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How Consistent are the Environmental Data in Environmental Product Declarations of Concrete Products? Comparative Analysis of European Data Sources

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Abstract. Given the significant contribution of cement in global greenhouse gas emissions (7%) and its extensive use in the construction sector, reducing its associated emissions has becoming a pressing challenge. However, several challenges are detected to measure and include the environmental impacts, including the embodied carbon emissions, in a harmonised and comparable way. This study provides a detailed analysis of data and information contained Environmental Product Declarations (EPDs) for precast concrete products, examining the approaches used for calculating embodied carbon, focusing on methodological assumptions, including the type of reference unit adopted, as well as system boundaries, life cycle stages, and life cycle scenario assumptions. A comprehensive classification of concrete products and their embodied carbon was conducted out, revealing significant variations in carbon performance among similar products. The findings highlight the urgent need for harmonised standards to ensure comparability across industry-wide and effectiveness of emission reduction strategies.

1. Introduction

The construction sector is responsible for a significant share of greenhouse gases GHG emissions, energy consumption, and raw material use (1). In recent years, in the European context, there has been a growing emphasis on improving environmental transparency and supporting the communication of whole-life cycle carbon emissions of buildings, especially promoted by the recast version of the EPBD (2). The regulation focuses on integrating the assessment of embodied carbon emissions with the already reported operational emissions. This means that the data about embodied emissions of construction materials are being intensively used by the industry and diverse stakeholders involved. Environmental product declarations (EPDs) have emerged as a key instrument for communicating the environmental performance of construction products in a standardised and verifiable manner (3). The EPDs are developed according to standards such as ISO 14025 and EN 15804 (4) and, provide structured information on the environmental impacts of products across various life cycle stages.

Currently, there is a growing tendency to develop this type of declarations (5,6), which are increasingly adopted by the industry. However, from a scientific perspective, ensuring that EPDs are



methodologically consistent and communicate accurate results is crucial for their credibility and for supporting robust, comparable environmental assessments. In this vein, the growing number of studies that focus on its analysis have detected various inconsistencies, discrepancies, and causes of results variations. For instance, studies (7,8) have focused on the analysis of this type of data as a basis for the end-of-life development of LCA of entire buildings, detecting inconsistencies and limitations in the transport to site module (A4). Other studies (9,10) have focused on the statistical analysis of the data included in EPDs that are available in machine-readable format to detect inconsistencies in the datasets. Another recent study (11) focuses on analysing the end-of-life evaluation in the EPD results, identifying the most relevant causes of results variation when modelling the end-of-life impacts.

However, this type of work generally focuses on all kinds of construction products. Nonetheless, Konradsen and Hansen (12) focused on a specific product, such as a triple-glazed window, to address the issue of how the methodological options used in the calculation process can affect the results. This study shows that decisions related to the scenarios definition, data modelling, among others can affect the results of EPDs. Many of them have to do with the specific characteristics of the context for which the EDPs are elaborated, but others not necessarily.

Yet, how do these methodological choices and the differences observed in EPD results affect concrete products? These products play a crucial role in the construction sector and bear significant responsibility in efforts to reduce its associated environmental impacts (13). Existing studies (14,15) have focuses on analysing cementitious products EPDs, highlighting that the main inconsistencies are detected in the combustion of waste in the cement kiln and the allocation of the impact to cementitious co-products. However, previous studies have not addressed the variability in EPD methodologies, system boundaries, and declared units of the concrete products.

To address the existing gaps in this field, this paper presents a comprehensive analysis of EPDs for concrete products from various European programme operators. The study adopts both qualitative and quantitative approaches. The qualitative analysis investigates key methodological choices, including the definition of the reference unit- Declared versus Functional Unit, as well as the delineation of system boundaries and the modelling of life cycle scenarios.

The quantitative analysis focuses on evaluating the environmental impacts reported for the A1–A3 modules-commonly associated with raw material supply, transport, and manufacturing- which generally represent the most significant contributions to the overall environmental footprint of concrete products (16). When available in the EPDs, modules beyond the gate were also evaluated, if declared.

By exploring the range and consistency of EPD data, this research aims to identify patterns, discrepancies, and opportunities for harmonisation in the reporting of environmental impacts across different programmes and product types. The findings contribute to the ongoing efforts to improve the reliability, comparability, and usefulness of EPDs in supporting decarbonisation efforts in construction practices and policy development across Europe.

