Environmental Product Declaration (EPD) Usage in Early Building Design Stages: Review of Effects on the Environmental Life Cycle of a Multi-Residential Building

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The building sector has seen recent growth in the number of published environmental product declarations (EPDs). EPDs share environmental data of construction materials, which can help building practitioners prioritize products with lower environmental impacts. However, EPDs rely on varying assumptions within their life cycle assessment (LCA). This study aimed to evaluate the use of EPDs as a data source instead of a generic data source and its effect on the life cycle impacts of a multi-residential building. This study focused on 19 North American EPDs of structural wood products. The impact assessment results found in the EPDs were compared to the Ecoinvent V3.8 database. The findings of the present study suggest that EPDs can generally be used without distinction compared to the data in the Ecoinvent V3.8 database. However, a few data were found to be outliers. In addition, EPDs of structural wood products only disclosed its manufacturing stage. Other life cycle stages, such as transport of the construction product, can have a significant impact on the building's LCA. Therefore, using EPDs to assess building impacts is recommended over their direct comparison for practitioners to make more comprehensive decisions towards embodied impacts of buildings.

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INTRODUCTION

The building sector is responsible for 13% of Canada's greenhouse gases (GHG) emissions or 18% when including electricity-related emissions (Natural Resources Canada 2022). The building sector accounts for the third-largest source of emissions in Canada. This is why decarbonization of this sector is important to achieve Canada's 2030 climate target, reduce emissions by 37% from 2005 to 2030, and a net-zero economy by 2050 (Natural Ressources Canada 2022). Considering the economic importance of the building industry and its share of environmental impacts, buildings have been subjected to many studies using life cycle impact assessment (LCA). LCA is a scientifically based methodology that quantifies the environmental impacts of any product or service over its life cycle (ISO 2006). Efforts have been made by the industry to reduce operational impacts by increasing energy efficiency in buildings (Azari 2019). However, a superior energy efficiency target may be achieved by increasing the use of materials in building envelopes, which can lead to higher embodied impacts of buildings (Feng *et al*. 2022; Larivière-Lajoie *et al*. 2022). Several studies suggest that buildings with improved operational energy performance or a low-impact energy mix can lead to embodied impacts being responsible for a greater share of the total impacts of the building (Thormark 2006; Chastas *et al*. 2016; Lessard *et al*. 2018; Röck *et al*. 2020). This is particularly the case for residential buildings, where operational energy is provided mostly by renewable energy, hydroelectricity, such as the province of Quebec in Canada. Therefore, reaching target emissions within the building sector must be done by acknowledging embodied carbon emissions by addressing whole building life cycle assessment (WBLCA) (Pomponi and Moncaster 2016). This requires the implication of all actors of the building sector, from manufacturers, architects, engineers, LCA practitioners to policy makers.

Structural elements are often responsible for a great part of the environmental impact from the production stage of a building, according to LCA (Chau *et al*. 2007; Lessard *et al*. 2018). There is great potential to use wood-based materials. Previous research suggests that substituting structural elements made of concrete or steel by wood-based products can help reduce environmental impacts of buildings (Essoua and Lavoie 2019; Hart *et al*. 2021; Robertson *et al*. 2012). However, these conclusions may vary depending on end-of-life scenarios (Hart *et al*. 2021) and carbon sequestration calculations made within the LCA methodology (Morris *et al*. 2021). Figure 1 presents three wood-based products used as structural elements in buildings. Glued laminated timber (GLT) is made of wood laminations bonded together parallelly with a moisture-resistant adhesive to form stress-rated engineered wood beams. Cross-laminated timber (CLT) is made of an odd number of layers (generally three, five or seven) of kiln-dried lumber boards bonded together perpendicularly with a structural adhesive to form a solid wood engineered panel. Laminated veneer lumber (LVL) is a type of structural composite lumber (SCL). LVL is made of multiple layers of thin wood veneer, parallel to the long direction, bonded together with a moisture-resistant adhesive to form headers and beams or a component of engineered I-joists.

Fig. 1. Structural wood products evaluated in this study: A) Glued laminated timber (GLT), B) cross laminated timber (CLT) and C) laminated veneer lumber (LVL)

Several standards and certification~~s~~ schemes are used to characterise environmental performance of building materials. The ISO 14020 series presents three types of environmental labels and declarations: type I, II, and III. Type III declarations, also named environment product declarations (EPD), are based on LCA methodology and are third-party verified. EPDs provide environmental data of construction products. EPDs follow guidelines from specific product category rules (PCRs) to conduct the LCA to enable comparison between products (Ingwersen *et al*. 2012; Del Borghi 2013; Modahl *et al*. 2013). PCRs contain information that should be found in the EPDs for a specific product category. Some PCRs are made for products within a same geographical context, while others do not specifically mention it. EPDs have the potential to facilitate comparison between products because of the quantitative information disclosed within (Cobut *et al*. 2013). Certified environmental claims inform architects about potential benefits of wood-based products.

