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To cite this article: M Signorini *et al* 2019 *IOP Conf. Ser.: Earth Environ. Sci.* **296** 012028

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Integrating environmental sustainability indicators in BIM-based product datasheets

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Abstract. This paper presents the findings of a research study conducted with the aim of assessing the effectiveness and completeness of the environmental sustainability indicators at national and international level. The need is to clarify the various constantly evolving regulations for sustainability in the construction sector and to have a unique list of indicators mixing the several existing approaches. Starting from the main regulations on sustainability of construction works, the research outlines the required environmental indicators. Since the construction sector is considered one of the most impacting from an environmental point of view, a great attention is given to the creation of a user friendly tool to collect and store different sustainability indicators to support design choices and to increase the awareness of construction and manufacturing companies and end users. Nowadays manufacturers use EPD (Environmental product declaration), which is regulated by the European Standard EN 15804: 2014 and at the same time by the International ISO 21930: 2017, as an environmental certification and communication tool by which they can declare the environmental performance of their products through the use of specific indicators. After analysing the actual European and International regulations about the sustainability of construction works, the draft of the European standard has been examined in order to compare the used indicators and create an integrated and complete version of product data template in order to collect all of these parameters. Furthermore, the Ministerial Decree of April 10, 2013 has introduced the so called CAM (Italian acronyms for Minimum Environmental Criteria) - made mandatory by Legislative Decree 20/2016 Procurement Code, amended by Legislative Decree 56/2017 - in order to give the general criteria and technical indications required by tin Italy to help the public administration to identify and choose among several works and products those with a lower environmental impact. The paper shows an integrated BIM-based template to be adopted for product datasheets that can be exploited by manufactures, designers, facility managers and consumers in order to ease the information exchange about environmental impacts.

1. Introduction

Every intervention in construction can cause serious consequences on a global scale on the environment and therefore on populations. Consumption of earth's limited resources and climate change have become central in the public debate. The word "sustainability" is usually associated to renewable fuel sources, reducing carbon emissions, protecting environments and a way of keeping the delicate ecosystems of our planet in balance. In short, sustainability looks to protect our natural environment, human and ecological health, while driving innovation and not compromising the way of life [1].



The environmental sustainability topic is also connected to the construction sector because of two main reasons: on the one hand the fact that the sector is the principal responsible of impacts on the environment and on the other hand the fact that men want to live comfortable and healthy buildings.

The construction sector is one of the main characters within the environmental issue because it exploits non-renewable material resources, it is responsible of the high energy consumption during all the life cycle and it produces a great amount of waste material [2]. According to 2010 data, 45% of world energy and 50% of water are used by buildings. Looking at environmental effects, 23% of air pollution, 50% of greenhouse gas production, 40% of water pollution and 40% of solid waste in cities are environmental problems caused by buildings [3].

To build means generating impacts on the environment not only during the construction phase, but also during all the process from the provision of raw materials, production and transport to the dismantling of the building and disposal of waste

Since the impact of the construction sector on the environment is so relevant and it isn't limited to a specific phase of the life cycle of the product or component, the approach of the Life Cycle Assessment (LCA) methodology is used due to its ability to determine the sustainability of a material evaluating it during its whole life cycle from extraction of raw materials to its disposal (substantially from cradle to grave approach).

In order to monitor the environmental impact and other detailed impact categories, the presence of indicators is essential. The environmental sustainability indicators are the starting point in order to assess a reduction or an improvement of the environmental impact of the system or substantially the condition of a system from a specific point of view.

In this regard, many regulations at national, European and international level treat the sustainability topic in the construction sector, trying to give a common framework to follow. The EN 15804:2012 + A1:2013 [4] is the European regulation about the sustainability of construction works: it provides core product category rules (PCR) for Type III environmental declarations for any construction product and construction service. Simultaneously, at international level the ISO 21930:2017 [5] is the reference for the sustainability in buildings and civil engineering works, containing the core rules for environmental product declarations of construction products and services. Within the two regulations, several indicators as a measure of the environmental impact are reported and they should be considered by producers, who use the EPD or the Environment Product Declaration to communicate transparent and comparable information about the life cycle environmental impact of a product [6].

Moreover, at national level in Italy, the art. 34 of the Legislative Decree 50/2016 - New Procurement Code requires the insertion of the technical specifications and contractual clauses contained in the minimum environmental criteria (CAM) adopted by decree of the Minister for the Environment [7] in the design and tendering documentation for any kind of public contracts in order to enhance the principle of sustainable development. CAM for building sector are general criteria and technical indications to help the public administration identifying and choose among several works and products those with a lower environmental impact.