2. Methods

This study first focuses on identifying existing EPD programmes that support the development of geographically representative EPDs within the European context. The review includes publicly available EPDs valid through at least July 2023. It encompasses EPDs from European programme operators such as Environdec, EPD HUB, EPD Norge, The Building Information Foundation RTS, EPD Italy, EPD Ireland, EPD Denmark, the Irish Green Building Council, ITB EPD Poland, and INIES. The

search targeted concrete products such as concrete blocks, precast panels, beams and columns, floors, pavements, and other related products.

Following the data collection, the information provided in the EPDs was analysed. The study included a qualitative assessment of key aspects, such as the declared unit, system boundaries, and scenarios for transport (A4), installation (A5), use phase including carbonation (B1), end-of-life stages (C1–C4), and benefits beyond the system boundary (D). A quantitative analysis was also conducted, focusing on a comparison of the environmental data for modules A1–A3, which are typically the most impactful. This comparison aimed to determine the variability range in the reported data.

3. Results and Discussion

3.1. Summary of the main findings

The results related to the EPD analysed (Figure 1) show the number of EPD of concrete products included in the study.

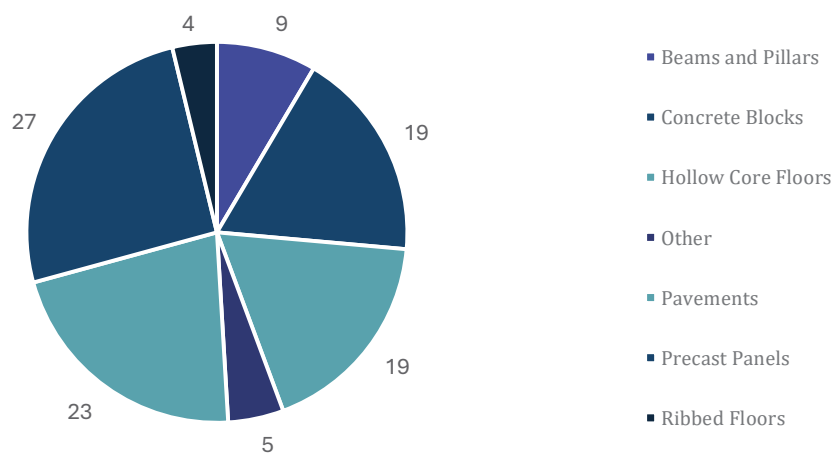


Figure 1. Number of construction product EPDs included in the study.

3.2. Summary of the Qualitative Analysis

Table 1 shows the main results obtained in the data and information collection. The table includes a summary of the most important cases that were detected. In the characterisation of the products included in the assessment, two types of concrete blocks were detected. One type included with insulation and without insulation.

The analysis of the declared unit reveals inconsistencies in the units used for HC floor pavements and RI floors.

As shown in Table 1, the most harmonised products in terms of declared units and system boundaries are predalles slabs and lattice joists, which fall under the “others” category. All these products were assessed using the same Operator programme, ensuring consistency across the analysis.

There are also notable similarities in the transport to site (A4) and concrete carbonation (B1) between beams, pillars, and hollow-core floor elements. However, for the modelling of transport to site (A5), there is a wide variation in distances, reflecting different logistical conditions across

countries. In contrast, the modelling of transport during the end-of-life phase is more consistent across the cases analysed.

Table 1. Summary of the main analysis results.

