

The Circularity of Materials from the Perspective of the Product Life Cycle: A Case Study of Secondary Fence Board, Part 2 (Scenario Analysis)

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Life cycle of multi-material packaging (*HDPE = 30%; PP = 30%; PC = 10%; PA = 10%; ABS = 10%; ALU = 10%)
Function provided → contain and protect the product; enable its transport and storage

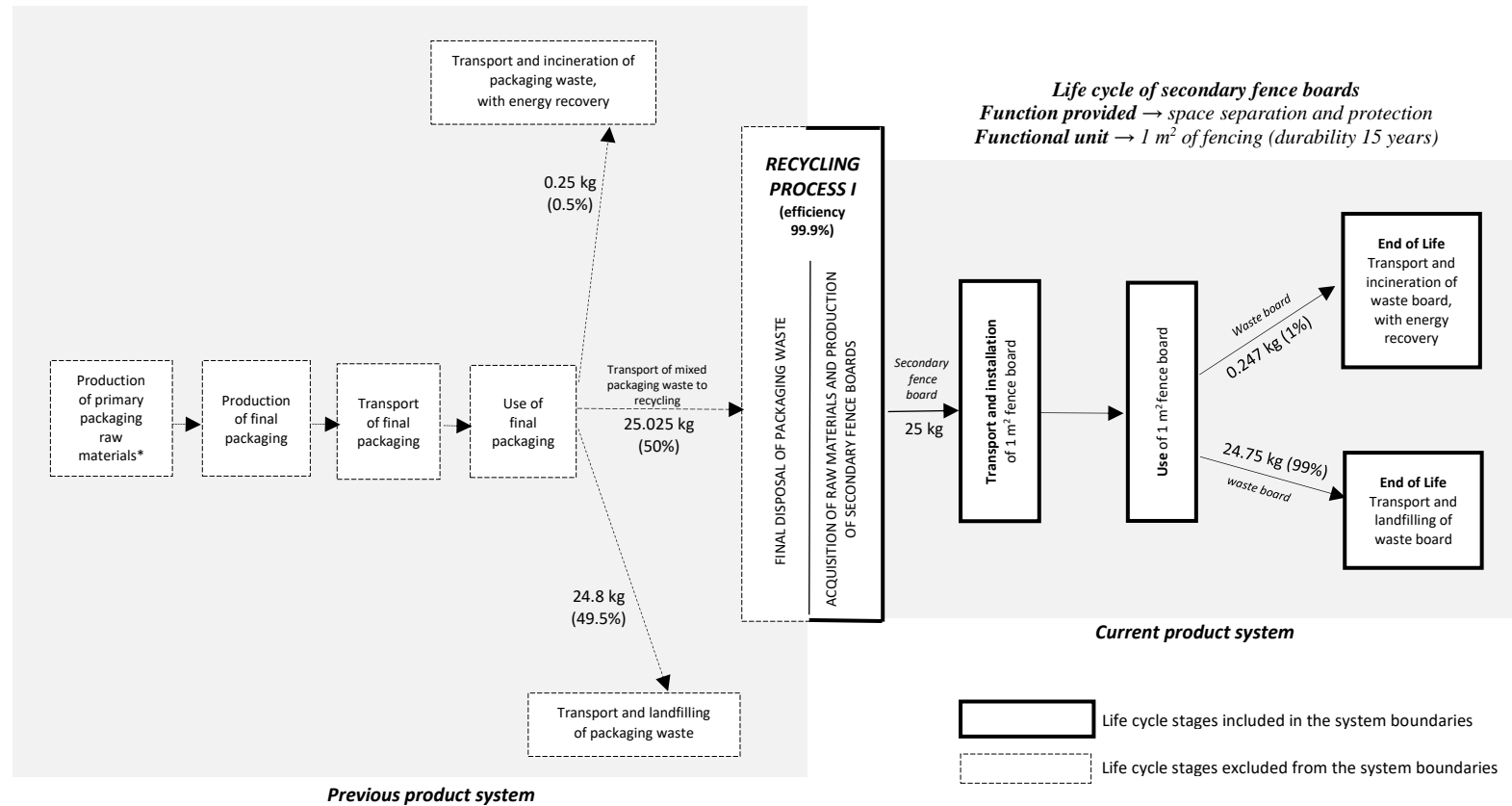


Figure S1. System boundaries in the scenarios 1A (baseline), 2A, 3A and 4A

