Università degli Studi di Padova

Padua Research Archive - Institutional Repository

Mapping diffusion of Environmental Product Declarations released by European program operators

Original Citation:

Availability:

This version is available at: 11577/3285628 since: 2019-01-07T09:49:51Z

Publisher:

Elsevier

Published version:

DOI: 10.1016/j.spc.2018.09.004

Terms of use:

Open Access

This article is made available under terms and conditions applicable to Open Access Guidelines, as described at <http://www.unipd.it/download/file/fid/55401> (Italian only)

(Article begins on next page)

Accepted Manuscript

Mapping diffusion of Environmental Product Declarations released by European program operators

Sara Toniolo, Anna Mazzi, Matteo Simonetto, Filippo Zuliani, Antonio Scipioni

PII: S2352-5509(18)30151-9
DOI: <https://doi.org/10.1016/j.spc.2018.09.004>
Reference: SPC 171

To appear in: *Sustainable Production and Consumption*

Received date : 17 April 2018
Revised date : 10 September 2018
Accepted date : 27 September 2018

Please cite this article as: Toniolo S., et al., Mapping diffusion of Environmental Product Declarations released by European program operators. *Sustainable Production and Consumption* (2018), <https://doi.org/10.1016/j.spc.2018.09.004>

This is a PDF file of an unedited manuscript that has been accepted for publication. As a service to our customers we are providing this early version of the manuscript. The manuscript will undergo copyediting, typesetting, and review of the resulting proof before it is published in its final form. Please note that during the production process errors may be discovered which could affect the content, and all legal disclaimers that apply to the journal pertain.

Mapping diffusion of Environmental Product Declarations released by European Program Operators

Sara Toniolo¹, Anna Mazzi¹, Matteo Simonetto¹, Filippo Zuliani¹, Antonio Scipioni^{1,*}

¹*CESQA, University of Padova, Department of Industrial Engineering, Via Marzolo 9, 35131 Padova, Italy*

*Corresponding author: tel.: +390498275539; fax: +390498275735. E-mail address: scipioni@unipd.it

Abstract:

In order to facilitate the adoption of green requirements in public procurement, European Commission has developed the Green Public Procurement (GPP) criteria for various typologies of products and services. Almost all GPP criteria require environmental labels as means of proof that the goods or supplies correspond to the required environmental characteristics. Among the labels required, there are type III labels, based on a life cycle assessment study.

The aim of this study is to (i) investigate to what extent a specific type III label, called Environmental Product Declaration (EPD), is spread in Europe and (ii) explore whether there is a correspondence between institutional initiatives towards GPP and the market.

This study explored the valid EPDs presented on the websites of the European program operators between September and December 2016. The identified EPDs were quantified and classified according to the program operator, title of the reference Product Category Rule (PCR), country, language and the product based on a classification system developed by the United Nations.

In total, 4,888 EPDs were collected mainly released by the Institut Baum und Umwelt e.V. (IBU) and PEP ecopassport (PEP). The obtained results showed that countries with the greater number of EPDs are France and Germany and that construction products are the types of products labelled most. The analysis of the languages used in the EPDs showed that 45% of the identified EPDs are written in

local languages. The obtained results have been cross-referenced with the national situations in terms of presence of National Action Plans (NAPs) and mandatory rules regarding GPP.

Our analysis revealed that there is correspondence between the presence of a NAP with principles towards GPP and the spread in the market of environmental labelling and that the product sectors covered by EPDs correspond to the sectors covered by GPP criteria.

Keywords: Environmental Product Declarations, EPD, Product Category Rules, Type III labels, Program Operators

Highlights:

- The diffusion of EPDs, which are type III labels, was analysed
- The EPDs emitted by Europe-based program operators were studied
- The EPDs were cross-referenced with GPP actions plans and criteria
- Construction products and electronics are the most labelled products
- The countries with greater number of EPDs are France and Germany

1 Introduction

In Europe the procedure of public procurement is regulated by Directive 2014/24/EU of the European Parliament and of the Council published in 2014 (EU, 2014). Among the numerous principles and requirements reported in this Directive, it is stated that when contracting authorities intend to purchase goods or services with specific environmental characteristics they may require a specific label, based on objectively verifiable and non-discriminatory criteria, as mean of proof that the goods or supplies correspond to the required characteristics. The labels that can be used have to be established in an open and transparent procedure in which all relevant stakeholders may participate; have to be accessible to interested parties and the related requirements have to be set by a third party (article 43) (EU, 2014). Consequently, contracting authorities have to require environmental labels

meeting the requirements of Directive 2014/24/EU, but at the same time companies that aim at taking part in a public tender have to extricate themselves among several labels.

At international level, labelling schemes can be classified into three typologies, namely type I, II, and III, based on the methodology used. Specific standards exist for each typology: the International Standards Organization (ISO) has published ISO 14024 for type I labelling scheme (ISO, 1999), ISO 14021 for type II labels (ISO, 2016), and ISO 14025 for type III labels (ISO, 2006). Type I environmental labelling is a scheme which awards a mark or a logo based on the fulfilment of a set of environmental criteria and type II environmental declaration is a self-declared claim made by manufacturers (ISO, 2012). Type III environmental declarations present environmental information on the life cycle of a product to allow comparisons between goods with the same function and to help purchasers and users to make informed comparisons between products. They are aimed to be used in business-to-business communication, but they can also be used in business-to-consumer communication (ISO, 2010).

In order to facilitate the adoption of green requirements in line with Directive 2014/24/EU, European Commission has also developed the Green Public Procurement (GPP) criteria for various typologies of products and services (EC, 2018). With reference to the environmental characteristics of products or services, almost all GPP criteria refer to type I labels whereas some GPP refer to type III labels (Dodd et al., 2016). As reported in ISO 14025, in the practice of developing type III environmental declarations, programmes and declarations themselves are referred to using various names, among which Environmental Product Declarations (EPDs) (ISO, 2010).

The elaboration process of EPDs is managed by a specific body, called the program operator or EPD operator which in general conducts an environmental declaration programme (Ingwersen and Stevenson, 2012). The program operator can be a company, a public authority, a scientific body or another organisation. An EPD has to be created based on an appropriate set of specific rules, called Product Category Rule (PCR), which identifies and describes the process of preparing an EPD,

making it comparable and verifiable (Butt et al., 2015). Besides the programme operators, also the European Committee for Standardization (CEN) has developed some European Standards to be used as PCRs recently. For instance, EN 15804:2012+A1:2013 provides core product category rules for all construction products and services and allows that EPDs of construction sector are derived, verified and presented in harmonised way (CEN, 2013). Other European Standards complementary to EN 15804 are EN 16810 (CEN, 2017a), EN 16783 (CEN, 2017b), EN 16757, (CEN, 2017c), EN 16485 (CEN, 2014) and EN 16908 (CEN, 2017d).

In this context, the debate on the relationship between environmental issues and business performance at the company level is still ongoing (Boons and Wagner, 2009; Mazzi et al, 2016) and as highlighted by Yenipazarli (2015), companies should identify more suitable ways to label their products, but they should also understand the implications, market needs, and production constraints. Besides the introduction section, this article is organised as follows: a literature review about the evolution of the studies about EPDs and the usefulness of GPP as environmental friendly policy is presented in section 2; the research goals are presented in section 3; the methodology used to develop this study is described in section 4; the results obtained are presented in section 5 and discussed in section 6. The study is concluded in section 7.

