Environmental Evaluation of Experimental Heat-treated Oriented Strand Board

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The use of wood-based panels such as Oriented Strand Board has grown in civil construction. This follows the contemporary trend towards low environmental impact materials. However, there is a lack of relevant information about their life cycle assessment, appearing as a current and relevant research topic. Experimental panels made with *Eucalyptus* wood and castor oil-based polyurethane adhesive already demonstrated great physical-mechanical performance. Therefore, this study aimed to continue the evaluation of this innovative product, estimating their potential environmental impacts using life cycle assessment from a cradle-to-gate perspective and comparing the results with traditional panels and literature data. System boundaries, environmental impacts and environmental hotspots were identified using the ReCiPe H method in terms of ten impact categories. Comparing experimental (heat-treated) and traditional panels, the experimental versions performed better in most categories and showed safer behavior in categories related to human health in addition to not using paraffin, termiticide, and other organic chemicals presented in the traditional panels. Though made of different types of adhesives, the adhesive was the main environmental hotspot for both types.

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INTRODUCTION

Due to its influence, the construction industry must play an important role in the decrease of use of natural resources, energy consumption, and waste generation. In this way, life cycle assessment (LCA; ISO 2006a,b) is a valuable method to identify systems or elements of the buildings that have negative effects on the environment, and it is recommended to be performed to positively guide the choice of better environmentally friendly solutions (Cascione *et al.* 2022).

Technological innovations in the construction industry are consistently related to the development and application of new materials (van de Kuilen and Dias 2011; Monteiro *et al.* 2015; Santos *et al.* 2015). Wood-based panels have been increasingly applied in building consstruction, given the existent inclination towards materials with reduced environmental impacts (Pozzer *et al.* 2020). These benefits include low energy consumption and low CO_2-emissions (De Windt *et al.* 2018).

Wood-based panels are engineered wood products made with wood glued with adhesives (Farjana *et al.* 2023). They are commonly used in civil construction as an affordable and adaptable alternative. The performance of the panels is greatly affected by the adhesives used in their manufacture (Lee *et al.* 2023). However, the frequently used adhesives are linked to worries related to the non-renewable origin, volatile organic compounds, and dangerous substances because of their toxicity and carcinogenic nature (Barbirato *et al.* 2019a).

Concerns are emerging regarding the environmental impacts resulting the manufacture of engineered wood products and end-of-life management as a result of the growing demand for wood-based products in the worldwide building sector (Farjana *et al.* 2023), which is supported by the embodied impact of biogenic carbon of timber-frame buildings (Norouzi *et al.* 2023).

These products have presented possibilities of increasing applications in several industrial sectors, with emphasis in civil construction and furniture industry. With this growth, it becomes an essential matter to produce new materials in a sustainable way, presenting similar properties, durability, and quality if compared with the industrial products already available in the market (de Carvalho Araújo *et al.* 2022).

Despite the carbon-neutral characteristic of the wood materials, they usually present a long service life and a multifunctional production chain, provoking concerns connected to their life cycle. In this sense, because of their potential challenges, it is fundamental to perform and understand the environmental aspects to handle possible issues (Garcia and Freire 2014). LCA is an effective tool to do these evaluations (Deng *et al.* 2023).

LCA is not only an instrument to improve the environment, but it also plays an important role in advancing competitive and sustainable growth as an instrument for industry. LCA has potential to reveal cost savings and competitive advantages, in addition to its role in saving natural resources and energy and in minimizing pollution and waste. LCA expertly supports decision-makers with scientific data and value sets and is also an essential source for eco-labeling required by consumers, NGOs, and international authorities. In this sense, new materials and products should be based on the LCA concept (Jensen *et al.* 1997).

LCA addresses the environmental aspects and potential environmental impacts, for example, use of resources and the environmental effects of releases, related to the functional unit of a product system through a life cycle from raw material acquisition through production, use, end-of- life treatment, recycling, and final disposal (ISO 2006).

There are numerous published studies that have assessed the environmental aspects of wood-based products applied as building materials in civil construction, such as roundwood (Dias and Arroja 2012; Kuka *et al.* 2019; Dias *et al.* 2022), structural engineered wood products (Hill and Dibdiakova 2016; Laurent *et al.* 2016; Scouse *et al.* 2020; Dias *et al.* 2020, 2021a), wooden floors (Dossche *et al.* 2018; Dias *et al.* 2021a,b) wooden doors (Deng *et al.* 2023; Wang *et al.* 2023), and different types of wood-based panels or products made with wood panels (Rivela *et al.* 2007; Benetto *et al.* 2009; González-García *et al.* 2011; Silva *et al.* 2013; Garcia and Freire 2014; Maoduš *et al.* 2016; Ferro *et al.* 2018; Li *et al.* 2019; de Carvalho Araújo *et al.* 2022; Farjana *et al.* 2023).

However, particularly related to Oriented Strand Board panels (OSB), there is a relative scarcity of relevant information across their life cycle sustainability evaluation. Most of the studies available in the literature have only focused on the performance of the wood panels in measuring their physical and mechanical properties (Werner and Richter 2007). But to manufacture sustainable construction materials, it is imperative to also assess their environmental impacts (Sugahara *et al.* 2023).

