Green Public Procurement and Construction Sector: EPD and LCA Based Benchmarks of the Whole-Building

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Abstract The paper discusses the possible use of Life Cycle Assessment (LCA) and Environmental Product Declarations (EPDs) in European and Italian Green Public Procurement (GPP) for the building sector, in order to define targets based on objective and reliable building environmental impacts information. The research objective is to define how to set LCA benchmarks towards the improvement of GPP requirements. The study analyses the GPP criteria based on LCA in Europe with a focus on Italy; it proposes LCA benchmarks for selected groups of construction materials and scenarios for the implementation of LCA benchmarks related to buildings elements and whole-buildings. It also illustrates how public administrations can verify the GPP criteria achievement using EPDs.

1 Introduction

Life Cycle Assessment (LCA) practice is increasing in the construction sector to evaluate the environmental sustainability of buildings. Generally, the definition of the better environmental profile between buildings providing a similar function is performed through the simple comparison of the LCA impacts results. This approach should be completed by objective LCA-based environmental benchmarks (reference values) to be set, which can be used for setting sustainable construction and production targets. Environmental LCA-based benchmark values are used in several Green Building Rating Systems (GBRSs) and in buildings energy certifications. In these certifications (such as LEED, BREEAM, Verde, Green Star,

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Minergie, etc.) the LCA benchmarks are not performed on a common basis, inducing the consideration of different repositories for each, making the comparison of different LCA-based benchmarks impossible for the building sector. The benchmarks used in these certifications are often established from the statistical analysis of LCA data obtained from a reference buildings sample with specific environmental performances [1, 2], or from a reference building modelled according to national standards and prescriptions [3–5].

Considering the lack of a common framework for setting environmental sustainable targets for the construction sector, the present study aims at presenting a new benchmarking approach, fixing LCA-based benchmark "code of practice" for construction materials, building elements and whole-building. LCA benchmark values can improve European and Italian Green Public Procurement (GPP) criteria required for the construction sector, and it can also support stakeholders with sustainable construction strategies and improvement of buildings environmental performances. It could also support the GPP verification process made by public administrations.

The study is divided into four sections. First, the use of LCA in the GPP for buildings is examined, illustrating which EU Members have already included LCA approach and consideration of Environmental Product Declarations (EPDs) in the national GPP. Second, the benchmarking methodology and the environmental benchmarks related to building materials are illustrated, as well as the proposed EPD-based verification process for the contracting authorities. Finally, the approach used to set LCA-based environmental benchmarks for building elements and whole-buildings is explained.

2 LCA Data, EPDs and GPP in Europe

This section investigate the possibility to introduce LCA in GPP criteria for the construction sector, through the analysis of GPP requirements from the EU Commission. The EU Nations are encouraged to draw up National Action Plans (NAPs) for reducing environmental impacts from public tenders managed by contracting authorities and the associated procurements of goods, services and works. GPP criteria for buildings are often developed in NAPs, including environmental design and planning strategies in the national political framework. GPP is a voluntary instrument, aiming at stimulate the market demand for more sustainable goods and services. LCA-based criteria are required in the optional EU-GPP for "Office Building Design, Construction and Management" [6], including the environmental evaluation of impacts during all the stages of the buildings life cycle (production of materials and elements, construction, use stage and end of life), promoting the application of a cradle-to-grave LCA. In GPP requirements for buildings, the promotion of energy efficiency and the use of products with a specific percentage of recycled content material are also integrated. There is only one LCA-based indicator required in GPP for new office buildings

which is the total amount of Global Warming Potential (GWP) for the building whole-life. It can be partly calculated by practitioners through the aggregation of EPDs results for the main building elements (foundations and substructures, structural frame, external walls, floors and ceilings, internal walls, windows and roofs), and/or based on a complete cradle-to-grave LCA. The LCA and use of EPDs provide a quantitative assessment of the building environmental performances, however, the comparability between two options remains sensitive even if the EPDs are compliant with the related existing standards and Product Category Rule (PCR).

The use of GPP for buildings in European Nations has been investigated (Table 1), analysing the use of the LCA approach in GPP criteria and the related use of EPDs for the LCA in order to understand how the environmental products labels are used by contracting authorities to verify the GPP criteria achievement.