2 Literature Review

2.1 Development of the EPDs for environmental performance measurement

Fet and Skaar (2006) presented one of the first papers about PCRs and certification procedures of labels based on ISO 14025 requirements. They aimed at demonstrating how EPDs were developed based on PCRs and in line with ISO 14025 taking into considerations examples from the furniture industry in Norway. They established an environmental database for Norwegian furniture and then prepared PCRs and EPDs for a selected product group, obtaining a consensus document for seating accommodation. The opportunities for companies in the development of EPDs were investigated by

103 Manzini et al. (2006). They conducted an empirical analysis on 17 companies explaining that the
 104 attractiveness of EPDs is a result of the synergic action of firm specific factors, such as Life Cycle
 105 Assessment (LCA) competence, financial resources and strategy, and industry level factors, such as
 106 product complexity supply chain fragmentation and stakeholders.

107 Del Borghi et al. (2007) performed four LCA studies of four waste disposal sanitary landfills in the
 108 framework of the International EPD® System (IES), a programme operator based in Sweden. In
 109 particular they analysed the comparability of EPDs results for different products in the same product
 110 category and obtained that it was possible to compare different EPDs for the same product category
 111 under specific conditions. Zackrisson et al. (2008) investigated EPDs as a mean to overcome the
 112 communication barriers, discussing the experience of 10 European companies; whereas Steen et al.,
 113 (2008) developed three interpretation keys to improve understanding of data and results of EPDs.

114 Two papers contributing to the development of two specific PCRs were published for food products
 115 (Shau and Fet, 2008) and for waste water treatment (Del Borghi et al., 2008).

116 Some studies were elaborated focusing on alignment between PCRs and comparison between EPDs
 117 and so providing a worldwide overview and a list of the existing program operators. These studies
 118 were developed by Subramanian et al. (2012) which elaborated a template to compare different PCRs
 119 towards a global alignment for five different product categories, such as milk, dairy products,
 120 horticultural products, wood and laundry detergents and by Ingwersen and Stevenson (2012) which
 121 analysed the development process of PCRs highlighting the critical aspects hindering their alignment.

122 Among the recommendations suggested by Ingwersen and Stevenson (2012) there were the use of a
 123 classification system to develop a clear structure for mapping products to categories, the elaboration
 124 of national and international data for key processes and the creation of global PCRs in order to limit
 125 geographical, restricted PCRs.

126 In 2013 Modhal et al. studied the importance of precise definitions regarding data quality in EPDs
 127 based on the fact that differences in the utilisation of data when performing an LCA may lead to
 128 incomparable EPDs.

129 Successively, in order to identify harmonisation potential, Hunsager et al. (2014) compared PCR
 130 development quantifying existing PCRs and EPDs in the world and studying rules and requirements
 131 among different programme operators. They identified, through their analysis conducted in May
 132 2013, 27 programme operators, 556 PCR documents and 3614 EPDs.

133 In parallel, Minkov et al. (2015) analysed how many Type III programme operators existed, how they
 134 developed and if there was harmonization among them. They reviewed the active programme
 135 operators, their reference documents and existing approaches for harmonization and showed that
 136 there were differences among the rules of different programme operators even if ISO 14025 was
 137 considered a common reference, however they also highlighted that supplementary documents
 138 specific for countries, or sectors, provided more explicit guidance. In the same year, Butt et al. (2015)
 139 focused on the appropriateness of LCA and also of PCRs for green procurement, limiting however
 140 the analysis to the case of road construction.

141 Besides this, Ibáñez-Forés et al. (2016) analysed the evolution of PCRs and the demand of EPDs
 142 through the Swedish program operator FES and conducted a survey to identify the factors that had led
 143 companies, mainly based in Sweden, Spain, and Italy, to adopt EPDs as communication tool. They
 144 observed that the categories “Food & agricultural products” and “services”, followed by “construction
 145 products” presented the greater number of EPDs and that the countries with the highest number of
 146 products with EPDs were Italy, Sweden and Switzerland. They also revealed that the main factors for
 147 adopting EPDs by companies were communicating objective information and improving corporate
 148 identity, whereas the main weakness was lack of knowledge of consumers about EPDs. Strazza et al.
 149 (2016) explored the utilisations of EPDs not only as a communication tool but also as a source of
 150 data for LCA. They analysed the effects of using data reported in EPDs for a specific case study of

151 water bottles distributed on board of a cruise ship. They obtained that this practice generated
152 consistent results under specific conditions.

153 More recently, several papers have been published with reference to the construction sector. For
154 instance, some authors deepened the issue of harmonization: Schlanbusch et al. (2016) explored the
155 experiences with LCA in the Nordic building industry and highlighted the need to harmonize the
156 existing building LCA tools and Gelowitz and McArthur (2016) investigated the effects of EPDs in
157 Leadership in Energy and Environmental Design (LEED) rating system. They highlighted that EPDs
158 were useful to justify specific material selections however the number of EPDs in North American
159 market was limited and the lack of EPDs harmonization could lead to the exclusion of a well-
160 performing product. In sight of this they conducted an analysis of 50 EPDs of three types of
161 construction products and showed that 82.5% of analysed EPDs were not completely in line with ISO
162 14025 and 8% contained contradictory information (Gelowitz and McArthur 2017). In parallel, other
163 authors presented new program operators, for instance Sariola and Ilomäki (2016) discussed the
164 importance of reliable sources of environmental information regarding the building products in
165 Finland with reference to the Finnish national EPD program launched in 2016 and Mukherjee and
166 Dylla (2017) discussed the challenges encountered during the creation of an EPD programme for
167 asphalt mixture. Other authors focused on specific aspects, such as Cordella and Hidalgo (2016)
168 which analysed the key environmental areas in the design and labelling of furniture products using
169 several EPDs and Achenbach et al. (2016) which analysed the EPDs in accordance with EN 15804
170 and EN 16485.

171

172 2.2 GPP as a tool to support green products

173 Public procurement represents 14 % of the European Gross Domestic Product (EC, 2017). The
174 Commission is developing and updating voluntary green public procurement criteria for goods,
175 services and works in areas with high environmental impact in order to help public authorities using

176 GPP in a more strategic manner and contributing to a more innovative and sustainable economy. In
 177 addition, according to Directive 2010/31/EU on the energy performance of buildings, from 1 January
 178 2019, all new public buildings must be “nearly zero-energy buildings” (EC, 2016). Specific criteria
 179 will need to be applied systematically, leading to the need of practical support, for instance
 180 dissemination of standards and regular updates of labels (EC, 2017).

181 One of the first documents where the European Commission encourage Member States to develop
 182 publicly available plans, called National Actions Plans (NAPs), to make greener their public
 183 purchases, was the Communication on Integrated Product Policy (EC, 2003). Years later, 23
 184 countries have a NAP in force, even if still 5 countries have no NAP, namely Estonia, Greece,
 185 Hungary, Luxembourg, Romania (EC, 2018b).

186 NAPs have the task to improve knowledge and raising awareness about GPP and set general
 187 principles, even if they are not legally-binding. Despite of this, some countries have developed
 188 mandatory rules to increase the application of green criteria in GPP for some sectors. For instance,
 189 Austria and Bulgaria have mandatory rules for vehicles and energy efficiency; Croatia for energy
 190 efficiency; Czech Republic for furniture and IT equipment; Denmark for timber, vehicles and energy
 191 efficiency; France for vehicles, dematerialized communication technology, sustainably managed
 192 wood, organic and sustainably-made food, the development of car-sharing transportation, and the
 193 making of a carbon footprint on the State buildings; Germany for wood; Italy for several product
 194 sectors such as construction, clean services, waste management, street and office furniture (EC,
 195 2018c).