Buildings with frame structures generally have a more favorable impact on the environment if compared to buildings with heavy load-bearing walls, which consume more materials (Jasiołek *et al.* 2023). OSB panels are the most widely used wood-based panels in the light-frame wood construction (Lee *et al.* 2023).

The OSB production and consumption worldwide is growing, having increased approximately 24% and 26%, respectively, between the years 2016 and 2020 (FAO 2022). But despite the growth in consumption, is also notable that the traditional components of the OSB can possibly be made of harmful chemicals, and they may be questionable in terms of sustainability (Farjana *et al.* 2023). For example, they may incorporate formaldehyde-based adhesives that can present toxic and carcinogenic nature (Barbirato *et al.* 2019a). They also may contain the pyrethroid termiticide. The latter is applied in panels to improve their durability against the attack of wood decay organisms, but it can show worrisome contributions to environmental impact (Ferro *et al.* 2018).

The bio-based products, such as the wood-based, became a priority area because they can act as a solution for substituting materials and can also show improvements related to the biodegradability, renewability, or composability concerns of the products (Bianco *et al.* 2021).

In addition to the necessity for more sustainable alternative materials, it is vital to research diverse types of materials and methods to guarantee that the panels meet the requirements (structural, durability, and aesthetic), to be safely employed. Regarding this, it is imperative to study alternative lignocellulosic resources, adhesives, and techniques to assure the resistance against termite attack, replacing chemical preservatives with systems possibly less dangerous, as the heat treatment (Sugahara *et al.* 2022c).

Taking this scenario into account, the assessment of environmental hotspots linked to the manufacture of OSB is a contemporary and appropriate field of research presenting great relevance (Sugahara *et al.* 2023). In previous studies, it already has been established that experimental OSB panels made with *Eucalyptus* wood and castor oil-based polyurethane adhesive achieved physical-mechanical performance compatible with the EN 300 classification for OSB, presenting technical feasibility and excellent structural profile for civil construction applications (Sugahara *et al.* 2022b). However, there is still no LCA study that addresses the environmental performance of this type of board.

This study had the following objectives: i) to estimate the potential environmental impacts related to the experimental production of heat-treated OSB made with these alternative raw materials by using LCA methodology in a cradle-to-gate perspective, and ii) to compare the results with the environmental impacts of traditional panels and literature data. By evaluating the potential environmental impacts of this innovative solution, this study reported advances in the field presenting alternatives to contribute to the accomplishment of the global sustainability targets.

EXPERIMENTAL

This section describes the details and limitations of the LCA modelling of the OSB panels. It also defines the goals and scope, functional unit, system boundaries and the impact categories under assessment, and the phases of life cycle inventory (LCI), life cycle impact assessment (LCIA) and interpretation.

Goal and Scope Definition

This paper aimed to quantify the potential environmental impacts related to the experimental production of heat-treated OSB (H_OSB) made with alternative raw materials by using LCA methodology. The results were analyzed and compared with the environmental impact results of traditional panels (G_OSB) available in the software database and literature data.

To assess the experimental panels, the data were acquired *via* a survey of manufacturers following the ISO14040 standard (2006a), previous studies, literature review, and databases of processes available in the software (for example, Ecoinvent).

The functional unit adopted was 1 m³ of OSB, assuming a nominal density of 780 kg/m³ for experimental panel, without covering. The scope of the study was from cradle-to-gate, including the raw materials extraction and preparation, and the production of OSB panels (the construction, product use and end of life phases weren't considered in this evaluation). For this study, the intended audience consists of researchers of OSB and raw materials, industry representatives, decision-makers, and LCA practitioners.

Table 1. Environmental Impact Category Indicators Used

Impact Category	Description
Climate change (CC)	Describes the increment in the average temperature of the planet because of emissions of greenhouse gases of anthropogenic origin (de Carvalho Araújo *et al.* 2022). Measured in kg CO_2 eq.
Ozone depletion (OD)	The ozone depletion represents the relative strength of a product or a process to destroy the stratospheric ozone layer by anthropogenic emissions of ozone-depleting substances (de Carvalho Araújo *et al.* 2022; Dias 2022). Measured in kg CFC-11 eq.
Terrestrial acidification (TA)	Calculated in terms of H^+ releases without addressing the destiny of chemicals in air and in soil emissions and following depositions. Happens predominantly due to precipitation of NH_3, NO_2, NO, SO_2 and SO_3 (Dias 2022). Measured in kg SO_2 eq.
Freshwater eutrophication (FE)	Assess the effects of eutrophication on maritime ecosystems (Dias 2022). Associated to the elevated level of nutrients in ecosystems, especially in aquatic algae multiplication (de Carvalho Araújo *et al.* 2022). Measured in kg P eq (FE) and kg N eq (ME).
Marine eutrophication (ME)	
Human toxicity (HT)	Evaluate the impacts of chemicals elements on human health through air, soil, and water (Dias 2022) (with carcinogenic effects). Measured in kg 1,4-DCB.
Photochemical oxidant formation (POF)	Addresses the impacts from ozone and another oxygen compounds produced by the oxidation of Volatile Organic Compounds (VOC), under the influence of sunlight (Dias 2022) in human health. Measured in kg NOx eq.
Terrestrial ecotoxicity (TET)	Quantifies the impacts of chemical substances that affect different species and ecosystems (de Carvalho Araújo *et al.* 2022; Dias 2022). Measured in kg 1,4-DCB.
Freshwater ecotoxicity (FET)	
Fossil depletion (FD)	Related to the use of fossil resources (Dias 2022). Measured in kg oil eq.

