has been tested on over 20 product groups for which Product Environmental Footprint Category Rules (PEFCR) were developed. The initiative intends to eliminate the consumer confusion of having multiple LCA standards within the European Union (EU) (Ganley 2013) and provides specifications for selected LCA aspects.

Since 2018, the initiative is in a transition phase. By the end of it (around end-2021), decisions are expected on how the policy implementation of the method would be foreseen in a European context (Bach et al. 2018). The use of PEF for communication and ecolabelling is one of its potential applications. However, this remains one of the critical aspects of the PEF development that has not yet been fully resolved nor investigated (Finkbeiner 2014; Lehmann et al. 2016; Vincent-Sweet et al. 2017). Opinions of experts being involved in the PEF pilot phase apparently diverge on this matter, e.g., there is support in favor of developing different approaches for business-to-consumer (B2C) and business-to-business (B2B) communication (Vincent-Sweet et al. 2017). Others assume that a more beneficial use of PEF would be to support existing ecolabels or to be applied only for, e.g., in-house product improvement (Bach et al. 2018).

One existing ecolabel also administered by DG ENV under EU Regulation No. 66/2010 (EC 2010) is the European Ecolabel (the EU Flower or EUF, called for short). Established in 1992, it is a multi-criteria approach recognized and applied throughout Europe. It ensures that improvements are addressed for the main environmental impacts caused by the products over their life cycle (EC 2019). EUF is an important element of the SCP/SIP Action Plan of the EU, and for many years, it has been the only concrete EU-wide tool setting product design targets (EC 2010; BEUC 2014).

The objective of this work is to investigate the interface and relation between PEF and EUF. This includes an assessment which LC stages, processes, and environmental issues they cover by analyzing three different case studies. Based on this inquiry, a reciprocal analysis of synergies, gaps, and potential conflicts is performed. Finally, concepts for achieving mutual benefits between both approaches and their consistent integration for the communication of PEF results in B2B and B2C context are provided. The results of this work are intended as a general contribution to the scientific debate on the communication of LCA results and may also support the EC in their decision-making process for future application of PEF.

1.2 Background

Currently, scientific research on the interlinkage and interoperability between PEF and EUF (or any other typical pass-fail type I awarding format) is limited. In the following section, we present the background framework derived from a literature review to scrutinize on the relation between LCA, ecolabelling, PEF, and their affiliation to communication.

1.2.1 LCA and communication

The International Organization for Standardization (ISO) defines three major types of ecolabels, namely types I, II, and III that are governed by the ISO 14020-series, i.e., ISO 14024 (2018), ISO 14021 (2016), and ISO 14025 (2006b), respectively. However, many ecolabels exist that do not clearly fit within the classification of ISO (Minkov et al. 2019; Taufique et al. 2014). Minkov et al. (2019) analyzed an ecolabel sample in which almost 60% of the ecolabels could not be attributed to any ISO typology.

LCA is used in many applications, one of them being ecolabelling. Some authors argue that the relationship between LCA and ecolabelling is not an obvious one (Münch 2012). Others believe that the most credible ecolabelling schemes are those that apply LCA (Taufique et al. 2014). Yet, its application is different, depending on the type and the purpose of the ecolabel, the nature of the claim, and the product category (Neitzel 1997). For example, LCA for type I ecolabels (such as EUF) shall be based on "new or existing LCA studies" (EC 2010) to identify environmental hotspots for a specific product group (Baldo et al. 2002). Further, ecolabel awarding criteria are developed under the consideration of those hotspots and their prioritization, but an LCA study is not required to fulfill any criterion by the applicant for the certification. The chosen way to execute LCA as part of the type I criteria definition is kept rather flexible by the different operators and institutions (Münch 2012).

On the contrary, type III environmental labels (also known as environmental product declarations (EPDs)) are a tool for declaration and communication of LCA results via a pre-

defined list of life cycle impact assessment (LCIA) categories, applicable in B2B communication and largely applied in industry today (e.g., in the construction sector). These categories, as well as the overall rules for the elaboration of the LCA study needed to create an EPD (e.g., definition of the functional unit or selection of LCIA categories), are defined in product category rules (PCR) (ISO 2006b). EPDs are a growing field (Minkov et al. 2015), and their demand has been confirmed to increase in the recent years (Del Borghi et al. 2019).

These two cases of LCA application and awarding format are extreme and bring along certain pros and cons. On the one hand, type I ecolabels usually apply a binary awarding system (pass-fail) that gives only a single incentive threshold for producers (Kneppers and Howard 2010). Usually criteria are set in a way that only a certain share of the products (10–20%) of a given product category on a market qualify for the label (Minkov et al. 2018; EC 2018a). Hence, certified products can be considered "best in class" (NEF Group 2017; Rubik 2015) and claim environmental excellence in comparison to non-certified ones. Nevertheless, the LCA profile of the product is not communicated (since an LCA study is not required) and despite being based on a hotspot analysis, the awarding criteria could in certain cases also reflect certain political priorities or "specific issues relevant for some stakeholders" (Galatola 2019). Therefore, certain type I ecolabels (e.g., EUF) might not always reward products that actually have the best overall environmental performance as determined by a comprehensive LCA, although open discussions with interested stakeholders to fine tune the criteria are usually foreseen. On the other hand, a type III label could virtually be issued for every product, as there is not a requirement for certain minimum environmental performance of the product or thresholds under type III certification. Consequently, in their current form, type III declarations can be used for comparison with products from the same product category, but communication of preferable or superior environmental qualities is not allowed (ISO 2006b).

1.2.2 PEF and communication

There is still no clear conception how an LCA quantification tool as PEF can be used for communication (especially to external stakeholders) (Minkov et al. 2015). The linkage between PEF and ecolabelling may appear straightforward, as communication and the control of proliferation of ecolabels was one of the justifications to start the whole PEF process (EC 2013b). However, when it comes to more technical aspects of how such an integration could be implemented, there are several options, but also challenges. As part of the PEF pilot phase, potential communication options of PEF were investigated by three projects.

The first one by the EC (2013b) introduced around 20 different communication vehicles (CVs) that could be used for PEF studies. CVs are "all the possible ways that can be used to communicate the results of the EF study to the stakeholders" (EC 2018b). This attempt aimed to gather learnings and "to help reduce proliferation in the future" (EC 2013b). This report served as basis for the PEF pilots to test different approaches for results communication.

The second study we refer to is a discussion paper by the Nordic Environmental Footprint (NEF) Group (NEF Group 2017). It described a long-term vision for applying PEF in communication developed near the end of the pilot phase. It has been based on the testing of different CVs by the PEF pilot projects, but being only a vision, it contained a lot of unproven prerequisites and assumptions. Among other broader aspects, the authors of the vision proposed the development of a separate "PEF label" that should be introduced to all products on the EU market.

The third study by Lupiáñez-Villanueva et al. (2018) is a deliverable of long-term project commissioned by the EC that had a more practical approach, based on surveys among consumers and SMEs on the use and effectiveness of CVs. The authors concluded that a PEF rating label (A–E) that also gives an average product score (i.e., a benchmark) would be overall a more effective B2B solution, than just EUF or a "PEF+ Ecolabel" combination. In a B2B setting, labels are preferred as the most effective communication vehicle, followed by environmental reports, product passports, and EPDs (Lupiáñez-Villanueva et al. 2018).

A PEF study shall be conducted based on a PEFCR, which complements the general methodological guidance for a PEF study by providing and fixing product-specific LCA rules for a particular product category (EC 2018b). A PEF study is essentially an LCA study, following the explicit PEF methodological guidance (Saouter et al. 2018); likewise, PEFCRs are the PEF equivalent of PCRs. If the application of a PEF study is not specified and only the unweighted results are presented, a PEF profile could virtually be acknowledged as an EPD. Nevertheless, important features of PEF are still missing to account PEF profiles as ISO 14025 conformant EPDs (e.g., a program operator shall be assigned to assure the quality and certification of the declarations). Moreover, due to several potential methodological divergences (e.g., different characterization methods used), PEF and EPD cannot substitute one another (Del Borghi et al. 2019). Furthermore, in contrast to EPDs, PEF requires the results of the representative product to be normalized and weighted, in order to identify the most relevant impact categories, life cycle stages, processes, and elementary flows in each product group and PEFCR, respectively (EC 2018b). Once the PEF method is settled, the definition of these would not involve any participatory process for any new PEFCR.

2 Methods

In order to reach the objective of the study, we developed a systematic evaluation procedure for a parallel examination of PEFCRs and EUF awarding criteria for similar product groups, allowing for an evaluation of their potential for synergies and conflicts, as well as potentials for generating mutual benefits. This procedure is applied to three case studies, i.e., three different product groups for which both PEFCR and EUF are available.

2.1 Establishment of a procedure for evaluating the interface between PEF and EUF

The EUF awarding criteria for each case study were assigned to each LC stage as per the PEFCR system boundaries. We indicated the most relevant LC stages, processes, and impact categories as defined by the PEFCR and mapped them with the ecolabel criteria. We then undertook a reciprocal analysis of PEF and EUF to evaluate their complement, resemblance, and difference. This has been done based on several research questions addressing five topics. The evaluation framework is shown in Table 1.

We further used the results of the evaluation of the interface between PEF and EUF—together with the findings of the literature review in Sect. 1.2—to conceptualize scenarios for mutual integration and co-existence of the two approaches (presented in Sect. 3.5). Ultimately, we proposed an additional categorization of the EUF awarding criteria (shown in Table 2) to reflect the different levels targeted by certain ecolabel criteria. We found this necessary, because criteria usually differ from a few to over 25 for certain product groups. For example, for decorative paints only seven criteria exist, whereas for textile products, there are 28.

2.2 Selection of product groups for the case studies

In order to determine the case studies, we compared the list of PEF pilots with the list of product groups, for which EUF awarding criteria exist. We then selected three PEFCRs to compare against the respective EUF awarding criteria. Our selection was mostly driven by three arguments: (1) we looked for best resemblance of the product group and the representative product between the PEFCR and the ecolabel criteria; (2) we endeavored to work with PEFCRs whose final version is published, and last but not least, (3) we endeavored to select

Table 1 Framework for the evaluation of the interface between PEF and EUF

Topic	Questions
1. Product group definition and scope	1.1 Are there divergences in the scope and product group definitions of the ecolabel and the PEFCR?
	1.2 How many ecolabel criteria exist for the respective product group and how do they cover the product's LC?
2. Relevant LC stages	2.1 Which are the most relevant LC stages identified by the PEFCR?
	2.2 How many of the ecolabel criteria concur with the most relevant LC stages identified by the PEFCR?
	2.3 Do ecolabel criteria address other LC stages that are not identified as most relevant by the PEFCR? Which one?
3. Relevant processes	3.1 Which are the most relevant processes in the product's LC identified by the PEFCR?
	3.2 How many of the ecolabel criteria address any of the most relevant processes identified by the PEFCR?
	3.3 Are there any other processes that are in focus of the ecolabel, but not accounted as relevant by the PEFCR? Which one?
4. Relevant environmental aspects and potential impacts	4.1 Which environmental aspects and potential environmental impacts are in focus of the ecolabel criteria?
	4.2 Do the ecolabel criteria employ any approach for quantifying the magnitude and significance of the potential environmental impacts of the product?
	4.3 Which are the most relevant ICs identified by the PEFCR?
	4.4 Are there any divergences between the ecolabel criteria and the PEFCR in terms of ICs and/or impact assessment methods used for similar environmental impacts?
5. Addressed aspects and impacts beyond environmental focus	5.1 Do the ecolabel criteria and the PEFCR address any other aspects or impacts beyond environmental?
	5.2 If yes, which are they and what do they focus on?

Table 2 Categorization of the EUF ecolabel criteria

Type of ecolabel criterion	Definition
Environmental performance	Relates to the environmental characteristics of the product, requirements for content limits or prohibition of certain substances, emission limits or threshold
Product performance	Relates to requirements regarding the performance of the product (e.g., during use phase)
Managerial	Covers requirements for conformance with certain standards or the existence of certain plans
Consumer information	Relates to any user-specific information that shall appear on the product
Social	Covers social-related issues apart from environmental ones

product groups that are distinguishable from one another, thus providing a more diverse picture.

We shortlisted five PEF pilot studies and the respective product groups for which EUF awarding criteria exist. For the remaining 15 PEF pilots, EUF awarding criteria do not exist. Another five pilots were discontinued during the pilot phase, thus were also not accounted herewith.

From the five shortlisted ones, two pilots were on products that were not straightforward to compare with the respective product group with existing EUF criteria. Thus, we concluded to work with three PEFCRs, namely "Decorative paints" (CEPE 2018), "Household Heavy Duty Liquid Laundry Detergents (HDLLD) for machine wash" (or "Household detergents" for short) (A.I.S.E. 2019) and "T-shirts" (Pesnel and Payet 2019). The selected PEFCRs are valid and publicly accessible as official final versions and are conformant with the PEFCR Guidance v6.3 (EC 2018b). The respective ecolabel criteria on "Indoor and outdoor paints and varnishes" (EC 2014a), "Laundry detergents" (EC 2017) and "Textile products" (EC 2014b) are also valid and public.

3 Results

In the following, we present the results of the examination of the three cases. A detailed description of our findings is provided for product group "Decorative paints." Regarding the other two cases—household detergents and T-shirts—we only present the findings without the same level of description for the sake of brevity of the text. Nevertheless, in the Electronic Supplementary Material to this article, we provide the metadata used for the analysis, as well as a comparative summary of the PEFCR and EUF specifications for each case study.

3.1 Decorative paints

In the examined product group "Decorative paints," the respective PEFCR and EUF awarding criteria consider identical product groups, both referring to the classification of Directive 2004/42/CE on the limitation of emissions of volatile organic compounds (VOCs) in certain paints and varnishes (EC 2004a). A difference occurs regarding the considered representative products. The PEFCR is limited to selected paint types (subcategories A–D of the Directive), whereas EUF covers all of them.

The PEFCR has a cradle-to-grave scope and system boundaries consisting of five LC stages and 14 sub-stages. Despite the scale of detail of the sub-stages, in the PEFCR, only the most relevant processes are described on this level, whereas the most relevant LC stages and impact categories are given on the level above in the PEFCR. Nevertheless, this work looks at the sub-stage level, in order to emphasize on the differences and the importance of the different sub-stages. Figure 1 visualizes the system boundaries, defined by the PEFCR and indicates the most relevant LC stages and most relevant process (in orange and light-orange color, respectively), as well as the seven ecolabel criteria (in blue), allocated to the respective LC stage. We split the ecolabel criterion 1 into two parts: (a) and (b), as they are allocated to different LC stages.

The PEFCR identifies three most relevant stages: (1) Raw materials, (3) Use, and (5) End-of-life. When they are further broken down on sub-stage level, we identify four most relevant sub-stages out of 14, based on where the most relevant processes occur. These are (1a) Raw material acquisition and pre-processing, (1b) Packaging material acquisition, (4b) Application, and (5b) End-of-life of paint film.

In the first two sub-stages (1a and 1b), the production of raw materials (e.g., titanium dioxide (TiO_2), paint additives, sodium silicate powder, etc.) and packaging materials (e.g., polypropylene granulates) have a relevant contribution to the PEF profile of the product. Among these relevant processes, only TiO_2 pigment production is acknowledged by the ecolabel criteria as a relevant environmental aspect by setting emission and discharge of waste limits from its production (criterion 2), as well as TiO_2 content limit in the final product (criterion 1a). The PEFCR does not set such limitations—neither emission nor content limits. The content of TiO_2 in the product is only part of the mandatory declaration of the average paint formulation.

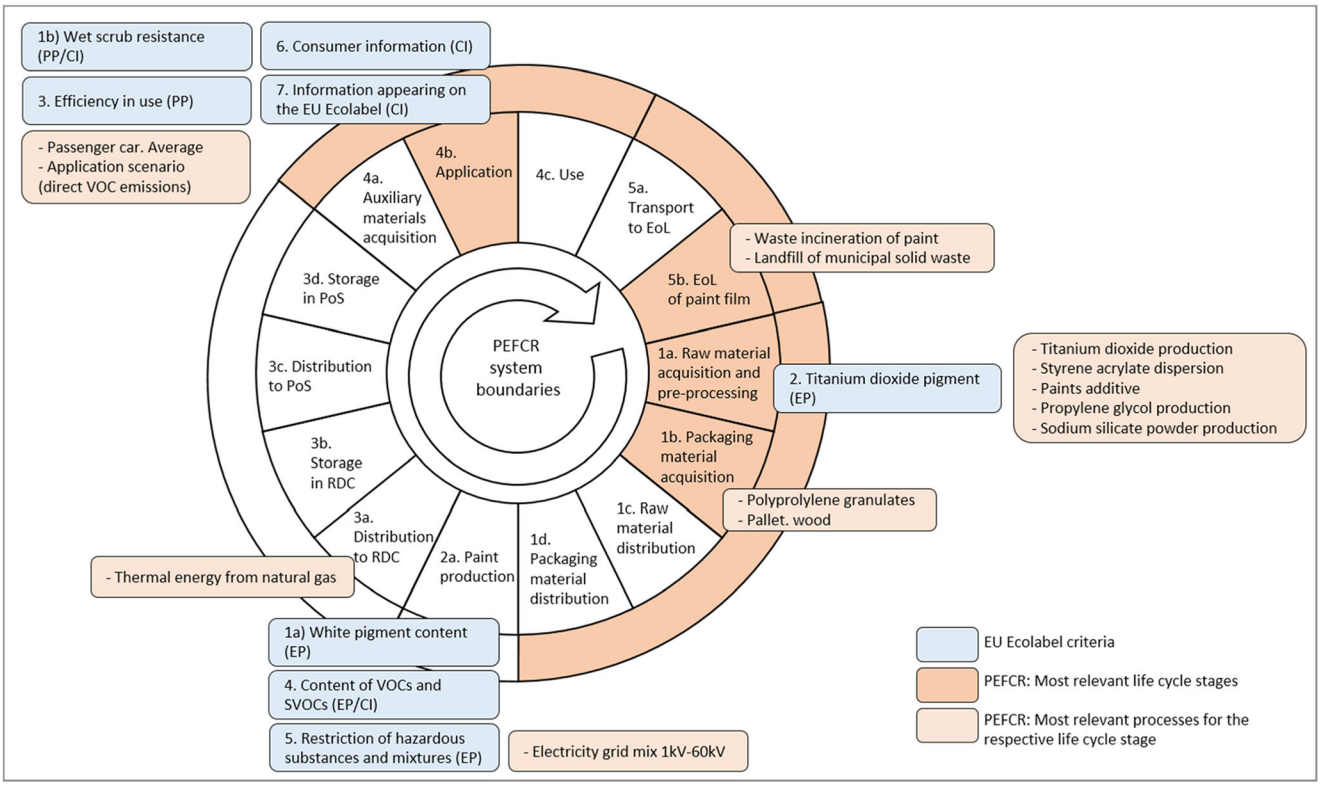

Fig. 1 A map of the most relevant LC stages and processes, based on the PEFCR system boundaries and EUF criteria for product group "Decorative paints." EP environmental performance, PP product performance, CI customer information

Sub-stage 2a (Paint production) is not considered as a relevant LC stage by the PEFCR, whereas three ecolabel criteria could be assigned here: on white pigment content (criterion 1a), on the content of VOCs and semi-VOCs (criterion 4), and on the content and restriction of certain substances of very high concern (SVHCs) and other specific substances and mixtures (criterion 5) in accordance with Regulation (EC) No. 1272/2008 on Classification, Labelling and Packaging (CLP) (EC 2008b).