196 The fact that public procurement can act a key role towards environmentally friendly procurement is
 197 also highlighted in the scientific literature. An environmental oriented public procurement means to
 198 give greater consideration to products and services with better environmental characteristics and with
 199 eco-labels (Tarantini et al., 2011; Bakir et al., 2018). Brusselaers et al. (2017) quantified the leverage
 200 effect of GPP in Europe on the consumption and production of green wood. They showed that the

GPP for wood in Europe stimulates the consumption and production of certified wood. However, this leverage effect is not transposed into each region's consumption. Testa et al. (2012) assessed the determinants and drawbacks of green procurement adoption. Based on survey data and by applying a regression they found that effectiveness of GPP is strongly related with the investments in technological innovations and reputation. They showed that environmental policies, such as GPP, are able to influence the innovation abilities of the firms (Testa et al., 2012), and that relevant limitations linked to the small size of public authorities can be faced with national and local supporting initiatives (Testa et al., 2016).

Fuentes-Bargues et al., (2017) conducted a study of the use of environmental tendering criteria in the Spanish public construction. The results showed that the use of environmental criteria in Spanish public sector construction procurement is low in comparison to a certain group of countries, known as “Green 7” (Austria, Denmark, Finland, Germany, Great Britain, The Netherlands, and Sweden).

Ghisetti (2017) investigated the role of governmental demand in stimulating ‘greener’ production choices and confirmed the importance of green procurement to achieve a decarbonised and sustainable growth.

As exposed by Cheng et al. (2018), in their extensive literature review about adoption and development of GPP, the public sector can influence green procurement with suitable policies and encouraging “green” markets through public purchases, even if with different paces in different countries. Cheng et al., (2018), showed that there is an overall lack of studies about GPP, that the adoption of LCA-based award criteria in real life is limited and that there is a lack of analyses in environmental performance tracking and measurement. They also highlighted a limited reference to life cycle analyses and eco-labels.

3 Research goals

In recent years, different studies have explored the development and the utilisation of environmental labels such as EPDs, however, as highlighted by Cheng et al. (2018), there is an overall lack of studies about GPP. There are still some weak points in the analysis of the adoption of environmental labels with reference to GPP, namely (i) the lack of studies focusing on the diffusion of the EPDs released by Europe-based programme operators after the publication of Directive 2014/24/EU and (ii) the lack of studies exploring whether the market is ready to fulfil the environmental requirements of Directive 2014/24/EU, specifically whether their products present environmental labels with the requested features of EU (2014) – article 43.

Thus, in order to solve the above-mentioned gaps, this study aims at (i) investigating to what extent EPDs are spread years later the publication of Directive 2014/24/EU, identifying which are the countries with the greater number of EPDs and (ii) exploring whether there is a correspondence between national institutional initiatives and the initiatives of firms in terms of environmental labelling. This study aims at knowing how many EPDs are spread in Europe, in which market sector, for each European country analysed, also considering the presence of national NAPs and mandatory rules.

Thus the novelty of this paper is the following: this is the first analysis about the diffusion of EPDs after the publication of Directive 2014/24/EU with the highest number of EPDs analysed, this is the first comparison over time and the first identification of countries, sectors and languages together. It is also the first analysis which cross-references the activities of the European firms in terms of products' labelling and the institutional activities in terms of GPP.

4 Methodology

This study analyses the diffusion of EPDs after the publication of the European Directive 2014/24/EU and thus it is focused on EPDs released by European program operators, which represent 56% of program operators in the world (Minkov et al., 2015).

250 The methodology used for this study follows the steps implemented by Ibáñez-Forés et al. (2016) for
 251 their analysis of the implementation of EPDs. Ibáñez-Forés et al. (2016) developed a twofold
 252 analysis: firstly they analysed the evolution of the implementation of EPDs and PCRs counting and
 253 classifying the documents released by IES and then elaborated and distributed a questionnaire to
 254 companies to understand the factors affecting the demand of EPDs. Our study makes reference only
 255 to the first part of the study developed by Ibáñez-Forés et al. (2016).

256 The most updated list of program operators, namely that elaborated by Minkov et al. (2015), was
 257 analysed and 18 European program operators were selected. Out of 39 worldwide programs they
 258 listed. To update this list, further program operators were investigated through a repeated internet
 259 search and only considering the programs stating their conformity to ISO 14025. Through this step,
 260 two new program operators were added: Building Information Foundation RTS (RTED/RTS) based
 261 in Finland and EPD Italy (EPDI) based in Italy. In total, 20 program operators were selected. The
 262 first, second, and third columns of Table 1 shows the names of the program operators, their
 263 abbreviations, and origin, respectively. PCRs and EPDs were searched in published documents
 264 available on the websites of the considered program operators. The consulted websites are reported in
 265 the last column of Table 1. In some cases, operators were contacted via email for more detailed
 266 information, for instance about PCRs in use and about compliance with ISO 14025.

267 In order to select the EPDs to be analysed, the following selection criteria were defined: the EPDs
 268 must be valid, namely not expired, and verified by third parties. Thus, pre-documents and expired
 269 documents were not considered. For the EPDs presented in two or more databases, only one of them
 270 was considered to avoid double counting.

271 To assure uniformity among different program operators EPDs were downloaded in a limited period
 272 of time. Thus, the definitive download of EPDs was conducted from September 2016 to December
 273 2016.

274 All the available EPDs were analysed by cataloguing the following information: the program
 275 operator, title of the reference PCR, name of the product, and the United National Central Product
 276 Classification (UN CPC) code. They were also analysed for the language of the PCR, language of the
 277 EPD, company. It is important to highlight that 107 EPDs released by PEP and 94 released by MRPI,
 278 representing 4% of the total number of identified EPDs, were not fully available and only some
 279 details were available for further classification presented in Sections 3.2-3.5. The reference PCRs
 280 were missing, and this led to a higher difficulty in the classification of the products.

281 To analyse the implementation of EPDs by economic sector the information on the program
 282 operators and the title of reference PCRs were collected to allow a proper classification of EPDs. The
 283 UN CPC code version 2.1 (United Nations, 2015) was used to classify the EPDs because it is
 284 internationally accepted, easily accessible, and already used by some program operators as also
 285 suggested by Subramanian et al. (2012). However, only two program operators (IES and EPD Italy)
 286 reported the CPC codes in their PCRs or EPDs; hence, it was necessary to hypothesize an appropriate
 287 CPC code for most the EPDs. In many cases, the definition of the CPC code was based on Hunsager
 288 et al. (2014), which assigned this code to a large number of EPDs. The first digit of the code
 289 corresponding to a specific section was reported to make the grouping of all the analysed products
 290 more feasible. Each section is subdivided into a certain number of divisions, for instance the
 291 divisions of section 3 are: 31 Products of wood, cork, straw and plaiting materials; 32 Pulp, paper and
 292 paper products; printed matter and related articles; 33 Coke oven products; refined petroleum
 293 products; nuclear fuel; 34 Basic chemicals; 35 Other chemical products; man-made fibres; 36 Rubber
 294 and plastics products; 37 Glass and glass products and other non-metallic products; 38 Furniture;
 295 other transportable goods and 39 Wastes or scraps. Each division is divided in a certain number of
 296 group and each group is divided into a certain number of classes (United Nations, 2015).

