Bureau Veritas Certification - Brazil

PEGADA DE CARBONO DE PRODUTO (CFP) –
PRODUCT CARBON FOOTPRINT (CFP) -
Suporte de PEAD para sinalização rodoviária vertical
HDPE support for vertical road signs

ECOPOSTE
ECOPOSTE

Version: 03
AUGUST 2023

Table 1. Data on the requesting

Company name	CNPJ	Operating Segment	CNAE
ECOPOSTE COMERCIO E SERVICOS DE SINALIZACAO E SEGURANCA VIARIA LTDA	07.457.797/0001-08	Retail trade in other products not previously specified	47.89-0-99
Address	Rua Taperoá, 58, Sala 2, Cidade Monções, São Paulo - SP. ZIP CODE: 04571-060		

Table 2. Data on the executing company

Company name	CNPJ	Operating Segment	CNAE
BVQI DO BRASIL CERTIFIFICADORA LTDA	72.368.012/0002-65	Other non-specific professional, scientific and technical activities previously	74.90-1-99
Address	Av. Angélica, 2546, Andares 14°, 15°, 16°, Consolação, São Paulo - SP. ZIP CODE: 01228-200		

Table 3. Bureau Veritas team

Technical Coordination Francisco Martins de Almeida Rollo	 francisco-martins.rollo@bureauveritas.com
Consultants Samuel Alex Sipert Miranda Marcela Valles Lange Ferron	 ssipert@hotmail.com marcela.ferron.ext@bureauveritas.com

Table 4 - Team responsible - Requesting company

Celso Fabrini - CFO Fábio Cunha - Executive Director	celso.fabrini@renovaurb.com.br fabio@renovaurb.com.br

EXECUTIVE SUMMARY

- **Product:** support made of recycled polymeric material, called "Ecoposte";
- **Manufacturing process:** Extrusion;
- **Frontier:** cradle to grave;
- **Modeling:** attributional;
- **Functional unit: To** provide a support structure for a steel sign used in a vertical road signage system with an area of 2.0 m², for a period of 50 years. For the cradle to gate assessment, a declared unit of 1 kg of "Ecoposte" was adopted.
- **Reference flow used:** 52 kg of "Ecopost" (estimated mass for 2 supports 80 mm x 80 mm with a length of 4 meters).
- **Data sources:** Measured, calculated or estimated;
- **Reference year:** 2022;
- **Impact category:** Climate change (IPCC GWP100, AR6);
- **Software:** OpenLCA v. 2.0;
- **Database:** Ecoinvent v 3.8;
- **Carbon Footprint:**
    - Cradle at the gate
        - For 1 kg of "Ecoposte": 0.552 kg CO_2e

Processes	GWP 100/ kg CO2e/kg	Contribution/ %
HDPE support for road signs, production, "Ecoposte"	**0,552**	**100,00%**
Production of recycled HDPE (collection, separation, washing, crushing	0,230	41,68%
Steel production, rebar	0,189	34,20%
Electricity generation and transmission	0,125	22,60%
Production of vehicular natural gas	0,003	0,57%
Transportation of inputs	0,003	0,47%
Epoxy resin-based paint production	0,001	0,21%
Paint solvent production	0,001	0,20%
Waste treatment	0,0002	0,04%
Treated water production	0,0001	0,02%
Wood production	0,0001	0,02%

-
    - Cradle to grave
        - For the UF considered: 46.428 kg CO_2e

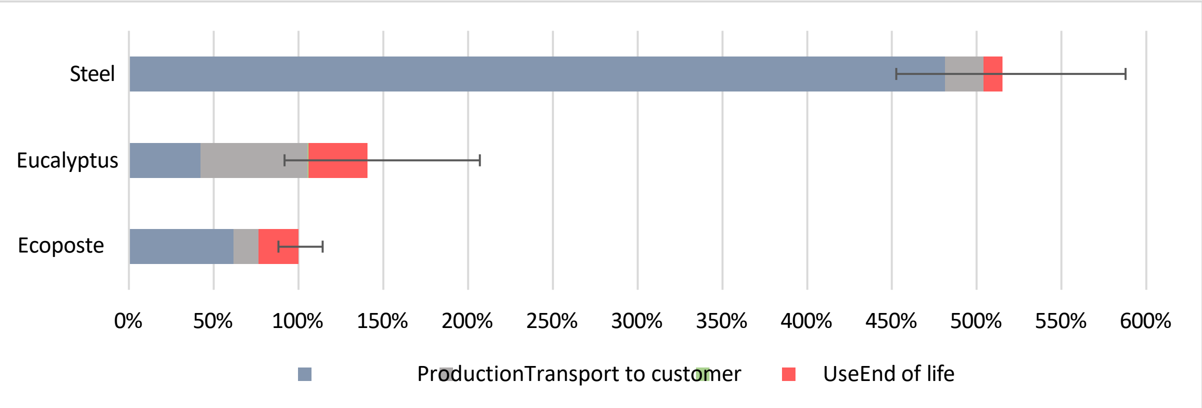
Processes	GWP 100/ kg CO2e/kg	Contribution/ %
Double support, "Ecoposte", 2 m² sign, 50-year lifespan	46,428	100,00 %
Production	28,695	61,80%
Transport to the customer	6,920	14,90%
Use	0,000	0,00%
Final disposal, end of life	10,82	23,30%

- **Benchmarking:**
  - Results for the carbon footprint of the "Ecoposte" were compared with products of the same function based on secondary data extracted from the Ecoinvent 3.8 database;
  - ***Functional unit: To*** provide a support structure for a steel sign used in a vertical road signage system with an area of 2.0 m², for a period of 50 years;
  - ***Border:*** cradle to grave
  - ***Inventory data for comparative products:***

Information	Unit	Product 1	Product 2	Product 3
Material	-	Ecopost	Eucalyptus	Steel profile
Useful life	years	50	15	40
Number of supports for the functional unit	Unit	2,00	6,67	2,50
Support section	mm³	Rectangular (80 x 80)	Rectangular (100 x 100)	Folded C-profile (150 x 85 x 25 x 2.7)
Weight per meter	Kg/m	6,50	8,25	7,90
Production				
Reference flow	kg	52	220	79
Transport to the customer				
Transport distance, truck	km	1 111,9	1 111,9	1 111,9
Transport service, truck	t.km	57,82	244,61	87,84
Transportation distance, ship	km	55,55	55,55	55,55
Transportation service, ship	t.km	2,89	12,22	4,39
Use				
Transportation service to replacement	t.km	-	2,31	0,24
End of life				
Landfill	%	56 %	100 %	40 %
Recycling	%	44 %	-	60 %
Incineration	%	-	-	-

  - ***Results:***

Processes	Product1 (Ecoposte)	Product 2 (Eucalyptus)	Product 3 (Steel)
	GWP 100/ (kg CO2eq/ UF)		
Production	28,69	19,67	223,52
Transporting poles to the customer	6,92	29,27	10,51
Use	0,00	0,28	0,03
Final destination	10,82	16,07	5,07
Total	46,43	65,28	239,13



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TERMS AND DEFINITIONS

For the purposes of this document, the terms and definitions of ABNT NBR ISO 14040 (ABNT, 2014a) and 14044 (ABNT, 2014b) and the following apply:

Life Cycle Assessment (LCA): compiling and evaluating the inputs, outputs and potential environmental impacts of a product system throughout its life cycle;

Life Cycle Inventory Analysis (LCI): phase of life cycle assessment involving the compilation and quantification of the inputs and outputs of a product system throughout its life cycle;

Life Cycle Impact Assessment (LCIA): phase of life cycle assessment that aims to understand and evaluate the magnitude and significance of the potential environmental impacts of a product system throughout the product's life cycle;

Process: a set of interrelated or interactive activities that transform inputs into outputs;

Product: any good or service;

Co-product: any one of two or more products coming from the same elementary process or product system;

Raw material**:** primary or secondary material that is used to produce a product;

Allocation: distribution of the input or output flows of a process or product system between the product system under study and other product system(s);

Product system: set of elementary processes, with elementary and product flows, performing one or more defined functions and which models the life cycle of a product;

System boundary: set of criteria that specify which elementary processes are part of a product system;

Functional unit: quantified performance of a product system for use as a reference unit.

SUMMARY

1 INTRODUCTION

Growing awareness of the importance of environmental protection and the possible impacts associated with products and services throughout their life cycle, i.e. including processes from the extraction of raw materials to consumption and end of life, has increased interest in developing methods to better understand and quantify these impacts. In this context, Life Cycle Assessment (LCA) is a structured and internationally standardized methodology (ABNT, 2014a, 2014b) that seeks to quantify emissions and resources consumed in a product system and, based on this data, uses models to estimate impacts related to the consumption of natural resources, human health and the environment (EUROPEAN COMMISSION, 2014; GITLEMAN, 2018). When it is used for only the specific impact category of climate change, the LCA study can also be referred to as a Product Carbon Footprint (PCF), reporting the sum of greenhouse gas (GHG) emissions and removals from the system, expressed in CO_2 equivalents (CO_{2e}) (ABNT, 2023).

This document presents the final report, prepared by Bureau Veritas Certification, of the study aimed at assessing the Carbon Footprint for the life cycle of recycled polymeric material used for vertical road signs, by the company Ecoposte Comércio e Serviços de Segurança Viária LTDA, in accordance with the specifications of the ABNT ISO/TS 14067:2023 standard (ABNT, 2023).

