Methodological Challenges in Aligning EPDs with Whole Life Carbon Limits for Buildings

A B2B Approach

Brisson Stapel, Emilie; Balouktsi, Maria; Grau Sørensen, Christian; Birgisdottir, Harpa

Published in:
IOP Conference Series: Earth and Environmental Science

DOI (link to publication from Publisher):
10.1088/1755-1315/1402/1/012025

Publication date:
2024

Document Version
Publisher's PDF, also known as Version of record

IOP Conference Series: Earth and Environmental Science

PAPER • OPEN ACCESS

Methodological Challenges in Aligning EPDs with Whole Life Carbon Limits for Buildings: A B2B Approach

To cite this article: Emilie Brisson Stapel *et al* 2024 *IOP Conf. Ser.: Earth Environ. Sci.* **1402** 012025

Methodological Challenges in Aligning EPDs with Whole Life Carbon Limits for Buildings: A B2B Approach

Emilie Brisson Stapel[1*], Maria Balouktsi[1], Christian Grau Sørensen[1], Harpa Birgisdottir[1]

[1] Department of the Built Environment, Aalborg University, Copenhagen, Denmark

*Emilie Brisson Stapel: eebj@build.aau.dk

Abstract. The environmental performance from the materials used in buildings is pivotal in reducing greenhouse gas (GHG) emissions from the building sector; buildings are in the top three of the world's most significant contributors of GHG emissions and are responsible for one-fifth of the overall resource consumption. Alongside multiple countries enforcing legal GHG limits and requiring Life Cycle Assessment (LCA) for new buildings, the availability of product-level environmental data, known as Type III Environmental Product Declarations (EPDs) has increased exponentially. EPDs were originally used for Business-to-Business purposes but are now the main data source for building-level LCAs. However, this often comes with a large set of uncertainties, as EPDs are still evolving as a documentation approach, and not always readily applicable in the whole life cycle approach. There are a multitude of complex areas to engage into, this study focuses on how use-stage modules are documented in EPDs, and how varied approaches create further complexity and perils in relation to their use in LCA and regulations, in the sense of, potential leading to high uncertainties and wrongful interpretations. The study aims to address the methodological gaps associated with the use of EPDs as data inputs in legally binding LCA requirements particularly concerning modules B1-5, which constitute the embodied part of the use-stage. The findings reveal a significant margin of error if EPDs are not correctly implemented, underscoring the importance of the Business-to-Business documentation approach.

Keywords: Life Cycle Assessment (LCA), Use-stage modules, Environmental Product Declarations, Reliability, Harmonisation

1. Introduction

Accordingly to the UN Environment Programme, a substantial 12% of energy and process-related GHG emissions arise from the production of construction materials and associated building processes [1], emphasise the crucial role buildings play in both reducing greenhouse gas emissions and advancing the transition towards carbon-neutral societies [2].

Historically, construction efforts primarily aimed at minimizing the operational energy consumption of buildings. Nevertheless, there has been a noticeable transition in recent times towards confronting the environmental impact stemming from the production and utilization of building materials. The reliance on Environmental Product Declarations (EPDs) as a cornerstone of data in building Life Cycle Assessments (LCA) is thus crucial for addressing the environmental repercussions of construction endeavors [3]. Nonetheless, literature also underscores the challenges regarding transparency and comparability, casting doubt on their reliability and sparking multiple debates. This debate underlines the widespread disparities in documentation, significant variation in data quality, transparency, and

IOP Conf. Series: Earth and Environmental Science **1402** (2024) 012025 doi:10.1088/1755-1315/1402/1/012025

specificity, frequently leading to erroneous comparisons [4–6]. EPDs, classified as Type III environmental declarations following ISO 14025 standards [7], play a vital role in conveying environmental impacts within the construction sector, primarily enabling communication between businesses-to-business (B2B).

In response, it becomes crucial to distinguish between generic and specific data models within EPDs to ensure regulatory compliance and enhance the accuracy of environmental assessments. Moreover, integrating EPDs into building-level assessments is imperative, as they provide a means to mitigate the overestimation of impacts [8,9], particularly pertinent in contexts with tightening limit values, such as the proposed 5.8 $kgCO_2e/m^2/yr$ limit by the initiative Reduction Roadmap 2.0 in Denmark. However, while regulation initially adopts a limited life cycle scope, an anticipated transition to a full life cycle scope is imminent due to the revised Energy Performance of Buildings Directive (EPBD) [10]. Overcoming these challenges requires a thorough grasp of product-specific data availability and allocation methods. Despite the regulatory momentum, challenges persist, including the lack of harmonization as well as disparities within specific material categories [3,11]. Moreover, while EPDs typically encompass stages A1-A3 in EN15804+A1 [12] and lastest also C1-4 and D with EN15804+A2 [13], the absence of mandatory use-stage modules poses a barrier to responsibly incorporating B stages into LCA tools. Addressing these challenges necessitates a comprehensive understanding of product-specific data availability and allocation approaches.