	Beams and columns	Concrete block	Hollow-core floor	Others	Pavements	Precast panels	Ribbed floor
Unit Declared	1 m ³	1m ² Harmonised	1 ton / 1m ²	1m ²	1m ² / 1 ton	1 ton	1m ² (1 EPD)/ 1 ton (3 EPD)
Operator program	INIES; EPD-HUB; EPD NORGE; Environdec; EPD Italy	INIES, Environdec, DAP Habitat	Environdec; EPD HUB; EPD Denmark IGB ; ITB-EPD Poland, INIES; IBU	INIES	IBU; EPD HUB; EPD Italy; EPD Denmark EPD Ireland; INIES;	Environdec; EPD HUB; EPD Norge; RTS ; EPD Italy ; EPD Denmark; ITB, IBU;	Environdec, EPD HUB, EPD Denmark
System boundaries	A1-A5, B1; C1-C4, D (1 EPD) A1-A5; C1-C4; D (1 EPD) A1-A4; C1-C4, D (1 EPD) A1-A4; C1-C4, (2 EPD) A1-A3; C1-C4 (3 EPD) A1-A4, (1 EPD)	A1-A5, B1; C1-C4 (14 EPD) A1-A5, (5 EPD)	A1-A5, B1; C1-C4, D (6 EPD) A1-A5; C1-C4; D (3 EPD) A1-A4; C1-C4, D (1 EPD) A1-A4; C1-C4, (2 EPD) A1-A3; C1-C4 (3 EPD) A1-A4, (1 EPD)	A1-A5, B1; C1-C4 Harmonised	A1-A3, A5; C1-C4-D (4 EPD); A1-A3, (6 EPD) A1-A5; C1-C4-D (6 EPD); A1-A4; C1-C4-D (2 EPD); A1-A3; C2-C4, D (2 EPD); A1-A4, B1, C1-C4, D (1 EPD) A1-A4; B1, B4; C1-C4, D (2 EPD)	A1-A5; C2-C4 (3 EPD) A1-A4; C2-C4 (3 EPD) A1-A3; C2-C4 (2 EPD) A1-A4, (3 EPD)	A1-A5, B1; C1-C4 (1 EPD) A1-A5, B1 (3 EPD)
Modelling of A4	Distance variation from 30 to 2570 km.	Distance variation from 30km to 125km.	Distance variation from 30 to 2570 km.	Incompleted information	Distance variation from 75 to 774 km.	Distance variation from type of transport from 127 to 747 km.	Distance variation from 56,8 to 108,9 km
Modelling of A5	42 MJ 0,006 kWh	Min 0.0059 kWh Max. 29.4 kWh	Min. 0,0025 kWh Max. 0,0377 kWh	Incompleted information	Manual process	Min 42MJ/ton Max 55,2 MJ/ton	Incompleted information
Modelling of B1	Min -2,13 kg CO2 Max -2,28 kg CO2	Min -2,554 kg CO2 Max -4.73 kg CO2	Min -2,181 kg CO2 Max -2,28 kg CO2	Incompleted information	Min. -0,652 kg Máx. -1,28 kg CO2 eq.	Incompleted information	Incompleted information
Modelling of C1-C4	Distances variation from 20 to 100 km	30-300 km (landfill) 30-300 km (recovery)	Distances variation from 30 to 297 km	Incompleted information	Distances variation from 30 to 100 km.	Incompleted information	Incompleted information
Modelling of D	Recycled Aggregate	Recycled Aggregate	Recycled Aggregate	Incompleted information	Recycled Aggregate	Incompleted information	Recycled Aggregate

For module D, all products and EPDs that include this module assume a scenario in which the material is reused as recycled aggregate, aligning with expected circular economy practices. The ribbed floor product EDP from EPD Denmark has a different unit declaration (1 m²), and the system boundaries covers A1-A5, B1; C1-C4 information modules.

3.3. Summary of the quantitative analysis results

The qualitative analysis focused on the most impactful information modules (A1–A3) due to the length constraints of this work. Figure 2 shows that the concrete blocks without insulation have greater variability than the one with insulation and is the product with greater variability, from 3.79 to 91.4 kgCO₂ eq. per m². Figures 2 and 3 show that hollow-core elements and pavements differ in their declared units; therefore, the results are presented separately. The product with the greatest variation in the results is the concrete block without insulation. The products with the lowest variation are pavements for EPDs that use one ton as a functional unit.

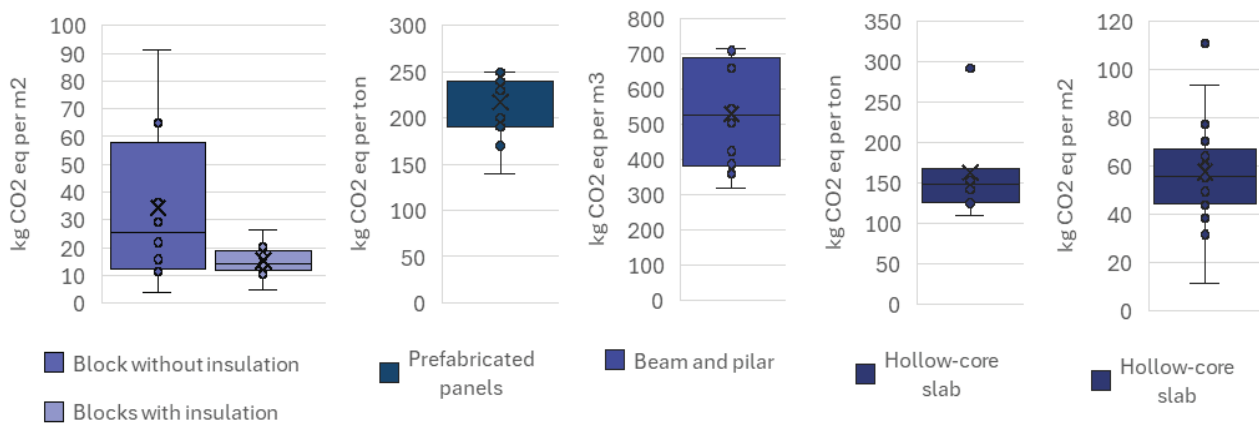


Figure 2. A1-A3 results of GWP for the concrete blocks, precast panels, beams and pillars, and hollow-core slabs.