For each EU member State, Table 1 shows the presence of National Action Plans (NAP), the adoption of GPP for buildings, the use of the Life Cycle Assessment (LCA) and the use of Environmental Product Declarations (EPDs).

Table 1 shows a restricted view of the use of LCA and EPDs in GPP for buildings, however the information found is useful in order to understand how some EU Nations insert environmental criteria in public procurement. Belgium inserts LCA in GPP-Office Buildings criteria using the GBRSs (i.e. LEED and BREEAM) which just involve the life cycle approach in their criteria; Denmark suggests the use of LCA and EPDs for an environmental products comparison; Lithuania introduces the LCA and the Life Cycle Costing as mandatory analysis; Luxembourg introduces voluntary LCA criteria; The Netherlands requires mandatory LCA analysis for groundworks, roads and hydraulic engineering constructions.

The study focused on the Italian GPP requirements for building products, in order to develop propositions for improving environmental sustainability criteria. The new Italian procurement code (Codice degli Appalti) requires compulsory environmental criteria (Criteri Ambientali Minimi–CAMs) to enhance the sustainability process of construction products, of new public and refurbished buildings and of public construction sites management [7]. CAMs criteria are set on three design reference steps: the sustainable site analysis, in which the considered building is located; the buildings technical specifications, which include dynamic energetic simulations, the use of new energy supplies, indoor air quality and comfort and the materials technical specifications, which set the recycled content value for specific material categories.

The CAMs criteria related to the environmental sustainability of building products, do not include LCA. CAMs set mandatory recycled content percentage value for different material categories (i.e. the concrete must contain at least 5% of recycled content on the product's weight, as well as bricks and gypsum plasterboards). The contracting authorities can check the latter criteria achievement with the use of materials environmental performances issued from environmental/energy building certifications (i.e. LEED, BREEAM, etc.) and/or construction products environmental labels (labels type I, II and III). However, the use of EPDs in CAMs is underestimated, despite for the first time the use of EPDs is incentivised.

Table 1 Analysis of GPP-LCA criteria application for buildings in European Nations

Nations	National Action Plans *Provided by "National GPP Action Plans (policies and guidelines)", EU Commission, DG Environment (updated to May 2017)*	GPP Buildings *Collected through the national GPP website*	Life Cycle Assessment *Collected through the national GPP website*	EPDs
Austria	●	●	○	○
Belgium	●	●	●	●
Bulgaria	●	○	n.a.	n.a.
Croatia	●	●	○	○
Cyprus	●	n.a.	n.a.	n.a.
Czech Republic	●	n.a.	n.a.	n.a.
Denmark	●	●	●	●
Estonia	○	○	n.a.	n.a.
Finland	●	●	○	●
France	●	●	n.a.	n.a.
Germany	●	●	○	○
Greece	○	○	n.a.	n.a.
Hungary	○	○	n.a.	n.a.
Ireland	●	u.d.	n.a.	n.a.
Italy	●	●	○	●
Latvia	●	n.a.	n.a.	n.a.
Lithuania	●	●	●	○
Luxembourg	○	●	●	○
Malta	●	●	n.a.	n.a.
The Netherlands	●	●	●	○
Poland	●	○	n.a.	n.a.
Portugal	●	u.d.	n.a.	n.a.
Romania	○	○	n.a.	n.a.
Slovakia	●	u.d.	n.a.	n.a.
Slovenia	●	●	n.a.	n.a.
Spain	●	●	n.a.	n.a.
Sweden	●	●	n.a.	n.a.
Norway	●	●	○	○
Swiss	●	n.a.	n.a.	n.a.
UK	●	●	n.a.	n.a.

Legend
Black circle: present topic
White circle: not present topic
n.a. information not available
u.d. topic under development

Therefore it induced the promotion of EPDs on the market: the manufacturers are encouraged to certify their products in order to compete in public tenders, while the practitioners are stimulated toward environmental strategies choosing certified products. Increasing the use of EPDs in the construction sector could lead to a growth of available transparent LCA data on market and to a possible introduction of LCA benchmarks in CAMs criteria. Moreover, with the LCA benchmarks insertion in CAMs, the EPDs could become simple verification instruments for public administrations.

3 LCA Benchmarks for Construction Products

This section aims at demonstrating how LCA-based benchmark values for construction products can be defined, and how could EPDs be integrated into CAMs criteria in order to facilitate the verification process by the public administrations in charge of analysing different options.