297 Minkov et al. (2015), who commented on the language used by program operators, highlighted that
 298 some program operators presented insufficient information in English, thus EPDs were catalogued

299 based on language used to evaluate the diffusion of the information and the usability of these
300 documents.

301 To analyse the implementation of EPDs by country and map the diffusion of EPDs, the name of the
302 company and the country where it is based were classified. The country of the company was found in
303 the address contained in EPDs, where the national headquarter is indicated.
304 Successively, the situation of the countries, in terms of presence of EPDs, was cross-referenced with
305 the presence of a NAP and of mandatory rules.

306

307 Table 1 List of the program operators included in this study

Name of the program operators	Abbreviation	Origin	Website
Building Information Foundation	RTED/RTS	FI	www.rakennustieto.fi
BAU EPD	BMT	AT	www.bau-epd.at
BRE Global Limited	BRE	UK	www.bre.co.uk/breglobal
Centrum environmentalnich prohlášení	CENDEC	CZ	www.cendec.cz/cs/cendec
Danish Environmental Protection Agency	EPD-DK	DK	www.eng.mst.dk
EPD Italy	EPDI	IT	www.epditaly.it
European Aluminium Association	EAA	EU	www.european-aluminium.eu
FDES INIES	FDES	FR	www.inies.fr
Ift Rosenheim	IFT	DE	www.ift-rosenheim.de
Institut Baun und Umwelt e.v.	IBU	DE	ibu-epd.com
Instytut Techniki Budowlanej	ITB	PL	www.itb.pl
PEP ecopassport	PEP	FR	www.pep-ecopassport.org
PlasticsEurope	PE	EU	www.plasticseurope.org
Sistema Declaraciones Ambientales de Productos para la construcción	DAPc	ES	www.csostenible.net/index.php/es/sistema_dapc
Slovenian National Building and Civil Engineering Institute	ZAG EPD	SI	www.zag.si
The Association for Environmental Relevant Product Information	MRPI	NL	www.mrpi.nl

The DAPHabitat System	DAPH	PT	www.daphabitat.pt
The International EPD System	IES	SE	www.environdec.com
The Norwegian EPD Foundation	NEF	NO	www.epd-norge.no
The Spanish Association for Standardisation and Certification	AENOR	ES	www.en.aenor.es/aenor/inicio/home/home.asp

5 Results

The results section is structured as follows. Section 5.1 presents the total number of EPDs identified in this study released by the program operators listed in Table 1 and the number of PCRs published; section 5.2 shows the mapping of the identified EPDs per country, with a focus on the languages used in order to evaluate the diffusion of the information and their usability; Section 5.3 shows the EPDs by sector.

5.1 Quantification of the extension of EPDs diffusion

In 2016, the total number of identified EPDs emitted by program operators based in Europe was 4,888 (Table 2).

Four main program operators, namely PEP, IBU, IES, and FDES INIES released together 80% of the EPDs emitted: PEP released 52%, IBU 28%, IES and FDES INIES 10% of the EPDs emitted. These four operators were the first ones established in Europe and in particular IBU and IES were the two program operators which published the highest number of PCRs in 2016. 56% of the identified PCRs were published by IES and 25% by IBU. The total number of identified PCRs was 318.

Based on the fact that the operators are partnering organizations with contractual agreements to use each other's PCRs, the PCRs provided by IBU and IES are often utilized also by other operators; for instance, CENDEC uses the PCRs published by IES and ZAG EPD uses the PCRs published by IBU. The number of PCRs published by other operators is low because those operators often make use of a general PCR accompanied by other specific documents; for instance, PEP uses one PCR but presents

11 Product Specific Rules (PSR), reference documents which complement and explain the PCR for Product Environmental Profile defined by PEP program, and EPD-DK uses EN 15804 as the general PCR and then makes use of the PCRs published by CEN, such as CEN (2014). Analysing the evolution over time, in 2013, the total number of EPDs released by Europe-based program operators was 1,954 (Hunsager et al., 2014), namely in just three years the number of EPDs grew of about 2,934 items. The results presented in this Section are discussed in Section 6.1.

336

337

Table 2 Quantification of the EPDs released and PCRs published by Europe-based program operators (PO)

Name of the program operators	Abbreviation	N. of EPDs emitted	N. of own PCRs
Building Information Foundation	RTED/RTS	0	1
BAU EPD	BMT	14	8
BRE Global Limited	BRE	40	1
Centrum environmentalnich problemat	CENDEC	17	0
Danish Environmental Protection Agency	EPD-DK	12	0
EPD Italy	EPDI	10	1
European Aluminium Association	EAA	15	1
FDES FDES	FDES	491	2
Ift Rosenheim	IFT	227	13
Institut für Umwelt e.V.	IBU	1347	81
Instytut Techniki Budowlanej	ITB	28	1
PEP eopassport ^c	PEP	1582	1
PlasticsEurope	PE	23	1
Sistema Declaraciones Ambientales de Productos por la construccion	DAPc	17	3
Slovenian National Building and Civil Engineering Institute ^d	ZAG EPD	2	0
The Association for Environmental Relevant Product Information	MRPI	94	1

The DAPHabitat System	DAPH	4	1
The International EPD System	IES	500	179
The Norwegian EPD Foundation	NEF	194	19
The Spanish Association for Standardisation and Certification	AENOR	71	4
Total		4888	318

5.2 Quantification of the EPDs per country

Table 3 shows the results obtained by mapping the diffusion of the EPDs released by Europe-based program operators. Even if our study is focused on European programs, some EPDs they have released are spread outside Europe; for instance, in Argentina, Australia, Brazil, Canada, India, Japan, Malaysia, Mexico, New Zealand, Qatar, Russia, Singapore, Thailand, United Arab Emirates, and the United States. In total, the EPDs that belong to companies outside Europe are 222 and represent 5% of the total collected EPDs.

Most EPDs belong to French (1,794) and German companies (1,134) – they cover 60% of the total EPDs identified – followed by Norwegian companies (320). These EPDs belong to companies located in countries with national program operators, namely PEP and FDES in France, IBU and IFT in Germany, and NEF in Norway. Italian companies follow with 267 EPDs; however, even if Italy has a national program operator, it has been recently developed and contributes only to 10 EPDs. On the contrary, Spanish companies present 185 EPDs even if two Spanish program operators are identified (AENOR and DAPH). The results presented in this Section are discussed in Section 6.2.

361 Table 3 Mapping of the EPDs released by Europe-based program operators

Country	N. of EPDs	%
Argentina	12	0%
Australia	35	1%
Austria	64	1%
Belgium	121	2%
Brazil	16	0%
Bulgaria	1	0%
Canada	7	0%
Croatia	1	0%
Czech Republic	24	0%
Denmark	81	2%
Finland	27	1%
France	1794	37%
Germany	1134	23%
Greece	8	0%
Hungary	1	0%
India	2	0%
Ireland	4	0%
Israel	4	0%
Italy	267	5%
Japan	1	0%
Latvia	13	0%
Liechtenstein	2	0%
Lithuania	5	0%
Luxemburg	14	0%
Malaysia	3	0%
Mexico	4	0%
Netherlands	162	3%
New Zealand	2	0%
Norway	320	7%
Iceland	36	1%
Portugal	19	0%
Qatar	1	0%
Romania	8	0%
Russia	5	0%
Singapore	1	0%
Slovenia	8	0%
Spain	185	4%
Switzerland	44	1%
Sweden	130	3%
Thailand	2	0%
Turkey	90	2%
United Arab Emirates	2	0%
United Kingdom	103	2%
United States	124	3%

362

363

364 Figure 1 shows the results regarding the languages used in identified EPDs. A total of 2,117 EPDs
 365 were written in English and 566 were in two languages including English. Few EPDs were written in
 366 more than two languages. Overall, the EPDs written in English cover 55% of all EPDs identified.
 367 This means that 45% were written in a local language.