To characterize a building's material environmental impact, a large amount of data on processes and materials is required. Published databases such as Ecoinvent are generally used to conduct LCAs. As these databases may not always have processes representing specific building materials, EPD results are being used as data to conduct building LCAs in several certification schemes. Primary data, or specific data, refers to data from a specific process within the supply chain of the manufacturer (European Commission 2016). Secondary data, or generic data, is obtained from third-party life cycle inventory (LCI) database or other sources. Published databases such as Ecoinvent, GaBi, and industry-average data are considered secondary data. EPDs are a specific case: They can rely on both primary and secondary data. For the end user consulting the EPD, it may not always be clear which life cycle stage is based on which type of data or assumption. More in-depth information for each life cycle stages is not disclosed in EPDs, as such information would be for a process in an Ecoinvent database.

The amount of building environmental assessment schemes using EPDs is rising in developed countries (Arvizu-Piña and Cuchí Burgos 2017). Consequently, the construction sector saw an increase in demand and publication of EPDs (Gelowitz and McArthur 2016; Bernardi *et al*. 2017). The architecture, engineering, and construction (AEC) industry seems to use EPDs more often since its adoption as credits in Green Building Rating Systems (GBRS) such as Leadership in Energy and Environmental Design (LEED) (Burke *et al*. 2018). A study performed by Gelowitz and McArthur (2018) on Canada's first LEED v4 platinum commercial project discussed the client's, designer's, and contractor's experience with the use of EPD for obtaining the material disclosure and optimization's credits. Designers found EPDs to be more appropriate for use in whole building assessment rather than direct comparison between similar products due to the lack of harmonization of PCRs. To avoid potential pitfalls, the use of the Integrative Design Process (IDP) was mentioned to be essential for this project, as it allowed all stakeholders to learn about EPDs and facilitate their insertion into the project.

An EPD can help manufacturers to identify and improve a manufacturer's most impactful process. On the other hand, EPDs are also used to communicate environmental impacts of products to individuals who might not have LCA knowledge (Bergman and Taylor 2011). However, interpretation of LCA results can be difficult for individuals with less experience in LCA (Modahl *et al*. 2013; Ibáñez-Forés *et al*. 2016). In practice, lack of harmonization between developed PCRs are responsible for difficulties to compare EPDs (Del Borghi 2013; Hunsager *et al*. 2014; Gelowitz and McArthur 2017; Kerr *et al*. 2022). Attempting to compare different types of products using their EPDs can lead to poor comparison assessment, as their respective PCR mandates different rules such as declared unit or LCA scope (Kerr *et al*. 2022).

Considering the increasing interest in data sources such as EPDs (Burke *et al*. 2018) and potential difficulties of misunderstanding EPDs by practitioners in the construction industry, this study aims to observe the impact of using EPD results in a LCA of a multi-residential building with a specific focus on wood structural products. The objective of this study was to analyze the impact of replacing the data from Ecoinvent V3.8 of the main wood structure by data available publicly from EPDs. This study focused on structural wood EPDs from the North American market. The multi-residential building used for this study is a hypothetical mass timber building constructed in Quebec City.

EXPERIMENTAL

The project was carried out into two main steps simultaneously: searching and comparing EPDs for the main structural wood elements (LVL, GLT and CLT), and completing a building's LCA with a structure made of CLT and LVL (Fig. 2).