2 OBJECTIVE OF STUDY

The aim of this study is to calculate the potential contribution of recycled polymeric material support to global warming expressed as CO_{2e} by quantifying all significant GHG emissions and removals throughout its life cycle.

The reasons for carrying out this study include supporting the company's commitment to tackling climate change, providing information for internal decision-making, as well as providing information for consumers on the emissions of the products produced.

It is the company's intention to make the information in this report public to consumers, and to do so the footprint communication requirements of ABNT NBR ISO 14026 must be followed.

3 SCOPE OF STUDY

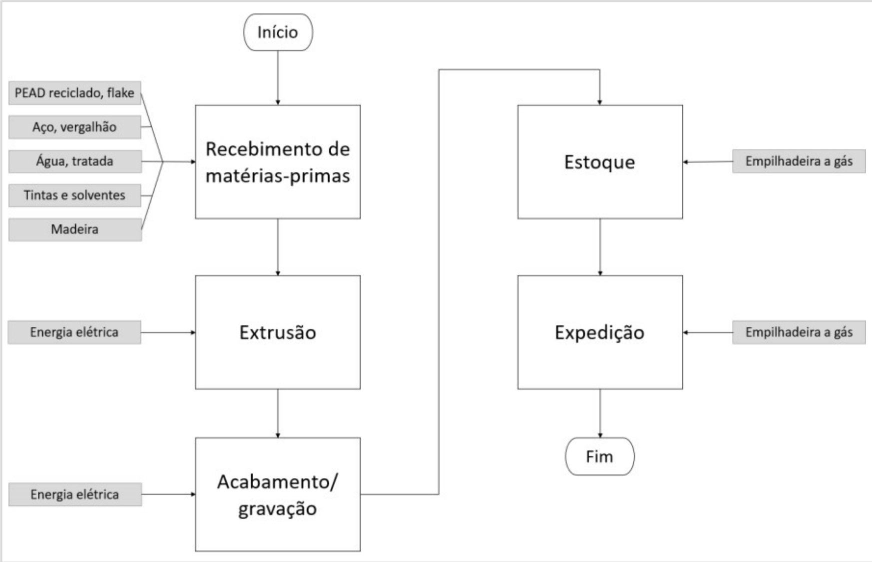
3.1 PRODUCT SYSTEM AND FUNCTION

The recycled polymeric material supports are manufactured from an extrusion process using recycled high-density polyethylene (HDPE), reinforced with steel rebar. The product's dimensional and mechanical requirements must meet the requirements of NBR 16033 (ABNT, 2021).

The supports, called "Ecopostes" by the company, vary in size according to the intended function, and can be circular (diameter 2 ½"), square (55 mm x 55 mm, 80 mm x 80 mm and 100 mm x 100 mm families) and rectangular (70 mm x 150 mm family), for boards with areas ranging from 0.5 m² to 12 m².

The production system (Figure 1) begins with the receipt of raw materials, which mainly consist of recycled HDPE crushed after a cleaning process, CA-50 steel rebar, paints and solvents, treated water and pieces of wood. The HDPE and rebar are sent to the extrusion stage, which is carried out using an extruder with a power of 100 hp. After extrusion and cooling in water baths, the parts are sent for finishing and engraving. At this stage, they receive resin-based paint to protect the supports from UV radiation with flame retardant additives, as well as being engraved for identification. Painting and engraving equipment consumes electricity. The "Ecoposts" are transferred for storage using forklifts powered by vehicular natural gas (CNG), conditioned using pieces of wood from pine. The production process uses electricity from the distribution network and generates waste in the form of scrap polymer material during the extrusion stage, which is sent to landfill.

Figure 1. Flowchart of the "Ecopostes" production process



3.2 UNIT FUNCTIONAL

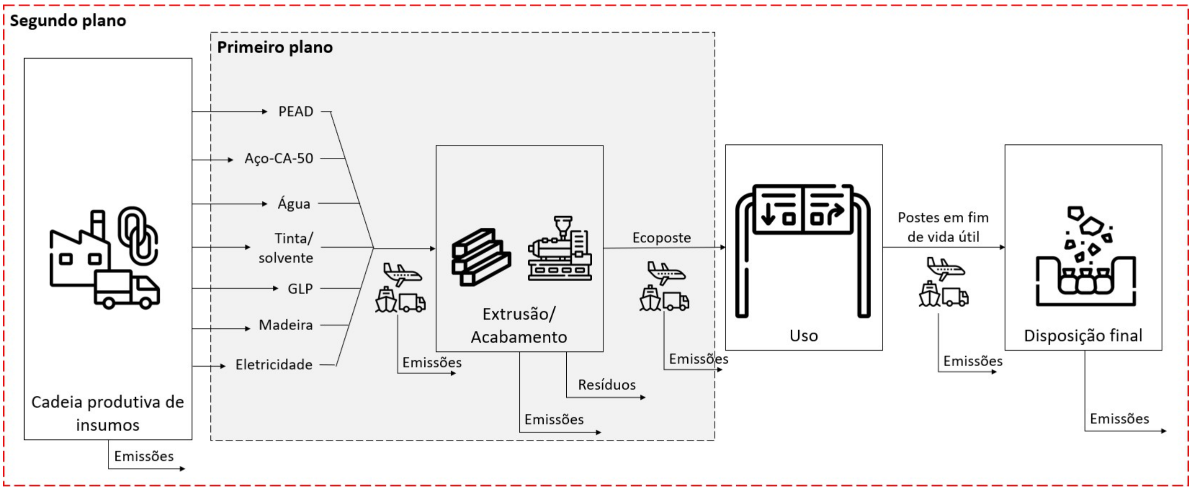
For this study, the functional unit was defined as providing a support structure for a steel sign used in a vertical road signage system with an area of 2.0 m², over a period of 50 years. The reference flow adopted was 52 kg of recycled HDPE support, this being the estimated mass for a double support with dimensions of 80 mm x 80 mm and a length of 4 meters each. A declared unit of 1 kg of "Ecopost" was used to analyze the system at the cradle-to-gate boundary.

3.3 SYSTEM BORDER

The system boundary considered processes for a cradle-to-grave extension (Figure 2). The foreground boundary included the stages of manufacturing and transportation of products to customers, where it was possible to collect direct data. In the background, the other stages of the life cycle were considered, including the chain of production of inputs, use and final disposal after the end of the product's useful life.

Processes related to the construction and maintenance of the infrastructure used (factory) were omitted from the border.

Figure 2: Frontier of the system considered



3.4 DATA AND DATA QUALITY REQUIRED

Following the specifications of NBR 14067, data related to foreground processes, i.e. those under the financial or operational control of the organization carrying out the CFP study, was collected directly for the specific conditions of the site. This includes information on consumption of inputs and electricity, as well as average distances for shipping the product to the end consumer.

Secondary data was used for the background processes, namely the extraction of elementary flows from the environment, the production of intermediate products needed for the foreground activities, and emissions during the use and final disposal stages.

The quality of the foreground data sources was assessed using the Pedigree matrix method (WEIDEMA; WESNÆS, 1996) for the criteria of reliability, completeness, temporal correlation, geographical correlation and technological correlation, serving as a basis for estimating the uncertainties of the flows of matter and energy.

3.5 TIME LIMIT GIVEN

The results presented in this report refer to the base year 2022.

3.6 ALLOCATION PROCEDURES

For this study, the use of allocation was not necessary, given that the process only generates one product: recycled HDPE support, called "Ecopost". However, for data relating to background processes, product system expansion is used to avoid allocation within treatment systems, by means of the Allocation at Point of Substitution (APOS) approach, already implemented in the Ecoinvent database. Among materials that are not destined for treatment, the database uses economic allocation (i.e. allocation based on price) with a few exceptions, such as for energy, for which allocation is based on exergy.

4 LIFE CYCLE INVENTORY ANALYSIS

4.1 PRODUCTION (CRADLE-TO GATE)

4.1.1 Inputs

The mass of recycled HDPE and steel used in 2022 was estimated based on the quantity of supports produced per family and mass composition taken from the technical specification provided by the company (ANNEX A), shown in Table 5. According to the information collected, around 956,688.5 kg of supports were produced. Assuming the principle of conservation of mass, total inputs were estimated based on the sum of the materials incorporated into the finished products and the mass of scrap produced during the year. Table 6 shows the scrap data collected in meters, transformed into mass assuming a factor of 7.22 kg per meter, based on production information for 2022.

Table 5. Production of supports for the year 2022 and estimated weight of recycled HDPE and steel based on the technical specifications provided.