It is fundamental to have a common way to measure the sustainability other than support it through an appropriate behaviour. If the instrument used to calculate is the same for everyone, for every manufacturer or designer, it could be easier also the comparison among products to choose the best one in terms of environmental performance.

2. The environmental declaration of building products

The Environmental Product Declaration (EPD) is a type III eco-label seen by companies and producers as a tool to communicate objective, comparable and plausible information related to the environmental performances of products and services throughout their lifetime [8]. The performances reported in the EPD shall be based on the Life Cycle analysis according to the regulation of ISO 14040:2006 series [9], a methodological fundament which the objectivity of information comes from. Unlike the other labels, it conveys objective technical information on the environmental performance offered by the product, providing quantitative data (therefore comparable) on the environmental profile calculated according to the LCA method, as regards the identification, quantification and evaluation of environmental impacts.

Since it facilitates the comparison, it is particularly useful for designers and manufacturers when selecting materials and products to be used in the construction of a building. As a consequence, it promotes a choice based on the best relationship between reduction of environmental impact and market price. By the publication of the EPD the companies have a clear, transparent way to inform the market of the environmental impact of a product or service.

The EPD is regulated by the European Standard EN 15804:2012+A1:2013 and at the same time by the International ISO 21930:2017. The ISO 21930:2017 “Sustainability in buildings and civil engineering works - Core rules for environmental product declarations of construction products and services” is an International standard that concerns with the impacts and environmental aspects of construction products and that is intended to describe the principles, requirements and structure of the environmental declaration of type III of construction products, in order to give uniformity of the means, modalities and to guarantee the transparency, coherence and scientific solidity of the methodology with which we reach the environmental declaration. However, at European level the UNI EN 15804:2014 “Sustainability in buildings and civil engineering works – Environmental product declarations – Core rules for the product category of construction works” which has been transposed as a national standard by UNI, defines the framework rules for each product category (PCR) applicable to all construction products and services. It provides the structure capable of ensuring that all EPDs are processed, verified and communicated according to a harmonized format.

In order to create a more complete version of the actual environmental indicators, the actual European and International regulation about the sustainability of construction works (UNI EN 15804:2014, ISO 21930:2017), the draft of the European standard (UNI EN 15804:2014+A1/prA2) [10] too have been examined and compared.

3. Environmental indicators

Since an indicator is a quantitative, qualitative or descriptive measure representative of an aspect of a construction work or product that impacts one or more areas of protection, it shall represent aspects of the specific construction product that have a potential impact on protection areas of sustainable development. The principal areas of interest for this research study are ecosystems, natural resources, health and well-being. The main aspects of a construction product that are seen as having an impact on the areas of protection are categorized as emissions to air, use of non-renewable resources, fresh water consumption, waste generation, change of land use, etc. [11].

3.1. Indicators describing environmental impacts

A first indicators' category based on the LCIA (Life Cycle Impact Assessment) is the one of those indicators describing environmental impacts. In the Table 1 the indicators representing the first category according to the international standard are represented and in the Table 2 the ones according to the draft of the European standard.

Table 1. Indicators describing environmental impacts according to ISO 21930:2017.

Core mandatory impact indicators	Unit of measure
Global warming potential (GWP)	kg CO ₂ eq.
Depletion potential of the stratospheric ozone layer (ODP)	kg CFC11 eq.
Eutrophication potential (EP)	kg SO ₂ eq.
Acidification potential of soil and water sources (AP)	kg PO ₂ eq.
Formation potential of tropospheric ozone (POCP)	kg C ₂ H ₂ eq.
Additional optional impact indicators	Unit of measure
Abiotic depletion potential for non-fossil mineral resources (ADP elements)	kg Sb eq.

Table 2. Indicators describing environmental impacts according to EN 15804:2014+A1/prA2: 2017.

Core environmental impact indicators	Unit of measure
Global warming potential (GWP)	kg CO ₂ eq.
GWP fossil	kg CO ₂ eq.
GWP biogenic	kg CO ₂ eq.
GWP land use and land use transformation	kg CO ₂ eq.
Depletion potential of the stratospheric ozone layer (ODP)	kg CFC11 eq.
EP terrestrial	Mol N eq.
EP freshwater	kg PO ₄ eq.
EP marine	kg N eq.
Acidification potential of soil and water sources (AP)	kg PO ₂ eq.
Formation potential of tropospheric ozone (POCP)	kg C ₂ H ₂ eq.
Abiotic depletion potential for non-fossil mineral resources (ADP elements)	kg Sb eq.
Abiotic depletion potential for fossil resources (ADP fossil fuels)	MJ
User deprivation potential (water)	m ³ world eq. deprived
Additional environmental impact indicators	Unit of measure
Potential comparative toxic unit for humans	CTUh
Potential comparative toxic unit for ecosystems	CTUe
Potential soil quality index	Dimensionless
Potential incidence of disease due to PM emissions	Incidence of disease
Potential human exposure efficiency relative to U235	kBq U235 eq.