With these considerations in mind, this study aims to address methodological gaps in documenting and utilizing EPDs, especially regarding legally binding LCA requirements. Focusing on modules B1-5, representing the embodied part of Use-stages, we aim to clarify EPD modeling nuances and their implications for LCA comprehensibility. By exploring EPD implementation intricacies, we aim to propose strategies enhancing transparency, harmonization, interpretability, and overall effectiveness at the building level. Ultimately, our goal is to establish a robust framework for integrating EPDs into sustainable construction practices, enabling informed decision-making and contributing to broader sustainability goals.

2. Materials and Methods

The objective of this study is to deepen the comprehension regarding the documentation of modules in Environmental Product Declarations (EPDs), while exploring the diverse methodologies that contribute to increased complexity and risks within Life Cycle Assessment (LCA) and regulatory frameworks. These variations potentially lead to heightened uncertainties and misinterpretations. The study thus, addresses methodological deficiencies related to the utilization of EPDs as data sources in legally binding LCA mandates, particularly focusing on modules B1-5, which constitute the embodied aspect of the use-stage. Which is why the collection of EPDs was limited to third-party verified digitalized data, following the European standard EN15804 for construction materials.

2.1. The compilation and screening of data

his includes extracting data from EPDs available in digital format, specifically utilizing the ILCD+EPD format accessible through the ECO Platform Portals Web API (Web Application Programming Interface). This platform serves as a centralized repository for EPD data from various sources, ensuring consistent quality standards through verification criteria and routine audits [14].

On April 12, 2024, an assessment retrieved a total of 13,053 datasets (EPDs) from the ECO Platform Portal. Emphasis was placed on evaluating material types, modules, and associated emissions, particularly focusing on Global Warming Potential (GWP). After meticulous selection to remove expired or unverifiable data [Emilie Brisson Stapel, Maria Balouktsi, Christian Grau Sørensen, Harpa Birgisdottir, Type III Environmental Product Declarations – The perils and pitfalls of digitalization, NextBuilt 2024 (submitted, publication forthcoming)], 10,510 datasets were validated, with 28% conforming to EN15804+A1:2013 (+A1) and 72% to EN15804+A2:2019 (+A2) standards. Due to the discontinuation and small proportion of +A1 datasets and its discontinuation, they were excluded, resulting in a subset of 7,529 datasets related to +A2 for further assessment.

2.2. *Selection of data*

The EPD selection process primarily targets building-related elements, excluding infrastructure. The *Classification* field is utilized to categorize the specefic material types; however, a significant portion (68%) of the datasets lack this information. This absence poses a challenge for structuring the data for LCA purposes. In such cases, where the *Classification* field is missing, information from PCR types and *Product Names* is leveraged to attempt to derive a useful category and product type. The remaining datasets which lack this crucial information but contain modules B1-5, undergo manual scrutiny from the pdf to supplement the missing details. In alignment with the study's framework, the manual processing is focused solely on investigating five material categories: Precast concrete products: 237 (20 requiring manual checks), Floorings: 146 (6 requiring manual checks), HVAC systems: 42 (0 requiring manual checks), Windows, doors and shutters: 257 (5 requiring manual checks), Curtain walls: 15 (1 requiring manual checks).

2.3. *State of play in standardisation and legislation*

According to +A2 standard, modules A1-A3 (product stage), C1-C4 (end-of-life stage) and D (benefits beyond service life), are mandatory for all construction products. Additional other life cycle stages may be included in an EPD, depending on its purpose and goal. EPD program operators may set additional requirements to include further modules, e.g. RTS and EPD Norge require the inclusion of A4 module for all products and construction services, and A5 for certain sub-categories (e.g. EPD Norge requires module A5 in LCA for construction services). While the use-stage (modules B1-B7) are often underreported, they will become more significant from 2028 according to the Energy Performance of Buildings Directive (EPBD) [10] revision, which mandates whole life GWP for the building level.