The characterization factors described in the ReCiPe Midpoint (H) method was considered to conduct the assessment of the environmental impacts associated with the OSB production system. Ten environmental impact category indicators were analyzed, as described in Table 1.

For this LCA, the comparisons were made considering the limitations of impact categories, data gaps, characterization models, system boundaries, and inclusion/exclusion or differences of inputs and outputs described in the experimental section.

Case Study

The research object of this study is experimental OSB panels made with intended applications to have structural purposes in civil construction following the current European production processes available in the Ecoinvent database (Ecoinvent 3.6 2019).

The experimental OSB panels of this study were based on those produced in the work of Sugahara *et al.* (2022b), adopting similar materials and methods for production and heat treatment.

In this way, for the raw materials was considered the *Eucalyptus ssp*., a reforested wood with density of 520 kg/m³. And castor oil-based bicomponent polyurethane, that is a biodegradable adhesive with renewable origin obtained from vegetable oil (Barbirato *et al.* 2019a). After production, the experimental OSB was subjected to heat treatment, replacing the use of wood chemical preservatives, which can present potential toxicity (Sugahara *et al.* 2022c).

The LCA model applied in this study followed the procedures of the standards ISO 14040 (2006a), ISO 14044 (2006b), and EN 15804+A2 (2019), considering characterization factors reported by ReCiPe 2016 Midpoint (H) V1.04 / World (2010) H method. The software SimaPro (PhD with Share & Collect, release 9.1.0.7) was used to implement the LCI worldwide datasets of environmental impacts such as Ecoinvent 3, ELCD. In the next sections, the four stages of an LCA study: goal and scope definition, inventory, impact assessment, and interpretation, are detailed.

Description of the Product and System Under Assessment

The OSB assessed in this study is projected for structural uses with the physical and mechanical properties compatible with the requirements of EN 300 (2006). The items were modelled based on the OSB panels already produced in the previous work of Sugahara *et al.* (2022b), which meet the system boundaries of the generic OSB (G_OSB) available in the inventory of the Ecoinvent 3 database (Ecoinvent 3.6 2019). That process was used as a model for assessment and comparison in this study.

The OSB production system consists in the stages of strands manufacturing and drying, strands blending in a rotating drum with a mist of resin and wax, forming line of the mat of strands on a continuous belt conveyor with a cut-off saw, mat pressing under high temperature, and finishing (trimming and cutting) (Ecoinvent 3.6 2019).

For the experimental OSB (H_OSB), the same production system of G_OSB was considered, however, a stage of heat treatment was added after the OSB production.

The system boundaries of the OSB life cycle under study (cradle-to-gate) is presented in Fig. 1.

For the assessment of the environmental impacts of the experimental panels (H_OSB), some modifications were made to the data of the original file (G_OSB). In this context, data from secondary sources were used as a base for the LCI. These changes consisted of replacing some specific parameters of products and processes available in the software dataset from information obtained through a survey of manufacturers or previous studies and following the ISO 14040 standard (2006a). Table 2 explains the details of these modifications.