The PEFCR does not impose any emission limits of VOCs but requires that the content shall be the regulatory reportable amount as defined by Directive 2004/42/EC. Neither it provides a procedure for VOC determination. In contrast, EUF is in line with the Directive regarding concentration measurements and even applies more stringent emission limits than given in the regulation.

Sub-stage 4b (Application) is very consumer-oriented in both the PEFCR and the ecolabel criteria. The PEFCR here accounts for emissions to air and losses due to application of the paint, as well as impacts from disposal of generated waste, transportation processes, and fuel consumption. Along with the VOC emissions from the application of the paint, it identifies the process of professional and consumer transportation during paint application as relevant. In contrast, criterion 3 of the ecolabel focuses on efficiency specifications, by giving stringent requirements for a variety of performance characteristics (per paint and varnish types) that a product shall meet in order to be awarded with the ecolabel. Criterion 6 gives instructions on how to handle the product to reduce the use of it and on safety measures for the user. Criterion 7 relates to the optional label that contains good performance statements.

In the same sub-stage, the ecolabel requires all indoor wall and ceiling paints to declare a class of Wet Scrub Resistance (WSR)—the ability of a paint film to withstand scrubbing and cleaning—a threshold for products to claim superior durability (criterion 1b). WSR is also used in the PEFCR for indoor paints, but not as a durability prove. It is a part of a set of different durability characteristics to obtain the number of maintenance cycles over the lifetime of the building (maintenance multiplier), needed to define the reference flow. WSR here is an appropriate example how a common performance indicator is used differently in PEF and EUF.

As a scenario at end-of-life (stage 5b), "incineration with energy recovery" and "landfilling of paint" are modeled and accounted as relevant in the PEFCR. This is based on statistical information for Europe. End-of-life (EoL) processes seem irrelevant for the ecolabel criteria. Table 3 summarizes the findings of this case study. The

Table 3 Summary of the findings of the analysis for product group "Decorative paints"

Topic	Finding
1. Product group definition and scope	• No significant divergences in the product group and scope definition between the two approaches
	• The ecolabel criteria do not cover the complete LC of the product
2. Relevant LC stages	• Discrepancy between the most relevant LC stages identified by the PEFCR and the LC stages which the ecolabel criteria focus on:
	o Ecolabel criteria could be assigned to only two of the four most relevant sub-stages (1a and 4b)
	o In sub-stage 2a (Paint production), which is not relevant according to the PEFCR, three important environmental performance ecolabel criteria are assigned
	o Stages relating to distribution (3a to 3d) and EoL (5a and 5b) are not in focus of the ecolabel
3. Relevant processes	• Having an ecolabel criterion that focuses on limiting the emissions of TiO_2 confirms the finding of the PEFCR that TiO_2 production is a relevant process
	• Nevertheless, the ecolabel does not cover the other relevant production processes in sub-stage 1a) apart from TiO_2
	• The PEFCR considers production of packaging as relevant (sub-stage 1b), while EUF does not have criteria regarding this aspect
	• In the application (sub-stage 4b), background processes like transportation of workers to apply the paint are considered relevant in the PEFCR, but not in the ecolabel
	• In the EoL stage, which is relevant according to the PEFCR, two processes are listed. In contrast, the ecolabel does not consider EoL at all
4. Relevant environmental aspects and potential impacts	• The ecolabel criteria do not employ any approach for quantifying the magnitude or significance of the potential environmental impacts
	• The criteria are limited up to providing emission limits for certain relevant aspects that are identified as dangerous for the environment or human health
5. Addressed aspects and impacts beyond environmental focus	• No

numbering of the LC stages follows the indication in the PEFCR (see Fig. 1).

3.2 Household detergents

In the second observed group, despite the general name, the PEF pilot "Household detergents" actually covers only "Household Heavy Duty Liquid Laundry Detergents (HDLLD) for machine wash," as stated in the title of the PEFCR and their scope. The respective EUF category "Cleaning up" contains criteria for six products and one service. The most similar product group to the PEFCR is "Laundry detergents," which also contains a sub-category "Heavy duty detergents" and therefore, selected for this work. Both the PEFCR and the EUF criteria conform with the Detergent Regulation (EC) 648/2004 (EC 2004b). Figure 2 presents the system boundaries of the product group and the respective most relevant process and ecolabel criteria for detergents, according to the PEFCR.

Table 4 summarizes the key findings from the analysis of detergents. The numbering of the LC stages follows the indication in the PEFCR (see Fig. 2).

3.3 T-shirts

In the third selected product group, the examined PEFCR covers only T-shirts, whereas the EUF awarding criteria set is intended for a wider product group—textile products. Therefore, when analyzing the ecolabel, we pay special attention that we do not examine and account for criteria that are irrelevant for textile clothing (where T-shirts fall). Figure 3 presents the system boundaries of the product group and the respective most relevant process and ecolabel criteria for T-shirts, according to the PEFCR.

A summary of the key findings from the analysis of this product group are given in Table 5. The numbering of the LC stages follows the sequence as per the PEFCR (see Fig. 3).

3.4 Summary of the findings

Our analysis shows that there are divergences in the product group definitions between the ecolabel and the PEFCRs. Adjustments in selecting the appropriate sub-product group to work with were required for two of the three cases. In reference to the scope, none of the three observed ecolabel

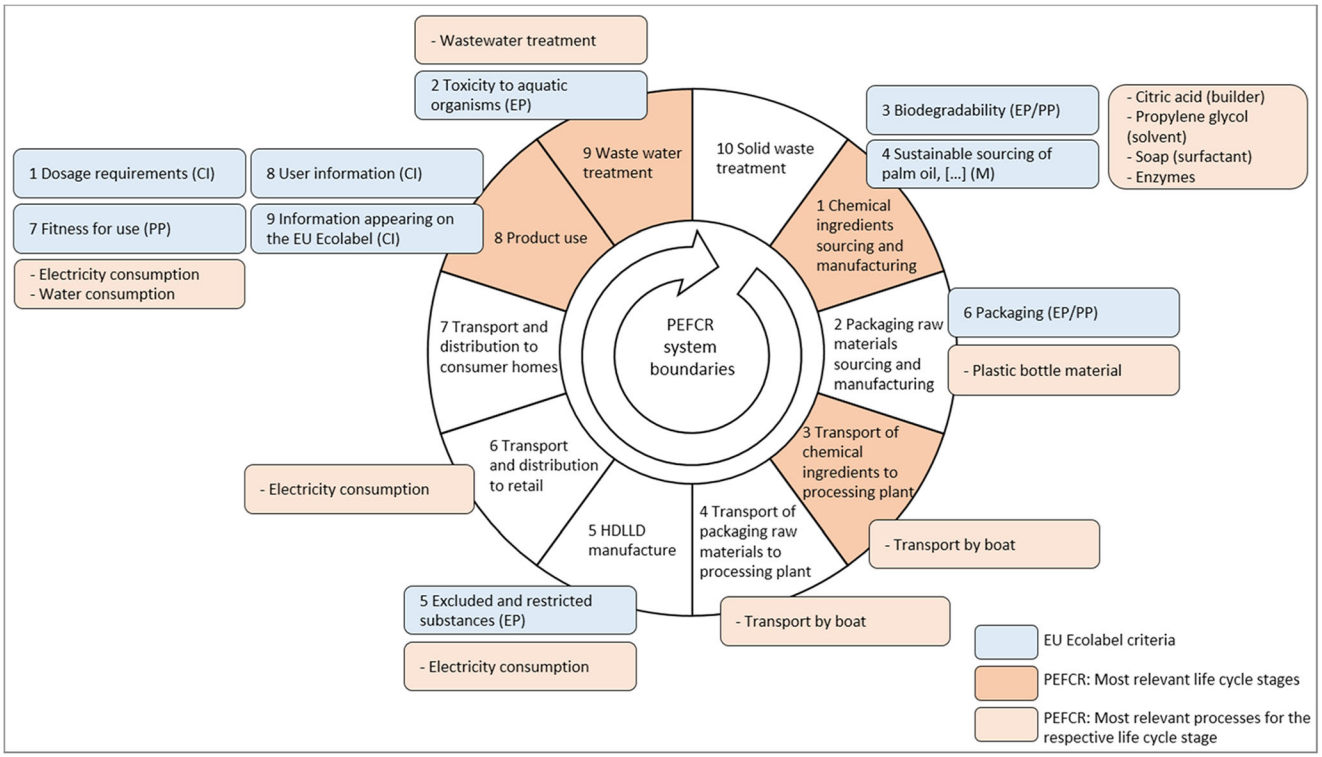

Fig. 2 A map of the most relevant LC stages and processes, based on the PEFCR system boundaries and EUF criteria for product group "Household detergents." EP environmental performance, PP product performance, M managerial, CI customer information

product groups has awarding criteria to cover the complete LC—criteria usually are issue-specific and not intended to address all LC stages, although a LC perspective is taken when the criteria are developed. Often, EUF criteria cannot be assigned to all relevant LC stages or processes identified by the PEFCR. This means that for certain processes that are assumed to have significant potential environmental impacts according to PEF, sometimes the ecolabel does not have a specifically assigned criterion to limit or mitigate these impacts. This issue is further discussed in Sect. 4.

In all three cases, we observe that the PEFCR identifies as relevant such processes that are rather background processes, or that indirectly relate to the product and are often subject to scenario assumptions (e.g., transportation processes). On the contrary, ecolabel criteria are oriented only to specific product-related issues and to such that are assumed to be particularly relevant with regard to reducing environmental impacts.

Processes related to packaging are covered only in one of the three ecolabel criteria sets. EoL processes are generally not in scope of any of the ecolabel product groups but often are found to be relevant from a PEF perspective.

The use phase is covered by ecolabel criteria in all three cases, although none of the examined product groups has an active use phase (e.g., direct energy consumption during operation). However, the criteria mostly relate to aspects for improved product performance and durability, followed by criteria on consumer information (e.g., how the product should be used). On the contrary, often the PEFCRs consider as relevant in this phase processes that are not directly linked to the product performance (e.g., electricity production for washing or drying of a T-shirt).

Overall, toxicity impact assessment is currently kept out of PEF due to lack of robustness of the available methods. Nevertheless, as regards aquatic ecotoxicity in the case of household detergents, the PEFCR recommends the use of ESC instead USEtox, i.e., a risk-based method, instead of a hazard-based one. As regards USEtox and CDV (used in the ecolabel), it seems on a first sight that they are applying two different methods to evaluate the same issue, and this could lead to controversial conclusions by the users. In fact, the CDV and USEtox should be considered as complementary (Saouter et al. 2018). Except for this case, overall the ecolabel criteria do not apply approaches for quantifying the magnitude or significance of the potential environmental impacts.

With respect to the type of ecolabel criteria that dominate in the three cases, such related to environmental performance lead (42%), followed by criteria on product performance (24%), customer information (23%), managerial (7%), and social (3%). Particularly paints and detergents product groups consist of many customer information criteria, i.e., how to apply the product in order to reduce the potential impact.

Impacts beyond the environmental focus, such as social aspects, were detected only in the T-shirts case for EUF.

Table 4 Summary of the findings of the analysis for product group "Household detergents"

Topic	Finding
1. Product group definition and scope	• Criteria for sub-category "Heavy duty detergents" of the "Laundry detergents" ecolabel product group are selected for best concurrence with the PEFCR on "HDLLD for machine wash"
	• The ecolabel criteria do not cover the complete LC of the product
2. Relevant LC stages	• Ecolabel criteria could be assigned to three of four LC stages identified as relevant in the PEFCR (stages 1, 8, and 9)
	• The assignment of two other ecolabel criteria to two non-relevant LC stages (i.e., stages 2 and 5) manifests for a disparity in the two approaches
3. Relevant processes	• In stage 1, the PEFCR considers the production of builders, solvents, surfactants and enzymes as relevant processes
	• The ecolabel very specifically focuses on biodegradability qualities of surfactants and organic compounds and on sustainable sourcing of ingredients containing palm oil (criteria 3 and 4)
	• In stages 3, 4, 5, and 6 the PEFCR identifies such processes as relevant that relate to infrastructure, capital goods and background processes; in contrast, the ecolabel accounts here for product-specific criteria that restrict or exclude the use of certain substances (criterion 5)
	• In stage 8 (product use), the non-product specific washing process turns out to be the most decisive for the product's whole life-cycle, i.e., the electricity and water consumption of the washing machine
	• The ecolabel focuses their criteria on dosing instructions and on recommendations for washing at lowest temperature in conformance with the respective EU protocols for wash performance
4. Relevant environmental aspects and potential impacts	• Water ecotoxicity is a relevant environmental impact in this product group acknowledged by both initiatives
	• There is a discrepancy in the impact assessment methods used for water ecotoxicity:
	o Generally, PEF requires USEtox that is however, currently temporarily excluded due to lack of robustness (EC 2018b); the PEFCR thus requires in addition the Environmental Safety Check (ESC) to be reported under "additional environmental information"
	o The ecolabel applies the Critical Dilution Volume (CDV) approach
	• Environmental Safety Check (ESC) is a risk-based approach, whereas USEtox and CDV are hazard-based
	• Although they seem similar, the product aquatic toxicity scores from the latter two approaches may lead to controversial conclusions, if not interpreted correctly
5. Addressed aspects and impacts beyond environmental focus	• Sustainable sourcing of palm oil is requested by the ecolabel

They are typically kept out of the scope of LCA, so it is in the case of PEF; neither the method currently covers criteria related to management or customer information.

3.5 Scenarios for mutual integration and co-existence of PEF and EUF

Based on the identified synergies, gaps and potential conflicts between PEF and EUF, we here systematize different perspectives how the two approaches could co-exist or be mutually integrated as instruments for communication of environmental product information.

3.6 The PEF and EUF perspectives

After the termination of the PEF pilot phase, a background document issued by DG ENV (EC 2018a) very briefly indicated options to integrate PEF in existing policies. One of the options scratches upon the interlinkage with EUF in two directions: (1) application of PEF as a hotspots identification method of new ecolabel awarding criteria and (2) integration of PEF results into conditions for award and communication. Based on this, Galatola (2019) conceptualized the work of DG ENV in few options for integration of PEF in the development of EUF criteria. By using these two studies and together with the learnings derived in Sect. 3, we establish possible

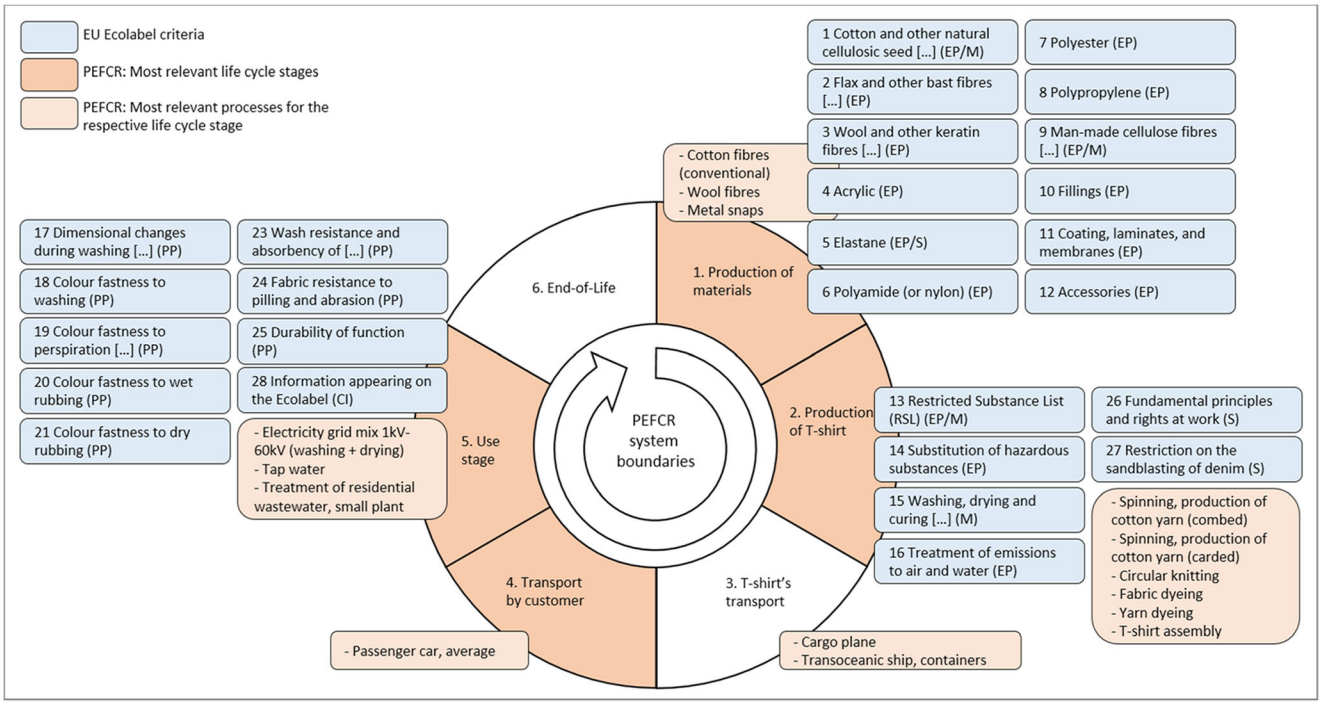

Fig. 3 A map of the most relevant LC stages and processes, based on the PEFCR system boundaries and EUF criteria for product group "T-shirts." EP environmental performance, PP product performance, M managerial, S social, CI customer information

application scenarios for the mutual integration and/or co-existence between PEF and EUF (see Table 6).

Another theoretical option for integrating PEF into EUF is to use classes of performance (potentially defined in a PEF study) supporting the extension of the EUF's seal type of awarding to a "performance label" (EC 2013b) or a "rating" ecolabel, as called by Minkov et al. (2019). However, we do not scrutinize further on this scenario, because the current PEFCR Guide (EC 2018b) has explicitly suspended the inclusion of performance classes in the PEFCRs and according to Galatola (2019) such integration in EUF would require changes in Regulation No. 66/2010 (EC 2010).