Aside from the building operation-related modules (B6 and B7), use-stage modules also include a material-related part as shown in **Figure 1** (based on prEN 15978 [15], revised version under consultation). However, data beyond modules A1-A3 in EPDs are applicable at the building-level only if they align with the assessed building's characteristics; otherwise, adjustments are necessary. Achieving alignment with building-level conditions requires transparent and comparable information on the environmental impact outlined in each EPD module, an unresolved issue highlighted by multiple studies [16]. From a regulatory perspective, European countries with climate impact declarations already in place, including use-stage modules other than B6, are Denmark (B4), Norway (B2), as well as France and the Netherlands (all B modules depending on data availability and relevance). Sweden also plans to expand the carbon declaration requirements to use-stage modules among others by 2027. This itensifies the urgent need for solutions that ensures data reliability, comparability, and advance these objectives, particularly through the digitalization of EPDs.

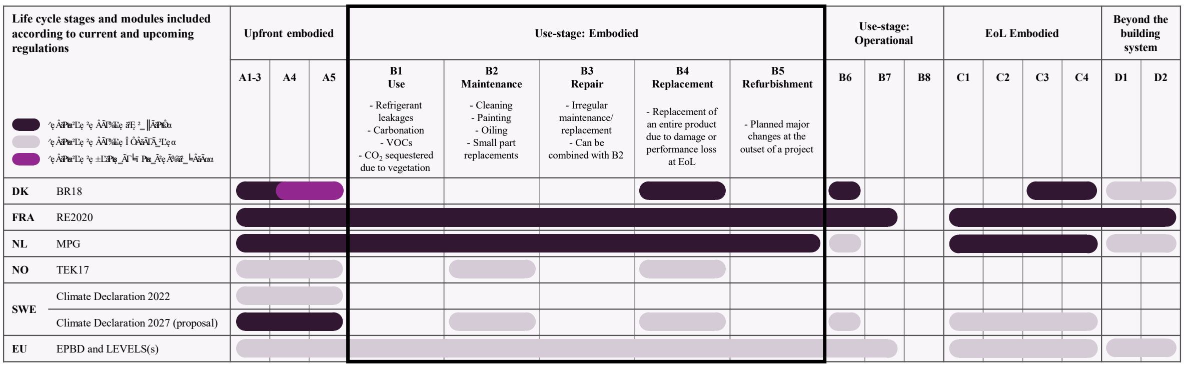

Figure 1. Overview of stages and modules demanded by various regulations in Europe, with cells in dark purple indicating inclusion in carbon limit values, while light purple denotes inclusion in carbon declarations. The modular structure follows prEN 15978, and more detailed content-wise descriptions are only provided for modules B1-5 being the primary focus

3. Results

3.1. Relevant product categories and level of data availability

While this study focuses on B modules, it is crucial to acknowledge that certain impacts addressed can extend beyond this stage and affect other aspects of the building life cycle. For instance, carbonation of concrete is not confined to the use phase; it also occurs post-demolition, with carbonation accelerating notably due to the increased exposed surface resulting from concrete crushing [17]. Table 1 provides an overview of products types for which B1-5 data are relevant.

In theory the advantages of carbonisation, can be considered as part of waste processing (C3), or as part of the subsequent life cycle in module D. Although there are a few EPDs for ready-mix concrete that addresses carbonation at the End-of-Life (EoL) it is presumed that these EPDs employ different scenarios. This ambiguity arises because European standards do not specify the duration of stockpiling post-demolition, which ultimately determines the overall significance of this effect. Furthermore, for technical systems including refrigerants, losses do not only occur during use in B1, but also at the EoL during decommissioning in C1, although the impact is minimal.

Table 1. Overview of product categories that are relevant for inclusion of the various B modules (embodied part, i.e. B1-5) in the life cycle scope. "X" denotes where availability of impact values are expected to be found, while "?" indicates alternative modules where values have been observed.