The benchmark values for construction materials developed in this study are fixed for different LCA impact categories and they could be integrated in GPP criteria, in order to set environmental sustainable levels for building products. The benchmarking methodology has been developed after a detailed literature review of five recent studies in which existing environmental benchmarks practices in the construction sector have been applied. The benchmarking methods were all based on the statistical analysis and interpretation of LCA data. In the analysed case-studies, LCA-based benchmarks were related to healthcare buildings in Portugal [8], for school buildings in South Korea [9] and for residential buildings in Italy [12], France [11] and Germany. In order to set LCA-based benchmarks for construction products, a reference sample composed by eight construction product categories was processed, categories are also contained in CAMs criteria (cement, bricks, wood-based materials, steel, gypsum plasterboards, glass wool panels, stone wool panels and ceramic tiles). The sample was made by building materials manufactured and sold in Europe in recent times (after the year of 2010) and it was considered representative of the European production/construction practices. The related LCA data were collected through EPDs, reporting transparent environmental impacts results for each product life cycle phase. The LCA system boundaries considered in this study are the one related to the product stage (LCA modules A1, A2 A3). Thirty-two EPDs were analysed for cement, eight for bricks, eleven for wooden-based materials, forty-five for steel, thirty-one for gypsum plasterboard, fifty for glass-wool panels, fifteen for stone-wool panels and twenty-five for ceramic tiles.

The EPDs collected were taken from European EPD Program Operators: BAU EPD (Austria), IBU (Germany), International EPD® System (Sweden), GlobalEPD (Spain), EPD Denmark (Denmark), DAPHabitat System (Portugal), FDES INIES (France), EPD Italy (Italy) and EPDNorge (Norway). In order to guarantee the comparability and the homogeneity between LCA data from different

national repositories, it was checked that the EPDs were compliant with the European standard EN 15804:2012 "Sustainability of construction works", and that they have mutual recognition between the Product Category Rules (PCRs).

Ten environmental impacts categories were considered: GWP, Ozone Depletion Potential (ODP), Acidification Potential (AP), Eutrophication Potential (EP), Photochemical Ozone Creation (POCP), Abiotic Depletion Potential for Non-fossil resources (ADNP), Abiotic Depletion Potential for fossil resources (ADP0), Total use of Renewable Primary Energy resources (PERT), Total use of Non-Renewable Primary Energy resources (PENRT), and the consumption of Fresh Water (FW). The method applied to set LCA-based benchmarks was a statistical analysis and interpretation of LCA data collected. It allows verification of wrong data (the outliers) and the assessment of the reliability of final results. For each material category and for each environmental impact category, three benchmark values have been set up: the limit value, the reference value and target value. The reference value represents the median value, which is not sensitive to the outliers in a sample composed of a small number of data. The target and the limit value are set using the quartile division of LCA data: the target value is fixed by the 1° quartile, which indicates a value of 25% lower than the median value (it represents the best manufacturing practice); the limit value is fixed by the 3° quartile, which represents a value of 25% higher than the median value (the lowest acceptable value in the evaluation scale).

In Table 2, the benchmarks fix the limit, the reference and the target values of GWP, AP, PENRT and FW.

In Table 2, the negative GWP value observed for wooden products is due to the CO_2 stored in the products, which is released into the atmosphere at the end of use stage. The LCA benchmarks presented in the study are European benchmark values, the LCA benchmarks could be divided and analysed per country, extrapolating single threshold values for each Nation (Fig. 1).

The three LCA-based benchmarks (limit, reference and target values) fix a sustainable range of values for each material group, so the public administration could decide which is the better sustainable level to apply in the public tender requirements. They can then check the GPP criteria achievement, verifying if the LCA data of specific building products (certified with EPD labels) fall into the LCA-based benchmark range.

The LCA benchmarks are based on a limited number of data due to the lack of EPDs and LCA-based data available on the market, despite the number of information published is increasing.