In both PEF and EUF perspectives, we include the "business as usual" scenario. It assumes that no changes in EUF would result from the existence of PEF and that PEF would find its way to be operational in product environmental communication in parallel to EUF.

The other two scenarios under the "PEF perspective" scrutinize PEF as a standalone tool that uses certain features of EUF to strengthen their performance as an ecolabel that communicates the PEF profile in a declaration format. One aspect is to use EUF criteria that allow for additional non-quantitative evaluation of the product. This way the PEF declaration could for instance deliver additional information also on the performance of the product or the latter could be used to increase the robustness in defining the functional unit (we further discuss this aspect in Sect. 4).

The last examined scenario under this perspective is the use of certain quantitative EUF criteria as threshold values that shall be met, in order to allow for a publication and communication of the PEF declaration (e.g., TiO_2 content in paint products shall not exceed the ecolabel limit). By doing this, only the products that are the best in their class would be awarded, which could also open the possibility for reaching not only B2B, but also B2C.

In the "EUF perspective," we explore the potential benefits for EUF when using certain PEF elements. EUF keeps their prevalent B2C focus in any of examined scenarios. One of the scenarios proposes to apply PEF as a standardized LCA-based method for hotspot identification. ISO 14024 (2018) on type I ecolabels does not recommend the use of any specific LCA method, but only that the complete life cycle should be considered. A benefit of using PEF in this sense would be that each new process for ecolabel criteria development would use a common LCA method. Moreover, the additional specifications for certain methodological aspects in PEF (e.g., modeling of end-of-life phase) given in comparison to ISO 14040/44 (ISO 2006a, c), could potentially improve the reproducibility and comparability of the outcomes. Unresolved methodological issues of PEF (e.g., see the ones listed by (Bach et al. 2018) could of course potentially have influence on the ecolabel.

At last in the "EUF perspective," we present a scenario, similar to the one developed by Galatola (2019). It assumes that the obtaining of data for certain EUF criteria is substituted by using LCA-based information. One of the benefits of this idea is that the fulfillment of LCA-based criteria can be done along the whole LC, but not only on isolated aspects and/or

Table 5 Summary of the findings of the analysis for product group "T-shirts"

Topic	Finding
1. Product group definition and scope	• Narrowing down the analysis only to t-shirts needed for the ecolabel criteria for textile clothing, due to the wider scope of the criteria set
	• The ecolabel criteria do not cover the complete LC of the product
2. Relevant LC stages	• Good concurrence between the relevant LC stages from the PEFCR and the assigned ecolabel criteria
	• The ecolabel does not provide requirements only to stage 4 that is relevant according to the PEFCR
	• EoL stage is irrelevant for both approaches
3. Relevant processes	• For both the production of materials and the t-shirt itself (stages 1 and 2), the PEFCR indicates six production processes as relevant
	• In the same stages, the ecolabel focuses on 12 criteria on specific requirements for the production of materials (e.g., organic production, pesticides use, emission limits, etc.) and on another six criteria, aiming on restricting the use of certain substances or minimizing the energy use and wastewater discharges in the production processes
	• The ecolabel does not take notice of any processes related to transportation, unlike the PEFCR that acknowledges them relevant in stages 3 and 4
	• In stage 5 (product use) the PEFCR indicates as most relevant the processes related to the washing, drying and ironing of the product, i.e., electricity production, water consumption and wastewater treatment
	• Alternatively, the ecolabel exclusively focuses on product performance and durability criteria in the use stage
4. Relevant environmental aspects and potential impacts	• The ecolabel criteria do not employ any approach for quantifying the magnitude or significance of the potential environmental impacts
	• The criteria are limited up to providing emission limits for certain relevant aspects that are identified as dangerous for the environment or human health
5. Addressed aspects and impacts beyond environmental focus	• In stage 2, ecolabel criteria focus on social responsibility practices, e.g., respecting the fundamental rights of workers

LC stages. However, this approach risks the dissipation of the product- and issue-specific focus.

3.7 Joint perspective: the hybrid approach

The scenarios for the first two perspectives presented in Table 7 are based on the assumptions that one of the initiatives could be improved by using elements of the other. Ultimately, the scenarios describe individual communication approaches, focusing on different end users, and assume parallel existence of both approaches. If hypothetically assumed, for example, that PEF benefits from certain elements of EUF, it could still only be applicable for B2B communication in its current form; thus, the need for a B2C label would still justify the existence of EUF (and vice versa, i.e., EUF would not solve the demand for LCA-based declarations mostly used in B2B). Moreover, if PEF becomes a trigger for the creation of a new ecolabel, it would add one more to the list of several hundred ecolabels that exist nowadays. Therefore, we here conceptualize a third, joint perspective implying a scenario for a hybrid integration. It is a combined approach that integrates the advantages of both PEF, as an LCA-based type III-like declaration, and EUF, as a classic type I ecolabel, in a new ecolabel typology. We call it "type IV" and describe its main characteristics in Table 7.

This concept rests on the scenario that—where possible—type I ecolabel criteria are based on a PEF profile, i.e., LCIA results. Assuming that a PEF study of the product would be the fundament for any certification, the applicant can benefit from the flexibility that it provides: on one hand, to use the PEF profile for B2B communication/relations, i.e., for a type III-like declaration, or for in-house purposes. On the other hand, the PEF profile can further be used as input for deriving the type I ecolabel awarding criteria, used as a B2C communication medium. The concept is visualized in Fig. 4.

The proposed type IV has many advantages over the individual combinations of the two approaches presented in Table 6. First, through a single certification process, it would be possible to obtain two different certificates and to simultaneously communicate towards two different end-user groups. On one hand, this would contribute to reducing the proliferation between the approaches for environmental communication. On the other hand, the concept for a consumer label based on a B2B-oriented environmental declaration could be a resource-efficient solution for the applicant by cutting down both on time and financial resources necessary for assessment,

Table 6 Scenarios for co-existence and mutual integration of PEF and EUF

Scenario	End-user focus*	Awarding format*	Brief description
PEF perspective			
Business as usual	B2B, in-house	Declaration (non-sealed)	• No integration of EUF into PEF • Only a PEF profile is communicated • PEF would contribute to the proliferation of ecolabels
Adopts EUF criteria in addition to the PEF profile	B2B	Declaration (non-sealed)	• EUF criteria are used for additional non-quantitative characterization of the product in addition to the quantitative PEF profile
Adopts EUF criteria as thresholds in addition to the PEF profile	B2B, (B2C)	Declaration (sealed)	• PEF profile is issued only when certain ecolabel criteria are met
EUF perspective			
Business as usual	B2C	Seal	• No integration of PEF into EUF • Already established, operational and well-known ecolabel • No standardized LCA-based method for hotspot identification
Adopts PEF as a background hotspot identification method**	B2C	Seal	• Standardized LCA-based method for hotspot identification
Adopts PEF results into conditions for award**	B2C	Seal	• PEF is used for awarding criteria for certain aspects (e.g., most relevant impact categories) • Fulfillment of LCA-based criteria can be done along the whole LC, but not only on isolated aspects and/or LC stages • Product- and issue-specific focus could be dissipated • EUF keeps its original application and focus

*Ecolabel attribute adapted from (Minkov et al. 2019)

**Scenario adapted from (Galatola 2019) and (EC 2018a)

compliance, and certification. Second, the incorporation of LCA-based criteria in type I ecolabelling would enable the applicant to self-define the focus of their environmental optimization efforts regarding their product in a more comprehensive way instead of only focusing on isolated aspects defined by the ecolabel criteria (EEB 2018). This would also assure that burdens are not shifted between LC stages. At the same time, by keeping the attributes of a type I ecolabel, the hybrid approach would still operate as a tool for setting product design targets and promoting "best in class" products.

4 Discussion

In the first part of this work, we analyzed the similarities and gaps between PEF and EUF. Overall, PEF is a relative approach and delivers information on the potential environmental impacts of the product. It only looks at environmental criteria based on certain product performance characteristics, use, and end-of-life scenarios. PEFCRs define rules to set the assessment to provide reliable results. Contrarily, EUF sets restrictions, limits, design, and product performance requirements and advices the user how to apply the product to mitigate the environmental damage. The approach is more flexible, taking also into consideration non-quantifiable information and qualitative expert judgments in the criteria setting.

Certain methodological shortcomings of the two approaches were also pointed out in this work. We give our "food for thought" on few of them with a focus on the future operationalization of a type IV. For example, our findings show that in certain cases, currently there is a discrepancy between the most relevant processes identified by the PEFCR and the processes in focus of the ecolabel criteria. It could be speculated that a cause is the difference between the current practice of EUF for prioritization of certain aspects over others and its inconsistency with the current weighting and normalization method applied in PEF. In a type IV setting, an investigation on the latter should be conducted to meet the objectives and the prioritization of EUF criteria. Furthermore, the awarding criteria development in EUF is by its nature an open and participatory process. The elaboration of PEF-based awarding criteria for type IV certification should preserve this. Threshold values should be open for discussion by stakeholders.

Further, most performance requirements and fitness-for-use criteria that are currently used by EUF cannot be substituted solely by LCA-based indicators, but they can be complementary. The analysis of the case studies revealed that performance characteristics of the product are also partly required in

Table 7 Joint perspective for common integration of PEF and EUF into a hybrid label (type IV)

Scenario	End-user focus	Awarding format	Brief description
Hybrid integration (type IV)	B2B, B2C, in-house	Declaration + seal	• Type I ecolabel based on a B2B-oriented environmental declaration (type III-like) • Flexibility when choosing the awarding format and end-user focus (declaration for B2B, seal for B2C) • PEF is used for awarding criteria for all environmental aspects • Fulfillment of PEF-based criteria can be done along the whole LC, but not only on isolated aspects and/or LC stages • Product- and issue-specific focus could be dissipated

the PEFCRs: they can be used to specify the functional unit and to allow for comparison, but not to set benchmarks for excellent performance as in EUF. According to Bach et al. (2018), the performance and quality of the product is currently not "adequately" covered by PEF. In this regard, EUF criteria on performance and durability of the product can be used in the hybrid approach to strengthen the determination of the functional unit, as currently set in PEF (to better answer the questions "How well?") alongside with their initial function for type I awarding. The use of already standardized methods for identifying different quality aspects (e.g., criterion 17 of the textile ecolabel on "Dimensional changes during washing and drying") is feasible and would meet the recommendation of the study by Bach et al. (2018) to consider parameters that measure the different performance or quality aspects.

Last, but not least—for certain ingredients or emissions—the ecolabel usually provides methods for their determination and also sets content and/or emission limits that shall be respected to obtain awarding. Limits could often be more stringent than the initiating EU legislation (e.g., VOC emission limits in the case study for paints). In the hybrid approach, a mechanism to "translate" these values into LCIA should be established; thus, the LCIA results can be used as limit/threshold values. These thresholds should be valid along the whole LCA profile to avoid burden shifting. Once this mechanism is developed, the LCIA-based thresholds could further be attuned to the "best in class" philosophy of type I (i.e., only 10–20% of the product of a given category to qualify for the label). This way, published LCA-based declarations under the same PEFCR could potentially be used as claims for environmental excellence.

5 Conclusions and outlook

PEF currently is on a crossroad in defining its future operationalization and use. This article contributes to the scarce scientific work on its possible application as a tool for communication of environmental information of products, and in particular—on their interface with EUF—the European type I ecolabel. We conducted a reciprocal topic-based analysis of PEF and EUF on three different product groups. The insufficiency to obtain an objective overview by working with only one product group was justified by our results. EUF criteria emphasize on issues that are product-related, and thus, the type and number of criteria for the different product groups significantly differ from case to case, so do our findings. We pointed out inconsistencies and gaps when PEFCRs and EUF criteria are compared. We provided different perspectives for the integration of one approach into the other, in order to serve different communication needs (B2B or B2C).

We conclude that in order to improve the current approaches for communication, the use of criteria that cover the complete LC of the product is imperative. Still, tailor-made instruments are needed that go beyond the calculation

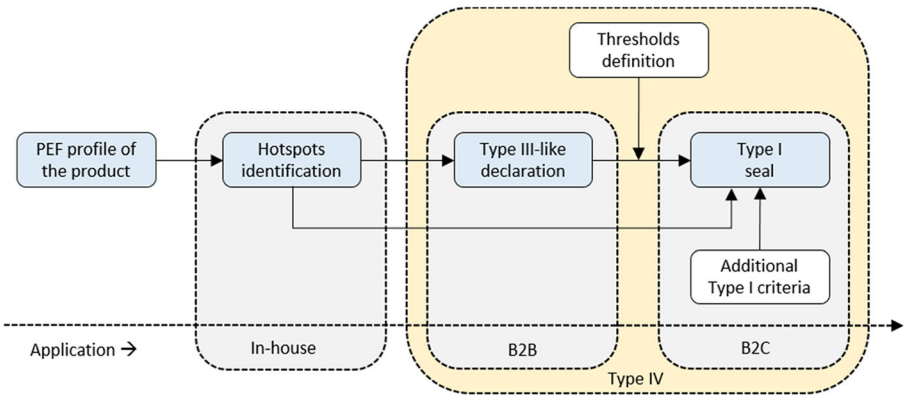

Fig. 4 Concept for a successive application of PEF for in-house use and for issuing of both a type III-like declaration and type I ecolabel for external communication into type IV

of an LCA or PEF profile and to cover issue- and product-specific aspects. In parallel, improved transparency and standardization of the processes, as well as assured open participation in the phase of prioritization of aspects and criteria setting, is essential. As a result, we ascertain that a step towards more precise, transparent, and improved communication that customers would benefit from is a combination of both PEF and EUF. A proposal for such is the type IV ecolabel that we conceptualized in this work. It is a hybrid combination between elements of type I and type III that allows for two different, but simultaneous product certifications depending on the end-user focus.

Several aspects that should be tackled in separate studies have been gathered. In this work, we do not discuss the technical realization of the described application scenarios, e.g., how conformance between PEF and ISO 14025 should be achieved to use PEF for type III declarations (e.g., who would be the program operator). Neither we elaborate on the cost-related implications when fulfilling PEF-based criteria and their comparison with the current procedure under EUF. This issue should be investigated from two perspectives, i.e., with or without the existence of a PEFCR. In case a PEFCR is not present, it would be interesting to examine how could the EC support companies in developing the rules, similarly to the EUF new criteria development process. This would give a better estimation whether type IV could be an affordable perspective or a barrier for innovators. Future efforts should also be put on identifying scientific-sound methodology to set thresholds and classes of performance, based on LCIA category results. Lastly, the results indicate that in certain product categories social criteria are applied, but such are usually not dealt in LCA; so it is in the case of PEF. It is a relevant subject for further investigation how social aspects could be incorporated in type IV along with the environmental assessment.

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4 Discussion

The following chapter presents an overarching discussion of the achievements of this thesis. It is not intended to repeat all discussion points that are raised in the individual publications of Chapter 3, but to build on them and to put them in a wider perspective. First, the findings of this work are discussed from the view point of their applicability (Chapter 4.1), followed by a discussion of the remaining methodological and practical challenges (Chapter 4.2).

4.1 Applicability of the findings

In this chapter, the applicability of the results is scrutinized. The first two discussion points refer to the two main instruments developed as an answer to the two research questions of this thesis. The first one is the ecolabel characterization scheme (Chapter 4.1.1), developed as a tool to mitigate the gaps in the existing characterization and classification approaches for ecolabels (RQ1). The second one is the hybrid ecolabelling approach Type IV (Chapter 4.1.2), established as an LCA-based approach contributing to the overall improvement of B2B/B2C communication and harmonization of ecolabels (RQ2).

The third and fourth discussion points are also based on the findings of the thesis but give a wider perspective on two relevant subjects that are also undeniably linked to both research questions, namely the continuous work of ISO on the standards related to ecolabels (Chapter 4.1.3) and the future of ecolabels in general (Chapter 4.1.4).

4.1.1 Ecolabel characterization scheme

The ecolabel characterization scheme developed in Chapter 3.1 (and overviewed in Appendix A.2) is a set of scientifically derived attributes to analyse ecolabels. It can be used by a variety of stakeholders and in a variety of applications. From the view point of ecolabel operators, they could compare their existing or prototyped initiatives against other existing ones or against the current ISO typologies. In case of organizations that aim at adopting a certain ecolabel for their product portfolio, they can use the scheme to analyse the selected initiative and to compare it against other initiatives and against options of

attributes, which are relevant for their operation. The ecolabel characterization scheme is of use also to consumer organizations to guide their members through the variety of existing ecolabels and to clearly demonstrate characterization attributes of certain initiatives versus others.

In the case of the characterization scheme application, presented in Chapter 3.1, an interesting finding is derived in relation to the self-declared Type II claims. None of the observed ecolabels declares to be Type II. It appears that Type II is not actually a distinguishable typology, rather a list of recommendations and a "code of good practice" on how to conduct self-declared claims. Therefore, such are designated as "undefined", due to the ISO perspective taken in this study. Furthermore, the listed attributes in the scheme show the many more aspects that an ecolabelling classification should take into consideration, in comparison with the currently existing one. If an analysis of a larger ecolabel sample is conducted beyond the ISO perspective, the characterization scheme can be handy to cluster ecolabels into groups for defining new development patterns. In this regard, the scheme is a first step to a consistent methodological framework to provide improvement in the classification of the plethora of ecolabels. The scheme could serve as a basis particularly for ISO in their work for improvement of the existing ecolabel typologies. This is taken up further in Chapter 4.1.3 where the fate of Type II and recommendations for improvement to the current ISO typology are discussed.

Another interesting example of the application of the characterization scheme is the case study of C2C Certified (presented in Chapter 3.2). The initiative comprises several attributes that go beyond the conformance requirements for a Type I or Type III ecolabel and are not covered in any of the respective ISO standards (e.g. the rating awarding format). However, they were possible to be detected by the characterization scheme after update and adjustments of certain attributes. In this regard, the current number of scheme attributes and their options is not exhaustive; the scheme seems to be easily adjustable to different application needs.

4.1.2 Hybrid approach – ecolabel Type IV

The proposed ecolabel Type IV is a hybrid structure, based on the synergies between Type I and Type III, as they are currently defined by the respective ISO norms. Presented in Chapter 3.4, a process for the development of awarding criteria and their certification is conceptualized, using PEF and EUF as an example. The main application of the hybrid Type IV is to support harmonization among ecolabels. The scientific back-end robustness of LCA-based declarations like Type III and the end-consumer front-end friendliness of a Type I awarding format are considered a workable solution for "simplifying" complex results.