Product Type	**Use-stage modules**					**Description of relevance**
	B1	**B2**	**B3**	**B4**	**B5**	
Precast concrete products	X					**Natural carbonation**: i.e. CO_2 absorption, when cementitious and lime-based surfaces are exposed to air during the use-stage.
Concrete, mortar, grout	X					
Cement-bonded boards	X	X				**Carbonation**: can occur due to the cement content. **Painting:** repainting of the board can be assumed as part of B2
Windows, doors and shutters		X	?	?		**Cleaning, painting and oiling (where relevant)**: involves use of cleaning agents, oils, water consumption, energy use for lifts/cranes, etc., and paints which must be reported under B2. **Replacement of sub-products**: replacement of constituent sub-products like insulating glass units, sealants, and fittings must be reported in B2 if their service life is shorter than the entire window (however, also seen in B3 or B4).
Curtain walling		X	?	?		
Floorings		X				**Cleaning and oiling (where relevant)**: involves use of cleaning agents, oils (e.g. for wooden floors), water consumption, energy use for vacumming, etc. which must be reported under B2.
Roofing membranes				X	?	**Renewal**: Usually, waterproofing sheets are not replaced at the end of their service life; instead, new sheets are laid on top of the existing ones. This method of replacing roofing felt is documented in EPDs either under B4 or B5.
Wall and ceiling cladding		X	?			**Cleaning, painting, oiling (where relevant)**: similar processes with floorings and windows
HVAC systems	X	X	?	?		**Refrigerant leakage**: air-conditioning systems and heat pumps typically include refrigerants/cooling agents that are leaked during operation (B1) and refill is needed when, e.g. more than 10% is lost during the use of a system (B2). **Filter replacement**: a common regular maintenance process for cooling systems and ventilation units to preserve a good indoor air quality. While this must be in B2 on building level, allocation on product level typically occurs in B4.
Photovoltaic systems		X				**Cleaning**: it can pertain to seasonal cleaning due to e.g. pollen from nearby trees which must be reported in B2
Fixed fixtures and furniture		X	?		?	**Cleaning and painting (where relevant)**: use of cleaning agents, water consumption, and paints (B2). **Replacement of sub-products**: replacements of constituent sub-products of a life shorter than the entire product must be in B2 but is also seen in B3 or B5.
Vegetated surfaces (e.g. green roofs)	X	X				**CO_2 sequestration**: such surfaces sequester CO_2 during their lifetime and release CO_2 and CH_4 during decomposition, achieving a relative carbon balance. While

	some aspects are usually reported under B1, diverse allocation approaches exist due to the lack of clear guidelines. **Fertilisers**: a common regular maintenance process for green roofs to preserve vegetation, reported in B2.

Figure 2 illustrates the varying degrees to which +A2 EPDs offer use-stage data based on selected examples of product categories. For instance, carbonation effect reported in the B1 module is only present in approximately one-third of precast concrete products, indicating a significant deficit in this information despite established European standards like EN 16757 and CEN/TR 17310. However, the inclusion of B1 reporting for various cementitious and lime-based products in EPDs is increasing, particularly in Nordic countries [18], although typically represented by one or two values reflecting different degrees of carbonation. Nonetheless, detailed differentiation among scenarios based on concrete surface layers, compressive strength, construction thickness, and other influencing factors affecting CO_2 absorption is largely absent. Transparently providing this information can be crucial, especially from 2028, when Member States are mandated to address carbon removals associated with carbon storage in or on buildings in addition to whole life GHG emissions, as per the revised EPBD.

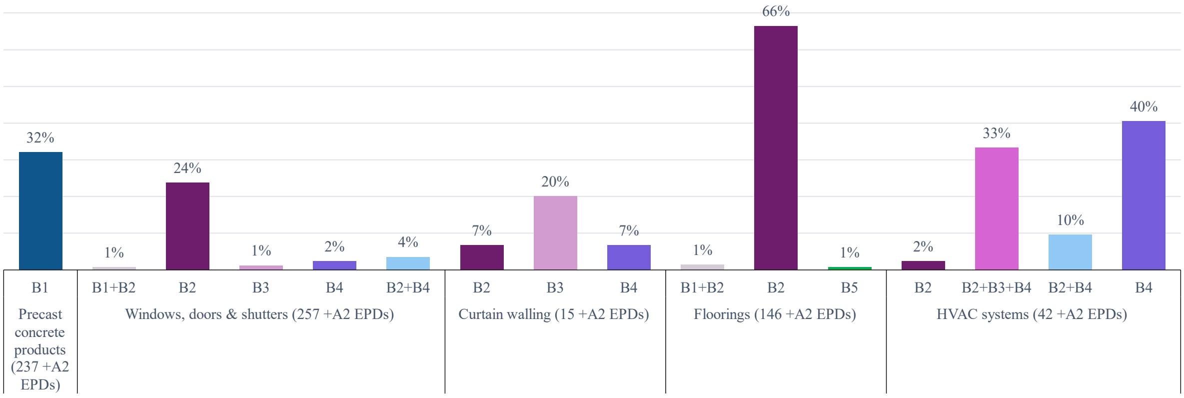

Figure 2. illustrates the level of data provision for individual use-stage modules or their combinations in EPDs for selected pertinent product categories.