368 Table 4 shows the results regarding the languages used in PCRs. Most operators elaborate PCRs in
 369 English or two languages (German/English or French/English), covering 287 documents,
 370 approximately 90% of the total PCRs published. However, some operators, even recently founded
 371 ones, only use the local languages such as German, French, Spanish, or Italian (Table 4), limiting the
 372 diffusion of the rules included in PCRs and thus hindering harmonization, as highlighted by Minkov
 373 et al. (2015).

374 It is important to highlight, that even if some operators make use of PCRs only in English, some
 375 related EPDs are written in local language. This is the case for instance of 8 EPDs released by EPD-
 376 DK, 5 EPDs by MRPI, 1 EPD by CENDEC, 1 EPD by IES, 5 by ITB and 3 by NEF. There are also
 377 several EPDs written in local languages which are released by program operators which make use of
 378 PCRs in local languages, for instance 12 EPDs by BMT, 71 by AENOR, 9 by DAPc, 220 by IFT and
 379 1 by EPDI.

380

381 Figure 1 EPDs identified by the main language

382

383

384

385

386

387

388 Table 4 Languages used in PCRs

Program Operators	Language used in PCRs
AENOR	Spanish
BMT	German
BRE	English
CENDEC	English
DAPc	Spanish
IES	English
EPDI	Italian
EPD-DK	English
EAA	English
FDES	French and French/English
IBU	German/English
IFT	German
ITB	English
MRPI	English
NEF	English
PEP	French/English
PE	English
ZAG EPD	English
DAPH	English and Portuguese

389

390

391 5.3 Quantification of the EPDs released by sectors

392 The number of EPDs per program operator associated with different UN CPC codes is reported in
393 Table 5. A total of 43 EPDs belong to section 1 - ores and minerals, electricity, gas, and water; 310
394 EPDs to section 2 - food products, beverages, tobacco, textiles, apparel, and leather products; 1,995
395 EPDs to section 3 - other transportable goods except metal products, machinery, and equipment;
396 2,399 EPDs belong to section 4 - metal products, machinery, and equipment; 132 EPDs to section 5 -
397 constructions and construction services; one EPD belongs to section 6 - distributive trade services;
398 accommodation food, and beverage services, and to section 9 -community, social, and personal
399 services; and seven EPDs belong to section 8 - business and production services.

400 Some program operators are active only for one UN CPC sector. For instance, Bau EPD, CENDEC,
401 DAPc, ITB, PE, ZAG EPD, and DAPH are active only for section 3, and EAA for section 4. The

section for which almost all the program operators released at least one EPD is section 3, followed by section 4 because of the large number of construction products, mainly covered by these sections. Sections 6, 8, and 9 are presented only in EPDs released by IES, which is the program operator that embraces all the sections identified. These results are in line with those presented by Hunsager et al. (2014), where section 4 is the section with most EPDs, followed by section 3.

408

Table 5 EPDs released by program operators and UN CPC section

Program Operators	UN CPC sections									Total	%
	1	2	3	4	5	6	8	9			
AENOR			44	27						71	1%
BMT			14							14	0%
BRE	1		14	25						40	1%
CENDEC			17							17	0%
DAPc			17							17	0%
IES	23	90	125	64	129	1	7	1		500	10%
EPDI			2	7	1					10	0%
EPD-DK			10	2						12	0%
EAA				15						15	0%
FDES	7	13	433	38						491	10%
IBU	3	207	619	518						1347	28%
IFT			150	77						227	5%
ITB			28							28	1%
MRPI	7		81	5	1					94	2%
NEF	2		346	45	1					394	8%
PEP			6	1576						1582	32%
PE			23							23	0%
ZAG EPD			2							2	0%
DAPH			4							4	0%
Total	43	310	1995	2399	132	1	7	1		4888	
%	1%	6%	41%	49%	3%	0%	0%	0%			

410

411

Products of Section 1 are labelled quite uniformly by French, Finnish, Spanish, Swiss, Swedish, Italian, Norwegian, UK, and German companies and products of Section 2 are mainly labelled by

Italian companies (90 EPDs), followed by German companies (68 EPDs). Products of section 3 and 4 are labelled mainly by French and German companies. In particular, the products of section 4 mostly belong to French companies, due to the PEP operator which is significantly active in the electronic sector (total of 1,317 EPDs). Products of section 5 and 9 are largely labelled by Italian companies, which are also prevalent relative to the products of Section 8 and 9.

Regarding the type of products for which the EPDs are published the most, for Argentina, Australia, Brazil, Canada, Czech Republic, Greece, Israel, Latvia, Lithuania, Luxembourg, Poland, Russia, Slovenia, Spain, Turkey, UK, and Ireland, the most labelled products belong to the construction sector. The products of this sector are also the most labelled in other countries. For instance, insulation products are the products labelled the most in Belgium; wood-based panels in Austria; floor covering and building boards in Denmark; doors and windows in Finland, Sweden, Switzerland, and the United States; adhesives and coatings in Germany; concrete in Norway; and floor coverings in the Netherlands and Portugal. The construction products are the most labelled ones for all countries analysed except for Italy, which presents the majority of EPDs for food and agriculture products and France, which has the majority of labels for the electronic products. The results presented in this Section are discussed in Section 6.3.

6 Discussion

The discussion section is structured as follows. Section 6.1 is about the total number of EPDs identified in this study; section 6.2 deals with the mapping of the identified EPDs per country and the presence of a NAP and mandatory rules; Section 6.3 concerns the EPDs by sector and GPP sectors covered by NAIs.

6.1 Discussion on the extension of EPDs diffusion

438 The obtained results showed that the total number of valid EPDs released by European program
439 operators was 4,888 in 2016, namely 150% higher than 2013 and higher than the total number of
440 valid EPDs in the world in 2013 (3,614) quantified by Hunsager et al. (2014).

441 This significant spread was mainly due to the growth of two program operators: i) PEP, which
442 presented 407 declarations in 2013 and 1,582 declarations in 2016 and ii) IBU, which presented 408
443 declarations in 2013 and 1,347 declarations in 2016.

444 The official registration process within PEP started in the end of 2011 (Vital et al., 2012) and year
445 after year PEP has published a set of PSRs - there was only one PSRs in use in 2013 and 11 PSRs in
446 2016. In parallel, IBU has grown and become the main program operator for construction products in
447 Europe. This great development mirrors the development of the interest of companies of the
448 construction sector, as discussed in paragraph 6.3.

449 On the other hand, within the 4,888 EPDs identified in this study, just a very small number was
450 released by the two more recently established programme operators: EPDI, founded in 2015, has
451 released 10 EPDs and RTED/RTS, launched in 2016, none. This shows that a higher number of
452 program operators does not lead to a significant increase of EPDs, necessarily.

453

454 6.2 Discussion on the EPDs per country

455 The obtained results show that most EPDs belong to companies located in France (1,794) and
456 Germany (1,134), namely two countries with two national program operators, PEP and FDES in
457 France, IBU and IFT in Germany. This shows that a high interest of the companies in EPDs leads to a
458 market development of program operators.