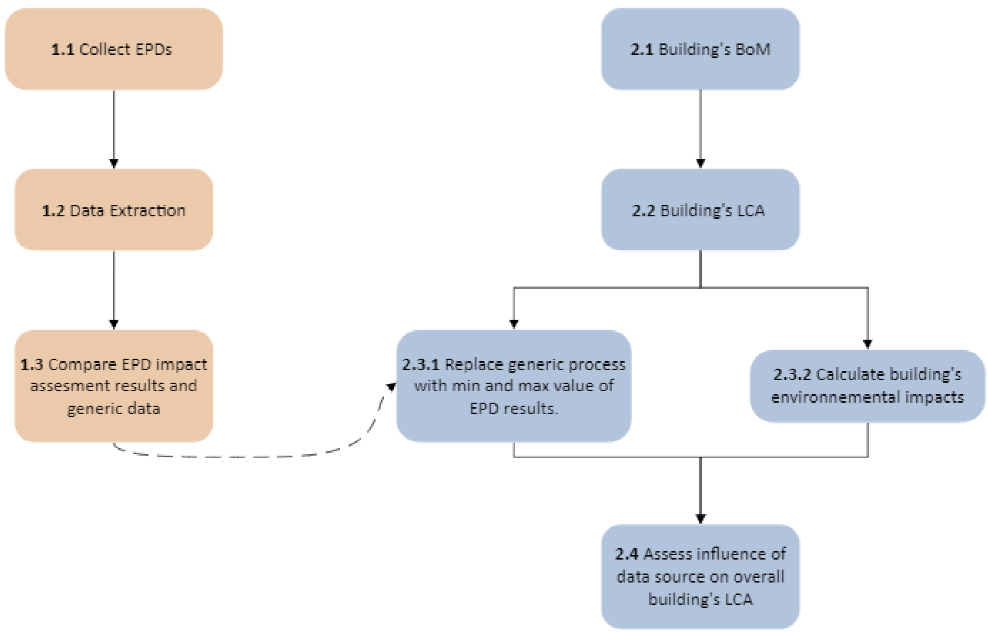

Fig. 2. Schematic view of the project's main methodological steps

Table 1. Data Extraction Criteria from EPDs Collected

Data	Description
Type of product	CLT, GLT, LVL
Scope	Life cycle stages declared
Type of EPD	Industry-wide, product specific, manufacturer specific
Proprietary	Industry association or manufacturer who declared the EPD
PCR	Name and version
Software	Name and version
LCI	Name and version
Date of issue	YYYY-MM-DD
Declared unit	Declared unit used to declare impact assessment results. $1m^3$
Density	Kg/m^3
Impact assessment results	Global Warming Potential (GWP), kg CO_2 eq. Acidification Potential (AP), kg SO_2 eq. Eutrophication Potential (EP), kg Ne eq. Smog Formation Potential (SFP), kg O_3 eq. Ozone Depletion Potential (ODP), kg CFC11 eq.

Searching and Comparing EPDs

The present study focused on North American EPDs. The EPDs follow ISO 14025 and are based on independently verified LCA data in accordance with the ISO 14040 series standard. The search for EPDs were done on the Transparency Catalog, a website that compiles every EPD from program operators in North America with different filter options (Substainable Minds 2022). A second search was conducted directly on an internet search engine, Google, to ensure that no EPDs were missed with the following keywords: CLT EPD, GLT EPD and LVL EPD. Data were collected before August 2022. EPDs were available in PDF format. Data were extracted manually from those EPDs and entered in an Excel spreadsheet. Data extracted from the EPDs and their description are presented in Table 1. If a data item wasn't available, a blank entry was left.

Impact assessment results from EPDs are compared to their corresponding dataset from the Ecoinvent v3.8 database. The Ecoinvent database was developed in Europe, but a large number of processes also represent other geographical regions in the world. It includes many construction material processes and has regional data available for the province of Quebec, Canada (Lesage and Samson 2016), where the construction site is located. If no processes from the province of Quebec were available, processes modeled for the rest of the world (RoW) were chosen.

Conducting the Building's LCA

The residential building used in this work has been created for the purpose of this study to limit subjectivity due to limitations that may occur in a typical project. A hypothetical six-story building, for a total of forty-eight units, had a mass timber structure (Fig. 3) and located in Quebec City, Canada. This building was previously used for another study: Hosseini *et al.* (2023). It was made by an architect to reflect the context of Quebec City. The main components of the structure are CLT, LVL, and steel stud and furring with a concrete foundation. The building envelope is made of stone wool and extruded polystyrene. The building had an underground parking area made of concrete. The building's facade was made of clay brick.

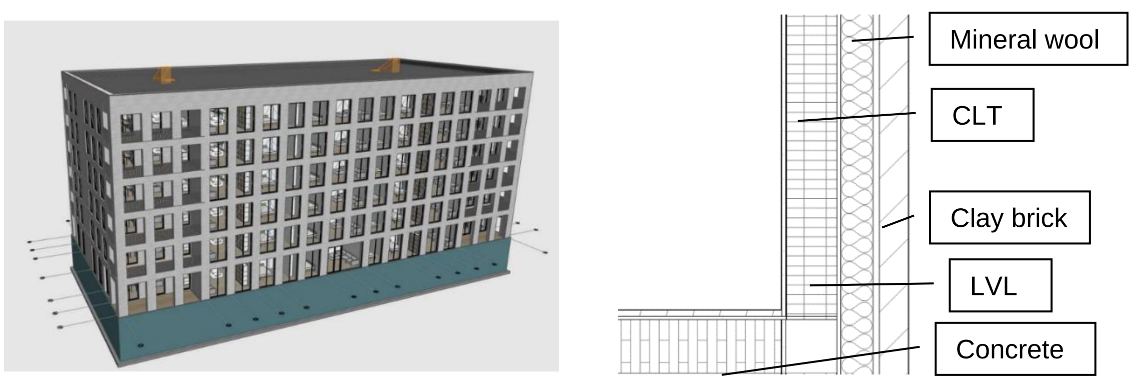

Fig. 3. 3D section view of the referenced residential building used for this study and exterior wall section

An attributional LCA was conducted on the residential building. The functional unit was designed to accommodate a six-story residential building of eight units per floor for a total of 6 196 m^2 (66 693 sq. ft.) in Quebec City (Canada) with a lifespan of 50 years. Based on a literature review of two decades of peer-review publications of environmental evaluations of low-rise and high-rise buildings, it was found that most studies use a lifespan of 50 years or longer (Bahramian and Yetilmezsoy 2020). The LCA software, LCI database and LCIA method used were SimaPro, Ecoinvent v3.8 and TRACI 2.1 respectively.

The system boundaries for the building assessment were cradle-to-grave, which includes manufacturing, construction, use and end-of-life stages (Fig. 4). Life cycle stages declared in EPD's of structural wood products were only the manufacturing stage, A1, A2 and A3 (Fig. 4). Details related to assumptions made for each life cycle stages are presented in Table 2.