Regarding flooring products, approximately two-thirds of +A2 EPDs already encompass the B2 module. Interestingly, one EPD reports maintenance processes under the B5 module, which is typically not relevant for product-level information, revealing a slight inconsistency in maintenance impacts allocation among EPD providers, as discussed further in Section 3.4. Inconsistency and poorer data availability are more evident in EPDs for windows, doors, and shutters, as well as curtain walls, where less than 30% include B modules. Moreover, the allocation of smaller subcomponent replacements (such as glass, sealants, ect.), during the use-stage can vary between B2, B3, and B4.

Among the product categories, HVAC systems demonstrate the highest level of reporting of use-stage data, notably, filter replacement, among other parts (e.g. valves), is predominantly accounted for under module B4, although on a building level this should be reported under module B2. This highlights a potential challenge and source of error in automatically transferring data from the product level to the building level. Notably, only one EPD reports filter replacement in B2, as detailed in Section 3.2. Despite including six EPDs for heat pumps and at least one heat recovery unit in the EPD sample for HVAC systems, no consideration of refrigerant leakage during use in B1 is accounted for.

In addition to the concerns of data availability and consistency of process allocation across various B modules, the issue of completeness of the necessary information to interpret the values provided in the B modules and adapt them for building-level assessments is also critical. The following sections delve deeper into three selected product categories.

3.2. HVAC systems

Although B1 can notably impact building-integrated technology systems utilizing refrigerants, such as air conditioners and heat pumps, depending on the refrigerant used and the leak rate [18], refrigerant impacts are rarely considered in LCAs. The EU F-gas regulation from 2015 has drawn considerable attention to the issue in recent years. This regulation includes sectoral bans on refrigerants with high climate impact while promoting the adoption of new and alternative refrigerants with lower climate impact and innovative technologies In addition to the type of refrigerant used in a system, the rate of leakages depends heavily on maintenance practices, hence loss rate assumptions. For instance, in a geothermal heat pump utilizing R32, the impact in module B1 can inxrease by more than 50% during a 50-year reference study period, if the annual leak rate elevates from 2% to 3% [18]. While no +A2 EPD accessible in EcoPlatform currently includes B1 in the reported modules of heat pumps and ventilation units with heat recovery, there are a few limited examples of EPDs that provide B1 and B2 values to cover refrigerant-related activities. Neverthless, detailed assumptions behind these calculation are not always provided (see Table 2 for examples). The absence of information regarding the quantitiy of refrigerants and the annual loss assumed hinders the adaption of the B1 to building-level scenarios.

Table 2. Comparison of critical information regarding general characteristics and B scenarios across two chosen EPDs of HVAC systems. Note: n.d.: no data. Highlighted are the B values GWP as given in the EPDs.

Information provided	**Selected HVAC products**	
	DAIKIN ALTHERMA M HW (INDOOR MONOBLOC)	aroTHERM plus 7 kW - air-to-water heat pump with monobloc technology.
Service life (SL)	17 years	15 years
B1 scenario	Refrigerant type: R134a GWP of refrigerant: 1430 kg CO2-eq/kg Refrigerant quantity: n.d. Refrigerant momentary leakage: 72.93 kg of CO2-eq	Annual refrigerant leakage: 2 % Refrigerant type: R290 GWP of refrigerant: 3 kg CO2e/kg Refrigerant quantity: 0.9 kg Refrigerant leakage per year: 54000 mgCO_2
B2 scenario	Number of refills: 3 Quantity of refill: n.d. Transport 1: person (80kg) + tools (2kg) in truck, 100km	Qantity of refill: 0.018 kg/year
B1 GWPtotal value	72.9 kgCO_2e/piece	0.81 kgCO_2e/piece
B2 GWPtotal value	19.7 kgCO_2e/piece	0.28 kgCO_2e/piece

Additionally, filters play a significant role in the total GHG emissions of certain air conditioning and ventilation systems due to their required replacement minimum once every year to ensure health and comfort standards by filtering out dust and other particles. A study based on a single EPD example showed that annual filter replacement for a unit with a 25-year service life can contribute to nearly 15% of the total life cycle impact of the system [18]. Typically, filter replacement is accounted for under the B4 module at the product level, potentially introducing errors when transferring data from the product level to the building level, ss depicted in Figure 1. Additionally, filter replacement is usual an annual or biannual activity (depending on the scenario assumed) and B4 depends on the service life of the system provided in the EPD. Therefore, when comparing products with different service lives or when a building-level method requires specific service lives for components, B4 should be converted to the same number of replacements or annualized values. However, if multiple elements are included in B4, this conversion becomes challenging. **Table 3** illustrates this challenge by comparing two EPDs of ventilation units of a similar class (airflow level) with a different service life and scenarios under B4.