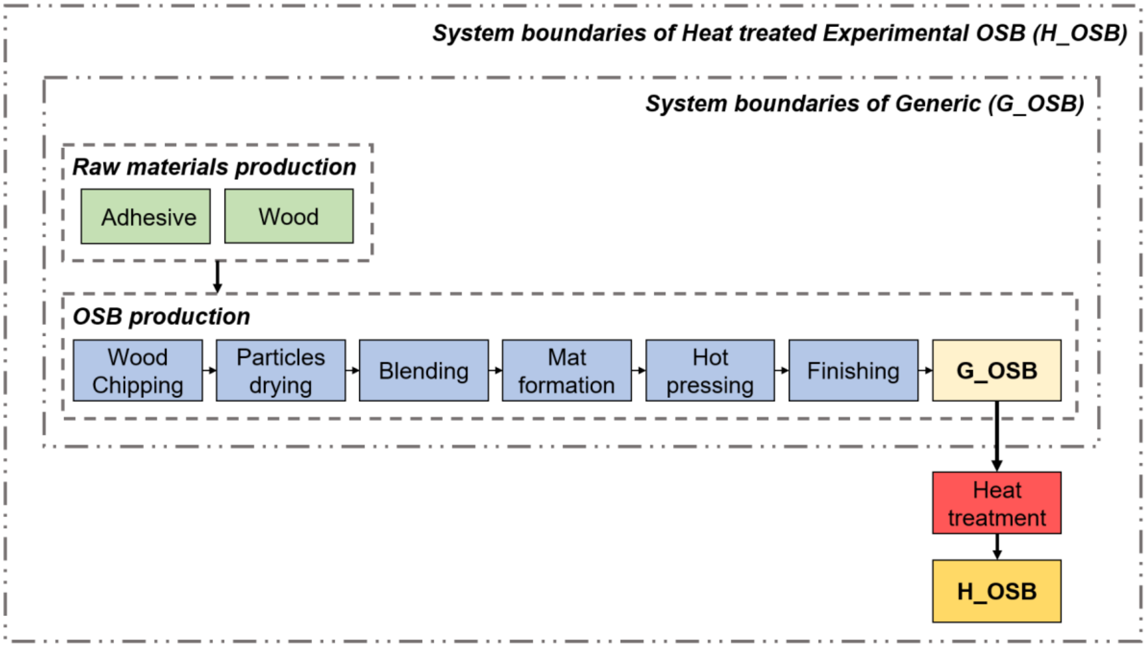

Fig. 1. System boundaries of the OSB panels

Table 2. Comments and Sources of Data/Procedures Used in the LCI

Item	Actions and Sources of Data/Procedures Used
OSB panels	Was considered for the H_OSB; nominal density of 780 kg/m³; used 10% of adhesive based on the dry mass of wood strands (Sugahara *et al.* 2022b).
Wood	The generic softwood of the G_OSB was replaced by *Eucalyptus spp*. wood in the H_OSB. Consequently, the quantity of carbon dioxide sequestrated was replaced according to the density of the wood used in the experimental OSB (520 kg/m³ at 12% of moisture content) (Sugahara *et al.* 2022b).
Adhesive	The adhesive MDI was replaced in the H_OSB by a new one that was created to represent the polyurethane adhesive derived from castor oil. For model this product, the data used was given by the industry of the adhesive and modelled following the same procedures described in the study of Sugahara *et al.* (2023).
Heat treatment	The heat treatment of the H_OSB modelled was carried out in an electric oven without atmosphere replacement at 175 °C, with the panel accommodated in the oven in a room temperature and kept there for 60 minutes of heat treatment after reach the expected temperature, totalizing 125 min and heating rate of approximately 2.7 °C/min (Sugahara *et al.* 2022b).
Others	In the H_OSB chemical additives such as Acetaldehyde, Formaldehyde, Methanol and NMVOC (non-methane volatile organic compounds, unspecified origin) related to the glue drying process for wood and wax were excluded (Sugahara *et al.* 2023). In the G_OSB was included the pyrethroid termiticide, which is applied in the panels to improve their resistance to attack by wood decay organisms, in a same quantity used to produce a m³ of OSB in the study of Ferro *et al.* (2018).

Life Cycle Inventory

The inventory of processes to model the LCA of the panels was mainly based on pre-defined processes included in the Ecoinvent database or created/adapted to the specific parameters of this work.

The Global inventory data per functional unit of the experimental heat-treated OSB (H_OSB) and a generic model of traditional panels (G_OSB) is presented in the Appendix.

RESULTS AND DISCUSSION

This section describes the life cycle impact assessment (LCIA) and interpretation phases of the assessment. Table 3 presents the environmental impacts obtained for each impact category per 1 m³ of H_OSB and G_OSB. To enrich the evaluation of the results, data referring to the work of Ferro *et al.* (2018), which also used the ReCiPe method to evaluate the environmental aspects of Brazilian OSB production, are presented as a source of literature data for comparison (named as B_OSB).

Table 3. Potential Environmental Impacts per 1 m³ of H_OSB, G_OSB, and B_OSB

Impact category		Unit	H_OSB	G_OSB	B_OSB
Global warming	CC	kg CO_2 eq	157.46	250.36	127.00
Stratospheric ozone depletion	OD	kg CFC11 eq	8.64E-04	1.16E-03	8.30E-06
Ozone formation, Human health	POF	kg NOx eq	1.03	1.15	1.86
Terrestrial acidification	TA	kg SO_2 eq	1.38	1.08	1.82*
Freshwater eutrophication	FE	kg P eq	0.02	0.02	0.01
Marine eutrophication	ME	kg N eq	0.12	0.04	0.07
Terrestrial ecotoxicity	TET	kg 1,4-DCB	417.40	789.26	0.03
Freshwater ecotoxicity	FET	kg 1,4-DCB	0.23	0.31	0.23
Human carcinogenic toxicity	HT	kg 1,4-DCB	0.89	8.76	10.00
Fossil resource scarcity	FD	kg oil eq	37.17	99.83	50.00
*Value in kg NMVOC eq					

The analysis of the potential environmental impacts showed that the H_OSB performed better than G_OSB in 7 of 10 impact categories (OD, POF, FE, TET, FET, HT, FD), while G_OSB performed better than H_OSB in 3 of 10 (CC, TA, ME). Comparing the 3 types of OSB (H_OSB, G_OSB, and B_OSB), it turns out that H_OSB exhibited the worst potential environmental impacts (in terms of higher values) in only one category (ME). G_OSB had the worst performance in 5 categories (OD, FE, TET, FET, FD) and B_OSB in 4 of 10 categories (CC, POF, TA, HT). Figures 2 and 3 display the relative contributions to each impact category from the main contribution factors involved in H_OSB and G_OSB cradle-to-gate life cycle.