Family	Dimensions	Total extruded length/ m	Average HDPE weight*/ kg/m	Average steel weight*/ kg/m	Total weight HDPE/ kg	Total weight steel/ kg
212	2 1/2"	4 186,8	3,00	0,96	12 560,4	4 019,3
300	3"	315,0	3,80	1,50	1 197,0	472,5
5555	55 mm x 55 mm	510,0	2,56	0,96	1 305,6	489,6
715	70 mm x 150 mm	12 836,0	7,90	2,40	101 404,4	30 806,4
808	80 mm x 80 mm	88 088,5	5,00	1,16	440 442,5	102 257,4
1010	100 mm x 100 mm	23 043,5	7,58	2,71	174 669,7	62 483,9
1212	120 mm x 120 mm	1 396,2	11,96	4,63	16 698,6	6 467,2
60180	60 mm x 180 mm	90,0	8,20	2,40	738,0	216,0
60200	60 mm x 200 mm	40,0	9,10	2,40	364,0	96,0
		TOTAL			**749 380,2**	**207 308,3**

* Final composition of the supports available in the Technical Specifications (ANNEX A)

Source: Ecoposte

Table 6. Scrap generation for the year 2022, by month

Month	Scrap losses/ m	Losses* /kg
January	15,50	113,55
February	29,00	212,45
March	61,00	446,87
April	39,00	285,70
May	18,50	135,53
June	10,50	76,92
July	25,50	186,81
August	22,00	161,17
September	7,00	51,28
October	3,50	25,64
November	19,50	142,85
December	15,00	109,89
TOTAL		**1948,64**

* Transformation considering an average weight per meter of 7.33 kg/m

Source: Ecoposte

The amount of water purchased for the cooling process of the supports after extrusion was taken from data provided by the company, available in Table 7.

Table 7. Treated water purchase data, base year 2022

Month/2022	Water purchased/ L
January	6 667
February	10 000
March	10 000
April	20 000
May	16 667
June	13 333
July	10 000
August	13 333,33
September	20 000
October	20 000
November	30 000
December	13 333
TOTAL	**183 333,33**

Source: Ecoposte

The consumption of paints and solvents, vehicular natural gas and pieces of wood during the year of production was estimated based on average data, shown in Table 8, Table 9 and Table 10.

Table 8. Paint and solvent consumption data, base year 2022

Input	Monthly consumption/ L	Annual consumption/ L
Paint	20	**240**
Solvent	40	**480**

Source: Ecoposte

Table 9. Estimated CNG consumption for forklifts, base year 2022

Data	Quantity	Unit	Source
Number of shifts (Jan to Dec 2022)	632	shifts	Provided by the company
Forklift hours worked	2	h/shift	Provided by the company
Gas consumption	4	kg/h	Provided by the company
Total forklift gas	**5 056**	**kg**	**-**

Source: Ecoposte

Table 10. Estimated timber purchases, base year 2022

Data	Quantity	Unit	Source
Monthly wooden feet	500	un/month	Manufacturer
Annual wooden feet	6 000	un/year	Dear
Volume of a wooden foot (5 cm x 5 cm x 80 cm)	0,002	m^3	Manufacturer
Total wood per year	**12**	**m^3/year**	**-**

Source: Ecoposte

4.1.2 Electricity

Direct data on electricity use during the extrusion process could not be collected directly by the company, which only has one meter for the entire factory. Therefore, electricity consumption for the base year was estimated using data on the power of the equipment and the respective times of use during manufacturing (Table 11).

Table 11. Data used to estimate electricity consumption for manufacturing during the year of study

Equipment	Power/ kW	Usage time in 2022/ hours	Total energy consumption/ kWh
Extruder	73,6	5 544	408 038,40
Blower	1,10	5 544	6 120,58
Units Hydraulic	4,05	5 544	22 442,11
Pump 01	1,10	5 544	6 120,58
Pump 02	1,10	5 544	6 120,58
Pump 03	1,10	5 544	6 120,58
Pump 04	1,10	5 544	6 120,58
Pump 05	1,10	5 544	6 120,58
Pump 06	1,10	5 544	6 120,58
Pump 07	3,68	5 544	20 401,92
Water cooling fan	3,68	5 544	20 401,92
Compressor 01	1,47	5 544	8 160,77
Compressor 02	1,47	5 544	8 160,77
Peripherals	1,10	5 544	6 120,58
TOTAL			**536 570,50**

*weighted average time based on production in 2022

Source: Ecoposte

4.1.3 Transportation of inputs

Data on the origin and distances traveled provided by the company was used to survey the transportation required for the inputs in the process. The transportation inventory for the main inputs can be seen in Table 12.

Table 12. Inventory for the transportation of inputs

Inputs	Origin	Modal	Distance/ km	Return empty?	Total distance traveled/ km
HDPE, flake, recycled	São Paulo - SP	Road	5,4	Yes	10,8
Steel, rebar, CA-50	São Paulo - SP	Road	60	No	60,0
Paint	-	Road	100	No	100,0
Solvent	-	Road	100	No	100,0
wood, Pinus	-	Road	100	Yes	200,0

Source: Ecoposte

4.1.4 Management of waste

The waste generated during production is collected at the company by truck and sent to the landfill. A distance of 30 km was assumed between the company and the landfill.

4.2 TRANSPORTATION/DELIVERY TO CUSTOMER

Transportation for the distribution of products to consumers was based on the sales invoices issued by the company for the year 2022. Table 13 shows the data compiled on the quantity transported and the aggregate weighted average distance per location. The distance between the company and the delivery towns was estimated using Google Maps.

Table 13. Data used to calculate the weighted average distance for distribution

Destination	Quantity transported/ kg	Participation/ %	Average distance truck/ km	Average distance ship/ km
National				
AL	7 395,76	0,77 %	2 445,00	-
AP	2 879,71	0,30 %	3 222,00	-
BA	3 835,16	0,40 %	1 930,05	-
EC	16 121,46	1,69 %	2 936,53	-
ES	1 493,28	0,16 %	1 091,00	-
GO	13 174,42	1,38 %	776,05	-
MG	81 962,36	8,57 %	613,01	-
MS	6 907,70	0,72 %	728,00	-
MT	109 257,14	11,42 %	1 646,25	-
PA	153 662,13	16,06 %	2 426,00	-
PB	7 384,32	0,77 %	2 777,00	-
PE	25 938,20	2,71 %	2 683,00	-
PR	70 288,64	7,35 %	622,97	-
RJ	53 747,21	5,62 %	576,22	-
RO	996,80	0,10 %	2 817,00	-
RS	14 722,55	1,54 %	1 589,48	-
SC	92 748,31	9,69 %	855,00	-
SE	11 132,89	1,16 %	2 160,00	-
SP	270 994,39	28,32 %	190,89	-
International				
Argentina	6 968,64	0,73 %	2 086,00	-
The Netherlands	4 568,90	0,48 %	230,00	10 024,00
Canada	568,30	0,06 %	290,00	12 934,97
AVERAGE DISTANCE			**1 111,86**	**55,55**

Source: Ecoposte

4.3 USE

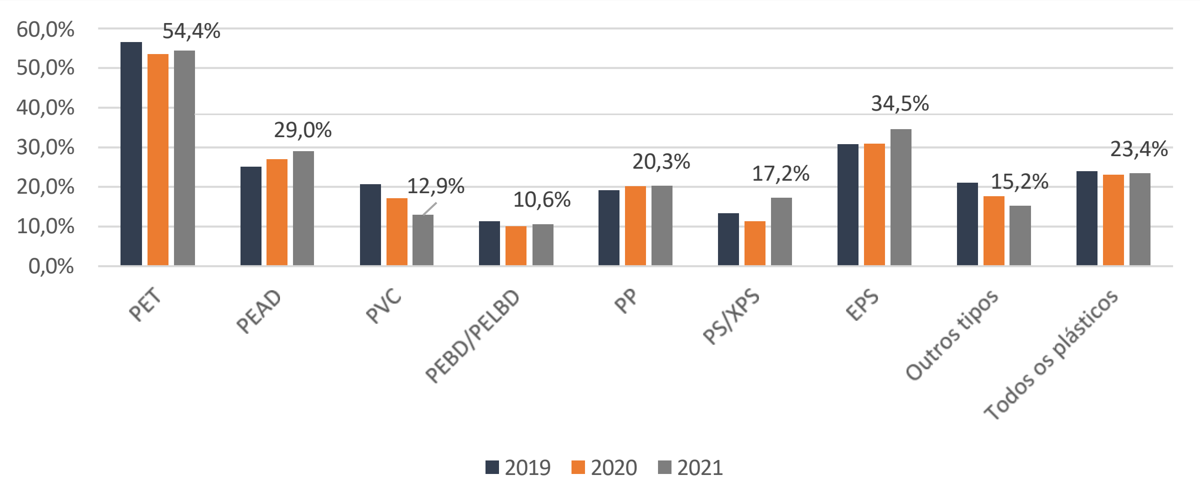
For the product system, impacts for the use stage would be caused mainly by the transportation needed to replace collapsed supports caused by a traffic accident. After verification by sensitivity analysis, it was assumed that these impacts would be insignificant considering the complete life cycle for the function considered.

4.4 END OF LIFE

For the end of life of the product, the same post-consumer recycling rate for HDPE in Brazil during 2021 of 29 % was considered for the plastic part of the support (Figure 3). The remainder was modeled using the process for plastic treatment in Brazil available on Ecoinvent. A sensitivity analysis was carried out for a scenario where 100 % of the poles would be destined for open-loop recycling processes. The modeling for end-of-life steel treatment also used the Ecoinvent database for steel rebar treatment mix.

The company has working instructions for separability and recyclability in the event of accidents of natural origin or caused by vehicle collisions occurring before the end of the poles' useful life. However, there is also concern about recyclability after the end of their useful life in order to generate a closed production cycle. In this context, a sensitivity analysis was carried out for this scenario.