If B4 is considered without any conversion, product (2) has more than 100% higher impact than product (1), while when annualised the difference is reduced to a 60% higher impact. Furthermore, the significant higher impact of product (2) cannot be readiliy explained since product (1) also includes fan replacements, in addition to the same frequency of filter replacements assumed in both products. Inconsistencies in providing information on the types of filters used in some EPDs hinder a comprehensive interpretation based solely on EPD-provided data.

Table 3. Comparison of critical information regarding general characteristics and B scenarios across three chosen EPDs of ventilation units. Note: n.d.: no data. Highlighted are the B values GWP as given in the EPDs.

Information provided	**Selected Ventilation unit products**		
	(1) ProAir Heat Recovery Ventilation Unit ProAir PA600LI (EPDIE-22-85)	(2) Vallox 145 MV (S-P-10358)	(3) AM500 decentralised ventilation unit (MD-23078-EN_Rev2)
Max Airflow (m^3/hr)	323	392.4	430
Service life (years)	20	25	25
B scenarios	**in B4** Fans: 3 replacements Filters: 38 replacements (assumingly around twice per year)	**in B4** Filters: twice per year	**in B2** Filters: once per year
B GWP_{total}	**B4:** 41.2 kgCO_2e/piece	**B4:** 86.4 kgCO_2e/piece	B2: 27.1 kgCO_2e/piece
Annualised GWP_{total}	B4: 2.1 kgCO_2e/piece/year	B4: 3.4 kgCO_2e/piece/year	**B2:** 1.1 kgCO_2e/piece/year

3.3. Windows, doors, shutters and curtain walls

Windows usually make up 10–25% of a building's façade, and infuence both operational performance (often responsible for more than 60% of its total energy loss) and embodied carbon, sometimes resulting in a trade-off [19], which can be even more pressing for curtain walling systems. Windows are complex building components that serve many functions, making it challenging to define a functional unit (FU) capable of encompassing uniform performance and ensuring a suitable basis for consistent results. [20].

There are four aspects associated with windows, doors and curtain walls that may affect the relevance, and type of data needed, for their use-stage modules: (1) small replacements of constituent parts of with a service life shorter than the frame, such as the glass replacement or other parts like sealings, etc. (a window as a multi-layered assembly of products where each individual constituent part may have a different service life); (2) the cleaning process comprised of using cleaning agents and sometimes also energy; (3) painting of frames; (4) oiling of movable parts comprised of using lubricating oils.

For instance, the service life of windows provided in EPDs can range from 25-75 years, with the lower values typically attributed to wooden building frames [19,20]. For windows with a service life of 40 years or more, this often results in at least one replacement solely for the insulating glass unit, as according to windows PCR it should not be more than 30 years (and even more replacementd for sealant strips and fittings). These replacements essentially become part of B2 according to the sector PCR for windows and door DS/EN 17213:2020. However, this allignment is not observed in some EPDs, as demonstrated in the three selected examples in **Table 4**. This results in a wide range of values, depending on whether part replacements are included in B2, in addition to variations in assumptions for cleaning, oiling, and painting. Furthermore, it is noteworthy that despite these differences in service lives of window sub-products, everal LCA methods, like those used in Denmark, do not currently incorporate the B2 module. Consequently, any form of replacement is accounted for in B4, resulting in a mismatch between allocation in product-level and building-level LCAs.

Another aspect is the differences observed in the functional units used for windows. Typically, LCAs utilize the gross surface area of the window, encompassing the external frame, to standardize measurements and remove reliance on specific dimensions. This normalization method may prove more beneficial, especially for larger windows, as it helps distribute the impact of the frame—often comparable or even greater than that of the glass components—across a broader area [20]. Among the data extracted and categorized as windows 10 out of 57 +A2 for windows have "pieces" as a unit. If we look at the entire family "windows, doors, shutters" we have 38 out of 257.

Table 4. Comparison of critical information regarding general characteristics and B scenarios of three selected EPDs of triple-glased windows. Note: Uw-value: thermal transmittance of the entire window; Rw: Sound Reduction Index.; n.d.: no data. Highlighted are the B values GWP as given in the EPDs.