Several points have already been raised in this work that can serve as a justification for the existence and applicability of the hybrid Type IV. On the one hand, the constant and increasing popularity of EPDs (shown in Chapter 3.3 and further discussed in Chapter 4.1.4) undoubtedly proves the credibility of using LCA in communication. Moreover, PEF was developed as a harmonized LCA-based method for provisioning environmental information of products with the potential to pave the way for firmer harmonization rules. Despite that by the time of drafting this thesis it is not yet decided how exactly it would be implemented in practice, its application in communication is not precluded and stakeholders often make an analogy of PEF result profiles with EPDs. However, a few issues exist regarding EPDs or PEF-based declarations and this is where Type IV provides a solution, intended as a pass-fail LCA criteria-based awarding. EPDs or PEF-based declarations are not eligible to claim environmental excellence (comparative assertions are not allowed). This makes it difficult for the end-consumers to justify their choice of a product with lower impact solely on an LCA profile of a product, meaning that such declarations are not suitable for B2C relations. Another argument that they are suitable mostly for B2B is that the complexity of the results profile requires considerable expertise by the user to interpret them properly.

On the other hand, in a B2C setting, consumers prefer "simple" and easy-recognizable labels that typical pass-fail Type I ecolabels support. They provide proof of compliance and are used to promote the front-runners in a respective product category. However, their robustness in that sense is critical and highly depended on a firm background evaluation methodology that could, however, differ between the different Type I ecolabels (Rubik and Frankl 2005). Another common critic to Type I is that, although awarding

criteria are usually derived from environmental problems, there are cases when they are also politically driven (e.g., EUF). These downsides can be compensated with Type IV by introducing more objective LCA-based criteria but keep the Type I awarding format.

The concept of a hybrid ecolabel lays on the assumption that it is capable to provide a two-step awarding of products, depending on the targeted communication channel (B2B or B2C). This is especially useful for categories of products that are in the scope of interest for both business purchasers and end consumers (e.g. computers and other electronic equipment, certain construction materials, paper products, etc.). Thus, companies, whose scope spreads out both to B2B and B2C would benefit the most out of such an ecolabel. In that sense, the Type IV ecolabel could be a practical solution on EU level. The EC prepares different impact assessments to develop and justify policy measures (EEB 2018), among which are the criteria and performance classes for the EU Energy label (EC 2017), awarding criteria for the EUF, GPP criteria, etc. By adapting PEF or another robust and standardized LCA method needed for the base of Type IV, the EC could become a Type IV operator that, beyond solely ecolabelling, could provide comparable and harmonized LCA data for the different policy measures. In case of a working Type IV operator in the EU, the benefits for the companies that must comply with the many different EU policies would be that by having a common LCA approach, the fulfilment of only one requirement (i.e. a basis LCA study of their products) would assure their compliance.

The EC to become a Type IV operator is just one example. Type IV implementation could be done on national level instead. Since most Type I programmes are governmental or quasi-governmental initiatives, Type IV is an opportunity for harmonization of Type I programmes on local/national level by adopting a standardized LCA methodology for their product awarding criteria. Further application of the hybrid approach in B2B is also not precluded and it is a practical alternative to existing EPD programmes.

4.1.3 The continuous work of ISO/TC 207/SC 3 on ecolabelling

The road-testing of GPCRD and the respective findings, presented in Chapter 3.3, are recognized in the latest two technical specifications (TS) that ISO/TC 207/SC 3 has been working on: ISO/TS 14027 and ISO/NP TS 14029, both already discussed in Chapter 3.3.1. In the first case, GPCRD has been used as a basis guiding document for the TS. The results of the practical test of GPCRD in the third publication (Chapter 3.3) evaluated the Guidance as operational and suggested ISO to use it for ISO/TS 14027 that was still under development by the time of submission of the publication. Again, in the same publication, methodological divergences in the PCR development procedures in the GPIs of the examined programme operators are described, using GPCRD as a frame. In this relation, similar process is intended to be applied in the new proposal ISO/NP TS 14029 on principles and procedures for mutual recognition between Type III programme operators. It is believed that the procedure taken in this thesis could also be useful for the method development in the new TS regarding the assessment of the similarities and differences of different work elements of GPI (as far as PCR development is concerned).

Despite the concurring findings of this work with the actions undertaken by ISO in the two TS mentioned, the improvements in the standardization of ecolabels in the recent years are minor. Both published in 1999, the ISO norms on Type I and Type II – were revised in 2018 and 2016, respectively. However, the modifications that have been introduced were rather cosmetic and the concepts they represent did not change. Similarly, ISO 14025 has not been updated along its 13 years of existence, despite the constant interest in EPDs and the spreading out of initiatives for mutual recognition, technical equivalence and harmonization between operators.

In this regard, this thesis contributes further with discussion points and recommendations for improvements to ISO/TC 207/SC 3, already listed in Chapter 3.1. Here further emphasis is given on the following issues:

- Awarding format of ecolabels

Despite the classic Type I "pass-fail" and the Type III "declaration" awarding formats, the characterization scheme identifies more existing formats. All options are listed and described in Chapter 3.1, but especially relevant is the "rating" or also known as the "performance" format of awarding. Rating awarding can be used to demonstrate a level

of superiority between products by ranking them on a predefined scale. There are many challenges in setting a rating scheme on LCA, especially if the scope of awarding is beyond a single life cycle stage and more than one environmental aspect is considered (Gül et al. 2015). Nevertheless, this new rising awarding format is a good opportunity for ISO to take a leading position in setting a methodology for definition of performance classes (also discussed in Chapter 5.2).

- Aspects diversity

Social, health and safety aspects or such related to material efficiency, reparability or longevity of products are becoming popular in ecolabelling in combination with environmental aspects. The debate around these topics is becoming more relevant lately also in view of the latest action plans that passed on EC level, e.g., the Circular Economy Action Plan (EC 2019). A recent study by Spengler et al. (2019) also predicted that such criteria will most likely result in more product groups in Type I ecolabels in the near future. To date, social considerations are not officially taken up into any ISO standard on environmental communication, although they are not forbidden. In Chapter 3.1 of this work, the inclusion of social elements in an additional norm and to establish sub-typologies to the existing ones is recommended. This way there would not be a need for modification of the existing typologies solely because of this.

- Reconsideration of the usability of ISO 14021

As already discussed in Chapters 3.1 and 4.1.1, as currently defined by ISO 14021, the provisions written for Type II are rather recommendations and minimum requirements to following broader principles for self-declared claims. Type II is currently neither a distinctive ecolabel typology, nor the standard is a manual on how to develop a Type II ecolabel. Therefore, either the scope of the standard should be better specified and narrowed down, or if kept as it is currently, the term "Type II" should be made available to describe a specific ecolabel typology, as currently Type I and Type III do.

- Improved ISO classification

Building on the point above and given the proven necessity for a more detailed and improved ecolabel classification shown in this work, the need for further maintenance of the current form of the three typologies should be evaluated. It should be investigated

how to reflect additional forms of communication if kept as they are, or how to be reorganized or extended. ISO/TC 207/SC 3 should decide if there is a need for differentiation on typologies or a completely new concept would be more useful.

As of August 2019, a new working plan of ISO/TC 207/SC 3 for the period 2019-2023 should have already been approved. The outcomes of this thesis can serve as a sound source for inspiration and setting more certain and ambitious goals for improvement of the ISO 14020-suite of standards during the upcoming period. ISO has become a reference for quality and trust in many countries around the globe. A modification or an update of the existing classification on ecolabels would further increase the robustness and credibility of ISO, which would result in higher adoption of their classification. This would mean a potentially improved transparency of the operation of the ecolabel schemes, thus, better market positioning and larger uptake.

4.1.4 The future of ecolabels

Although the findings of the present thesis provide a solid basis for estimating in which way ecolabels could go further and even a new Type IV is proposed, the prediction their future in terms of evolution and application is still a challenging task. As shown by the results of the characterization scheme (Chapters 3.1), as of today, Type I and Type III are the two most distinguishable groups of voluntary communication initiatives; thus, they are discussed with priority in the following.

In 2005, UN Environment seems to have correctly predicted that ecolabels and requirements for ecolabels will spread through the supply chains and private procurement policies, rather than "through [end-]consumer demand or formal trade policy" (UN 2005). This is also confirmed in this work by demonstrating the constantly increasing and unabated interest in EPDs and Type III programmes that is expected to continue in the future. The reasons can be justified by the following.

First, the integrity and robustness of the methodology that stays behind EPDs is undoubted. Although there are certain proponents against the application of LCA in ecolabelling, because it is seen as too complex (Laurent et al. 2012, Molina-Murillo and Smith 2009), expensive (Morris 1997, Mungkung et al. 2006) or consisting of too many limitations (Clift 1993), product communication initiatives that apply a life cycle

perspective and use LCA are constantly building credibility, especially in a B2B constellation.

Second, although EPDs are not yet a tool for claiming the environmental excellence of a product, LCA-based declarations allow for bringing a quantified list of impact category results for a given product (together with non-mandatory additional environmental information). This is especially attractive in the building and construction sector, because EPDs are very often used as a proof for commitment of the supplier and a piece of the puzzle of a larger product or service. Their modular properties and the unification and harmonization of their development requirements by initiatives such as e.g., EN 15804:2012+A1:2013 (2013) are a convenient way to collect life cycle-based environmental performance data on many components of a bigger whole. One example for this is the recognition of EPD-based results for obtaining additional points in green building certification, as in LEED (USGBC 2019). Another example is the initiation in 2015 of the working group International Open Data Network for Sustainable Building (WG InData)[4] that established "an online based international LCA data network structure for LCA/EPD data using a common data format and open source software" (InData 2017). The latter is a response to meet the increasing demand for environmental data in digital format (see Chapter 5.2 for more on digitalization and ecolabels) and it is an initiative between several Type III operators, software developers and EU Member State public authorities.

Third, the increasing demands of downstream buyers (such as e.g., construction companies that apply for green building certification) put suppliers into a quasi-mandatory position to develop EPDs (especially in the building and construction sector in Europe). Moreover, most Type III programmes are managed by private, for-profit organizations that are driven by competitiveness and market demands. Cooperation initiatives between different B2B supply chain actors can lead to (artificially) increased demand and dynamics on the market.

In contrast to EPDs, Type I ecolabels have a much more restrained development curve. They are mostly used by companies to advertise their products as eco-innovative to end-consumers (B2C). The reputation of the ecolabelling programme is often used as an

[4] For more information, see: https://www.indata.network/resources

assurance that the labelled product necessarily has a better environmental performance than the non-labelled one. However, being mostly governmental initiatives, the market response to the Type I ecolabelling is often dependent on the supporting activities (e.g., GPP criteria to select only ecolabelled products) or barriers that the public institutions create. This is one of the main challenges for companies that ecolabel their products. Often the lacking awareness of the consumers regarding the ecolabel, due to the insufficient promotion and support by public institutions, is to be blamed for the fewer than the expected rewards for the companies of using the ecolabel (Iraldo and Barberio 2017).

Type I ecolabelling will probably continue to be a voluntary and complementary consumer-oriented instrument of governments used to create incentives and to stimulate product innovation towards more sustainable production and consumption patterns. The possibility that Type I ecolabelling allows the inclusion of politically driven argumentation sometimes in the setting of the awarding criteria or for the inclusion of certain product groups in the scope of the ecolabel would still be used by governments to influence and steer consumption patterns. In a particular case like EUF, its linkage to other EU policies would continue to justify its necessity as a "pull" instrument for achievement of these policies, but it is not expected to bloom. However, as Type I ecolabels are intended to deliver easily digestible information to final consumers, but not quantified data on the impacts of the product, they are not expected to have an active role in trending activities, such as digitalization of environmental data, in comparison to Type III (see Chapter 5.2).

Many "undefined" ecolabels cannot classify under any of the common typologies and therefore, they cannot be discussed here on a group level, as it is done above regarding Type I and Type III. Same applies for Type II, as explained in Chapter 4.1.1. Ecolabel initiatives can, however, be analysed and discussed individually. In this thesis, this is shown in the case study of C2C Certified (presented in Chapter 3.2). In the context of "undefined" ecolabels, C2C Certified is an example of an initiative that follows their own traction of development without striving to be conformant with any ISO typology. Often such initiatives do not rely on the ISO credentials to market their services as scientifically sound and to persuade their audience that their certification assures that products are less environmentally impactful than non-certified ones.

As shown in the ecolabel sample (Appendix A.1) several ecolabels apply rating (or performance) awarding format. The majority of these initiatives are relatively new

(founded within the last 10 years). Rating products according to distinct levels of environmental performance (through e.g., colour codes or ABC classification, or others) seems to have the potential for expansion in the future, especially in a B2C setting, where such a distinction between products facilitates consumers' choices.

4.2 Methodological and practical challenges

Each chapter of the results in this thesis briefly discusses the respective challenges that have been faced. In the following, some of them, as well as additional remaining challenges are discussed.

4.2.1 Ecolabel characterization scheme

The characterization scheme is based on the analysis of a sample of ecolabels. Limiting the scope to one product group to derive the sample is a value choice that undeniably introduces uncertainty in the outcomes. In theory, the more product groups and ecolabels are covered, the higher the representation of ecolabels and the higher the possibilities to identify new characterization attributes or options of attributes and to optimize the scheme. Due to time and resource constrains, however, covering all existing ecolabels is particularly challenging in practice. In this regard, the case study on the characterization of C2C Certified shows that depending on the subject and objectives of the examination, the characterization scheme could lack certain attributes or options of attributes and needs adjustments.

Furthermore, the selectable options of certain attributes could be subjective and indicative of the performance of an ecolabel only in certain context. For example, attribute No. 19 evaluates the "Stakeholder involvement" (Appendix A.2). It cannot be quantified, and the user can only choose between three rather subjective options – low, medium and high – that bring useful information only in the context of comparison between two or more ecolabels.

Another challenge, but related to the application of the scheme, is the access to information when analysing different ecolabels. Often information is scarce or not translated in common languages; operation processes and evaluation methods are not fully transparent. Therefore, certain options of attributes sometimes have to be assigned to certain ecolabels based on assumptions.

Although the scheme was developed with the perspective to be able to characterize ecolabels also according to their ISO typology affiliation (attribute No. 1, see Appendix A.2), the scheme cannot identify any initiative specifically as Type II in practice. This actually is not a downside of the scheme, but of ISO 14021, since Type II does not really consist of particular characterization attributes, detectable by the characterization scheme. In practice, any self-declared environmental claim that is not independently third-party verified and contains certain environmental information, can classify as Type II, as currently defined in ISO 14021. However, such claims are currently classified as "undefined".

4.2.2 Hybrid approach – ecolabel Type IV

The hybrid concept stipulates that the Type I pass-fail criteria can be based on Type III LCA results. In this regard, the realization of an ecolabel Type IV brings along challenges – whether they are practical or methodological. In the following, they are separated into such that are carried over from LCA, Type I and III communication (inherited challenges) and such that are specific for Type IV (potential new challenges):

- Inherited challenges

Because Type IV is conceptualized to adopt PEF or any other LCA method, one should embrace the overall downsides of it. Like every method, LCA is not perfect and it is always subject of further improvement and development. Gaps and challenges in LCA have been widely discussed in the scientific domain, but to date the most comprehensive analysis has been done by Finkbeiner et al. (2014), who structured LCA gaps into inventory, impact assessment, generic and evolving aspects. PEF has also been in focus of several publications that discussed its methodological issues (see e.g., Finkbeiner (2014), Lehmann et al. (2014), Lehmann et al. (2015), Lehmann et al. (2016), Bach et al. (2018)).

The definition of the granularity and scope of the product group classification is a relevant issue both in Type I ecolabel criteria setting and in PCR development for Type III declarations. A universal solution has not been defined neither in PEF, where so far, each product group is dealt individually. However, the product group scope has major implications in every assessment, since a number of parameters are dependent on it. This is also relevant in the case for Type IV, where threshold values need to be derived for the pass-fail awarding format. This in theory could be done by deriving benchmarks based on

a statistically representative sample, but in practice it is challenging. If the product group scope is defined e.g., too broad, it is possible that products with different qualities, varieties and functionalities could fall under the same product group (Cordella et al. 2019).

Another challenge in LCA is to define a scientifically-sound way for identifying the life cycle impact assessment categories among the several used that would define the benchmarks. This could be done by prioritization of the impact categories by normalization and weighting, as currently done by PEF. However, due to its subjectivity and lack of scientific basis, weighting is widely criticized in general (see e.g., Bach et al. (2018)). The prioritization of relevant environmental aspects and production processes in Type I ecolabelling could also sometimes be subjective and there is not a single proven and operational approach to perform it.

Among the main practical challenges that Type III declarations face is the use of non-harmonized PCRs for similar product groups from different programme operators. This hinders the objective comparison between EPDs. In case of PEF is applied as an overarching LCA method, only one set of rules would be used, which could mitigate this current challenge.

Furthermore, LCA relies heavy on data that are often a subject of change and sourced by different providers. Even if PEF serves as the sole data provider, regular updates would be indispensable. In the current practice, Type I ecolabels are designed to expire and to undergo regular updates, but mostly to assure that changes in the product characteristics (e.g., design, performance, etc.) would still meet the ecolabel criteria. LCA in awarding criteria introduces an additional necessity for re-certification, in case of background inventory data updates (something that is already implied in the necessity to renew EPDs). This of course happens at a given price for the applicant.

In the same spirit, Spengler et al. (2019) address the issue to Type I, which is also valid for Type IV: one should bear in mind the trade-offs between covering the complete life cycle (and all related impacts) and the feasibility of the applicants to comply with the criteria (also from time and cost perspective).

- Potential new challenges

A classic Type I ecolabel does not necessarily consist of awarding criteria that cover the whole life cycle of the product; the focus is usually put on life cycle stages and processes

that are relevant and where, in the best case, improvement potentials exist. Following this materiality principle is seen as an advantage in a typical Type I setting, if scientific-sound argumentation is in place. When LCA-based criteria are used for Type IV, however, it is a challenge to put in place a mechanism that allows for deriving the threshold values on particular stages or processes, but not solely on the overall life cycle, and still to avoid burden shifting between stages and processes. Otherwise, the product- and issue-specific focus of the ecolabel could be dissipated, and the applicants could misbehave by applying "easy-to-achieve" reduction measures in non-relevant life cycle stages or processes.

Furthermore, consumers typically look for information about distinct product features that can be easily understood and "translated" into clear benefits that distinguish them from other products. To date, as shown in Chapter 3.4, LCA in general and PEF in particular are not capable of detecting and quantifying certain issues that are considered relevant by Type I awarding criteria. Such are e.g., performance- and fitness-for-use criteria that assure longer and less impactful use phase or criteria prohibiting certain ingredients, due to ethical or social constraints. In this regard, when creating LCA awarding criteria for Type IV, it is a challenge to identify which are the remaining issues beyond the scope of LCA, but relevant for the respective product group. An approach for identification of other sources of information and/or tools would be required that should be then skilfully combined with LCA. A two-tiered approach for Type IV awarding criteria could be implemented. Tier 1 could be based on plain environmental LCA indicators, as currently done in EPDs. In case of additional potential hotspots that cannot be covered by LCA results, a Tier 2 approach would combine the LCA indicator results with supplementary indicators as currently developed for certain awarding criteria in Type I.