Life cycle of multi-material packaging (*HDPE = 30%; PP = 30%; PC = 10%; PA = 10%; ABS = 10%; ALU = 10%)

Function provided → contain and protect the product; enable its transport and storage

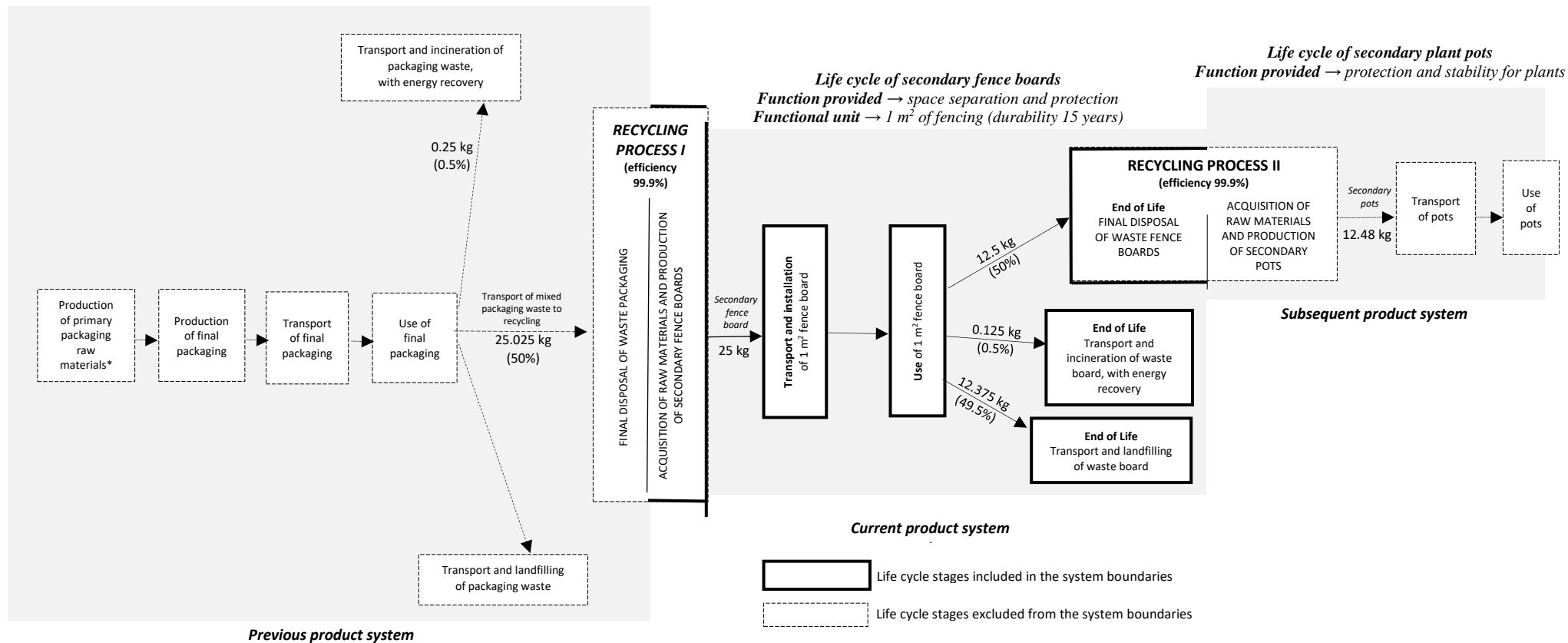


Figure S2. System boundaries in scenarios with options B, C and D

Table S1. Recycling at the cradle (E_{recycled}) and substitution modelling options for primary production (E_v), results per functional unit (1 m² of secondary fence board)

