Environmental Product Declarations for Building Materials: Advantages, Limits, Developments

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Abstract

This paper explains one of the environmental certifications tools that the construction sector can use to communicate the environmental performance of materials: the environmental product declaration (EPD) or type III environmental label. The need to be more transparent on environmental information is mandatory and can no longer be avoided. The paper describes the main environmental product declarations (EPDs), highlighting that over the last years the number of environmental product declarations (EPDs) published by the main European EPD programmes has increased. One of the main characteristics of the environmental product declaration (EPD) is the possibility to compare the environmental aspects of the considered products. The paper compares two case studies on the same material building type, published by two different EPD programmes, highlighting the difficulties of this comparison.

Keywords

Environmental product declaration (EPD) • Product construction rules (PCR) • LCA • ISO 14025 • Material construction

1 Introduction

In general, process, production/creation and product innovations are fostered by the (European, national and local) legislation—nowadays mostly on the environmental subject—and by market mechanisms that stimulate a productive competition for the professionals on the continuous enhancement of the product compared to a constantly changing demand made by planners, builders, buyers and final users. The difficulty of the subject corresponds to a quite complex framework of environmental directives—somehow still fragmented—requiring quite a massive effort to be implemented and most of all to verify the environmental effectiveness of the strategies enforced over the last few years. A first attempt at a systemic approach can be found in the Europe 2020 Strategy and in particular in a resource efficient Europe objective (European Commission, 2011a; b), which provides for the delineation of a set of economic-financial tools to assess the real costs and benefits of the use of resources and to encourage the use, in the long run, of solutions designed to an efficient use of natural resources.

It is established that the environmental subject is heavily affected by the building sector, which can play a decisive role in containing CO_2 emissions in the atmosphere given that globally in 2017, the building industry consumed 36% of energy and was responsible for almost 40% of carbon dioxide emissions (UN Environment, 2018). These percentages are referred to the total energy used by the building that is the sum of operational energy and embodied energy that contribute to the calculation of the total energy (Barucco et al., 2016; Gonzalez & Navarro, 2006; Treloar et al., 2001). Specifically, building emissions can be divided into three fields: direct emissions, coming from the burning of fossil fuels in buildings; indirect emissions, coming from the production of electrical and thermal energy; the embodied carbon or CO_2 emissions, coming from the production of materials. While direct and indirect emissions tend to decrease, the emissions coming from the production stage of materials are becoming increasingly important, especially those related to steel and cement which, from 1.8 gigatons of carbon dioxide ($GtCO_2$) released in 2017, will increase up to around 40% by 2060, according to the recent projections provided by the International Energy Agency (IEA, 2019).

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Therefore, the environmental issue, if referred to the building sector, traditionally well-structured and complex, highlights that it is increasingly necessary to create a system of the regulatory framework and of support decisional tools and to evaluate the environmental efficiency of materials and building components, innovative technologies and building techniques that can make an important contribution to the sustainability and eco-efficiency of the building industry (Pacheco-Torgal & Jalali, 2012). In recent years, the need for a simplified approach, quick to use by professionals and certain to be verified by inspectors, has favoured the spread of tools with checklists (protocols or rating systems such as LEED, BREEM, ITACA, etc.) or minimum environmental criteria for Green Public Procurement, based on a very detailed list of environmental criteria-requirements to be met in order to be awarded or to access tenders, in the case of the general public administration (Ganassali et al., 2016). Overcoming this typically qualitative attitude—on the basis of reasoned and grouped into class parameters— and the need for a verification of environmental effectiveness in strictly quantitative terms, in recent years, have pushed the standardization structures at international (ISO), European (CEN) and national (UNI) level to the implementation of tools, such as life cycle assessment (LCA), capable of quantitatively measuring resource flows and environmental impacts throughout all stages of the life cycle and the increase or reduction of environmental impacts related to process and product innovations.