Comparing with attention the two tables, it is possible to underline the following differences: first of all, within the core environmental impact indicators, the EN 15804:2014+A1/prA2: 2017 considers the “Total global warming potential (GWP)” as the sum of “GWP fossil”, “GWP biogenic” and “GWP land use and land use change”. Furthermore, there are different types of indicators about the eutrophication potential like “accumulated Exceedance, EP terrestrial”, “fraction of nutrients reaching freshwater end compartment, EP freshwater”, and “EP marine”.

Besides, in the EN 15804:2014+A1/prA2:2017 there are two types of “Abiotic depletion potential”: “ADP elements for non-fossil resources” and “ADP fossil fuels for fossil resources” both presents inside the mandatory environmental impact indicators. Furthermore, the “user deprivation potential” is added. Finally, the European standard describes all types of toxicological aspects among the additional indicators while the International one is more general.

3.2. Indicators describing resource use and environmental information

For improved transparency of the environmental performance of construction products description through the environmental impact indicators, four groups of indicators and environmental information based on LCI (Life Cycle Inventory) shall be declared as core indicators and non-environmental information. A second category of indicators is the one describing the use of primary and secondary resources as reported in Table 3 and Table 4.

Table 3. Indicators describing use of primary and secondary resources according to ISO 21930:2017.

Indicators describing use of primary resources	Unit of measure
Use of renewable primary energy excluding renewable primary energy resources used as raw materials (RPR _E)	MJ, net calorific value
Use of renewable primary energy resources used as raw materials (RPR _M)	MJ, net calorific value
Use of non-renewable primary energy excluding non-renewable primary energy resources used as raw materials (NRPR _E)	MJ, net calorific value
Use of non-renewable primary energy resources used as raw materials (NRPR _M)	MJ, net calorific value
Indicators describing use of secondary resources	Unit of measure
Use of secondary materials (SM)	kg
Use of renewable secondary fuels (RSF)	MJ, net calorific value
Use of non-renewable secondary fuels (NRSF)	MJ, net calorific value
Recovery energy (RE)	MJ, net calorific value

Table 4. Indicators describing use of primary and secondary resources according to EN 15804:2014+A1/prA2:2017.

Indicators describing use of primary resources	Unit of measure
Use of renewable primary energy excluding renewable primary energy resources used as raw materials (RPR _E)	MJ, net calorific value
Use of renewable primary energy resources used as raw materials (RPR _M)	MJ, net calorific value
Total use of renewable primary energy resources (primary energy and primary energy resources used as raw materials)	MJ, net calorific value
Use of non-renewable primary energy excluding non-renewable primary energy resources used as raw materials (NRPR _E)	MJ, net calorific value
Use of non-renewable primary energy resources used as raw materials (NRPR _M)	MJ, net calorific value
Total use of non-renewable primary energy resources (primary energy and primary energy resources used as raw materials)	MJ, net calorific value
Indicators describing use of secondary resources	Unit of measure
Use of secondary materials (SM)	kg
Use of renewable secondary fuels (RSF)	MJ, net calorific value
Use of non-renewable secondary fuels (NRSF)	MJ, net calorific value
Net use of fresh water	m ³

Looking carefully at Table 3 and Table 4 there are some elements to take into account: the EN 15804:2014+A1/prA2:2017 standard foresees two indicators describing respectively the “total use of renewable primary energy resources (primary energy and primary energy resources used as raw materials)” and the “total use of non-renewable primary energy resources (primary energy and primary energy resources used as raw materials)” which the ISO, according to Table 3, doesn’t include; then the indicator “Recovery energy” is present only in the ISO. In addition, the EN 15804:2014+A1/prA2: 2017 includes among indicators describing the resources use also the “net use of fresh water” with respect to the ISO that simply classifies it as a mandatory inventory parameter without including it in a specific group. Finally, indicators describing resource use include also the “ADP fossil” according the ISO 21930:2017 with respect to EN 15804:2014+A1/prA2:2017, which has contained with the “ADP for non-fossil resources” within the core environmental impact indicators.