As regards who could serve as and benefit from operating a Type IV programme, a few scenarios and possibilities are discussed in Chapter 4.1.2. Further exploration of the practical realization of these is challenging, due to the many-sidedness of the overall topic of ecolabelling (see next Chapter 4.2.3) that requires investigation of e.g., market dynamics, trade and competition implications.

4.2.3 Ecolabelling as a multifaceted phenomenon

The subject of ecolabelling does not rejoice at large popularity in terms of scientific attention and publications in the field of engineering and environmental studies. Among the reasons is that ecolabelling is a multifaceted phenomenon. As other scientific and technological challenges that face the world today, the research on the enhancement of product environmental communication expects a multidisciplinary perspective by addressing e.g., environmental issues through combined market economics and social trends. In this sense, one should bear the limitations and scope of the present thesis that have eventually led to certain unattained artefacts in the findings or left certain discussion points incomplete.

5 Conclusions and outlook

Environmental labelling is an instrument to deal with the asymmetry of product environmental information along the supply chain – from the producer to the final consumer. The importance of managing the communication of the product environmental performance has been highlighted by the EU as far back in the 2000s when the IPP has been settled. Aiming at also considering a life cycle perspective, environmental labelling is among the variety of policy tools that have been developed by the EC along the years to improve sustainable production and consumption practices. Nevertheless, some having started even earlier, ecolabels around the world have developed in many varieties and forms, leading to an "ecolabel jungle" and a "confusing cacophony of competing ecolabels" (Lyon 2010) on the marketplace.

This thesis contributes to the scientific work in the field of ecolabelling. It aims to enhance the communication of environmental information of products through improved characterization and harmonization of ecolabels.

5.1 Summary and added value of the findings

The objective of this thesis is achieved by answering two research questions, using the results of four publications (presented in Chapter 3). The main findings and results, as well as their added value are summarized in the following.

To mitigate the initially identified gaps in the existing approaches for characterization and classification of ecolabels, a scheme for their characterization is proposed. It is the foundation of this thesis. It consists of 22 distinctive characterization attributes, grouped in five categories and applied to a sample of 45 ecolabels. The scheme allows for analysis and comparison of future and existing ecolabels and it is applicable to variety of stakeholders. In this thesis, it is used to analyse the overall development of ecolabels and the most commonly used ecolabels classification, i.e. the one from ISO. The results show some clear flaws in the usefulness and usability of the three existing ISO typologies. Recommendations for mitigation of the existing gaps and improvement of the existing classification are derived.

Although this work shows that ISO rules on ecolabels are not ideal, nor the existing typology classification is perfectly set up to the present market needs, a minimum set of requirements for a credible communication initiative that ISO 14020-series provide is advantageous for ecolabel operators to be adhered to. Such are the requirements for e.g., transparency, third-party certification, or as the minimum – life cycle consideration in the awarding criteria to avoid burden-shifting of impacts between different life cycle stages and misbalance between the criteria. Many of these basis provisions are barely respected by most "undefined" ecolabels.

This is also shown by the case study on C2C Certified. It aims to demonstrate the applicability of the characterization scheme and to practically test and upgrade it. In parallel, C2C Certified is characterized as a mean for external communication of product environmental performance and recommendations for its improvement in this context are provided. This contributes to the several publications of other authors (listed and discussed in Chapter 3.2) that attained to analyse the operation of this product certification initiative, its background methodology and application for different purposes.

The work further emphasizes the usefulness and importance of applying LCA in ecolabelling. LCA is a key tool in identifying design options that can bring more environmental benefit and if relevant trade-offs exist (Cordella et al. 2019). Focus is given on LCA-based ecolabelling approaches (predominantly Type III operators), as they have been proven to be the most dynamic field of development and having the highest interest by stakeholders. A total of 48 programmes are identified until mid-2019, the majority of which operate in the building and construction sector. Furthermore, approaches for harmonization of PCRs and alignment of Type III programmes are described and categorized. GPCRD and PEF are shortlisted and put in focus for testing in case studies.

An analysis of the practicality of GPCRD to complement existing GPI of a Type III operator and an alignment of the requirements of the Guidance to a PCR under development are successfully conducted. In parallel, it is also a test for the likelihood and flexibility of the GPI in focus to take upon additional obligations, imposed by GPCRD. Evidence examples for inconsistencies and aspects for improvement of the current practices of programme operators are listed, allowing for a consistent development and alignment of PCRs between them.

As regards PEF, the thesis explores this EC initiative from the perspective of a tool for communication of product information that uses LCA. Based on three case studies, PEF is compared against EUF – a classic Type I ecolabel – to examine their common aspects and differences, as well as to investigate how an LCA-based initiative can benefit from adopting certain aspects of a Type I ecolabel and vice versa. Scenarios for mutual integration and co-existence of PEF and EUF are listed and discussed. As a result, a combination between the two is conceptualized in a hybrid ecolabel, called Type IV. It lays on the foundations of two different, but proven voluntary approaches, namely Type I and Type III that are operational and well-known on the market as a robust third-party verified communication medium, setting clear responsibilities and requirements. The new concept is a practical solution for awarding the product's environmental performance with the possibility to simultaneously fulfil the qualifications for communication to both B2B and B2C. It serves as an example for an action in reduction of the proliferation of ecolabels.

5.2 Suggestions for future research work

This last chapter of the thesis presents several aspects in addition to the discussed key challenges, outlining a direction for further research beyond the presented findings in this work. This should ultimately lead to further enhancement of the communication of product environmental information through ecolabels.

- Ecolabel characterization scheme and update of ISO typology

The proposed scheme for characterization of ecolabels and the recommendations to ISO are an initial step for the improvement of the existing ecolabel classifications. It is assumed to be an appropriate moment for such an action, given the current ongoing activities in ISO/TS 207/SC 3. It is endorsed to engage further developments in this field in a multidisciplinary cooperation between different scientific domains to best justify the needed upgrades and modifications of ISO's classification. Furthermore, the ecolabelling world would surely benefit from a larger scientific attention and interdisciplinary cooperation.

- The hybrid ecolabel – Type IV

The concept for Type IV ecolabel comes with many challenges and opportunities for future work. Future research should be concentrated on developing and testing a first set of LCA-based awarding criteria for B2C communication (Type I-like). A robust benchmarking definition approach based on LCA indicators is necessary. An open participatory process is needed for every product group, for which benchmarks are to be defined.

PEF initially had the intention to provide an approach to calculate classes of performance. However, currently the EC recommends each technical secretariat that develops PEFCR to define a method for identification of classes of performance, "in case they deem it appropriate and relevant" (Zampori and Pant 2019). Given the indications that consumers would prefer a rating label based on an average product score (Lupiáñez-Villanueva et al. 2018) and the findings in this work that rating ecolabels appear more often (see Chapter 3.1), a logical next step would be to concentrate further research work in defining a credible method for deriving performance classes based on LCA, assuring sufficient differentiation between products and classes. This again would be a specific task for each developed product group. The Type IV ecolabel could further adopt this approach to develop B2C performance (or rating) awarding format and to go beyond the pass-fail awarding. Overall, all recommendations for future research on Type IV need also field testing in case studies.

- Estimating the environmental benefits of ecolabels

"The correlation between ecolabelling and environmental issues, perhaps ironically, is almost impossible to establish" (Williams 2004). This is the harsh reality even 15 years after this statement has been made. The environmental importance of ecolabels is difficult to quantify. Ecolabels can influence consumer choices, but can they really reduce environmental impacts? It is not necessarily true that the higher the adoption rate of ecolabels, the higher the overall net environmental benefit. If ecolabels are going be used in future not only as an instrument to carry environmental information, but also as an assurance for environmental impact reduction, a method for evaluation and monitoring of the environmental effectiveness of ecolabels is indispensable. Very few studies attempted to investigate the environmental effects (be it positive or negative) of labelled

products, but an operation approach is not in place yet. A starting point could be to cluster ecolabel initiatives based on certain attributes of the characterization scheme and to study each cluster if and how they provide any positive environmental effects. As mentioned in the challenges (Chapter 4.2.3), however, due to the many-sidedness of the topic of ecolabels, methods for estimating the environmental effectiveness of ecolabels should be derived together with the examination of their relation to the fundamental market principles and current social trends.

- Digitalization and electronic ecolabelling

Living in a digitalized world, a legitimate further step would be to explore how current ecolabelling approaches could work in a contemporary digital setting, cooperating with existing and emerging digital tools for enhancing green purchasing and transmitting environmental information. Storing large information databanks online is certainly a clear advantage of the online solutions of today. Digital EPDs (i.e. machine-readable EPD information stored in a file format) are already available by some programme operators participating in the InData project (briefly discussed in Chapter 4.1.4) and digital EPD databases are being compiled. This digital information would be handy for variety of applications, e.g., public procurement or calculation tools. For ecolabels having pass-fail or rating awarding format (also concerning the Type IV) it is worth exploring whether end-consumers would benefit of accessing online information (like background data, LCA profile, etc.) in addition to the stamped label on the product. Taken from another perspective, with the increased volume of online trade, consumers much more often encounter the products first through their gadgets. It is interesting to explore whether currently existing approaches would be applicable in such cases or the online market demands something different.

As regards the ecolabel characterization scheme, it would be worth further exploring whether characterization attributes related to online presence and digitalization are relevant for consideration and implementation in the scheme.

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Appendix A.4

Glossary

Attribute of an ecolabel: a quality or feature regarded as a characteristic or inherent part of an ecolabel (adapted from Lexico (2019))

Awarding criteria: environmental requirements that the product shall meet in order to be awarded an ecolabel; they should be expressed in terms of impacts on the environment and natural resources, or whenever that is not practicable – environmental aspects, such as emissions to the environment (adapted from ISO 14024 (2018))

Benchmark: a standard or point of reference against which any comparison may be made

Business-to-business: business relations that are conducted between two or more companies; such relations could occur between parties along the whole supply chain of a product

Business-to-consumer: business relations that are conducted between the company and the consumer, who is the end-user of their products or services

Characterization of an ecolabel: description of the distinctive attributes of an ecolabel

Classification of an ecolabel: the process of classifying ecolabels into distinct types according to certain distinctive attributes

Communication of environmental product information: process conducted by an organization to provide information and to engage in dialogue with internal and external stakeholders to encourage a shared understanding on environmental issues, aspects and performance of a product (adapted from ISO 14050 (2009))

Comparative assertion: environmental claim regarding the superiority or equivalence of one product versus a competing product that performs the same function (ISO 2006c)

Ecolabel characterization scheme: a list of grouped distinctive attributes that list two or more options for characterizing the properties of an ecolabel

Ecolabel operator (or Type III operator, or programme operator): a body and its agents, which conduct an environmental labelling programme or an environmental declaration programme (adapted from ISO 14050 (2009))

Ecolabel programme (or Type III environmental declaration programme): voluntary programme for the development and use of environmental labels or environmental declarations based on set of operating rules (adapted from ISO 14050 (2009))

Environmental impact: an environmental change (adverse or beneficial) that can result (wholly or partially) from activities related to any of the product's life cycles

Environmental label (or environmental declaration): a claim that indicates the environmental aspects of a product or service (ISO 2000)

Life cycle: consecutive and interlinked stages of a product system, from raw material acquisition or generation from natural resources to final disposal (ISO 2006b)

Life Cycle Assessment (LCA): compilation and evaluation of the inputs, outputs and the potential environmental impacts of a product system throughout its life cycle (ISO 2006b)

PEF profile: the quantified results of a PEF study (Zampori and Pant 2019)

Product Category Rules (PCR): a set of specific life cycle-based rules, requirements and guidelines for developing Type III environmental declarations (adapted from ISO 14025 (2006a))

Product Environmental Footprint Category Rules (PEFCR): product category-specific, life cycle-based rules that complement general methodological guidance for PEF studies by providing further specification (EC 2018)

Threshold: the level of certain input (e.g., raw material, fuel, etc.) or output (e.g., emission effluent) occurring in any life cycle stage of a product that shall not be surpassed in order for the product to be compliant with a certain ecolabel awarding criterion

Appendixes

A.1 Supplementary material to Publication 1

This appendix contains the supplementary material to publication **(Minkov et al. 2019a)**:

> Minkov N, Lehmann A, Winter L, Finkbeiner M (2019) **Characterization of environmental labels beyond the criteria of ISO 14020 series.** Int J LCA 22 8:1744. https://doi.org/10.1007/s11367-019-01596-9

Table A.1.1. Ecolabel sample: abbreviations

№	Ecolabelling programme	Abbreviation
Forest and paper products (only)		
1	Ancient Forest Friendly™	AFF
2	Chlorine-Free Products Association	CFPA
3	Paper Profile	PP
Forest management		
4	Australian Forest Certification Scheme	AFCS
5	Forest Stewardship Council®	FSC
6	Sustainable Forestry Initiative	SFI
7	Programme for the Endorsement of Forest Certification	PEFC
Multi-sectorial covering forest and paper products among others		
8	Austrian Ecolabel	AE
9	B Corporation	B Corp
10	Biodegradable Products Institute Label	BPIL
11	Blue Angel	BA
12	Carbon Neutral® Certification	CNC
13	Carbon Trust Footprint Label	CTFL
14	CarbonFree® Certified	CFC
15	China Environmental Labelling	CEL
16	Climatop	Climatop
17	Cradle to Cradle Certified™ Products Program	CCCPP
18	Earthsure	Earthsure
19	Eco-Leaf	EL
20	EcoMark: Japan	EMJ
21	Environmental Choice New Zealand	ECNZ
22	Environmentally Friendly Label: Croatia	EFLC
23	EU Ecolabel	EUEco
24	EU Product Environmental Footprint Initiative	PEF
25	FP Innovations	FPI
26	Global GreenTag Certified	GGTC
27	Good Environmental Choice Australia	GECA
28	Green Good Housekeeping Seal	GGHS
29	Green Mark	GM
30	Green Products Standard	GPS
31	Green Seal	GS
32	Green Tick	GT
33	Korean Ecolabel	KE
34	LowCO2 Certification	LowCO2
35	Nordic Swan Ecolabel	NSE
36	SCS Global certified	SCS
37	Singapore Green Label Scheme	SGLS
38	Thai Green Label	TGL
39	The International EPD System	IEPDS
40	Verus Carbon Neutral Certification	VCNC
Others not covering forest and paper products		
41	Certified Wildlife Friendly®	CWF
42	EU Energy label	EUEn
43	Greenline Print	GP
44	UPS Eco Responsible Packaging Program	UPS
45	Windmade	WM

Table A.1.2. Ecolabel sample: general information and communication characteristics

№	Abbreviation	Country of establishment	Year of establishment	Communication characteristics					
				1	2			3	4
				ISO typology	Awarding format	Sub-category 'rating'	Sub-category 'declaration'	Aspects diversity	End-user focus
1	AFF	?	2011	?	Seal	-	-	Environmental	B2B
2	CFPA	US	1994	?	Seal	-	-	Environmental	B2B
3	PP	Finland	2000	?	Declaration	-	Non-sealed	Environmental	B2B
4	AFCS	Australia	2003	Type I	Seal	-	-	Both	both
5	FSC	Mexico	1994	?	Seal	-	-	Both	Both
6	SFI	US and Canada	1994	?	Seal	-	-	Both	both
7	PEFC	Switzerland	1999	?	Seal	-	-	Both	both
8	AE	Austria	1990	Type I	Seal	-	-	Environmental	B2C
9	B Corp	US	2010	?	Rating	Seal and rating	-	Both	B2B
10	BPIL	North America	1999	?	Seal	-	-	Environmental	B2B
11	BA	Germany	1978	Type I	Seal	-	-	Environmental	B2C
12	CNC	UK	2008	?	Seal	-	-	Environmental	B2B
13	CTFL	UK	2001	?	Seal	-	-	Environmental	B2B
14	CFC	US	2003	?	Seal	-	-	Environmental	Both
15	CEL	China	1993	Type I	Seal	-	-	Environmental	B2C
16	Climatop	Switzerland	2008	?	Seal	-	-	Both	both
17	CCCPP	US	2010	?	Rating	Seal and rating	-	Both	Both
18	Earthsure	US	2006	Type III	Declaration	-	Non-sealed	Environmental	B2B
19	EL	Japan	2002	Type III	Declaration	-	Non-sealed	Environmental	both
20	EMJ	Japan	1989	Type I	Seal	-	-	Environmental	B2C
21	ECNZ	New Zealand	2002	Type I	Seal	-	-	Environmental	Both
22	EFLC	Croatia	1993	Type I	Seal	-	-	Environmental	B2C

№	Abbreviation	Country of establishment	Year of establishment	Communication characteristics					
				1	2			3	4
				ISO typology	Awarding format	Sub-category 'rating'	Sub-category 'declaration'	Aspects diversity	End-user focus
23	EUEco	EU	1992	Type I	Seal	-	-	Environmental	Both
24	PEF	EU	2013	?	?	?	?	Environmental	Both
25	FPI	Canada	2007	Type III	Declaration		Non-sealed	Environmental	B2B
26	GGTC	Australia	2010	?	Rating	-	-	Both	Both
27	GECA	Australia	2001	Type I	Seal	-	-	Both	Both
28	GGHS	US	2009	?	Seal	-	-	Both	B2C
29	GM	Taiwan	1992	Type I	Seal	-	-	Environmental	B2C
30	GPS	?	2007	?	?	?	?	?	?
31	GS	US	1989	Type I	Seal	-	-	Both	B2C
32	GT	Australia and New Zealand	2004	?	Seal	-	-	Both	B2C
33	KE	Korea, Republic of	1992	Type I	Seal	-	-	Environmental	B2C
34	LowCO2	Australia	2007	?	Rating	Rating only	-	Environmental	Both
35	NSE	5 Nordics	1989	Type I	Seal	-	-	Environmental	Both
36	SCS	US	?	?	Seal	-	-	Both	Both
37	SGLS	Singapore	1995	Type I	Seal	-	-	Environmental	B2C
38	TGL	Thailand	1994	Type I	Seal	-	-	Environmental	B2B
39	IEPDS	Sweden	1998	Type III	Declaration	-	Non-sealed	Environmental	Both
40	VCNC	US	2008	?	Seal	-	-	Environmental	B2C
41	CWF	US	2007	?	Seal	-	-	Environmental	B2C
42	EUEn	EU	1992	?	Rating	Rating only	-	Environmental	B2C
43	GP	Estonia	2013	?	Rating	Rating only	-	Environmental	B2B
44	UPS	US	2010	?	Seal	-	-	Environmental	B2B
45	WM	Belgium	2011	?	Declaration	-	Sealed	Environmental	B2C