Figure 3: Post-consumer mechanical recycling rate in Brazil



Source: ABIPLAST (2022)

4.5 VALIDATION OF DATA

Data was validated during collection by checking the mass and energy balance for the elementary processes. All the estimated data and the methods adopted were discussed with the technical team of the requesting company. In addition, the characterization factors obtained during the quality assessment were used to estimate data uncertainty using the Pedigree matrix method (WEIDEMA; WESNÆS, 1996).

4.6 LIFE CYCLE INVENTORY

After collecting and validating the direct data, it was possible to construct the inventory for the production of 1 kg of "Ecoposte", cradle-to-grave border, for the base year of 2022, which can be seen in Table 14.

Table 14. Cradle to gate inventory for the production of 1 kg of "Ecoposte", base year 2022

Item	Quantity	Unit	DP	Source
Entries				
Electricity, medium voltage	0,55	kWh	1,099	Estimated based on the power of the equipment and time of use during the production year
HDPE, recycled, flake	0,78	kg	1,055	Estimated based on the composition and mass of poles produced and waste generated
Steel, rebar	0,21	kg	1,055	Estimated based on the composition and mass of the poles produced
Paint, epoxy resin base	0,00025	kg	1,251	Provided by the company
Paint solvent	0,00050	kg	1,251	Provided by the company
Vehicular natural gas	0,0052	kg	1,099	Estimated based on data provided by the company
Water, treated	0,19	kg	1,035	Provided by the company
Wood, pine	0,000010	m³	1,099	Estimated on the basis of dimensions and number of parts used over a year
Transportation, inputs, truck	0,022	t.km	1,419	Distances provided by the company
Outputs				
Reference product				
Ecopost	1,00	kg	-	-
Waste				
Waste, plastic	0,0020	kg	1,055	Provided by the company

From the direct data on transportation from production to customers, and assumptions and estimates on the use and end-of-life stages, it was possible to build the inventory for the functional unit, shown in Table 15.

Table 15. Cradle to grave inventory for the adopted functional unit, base year 2022

Item	Quantity	Unit	DP	Source
Entries				
Ecopost	52,00	kg	1,099	Estimated based on the power of the equipment and time of use during the production year
Transportation, distribution, truck	57,82	t.km	1,419	Distances provided by the company
Transportation, distribution, ship	2,89	t.km	1,419	Distances provided by the company
Transport, disposal end, truck	4,00	t.km	1,414	Estimated using the Ecoivent database
Outputs				
Reference product				
Double support, Ecoposte, 2 m² board	1,00	Item	-	-
Waste				
Waste, HDPE, for recycling	11,80	kg	1,060	Estimated using data for recycling HDPE in Brazil
Plastic waste, for landfill	28,91	Kg	1,060	Estimated using the Ecoivent database
Waste, steel, for recycling	11,23	kg	1,060	Dear
Waste, wood, for landfill	0,00067	kg	1,060	Dear

5 LIFE CYCLE IMPACT ASSESSMENT

For the calculation of impacts, the product system was modeled using the OpenLCA software version 2.0 and the Ecoinvent database version 3.8 (MORENO RUIZ et al., 2021) using the APOS (*At Point Of Substitution*) library. The background processes used in this study can be seen in Table A1 and Table A2 in ANNEX B. The propagation of uncertainties in the life cycle impact data for the foreground and background processes was carried out using Monte Carlo simulation with 1,000 iterations, for a 90% confidence interval.

Due to the lack of life cycle impact data for HDPE *flake* production, this study used data available in the Ecoinvent database for recycled HDPE granules (*polyethylene production, high density, granulate, recycled | polyethylene, high density, granulate, recycled | APOS, U - RoW*), modifying the process to subtract energy consumption during the extrusion stage in granule formation. This energy consumption was taken from the inventory for the production of recycled HDPE submitted to the Association of Plastic Recyclers (APR, 2018). A sensitivity analysis was carried out for a scenario of using virgin HDPE in the process in order to verify the system's behavior in terms of impact. For the steel production process, GHG emissions were extracted from the Environmental Product Declaration for rebar produced by ArcelorMittal Brasil published by the *Institut Bauen und Unwelt* program (IBU, 2021).

Following the guidelines of NBR ISO 14067 (ABNT, 2023), the climate change impact category was selected for the study using the *Global Warming Potential* (GWP) model for a 100-year period, developed by the Intergovernmental Panel on Climate Change (SMITH et al., 2021). The climate change impact potential of each greenhouse gas (GHG) emitted and removed from the product system was calculated by multiplying the mass of GHG released by the mass of GHG emitted.

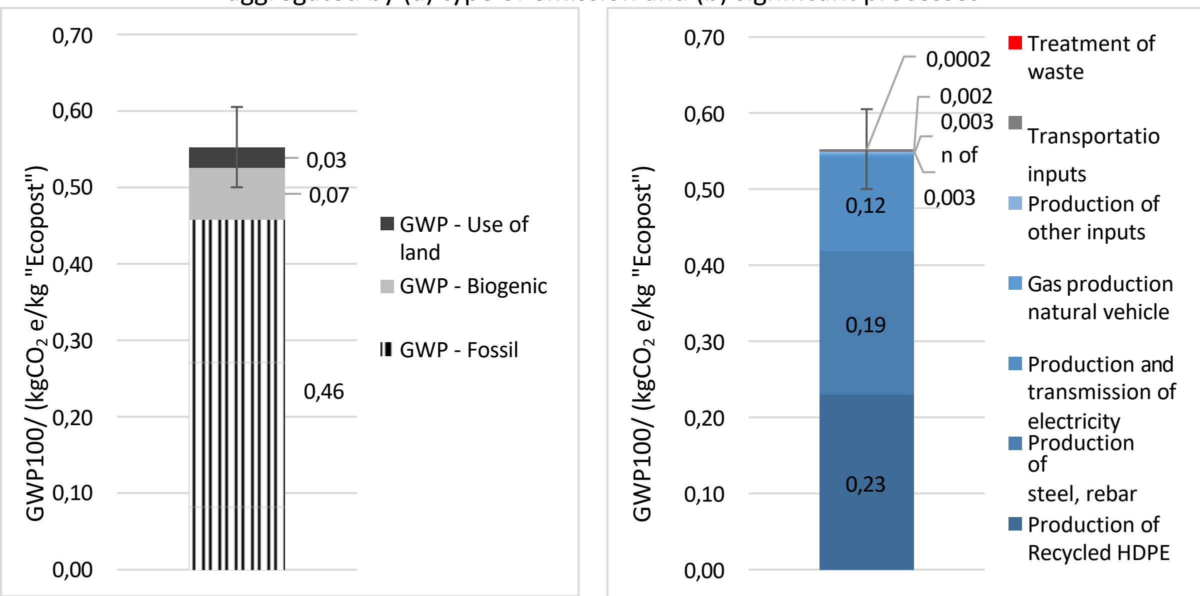
or removed by the 100-year GWP factor expressed in kg $_{CO_2e}$ per kg. The GWP100 factors used in this study were taken from the IPCC's sixth report on climate change (AR6).

The cradle-to-grave CFP results can be seen in Table 16. For the production of 1 kg of "Ecoposte", a potential climate change impact value of 0.552 kg $_{CO_2e}$ was calculated. Figure 4a groups the results into types of GHG emissions, while Figure 4b shows the results grouped by type of process.

Table 16. CFP results for the production of 1 kg of "Ecoposte", cradle to gate, base year 2022, aggregated by process with their respective contributions.

Processes	GWP 100/ kg CO2e/kg	Contribution/ %
HDPE support for road signs, production, Ecoposte	**0,552**	**100,00%**
Production of recycled HDPE (collection, separation, washing, crushing	0,230	41,68%
Steel production, rebar	0,189	34,20%
Electricity generation and transmission	0,125	22,60%
Production of vehicular natural gas	0,003	0,57%
Transportation of inputs	0,003	0,47%
Epoxy resin-based paint production	0,001	0,21%
Paint solvent production	0,001	0,20%
Waste treatment	0,0002	0,04%
Production of treated water	0,0001	0,02%
Wood production	0,0001	0,02%

Figure 4 - CFP results for the production of 1 kg of "Ecopost", cradle to gate, base year 2022, aggregated by (a) type of emission and (b) significant processes