459 There is a discrepancy between the results obtained in this study and the results obtained by Ibáñez-
460 Forés et al. (2016) which reported that the Countries with the highest number of EPDs was Italy
461 followed by Sweden and Switzerland. This is due to the fact that Ibáñez-Forés et al. (2016) focused
462 on IES and neglected the other European programs.

463 The obtained results also show that 45% of analysed EPDs are written in local languages highlighting
 464 the fact that a great number of EPDs are developed for national market or national tenders.

465 Thus this study allowed highlighting these two main points: 1) there is a higher diffusion of EPDs in
 466 countries hosting one or more program operators and so the need for more EPDs in a country can
 467 lead to the presence of more than one program operator and 2) several EPDs are written in local
 468 languages highlighting their utilisation for national or local market, and national tenders. This shows
 469 that several company are not ready or not interested in international tenders.

470 Table 6 cross-references the national situation in terms of presence of NAPs, year of release,
 471 presence of mandatory rules (EC, 2018c) and the number of EPDs found thorough our study. It is
 472 possible to distinguish two main groups of countries: countries without EPDs and countries with
 473 EPDs. The countries without EPDs present the following situations: they have not a NAP in force
 474 (Estonia); they have a recent NAP in comparison with the situation mirrored in our study (Malta and
 475 Slovakia); or they have a NAP but no EPDs (Cyprus). This reveals that companies in these countries
 476 are in line with the institutional situation and that they are not ready for GPP in terms of EPDs, but
 477 also their countries have not embraced yet the principles and recommendation of European
 478 Commission. Thus, this study reveals correspondence between market situation and institutional
 479 situation towards GPP policies.

480 On the other hand, the countries with EPDs present the following situations: they have a NAP in
 481 force but no mandatory rules; they have both a NAP and mandatory rules; they have no NAP.

482 The countries which have a NAP in force but no mandatory rules are Ireland, Latvia, Lithuania,
 483 Poland, Portugal, Sweden and the UK. The number of EPDs in these countries show that there are
 484 several companies ready for GPP and which are ahead future possible legal requirements; except for
 485 Ireland and Lithuania for which the number of EPDs is very limited. The countries which have a
 486 NAP and also mandatory rules are Austria, Belgium, Bulgaria, Croatia, Czech Republic, Denmark,
 487 Finland, France, Germany, Italy, the Netherlands and Norway, representing 79% of the total EPDs

collected in our studies. The number of EPDs in these countries shows that there are a great number of companies ready for GPP and which are in line or ahead legal requirements; except for Bulgaria and Croatia where the number of EPDs cannot be considered related to GPP (just 1 EPD) and Czech Republic, which presented a NAP in 2017, one year later the collection of the EPDs for this study. Thus, this study reveals correspondence between the presence of a NAP with principles towards GPP and the spread in the market of environmental labelling. The countries without NAP are Greece, Hungary, Luxemburg and Romania, which demonstrate that even without a national policy on GPP some companies have the interest to develop EPDs to meet market needs.

Table 6 National situation about GPP by country (EC 2018c) and number of EPDs by country

Country	NAP in force (Yes/No)	Year of NAP	Mandatory rules	EPDs
Austria	Yes	2010	Yes	64
Belgium	Yes	2009	Yes	121
Bulgaria	Yes	2014	Yes	1
Croatia	Yes	2015	Yes	1
Cyprus	Yes	2007	No	0
Czech Republic	Yes	2017	Yes	24
Denmark	Yes	2015	Yes	81
Estonia	No	-	No	0
Finland	Yes	2013	Yes	27
France	Yes	2007	Yes	1794
Germany	Yes	2008	Yes	1134
Greece	No	-	No	8
Hungary	No	-	No	1
Ireland	Yes	2010	No	4
Italy	Yes	2008	Yes	267
Latvia	Yes	2015	No	13
Liechtenstein	No	-	na	2
Lithuania	Yes	2015	No	5
Luxemburg	No	-	No	14
Malta	Yes	2015	No	0
Netherlands	Yes	2003	Yes	162
Norway	Yes	2007	Yes	320
Poland	Yes	2007	No	36
Portugal	Yes	2016	No	19

Romania	No	-	No	8
Slovakia	Yes	2016	No	0
Slovenia	Yes**	2009	Yes	8
Spain	Yes	2008	Yes*	185
Switzerland	na	-	na	44
Sweden	Yes	2017	No	130
United Kingdom	Yes	2011	No	103

6.3 Discussion on the EPDs released by sectors

The obtained results show that the construction products and the electronic products are the most labelled products in Europe. This study also shows that the UN CPC sections with most EPDs are section 4 and 3 which cover the largest number of construction products. Several obstacles were encountered in the definition of the UN CPC sections and this fact emphasizes the need of a shared classification system to develop a clear structure for mapping products, as already highlighted by Ingwersen and Stevenson (2012).

Based on the results discussed in Table 5 and Section 6.2, it is possible to cross-reference the criteria covered by GPP and the sectors which the EPDs belong to, focusing on the countries for which it has been revealed a correspondence between the presence of a NAP and the EPDs in order to understand whether the sectors covered by the EPDs correspond to the sector covered by GPP criteria. Table 7 shows the product sectors covered by the EPDs analysed through our study (second column) and the answer to the question ‘Are the product sectors of EPDs covered by national GPP?’ (third column). The answer is given cross referencing the EPDs sectors with the sectors reported in EC (2018c). Table 7 shows that for the majority of the analysed countries, the product sectors covered by EPDs correspond to the sectors covered by GPP criteria. In some cases, the correspondence is complete, in other cases the correspondence is partial, in the sense that GPP criteria cover more product sectors than EPDs.

520 With reference to the construction sector, which is the sector covered the most by EPDs and GPP
 521 criteria, the significant diffusion of EPDs is associated with the following reasons: a) the GPP criteria
 522 for the categories “office building design, construction and management” and “road design,
 523 construction and maintenance” consider EPDs as a proof that the goods or supplies correspond to the
 524 required environmental characteristics and thus companies are encouraged to develop EPDs; b) there
 525 are national regulations for public tenders which require labels as a proof of environmental
 526 features of products; c) EPDs contribute points under some rating system of the building sector, as
 527 highlighted by Gelowitz and McArthur (2016).

528 With reference to the electronic sector, the great diffusion of EPDs, mainly released by PEP, is due to
 529 the fact that PEP program operator was developed by electrical industry stakeholders, on a voluntary
 530 basis and its role is to elaborate suitable reference documents concerning electrical and electronic
 531 products (Hassanzadeh et al., 2013).

532

533

534 Table 7 Analysis of the product sectors covered by EPDs and correspondence with sectors covered
 535 by GPP criteria

Country	Product sectors covered by EPDs	Are the product sectors of EPDs covered by national GPP? (Yes/No)
Austria	Construction products	Yes
Belgium	Construction products and plastics product (non-construction)	Yes (construction); No (Plastic product)
Denmark	Construction products	No
Finland	Construction products Wood and paper product (non- construction)	Yes (construction); No (Wood)
France	Construction products Electronic products	Yes
Germany	Construction products Electronic products	Yes

Italy	Construction products	Yes (except for some products)
	Electronic products	
	Food and agricultural products	
	Fuel and chemical products	
	Glass and plastic (non-construction)	
	Laboratory facilities	
	Machinery	
	Textile and leathers	
Latvia	Wood and paper (non-construction)	Yes
	Construction products	
Netherlands	Construction products	Yes (construction); No (fuels, chemicals)
	Fuels and chemical products	
Norway	Construction products	Yes
	Furniture	
Poland	Construction products	Yes
Portugal	Construction products	Yes
	Metal products	
Slovenia	Construction products	Yes
	Construction products	
Spain	Metal products	Yes (construction, transport, furniture)
	Food and agricultural products	
	Furniture	
	Fuels and chemical products	
	Transport	
Sweden	Construction products	Yes (construction)
	Electricity	
	Machinery	
	Services	
	Fuels and chemical products	
United Kingdom	Construction products	Yes (construction)
	Electric products	
	Wood	

536

537

538 7 Conclusion

539 This study explored the valid type III labels presented on the websites of the European program
 540 operators between September and December 2016 with the aim of investigating to what extent EPDs
 541 were spread, identifying which were the Countries with the greater number of EPDs years later the
 542 publication of Directive 2014/24/EU and exploring whether the market is ready to fulfil the
 543 environmental requirements of Directive 2014/24/EU.