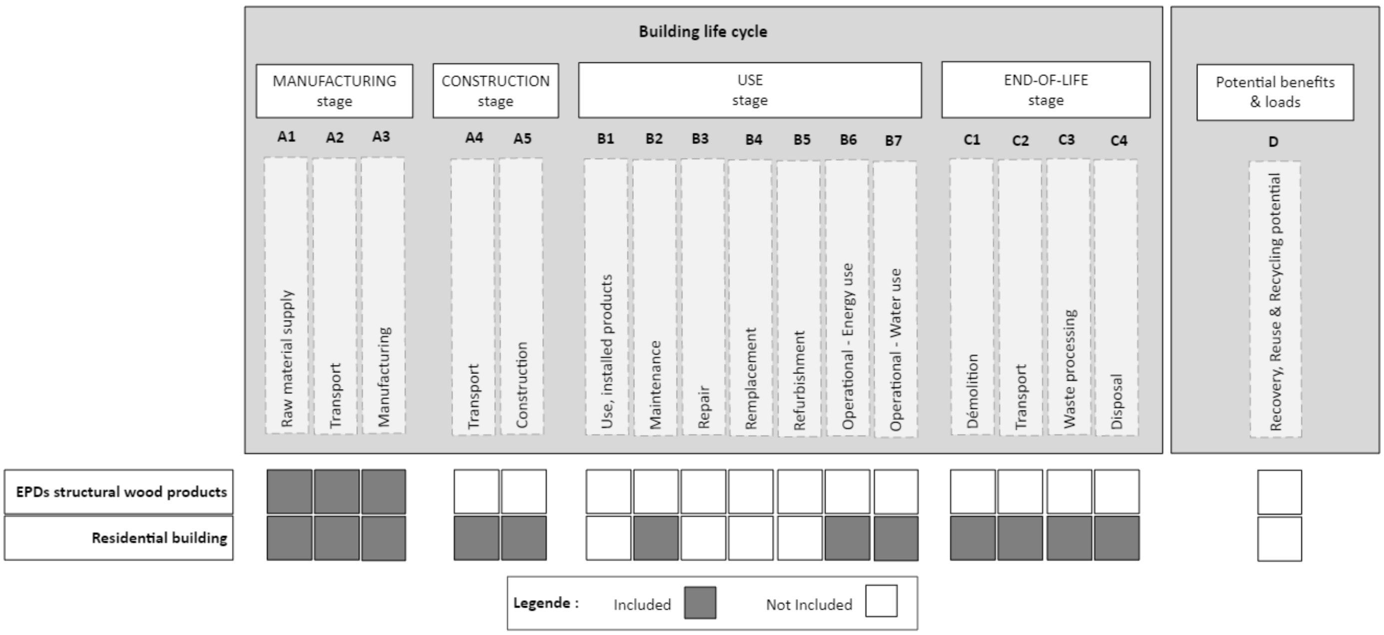

Fig. 4. Life-cycle stages declared for EPDs of structural wood products and the evaluated residential building. Source: Adapted from EN 15804:2012+A2 (CEN/TC 350 2019)

A bill of materials (BoM) representative of knowledge at early design stages of the modeled building is presented at Table 3. Processes used in Ecoinvent for each of them as well as total quantities per material are presented. These processes represent the manufacturing stages (A1-A2-A3) for the studied building. Based on their weight, concrete, CLT and brick have the highest proportion of construction materials. Based on their volume, CLT, stone wool, and concrete have the highest proportion of construction materials. The structural wood products evaluated in this study, CLT and LVL, represent 26% and 38% of weight and volume respectively. The impacts of the distance of transport were considered later in the analysis (see Table 5) and were analysed.

Table 2. LCI Assumptions for Each of the Building's Life Cycles Stages

Building Life Cycle Stages	Assumptions
Manufacturing Stage	
A1 - Raw material supply A2 - Transport A3 - Manufacturing	A manufacturing process for every material was found in Ecoinvent (table 3). The BOM of the referenced building includes materials known at the early design stages. Electrical, plumbing, doors, and windows components as well as interior and roof finishes were not considered. The geographical scope of the processes used were from the province of Quebec (CA-QC) when available. If regionalized data were not available, the processes chosen were the rest of the world (RoW), as no data regionalised for North America is available in Ecoinvent. No processes were modified: the processes representing the province of Quebec were already adapted to the energy mix. RoW processes represent construction materials that are often bought from a wholesaler who has multiple manufacturers. Consequently, the energy mix was not modified because the exact location of the manufacturer is not known.
Construction Stage	
A4 - Transport	As this study is done on a hypothetical building, there is no specific manufacturer for each construction material. Consequently, an average distance of at least 5 manufacturers (when available) from the site of construction was calculated. All materials were from the North American geographical area and was presumed to be transported by truck.
A5 - Construction	A construction waste factor was applied to materials based on a report from Brock Commons Tallwood House in British Columbia (Athena Institute 2018). Construction waste factor varied between 1% and 10% of manufactured building materials. The consumption of energy and fuel to operate machinery for construction was based on data from a 13 776 m^2 mass timber residential building (Essoua and Lavoie 2019) and adjusted for the surface of this present study.
Use Stage	
B2 - Maintenance	A majority of building material's lifespan exceed the building's (Athena Institute 2018). Consequently, the only maintenance considered was the re-caulking of brick veneer wall every 15 years for 15% of the wall area each time (Athena Institute 2002).
B6 - Operational (energy use)	The conservative average of energy consumption in residential buildings in the province of Quebec is 0,64 GJ/m^2/year (Chayer and Madavine 2019). Hydroelectricity is the main source (95%) of electricity grid mix of Quebec (CIRAIG 2014).
B7 - Operational (water use)	The water consumption of a similar residential building in Quebec was 1 919L/m^2/year (Chayer and Madavine 2019).
End of Life Stage	
C1 - Demolition	The energy and fuel consumption were the same as the construction stage.
C2 - Transport	Transport by truck of building materials to the nearest sorting facility was appointed.
C3 - Waste Processing	Materials are sorted for future disposal.
C4 - Disposal	Information of the different disposal methods of construction, renovation and demolition material were retrieved from Recyc-Québec (2018). The proportion of each material intended for landfill was modeled with the respective Ecoinvent process.
Potential Benefits and Loads	
D - Recovery, Reuse and Recycling potential	Cradle-to-grave is set as the boundaries of this LCA. Therefore, potential benefits are out of scope.