	SUBSTITUTION MODELLING OPTIONS – RECYCLING AT THE CRADLE			
	1	2	3	4
Recycled content R_1	$R_1 = 1$			
Recycling at the cradle E_{recycled}	Recycling Process I			
Functions provided by Recycling Process I	<ul style="list-style-type: none">• Treatment of multi-material packaging waste• Production of secondary fence board (final product)			
Output of Recycling process I (per FU, 1 m ² of fencing)	<ul style="list-style-type: none">• Treated 25.025 kg of packaging waste• 1 m² (25 kg) of secondary fence board with durability of 15 years			
The market affected by using recycled materials in the recycled product (secondary fence board)	Packaging market	Fencing market		
Reasons why the market is affected	Production of primary packaging materials potentially increased because of the unavailability of the recycled materials already used in the secondary fence board and absorbed by the fencing market	Production of primary fencing materials potentially increased because of unavailability of the recycled materials already used in the secondary fence board		
The primary production (E_v)	Production of primary packaging materials, mix based on the waste composition (HDPE = 30%, PP = 30%, PC= 10%, PA = 10%, ABS = 10%, aluminium	Production of primary plastic&composite fencing materials (plastic&composite = 100%)	Production of primary fencing materials, mix based on market shares (steel fencing = 52%, wood fencing = 30%, plastic&composite = 11%, concrete = 7%)	
The allocation factor A	0.5 (plastics) 0.2 (aluminium)	0.5		