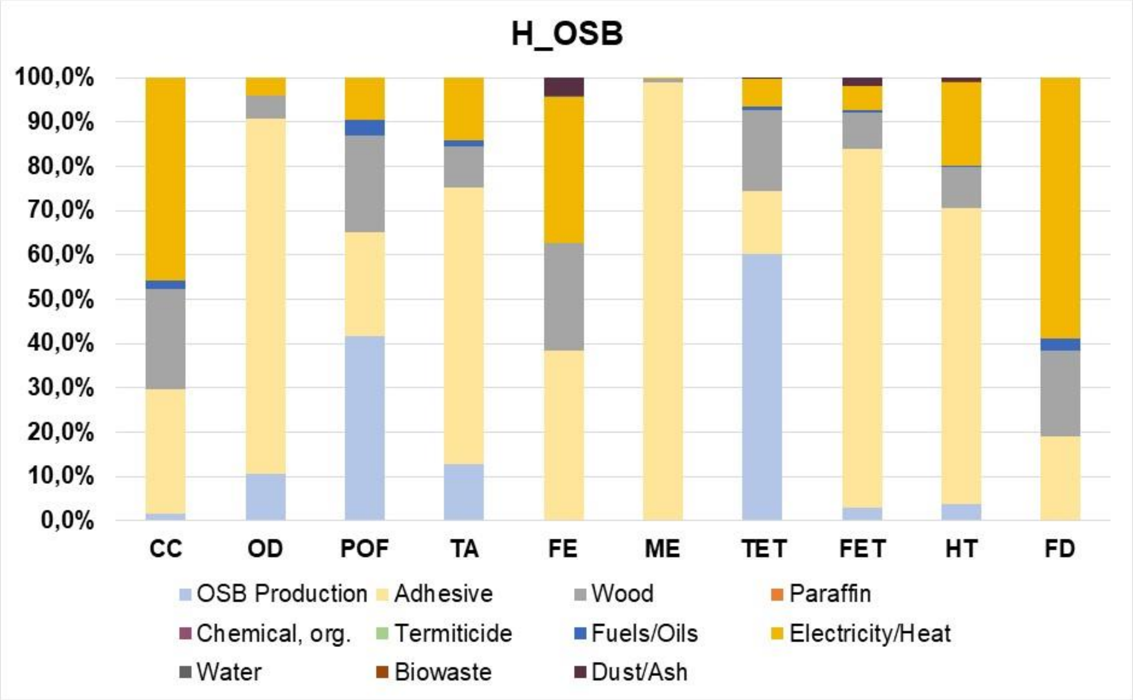

Fig. 2. H_OSB Relative Contributions (in %) to Each Impact Category per Outstanding Contribution Factors

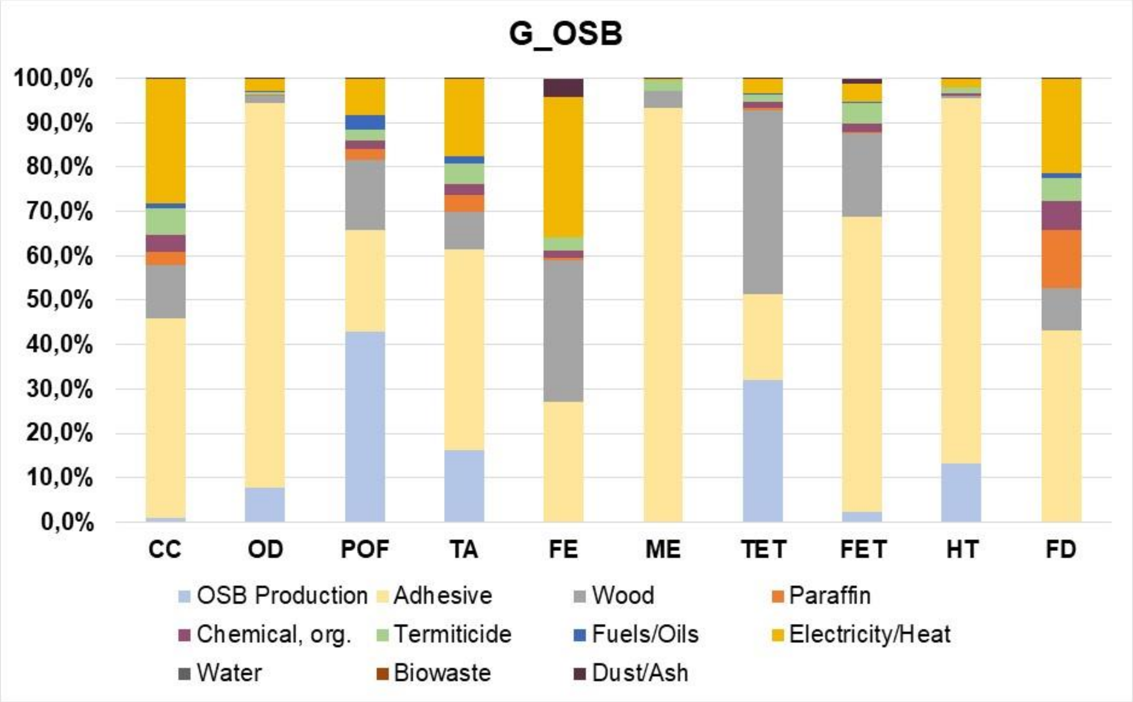

Fig. 3. G_OSB Relative Contributions (in %) to Each Impact Category per Outstanding Contribution Factors