Table 3. Bill of Material and Related Ecoinvent Processes for the Studied Building

Construction Material	Quantity		% kg	% m³	Ecoinvent Process
Steel stud and furring	40 186	kg	1%	0%	Steel, low-alloyed {CA-QC}| steel production, electric, low-alloyed | Cut-off, U
Stone wool insulation	127 944	kg	4%	27%	Stone wool, packed {RoW}| stone wool production, packed | Cut-off, U
Gypsum	4 311	kg	0%	9%	Gypsum plasterboard {RoW}| production | Cut-off, U
Concrete	690	m^3	52%	15%	Concrete, 35MPa {CA-QC}| concrete production 35MPa | Cut-off, U
CLT	1 591	m^3	23%	34%	Cross-laminated timber {RoW}| cross-laminated timber production | Cut-off, U
LVL	169	m^3	3%	4%	Laminated timber element, transversally prestressed, for outdoor use {RoW}| market for laminated timber element, transversally prestressed, for outdoor use | Cut-off, U
Insulation panel	4 166	kg	0%	3%	Polystyrene, extruded {CA-QC}| polystyrene production, extruded, CO2 blown | Cut-off, U
Brick	548 932	kg	17%	6%	Clay brick {RoW}| production | Cut-off, U
Hardwood floor	131	m^3	0%	3%	Sawnwood, beam, hardwood, dried (u=10%), planed {CA-QC}| planing, beam, hardwood, u=10% | Cut-off, U
Plywood	3	m^3	0%	0%	Plywood {CA-QC}| plywood production | Cut-off, U
Wood stud	8	m^3	0%	0%	Sawnwood, beam, softwood, dried (u=10%), planed {CA-QC}| planing, beam, softwood, u=10% | Cut-off, U

RESULTS AND DISCUSSION

EPD Dataset Highlights

A total of four LVL, six CLT, and nine GLT EPDs were found in the geographical scope of North America. To understand the structural wood-based product's industry and its small amount of data available, the number of manufacturers in North America was evaluated (Forest Economic Advisor 2022). The total number of manufacturers for these products in North America and its proportion that have published an EPD is presented in Table 4. Most manufacturers of mass timber products such as CLT and GLT have published an EPD.

Table 4. Proportion of Manufacturers in North America with an EPD, Type of EPD and the PCR's Program Operator According to the Type of Product

Product	Number of Manufacturers	Number of Product or Manufacturer Specific EPDs	Number of Industry Average EPDs	PCR FPInnovations	PCR UL Environment
CLT	10	6*	0	1	5
GLT	8	7*	2	2	7
LVL	10	3	1	1	3

*One manufacturer in each product category, CLT and GLT, declared two separate EPDs for the same product. These two EPDs represent the same product but manufactured at two different plants from the same manufacturer.

Every EPD declared a functional unit of 1 m^3 of structural wood product. The assessed life-cycle stages of all products were the production stage: A1 (extraction), A2 (transport), and A3 (manufacturing). However, as some EPDs only report total aggregated values (A1-A3), environmental impacts could only be compared for the whole production stage. Table 4 presents the proportion of EPDs according to their type and referenced PCR for each structural wood product. There were two different program operators for the PCR used by these EPDs: UL environment and FPInnovations. The FPInnovations PCR North American Structural and Architectural Wood Products was the first one to be published for this category of products. UL Environment followed in 2019 and published Product Category Rule Guidance for Building-Related Products and Services, Part B: Structural and Architectural Wood Products. As EPDs are valid for 5 years, a few EPDs from different referenced PCRs overlap until 2023. EPDs from different referenced PCR may not be comparable because of various reporting formats requested. Concerning the type of EPDs, 3 industry-wide EPDs and 16 product-specific EPDs were reported.