The goal of reaching high performances of the materials concerning for to environmental indicators, despite the complexity of the required framework to which the project must respond, gives to the project a double challenge. The first one is the relationship between the project and the matter: the research started over the last few years on the bio-based materials (Sposito & Scalisi, 2019; Maskell et al., 2015; Onchiri et al., 2014) are emblematic of the possibility of designing the characteristics of the materials not only from a technical performance —as for the advent of composite materials—and aesthetic point of view, but also from the environmental performance point of view. The second challenge concerns the opportunity to optimize the production processes of materials to reduce the most expensive stages from the point of view of resource consumption and generated impacts (Campioli et al., 2018), enhancing 'low energy consumption' solutions. In this context, a useful tool for assessing the environmental impacts of materials is the environmental product declaration (EPD) which aims to contribute to reducing the impact on climate of the building sector by encouraging planners and designers to use the LCA while planning and designing buildings (Bovea et al., 2014; Pacheco-Torgal, 2014; Del Borghi, 2013). This paper illustrates the main features of the EPD and its dissemination, focusing in particular on the analysis of two environmental product declarations relating to autoclaved aerated concrete, produced by two different EPD programmes, highlighting their strengths and limitations.

2 The Environmental Product Declaration (EPD) and the Product Category Rules (PCR)

The environmental product declaration (EPD) is one of the most recommended methods to report the environmental impacts of building materials. EPD is a certified environmental product declaration that provides environmental data on the life cycle of products in accordance with the international standard ISO 14025 (2006), is "[…] the input for a holistic building assessment considering the functional and technical performances in a building context. For a producer, this also means that his contribution to higher sustainability (environmentally, socially and economically) of course should be done by big and small improvements on every step in the building chain" (Gagari et al., 2013, p. 107). It is a voluntary project decided by the companies that through this tool can communicate the environmental data of their products. These data are processed by one or more organizations, based on life cycle assessment (LCA) in accordance with the ISO 14040 (2006) series of standards and are independently verified.

Therefore, the LCA method can provide important information on the stages of the whole life cycle to reduce environmental loads and impacts, also through the use of open access software (OpenLCA, 2019; SimaPro, 2019). This is why many green building rating systems have added LCA indicators in the criteria relating to materials and have fostered the use of products with EPD certification, allowing to identify the best material during the design stage based on verified environmental information. It should be noted that only one protocol, the German DGNB (2019), was born with the LCA evaluation of the building amongst the first criteria of the protocol, virtuously activating the whole supply chain and leading to a quick increase of EPD certified products, favouring the elimination of irrelevant and misleading data and enhancing primary data strictly linked to the specific product used in the building, stimulating the production sector to direct competition and environmental innovation of products. The general objective of EPD is to encourage the demand and supply of products entailing less stress on the environment while allowing the comparison between products that have the same function. The ISO 14025 (2006) standard establishes nine guidelines of the EPD in the following points: relationship with the ISO 14020 Standard (2000), voluntary nature, life cycle basis, modularity, the involvement of the interested parties, comparability, verification, flexibility and transparency.

The environmental product declaration is also known as a Type III environmental label, according to the classification of the international standards organization (ISO) which divides environmental labels into three types: the type I label describes the impact of products or services on the environment, its acquisition is voluntary-based and is regulated by ISO 14024 (1999); the type II label consists of self-declared environmental declarations of companies and organizations without third-party verification and is regulated by ISO 14021 (1999) and type III label or environmental product declaration label is regulated by ISO 14025 (2006). The developing process of an EPD consists of four stages: (1) the selection of type II environmental declaration programmes; (2) the research of product category rule (PCR) for the product that must be declared (if there is not a product category rule for the product category, it must be created); (3) the creation of a EPD draft based on the implementation of the LCA method, abide by the rules of the EPD programme and the outlining of a specific PCR for that product category and (4) the verification process that has to prove, before the EPD publication that the data collection and the enforcement of the LCA method are made according to the PCR and meet all ISO requirements.

The EN 15804 (2012) standard specifies the basic rules for EPDs relating to the category of building materials, as a guarantee that all declarations are uniformly represented and verified. Specifically, the product category rule (PCR) must list the stages of the life cycle to be included, the parameters to comply with and how the parameters must be collected and reported. The life cycle stages are established by the EN 15804 (2012): product stage, construction stage, use stage, end of life stage and an optional module reuse-recovery (D). In Fig. 1, the mandatory and optional stages are listed, according to the system limit considered: the 'cradle to gate' analysis evaluates only the Product stage (A1–A3), which is therefore mandatory; in the 'cradle to gate with options' analysis, the Product stage (A1–A3) is mandatory while all other stages are optional; in the 'cradle to grave' analysis all stages are mandatory except D) which is optional.