3.3. Indicators describing emissions and removals of biogenic carbon

Another classification can be done grouping indicators describing the emissions and removals of biogenic carbon. In fact, bio-based materials originating from renewable resources (such as wood, linseed oil, cork or bio-based polymers) contain biogenic carbon. The mass flows to and from nature and biogenic carbon removals and emissions throughout the product system shall be reported as a flow of biogenic carbon expressed in CO₂ in the LCI. When entering the product system (i.e. a flow to the technosphere from nature), the biogenic carbon flow shall be characterized in the LCIA with $-1 \text{ kg CO}_2\text{e/kg CO}_2$ of biogenic carbon in the calculation of the GWP, since it represents a removal of carbon that is part of the carbon cycle of bio-based materials. When this bio-based material, partly or as a whole, is converted to emissions, for example, by combustion or biodegradation, the flow shall be characterized with $+1 \text{ kg CO}_2\text{e/kg CO}_2$ of biogenic carbon in the calculation of the GWP.

According to the two standards, biogenic carbon contained in bio-based materials (as material in product, packaging or fuel) shall be declared as kg C per functional unit or declared unit for:

- the removal of the greenhouse gas CO₂ from the atmosphere incorporated/sequestered by bio-based materials used in the product system under study;
- the emissions of biogenic carbon as CO₂, CH₄ etc., to the atmosphere originated by bio-based materials used in the product system under study. The declared inventory data of emissions shall be aggregated across different substances (CO₂, CO, CH₄, etc.);
- biogenic carbon entering the product system from a previous product system as a negative transfer;
- biogenic carbon leaving the product system to the next product system as a positive transfer;
- biogenic carbon remaining in landfill after 100 years since deposition as a positive transfer.

Table 5. Indicators describing emissions and removals of biogenic carbon.

Indicators describing emissions and removals of biogenic carbon	Unit of measure
Biogenic carbon (C) contained in bio -based materials used in the product system under study describing removals of greenhouse gas CO ₂ from the atmosphere	kg C
Biogenic carbon (C) contained in bio -based materials used in the product system under study and released to the atmosphere	kg C
Transfer of biogenic carbon (C) contained in bio-based materials from a previous product system to the product system under study	kg C
Transfer of biogenic carbon (C) contained in bio-based materials from the product system under study to the next product system	kg C
Biogenic carbon (C) contained in bio-based materials used in the product system under study and remaining in landfill after 100 years since deposition	kg C

Although these indicators enhance the transparency on different contributions to the GWP in each module, they are considered as contributions to the GWP calculation.

These are the indicators about biogenic carbon emissions that the European and the International standards have in common. In the classification of indicators describing CO₂ emissions reported by ISO, there are two other parameters: the CO₂ from calcination and carbonation and the emissions from land use change, which are respectively the GWP fossil and GWP land use and land use change. These last two indicators are considered, according the EN 15804:2014+A1/prA2:2017, among the core environmental impact indicators in addition to the GWP biogenic as the sum of the total GWP.

3.4. Indicators describing waste categories and output flows

The fourth and fifth categories of indicators are respectively the ones describing waste categories and other material flows. They are output flows derived from the LCI and they are reported in Table 6 and in Table 7.

Table 6. Indicators describing waste categories according to ISO 21930:2017.

Indicators describing waste categories	Unit of measure
Hazardous waste disposed	kg
Non-hazardous waste disposed	kg
High-level radioactive waste	kg (or m ³)
Intermediate and low-level radioactive waste	kg (or m ³)

In this case, the only difference between the standards is the fact that the EN 15804:2014+A1/prA2:2017 does not do a distinction between high, intermediate or low radioactive waste but generally considers as indicator the radioactive waste disposed.

Table 7. Indicators describing output flows.

Indicators describing output flows	Unit of measure
Components for re-use	kg
Materials for recycling	kg
Materials for energy recovery	kg
Exported energy	MJ, net calorific value

There are no differences between the two standards concerning this group of indicators.

4. Minimum environmental criteria

Even at national level, standards or regulations are present in order to monitor or sustain the sustainable development. In Italy, for instance, there are the so called “CAM”, which are the Minimum Environmental Criteria. The Minimum Environmental Criteria are the environmental requirements defined for the various phases of the purchasing process, aimed at identifying the design solution, the product or the best service from an environmental point of view along the life cycle, taking into account the availability of the market.

CAM envisage requirements that direct the public administration towards a rationalization of consumption and purchases and provide "environmental considerations", linked to the different stages of the tendering procedures, aimed at qualifying the supplies from a point of view of environmental sustainability throughout the entire service/product life cycle.

The integration of environmental aspects into the purchasing process is based on an overview of the whole Life Cycle Cost (LCC) of a good/service/work, thus allowing to take into consideration not only

the aspects attributable to design, production, use and disposal (whole life cycle), but also the actual costs for the community.