The name of the database for the life cycle inventory (LCI) and the software used were declared for most EPDs. 58% of EPDs declared the use of three or four databases and 26% of EPDs declared the use of one database as their LCI. The use of multiple databases to conduct EPDs adds an additional variable in play when comparing EPDs between them. Therefore, if a single and harmonized background database were used for EPDs, specific data such as EPDs could be considered as added data that would be more consistent with another generic dataset (Lasvaux *et al*. 2015). More in-depth information about the elementary flows used are not disclosed. This made it difficult to understand where the differences in impact assessment results between EPDs come from. As for the software used, the use of two different software can lead to significant differences between compared scenarios or products (Emami *et al*. 2019). Differences between database and software used can add variability and make it more difficult to compare EPDs. These findings were supported by previous work of authors who showed difficulties comparing EPDs (Del Borghi 2013; Hunsager *et al*. 2014; Gelowitz and McArthur 2017; Kerr *et al*. 2022). However, this present study aims to evaluate if this uncertainty in EPDs limits their usage in a WBLCA.

Impact Assessment Results from EPDs

The environmental impact results from the EPDs were extracted and compared to data from the Ecoinvent V3.8 database. The impact results presented and chosen for comparison are part of the main categories disclosed in the EPDs. Most of EPDs had reported GWP emissions disaggregated: GWP emissions and sequestration of fossil carbon (GWP-fossil) and biogenic carbon (GWP-biogenic). GWP-fossil results, acidification potential (AP) and eutrophication potential (EP) were compared to generic data from the Ecoinvent V3.8 database (Fig. 5).

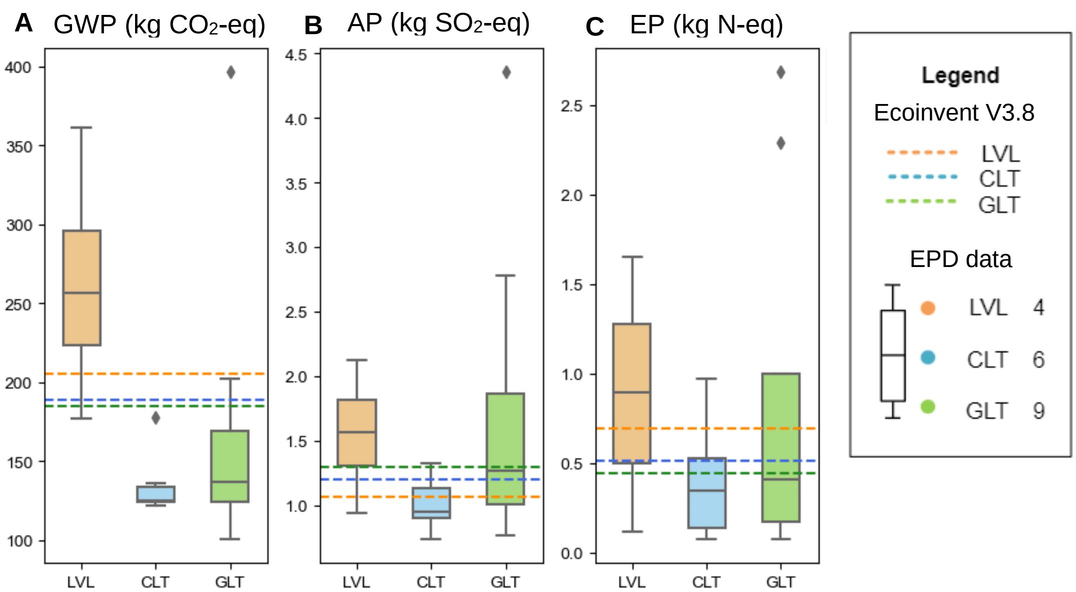

Fig. 5. Impact assessment results for a) global warming potential (GWP), b) acidification potential (AP) and c) eutrophication potential (EP) by type of structural wood products

The use of box plots was adapted for datasets greater than 5 (Krzywinski and Altman 2014), which was only the case for the CLT and GLT EPD dataset. The box plots length is defined by the upper quartile and lower quartile of the sample. It is the interquartile interval which represent 50% of the data (Statistics Canada 2021). The median is indicated by a line in the middle of the box plot. Whiskers range from the lower and upper quartile up to 1.5 times the interquartile range. If data points are located outside of this range, they are represented by dots and can be considered potential outliers (Statistics Canada 2021).

When compared to their corresponding generic data from Ecoinvent, GWP reported in EPDs had a more wide-ranging difference than their AP and EP results. LVL EPD products tend to have higher GWP results than its corresponding generic data but do overlap it. On the other hand, CLT and GLT EPD results had lower GWP than the generic data, but the GLT box plot overlapped the corresponding generic dataset. Therefore, for CLT and GLT, GWP values for the generic data were more conservative than EPD results, with the exception of one outlier for GLT products. This finding was also supported by Strazza *et al*. (2016), who studied the usage of EPDs as a source of data for LCA for a specific case study of water bottles distribution onboard a cruise ship. The results suggested that the use of EPDs could avoid overestimation of potential environmental impacts (Strazza *et al*. 2016). However, LVL EPDs seemed to overestimate GWP results compared to its generic data. As for the AP and EP indicator, all box plot from the EPD results overlapped with its generic dataset. Therefore, using AP and EP indicators presents less variation of EPD data and the Ecoinvent database than the use of GWP indicator.