Table 2 LCA-based benchmarks related to 1 kg of eight construction materials

Materials	Limit value	Reference value	Target value
GWP (kg CO_2 eq)			
Brick	2.63E−01	2.56E−01	2.18E−01
Cement	8.49E−01	7.52E−01	6.48E−01
Ceramic	4.89E−01	3.56E−01	3.25E−01
Plasterboard	2.59E−01	2.22E−01	2.12E−01
Glass wool	1.12E+00	1.08E+00	1.06E+00
Stone wool	1.22E+00	1.19E+00	8.86E−01
Steel	1.24E+00	5.46E−01	5.11E−01
Wood fibreboard	−9.81E−01	−1.20E+00	−1.22E+00
AP (kg SO_2 eq)			
Brick	7.32E−04	6.41E−04	5.51E−04
Ceramic	1.81E−03	1.23E−03	7.85E−04
Cement	1.37E−03	1.30E−03	9.98E−04
Plasterboard	6.53E−04	5.03E−04	3.40E−04
Glass wool	8.41E−03	6.31E−03	6.20E−03
Stone wool	1.11E−02	6.73E−03	5.35E−03
Steel	3.18E−03	2.59E−03	1.10E−03
Wood fibreboard	2.10E−03	1.70E−03	1.64E−03
PENRT (MJ)			
Brick	3.53E+00	3.39E+00	2.88E+00
Ceramic	4.96E+00	3.40E+00	2.52E+00
Cement	9.08E+00	7.32E+00	6.77E+00
Plasterboard	4.72E+00	4.09E+00	3.23E+00
Glass wool	3.22E+01	3.13E+01	3.02E+01
Stone wool	1.85E+01	1.71E+01	1.24E+01
Steel	1.50E+01	8.75E+00	8.71E+00
Wood fibreboard	1.09E+01	7.87E+00	6.73E+00
FW (m^3)			
Brick	8.52E−04	6.59E−04	3.66E−04
Ceramic	1.80E−01	1.68E−03	1.06E−03
Cement	3.47E−03	3.16E−03	2.28E−03
Plasterboard	1.33E−03	1.00E−03	8.55E−04
Glass wool	1.82E−02	1.79E−02	1.35E−02
Stone wool	4.42E−03	4.16E−03	3.48E−03
Steel	4.00E−02	3.21E−03	2.62E−03
Wood fibreboard	1.13E−02	3.83E−03	2.32E−03

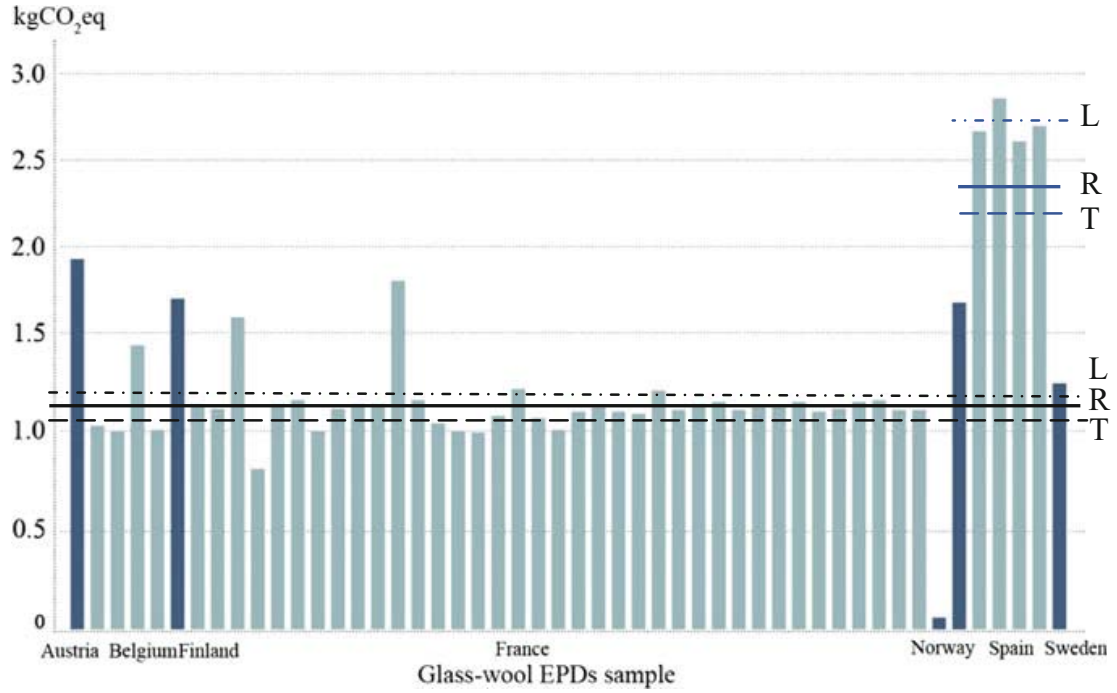

Fig. 1 European GWP benchmarks (black lines) and Spain GWP benchmarks (grey bars) related to 1 kg of glass-wool panel (LCA phases A1–3). *Legend* limit value (L), reference value (R), target value (T)