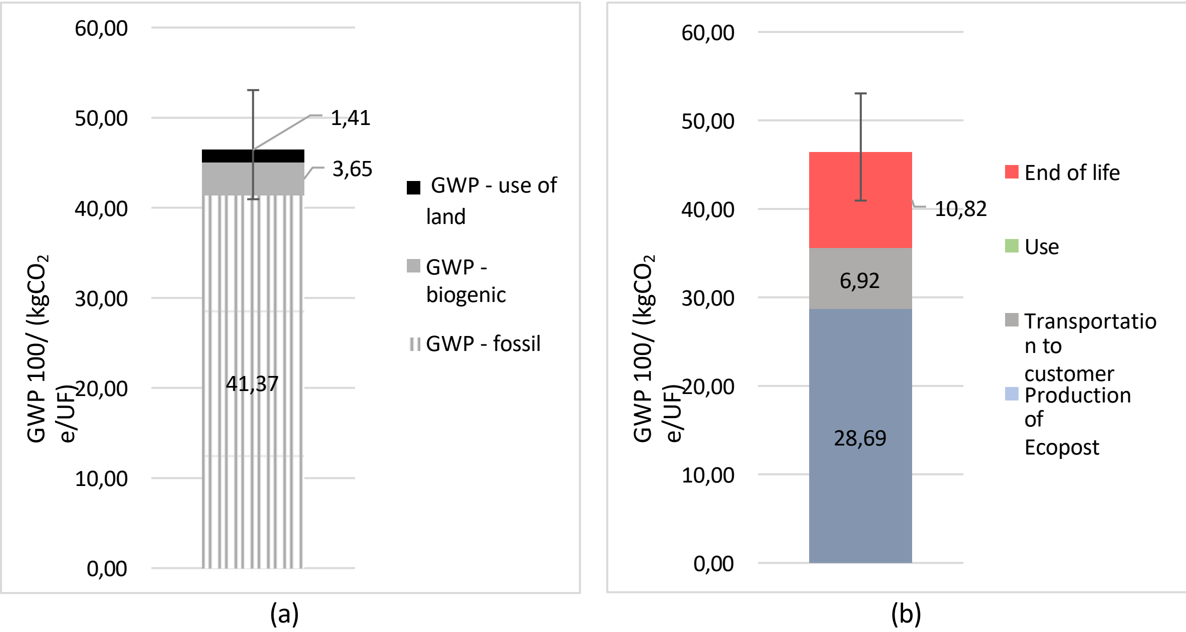
(a) (b)

Results considering the life cycle (cradle to grave) for the functional unit providing double support for a slab with an area of 2 m² over a period of 50 years can be seen in Table 17.

Table 17. CFP results for functional unit (reference flow 52 kg of "Ecopost"), cradle to grave, base year 2022, aggregated by process with their respective contributions.

Processes	GWP 100/ kg CO2e/kg	Contribution/ %
Double support, "Ecoposte", 2 m² sign	46,428	100,00 %
Production	28,695	61,80%
Transport to the customer	6,920	14,90%
Use	0,000	0,00%
Final disposal, end of life	10,82	23,30%

Figure 5: CFP results for the functional unit (reference flow 52 kg of "Ecopost", cradle to grave, base year 2022, aggregated by (a) type of emission and (b) life cycle stages



6 INTERPRETATION OF THE LIFE CYCLE

Analyzing the results for the cradle-to-grave border, i.e. just the production stage, it is possible to see that there are no direct GHG emissions for the Ecopost extrusion process. Emissions come from the input production chain, of which recycled HDPE is the main contributor, with 42 % of the global warming impact potential for production. The high contribution of recycled HDPE can be explained by its mass share in the composition of the post (around 80%) and by the impacts generated by the transportation stage and separation of recycled waste during processing, which are responsible for more than half of the emissions from this process.

The production of steel rebar was the second largest contributor (34 %), mainly related to the intensive use of fossil energy for the production of pig iron, the raw material for steel, followed by the production and transmission of electricity (23 %). Together, these three processes contributed around 98 % of the impacts related to the cradle-to-gate boundary.

The transportation of inputs did not make a significant contribution to the analysis, but this is due to the fact that the supply of the main inputs to the process (HDPE and steel) does not have long transportation distances associated with it.

Considering the life cycle results for the functional unit, cradle to grave, it was possible to note the majority contribution of the production stage, representing 62 % of the potential climate change impacts. The final disposal stage made a significant contribution (23 %), mainly due to landfill operations for the portion of the waste that was not disposed of.

recycled. To this end, a sensitivity analysis was carried out for the scenario in which 100% of the waste is recycled.

Transport processes for distribution accounted for 15 % of the total impacts, of which maritime transport contributed only 0.4 %. At the company's request, a sensitivity analysis was carried out for a scenario where production would be destined for Europe, more specifically sent to the Netherlands.

6.1 SENSITIVITY ANALYSIS

6.1.1 AS 1 - Use of virgin HDPE for production

In order to model the scenario for the production of polymeric supports with virgin HDPE, the recycled HDPE flow was changed to virgin HDPE, changing the provider to "polyethylene, high density, granulate, recycled to generic market for high density PE granulate | polyethylene, high density, granulate | APOS, U - RoW", available in the Ecoinvent 3.8 database. The quantities of the elementary input and output flows have not been changed.

6.1.2 AS 2 - Sending production to Netherlands

For the modeling of this scenario, land and sea transport values were changed in order to simulate the shipment of all production to the municipality of Rijswijk in the Netherlands. The transportation distance considered only the outward journey, estimated at 230 km by land and 10,024 km by sea.

6.1.3 AS 3 - Waste management for the end-of-life stage - open loop recycling

This scenario made the assumption that all the plastic waste collected after the end of the racks' useful life would be destined for open-circuit recycling, i.e. a recycling rate of 100 % instead of the 29 % used to model the base scenario.

6.1.4 AS 4 - Waste management for the end-of-life stage - recycling in a closed circuit

The scenario assumed that after the end of their life, the poles are sent back to the factory, where they are processed so that the HDPE and steel rebar can be reused in production, which would eliminate the need to use recycled HDPE from other sources and manufacture virgin steel. The allocation procedure followed the closed loop guidelines of NBR ISO 14067 (ABNT, 2023), using Equation 1:

$$EM = EV + EEoL - R \cdot EV \qquad (1)$$

Where: EM are the GHG emissions linked to the acquisition of raw materials and end-of-life operations; EV are the GHG emissions linked to the extraction or production of the raw material needed for the product, from natural resources, as if it were all primary material, which in this case would be the processes for recycling HDPE in the baseline scenario (collection, separation, cleaning and crushing); $EEoL$ are the GHG emissions linked to end-of-life operations (being part of the product system that supplies the recycled material); and R is the recycling rate of the material.

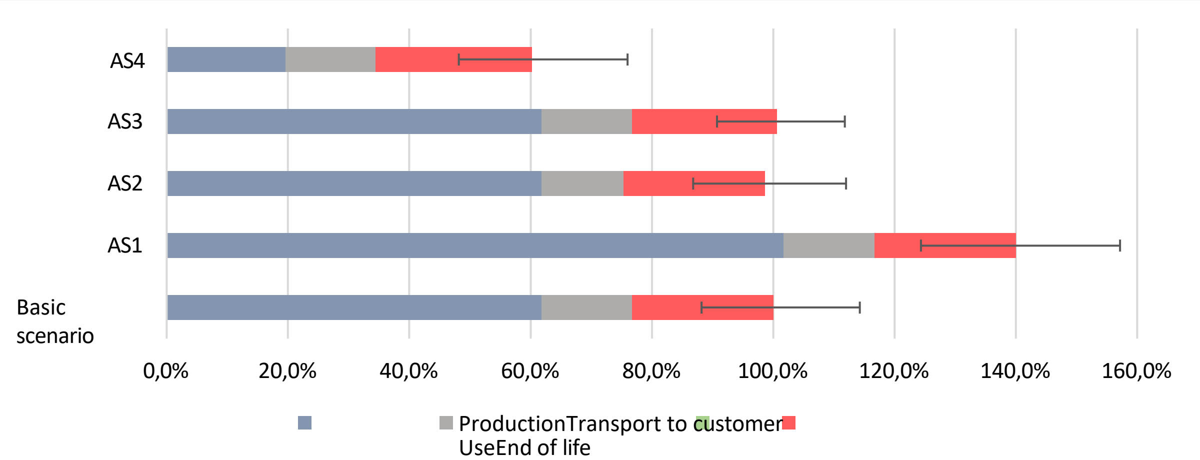
For this scenario, a recycling rate of 90% was assumed. Emissions modeling for $EEoL$ was based on energy and water consumption for the HDPE *flake* production process in the base scenario, seeking to simulate the crushing of poles to separate HDPE from rebar. The impact of transportation to the factory considered the same distance estimated for the distribution.

The results of the analysis can be seen in Table 18. Results for the base scenario with uncertainties are shown in the graph in Figure 6.

Table 18. Scenarios for sensitivity analysis

Scenarios	Description	GWP 100/ kg CO2e/ UF
Base	-	46,428
AS1	Use of 100 % virgin HDPE as an input in the production process	64,979
AS2	Shipping production to the Netherlands by sea	45,801
AS3	100% recycling of open-circuit poles	46,707
AS4	100 % recycling of poles in a closed circuit (90 % recyclability)	27,957

Figure 6 - Results for relative comparison of sensitivity analysis scenarios, with respective uncertainties



For the AS1 scenario, where production would use 100% virgin HDPE for extrusion supports, there was a significant 40% increase in potential global warming impacts, which reveals the system's sensitivity to the impacts associated with the raw material. The system also showed no sensitivity to the scenario in which production is destined for the Netherlands (AS2), given that, even though the average distance traveled is greater, the impacts of maritime transport are lower than those of land transport by truck.

There were also no statistically significant differences for the AS3 scenario compared to the base case results. This means that the system is not sensitive to changes in waste management, mainly due to the transportation and separation of recyclable materials. However, for the closed-loop recycling scenario (AS4) a significant 40 % reduction in impacts was observed compared to the base scenario, which is mainly due to the reduction in the use of virgin steel.