544 The identified EPDs were quantified and classified by the program operator and the UN CPC section,
 545 by country cross-referencing with the UN CPC section, and by the language used in EPDs and PCRs.

546 In total, 4,888 EPDs were collected, showing that the total number of valid EPDs released by
547 European program operators was 150% higher than 2013, and mirroring the growth of interest of the
548 companies toward the EPDs.

549 The obtained results also show that:

- 550 - It is possible to distinguish two main groups of countries in Europe: countries without EPDs
551 and countries with EPDs. With reference to countries without EPDs, this study reveals that
552 companies in these countries are in line with the institutional situation and that they are not
553 ready for GPP in terms of EPDs, but also their countries have not embraced yet the principles
554 and recommendation of European Commission. With reference to countries with EPDs, this
555 study reveals that there are several companies ready for GPP and which are in line or ahead
556 legal requirements and that there is correspondence between the presence of a NAP with
557 principles towards GPP and the spread in the market of environmental labelling.
- 558 - The product sectors covered by EPDs correspond to the sectors covered by GPP criteria. In
559 some cases, the correspondence is complete, in other cases the correspondence is partial, in
560 the sense that GPP criteria cover more product sectors than EPDs.

561 The main limitation of this study was the assignment of the UN CPC code to the products because
562 only some of them included the code in the content of the declaration. The codes were hypothesized
563 based on the descriptions reported in the declarations and on the related PCRs, limiting the
564 appropriateness of our classification. This limitation can be overcome by making the identification of
565 the UN CPC sections, which the labelled products belong to, mandatory in PCRs and EPDs.

566 Another limitation is due to the fact that 4% of the EPDs included in this study were not
567 downloadable (107 of PEP and 94 of MRPI) and preventing the collection of some details, namely
568 the language used and the reference PCR used to develop the EPD. This information was useful to
569 classify the product in the UN CPC section.

570 A difficult step in the development of this study was to understand the content of the EPDs because
571 they were often written only in local languages.

572 A further development of this study will be the investigation of each national law which regulates the
573 green public procurement in order to verify whether they make reference to EPDs also for other
574 products sectors besides the construction sector and whether the number of EPDs per sector can
575 mirror the national requirements of public tenders.

576

577 Acknowledgements:

578 Authors would like to express their appreciation and thanks to Carlo Trevisanello, Isabella Lotto,
579 Paola Serventi, Sofia Manfrin and Francesco Rocco for their work and their help in the development
580 of this study.

581

582 Declarations of interest: none

583

584

585

586

587

588

589

590

591

592

593

594

REFERENCES

- Achenbach H, Diederichs SK, Wenker JL, Rüter S. Environmental product declarations in accordance with EN 15804 and EN 16485 — How to account for primary energy of secondary resources? *Environ. Impact Assess. Rev.* 2016; 60: 134-138
- Bakir S, Khan S, Ahsan K, Rahman S. Exploring the critical determinants of environmentally oriented public procurement using the DEMATEL method. *J. Environ. Manag.* 2018; 225:325-335
- Boons F, Wagner M. Assessing the relationship between economic and ecological performance: Distinguishing system levels and the role of innovation. *Ecol Econ* 2009; 68: 1908-1914.
- Brusselaers J, Van Huylbroeck G, Buysse J. Green Public Procurement of Certified Wood: Spatial Leverage Effect and Welfare Implications. *Ecol. Econ.* 2017; 135: 91-102
- Butt AA, Toller S, Birgisson B. Life cycle assessment for the green procurement of roads: a way forward. *J.Clean Prod.* 2015; 90:163-170
- Cheng W, Appolloni A, D’Amato A, Zhu Q. Green Public Procurement, missing concepts and future trends - A critical review. *J. Clean. Prod.* 2018; 176: 770-784
- CEN (European Committee for Standardization) 2013. EN 15804:2012+A1:2013 Sustainability of construction works - Environmental product declarations - Core rules for the product category of construction products
- CEN (European Committee for Standardization) 2014. EN 16485 Round and sawn timber. Environmental Product Declarations. Product category rules for wood and wood-based products for use in construction
- CEN (European Committee for Standardization) 2017a. EN 16810 Resilient, textile and laminate floor coverings - Environmental product declarations - Product category rules
- CEN (European Committee for Standardization) 2017b. EN 16783 Thermal insulation products - Product category rules (PCR) for factory made and in-situ formed products for preparing environmental product declarations
- CEN (European Committee for Standardization) 2017c. EN 16757 Sustainability of construction works. Environmental product declarations. Product Category Rules for concrete and concrete elements
- CEN (European Committee for Standardization) 2017d. EN 16908 Cement and building lime - Environmental product declarations - Product category rules complementary to EN 15804
- Cordella M, Medda C. Analysis of key environmental areas in the design and labelling of furniture products: Application of a screening approach based on a literature review of LCA studies. *Sustainable Production and Consumption* 2016; 8:64-77

- 629 Del Borghi A, Binaghi L., Del Borghi M, Gallo M. The Application of the Environmental Product
630 Declaration to Waste Disposal in a Sanitary Landfill. *Int J Life Cycle Assess* 2007; 12:40-49
- 631 Del Borghi A, Gaggero PL, Gallo M., Strazza C. Development of PCR for WWTP based on a case
632 study. *Int J Life Cycle Assess* 2008; 13: 512-521
- 633 Dodd N, Garbarino E, Gama Caldas M. Green Public Procurement Criteria for Office Building
634 Design, Construction and Management. Technical background report and final criteria. 2016 EUR
635 27916 EN; doi:10.2791/28566
- 636 EC (European Commission), 2003. COM(2003) 302 final Communication from the Commission to
637 the Council and the European Parliament - Integrated Product Policy Building on Environmental
638 Life-Cycle Thinking.
- 639 EC (European Commission), 2016. Buying green! A handbook on green public procurement 3rd
640 Edition. © European Union, 2016. Printed in Belgium.
- 641 EC (European Commission), 2017. COM(2017) 572 final - Communication from the Commission to
642 the European Parliament, the Council, the European economic and social committee and the
643 committee of the Regions - Making Public Procurement work in and for Europe.
- 644 EC (European Commission), 2018a. EU GPP Criteria. Available at
645 http://ec.europa.eu/environment/gpp/eu_gpp_criteria_en.htm (last access 01/01/2018)
- 646 EC (European Commission), 2018b. GPP National Action Plans. Available at
647 http://ec.europa.eu/environment/gpp/action_plans_en.htm (last access 01/09/2018)
- 648 EC (European Commission), 2018c. National GPP Action Plans (policies and guidelines). Available
649 at http://ec.europa.eu/environment/gpp/pdf/GPP_NAPs_June_2018.pdf (last access 01/09/2018)
- 650 EU (European Union), 2014. Directive 2014/24/EU of the European Parliament and of the Council of
651 26 February 2014 on public procurement and repealing Directive 2004/18/EC. Strasbourg, France.
- 652 Fet AM, Skaar C. Eco-labeling, Product Category Rules and Certification Procedures Based on ISO
653 14025 Requirements. *Int J Life Cycle Assess* 2006; 11:49-54
- 654 Fuentes-Bargues JL, González-Cruz MC, González-Gaya C. Environmental Criteria in the Spanish
655 Public Works Procurement Process. *Int. J. Environ. Res. Public Health* 2017; 14: 204
- 656 Gelowitz MDC, McArthur JJ. Investigating the effect of environmental product declaration adoption
657 in LEED® on the construction industry: a case study. *Procedia engineering* 2016; 145:58-65
- 658 Gelowitz MDC, McArthur JJ. Comparison of type III environmental product declarations for
659 construction products: Material sourcing and harmonization evaluation. *J Clean Prod* 2017; 157:125-
660 133
- 661 Ghisetti C. Demand-pull and environmental innovations: Estimating the effects of innovative public
662 procurement. *Technol Forecast Soc Change* 2017; 125: 178-187