3 Contents of the Environmental Product Declaration and EPD Programmes

The environmental product declaration (EPD) has to facilitate the comparison between products' environmental characteristics that meet equivalent functional requirements. The information included basically concerns: identification and description of the organization that makes the declaration; the product description; the name of the programme and the address of the programme manager and, if necessary, the logo and website; the identification of the PCR; the publication date and the validity period; life cycle analysis data (LCA); additional environmental information; the presence of materials and substances that must be declared, for example, substances that can negatively affect public health

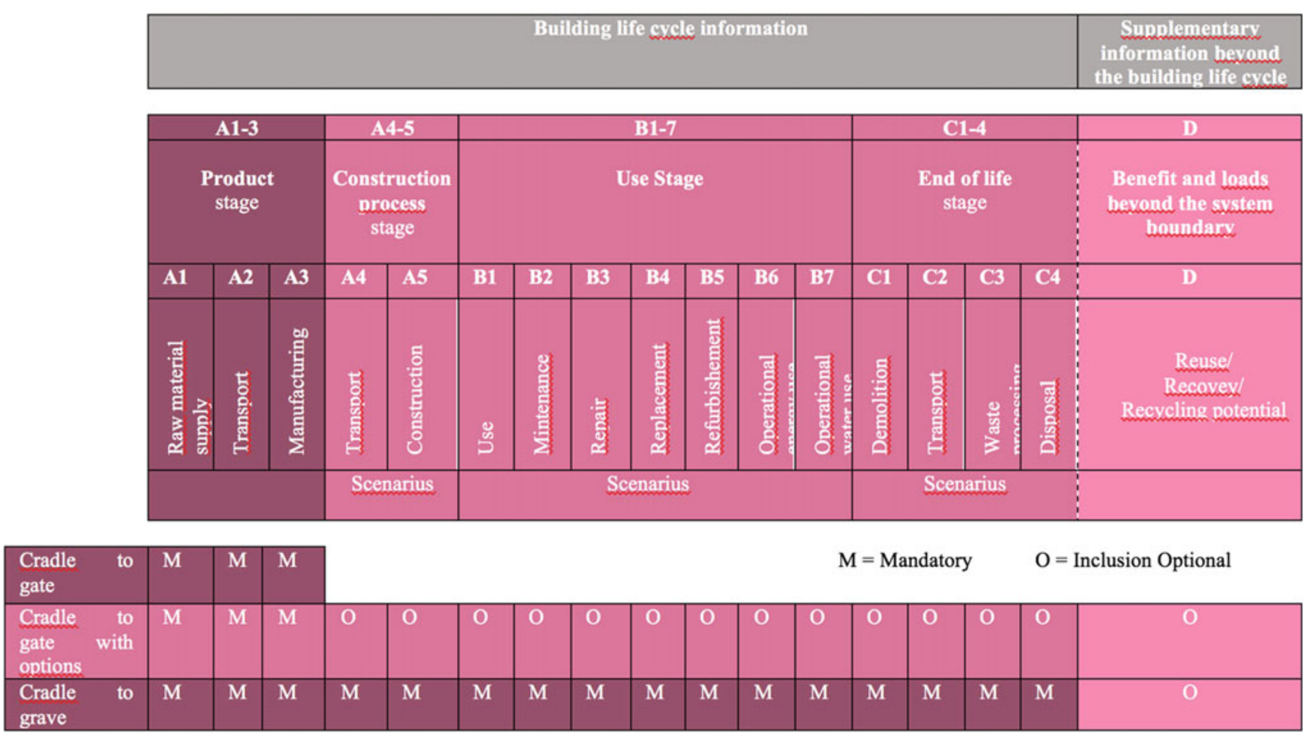

Fig. 1 Information modules for construction products, adapted from EN 15804:2012

and the environment at all stages of its life cycle; information on the stages that have not been taken into consideration, if the declaration is not based on a 'cradle to grave' LCA.