Considering the use of different PCR, database and software, direct comparison between EPDs is not recommended or should only be done with caution. Every whisker from EPD results overlapped its Ecoinvent generic dataset, with the exception of the GWP indicator for CLT products. The potential benefit of choosing a manufacturer from another is probably not as important as choosing a different kind of product in the context of a building project.

The use of EPDs as a data source also presented limitations. Access to background data is not disclosed in EPDs, which can limit the comprehension of the practitioners as to why a manufacturer's product has higher impact results than others. Elementary flows are disclosed in generic dataset and can be modified to better represent the geographical location of the scenario. In addition, environmental impacts were not always disclosed in disaggregated form.

Applying CLT and LVL EPDs to the building's LCA

A life cycle assessment was conducted on the hypothetical multi-story residential building with mass timber structure. The share of each life cycle stage for the environmental impact GWP is presented in Fig. 6. The three most contributive materials within the manufacturing stage are also presented.

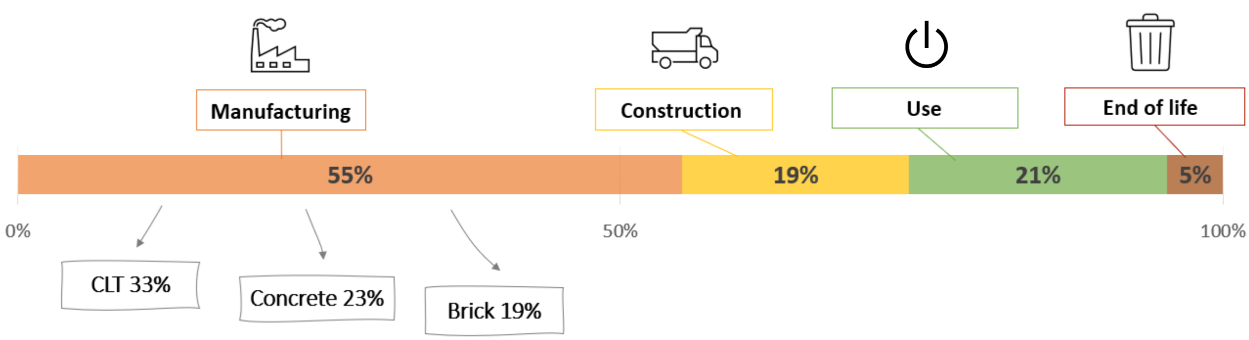

Fig. 6. Shares of environmental impacts of global warming potential (GWP) of the evaluated multi-story residential building for 50 years

The manufacturing stage was the most contributive phase accounting for 55% of the building's LCA evaluated. Within the manufacturing stage, the most contributive materials were CLT, concrete, and clay brick with respectively 33%, 23%, and 19% GWP. On the other hand, LVL contributed 4% GWP of the manufacturing stage. The superior proportion of embodied energy compared to operational energy can occur in the context of a low impact energy mix (Chastas *et al*. 2016; Lessard *et al*. 2018), such as in the province of Quebec where the reference building was located.

To evaluate the effect of replacing a process by the results found in an EPD of a specific material, the maximum and minimum GWP EPD impact results of CLT and LVL EPDs were used and were compared to the respective process in Ecoinvent. Table 5 presents the EPDs with the maximum and minimum GWP indicator for CLT and LVL products and its respective distance from the construction site. The distance between the manufacturing site and the construction site is not information disclosed in EPDs, as they reported only environmental impacts at the manufacturing stages. The distance between the manufacturing site and the construction site was considered in the construction stage (A4) and was used to represent each scenario. For the Ecoinvent scenario, the distance used was an average of 5 manufacturers, as mentioned in the methodology previously.

Table 5. Maximum and Minimum GWP Indicator for CLT and LVL EPDs and Their Respective Distance from the Construction Site

Source	Type of Product	Type of EPD	Distance from Construction Site (km)	GWP (kg CO_2 eq.)
Nordic	CLT	Specific	516	1.22E+02
SmartLam Montana	CLT	Specific	3811	1.78E+02
Redbuilt LLC	LVL	Specific	4808	1.77E+02
American Wood Council (AWC) Canadian Wood Council (CWC)	LVL	Industry	2000*	3.61E+02
*Hypothetic distance. Members of this association were not disclosed in the industry-wide EPD. The distance was set as the half distance to reach approximately east to west of North America.				

Data from Table 5 were used to assess three different scenarios for the mass timber building evaluated: maximum and minimum GWP indicator from EPDs and the generic data. Figure 7 presents the impacts assessment results for the cradle-to-grave LCA of the building and its variation when comparing the use of three different data sources for CLT and LVL products.