4 LCA Benchmarks for Building Elements and Whole-Building

The LCA-based benchmarks could also be applied to the main building elements and the whole-buildings in the GPP for buildings and in the CAMs criteria.

LCA benchmark values for the main building elements are already used in the construction sector [13]. According to the main studies analysed from the literature review [8–12], this study tried to define a benchmarking methodology to set environmental LCA-based benchmarks for building elements, explaining the possible methodological processes. The building elements categories to be considered should refer to construction technologies and practices commonly used, in this work four categories were considered: structure frame, floors, roof, external walls and internal walls. The related LCA-benchmarks should be set at least for five different generic building types, which are based on the classification often used in the main GBRSs: commercial buildings, educational buildings, healthcare buildings, residential buildings and retail. The elements analysed should be related to a specific context, recent (after 2010), in order to analyse the construction practices employed in average in the country of concern. According to the national energy parameters, prescriptions and construction practices, a range of similar constructing solutions it is modelled for each building element identified. The data collection for the building elements could be carried out using national databases, where buildings can be selected based on energy and environmental certifications [9, 10],

or through the screening of the calls for tenders [11]. As for materials the LCA data related to each building element should be processed through statistical analysis and interpretation, in order to establish the reference value [10]. The reference study period should be based on 100 years and the LCA system boundaries should be cradle-to-grave. The environmental impacts should be normalised to 1 m^2 of the building element, in order to allow comparison of building elements.

The benchmarking methods could be applied to set LCA benchmarks for whole-buildings. LCA-based benchmarks for the whole-buildings could be fixed through the statistical analysis of the LCA data related to a specific built environment [1, 2, 5] or modelling a reference building starting from national construction standards and prescriptions. The buildings sample should be composed by buildings realised after the year of 2010 and they should belong to a specific construction context, according to the national energy standards and the current construction practices. The buildings analysed should refer to the main five different generic buildings types: commercial buildings, educational buildings, healthcare buildings, residential buildings and retail. The LCA benchmarks should refer to the single building function, avoiding issues linked to building operational energy use and occupations (i.e. the educational buildings have different energy consumption than an office building related to the worktime and equipment use) [14]. The building typologies related to the functions can be divided into building archetypes, according to the specific built environment characteristics (i.e. the residential building could be divided into single-family house, terraced house, multi-family house and apartment block). A reference building should be modelled for each building archetype and each building function, fixing the reference service life (equal to 100 years) and the functional unit (1 m^2 of gross floor area), in order to compare the building environmental performances. The LCA system boundaries for the whole-building benchmark should be cradle-to-grave. Based on a statistical analysis, the median value should be set as the reference LCA benchmark for the whole-buildings [8–12]. As an example the Swedish developer and construction company Folkhem have certified a wooden residential house with the Swedish Program Operator "The International EPD® System": the EPD assesses the life cycle of a Folkhem's concept building, providing objective and reliable information on the environmental impacts of the whole-building. The use of EPDs, as well as the Folkhem's EPD, could be an easy tool for contracting authorities, in order to verify the GPP criteria achievement and to permit an appropriate check of the procurement contract executions.

5 Conclusions

The study proposes a simple benchmarking to set LCA-based benchmarks, incentivising the use of environmental performances values in GPP criteria, in order to facilitate the verification activities of public administrations. In this study, LCA benchmarks for construction products were fixed and an approach to fix building

elements and whole-building benchmarks is articulated. The inclusion of LCA benchmark values in GPP criteria for buildings can stimulate the use and the production of EPDs for the construction market, making available transparent LCA data and facilitating the integration of LCA in the GPP criteria. The EPDs could also be an instrument to verify the GPP criteria achievement by contracting authorities.

The use of LCA-based benchmarks could also be a way to stimulate the building market to reach new environmental sustainability targets.

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