Information provided	**Selected window products**		
	Extreme section – PVC window 1,23m x 1,48m (EPDITALY0509)	SSC Etri Fönster Inward opening windows (S-P-06939)	NorDan NTech One Tilt and Turn - ZD 105/80 (NEPD-5177-4507-EN)
Size	1,23m x 1,48m	1,23m x 1,48m	1,23m x 1,48m
Unit	1 m^2	1 m^2	window
Convertion factor	-	-	0,549 for 1 m^2
Uw-Value [W/m²k]	1,0 W/m^2K	1,21 W/m^2K	0,84 W/m^2K
Rw [dB]	44 maximum	n.d.	n.d.
Service life (SL)	30	50	60
B scenarios	**in B2** 0,1 L of water per m^2 and per cleaning operation Cleaning once per month (36L/FU) Lubricating oil:10mg/ window/year Lubricating once per year (0,16 kg/FU)	**in B2** Cleaning solution: 60 ml/m²/year Lubrication oil:10 ml/m²/year *Glass replacement: not considered despite a 50 year SL*	**in B2** Cleaning: 3 times/year Cleaning solution: 30 ml/window/year Water: 3L/ year Painting (aluminium cladding): 3 times during its lifetime from the inside Lubricating oil: 5gr/year for fittings and moving parts Replacements: 1 replacement of the insulating glass unit
B modules GWP_{total}	0.21 $kgCO_2e/m^2$	3.13 $kgCO_2e/m^2$	64 $kgCO_2e$/window *(35 $kgCO_2e/m^2$)**
Annualised GWP_{total}	0.007 $kgCO_2e/m^2$/year	0.0626 $kgCO_2e/m^2$/year	0.7 $kgCO_2e/m^2$/year

** Not given in the EPD*

3.4. Floorings

In the use-stage of flooring products, typical scenarios involve the definition of a schedule (frequency) and quantities of consumables: i.e. detergent and water used for cleaning, electricity used for non-manual cleaning, lacquer or oil used for wooden surfaces However, the frequency of cleaning and maintenance depends not only on the type of surface but also on the usage patterns and conditions of the building. Further, most floorings are declared per square meter but there are some examples with m3 or kg reference unit. In case of m3, the pdfs provide the density and thickness, but still it may be complicated when the thickness is given as a range. This means that having a fully usable flooring dataset on the building level, EPDs would need to provide clarity on the assumptions used for building types or usage conditions in the B module data. This allows for adjustment of values according to project-specific maintenance scenarios, and/or EPDs should offer relevant conversion factors for this purpose.

B2 thus holds significant importance for wooden and carpet floor, with average multilayered parquet accounting for approximately 35% of the total impact in the latest Ökobaudat version [18].

A detailed analysis of three selected EPDs primarily focusing on bio-based flooring options reveals several barriers to straightforward comparability. These barriers include discrepancies in critical technical information such as thermal conductivity, variations in module reporting of maintenance activities, differences in the reporting of impacts (whether for the full service life or annually), and discrepancies in cleaning frequencies. Despite the products being of similar nature, differences arise due to factors like the need for oiling in wooden floors.

Table 5 Comparison of critical information regarding general characteristics and B scenarios of three selected EPDs of bio-based flooring options. Note: n.d.: no data. Highlighted are the B values as given in the EPDs. Note: the highlighted cells represent the values as provided in the EPDs.

Information provided	**Selected flooring products**		
	DPL Laminate flooring (EPD-EPL-20210138-CBE1-EN)	3-layer wooden floorboards, Moland A/S (No. 474/2023)	Amorim Wise Cork Pure UV (EPD-ACF-20220040-ICA1-EN)
Thickness	8 mm	13,3 mm	8 mm
Thermal conductivity	n.d.	≤ 0,09 W/mK	n.d.
Service life/SL (years)	20	30	15
B Scenarios	**in B2:** Cleaning frequency: 120 times/year Water consumption (per year): 0.0068 m^3 Auxiliary (per year): 0.0507 kg Electricity consumption (per year): 0.074 kWh	**in B5** floor is oiled/varnished once every two years. no use of energy or water during the service life	**in B2** Wet cleaning frequency: 2/year Vacuum cleaning frequency: 52/year Water consumption: 0.001 m^3 Electricity consumption: 0.1 kWh Auxiliary (cleaning agent): 0.02 kg
B modules GWP$_{total}$	3.4 $kgCO_2e/m^2$	17.8 $kgCO_2e/m^2$	1.95 $kgCO_2e/m^2$
Annualised GWP$_{total}$	0.17 $kgCO_2e/m^2/year$	0.59 $kgCO_2e/m^2/year$	0.13 $kgCO_2e/m^2/year$

4. Conclusions and recommendation

This study identifies inconsistencies in Environmental Product Declarations (EPDs) for building materials, particularly in modules B1-5. Despite their importance, factors like concrete carbonation and refrigerant losses are inconsistently addressed. Windows, doors, HVAC systems, and flooring products face challenges in accurately reporting use-stage data. Standardized reporting and transparent data provision in EPDs are crucial for reliable building-level assessments and advancing sustainability goals.