Table A.1.3. Ecolabel sample: life cycle characteristics

№	Abbreviation	Life Cycle characteristics			
		5		6	7
		Life cycle perspective	Covered life cycle stages	Multiplicity of covered aspects	Operation scope
1	AFF	Non-LC based	Cradle-to-gate	Multi-attribute	Process
2	CFPA	Non-LC based	?	Single-attribute	Product
3	PP	Non-LC based	Cradle-to-gate	Multi-attribute	Product
4	AFCS	Non-LC based	Cradle-to-gate	Multi-attribute	Process
5	FSC	Non-LC based	Cradle-to-gate	Multi-attribute	Process
6	SFI	Non-LC based	Cradle-to-gate	Multi-attribute	Organization
7	PEFC	Non-LC based	?	Multi-attribute	Process
8	AE	LCA-based	Cradle-to-grave	Multi-attribute	Product
9	B Corp	Non-LC based	N/A	Multi-attribute	Organization
10	BPIL	Non-LC based	EoL	Single-attribute	Product
11	BA	LCA-based	Production, Use, EoL, C2G	Multi-attribute	Product
12	CNC	LC-based	Logistics, use, EoL	Single-attribute	Organization
13	CTFL	LC-based	Depends on the assessment	Single-attribute	Product, Organization
14	CFC	Non-LC based	Cradle-to-grave	Single-attribute	Product, Organization
15	CEL	LC-based	Cradle-to-grave	Multi-attribute	Product
16	Climatop	LCA-based	Cradle-to-grave	Single-attribute	Product
17	CCCPP	Non-LC based	Production, Use, EoL	Multi-attribute	Product
18	Earthsure	LCA-based	Cradle-to-grave	Multi-attribute	Product
19	EL	LCA-based	Cradle-to-grave	Multi-attribute	Product
20	EMJ	LC-based	Cradle-to-grave	Multi-attribute	Product
21	ECNZ	LC-based	Cradle-to-grave	Multi-attribute	Product
22	EFLC	LC-based	?	Multi-attribute	Product
23	EUEco	LCA-based	Cradle-to-grave	Multi-attribute	Product

№	Abbreviation	Life Cycle characteristics			
		5		6	7
		Life cycle perspective	Covered life cycle stages	Multiplicity of covered aspects	Operation scope
24	PEF	LCA-based	Cradle-to-grave	Multi-attribute	Product
25	FPI	LCA-based	Cradle-to-grave	Multi-attribute	Product
26	GGTC	LCA-based	Cradle-to-grave	Multi-attribute	Product
27	GECA	LC-based	Cradle-to-grave	Multi-attribute	Product
28	GGHS	LC-based	Production, Use	Multi-attribute	Product
29	GM	LC-based	?	Multi-attribute	Product
30	GPS	?	?	?	Product
31	GS	LC-based	Cradle-to-grave	Multi-attribute	Product
32	GT	LCA-based	Cradle-to-grave	Multi-attribute	Product, Processes, Organization
33	KE	?	?	Multi-attribute	Product
34	LowCO2	LCA-based	Cradle-to-grave	Single-attribute	Organization
35	NSE	LC-based	Cradle-to-grave	Multi-attribute	Product
36	SCS	Non-LC based	Cradle-to-grave	Multi-attribute	Product
37	SGLS	LC-based	?	Multi-attribute	Product
38	TGL	LCA-based	Cradle-to-grave	Multi-attribute	Product
39	IEPDS	LCA-based	Cradle-to-grave	Multi-attribute	Product
40	VCNC	LCA-based	Cradle-to-grave	Single-attribute	Product
41	CWF	Non-LC based	Cradle-to-gate	No-attribute	Organization
42	EUEn	Non-LC based	Use	Single-attribute	Product
43	GP	LC-based	Cradle-to-gate	Single-attribute	Product
44	UPS	Non-LC based	Logistics	Multi-attribute	Organization
45	WM	LC-based	Cradle-to-grave	Single-attribute	Product, Organization

Table A.1.4. Ecolabel sample: standard characteristics

№	Abbre-viation	Standard characteristics							
		8	9	10	11	12	13	14	15
		Sector scope	Geographic scope	Verification	Compulso-riness	Governance	Financing	Purpose	Longevity
1	AFF	Specific	International	?	Voluntary	NPO	Donations, Fees	Ideals-centric	?
2	CFPA	Specific	?	Third-party	Voluntary	NPO	Fees	Adversity-centric	Single-issued
3	PP	Specific	?	First-party	Voluntary	NPO	Member dues	Neutral	?
4	AFCS	Specific	National	Third-party	Voluntary	NPO	Fees	Ideals-centric	?
5	FSC	Specific	International	Third-party	Voluntary	NGO	?	Ideals-centric	Renewable
6	SFI	Multi	National	Third-party	Voluntary	NPO	Member dues	Ideals-centric	?
7	PEFC	Specific	International	Third-party	Voluntary	NGO	Fees	ideals-centric	Renewable
8	AE	Multi	National	Third-party	Voluntary	Governmental	Governmental, Fees	Ideals-centric	Renewable
9	B Corp	Multi	International	Second-party	Voluntary	NGO	Donations and grants from individuals, fees	Ideals-centric	Single-issued
10	BPIL	Multi	National	Third-party	Voluntary	NPO	Governmental, Member dues	Adversity-centric	Single-issued
11	BA	Multi	International	Third-party	Voluntary	Governmental	Fees	ideals-centric	Renewable
12	CNC	Multi	International	Second-party	Voluntary	PFP	Private, fees	Ideals-centric	?
13	CTFL	Multi	International	Third-party	Voluntary	NPO	?	Ideals-centric	Improvement-based
14	CFC	Multi	International	Third-party	Voluntary	NPO	Donations and grants from individuals, businesses and various organizations	Ideals-centric	?
15	CEL	Multi	National	Third-party	Voluntary	Governmental	Governmental, Fees	Ideals-centric	Renewable
16	Climatop	Multi	International	Third-party	Voluntary	NPO	Fees	Adversity-centric	Renewable
17	CCCPP	Multi	International	Third-party	Voluntary	NGO	Private, fees, member dues	Ideals-centric	Improvement-based
18	Earthsure	Multi	National	Third-party	Voluntary	NPO	Fees	Neutral	Renewable
19	EL	Multi	National	Third-party	Voluntary	Governmental	?	Neutral	Renewable
20	EMJ	Multi	National	Third-party	Voluntary	NPO	Fees	Ideals-centric	Renewable
21	ECNZ	Multi	National	Third-party	Voluntary	Governmental	Fees	Ideals-centric	Renewable

№	Abbre-viation	Standard characteristics							
		8	9	10	11	12	13	14	15
		Sector scope	Geographic scope	Verification	Compulso-riness	Governance	Financing	Purpose	Longevity
22	EFLC	Multi	National	Third-party	Voluntary	Governmental	?	Ideals-centric	Renewable
23	EUEco	Multi	Regional	Third-party	Voluntary	Governmental	Fees, Member dues	Ideals-centric	Renewable
24	PEF	Multi	Regional	?	?	Governmental	?	Ideals-centric	?
25	FPI	Specific	National	?	Voluntary	NPO	?	Neutral	Renewable
26	GGTC	Multi	International	Third-party	Voluntary	PFP	Fees	Ideals-centric	?
27	GECA	Multi	National	Third-party	Voluntary	NPO	Fees *Other	Ideals-centric	Renewable
28	GGHS	Multi	National	Second-party	Voluntary	PFP	?	Ideals-centric	?
29	GM	Multi	National	Second-party	Voluntary	NPO	?	Ideals-centric	Renewable
30	GPS	?	?	Second-party	Voluntary	PFP	?	?	?
31	GS	Multi	National	Second-party	Voluntary	NPO	Private	ideals-centric	Renewable
32	GT	Multi	International	Third-party	Voluntary	PFP	Private, fees	Ideals-centric	?
33	KE	Multi	National	Third-party	Voluntary	Governmental	Fees	Ideals-centric	Renewable
34	LowCO2	Multi	?	Second-party	Voluntary	PFP	Private, Fees, Member dues	Ideals-centric	Renewable
35	NSE	Multi	International	Third-party	Voluntary	Governmental	Governmental, Fees	Ideals-centric	Renewable
36	SCS	Multi	International	First-party	Voluntary	PFP	Fees	Ideals-centric	Renewable
37	SGLS	Multi	International	Second-party	Voluntary	NGO	Fees	Ideals-centric	Renewable
38	TGL	Multi	?	Third-party	Voluntary	NGO	Governmental, Fees	Ideals-centric	Renewable
39	IEPDS	Multi	International	Third-party	Voluntary	PFP	Fees	Neutral	Renewable
40	VCNC	Multi	?	Second-party	Voluntary	PFP	Fees	Ideals-centric	?
41	CWF	Specific	International	Second-party	Voluntary	PFP	Fees	Adversity-centric	?
42	EUEn	Specific	Regional	First-party	Mandatory	Governmental	N/A	Ideals-centric	Single-issued
43	GP	Specific	?	Second-party	Voluntary	PFP	Private, Fees	Ideals-centric	?
44	UPS	Specific	International	Second-party	Voluntary	PFP	Fees	Ideals-centric	Single-issued
45	WM	Multi	International	Third-party	Voluntary	NPO	Fees	Ideals-centric	?

Table A.1.5. Ecolabel sample: conclusive characteristics

№	Abbreviation	Conclusive characteristics				
		16			17	18
		Transparency (label setting process)	Transparency (awardees)	Transparency (financing)	Comparability	Environmental excellence
1	AFF	No	No	Yes	?	?
2	CFPA	Yes	No	Yes	?	?
3	PP	Yes	No	Yes	?	?
4	AFCS	Yes	Yes	Yes	Medium	Intended
5	FSC	Yes	Yes	Yes	?	?
6	SFI	Yes	Yes	Yes	?	?
7	PEFC	Yes	Yes	Yes	?	?
8	AE	Yes	Yes	Yes	Medium	Intended
9	B Corp	Yes	Yes	Yes	?	?
10	BPIL	Yes	Yes	Yes	?	?
11	BA	Yes	Yes	Yes	Medium	Intended
12	CNC	Yes	Yes	Yes	?	?
13	CTFL	Yes	Yes	Yes	?	?
14	CFC	Yes	Yes	Yes	?	?
15	CEL	Yes	Yes	Yes	Medium	Intended
16	Climatop	Yes	Yes	Yes	?	?
17	CCCPP	Yes	Yes	Yes	?	?
18	Earthsure	Yes	Yes	Yes	High	Not intended
19	EL	Yes	Yes	No	High	Not intended
20	EMJ	Yes	No	No	Medium	Intended
21	ECNZ	Yes	Yes	Yes	Medium	Intended
22	EFLC	No	No	No	Medium	Intended

№	Abbreviation	Conclusive characteristics				
		16			17	18
		Transparency (label setting process)	Transparency (awardees)	Transparency (financing)	Comparability	Environmental excellence
23	EUEco	Yes	Yes	Yes	Medium	Intended
24	PEF	Yes	Yes	No	?	?
25	FPI	Yes	Yes	No	High	Not intended
26	GGTC	Yes	Yes	Yes	?	?
27	GECA	Yes	Yes	Yes	Medium	Intended
28	GGHS	Yes	Yes	No	?	?
29	GM	Yes	No	No	Medium	Intended
30	GPS	No	No	No	?	?
31	GS	Yes	Yes	Yes	Medium	Intended
32	GT	Yes	No	Yes	?	?
33	KE	Yes	No	Yes	Medium	Intended
34	LowCO2	Yes	No	Yes	?	?
35	NSE	Yes	No	Yes	Medium	Intended
36	SCS	Yes	Yes	Yes	?	?
37	SGLS	Yes	Yes	Yes	Medium	Intended
38	TGL	Yes	Yes	Yes	Medium	Intended
39	IEPDS	Yes	Yes	Yes	High	Not intended
40	VCNC	Yes	No	No	?	?
41	CWF	Yes	Yes	Yes	?	?
42	EUEn	Yes	No	No	?	?
43	GP	Yes	Yes	Yes	?	?
44	UPS	Yes	No	No	?	?
45	WM	Yes	Yes	Yes	?	?

Table A.1.6. Excerpt of the characterization attributes and their occurrences in the ecolabel sample

№	Attribute	Attribute option	Result
1	ISO typology	Type I	33%
		Type II	0%
		Type III	9%
		Undefined	58%
2	Awarding format	Seal	69%
		Declaration	13%
		Rating	13%
		?	4%
	Sub-category 'rating'	Seal and rating	40%
		Rating only	60%
	Sub-category 'declaration'	Sealed	17%
		Non-sealed	83%
3	Aspects diversity	Environmental	69%
		Both	29%
		?	2%
4	End-user focus	B2B	27%
		B2C	33%
		Both	38%
		?	2%
5	Life cycle perspective	Non-LC based	33%
		LC-based	31%
		LCA-based	31%
		?	4%
	Covered life cycle stages	LCA Type III	29%
		LCA Others	29%
		LCA Unclear	43%
6	Multiplicity of covered aspects	Single-attribute	24%
		Multi-attribute	71%
		No-attribute	2%
		?	2%
7	Operation scope	Product	78%
		Organization	13%
		Process	9%
		?	0%
8	Sector scope	Multi	73%
		Specific	24%
		?	2%
9	Geographic scope	National	36%
		Regional	7%
		International	42%
		?	16%
10	Verification	First-party	7%
		Second-party	27%
		Third-party	60%
		?	7%
11	Compulsoriness	Voluntary	96%
		Mandatory	2%
		?	2%
12	Governance	Governmental	24%
		NGO	13%
		NPO	36%
		PFP	27%
		?	0%
13	Financing	-	-
14	Purpose	Adversity-centric	9%
		Ideals-centric	78%
		Neutral	11%
		?	2%

№	Attribute	Attribute option	Result
15	Longevity	Single-issued	11%
		Renewable	51%
		Improvement-based	4%
		?	33%
16	Transparency (label setting process)	Yes	93%
		No	7%
	Transparency (awardees)	Yes	69%
		No	31%
	Financing	Yes	76%
		No	24%
17	Comparability	High	9%
		Medium	33%
		Low	0%
		?	58%
18	Environmental excellence	Intended	33%
		Not intended	9%
		?	58%

A.2 Supplementary material to Publication 2

This appendix contains the supplementary material to publication **(Minkov et al. 2018)**:

> Minkov N, Bach V, Finkbeiner M (2018) **Characterization of the Cradle to Cradle Certified™ Products Program in the Context of Eco-labels and Environmental Declarations.** Sustainability 10 3:738. https://doi.org/10.3390/su10030738

Table A.2.1. Updated ecolabel characterization scheme and attributes description

Attribute and features	Description
Communication characteristics	
1 ISO Typology Type I Type II Type III	Defines to which typology from the categorization of the ISO 14020-series an ecolabel is assigned.
2 Awarding format Seal Rating (non-sealed) Rating (sealed) Declaration (non-sealed) Declaration (sealed)	Defines the level of information that the consumer receives through an ecolabel. A seal provides a simple binary pass-fail information. A rating demonstrates a level of superiority. A declaration provides quantified information in a pre-set list of categories.
3 Multiplicity of covered aspects Single-aspect Multi-aspect	Defines whether an ecolabel cover one or multiple aspects.
4 Aspects diversity Environmental Social Health	Defines whether an ecolabel covers additional aspects different from environmental.
5 End-user focus Business-to-consumer Business-to-business Both	Defines the audience, on which an ecolabel is focused. The end-user focus could be a key factor for the definition of other attributes, e.g., the awarding format.
Scope	
6 Sector scope Sector-specific Multi-sectorial	Defines whether an ecolabel covers products from only one specific sector or multiple sectors. In the latter case, awarding criteria are usually developed for each product group individually.
7 Operation scope Product Production process/ method Business/organization	Defines whether an ecolabel characterizes a property of the product or a step of or the whole production process, or an achievement of an organization.
8 Geographic scope National Regional International	Defines the scope in geographical terms, to which an ecolabel spreads out (i.e. is being recognized and its awarding criteria are valid).
9 Awarding criteria scope Product-specific Generic	Defines whether the awarding criteria of an ecolabel are product-specific or are general and apply equally to all products under verification.
10 Materiality principle Yes Neutral No	Defines whether the awarding criteria of an ecolabel focus on the key performance characteristics of the product. This attribute is closely related to the Awarding criteria scope.
11 Life cycle (LC) perspective Non-LC based LC based LCA based	Defines the level of a life cycle perspective considered in the awarding criteria of an ecolabel. Non-LC based ones usually consider only a single stage or attribute of the product. LC based ones require only a qualitative LC screening of a product under consideration, whereas the analysis is undertaken on particular LC stages only. LCA based labels consider all relevant environmental aspects of a product and requires full conformance with ISO 14040.
Standard characteristics	
12 Compulsoriness Voluntary Mandatory	Defines whether the application and use of an ecolabel is voluntary or mandatory.
13 Financing [1] Fees and/or member dues Governmental subsidies Industry funding	Defines the source or the combination of sources that an ecolabel uses for funding.

Attribute and features	Description
Donations Other	
14 Purpose Ideals-centric Adversity-centric Neutral	Defines the purpose of an ecolabel. An ideals-centric ecolabel serves as a benchmark of achieving certain ideals or excellence. An adversity-centric ecolabel serves at the bottom line to show the avoidance of certain adversities, e.g. a "chlorine free paper" ecolabel. A neutral is a declaration type of ecolabel.
15 Longevity Single-issued Renewable Reduction-based	Defines the format of expiration of an ecolabel. A single-issued ecolabel is issued once and never be a subject of further verification again. A renewable ecolabel can be revised and reissued after expiration or after change in rules or in system elements. A reduction-based ecolabel requires a demonstration of improved performance on a regular basis in order to be recertified.
Governance characteristics	
16 Governance Governmental Quasi-governmental Private (PFP, NPO, NGO)	Defines the type of governance of an ecolabel. A quasi-governmental ecolabel is such initiated by a government, but managed by a private company. A private ecolabel can be managed by private for profits (PFP), private for non-profits (NPO) or non-governmental organizations (NGO).
17 Verification First party Second party Third party	Defines the approach to confirmation that all criteria and requirements of an ecolabel are met. First-party verification is performed by the organization that applies for the ecolabel itself. Second-party verification is done by the ecolabelling program. Third-party verification is performed by an independent third-party verification body that could be internal or external to the applicant.
18 Awarding criteria revision Yes, regularly Yes, randomly No	Defines whether an ecolabel sets rules for revision of the awarding criteria.
19 Stakeholder involvement Low Medium High	Evaluates the level of involvement of external to the operator stakeholders in the process of ecolabelling programme setting and update, or during the process of definition of a new product group and/or awarding criteria.
Conclusive characteristics	
20 Transparency [2] Label-setting process Awardees Funding Verification report	Evaluates the level of transparency (i.e. access to information) of an ecolabel regarding the listed features (answered with *yes* for transparent and with *no* for non-transparent).
21 Comparability Low Medium High	Evaluates the level of comparability that an ecolabel allows between labelled products themselves and between awarded and non-awarded products from the same product category.
22 Environmental excellence Intended Not intended Possible	Defines whether the setting of an ecolabel is intended to promote environmental excellence through the awarding.