The LCA results are divided into three categories on environmental impact, use of resources, output flows and waste categories. The environmental impact includes the parameters relating to the global warming potential, stratospheric ozone layer depletion, soil and water acidification potential, eutrophication potential, tropospheric ozone and photochemical oxidants formation potential and abiotic degradation of non-fossil resources potential, abiotic degradation of fossil resources potential.

The use of resources includes the parameters on the use of: renewable primary energies as an energy source; renewable primary energy resources as raw materials; renewable primary energy resources; non-renewable primary energies as energy sources; non-renewable primary energy resources such as raw materials; non-renewable primary energy resources; secondary materials; secondary renewable fuels; non-renewable secondary fuels and net consumption of water resources. In the output flows and waste categories, the following parameters are included: hazardous waste disposed of, non-hazardous waste disposed of, radioactive waste disposed of, components destined for re-use, materials destined for recycling, materials destined for energy recovery, exported electricity and exported thermal energy. Finally, additional information on environmental issues can be provided such as the potential impact on biodiversity or the assessment of risks to public health and the environment.

Amongst the many independent organizations or highly organized structures that develop the EPD, it is certainly worth mentioning the International EPD® System which, established in 1999, was the first EPD programme developed on a global scale and still is one of the most widespread in Europe (Hunsager et al., 2014). Table 1 lists the 14 most important EPD programmes in Europe—sorted by the number of EPDs processed—almost all created for the building materials certification, except for the EPD-Norge and the International EPD System. The data in the Table, if compared with the numbers shown in previous studies (Bovea et al., 2014), show a significant increase—from 2014 to date—of the EPDs that have increased from 249 to 1087 in the International EPD® System and from 280 to 1613 in the IBU-EPD, as a reaction from the world of producers to a new sensitivity towards eco-oriented materials and building components by the users.

4 Methodology

This paper has examined two of the main EPD programmes, the International EPD® System and the IBU-EPD. The choice has quantitative reasons justified by the fact that the first one is the most widespread in Europe while the latter has a considerable number of EPDs—the second after the French FDES INIES—but above all, it reports the greatest number of PCR elaborated by an EPD programme in Europe. The first difference between the two programmes can be found in the field of the processed products: while the IBU-EPD deals exclusively with building materials, the International EPD® System has also other categories such as food and beverages, chemical products, textiles, footwear and apparel and paper products. The number of the products in the archive is also different: the IBU-EPD has 1613 building materials while the

Table 1 EPD programmes: construction products (processed data on 14 December 2020)

EPD programmes	Link	Number of EPDs	Country
FDES INIES	www.hqegbc.org/accueil/	3516	France
IBU-EPD	http://www.ibu-epd.com/	1613	Germany
International EPD® system	http://www.environdec.com	1087	Sweden
EPD-NORGE Norwegian EPD foundation	http://www.epd-norge.no	500	Norway
MRPI®	www.mrpi.nl/	135	Holland
EPDItaly	www.epditaly.it/	108	Italy
EPD Ireland	www.igbc.ie/epd-home/	101	Ireland
RTS EPD	http://www.epd.rts.fi/en/	88	Finland
BRE	www.greenbooklive.com	77	United Kingdom
DAP construcción®	www.csostenible.net/home/index?locale=es	73	Spain
EPD Danmark	www.epddanmark.dk/	31	Denmark
ZAG	www.zag.si/si/	14	Slovenia
DAP habitat system	http://www.daphabitat.pt/	13	Portugal
Bau EPD	www.bau-epd.at	8	Germany

International EPD® System 1087, even if the latter can be found in more countries (25 in Europe alone). Concerning the Construction Product Rules, it is worth mentioning that the International EPD® System has developed a PCR entitled Construction Products and Services (and 12 Sub-PCRs related to different material categories, valid at the access date of 29 April 2019), updated with the Product Category Rules (PCRs) for Construction Products, compliant with the European standard EN 15804: 2012 +A2:2019 (Sustainability of construction works-Environmental Product Declarations-Basic Product Category Rules for Construction Products), valid at the access date of 14 December 2020; the 8 c-PCRs currently existing, and to be used in addition to this document for the relevant product categories, shown in Table 2, and the 11 c-PCRs currently under development.