<p>The amount of Recycling process I allocated to the secondary fence board (per FU)</p> <p>$R_1 \times (A E_{\text{recycled}})$</p>	<p> $1 \times (0.5 \times 25 \text{ kg} \times 0.3) = 3.75 \text{ kg } (E_{\text{recycled_HDPE}})$ $1 \times (0.5 \times 25 \text{ kg} \times 0.3) = 3.75 \text{ kg } (E_{\text{recycled_PP}})$ $1 \times (0.5 \times 25 \text{ kg} \times 0.1) = 1.25 \text{ kg } (E_{\text{recycled_PC}})$ $1 \times (0.5 \times 25 \text{ kg} \times 0.1) = 1.25 \text{ kg } (E_{\text{recycled_PA}})$ $1 \times (0.5 \times 25 \text{ kg} \times 0.1) = 1.25 \text{ kg } (E_{\text{recycled_ABS}})$ $1 \times (0.2 \times 25 \text{ kg} \times 0.1) = 0.5 \text{ kg } (E_{\text{recycled_aluminium}})$ </p> <p>Total $E_{\text{recycled}} = 11.75 \text{ kg}$</p>	<p>$1 \times (0.5 \times 25 \text{ kg}) = 12.5 \text{ kg}$</p> <p>Total $E_{\text{recycled}} = 12.5 \text{ kg}$</p>		
<p>Quality correction $Q_{\text{Sin}}/Q_{\text{P}}$</p>	<p>1 (plastics) 0.9 (aluminium)</p>	<p>E_v parameter indirectly integrates the $Q_{\text{Sin}}/Q_{\text{P}}$ parameter (expressed by differences in the durability of fencing), and therefore the Q_{Sin} and Q_{P} parameters are not part of the CFF</p>		
		<p>The analysed secondary board and a plastic market board have the same durability (15 years)</p>	<p>The analysed secondary board and all market fence boards have the same durability (15 years)</p>	<p>The analysed secondary board and all market fence boards have different durability</p>
<p>The amount of primary production allocated at the cradle (as debit) to the secondary fence board (per FU)</p> <p>$R_1 \times (1-A) E_v \times Q_{\text{Sin}}/Q_{\text{P}}$</p>	<p> $1 \times ((1-0.5) \times 25 \text{ kg} \times 0.3 \times 0.9) = 3.375 \text{ kg } (E_{v_primary_HDPE})$ $1 \times ((1-0.5) \times 25 \text{ kg} \times 0.3 \times 0.9) = 3.375 \text{ kg } (E_{v_primary_PP})$ $1 \times ((1-0.5) \times 25 \text{ kg} \times 0.3 \times 0.9) = 3.375 \text{ kg } (E_{v_primary_PC})$ $1 \times ((1-0.5) \times 25 \text{ kg} \times 0.1 \times 0.9) = 1.125 \text{ kg } (E_{v_primary_PA})$ $1 \times ((1-0.5) \times 25 \text{ kg} \times 0.1 \times 0.9) = 1.125 \text{ kg } (E_{v_primary_ABS})$ $1 \times ((1-0.2) \times 25 \text{ kg} \times 0.1 \times 1) = 0.5 \text{ kg } (E_{v_primary_aluminium})$ </p> <p>Total $E_v = 10.625 \text{ kg}$</p>	<p> $(1 \text{ m2 fence} = 28 \text{ kg PVC})$ $1 \times (1-0.5) \times 28 \text{ kg} \times 15\text{yrs}/15\text{yrs} = 14 \text{ kg } (E_{v_plastic\&composites_15\text{years}})$ </p> <p>Total $E_v = 14 \text{ kg}$</p> <p>If the secondary fence board and the plastic market board have the same durability, then the secondary fencing product system is to</p>	<p> $(0.52 \text{ m2 fence} = 82.1 \text{ kg steel})$ $1 \times (1-0.5) \times 82.1 \text{ kg} \times 15\text{yrs}/15\text{yrs} = 41.04 \text{ kg } (E_{v_steel_15\text{years}})$ </p> <p> $(0.3 \text{ m2 fence} = 4.2 \text{ kg wood})$ $1 \times (1-0.5) \times 4.2 \times 15\text{yrs}/15\text{yrs} = 2.10 \text{ kg } (E_{v_wood_15\text{years}})$ </p> <p> $(0.11 \text{ m2 fence} = 3.0 \text{ kg PVC})$ </p>	<p> $(0.52 \text{ m2 fence} = 82.1 \text{ kg steel})$ $1 \times (1-0.5) \times 82.1 \text{ kg} \times 15\text{yrs}/40\text{yrs} = 5.77 \text{ kg } (E_{v_steel_40\text{years}})$ </p> <p> $(0.3 \text{ m2 fence} = 4.2 \text{ kg wood})$ $1 \times (1-0.5) \times 4.2 \times 15\text{yrs}/20\text{yrs} = 0.53 \text{ kg } (E_{v_wood_20\text{years}})$ </p> <p> $(0.11 \text{ m2 fence} = 3.0 \text{ kg PVC})$ $1 \times (1-0.5) \times 3.0 \text{ kg} \times 15\text{yrs}/15\text{yrs} = 1.49 \text{ kg } (E_{v_plastic\&composites_15\text{years}})$ </p>

	<p>The secondary fencing product system is to be debited at the cradle with 10.625 kg of primary production of packaging materials (per FU, 1 m² of fencing).</p>	<p>be debited at the cradle with 14 kg of primary PVC fencing production (per FU, 1 m² of fencing).</p>	<p> $1 \times (1-0.5) \times 3.0 \text{ kg} \times 15\text{yrs}/15\text{yrs} = 1.49 \text{ kg}$ (EV_plastic&composites_15years) </p> <p> $(0.07 \text{ m}^2 \text{ fence} = 3.5 \text{ kg concrete})$ </p> <p> $1 \times (1-0.5) \times 3.5 \text{ kg} \times 15\text{yrs}/15\text{yrs} = 1.76 \text{ kg}$ (EV_concrete_15 years) </p> <p>Total E_v = 46.39 kg</p> <p>If all fence boards have the same durability, then the secondary fencing product system is to be debited at the cradle with 46.39 kg of primary production of different fencing materials (per FU, 1 m² of fencing).</p>	<p> $(0.07 \text{ m}^2 \text{ fence} = 3.5 \text{ kg concrete})$ </p> <p> $1 \times (1-0.5) \times 3.5 \text{ kg} \times 15\text{yrs}/40\text{yrs} = 0.25 \text{ kg}$ (EV_concrete_40 years) </p> <p>Total E_v = 8.04 kg</p> <p>If fence boards have different durability, then the secondary fencing product system is to be debited at the cradle with 8.04 kg of primary production of different fencing materials (per FU, 1 m² of fencing).</p>
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Table S2. Recycling at the EoL ($E_{\text{recycling_EoL}}$) and substitution modelling options for credited primary production (E^*_v), results per functional unit (1 m² of secondary fence board)