6.2 CONCLUSIONS, LIMITATIONS AND RECOMMENDATIONS

This study presented the results for the CFP of recycled HDPE supports for vertical road signs, also known as "Ecoposte", by the company Ecoposte Comércio e Serviços de Segurança Viária LTDA. The functional unit used was to provide a support structure for a steel sign used in a vertical road signage system with an area of 2.0 m², for a period of 50 years. The reference flow adopted was 52 kg of recycled HDPE support (mass for double support with dimensions of 80 mm x 80 mm and a length of 4 meters each). The partial CFP (cradle to gate) was 0.552 kg $_{CO2e/}$ kg of "Ecopost" for the base year 2022. The complete CFP (cradle to grave) for the functional unit was 46.428 kg $_{CO2e/UF}$. The largest contribution came from the production of the supports, with a contribution of 62 %. The sensitivity analysis showed that there would be a 40 % increase in the carbon footprint if 100 % virgin HDPE was used, and a 40 % reduction in the case of closed-loop recycling.

Specific limitations of this study include:

- Impossibility of direct measurement for the electrical energy consumption of the product system: Energy consumption was estimated based on power data and time of use, which have significant uncertainties;
- Need to adapt the HDPE *flake* production inventory from the Ecoinvent database to better represent the system under study;
- There is no specific data for the end-of-life scenario for the supports. The end-of-life waste management scenario was estimated based on national HDPE recycling data.

Inherent limitations of CFPs according to ISO 14067 (ABNT, 2023):

- Focus on climate change as the only impact category: Decisions on the impacts of a product that are only based on an exclusive environmental issue can conflict with goals and objectives related to other environmental issues;
- Methodological constraints of Life Cycle Assessment: the accuracy of CFP quantification is limited and difficult to assess, given that the establishment of the functional unit and system boundary, the availability and selection of appropriate data sources, allocation rules and assumptions about use and end-of-life scenarios are defined by the author and can have an influence on the results. Because of the above limitations, the results of a CFP quantification according to this Technical Specification are often not a solid basis for comparisons.

7 BENCHMARKING

As indicated in Section 4 and Annex B of NBR ISO 14067 (ABNT, 2023), a CFP study cannot be used to communicate the overall environmental superiority of one product versus another. Comparison based on the CFP of different products is only permitted if the CFP calculation of the products to be compared follows the identical CFP quantification and communication requirements.

Products cannot be compared on the basis of their partial CFP, unless the product function is included and the processes taken from the product system are identical and/or not relevant for all compared products. Comparison of products on the basis of their CFP is permitted, if the CFP calculation is made according to an equivalent or mutually recognized product category rule.

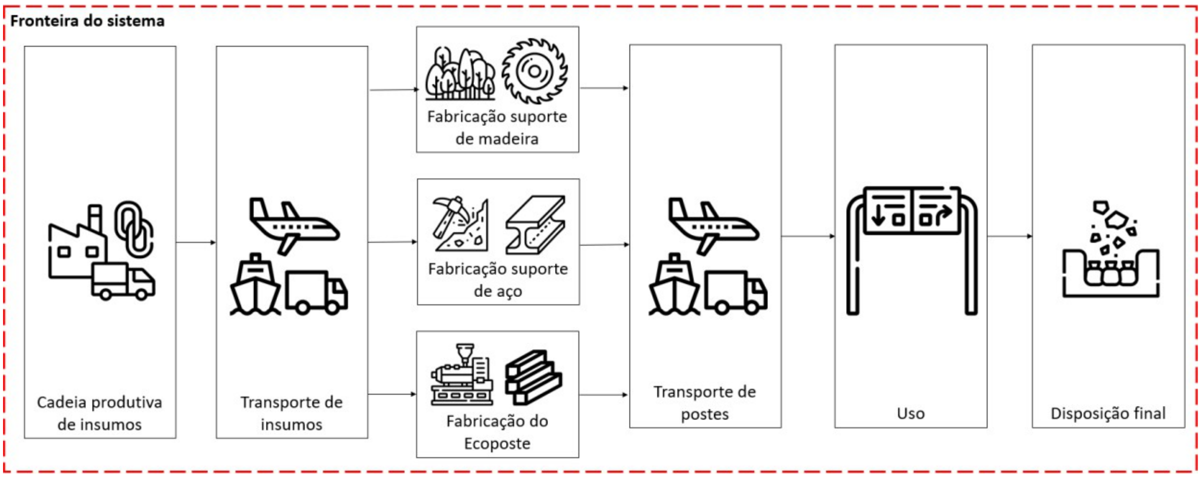
Within this context, a simplified comparison was carried out, outside the standards set by the norm, just for internal communication purposes within the company. Supports with different materials (recycled HDPE, eucalyptus and steel) were compared considering the same functional unit. For this analysis, it was assumed that the three types of poles would be produced in the same location.

7.1 DEFINITION OF PURPOSE AND SCOPE

The system boundary for this study included the steps that can be seen in Figure 7 for a cradle to grave extension. The functional unit adopted was the same as in the CFP study for the "Ecoposte", which was to provide a support structure for a steel sign used in a vertical road signage system with an area of 2.0 m², over a period of 50 years.

Direct data was used to build the production inventory of "Ecoposts", presented in this report in section 4. For the case of eucalyptus and steel support production systems, secondary data extracted from the Ecoinvent database version was used.
3.8. We considered using eucalyptus wood that had been treated by autoclaving and impregnated with chromium-based preservatives, and for the steel, using galvanized type "C" profiles.

Figure 7. System frontier for benchmarking analysis



The number of supports needed to serve the functional unit was estimated based on the projected useful life of each material. A useful life of 15 years was assumed for treated eucalyptus (UNIÃO MADEIRAS, 2023), 40 years for the steel profile and 50 for HDPE (MISHRA, 2023). The use of two supports, each 4 meters long, was considered.

The distance from the production site to the facility was considered the same for the three product systems, and was based on the average transportation distance for Ecoposte during the year 2022, as per section 4.

The use stage only considered the transportation of the poles to be replaced, for a distance between the base of the company responsible for the highway and the replacement site of 60 km (round trip).

Due to the lack of data to generate possible end-of-life scenarios, the final disposal of waste based on Ecoinvent was assumed. The data used to construct the scenarios, including the dimensions of the supports, is shown in Table 19.

Table 19. Data used to build the inventories for the UF

Information	Unit	Product 1	Product 2	Product 3
Material	-	Ecopost	Eucalyptus	Steel profile
Useful life	years	50	15	40
Number of supports for the unit functional	Unit	2,00	6,67	2,50
Support section	mm³	Rectangular (80 x 80)	Rectangular (100 x 100)	Folded C-profile (150 x 85 x 25 x 2.7)
Weight per meter	Kg/m	6,50	8,25	7,90
Production				
Reference flow	kg	52	220	79
Transport to the customer				
Transport distance, truck	km	1 111,9	1 111,9	1 111,9
Transport service, truck	t.km	57,82	244,61	87,84
Transportation distance, ship	km	55,55	55,55	55,55
Transportation service, ship	t.km	2,89	12,22	4,39
Use				
Transportation service for replacement	t.km	-	2,31	0,24
End of life				
Landfill	%	56 %	100 %	40 %
Recycling	%	44 %	-	60 %
Incineration	%	-	-	-

7.2 ANALYSIS OF INVENTORY

The inventory of eucalyptus wood production, wood pole production, and the use and end-of-life stages of wood poles for the selected functional unit can be seen in Table 20, Table 21 and Table 22, respectively

Table 20. Cradle to gate inventory for the production of 1 m³ of trimmed eucalyptus wood

Item	Quantity	Unit	DP	Ecoinvent process
Entries				
Diesel, burned in machinery	31,04	MJ	1,372	market for diesel, burned in building machine | diesel, burned in building machine | APOS, U - GLO
Electricity, medium voltage	18,89	kWh	1,649	market group for electricity, medium voltage | electricity, medium voltage | APOS, U - BR
Lubricating oil	0,095	kg	1,372	market for lubricating oil | lubricating oil | APOS, U - RoW
Wood, eucalyptus	1,490	kg	1,649	market for sawlog and veneer log, eucalyptus ssp., measured as solid wood under bark | sawlog and veneer log, eucalyptus ssp., measured as solid wood under bark | APOS, U - RoW
Sawmill	1,942E-7	Item(s)	1,649	market for sawmill | sawmill | APOS, U - GLO
Outputs				

Reference product				
Wood trim, eucalyptus	1,00	m^3	-	-
Waste				
Bark	90,96	kg	1,080	bark chips production, hardwood, at sawmill | bark | APOS, U - RoW
Wood dust	98,24	kg	1,648	suction, sawdust | sawdust, loose, wet, measured as dry mass | APOS, U - RoW
Mineral oil residue	0,014	kg	1,372	market for waste mineral oil | waste mineral oil | APOS, U - RoW

Table 21. Cradle to gate inventory for the production of 1 kg of wood support

Item	Quantity	Unit	DP	Ecoinvent process
Entries				
Chipped wood, eucalyptus	0,0012	m^3	1,050	-
Wood preservation process, vacuum application	0,012	kg	1,050	wood preservation, vacuum pressure method, inorganic salt, containing Cr, outdoor use, ground contact | wood preservation, vacuum pressure method, inorganic salt, containing Cr, outdoor use, ground contact | APOS, U - RoW*
Outputs				
Reference product				
Stand, wood	1,00	kg	-	-

*Process was modified so that water and electricity sources were Brazilian. Table 22. Gate-to-tomb inventory for eucalyptus support, for UF

Item	Quantity	Unit	DP	Ecoinvent process
Entries				
Stand, wood	220,00	kg		-
Transport, trucks, distribution	244,61	t*km	1,416	market for transport, freight, lorry 16-32 metric ton, EURO3 | transport, freight, lorry 16-32 metric ton, EURO3 | APOS, U - BR
Transportation, shipping, distribution	12,22	t*km	1,416	market for transport, freight, lorry 16-32 metric ton, EURO3 | transport, freight, lorry 16-32 metric ton, EURO3 | APOS, U - BR
Transport, truck, replacement	2,31	t*km	1,416	market for transport, freight, sea, container ship | transport, freight, sea, container ship | APOS, U - GLO
Outputs				
Reference product				
Double stand, eucalyptus, 2 m^2 board	1,00	Item(s)	-	-
Waste				
Wood waste	220,00	kg	1,253	market for waste wood pole, chrome preserved | waste wood pole, chrome preserved | APOS, U - RoW

The inventory for the production of steel supports and the use and end-of-life stages for the selected functional unit are available in Table 23 and Table 24, respectively.