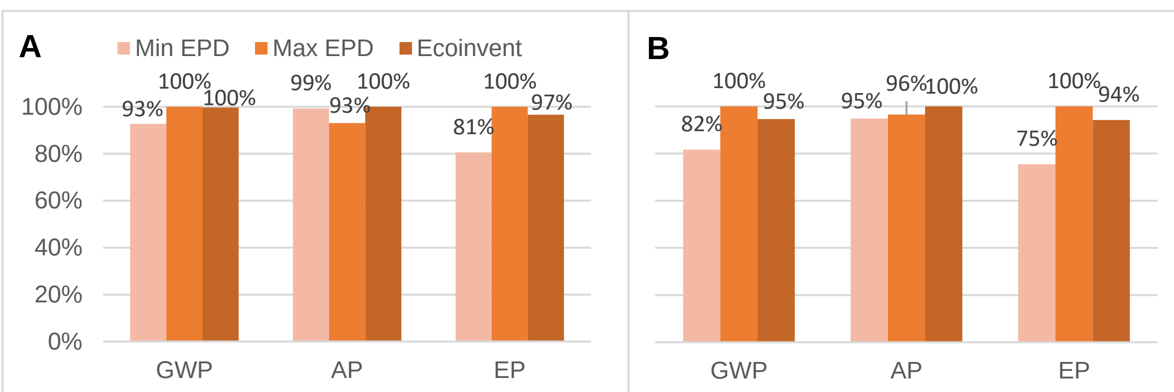

Fig. 7. Impact assessment results, global warming potential (GWP), acidification potential (AP) and eutrophication potential (EP) of a cradle-to-grave multistory building according to the process used for CLT and LVL products. A) The transport's distances are the same for each scenarios B) The transport's distance of CLT and LVL products from Table 5 is considered.

For the GWP of the multi-residential building, a difference of 7%, or 1.20E+05 kg CO_2 eq, was observed when comparing the different types of data used, as presented in Fig. 7A. When inserting EPD data for the structural materials of a building without changing any other LCI of the LCA, there is a potential 7% reduction on the overall LCA. For the GWP indicator, a minimum of 10% variation between scenarios is considered a significant difference (Humbert *et al*. 2014; Chen *et al*. 2021).

EPDs such as structural wood products disclose a scope limited to the manufacturing stages. Consequently, some environmental impacts would not be considered if practitioners only conducted direct comparison between EPDs. EPD results should be used in building LCA with consideration of the other stages that may be impacted, such as the distance of transportation of CLT and LVL products between the manufacturer and the construction site (Fig. 7B). When considering the different transport's distances from the respective manufacturers, Fig. 7B presents a significative reduction of 18% for the GWP indicator. CLT was the most contributive construction material (Fig. 6), which explains how the gap between the minimum and maximum scenario exhibited a greater gap: the CLT EPD with the highest GWP indicator was also the furthest from the construction site. Transport of construction materials can have a significant impact depending on the origin and the transport method (Hemmati *et al*. 2022).

This article aimed to evaluate to observe the impact of using EPD results in a LCA of a multi-residential building with a specific focus on wood structural products. EPDs are being used more widely as a data source for building LCA by practitioners. Previous work suggested there are difficulties for comparing EPDs between them, as also acknowledge in the first findings of this study. However, this study suggests that the uncertainty of EPDs does not limit them from being used in WBLCA: the results fall into the uncertainty tolerated within LCAs. Using EPD results or an Ecoinvent process for the structural products of a mass timber residential building does not have an important impact on the overall building's LCA. Therefore, EPDs can be regarded as valuable and accessible information for practitioners to make an LCA. In addition, this study suggests the importance of using EPDs within an LCA rather than only direct comparison between EPDs for decision making. As buildings are a complex system, failing to consider the WBLCA may result in shifting environmental impacts to other stages. Using only EPD's results for decision making may lead to neglecting other environmental impacts not considered in the EPD's scope. Considering the distance of transport between the manufacturer and the construction site was found to be an important parameter that is not disclosed in structural wood products EPDs analyzed in this study. Other life cycle stages must be considered to have a more holistic view and choose the best suited construction product.

CONCLUSIONS

1. From a methodological standpoint, environmental product declarations (EPDs) are notably hard to compare and analyse due to their use of different product category rules (PCRs) and databases. In addition, EPDs in their current form do not provide enough information or transparency for the practitioners to be able to understand why an environmental impact result is higher than another EPD. Environmental impact results were also presented differently between EPDs (aggregated life cycle stages).
2. From a practical standpoint, this study suggests that practitioners using EPDs as a source of data to conduct a whole building life cycle analysis (WBLCA) can get a relatively accurate picture of their project. In the context of growing demand for

environmental assessments of products and buildings, EPDs are an accessible and reliable source of data for practitioners having to assess a building's environmental impacts.

3. Direct comparison between EPDs by practitioners should be limited. Using EPD data is more appropriate in whole building assessment than on a simple comparison basis. EPDs don't always disclose all life cycle stages depending on the followed PCR: other environmental impacts could be overlooked or transferred. Environmental impacts at the construction stage such as the transport of construction materials can have a significant impact. The use of EPD data within whole building LCA can help practitioners make a more comprehensive and exhaustive decision for the choice of building materials.
4. This study focused on EPDs of structural wood products. More research on other types of construction materials should be pursued to document the impact of their use as a data source for WBLCA.

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