[1] The evaluation of this attribute could result as a sum of two or more features; [2] The features of this attribute are evaluated individually. ISO: International Organization for Standardization, NGO: or non-governmental organizations, NPO: private for non-profits, PFP: private for profits.

A.3 Supplementary material to Publication 3

This appendix contains the supplementary material to publication **(Minkov et al. 2015)**:

> Minkov N, Schneider L, Lehmann A, Finkbeiner M (2015) **Type III Environmental Declaration Programmes and harmonization of product category rules: status quo and practical challenges.** J Clean Prod 94:235–246. https://doi.org/10.1016/j.jclepro.2015.02.012

Table A.3.1. Description of surplus requirements and actions for alignment as per GPCRD PCR template

Field	Description[1]	Justification/Action taken in the PCR in focus
Product category	*Provide the name and description of the product category. Identify the product category by one or more product standards (national and international), if relevant. Identify the products not covered by the PCR as a clarification for similar products.*	Additional description regarding "*products not covered by the PCR*" is given.
Language of PCR	*Name the original language of publication of the PCR as well as the translation languages in which the PCR is available, and accreditation of translator(s).*	Additional row in "General Information" table is provided.
Open consultations	*Provide the name and affiliation of the stakeholders who participated to the open consultation. Provide the dates of the open consultation period.*	Additional description regarding "*name and affiliation of the stakeholders who participated to the open consultation*" in table "General Information" is given.
Reasoning for development of PCR	*Describe motivation for development of PCR. Describe any attempt to harmonize PCR or align with existing PCRs.*	Additional description regarding "*motivation for development*" is given.
Impact indicators	*List the impact indicators in bullets with (1) LCA characterization methodology, and (2) references in parenthesis.*	Although provided on their webpage, IES[2] does not require "*references in parenthesis*" in text; thus, they are additionally provided.
Impact indicator selection justification	*Justify the selection of the impact indicators and the methodologies selected.*	Impact indicators and LCIA methodologies are selected based on Operator's recommendation. Justification is given.
Interpretation	*Describe procedures required to assist with interpretation of results. Describe how results may be described.*	Complementary information is given in section 10.5 "Presentation of LCA results". Additional input from TC is also provided, because of the PCR review.
Assumptions and limitations	*List assumptions and limitations associated with results.*	More details are given in text, as IES PCR template does not require such as a separate section.
Uncertainty	*Describe procedures for reporting uncertainty of results.*	Additional requirement for data uncertainty assessment according to ISO 14040/44:2006 is given.
PCR Review Report	*Attach PCR Review Report.*	PCR Review Report is not mandatory document according to IES's GPI. TC was asked to elaborate such particularly for this case. Report is issued and kept in the library of the operator, but not attached to the PCR. It is available upon request.
PCR Committee Member Conflicts of Interest	*Attach Conflict of Interest forms for PCR committee members […]*	Such statements were developed and signed by PCR committee members, although this is not required by the Operator. Statements are not attached, but available upon request.
Sample claim	*Provide a sample claim developed from the PCR.*	Not provided.
Outstanding methodological issues	*Describe issues brought to the PCR developers' attention during the process by the PCR committee, reviewers or other stakeholders.*	Such are described in text, but not as in separate section.

Field	Description[1]	Justification/Action taken in the PCR in focus
Additional requirements in standards not covered in PCR	*If a PCR is designed to be compliant with more than one standard, list requirements for any claim that intends to be compliant with these standards.*	Such are described in text, but not as in separate section.
Conformance with the PCR Guidance	*Summarize the conformity assessment with the 'Guidance for Product Category Rule Development, v1.0' based on the use of the assessment form, attached as an appendix.*	Summary of the conformance is given in the PCR Review Report and available upon request, as it is not an obligation by the IES to attach it to the PCR.

[1] Text in columns "Field" and "Description" is taken from GPCRD's PCR template (PCR Guidance Development Initiative 2013); [2] IES stands for "The International EPD® System" – a Type III programme operator from Sweden (www.environdec.com)

Table A.3.2. Description of surplus requirements and actions for alignment as per GPCRD CAF

№	Requirement[1]	Justification/Action taken in the PCR in focus
6	*"The program operator shall see that the PCR committee is composed of enough independent members to assure that the interests of one party do not dominate the PCR development process"*	Currently, neither IES, nor any other programme operator assures this by requiring specific actions. It is more likely that only (oral) recommendations by the operator are given. This requirement is considered useful to be adopted in future updates of GPIs of different operators. For the development of the present PCR, no domination of any party was observed, neither the operator raised the question. Several companies from the industry, a consultancy and academia were involved.
7	*"No single organization or value chain shall dominate the PCR committee by holding more than 50% of the membership of a PCR committee"*	This requirement is covered by the PCR (based on the above-mentioned variety of participants), although IES's GPI does not provide specific requirements. GPCRD is the pioneering guidance document to demand such details on this topic. Special attention has to be paid on the term "value chain", as GPCRD does not define it explicitly, whereas stakeholders often confuse the term with "supply chain".
8	*"To assure that conflicts of interest are addressed, program operators shall provide forms for each PCR committee member to disclose any conflicts of interest […]"*	This is not a practice by any Operator. "Conflict of Interest Disclosure" statements were developed additionally and send out to PCR committee members for signature. No violations were announced.
36	*"Where data are unavailable, the PCR shall provide default values, which shall be worst-case scenario data for the specified processes"*	Although not specifically addressed in IES's GPI, this is covered by the PCR.
41	*"The PCR shall specify that a data quality assessment be performed for the primary data collected"* and	Such requirements are lacking from all GPIs observed. Based on TC recommendation, reference to operator's GPI is made, including additional clarification and recommendation in the PCR. Rules for primary data quality assessment are adopted based on the requirements for generic data.
42	*"The PCR shall also specify that wherever primary data are gathered, the data are verified to be compliant with the data quality requirements"*	
48	*The PCR shall provide instructions on the following aspects of reporting and interpretation of LCA results:* *- how and which results are to be reported;* *- the methods that are to be used to identify and to report the main contributing unit processes, groups of processes, and elementary flows to the results;* *- the completeness checks of the inventory data, process coverage and impact calculations that are to be performed;* *- the consistency checks of assumptions, methods and data quality considerations that are to be performed;* *- the quantitative approaches to interpretation to be used;* *- the limitations to be stated;*	Very detailed requirements that go beyond the instructions of any EPD scheme. The TC gave additional requirements on the reporting and interpretation of LCA results. Such are beyond the requirements in the GPI. The PCR amended additional texts in order to fulfil these requirements.

№	Requirement[1]	Justification/Action taken in the PCR in focus
53	*The panel members shall disclose any conflicts of interest using the conflict of interest form.*	The TC of IES carried out the PCR review. Committee members were required to recuse themselves from review of the PCR in case they had any conflict of interest. No conflicts of interests were announced.
58	*"Public consultation shall be utilized during the PCR review process. The public consultation of the completed draft PCR shall include at a minimum a 30-calendar-day time period for comments to be submitted"*	Here, a difference of the stage division between the two approaches causes inconsistency. According to GPCRD, the "review phase" equals to IES's GPI "consultation" and "PCR review" phases together. Thus, GPCRD does not require anything additional that is not covered by IES's GPI procedure.
64	*"Before the PCR is updated, the program operator shall notify the public of the changes that will be made and allow for comments to be submitted in response to those changes. The program operator shall diligently consider the comments before making changes to the PCR. Whenever a PCR is updated, the program operator shall publicize the updated PCR, preferably through a centralized notification mechanism."*	IES's GPI does not fully conform to this requirement, as the GPI require a less formal stakeholder involvement before a PCR is updated. According to it, "a reminder of the need for an eventual update of a PCR document may be indicated on the website". We consider that in GPCRD a step is missing or not well described in the Guidance: before the need of PCR update (in case if the PCR is not close to its expiration date, but because there are too many reasons for change), the users should be allowed to submit comments and requests such changes. Instruction for this however, is not given. Moreover, we consider GPCRD's requirement to be unnecessary strict, regarding the fact that: 1) the stakeholders should be the party informing the operator for eventual needs for changes, which then the operator should collect, and 2) the operator cannot notify the public about the changes that will occur, as long as these changes are not communicated and accepted by the PCR Committee. Furthermore, IES's GPI requires the PCR moderator (by informing the operator) to be responsible for such activities, whereas GPCRD gives responsibility only to the operator.

[1] Number of requirement and text in columns "Requirement" is taken from GPCRD's PCR template (PCR Guidance Development Initiative 2013)

Table A.3.3. Description of non-obligatory recommendations and actions for alignment as per GPCRD CAF

№	Recommendation[1]	Justification/Action taken in the PCR in focus
9	*"The PCR Committee should include:* *- at least two industry representatives from independent organizations;* *- at least one LCA expert (who may be an employee of the program operator);* *- at least one interested party, such as a member of a non-governmental or governmental organization;"*	List of experts with specific qualifications and competences (in recommendation (10) after in the CAF) is provided; we consider such requirements as very important, since our experience has showed that often PCR developing groups consist of members with insufficient qualification and/or competences; often the need for background LCA knowledge is underestimated.
46	*"PCRs should be flexible to regional differences in definitions of co-products and wastes. PCRs should be clear on defining rules for allocation and recycling for each region. A PCR should specify how the LCA rules for one region can be altered to fit those of another region"*	As the PCR under development has European scope only, this recommendation is not considered; however, for general application we find it useful and encourage operators to adopt it.
50	*"The PCR should provide a reference to a description of the environmental mechanisms for all selected impact categories"*	Environmental mechanisms for the selected impact categories are anyhow described by the cited impact assessment methods used for each impact category, therefore, we consider this recommendation unnecessary.
51	*"To ensure that claims are truly comprehensive, PCRs should include requirements for quantification and/or description of environmental or social attributes associated with the product that cannot be quantified in an LCA. Environmental, social and economic aspects in all countries producing products within the product category should be considered"*	Here, the authors of Guidance extend the scope of the regular PCR by approaching the other two pillars of sustainability. However, this is not included in the document, but it is recommended henceforth.

[1] Number of recommendation and text in columns "Recommendation" is taken from GPCRD's PCR template (PCR Guidance Development Initiative 2013)

A.4 Supplementary material to Publication 4

This appendix contains the supplementary material to publication **(Minkov et al. 2019b):**

> Minkov N, Lehmann A, Finkbeiner M (2019) **The Product Environmental Footprint communication at the crossroad: integration into or co-existence with the European Ecolabel?** Int J LCA 10 8:2898 https://doi.org/10.1007/s11367-019-01715-6

Table A.4.1. General information: comparative summary of the specifications of the PEFCR and EUF criteria for each case study

Characteristic	Decorative paints		Laundry detergents		T-shirts	
	PEFCR	EUF	PEFCR	EUF	PEFCR	EUF
Title	Decorative paints	Indoor and outdoor paints and varnishes	Household Heavy Duty Liquid Laundry Detergents (HDLLD) for machine wash	Laundry detergents	T-shirts	Textile products
Document version	PEFCR v1.0 Publication: 04.2018 Expiration: 31.12.2020	EC Decision 2014/312/EU + Amendments (EU) 2015/886 and (EU) 2016/397 Expiration: 31.12.2022	PEFCR v1.0 Publication: 02.2019 Expiration: 31.12.2020	EC Decision (EU) 2017/1218 of 23 June 2017 Expiration: 26.06.2023	PEFCR v1.0 Publication: 02.2019 Expiration: 31.12.2020	EC Decision 2014/350/EU + Amendment (EU) 2017/1392 Expiration: 5.12.2020
Scope	Paints that are included in product categories (a) through (d) of the Paints Directive 2004/42/EC	Indoor and outdoor decorative paints and varnishes, woodstains and related products […] falling under the scope of Directive 2004/42/CE	"HDLLD for Machine Wash," including 100% liquid capsules.	"any laundry detergent or pretreatment stain remover falling under the scope of Regulation (EC) No 648/2004 […]which is effective at 30 °C or below"	Covers the following products: - T-shirts used for sport activities - Singlets and other vests - T-shirts with long and short sleeves - Sleeveless T-shirts - Polo shirts - Un-printed and printed T-shirts - T-shirts with or without accessories - T-shirts with or without specific treatment (moisture transfer…)	Comprises the following: - Textile clothing and accessories - Interior textiles - Fibres, yearn, fabric and knitted panels - Non-fibre elements - Cleaning products
Product classification	CPA C20.3.0 and F43.3.4	44	CPA 20.41.32	6	CPA C14.14.3	16

Characteristic	Decorative paints		Laundry detergents		T-shirts	
	PEFCR	EUF	PEFCR	EUF	PEFCR	EUF
Representative product(s)	Four representative products: Indoor wall paint, indoor wood paint, outdoor wall paint (outdoor mineral wall paint), outdoor wood paint (exterior trim and cladding paints for wood)	Paints and varnishes (with their subcategories identified according to the Directive 2004/42/EC)	"Model" of concentrated liquid detergent products dosed at 75ml/wash (i.e. one washing machine cycle) sold in the EU market in 2014.	Real products – 'heavy-duty detergents' used for ordinary washing of white textiles at any temperature	Five representative products: one t-shirt for each sub-category, i.e. men, women, children (2 to 7 years old), children (8 to 14 years old), babies	-
Functional unit	To protect and decorate 1 m2 of substrate for 50 years at a specified quality level (minimum 98% opacity).	-	Wash 4.5 kg of dry fabric with the recommended dosage for: a 4.5 kg load; normally soiled fabric; with a medium water hardness; in a 6 kg capacity machine wash at 75% loading".	-	To wear a clean T-shirt until it becomes dirty 52 times	1 kg of textile product at normal conditions (65 % RH ± 4 % and 20°C ± 2°C)
System boundaries	Cradle-to-grave: 5 stages / 14 sub-stages	Raw materials extraction, paint production and use stages (no distribution and end-of-life stage)	Cradle-to-grave: 10 stages	All LC stages without transportation and distribution processes	Cradle-to-grave: 6 LC stages	All LC stages besides transportation and EoL

Table A.4.2. Decorative paints: EUF awarding criteria and the PEFCR most relevant processes and impact categories based on the PEFCR system boundaries (stages 1a-2a)

EUF criteria for decorative paints		System boundaries of PEFCR for decorative paints				
		1. Raw materials				2. Manufacturing
		1a. Raw material acquisition and pre-processing	1b. Packaging material acquisition	1c. Raw material distribution	1d. Packaging material distribution	2a. Paint production
1	White pigment and wet scrub resistance	-	-	-	-	Minimum requirement for: 1a) White pigment content (TiO2 content limit g/m2)
2	Titanium dioxide pigment	If the product contains more than 3,0 % w/w of TiO2, the emissions and discharges of wastes from the production of any titanium dioxide pigment used shall not exceed the following: […]	-	-	-	-
3	Efficiency in use	-	-	-	-	-
4	Content of Volatile and Semi-volatile Organic Compounds (VOCs, SVOCs)	-	-	-	-	The maximum content of VOCs and SVOCs shall not exceed the limits given in Table 3. Products with a VOC content within the limits may display 'reduced VOC content' next to the ecolabel.
5	Restriction of hazardous substances and mixtures	-	-	-	-	The final product shall not contain hazardous substances and mixtures in accordance with the rules set out in the following [...] 5a) Overall restriction to hazard classifications and risk phrases 5b) Restrictions that apply to SVHCs 5c) Restrictions that apply to

EUF criteria for decorative paints		System boundaries of PEFCR for decorative paints				
		1. Raw materials				2. Manufacturing
		1a. Raw material acquisition and pre-processing	1b. Packaging material acquisition	1c. Raw material distribution	1d. Packaging material distribution	2a. Paint production
						specific hazardous substances
6	Consumer information	-	-	-	-	-
7	Information appearing on the EU Ecolabel	-	-	-	-	-
PEFCR	Most relevant LC stages	Yes				No
	Most relevant LC stages as a function of the most relevant processes	RER: titanium dioxide production GLO: Styrene acrylate dispersion GLO: Paints additive RER: Propylene glycol production RER: Sodium silicate powder production	EU-28+EFTA: PP granulates EU-28+EFTA: Pallet. wood (80x120)	No	No	EU-28+3: Electricity grid mix 1kV-60kV
	Most relevant impact categories per LC	Climate change Particulate matter Acidification Resource use, fossils Resource use, energy carriers Photochemical ozone formation				No

Table A.4.3. (cont.) Decorative paints: EUF awarding criteria and the PEFCR most relevant processes and impact categories based on the PEFCR system boundaries (stages 3a-5b)

EUF criteria for decorative paints		System boundaries of PEFCR for decorative paints								
		3. Distribution			4. Use			5. EoL		
		3a. Distribution to RDC	3b. Storage in RDC	3c. Distribution to PoS	3d. Storage in PoS	4a. Auxiliary materials acquisition	4b. Application	4c. Use	5a. Transport to EoL	5b. EoL of paint film
1	White pigment and wet scrub resistance	-	-	-	-	-	Minimum requirement for: 1b) Wet Scrub Resistance, WSR (for indoor paints only) Only WSR class 1 and 2 paints can claim WSR on the label or other marketing documents.	-	-	-
2	Titanium dioxide pigment	-	-	-	-	-	-	-	-	-
3	Efficiency in use	-	-	-	-	-	Use efficiency to be demonstrated by tests (indicated in Table 2) on "Performance requirements for different kind of paints and varnishes" a) spreading rate b) resistance to water c) adhesion d) abrasion e) weathering f) water vapour permeability g) liquid water permeadbility h) fundal resistance i) crack bridging j) alkali resistance k) corrosion resistance	-	-	-
4	Content of Volatile and Semi-volatile Organic Compounds (VOCs, SVOCs)	-	-	-	-	-	-	-	-	-