To understand the detailed discussion of the impacts on each category, it is important to note that adhesives and wood species are different for both OSB types evaluated, *i.e.*, polyurethane adhesive derived from castor oil and *Eucalyptus* wood for the innovative OSB (H_OSB) and Generic Softwood and MDI resin for the generic OSB (G_OSB). The contributing factors: termiticide, chemical, org., and paraffin had no influence on the analysis of H_OSB in any category, since these materials were not used in the production of H_OSB. The followed paragraphs discuss and compare the contribution of each unitary process on each environmental category:

Global warming (CC): For H_OSB, the electricity/heat (46%) was the major contribution factor, followed by adhesive (28%), wood (23%), fuels/oils (2%) and production (1%). For G_OSB the adhesive (45%) was the main contributor, followed by electricity/heat (28%), wood (12%), termiticide (6%), chemical, organic (4%), paraffin (3%), production (1%) and fuels/oils (1%).

In this category, while H_OSB had a greater influence on electricity, possibly related to the increase of the heat treatment step that does not exist in the generic panel, G_OSB had a greater influence related to the adhesive used. H_OSB and B_OSB (Ferro *et al.* 2018) also showed the adhesive (MDI, a petroleum-based resin) as the main factor (38%) in the climate change potential category, relating this result to the use of crude oil in its manufacturing.

The petroleum-based resins are significant polluters whose emissions influence beyond the global warming category, also the oxidant formation, acidification, eutrophication, and toxicity (Bucklin *et al.* 2022).

Stratospheric ozone depletion (OD): H_OSB demonstrated contribution of 80% from adhesive, 11% from production, 5% from wood, and 4% from electricity/heat. G_OSB had 86% from adhesive, 8% from production, 3% from electricity/heat, 2% from wood, and 1% from termiticide. The 3 most influential factors for B_OSB (Ferro *et al.* 2018) were chemicals, with 30% for paraffin and pyrethroid termiticide linked with the methane (CH_4) emitted during the production of the termiticide, wood (19%) and adhesive (15%).

Ozone formation, Human health (POF): For H_OSB, the production represents 42% of the total contribution, adhesive 23%, wood 22%, electricity/heat 9%, and fuels/oils 4%. In G_OSB, production represents 43%, adhesive 23%, wood 16%, electricity/heat 8%, paraffin 3%, and fuels/oils 3%, termiticide 2%, and chemical, organic 2%.

Comparing H_OSB and G_OSB it is notable that, despite the difference with respect to heat treatment and some other details, the impacts of adhesive, wood, and electricity/heat show same order of influence and close values. G_OSB also has the presence of paraffin, termiticide and other chemicals that are not present in H_OSB. Thus, the difference in the total potential environmental impacts per 1 m^3 in kg NOx eq of H_OSB (1.03), which is smaller than that of G_OSB (1.15), is possibly attributable to the presence of these factors. For B_OSB (Ferro *et al.* 2018), emissions from the heat generation are responsible for 81% of the total, followed by the adhesive (7%), totaling 1.86 kg NMVOC eq.

Terrestrial acidification (TA): H_OSB exhibited a contribution of 63% from adhesive, 14% from electricity/heat, 13% from production, 9% from wood, and 1% from fuels/oils. G_OSB had 45% from adhesive, 17% from electricity/heat, 16% from production, 8% from wood, 5% from termiticide, 4% from paraffin, 3% from chemical, organic and 2% from fuels/oils. In B_OSB (Ferro *et al.* 2018) heat generation were responsible for 71% followed by adhesive with 12%.

Freshwater eutrophication (FE): For H_OSB, the adhesive (39%) was the major contribution factor, followed by electricity/heat (33%), wood (24%), and dust/ash (4%). In H_OSB wood (32%) was the main factor, followed by electricity/heat (31%), adhesive

(27%), dust/ash (4%), termiticide (3%), chemical, organic (2%), and paraffin (1%). B_OSB (Ferro *et al.* 2018) presented 35% of the total contribution related to the production of chemicals (such as paraffin and pyrethroid termiticide, where pyrethroid termiticide was the leading) and the second largest contributor (25%), was the forest operations.

Marine eutrophication (ME): The adhesive was the main factor with almost all the contribution (99%) with a small representation of 1% of wood in H_OSB. For G_OSB, adhesive showed 94%, wood 4%, and termiticide 2%. However, for B_OSB (Ferro *et al.* 2018), 75% of the impacts were related to the emissions produced during the heat generation process and the second main contributor was the adhesive with 9%.

Terrestrial ecotoxicity (TET): In this category, H_OSB contributed 60% related to the production, followed by wood (18%), adhesive (14%), electricity/heat (6%), fuels/oils (1%), and dust/ash (1%). For G_OSB, 42% was associated with wood, being followed by production (32%), adhesive (19%), electricity/heat (3%), termiticide (2%), chemical, organic (1%), and paraffin (1%). Nevertheless, for B_OSB (Ferro *et al.* 2018), electricity represented more than 72% of the impacts and the adhesive (10%) was the second major contributor.