The IBU-EPD has developed 105 PCR divided into three large groups called 01) basic materials and precursors, 02) building products, 03) building services engineering, in which we can find some subgroups. For example, group 01 Basic materials and precursors includes 4 subgroups named 'Aggregates', 'Cement, building limes and other hydraulic binders', 'Other basic materials and precursors', and 'Products related to concrete, mortar and grout'. Within the subgroups, one finds the PCRs of the materials, as shown in Table 3. It should be noted that some materials with the same PCR are found in the same subgroups, which is a useful expedient to facilitate searching within the database; among others, we mention bulk granulate, both in the subgroups "Aggregate" and "Products related to concrete, mortar and grout".

5 The Case Study

Further analysis has been carried out on the LCA found in the EPDs of the material called autoclaved aerated concrete —of which, for confidentiality reasons, the manufacturing companies are not mentioned (see: www.ibu-epd.com; www.environdec.com)—developed by the two programmes (Tables 4, 5 and 6). Specifically, EPD developed by the International EPD® System based on the PCR '2012:01—Construction products and construction services 2.2', while the one developed by IBU-EPD is based on PCR 'Aerated concrete'. Both documents describe the field and objective of the LCA and establish the parameters for the assessment of the environmental performances necessary for the development of an EPD. What immediately seems clear is the different limit of the system used in the two cases. In the case of the EPD developed by the International EPD® System, the mentioned limit is cradle to gate with Options, related to Module A1–A3 (product stage) and Module C4 (Disposal) while in the case of the IBU-EPD the life cycle assessment refers to a cradle-to-gate analysis, therefore exclusively related to Module A1A3 (Product stage).

Table 2 PCR e sub-PCR developed by the International EPD® system (Access 14 December 2020)

PCR	Sub-PCR
PCR 2019: 14 construction products (EN 15804:A2)	c-PCR-001 cement and building lime
	c-PCR-002 ceramic tiles
	c-PCR-003 concrete and concrete elements
	c-PCR-004 resilient, textile and laminate floor coverings
	c-PCR-005 thermal Insulation products
	c-PCR-006 wood and wood-based products for use in construction
	c-PCR-007 windows and doors
	c-PCR-008 lifts (elevators)

Table 3 PCR and sub-PCR developed by IBU-EPD (Access 14 December 2020)

01 basic materials and precursors		PCR
	Aggregates	– Natural aggregates – Bulk granulate – Processed fly ash
	Cement, building limes and other hydraulic binders	– Cement
	Other basic materials and precursors	– Synthetic carpet yarns – Synthetic granulate – Rare earth oxides, metals, alloys and compounds
	Products related to concrete, mortar and grout	– Bulk granulate – Concrete admixtures

Table 4 Environmental impact of the autoclaved aerated concrete. EPDs developed by the International EPD® System and by the IBU-EPD (Access 14 July 2020)

Autoclaved aerated concrete Environmental impact						
Parameters	Unit	International EPD® system				IBU-EPD
		A1	A2	A3	C4	A1–A3
Global warming potential (GWP)	kg CO_2 eq	159	4.59	32.5	2.80	167.00
Acidification potential (AP)	kg SO_2 eq	332×10^{-3}	19.0×10^{-3}	90×10^{-3}	16.0×10^{-3}	1.83E−1
Ozone depletion potential (ODP)	kg CFC 11 eq	5.18×10^{-6}	851×10^{-9}	2.10×10^{-6}	716×10^{-9}	1.62E−10
Eutrophication potential (EP)	kg PO_4^{3-} eq	86.5×10^{-3}	4.32×10^{-3}	35.8×10^{-3}	5.99×10^{-3}	2.33E−2
Formation potential of tropospheric ozone (POCP)	kg C_2H_4 eq	19.6×10^{-3}	761×10^{-6}	6.52×10^{-3}	914×10^{-6}	1.68E−2
Abiotic depletion potential—elements	kg Sb eq	48×10^{-6}	8.12×10^{-6}	27.1×10^{-6}	2.52×10^{-6}	4.48E-4 ?
Abiotic depletion potential—fossil resources	MJ, netcalorific value	736	69.9	493	60.7	1.00E + 3
Water scarcity potential	m^3 eq	611	0.521	63.9	2.93	NOT PRESENT