In Italy, the effectiveness of the CAM has been ensured thanks to the art. 18 of Law 221/2015 [12] and, subsequently, to art. 34 on "Energy and environmental sustainability criteria" of Legislative Decree 50/2016 Procurement Code - modified by Legislative Decree 56/2017 [13] which made it mandatory for all contracting authorities to apply.

In recent years, many studies have investigated the environmental issue in the construction sector, providing the designer with useful design criteria to reduce the impact on the environment. The legislator also provided an important indication on this by introducing the Minimum Environmental Criteria (CAM) for Construction adopted with the Ministerial Decree of January 11, 2017 [14].

The CAM Construction document contains some general indications that consist of references to the relevant legislation and further indications proposed to the contracting authorities in relation to the completion of the related tender and the execution of the contract.

The main objective is therefore to provide all the actors of the building process with guidelines to reduce the environmental impact, from the project to the construction, facilitating monitoring activities and facilitating potential bidding companies, as they make immediately evident the environmental characteristics required by the contracting authority.

Basic criteria such as energy performance, the ability to apply environmental management measures or reward criteria in relation to the improvement of the environmental performance of the building, the use of renewable materials, the distance of supply of products and the technical skills of the designers are expected in CAM.

4.1. CAM common to all building components

In order to reduce the environmental impact on natural resources, to increase the use of recycled materials increasing consequently the recovery of waste (coherently with the goal to recover and recycle at least the 70 % of not hazardous construction and demolition waste by 2020), the project of a building shall respect the following criteria common to all building components:

- Disassembly
- Recovered or recycled substances
- Ozone-damaging substances
- Hazardous substances

The designer must make technical project choices, specify the information about the environmental requirements of the products chosen and to provide the technical documentation to meet these. He must also prescribe that during the supply phase the contractor will have to make sure the compliance with these common criteria through the documentation indicated in the verification of each criterion.

4.2. Specific CAM for building components

Finally, in order to reduce the use of non-renewable and to improve the waste recycle, with special attention to demolition and construction waste, the project shall respect the materials use as specified in the following criteria, the so-called specified criteria for building components.

- Concretes packed in construction site, pre-packaged and prefabricated
- Bricks
- Sustainability and legality of wood
- Cast iron, iron, steel
- Plastic content components
- Masonry in stones and mixed
- Partitions and false ceilings
- Thermal and acoustic insulations
- Floors and coatings
- Paints and varnishes

5. Results: integration proposal

After analysing the different regulations concerning the environmental indicators, in particular the ISO 21930:2017 and the UNI EN 15804:2014, the main differences, if present, between the two regulations have been reported in order to highlight some useful indicators not present in the sustainability indicators datasheet yet. In addition, we have compared the indicators present in the UNI EN 15804:2014+A1/prA2:2017 with respect to the default indicators characterising all the EPDs that nowadays are present in the building market. The actual datasheet doesn't comprehend some of the indicators that the European standard actually in approval foresees.

Once discovered the sustainability background, the next step consisted in developing a new integrated products datasheet according to the UNI 11337-3:2015 [15].

In the Figure 1 below, it is possible to see the capture of the several pages of product datasheet according to UNI/TS 11337-3: 2015 model with the indicators - highlighted in green – that were added according to the UNI EN 15804:2014+A1/prA2: 2017 and ISO 21930:2017, including also generic CAM thanks to the above described research activity.

Figure 1. Captures of UNI/TS 11337-3: 2015 Product datasheet

6. Conclusion

In conclusion, the work started from the analysis of the principal regulations about the sustainability of construction works in order to define which are the environmental indicators requested. In particular the regulations analysed are the European standard EN 15804:2012+A1:2013/prA2:2017 a regulation that is actually in approval; in fact, the current regulation is the UNI EN 15804:2014 and the International standard ISO 21930:2017.

Furthermore, we focused our attention also on another element always more important at national level: CAM (Italian acronym for “Criteri ambientali minimi”, which means minimum environmental criteria). CAM are technical indications that help the public administration make purchases, highlighting products, services and works that produce a lower environmental impact. They are defined as “minimum” environmental criteria because they require a level that should be able to satisfy at the same time the requests of the market and answer to environmental objectives that the public administration wants to achieve through public contracts. There are different types of CAM, but we analyse CAM for the construction sector – Assignment of design services and works for the new construction, renovation and maintenance of public buildings- approved with DM 11 October 2017.

The work has brought to a collection of information about environmental indicators and the definition of a list of indicators that merge those from the European and International standards together with CAM for buildings. The result of this research activity has contributed on a proposal for integration of the sustainability part of the product datasheet indicated by UNI 11337-3: 2015.

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