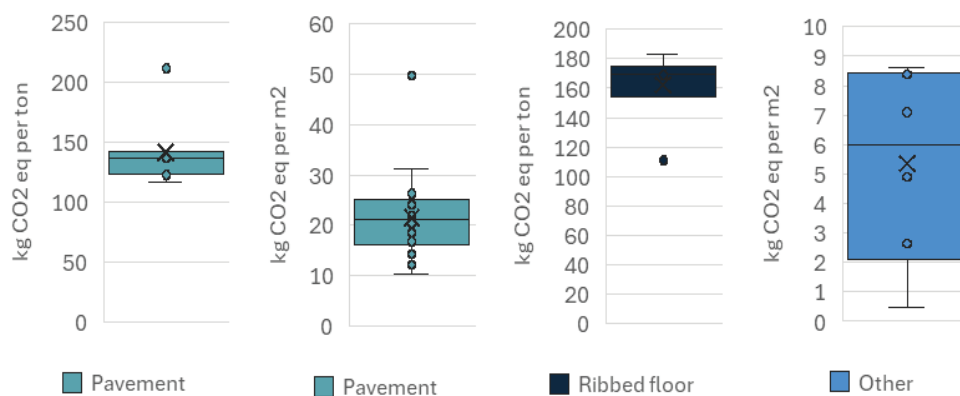


Figure 3. A1-A3 results of GWP for the pavements, ribbed floor, and other products.

3.4. Challenges and Limitations

The findings indicate that, among concrete products, pavements have the highest number of published EPDs. Figures 2 and 3 show discrepancies in the declared units for blocks, hollow-core slabs, and pavements. These findings highlight the significant influence of material thickness on the GWP total results. When the comparison is based on the material’s weight, the variation is smaller;

however, when the comparison focuses solely on the quantity of product required per square metre, the variation is much greater.

The analysis shows that Predalles slabs and lattice joists, grouped under the “others” category, exhibit the highest level of harmonisation across the assessed aspects. Several product types, including beams and columns, concrete blocks, hollow-core floors, pavements, precast panels, and ribbed floors, continue to face harmonisation challenges.

The transport modelling highlights that reliance on country- or region-specific data can limit the applicability of results when the EPD scope extends beyond national borders. In regions with uniform logistical characteristics, such as islands, this modelling approach may be broadly representative. However, flexible and adaptable models are needed in more diverse contexts. The analysis identified opportunities to enhance and increase the flexibility of transport modelling methods.

Notable variations were also observed in the installation (A5) and carbonation (B1), though the underlying causes of these discrepancies are not clearly defined. Developing more transparent and well-justified modelling rules for processes such as installation and carbonation would help reduce variability and improve the consistency of results.

Variations in assumptions in end-of-life scenarios about waste treatment, final disposal and transport distances of waste are relatively minor, with limited discrepancies observed in this phase.

4. Conclusion

Focused on analysing the consistency of EPDs for concrete products manufactured in Europe, this study shows that, despite ongoing efforts to improve the harmonisation of modelling approaches and the communication of results, several discrepancies remain. This identification of patterns, inconsistencies, and opportunities for harmonisation indicate that the elements that show the highest level of harmonisation in terms of data and scenarios are those developed under the same Programme Operator. Therefore, greater alignment between the PCRs of the different Programme Operators could significantly improve the harmonisation of results.

Furthermore, the results show that the declared unit definition influences the variability of results. When comparing products that use different functional unit types, those expressed by weight as the declared unit exhibit less variability than those expressed per square meter. This implies that reporting results per kilogramme or ton of material can provide a fairer basis for comparison. Alternatively, using both types of declared units may help enhance the harmonisation of results. The study also highlights additional areas where improved transparency and comparability of EPD results are needed, particularly in the modelling of transport, installation processes, and carbonation, while fewer discrepancies were found in the EOL modules. Future work may focus on incorporating both qualitative and quantitative analyses of additional information modules and expanding this type of study to include a wider range of construction products.

5. Declaration of generative AI and AI-assisted technologies

During the preparation of this work, the authors used GPT-4 to enhance the language and clarity. After using this tool, the author reviewed the texts and edited the content as needed and take full responsibility for the content of this publication.

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