Table 5 Use of resources of autoclaved aerated concrete. EPDs developed by international EPD® system and by the IBU-EPD (Access 14 July 2020)

Autoclaved aerated concrete Use of resources						
Parameters	UNIT	International EPD® system				IBU-EPD
		A1	A2	A3	C4	A1–A3
Primary energy resources—renewable TOT	MJ, net calorific value	51.3	0.907	588	1.60	3.63E+2
Use as energy carrier	MJ, net calorific value	51.3	0.907	588	1.60	1.98E+2
Used as raw materials	MJ, net calorific value	0	0	0	0	1.65E+2
Primary energy resources—Non-renewable TOT	MJ, net calorific value	839	75.4	560	65.5	1.09E+3
Use as energy carrier	MJ, net calorific value	839	75.4	560	65.5	1.02E+3
Used as raw materials	MJ, net calorific value	0	0	0	0	6.87E+1
Secondary material	kg	0	0	0	0	0.00
Renewable secondary fuels	MJ, net calorific value	0	0	0	0	0.00
Non-renewable secondary fuels	MJ, net calorific value	0	0	0	0	0.00
Net use of fresh water	m^3	207	4.26	112	3.11	2.47E−1

Table 6 Waste production and output flows of autoclaved aerated concrete. EPDs developed by the International EPD® system and by the IBU-EPD (Access 14 July 2020)

Autoclaved aerated concrete Waste production and output flows						
Parameters	Unit	International EPD® system				IBU-EPD
		A1	A2	A3	C4	A1–A3
Waste production						
Hazardous waste disposed	kg	–	–	0.092	–	4.02E−6
Non-hazardous waste disposed	kg	–	–	0.215	385	1.45E+1
Radioactive waste disposed	kg	–	–	–	–	3.21E−2
Output flows						
Components for reuse	kg	–	–	0	0	0.00
Material for recycling	kg	–	–	0	0	0.00
Materials for energy recovery	kg	–	–	0	0	0.00
Exported energy, electricity	MJ	–	–	0	0	0.00
Exported energy, thermal	MJ	–	–	0	0	0.00

6 Discussions

The case study allows underlining the difficulty of comparing materials of the same type, in this specific case autoclaved aerated concrete, highlighting the system boundaries used (also because the case study is not an exception). We can compare only the results of the modules common to both (for this comparison we refer to the following study, since in this paper we have focused only on the comparison of the system boundaries), without being able to examine the others used only by one of the EPDs, a limit that makes an exhaustive and well-founded comparative evaluation difficult.

One of the basic characteristics of the EPD is the possibility of comparing the environmental aspects of the evaluated products, as in the examination of the case studies. However, as it is highlighted in this paper, this can happen correctly only if the same system boundaries are taken into consideration. Despite the efforts dedicated to the standardization of the declaration rules, especially with the implementation of EN 15804, this aspect must be considered more carefully.

Therefore, EPDs can be an important starting point to develop a new approach towards the project. They can have a significant influence on the evolution of environmental awareness in the building industry, calling design to define technical-building choices with a more sustainable environmental and energy profile, but mostly giving, in every decision-making step, a central role to the environmental impact of the entire life cycle of materials, components and building systems. At the same time, the EPDs can be an excellent lever both for greater and more aware qualifications of designers and companies and for the economy of the sector in increasing the turnover thanks to eco-friendly investments. If this tool was already used in the design stage it would produce a paradigm shift—not immediate and rather complex due to the number of subjects involved and the large amount of information to find and to consider—to change the way of considering materials: from things (products and technologies) to systems (parts linked to each other and to the surrounding environment) conceived throughout their entire life cycle. In addition to the performance, technical and aesthetic characteristics, environmental parameters such as the embodied energy and the embodied carbon, environmental impacts (for example through EPDs) and the possible effects on public health (for example through the health product declarations) and, obviously, the economic effects (Arroyo et al., 2012) would support the decision-making stage. Everything would be organized systemically through software that finds valid operational support in the building information modelling (BIM). The challenge is on.