Additionally, refrigerant impacts and filter replacements play significant roles in building-integrated systems' environmental performance but are often overlooked in EPDs. Standardized reporting and transparent data provision are necessary for accurate assessments. Furthermore, windows, doors, and curtain walls' complexity poses challenges for environmental impact assessment due to variability in service life and replacement practices. Standardized reporting practices are needed to ensure reliable comparisons. Lastly, variations in cleaning and maintenance practices complicate the assessment of flooring products' environmental impacts. Clear assumptions and standardized reporting are necessary for accurate comparisons.

References

[1] UNEP 2023 *UN Environment Programme 2022*

[2] Kuittinen M and Häkkinen T 2020 Reduced carbon footprints of buildings: new Finnish standards and assessments *Buildings and Cities* **1** 182–97
[3] Waldman B, Huang M and Simonen K 2020 Embodied carbon in construction materials: a framework for quantifying data quality in EPDs *Buildings and Cities* **1** 625–36
[4] Gelowitz M D C and McArthur J J 2017 Comparison of type III environmental product declarations for construction products: Material sourcing and harmonization evaluation *J Clean Prod* **157** 125–33
[5] Lauri L, Roope H, Atsushi T, Tuovi V and Olli D 2020 Environmental product declaration of timber products: The impact of allocation method to the impact categories *J Clean Prod* **256** 120386
[6] Rasmussen F N, Andersen C E, Wittchen A, Hansen R N and Birgisdóttir H 2021 Environmental product declarations of structural wood: A review of impacts and potential pitfalls for practice *Buildings* **11**
[7] Danish Standards Association 2010 *EN ISO 14025: Environmental labels and declarations - Type III environmental declarations - Principles and procedures* (Geneva, Switzerland)
[8] Tozan B, Stapel E, Sørensen C and Birgisdóttir H 2022 The influence of EPD data on LCA results *IOP Conf Ser Earth Environ Sci* **1078**
[9] Loli A, Skaar C, Bergsdal H and Reenaas M 2023 Comparing embodied GHG emissions between environmental product declaration and generic data models: Case of the ZEB laboratory in Trondheim, Norway *Build Environ* **242** 110583
[10] European Parliament legislative resolution 2024 European Parliament legislative resolution of 12 March 2024 on the proposal for a directive of the European Parliament and of the Council on the energy performance of buildings (recast)
[11] AzariJafari H, Guest G, Kirchain R, Gregory J and Amor B 2021 Towards comparable environmental product declarations of construction materials: Insights from a probabilistic comparative LCA approach *Build Environ* **190**
[12] Danish Standards Association 2019 DS/EN 15804:2012 + A1:2013: Sustainability of Construction works - Environmental product declarations - Core rules for the product category of construction products
[13] Danish Standards Association 2013 *DS/EN 15804:2012 + A2:2019: Sustainability of Construction works - Environmental product declarations - Core rules for the product category of construction products*
[14] Eco Platform Home - Eco Platform en
[15] Danish Standards Association 2012 DS/EN ISO 15978: Bæredygtighed inden for byggeri og anlæg: Vurdering af bygningers miljømæssige kvalitet 64
[16] Anderson J and Moncaster A 2020 Embodied carbon of concrete in buildings, Part 1: analysis of published EPD *Buildings and Cities* **1** 198–217
[17] Saade M R M ;, Balouktsi M ;, Da Silva M G and Gomes V 2023 When means and ends meet: examining strategies and carbon accounting fit for Our Global Future (Ecohouse Initiative Ltd.) pp 450–62
[18] Balouktsi M ; and Birgisdottir H 2023 *Analysis of new modules in connection with calculation of the climate impact of buildings*
[19] Marinello Jorba V, Palumbo E, Del Rosario P and Traverso M Comparison of Environmental and Thermal Performance of Wooden Windows Based on Epds:An Application in the Italian Climate
[20] Asdrubali F, Roncone M and Grazieschi G 2021 Embodied Energy and Embodied GWP of Windows: A Critical Review *Energies 2021, Vol. 14, Page 3788* **14** 3788