Freshwater ecotoxicity (FET): For H_OSB, adhesive (81%) exhibited large contribution, accompanied by wood (8%), electricity/heat (6%), production (3%), and dust/ash (2%). In H_OSB adhesive (66%) also was the main factor, followed by wood (19%), termiticide (5%), electricity/heat (4%), production (2%), chemical, organic (2%), dust/ash (1%), and paraffin (1%). B_OSB (Ferro *et al.* 2018) showed 42% related to the production of chemicals (mainly the pyrethroid termiticide) and adhesive represented 16% of the impacts.

Human carcinogenic toxicity (HT): adhesive (67%) exhibited higher contribution in H_OSB, with less influence of electricity/heat (19%), wood (9%), production (4%), and dust/ash (1%). For G_OSB, adhesive had the main contribution (82%), followed by production (13%), electricity/heat (2%), termiticide (1%), wood (1%), and chemical, organic (1%). In B_OSB (Ferro *et al.* 2018), the highest contribution (34%) was connected to the production of chemicals (paraffin and mostly the pyrethroid termiticide - due to air emissions of metals) and in second place was the adhesive with 17%.

Fossil resource scarcity (FD): In this category, H_OSB obtained 59% associated to electricity/heat, followed by wood (19%), adhesive (19%), and fuels/oils (3%). For G_OSB, the results demonstrated 43% to adhesive, accompanied by electricity/heat (22%), paraffin (13%), wood (10%), chemical, organic (7%), and termiticide (5%). The adhesive (48%) was the main contributor in B_OSB (Ferro *et al.* 2018), and the chemicals (paraffin and pyrethroid termiticide) represented 27%.

Of the ten categories considered, for H_OSB the adhesive was the main contributor in 6 (OD, TA, FE, ME, FET, and HT), in second was the production with 2 categories (POF and TET), and electricity/heat in third with 2 (CC and FD). For G_OSB adhesive also was the principal contributor in 7 of 10 categories (CC, OD, TA, ME, FET, HT, and FD), followed by wood (FE and TET) and production (POF).

The dangerous chemical pollutants in the building materials have attracted concern because they can negatively impact the human comfort, health, and productivity. Therefore, knowing the emission characteristics of construction materials and the associated health risk is a requirement for choosing the materials effectively, to build in a sustainable way (Xiong *et al.* 2016). The indoor VOC concentration related to the building materials plays an important role in the air quality with several scientific evidence for their adverse health effects. Thus, one of the most efficient ways to limit the dangerous emissions is by removing the main emission sources indoors; this involves identifying the source based on the understanding of chemical composition and strength of the emission (Liang *et al.* 2014).

It is notable that the adhesive was the main environmental hotspot in this evaluation, even with the 2 types of OSB presenting different types of adhesives (H_OSB produced with polyurethane adhesive derived from castor oil and G_OSB with MDI resin).

It is also verified that the H_OSB presented better behavior (minor total amount of potential environmental impacts) in categories related to human health (POF, HT) in addition to not using paraffin, termiticide, and other organic chemicals in its production.

According to Ferro *et al.* (2018), since changes in the resin type could decrease the technical properties of the panels, it is firstly mandatory to assess the effects of the bio-resins on the physic-mechanical properties of the manufactured boards. However, the technical performance of H_OSB has already been successfully evaluated in the work of Sugahara *et al.* (2022b) and the potential of use of the polyurethane adhesive derived from castor oil in wood panels has already been established in several other studies (Barbirato *et al.* 2019b, 2020; Sugahara *et al.* 2019, 2022a).

The heat treatment was made in H_OSB in order to avoid the use of the termiticide. By this means, the additional process in the oven to do the treatment led to an increase in electricity consumption. However, the electricity/heat was the main contributor in only 2 categories (CC and FD) in H_OSB. Additionally, the difference in the electricity consumption (in kWh), was 3,6% higher than the global inventory data of H_OSB and G_OSB (Annex section). The termiticide used in the G_OSB presented some contribution in all categories evaluated.

These are important findings that can support decision makers to make good choices in the selection of the materials. This work shows the potential of H_OSB to be less harmful to humankind and the environment.

CONCLUSIONS

This study used the LCA methodology in a cradle-to-gate perspective to quantify the potential environmental impacts related to the experimental production of heat-treated OSB panels made with *Eucalyptus* wood and castor oil-based polyurethane (H_OSB) and compared them with the environmental impacts of traditional panels (G_OSB) and literature data (B_OSB). The research identified the system boundaries, environmental impacts, and environmental hotspots in OSB production using the ReCiPe H method in terms of ten impact categories: global warming (CC), stratospheric ozone depletion (OD), ozone formation and human health (POF), terrestrial acidification (TA), freshwater eutrophication (FE), marine eutrophication (ME), terrestrial ecotoxicity (TET), freshwater ecotoxicity (FET), human carcinogenic toxicity (HT), and fossil resource scarcity (FD).

The following results obtained are:

1. The H_OSB performed better than G_OSB in 7 of 10 impact categories (OD, POF, TA, FE, ME, TET, FET, HT, FD), while G_OSB performed better than H_OSB in 3 of 10 (CC, TA, ME). Comparing the 3 types of OSB (H_OSB, G_OSB and B_OSB), H_OSB has the major potential environmental impact (in terms of higher values) in only one category (ME).