7 Conclusions

The current regulatory framework (Regulation 305/2011/UE on construction products, ZEB directive, CEN standards, GPP, etc.) and the many operational tools available (environmental assessment protocols, EPD certification, etc.), fostered by different bodies and born in different contexts and with different purposes, although worthy of having started a sustainability programme in building, they often appear in competition/conflict, generating confusion and disorientation amongst stakeholders. The environmental subject is often dealt with in a fragmentary way through the breakdown into sub-themes that leads to seek the optimization of some aspects to the detriment of others, without a systemic approach. One of the environmental certification tools that the building sector can use to address the environmental issue and to communicate the environmental performance of its materials and components but also to convey the process and product innovation, as reported in this paper, can be supplied by the environmental product declaration, regulated by ISO 14025 (2006).

The need to be more transparent on environmental information (Campioli & Lavagna, 2013) is mandatory and can no longer be avoided, and in this regard, the increase of EPDs published over the last few years underlines this aspect.

Amongst the subjects that can benefit from it, we include the producers, who can transparently declare the environmental performance of their products, the designers, who can select material also based on its environmental profile, and the users, whose purchases can be more informed and respectful of the environment. Since it is a voluntary-based tool, understanding the reasons that can push manufacturers to use it is important. According to a study published in 2016 (Ibáñez-Forés et al., 2016), 80% of producers state that the greatest limitation of the EPD lies in the fact that many users still do not know this tool, while its strength lies in the objectivity of the results reported and in the fact that using this tool improves the image of the company. Therefore, the dissemination of EPDs has not to be taken for granted because, on the one hand—to paraphrase Sinopoli and Tatano (2002)—the tool is taken in slowly before being able to change long-established practices, on the other, it must deal with limited knowledge or reticent professionals.

In Italy, an important boost to the spread of EPDs may come from the National Action Plan on Green Public Procurement (NAPGPP) with which the Ministerial Decree of 11 October 2017 made the Minimum Environmental Criteria (CAM) for public works operational (MATTM, 2017). These criteria establish the percentages of recovered or recycled materials, which can also be certified through a Type III Environmental Product Declaration. Actually, two recent surveys on the implementation of CAM—in the first (short) period of reference—do not show a prompt response from the Public Administration: the first survey reports that in 2017 out of a sample of 40 municipalities that organised 119 building-related tenders, only 6 (5%) included CAM among the project requirements (Punto 3 and Associazione dei Comuni Virtuosi, 2018); the second survey, conducted by Legambiente's Green Procurement Observatory on a sample of 54 administrative centres, reports a slightly higher percentage of 7. 1% (Nuova Ecologia, 2018). Both data are definitely not satisfactory, but we must take into account that we are in a transition stage in which, despite the contract law explicitly refers to the use of CAMs, their implementation clashes with the lack of preparation of the technical offices on handling them while evaluating the offers (since there are no official price lists or reference analysis) and with the necessary revision of the economic frameworks of the already planned works.

'Innovative', 'advanced', 'nanostructured' or 'resilient' are adjectives expressing a change referred to new ways to create and develop materials, components and building systems that today must necessarily be 'eco-friendly', for which the project can be a great driver, provided that its potential is understood and its effectiveness optimized (Lucarelli et al., 2012). The complexity of the building system—due to the relationships between the different sub-systems and between them and the whole building—requires accurate and detailed planning, capable of optimizing at the same time technologies that are very different (Campioli, 2011, p. 64) towards a single purpose: the sustainability of the 'building system'. Maria Chiara Torricelli has the same opinion (2017, p. 24), as she states: "The acceleration in technological innovations from other scientific and industrial areas has shifted the role of technological skills from those who systematize and design technology to those who know how to interpret it, finalize it, use it and make it work in the complex system of the design".

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