- 663 Hassanzadeh M, Theoleyre S, Jollain C, Metz R. Environmental Declaration in compliance with ISO
664 14025 thanks to a collaborative program of electrical and electronic industry: the PEP ecopassport
665 program. 22nd International Conference on Electricity Distribution, Stockholm 10-13 June 2013.
666 Paper 0138
- 667 Hunsager EA, Bach M, Breuer L. An institutional analysis of EPD programs and a global PCR
668 registry. *Int J Life Cycle Assess* 2014; 19:786–795
- 669 Ibáñez-Forés V, Pacheco-Blanco B, Capuz-Rizo SF, Bovea MD. Environmental Product
670 Declarations: exploring their evolution and the factors affecting their demand in Europe. *J. Clean*
671 *Prod.* 2016; 116: 157-169
- 672 Ingwersen WW, Stevenson MJ. Can we compare the environmental performance of this product to
673 that one? An update on the development of product category rules and future challenges toward
674 alignment. *J. Clean Prod.* 2012; 24:102-108
- 675 ISO (International Organization for Standardization), 1999. ISO 14024: Environmental labels and
676 declarations -- Type I environmental labelling -- Principles and procedures
- 677 ISO (International Organization for Standardization), 2000. ISO 14020: Environmental labels and
678 declarations — General principles
- 679 ISO (International Organization for Standardization), 2006. ISO 14025: Environmental labels and
680 declarations -- Type III environmental declarations -- Principles and procedures
- 681 ISO (International Organization for Standardization), 2012. Environmental labels and declarations -
682 How ISO standards help. ISO Central Secretariat, Genève, Switzerland ISBN 978-92-67-10586-4
- 683 ISO (International Organization for Standardization), 2016. ISO 14021: Environmental labels and
684 declarations -- Self-declared environmental claims (Type II environmental labelling).
- 685 Manzini R, Noci G, Ostinelli M, Pizzurno E. Assessing Environmental Product Declaration
686 Opportunities: a Reference Framework. *Bus. Strat. Env.* 2006; 15:118–134
- 687 Mazzi A, Toniolo S, Manzardo A, Ren J, Scipioni A. Exploring the direction on the environmental
688 and business performance relationship at the firm level. Lessons from a literature review.
689 *Sustainability* 2016; 8, 1200
- 690 Minkov N, Schneider I, Lehmann A, Finkbeiner M. Type III Environmental Declaration
691 Programmes and harmonization of product category rules: status quo and practical challenges. *J.*
692 *Clean Prod.* 2015; 94:233-246
- 693 Modahl IS, Askham C, Lyng K-A, Skjerve-Nielssen C, Nereng G. Comparison of two versions of an
694 EPD, using generic and specific data for the foreground system, and some methodological
695 implications. *Int J Life Cycle Assess* 2013; 18:241-251.

- 696 Mukherjee A, Dylla H. Challenges to Using Environmental Product Declarations in Communicating
697 Life-Cycle Assessment Results. *Transportation Research Record: Journal of the Transportation*
698 *Research Board* 2017; 2639:84-92
- 699 Sariola L, Ilomäki A. RTS EPD's – Reliable Source of Environmental Information of Building
700 Products in Finland. *Energy Procedia* 2016; 96:77-81
- 701 Schau EM, Fet AM. LCA Studies of Food Products as Background for Environmental Product
702 Declarations. *Int J Life Cycle Assess* 2008; 13:255-264.
- 703 Schlanbusch RD, Fufa SM, Häkkinen T, Vares S, Birgisdottir H, Ylén P. Experiences with LCA in
704 the Nordic building industry – challenges, needs and solutions. *Energy Procedia* 2016; 96:82-93
- 705 Steen B., Gärling A., Imrell A-M, Sanne K. Development of interpretation keys for environmental
706 product declarations. *J. Clean Prod.* 2008; 16: 598-604.
- 707 Strazza C, Del Borghi A, Magrassi F, Gallo M. Using environmental product declaration as source of
708 data for life cycle assessment: a case study. *J. Clean Prod.* 2016; 112:333-342
- 709 Subramanian V, Ingwersen W, Hensler C, Collie H. Comparing product category rules from different
710 programs: learned outcomes towards global alignment. *Int J Life Cycle Assess* 2012; 17:892-903
- 711 Tarantini M, Loprieno AD, Porta PL. A life cycle approach to green public procurement of building
712 materials and elements: a case study on windows. *Energy* 2011; 36: 2473–2482.
- 713 Testa F, Iraldo F, Frey M, Daddi T. Which factors influence the uptake of GPP (green public
714 procurement) practices? New evidence from an Italian survey. *Ecol. Econ.* 2012; 82: 88-96
- 715 Testa F, Annunziata E, Iraldo F, Frey M. Drawbacks and opportunities of green public procurement:
716 an effective tool for sustainable production. *J. Clean. Prod.* 2016; 112: 1893-1900
- 717 UNSD (United Nations Statistics Division), 2008. Detailed Structure and Correspondences of the
718 Central Product Classification (CPC) Ver.2 Subclasses to ISIC Rev.4 and HS 2007.
719 https://unstats.un.org/unsd/cr/registry/docs/CPCv2_structure.pdf (accessed 06.03.2017)
- 720 Vital X, Théoleyre S, Lizotte R. P.E.P. Ecopassport – An ISO 14025 Compliant Program. Joint
721 International Conference and Exhibition on Electronics Goes Green (EGG), Berlin, Germany. 2012,
722 ISBN: 978-3-8396-0435-7 978-1-4673-4512-5
- 723 Yenipazarli A. The economics of eco-labeling: Standards, costs and prices. *Int. J. Production*
724 *Economics* 2015; 170:275-286
- 725 Zackrisson M., Rocha C., Christiansen K., Jarnehammar A. Stepwise environmental product
726 declarations for SME case studies. *J. Clean Prod.* 2008; 16:1872-1886

Figure 1 EPDs identified by the main language

729

730 Highlights:

- 731 - The diffusion of EPDs, which are type III labels, was analysed
- 732 - The EPDs emitted by Europe-based program operators were studied
- 733 - The EPDs were cross-referenced with GPP actions plans and criteria
- 734 - Construction products and electronics are the most labelled products
- 735 - The countries with greater number of EPDs are France and Germany

736

737