EUF criteria for decorative paints		System boundaries of PEFCR for decorative paints								
		3. Distribution			4. Use			5. EoL		
		3a. Distribution to RDC	3b. Storage in RDC	3c. Distribution to PoS	3d. Storage in PoS	4a. Auxiliary materials acquisition	4b. Application	4c. Use	5a. Transport to EoL	5b. EoL of paint film
5	Restriction of hazardous substances and mixtures	-	-	-	-	-	-	-	-	-
6	Consumer information	-	-	-	-	-	The following texts shall appear on the packaging […] The following general information and advice shall be provided on or be attached to the packaging […] The following advice and recommendations on how to handle the paint shall be provided on or be attached to the packaging [...]	-	-	-
7	Information appearing on the EU Ecolabel	-	-	-	-	-	The optional label with text box shall contain, where relevant, the following texts […]	-	-	-
PEFCR	Most relevant LC stages	No	No	No	No	Yes			Yes	
	Most relevant LC stages as a function of the most relevant processes	EU-28+3: Thermal energy from natural gas	No	No	No	No	GLO: Passenger car. Average Application Scenario (direct VOC emissions)	No	No	EU-28+EFTA: Waste incineration of paint EU-28+EFTA: Landfill of municipal solid waste
	Most relevant impact categories per LC	No			Climate change Particulate matter Acidification Resource use, fossils Resource use, energy carriers Photochemical ozone formation			Climate change		

Table A.4.4. Detergents: EUF awarding criteria and the PEFCR most relevant processes and impact categories based on the PEFCR system boundaries (stages 1-5)

EUF criteria for laundry detergents		System boundaries of PEFCR for detergents				
		Sourcing and manufacturing		Transport		
		1 Chemical ingredients	2 Packaging raw materials	3 Chemical ingredients	4 Packaging raw materials	5 HDLLD manufacture
1	Dosage requirements	-	-	-	-	-
2	Toxicity to aquatic organisms	-	-	-	-	-
3	Biodegarada-bility	a) Biodegradability of surfactants b) Biodegradability of organic compounds	-	-	-	-
4	Sustainable sourcing of palm oil, […] and their derivates	Certification from sustainable production schemes	-	-	-	-
5	Excluded and restricted substances	-	-	-	-	a) Specified excluded and restricted substances (shall not be included…) b) Hazardous substances (final product shall not be classified… and shall not contain ingoing substances…) c) SVHCs (shall not contain...) d) Fragrances (shall be manufactured following…) e) Preservatives (may only include...) f) Colouring agents (shall not be bio-accumulating) g) Enzymes (only ... shall be used)

EUF criteria for laundry detergents		System boundaries of PEFCR for detergents				
		Sourcing and manufacturing		Transport		
		1 Chemical ingredients	2 Packaging raw materials	3 Chemical ingredients	4 Packaging raw materials	5 HDLLD manufacture
6	Packaging	-	Weight/utility ratio (WUR) of primary packaging (only) to be calculated. And shall not exceed (kg/kg laundry, table 1) Reuse rate set as a default value DfRecycling - Plastic packaging shall be designed to facilitate effective recycling Table 4 - materials and components excluded from packaging elements	-	-	-
7	Fitness for use	-	-	-	-	-
8	User information	-	-	-	-	-
9	Information appearing on the EU Ecolabel	-	-	-	-	-
PEFCR	Most relevant LC stage? Relevant respective processes	Yes Citric acid (builder) Propylene glycol (solvent) Soap (surfactant) Enzymes	No Plastic bottle material (HDPE granulates and screw cap)	Yes Transport by boat	No Transport by boat	No Electricity consumption
	Most relevant impact categories per LC	Climate change Resource use, fossils Acidification Particulate matter	Climate change Resources use	Climate change Resources use Acidification Particulate matter	Particulate matter	Resources use Particulate matter

Table A.4.5. (cont.) Detergents: EUF awarding criteria and the PEFCR most relevant processes and impact categories based on the PEFCR system boundaries (stages 6-10)

EU Ecolabel criteria for laundry detergents		System boundaries of PEFCR for detergents				
		Transport and distribution		8 Product use	End-of-Life	
		6 To retail	7 To consumer homes		9 Wastewater treatment	10 Packaging waste treatment
1	Dosage requirements	-	-	The reference dosage shall not exceed the following amounts…	-	-
2	Toxicity to aquatic organisms	-	-	-	Critical Dilution Volume (CDV) shall not exceed… CDV considers ONLY emissions to water (freshwater tox)	-
3	Biodegaradability	-	-	-	-	-
4	Sustainable sourcing of palm oil, […] and their derivates	-	-	-	-	-
5	Excluded and restricted substances	-	-	-	-	-
6	Packaging	-	-	-	-	-
7	Fitness for use	-	-	Wash performance at the lowest temperature and dosage recommended in accordance with "EU Ecolabel protocol for testing laundry detergents" or "EU Ecolabel protocol for testing stain removers"	-	-
8	User information	-	-	Dosing instructions / Environmental info	-	Packaging disposal info
9	Information appearing on the EU Ecolabel	-	-	Among others, the applicant may choose to include an optional text box on the label […]	-	-

EU Ecolabel criteria for laundry detergents		System boundaries of PEFCR for detergents				
		Transport and distribution		8 Product use	End-of-Life	
		6 To retail	7 To consumer homes		9 Wastewater treatment	10 Packaging waste treatment
PEFCR	Most relevant LC stage? Relevant respective processes	No Electricity consumption	No -	Yes Electricity consumption Water consumption	Yes Wastewater treatment	No -
	Most relevant impact categories per LC	Climate change Resources use Acidification Particulate matter	-	Climate change Resources use Acidification Particulate matter	Climate change Resources use Acidification Particulate matter ESC (+USEtox when included in PEF)	-

Table A.4.6. Textile products: EUF awarding criteria and the PEFCR most relevant processes and impact categories based on the PEFCR system boundaries (stages 1-3)

EUF criteria for textile products			System boundaries of PEFCR for T-shirts		
			1 .Production of materials	2. Production of T-shirt	3. T-Shirt's transport
1. TEXTILE FIBRE CRITERIA	1	Cotton and other natural cellulosic seed fibres (including kapok)	1a) Organic production standard to be respected (min 10% of the cotton; 95% for T-shirts). 1b) Cotton production according to IPM principles (min 20% of the cotton; 60% for T-shirts). 1c) Pesticide restrictions applying to conventional and IPM cotton 1d) Traceability requirements applying to organic and IPM cotton	-	-
	2	Flax and other bast fibres (including hemp, jute and ramie)	2a) Flax and other bast fibres shall be retted under ambient conditions and without thermal energy inputs. 2b) Where water retting has been used the wastewater from retting ponds shall be treated so as to reduce the COD or TOC […]	-	-
	3	Wool and other keratin fibres (including wool from sheep and lambs, and hair from camel, alpaca and goat)	3a) […] ectoparasiticide concentrations on raw wool prior to scouring shall not exceed […] 3b) Wool scouring operations shall minimise effluent COD […] (emission limits in Table 3) 3c) Wool scourers shall implement at least one of the following measures to recover value from either oxidised grease, fibre, suint or sludge arising from the scouring site used for the ecolabelled wool products: [...]	-	-
	4	Acrylic	4a) The emissions to air of acrylonitrile (during polymerisation and up to the solution ready for spinning), expressed as an annual average, shall be less than 10 g/kg fibre […] 4b) The workplace emissions to air of N,N-dimethylacetamide (127-19-5) during polymerisation and spinning shall not exceed [...]	-	-

EUF criteria for textile products			System boundaries of PEFCR for T-shirts		
			1 .Production of materials	2. Production of T-shirt	3. T-Shirt's transport
	5	Elastane	5a) Organotin compounds shall not be used […] 5b) The workplace emissions to air of the following substances shall not exceed […]	-	-
	6	Polyamide (or nylon)	Polyamide products shall comply with at least one of the production standards listed in sub-criteria 6(a) and 6(b). 6a) Fibres shall be manufactured using a minimum content of 20 % nylon that has been recycled from pre and/or post-consumer waste. 6b) Emissions to air of N2O from nylon monomer production [...] shall not exceed […]	-	-
	7	Polyester	7a) The level of antimony present in the polyester fibres shall not exceed […] 7b) Fibres shall be manufactured using a minimum content of PET that has been recycled […] 7c) The emissions of VOCs during the production of polyester […] shall not exceed [...]	-	-
	8	Polypropylene	Lead based pigments shall not be used.	-	-
	9	Man-made cellulose fibres (including viscose, modal and lyocell)	9a) A minimum 25 % of pulp fibres shall be manufactured from certified wood 9b) Pulp produced from cotton linters shall, as a minimum, meet with the requirements of either cotton criterion 1a or 1b 9c) Pulp used to manufacture fibres shall be bleached without the use of elemental chlorine […] The resulting total amount of cholrine […] shall not exceed […] 9d) A minimum of 50 % of the pulp used to manufacture fibres shall be purchased from dissolving pulp mills […] 9e) For viscose and modal fibres, the sulphur content of the emissions of sulphur compounds […] shall not exceed […] (Table 4)	-	-

EUF criteria for textile products			System boundaries of PEFCR for T-shirts		
			1 .Production of materials	2. Production of T-shirt	3. T-Shirt's transport
2. COMPONENT AND ACCESSORIES CRITERIA	10	Fillings	10a) Filling materials consisting of textile fibres shall comply with the textile fibre criteria (1–9) where appropriate. 10b) Filling materials shall comply with the textile RSL' requirements for biocides and formaldehyde. 10c) Detergents and other chemicals used for the washing of fillings shall comply with the textile RSL' requirements for auxiliary chemicals and for detergents, softeners and complexing agents	-	-
	11	Coatings, laminates and membranes	11a) Components made of polyurethane shall comply with Textile fibre criteria […] 11b) Components made of polyester shall comply with Textile fibre criteria […] 11c) Polymers shall comply with restriction g(v) of the RSL […]	-	-
	12	Accessories	Metal and plastic components such as zips, buttons and fasteners shall comply with the RSL' requirements for accessories	-	-
3. CHEMICALS AND PROCESS CRITERIA	13	Restricted Substance List (RSL)	-	13a) General: The final product and the production recipes used to manufacture the final product shall not contain the hazardous substances listed in the RSL [...] The RSL shall be communicated to suppliers and agents [...] 13b) SVHCs: The final product including any component or accessory shall not, unless specifically derogated, contain substances that [...]	-
	14	Substitution of hazardous substances used in dyeing, printing and finishing	-	Substances applied to fabrics and knitted panels during [...] meet the criteria for classification with the hazard classes or risk phrases listed [...] shall not be used [...] 14a) Hazard classification restrictions (Table 5, CLP categorization) 14b) Derogations that apply to textile substance groups (Table 6)	-

EUF criteria for textile products			System boundaries of PEFCR for T-shirts		
			1 .Production of materials	2. Production of T-shirt	3. T-Shirt's transport
	15	Washing, drying and curing energy efficiency	-	The applicant shall demonstrate that the energy used in washing, drying and curing steps associated with dyeing, printing and finishing steps [...] is measured and benchmarked as part of an energy or CO2 emissions management system. Furthermore, they shall demonstrate that production sites have implemented a minimum number of Best Available Techniques (BAT) energy efficiency techniques as specified in Table 7	-
	16	Treatment of emissions to air and water	-	16a) Wastewater discharges from wet processing: […] shall not exceed […] 16b) Emissions to air from printing and finishing processes: total emissions of organic compounds […] shall not exceed […]	-
4. FITNESS FOR USE CRITERIA	17	Dimensional changes during washing and drying	-	-	-
	18	Colour fastness to washing	-	-	-
	19	Colour fastness to perspiration (acid, alkaline)	-	-	-
	20	Colour fastness to wet rubbing	-	-	-
	21	Colour fastness to dry rubbing	-	-	-
	22	Colour fastness to light	-	-	-
	23	Wash resistance and absorbency of cleaning products	-	-	-
	24	Fabric resistance to pilling and abrasion	-	-	-
	25	Durability of function	-	-	-
5. CSR CRITERIA	26	Fundamental principles and rights at work	-	Applicants shall ensure that the fundamental principles and rights at work as described in […] shall be observed by all […] production sites […]	-

EUF criteria for textile products			System boundaries of PEFCR for T-shirts		
			1 .Production of materials	**2. Production of T-shirt**	**3. T-Shirt's transport**
	27	Restriction on the sandblasting of denim	-	The use of manual and mechanical sandblasting to achieve distressed denim finishes shall not be permitted.	-
	28	Information appearing on the Ecolabel	-	-	-
PEFCR	Most relevant LC stage? Relevant respective processes		Yes GLO: Cotton fibres (conventional) GLO: Wool fibres GLO: Metal snaps	Yes GLO: Spinning, production of cotton yarn (combed) GLO: Spinning, production of cotton yarn (carded) GLO: Circular knitting GLO: Fabric dyeing GLO: Yarn dyeing GLO: T-shirt assembly	No GLO: Cargo plane GLO: Transoceanic ship, containers
	Most relevant impact categories (the same repeat in each LC)		Acidification terrestrial and freshwater Climate Change Resource use, energy carriers Resource use, mineral and metals Respiratory inorganics Water scarcity Freshwater eutrophication Marine eutrophication		

Table A.4.7. (cont.) Textile products: EUF awarding criteria and the PEFCR most relevant processes and impact categories based on the PEFCR system boundaries (stages 4-6)

EUF criteria for textile products			System boundaries of PEFCR for T-shirts		
			4. Transport by customer	5. Use stage	6. End of Life
1. TEXTILE FIBRE CRITERIA	1	Cotton and other natural cellulosic seed fibres (including kapok)	-	-	-
	2	Flax and other bast fibres (including hemp, jute and ramie)	-	-	-
	3	Wool and other keratin fibres (including wool from sheep and lambs, and hair from camel, alpaca and goat)	-	-	-
	4	Acrylic	-	-	-
	5	Elastane	-	-	-
	6	Polyamide (or nylon)	-	-	-
	7	Polyester	-	-	-
	8	Polypropylene	-	-	-
	9	Man-made cellulose fibres (including viscose, modal and lyocell)	-	-	-
2. COMPONENT AND ACCESSORIES CRITERIA	10	Fillings	-	-	-
	11	Coatings, laminates and membranes	-	-	-
	12	Accessories	-	-	-
	13	Restricted Substance List (RSL)	-	-	-

EUF criteria for textile products			System boundaries of PEFCR for T-shirts		
			4. Transport by customer	5. Use stage	6. End of Life
3. CHEMICALS AND PROCESS CRITERIA	14	Substitution of hazardous substances used in dyeing, printing and finishing	-	-	-
	15	Washing, drying and curing energy efficiency	-	-	-
	16	Treatment of emissions to air and water	-	-	-
4. FITNESS FOR USE CRITERIA	17	Dimensional changes during washing and drying	-	The dimensional changes after washing and drying at either domestic or industrial washing temperatures and conditions shall not exceed […]	-
	18	Colour fastness to washing	-	The colour fastness to washing shall be at least level 3-4 for colour change and at least level 3-4 for staining.	-
	19	Colour fastness to perspiration (acid, alkaline)	-	The colour fastness to perspiration (acid and alkaline) shall be at least level 3-4	-
	20	Colour fastness to wet rubbing	-	The colour fastness to wet rubbing shall be at least level 2-3.	-
	21	Colour fastness to dry rubbing	-	The colour fastness to dry rubbing shall be at least level 4.	-
	22	Colour fastness to light	-	For fabrics intended for furniture, curtains or drapes, the colour fastness to light shall be at least level 5.	-
	23	Wash resistance and absorbency of cleaning products	-	Cleaning products shall be wash resistant and absorbent according to the relevant testing parameters […]	-
	24	Fabric resistance to pilling and abrasion	-	Non-woven fabrics and knitted garments, accessories and blankets made of wool, wool blends and polyester (including fleece), shall resist pilling to rating of a minimum of 3 […]	-

EUF criteria for textile products			System boundaries of PEFCR for T-shirts		
			4. Transport by customer	**5. Use stage**	**6. End of Life**
	25	Durability of function	-	Finishes, treatments and additives that impart water, oil and stain repellency flame retardancy and easy care to the textile product when it is in use shall be durable according to the values and parameters set out in sub-criteria 25(a), (b) and (c). 25a) Water, oil and stain repellent functions 25b) Flame retardant functions 26c) Easy-care (also referred to as non-crease or permanent press)	-
5. CSR CRITERIA	26	Fundamental principles and rights at work	-	-	-
	27	Restriction on the sandblasting of denim	-	-	-
	28	Information appearing on the Ecolabel	-	The optional label with text box may contain wording selected from the following […]	No -
PEFCR	Most relevant LC stage? Relevant respective processes		Yes GLO: Passenger car, average	Yes EU-28+3: Electricity grid mix 1kV-60kV (washing+drying) EU-28+3: Tap water EU-28+EFTA: Treatment of residential wastewater, small plant	
	Most relevant impact categories (the same repeat in each LC)		Acidification terrestrial and freshwater Climate Change Resource use, energy carriers Resource use, mineral and metals Respiratory inorganics Water scarcity Freshwater eutrophication Marine eutrophication		

Table A.4.8. Classification of the EUF criteria of the three case studies

EUF criterion		Type*
Decorative paints		
1	White pigment and wet scrub resistance	EP / PP / CI
2	Titanium dioxide pigment	EP
3	Efficiency in use	PP
4	Content of Volatile and Semi-volatile Organic Compounds (VOCs, SVOCs)	EP / CI
5	Restriction of hazardous substances and mixtures	EP
6	Consumer information	CI
7	Information appearing on the EU Ecolabel	CI
Laundry detergents		
1	Dosage requirements	CI
2	Toxicity to aquatic organisms	EP
3	Biodegaradability	EP/PP
4	Sustainable sourcing of palm oil, […] and their derivates	M
5	Excluded and restricted substances	EP
6	Packaging	PP / EP
7	Fitness for use	PP
8	User information	CI
9	Information appearing on the EU Ecolabel	CI
Textile products		
1	Cotton and other natural cellulosic seed fibres (including kapok)	EP/M
2	Flax and other bast fibres (including hemp, jute and ramie)	EP
3	Wool and other keratin fibres (including wool from sheep and lambs, and hair from camel, alpaca and goat)	EP
4	Acrylic	EP
5	Elastane	EP/S
6	Polyamide (or nylon)	EP
7	Polyester	EP
8	Polypropylene	EP
9	Man-made cellulose fibres (including viscose, modal and lyocell)	EP/M
10	Fillings	EP
11	Coatings, laminates and membranes	EP
12	Accessories	EP
13	Restricted Substance List (RSL)	EP/M
14	Substitution of hazardous substances used in dyeing, printing and finishing	EP
15	Washing, drying and curing energy efficiency	M
16	Treatment of emissions to air and water	EP
17	Dimensional changes during washing and drying	PP
18	Colour fastness to washing	PP
19	Colour fastness to perspiration (acid, alkaline)	PP
20	Colour fastness to wet rubbing	PP
21	Colour fastness to dry rubbing	PP
22	Colour fastness to light	PP/NA
23	Wash resistance and absorbency of cleaning products	PP
24	Fabric resistance to pilling and abrasion	PP
25	Durability of function	PP
26	Fundamental principles and rights at work	S
27	Restriction on the sandblasting of denim	S
28	Information appearing on the Ecolabel	CI

*EP – environmental performance; PP – product performance; CI – consumer information; M – management; S – social