2. It was identified that the adhesive is the main environmental hotspot of this evaluation for both types of panels analyzed (H_OSB and G_OSB) even the panels being made of different types of adhesives (H_OSB produced with Polyurethane adhesive derived from castor oil and G_OSB with MDI resin). However, the H_OSB showed greater behavior in categories related to human health (POF, HT) in addition to not using paraffin, termiticide, and other organic chemicals present in the G_OSB.
3. Related to the use of heat treatment (H_OSB) instead of the termiticide (G_OSB), the electricity/heat was the main contributor in only 2 categories in H_OSB (CC and FD). Nonetheless, it presented a small increase in energy consumption (3.6%), while the termiticide used in the G_OSB showed contribution in all categories evaluated.
4. It is concluded that this work establishes the potential of H_OSB to be less harmful to humankind and the environment if compared to the generic ones evaluated in this research (G_OSB and B_OSB).

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APPENDIX

Global Inventory Data per Functional Unit

	Unit	G_OSB	H_OSB
PRODUCTS			
Oriented Strand Boards (OSB)	m^3	1.00	1.00
INPUTS FROM ENVIRONMENT			
Water	kg	204.18	204.18
INPUTS FROM TECHNOSPHERE			
Materials/Fuels			
Wood (Softwood)	m^3	1.91	-
Wood (*Eucalyptus*)	m^3	-	1.36
MDI resin	kg	18.30	-
Polyurethane adhesive derived from castor oil	kg	-	70.86
Paraffin	kg	10.94	-
Pyrethroid termiticide	kg	0.96	-
Chemical, organic	kg	5.21	-
Dust collector, electrostatic precipitator	p	4.73E-06	4.73E-06
Lubricating oil	kg	0.06	0.06
Wooden board factory organic bonded	p	3.79E-08	3.79E-08
Technical wood drying facility	p	-	3.66E-06
Electricity/heat			
Diesel, burned in building machine	MJ	33.52	33.52
Electricity, medium voltage	kWh	116.25	120.45
Furnace, wood chips	p	2.36E-05	2.36E-05
Furnace, wood chips, with silo	p	9.99E-05	9.99E-05
Heat, district or industrial, natural gas	MJ	344.66	344.66
Heat, district or industrial, other than natural gas	MJ	2.49	2.49
OUTPUTS TO TECHNOSPHERE			
Waste to treatment			
Ash	kg	1.70	1.70
Biowaste	kg	0.26	0.26
OUTPUTS TO ENVIRONMENT			
Emissions to air			

Acetaldehyde	kg	5.59E-04	-
Ammonia	kg	0.01	0.01
Arsenic	kg	3.58E-06	3.58E-06
Benzene	kg	3.26E-03	3.26E-03
Benzene, ethyl-	kg	1.07E-04	1.07E-04
Benzene, hexachloro-	kg	2.58E-11	2.58E-11
Benzo(a)pyrene	kg	1.79E-06	1.79E-06
Bromine	kg	2.15E-04	2.15E-04
Cadmium	kg	2.50E-06	2.50E-06
Calcium	kg	0.02	0.02
Carbon dioxide, biogenic	kg	364.85	364.85
Carbon monoxide, biogenic	kg	0.72	0.72
Chlorine	kg	6.44E-04	6.44E-04
Chromium	kg	1.42E-05	1.42E-05
Chromium VI	kg	1.43E-07	1.43E-07
Copper	kg	7.87E-05	7.87E-05
Dinitrogen monoxide	kg	0.01	0.01
Dioxin, 2,3,7,8 Tetrachlorodibenzo-p-	kg	1.07E-10	1.07E-10
Fluorine	kg	1.79E-04	1.79E-04
Formaldehyde	kg	0.02	-
Hydrocarbons, aliphatic, alkanes, unspecified	kg	3.26E-03	3.26E-03
Hydrocarbons, aliphatic, unsaturated	kg	0.01	0.01
Lead	kg	8.94E-05	8.94E-05
Magnesium	kg	1.29E-03	1.29E-03
Manganese	kg	6.08E-04	6.08E-04
Mercury	kg	1.07E-06	1.07E-06
Methane, biogenic	kg	0.01	0.01
Methanol	kg	0.02	-
m-Xylene	kg	4.29E-04	4.29E-04
Nickel	kg	2.15E-05	2.15E-05
Nitrogen oxides	kg	0.43	0.43
NMVOC, non-methane volatile organic compounds	kg	0.33	-
PAH, polycyclic aromatic hydrocarbons	kg	3.97E-05	3.97E-05
Particulates, < 2.5 um	kg	0.01	0.01
Particulates, > 10 um	kg	0.10	0.10
Phenol, pentachloro-	kg	2.90E-08	2.90E-08
Phosphorus	kg	1.07E-03	1.07E-03

Potassium	kg	0.08	0.08
Sodium	kg	4.65E-03	4.65E-03
Sulfur dioxide	kg	0.01	0.01
Toluene	kg	1.07E-03	1.07E-03
Zinc	kg	1.07E-03	1.07E-03