Table 23. Cradle to gate inventory for the production of 1 kg of steel support

Item	Quantity	Unit	DP	Ecoinvent process
Entries				
Steel profile production	1,00	kg	1,050	market for section bar rolling, steel | section bar rolling, steel | APOS, U - GLO
Steel, low alloy	1,00	kg	1,050	steel production, converter, low-alloyed | steel, low-alloyed | APOS, U - RoW *
Galvanizing	0,091	m²	1,050	market for zinc coat, pieces | zinc coat, pieces | APOS, U - GLO
Outputs				
Reference product				
Bracket, steel	1,00	kg	-	-

*Process was modified so that water and electricity sources were Brazilian. Table 24.

Inventory of gate to tomb for steel support, for UF

Item	Quantity	Unit	DP	Ecoinvent process
Entries				
Bracket, steel	79,00	kg		-
Transport, trucks, distribution	87,84	t*km	1,416	market for transport, freight, lorry 16-32 metric ton, EURO3 | transport, freight, lorry 16-32 metric ton, EURO3 | APOS, U - BR
Transportation, shipping, distribution	0,24	t*km	1,416	market for transport, freight, lorry 16-32 metric ton, EURO3 | transport, freight, lorry 16-32 metric ton, EURO3 | APOS, U - BR
Transport, truck, replacement	4,39	t*km	1,416	market for transport, freight, sea, container ship | transport, freight, sea, container ship | APOS, U - GLO
Outputs				
Reference product				
Double support, steel, plate with 2 m²	1,00	Item	-	-
Waste				
Steel waste	79,00	kg	1,099	market for waste reinforcement steel | waste reinforcement steel | APOS, U - RoW

7.3 EVALUATION OF IMPACTS

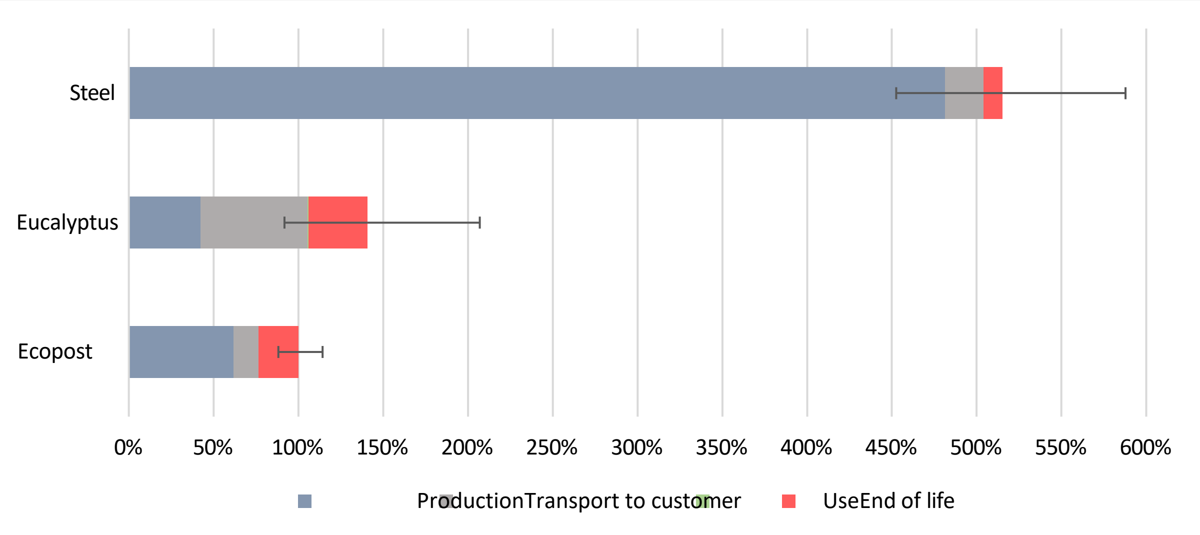
Inventory data was modeled using OpenLCA software version 2.0 and the Ecoinvent database version 3.8. A Monte Carlo simulation with 10,000 iterations was used to propagate the process uncertainties to the impact indicator result, for a 90% confidence interval.

Table 25 shows the results for the quantification of potential climate change impacts for the three products considering the functional unit, separated by life cycle stages. Figure 8 shows the results for the three products compared along with their respective uncertainties.

Table 25. Comparative GWP 100 impact result for the products considered, cradle to grave

Processes	Product 1 (Ecoposte)	Product 2 (Eucalyptus)	Product 3 (Steel)
	GWP 100/ (kg CO2eq/ UF)		
Production	28,69	19,67	223,52
Transporting poles to the customer	6,92	29,27	10,51
Use	0,00	0,28	0,03
Final destination	10,82	16,07	5,07
Total	46,43	65,28	239,13

Figure 8. Comparison of GWP100 relative impacts, cradle to grave, for the selected UF



The results revealed a significant difference between the steel production stages and the other products. The potential global warming impacts for the production stage of steel supports alone are equivalent to 4.8 and 3.4 times the impacts of the entire life cycle of HDPE supports and eucalyptus. As previously discussed, this contribution is closely linked to the production of pig iron, the raw material for steel. In the case of the production of eucalyptus supports, the greatest contribution in terms of impact is linked to the operations of wood processing and the application of preservatives. Impacts from the transportation stage to the customer were higher in the life cycle of eucalyptus supports, accounting for 45 % of their total impacts. This is mainly due to the greater need for wood supports given their shorter useful life for the period considered in the functional unit. The final disposal stage was more significant for the life cycle of HDPE supports, given the significant contribution of landfill impacts.

In general terms, the recycled polymer and eucalyptus supports showed an advantage in terms of GHG emissions when compared to the steel supports. However, it was not possible to define a statistically significant difference in potential climate change impacts between the "Ecoposte" and the eucalyptus wood support.

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ANNEX A: TECHNICAL SPECIFICATIONS - "ECOPOSTE"

ecoposte	TE - Tabela de Especificação	Identificação TE-002-ECO	
	PESO DE SUPORTES	Revisão 01	Folha 1/1

Peso dos ferros: 6mm = 0,240g / 8mm= 0,375g / 10mm = 0,600g / 12mm = 0,950g

Dimensões	Qtde. e bitola dos ferros		Comprimento (m)	Peso dos 4 ferros (kg/m)	Peso do Nominal do plástico (kg/m)	Tolerância do plástico (kg/m)	Peso total da peça (kg/m)
	Qtde. (pçs)	Bitola (mm)					
80x80x2,0m	4	6	1,0	0,96	5,0	-0,5 / +0,2	5,96
80x80x2,5m	4	6	1,0	0,96	5,0	-0,5 / +0,2	5,96
80x80x2,7m	4	6	1,0	0,96	5,0	-0,5 / +0,2	5,96
80x80x3,0m	4	6	1,0	0,96	5,0	-0,5 / +0,2	5,96
80x80x3,2m	4	6	1,0	0,96	5,0	-0,5 / +0,2	5,96
80x80x3,5m	2	6	1,0	0,48	5,0	-0,5 / +0,2	6,23
	2	8		0,75			
80x80x4,0m	2	6	1,0	0,48	5,0	-0,5 / +0,2	6,23
	2	8		0,75			
80x80x4,5m	4	8	1,0	1,5	5,0	-0,5 / +0,2	6,5
80x80x5,0m	4	8	1,0	1,5	5,0	-0,5 / +0,2	6,5
80x80x5,5m	4	8	1,0	1,5	5,0	-0,5 / +0,2	6,5
10x10 x todos sem tubo	4	10	1,0	2,4	7,58	-0,5 / +0,2	9,98
10x10 x todos com tubo	4	10 (+2 tb 19,05)	1,0	2,4 (+0,460)	7,58	-0,5 / +0,2	10,44
12x12 x todos com tubo	4	12 (+2 tb 39,05)	1,0	3,8 (+0,832)	11,96	-0,5 / +0,2	16,59
7x15 todos	4	10	1,0	2,4	7,9	-0,5 / +0,2	10,3
5,5x5,5 até 2,5m	4	6	1,0	0,96	2,56	-0,5 / +0,2	3,52
2. 1/2" até 3,6m	4	6	1,0	0,96	3,00	-0,5 / +0,2	3,96

Revisão		HISTÓRICO DAS ALTERAÇÕES
Data	Número	
17/03/2021	01	Correção nos valores dos pesos dos Suportes.
12/11/2020	00	Criação desta Tabela de Especificação.

ANNEX B: SUPPLEMENTARY INFORMATION

Table A1. Ecoinvent 3.8 processes used for the background boundary for the inventory of the "Ecopost"

Item	Ecoinvent process
Entries	
Electricity, medium voltage	market group for electricity, medium voltage | electricity, medium voltage | APOS, U - BR
HDPE, recycled, *flake*	polyethylene production, high density, flaked, recycled | polyethylene, high density, granulate, recycled | APOS, U (Ecoposte) - RoW*
Steel, rebar	reinforcing steel production (ArcelorMittal - BR)**
Paint, epoxy resin base	epoxy resin production, liquid | epoxy resin, liquid | APOS, U - RoW
Paint solvent	turpentine to generic market for solvent for paint | solvent for paint | APOS, U - GLO
Water, treated	market for tap water | tap water | APOS, U - BR
Vehicular natural gas	market for liquefied petroleum gas | APOS, U - BR
Wood, pine	softwood forestry, pine, sustainable forest management | sawlog and veneer log, softwood, measured as solid wood under bark | APOS, U - RoW
Transportation, inputs, truck	market for transport, freight, lorry 16-32 metric ton, EURO3 | transport, freight, lorry 16-32 metric ton, EURO3 | APOS, U - BR
Outputs	
Reference product	
Ecopost	-
Waste	
Waste, plastic	treatment of waste plastic, mixture, sanitary landfill | waste plastic, mixture | APOS, U - RoW

* The process was modified so that the water and energy flows referred to Brazilian conditions and the energy consumption was adjusted for the production of recycled HDPE *flake*, according to the inventory extracted from the APR (2018);
**Rebar production emissions modeled for Brazilian conditions. Inventory data taken from IBU, (2021)

Table A2. Ecoinvent 3.8 processes used for the background boundary for the functional unit inventory

Item	Ecoinvent process
Entries	
"Ecopost"	-
Transportation, distribution, truck	market for transport, freight, lorry 16-32 metric ton, EURO3 | transport, freight, lorry 16-32 metric ton, EURO3 | APOS, U - BR
Transportation, distribution, ship	market for transport, freight, sea, container ship | transport, freight, sea, container ship | APOS, U - GLO
Outputs	
Reference product	
Double support, "Ecoposte", sign with 2 m²	-
Waste	
Waste, HDPE, for recycling	market for waste polyethylene, for recycling, unsorted | waste polyethylene, for recycling, unsorted | APOS, U - RoW
Plastic waste, for landfill	market for waste plastic, mixture | waste plastic, mixture | APOS, U - BR
Waste, steel, for recycling	market for waste reinforcement steel | waste reinforcement steel | APOS, U - RoW
Waste, wood, for landfill	market for waste wood, untreated | waste wood, untreated | APOS, U - BR

ANNEX C: EXPERT VERIFICATION INTERNAL

- **Expert:** Marcela Valles Lange Ferron

Initials	Contents	Paragraph/ Figure/ Table	Type of comment	Reviewer's comments	Reviewer's recommendation	Answer
MVLF	Executive summary	"Functional unit" and "reference flow used"	technical	It is not clear that the evaluation will be carried out for 1kg of pole.	As evaluations are made in two scopes (cradle to gate and cradle to grave), when indicating the functional unit it would be interesting to also add the unit declared for the cradle to gate scope.	In the description of the functional unit in the executive summary, the following sentence was added: "For the cradle to gate assessment, a declared unit was adopted of 1 kg of "Ecoposte"."
MVLF	2	Third paragraph	technical	I believe that the sentence "It is the company's intention to make the information in this report public to consumers, but this process should follow the guidelines of NBR ISO 14067, which provides for the development of a disclosure report according to the ISO 14026." also includes terms from the previous version of the standard	Writing suggestion: "It is the company's intention to make the information in this report public to consumers, and the footprint communication requirements of ABNT NBR ISO 14026 should be followed."	Answered.
MVLF	3.2	First paragraph	technical	It is not clear that the evaluation will be carried out for 1kg of pole.	As evaluations are made in two scopes (cradle to gate and cradle to grave), when indicating the functional unit it would be interesting to also add the unit declared for the cradle to gate scope.	The following sentence has been added to the end of the paragraph: "To analyze the system at the cradle-to-gate boundary, a unit has been adopted declared 1 kg of "Ecoposte".
MVLF	3.3	First paragraph	editorial	In the sentence "In the background were the other stages of the life cycle, including the chain of production of inputs, use and final disposal after the end of the product's useful life", the final point is missing.	Add a period.	Answered.
MVLF	3.6	First paragraph	technical	In the sentence "However, for data referring to b a c k g r o u n d processes, the allocation of impacts referring to the recycling of waste considered the Allocation at the Point of Substitution (APOS) approach, already implemented in the Ecoinvent database." The APOS approach could be better explained.	Writing suggestion: "However, for data relating t o background processes, expansion of product systems is used to avoid allocation within treatment systems, by means of the Allocation at Point of Substitution (APOS) approach, already implemented in the Ecoinvent database. Among materials that are not intended for treatment, the d a t a b a s e uses economic allocation (i.e. price-based allocation) with a few exceptions, such as for energy, for which the allocation is based on exergy."	Answered.
MVLF	5	First paragraph	technical	The confidence index is shown as 95%.	Check that the confidence interval is really 95%.	Corrected to a range of 90% confidence.

MVLF	5	Table 16	technical	In Table 16, the impact refers to electricity production and transmission, I believe. For the others as I understand it, transportation is separate.	It would be interesting to include the transmission in the text, to make it clear that it is accounted for.	Serviced. Corrected to "production and transmission of electricity" in Table 16.
MVLF	5	Table 16	technical	In Table 16, the consumption of paint, solvent, CNG, water and wood and the generation of waste do not appear.	Is it because they're so small? I think it would be interesting to show them anyway.	Answered. Values have been recalculated and now include all processes.
MVLF	5	Table 17 and Figure 5	editorial	In the captions in Table 17 and Figure 5, the endings were missing. quotes in "Ecoposte.	Finish with quotation marks.	Answered.
MVLF	6	Second paragraph	technical	It is stated that the processing operations of recycled HDPE are responsible for 17 % of the impact, but it is not explained why.	It would be interesting to explain which stream is responsible for the high impact attributed to the recycling process. HDPE.	Answered.
MVLF	6	Third and fourth paragraphs	technical	Two of the sensitivity analysis scenarios that will be evaluated are indicated, but not the scenario of using 100% virgin HDPE.	Here it would be interesting to include the information that a sensitivity analysis was also carried out for the scenario of using 100% virgin HDPE, since the following were indicated the other scenarios.	This information was written in section 5, paragraph 2.
MVLF	6	Fourth paragraph	technical	The results of this sensitivity analysis ("A sensitivity analysis was carried out considering a scenario for a EURO 5 fleet and no statistically significant difference was found. significant between the results") are not described.	As the results of this sensitivity analysis are not described, I think it would be better not to mention it in the text.	Taken care of. Ticket has been withdrawn.
MVLF	6.1	Second paragraph	technical	The sentence "This means that the system is not sensitive to changes in waste management, given that the process already uses recycled waste, although it was possible to notice a reduction in impacts for the end-of-life stage in the AS2 scenario." leaves open the possible interpretation that there is a significant difference in the waste management processes. results for this scenario.	It would be interesting to include "non-statistically significant reduction in impacts".	Answered.
MVLF	6.2	Second paragraph	technical	Some limitations may be included.	It would be interesting to include as limitations the need to adapt the HDPE flake production inventory, as well as the lack of specific data for the end of life of poles.	Answered.
MVLF	Annex B	Table A1	technical	The production inventories for steel and recycled HDPE were used as they appear in the database, as can be seen in the table.	Suggestion: if steel and recycled HDPE are produced in Brazil, the energy consumption in ecoinvent's inventories could be adapted to the Brazilian grid.	Answered.
MVLF	6.1	First paragraph	technical	A more detailed description of each scenario used in the sensitivity analysis is missing.	It would be interesting to describe each of the scenarios modeled in the sensitivity analysis and the changes made in terms of modeling (processes considered, allocation approach) for each one theirs.	Subsections have been added to explain the modeling of the scenarios.

MVLF	7.3	Entire item	technical	The products are presented as scenarios.	As the term "scenario" has already been used in the sensitivity analysis, I think it would be better not to use it here. lo. Use the same "product" comparison.	Answered. The word "scenario" has been replaced by "product" in this section.
MVLF	Annex B	Table A1	technical	The production inventories for steel and recycled HDPE were used as they appear in the database, a s can be seen in the table.	I saw here in the reply that adaptations have been made, but I couldn't find an indication of these adaptations in the report. If they aren't there, it would be interesting to include them.	The adaptations have been included in the legend to Table A1.