	SUBSTITUTION MODELLING OPTIONS - RECYCLING AT THE END OF LIFE					
	A	excluded	excluded	B	C	D
Recycling rate R ₂	R ₂ = 0	R ₂ = 0.499				
Recycling at EoL (E _{recycling_EoL})	n.a.	Recycling process II				
Functions provided by Recycling process II	n.a.	<ul style="list-style-type: none">• Treatment of waste secondary fence board• Production of secondary pots (final product)				
Output of Recycling process II (per FU of 1 m ² of fencing)	n.a.	<ul style="list-style-type: none">• Treated 12.5 kg of waste secondary fence board• 12.48 kg of secondary pots with durability of 5 years and total capacity of 39 liters				
What market is to be affected by generating the recycled product (secondary pots)?	n.a.	Packaging market	Fencing market	Pots market		
Why is the market to be affected?	n.a.	Quality of waste secondary board is too low to be considered as a source of recycled materials for packaging industry. <i>Additionally,</i> Recycling process II generates a clearly defined secondary final	In theory, the waste secondary board could be used to generate recycled materials and produce secondary fencing (closed-loop recycling). Then the fencing market would be affected by	Use of waste secondary fence board to generate recycled materials by Recycling process II and to produce secondary pots (<i>open-loop recycling</i>) affects the pots market by reducing the production of pots made of primary materials.		

		product with a strict application of providing protection and stability for plants. For this reason, we assumed that Recycling process II does not affect the packaging market.	reducing the production of primary fencing. However, in our example, we assumed that Recycling process II generates a clearly defined secondary final product with a strict application of providing protection and stability for plants. For this reason, we assumed that Recycling process II does not affect the fencing market.		
What is the primary production? E_v^*	n.a.	No reason to model production of primary packaging materials as E_v^*	No reason to model production of primary fencing materials as E_v^*	Production of primary plastic pots (HDPE material = 100%)	Production of primary pots, mix based on market shares (refractory materials = 47%, polymer = 31%, metal = 13%, wood = 9%)
Allocation factor A	n.a.	Excluded		0.5	

<p>What amount of Recycling process II is allocated to the secondary fence board (per FU)?</p> $(1-A)R_2 \times E_{\text{recyclingEoL}}$	n.a.	Excluded	$(1-0.5) \times 0.499 \times 25 \text{ kg} = 12.48 \text{ kg}$ Total $E_{\text{recycling_EoL}} = 12.48 \text{ kg}$		
<p>Quality correction</p> $\frac{Q_{\text{Sout}}}{Q_p}$	n.a.	Excluded	<p>E^*_v parameter indirectly integrates the Q_{Sout}/Q_p parameter (expressed by differences in durability of pots), and therefore the Q_{Sout} and Q_p parameters are not part of the CFF)</p>		
			Polymer pots have durability of 5 years	Pots have the same durability of 5 years	Pots have different durability
<p>What amount of primary production is allocated at the EoL (as credit) to the secondary fence board (per FU)?</p> $(1-A)R_2 \times (-E^*_v \times \frac{Q_{\text{Sout}}}{Q_p})$	n.a.	Excluded	<p>(39 litres x 1 x 0.25 kg/litre = 9.75 kg polymer/HDPE/)</p> <p>$(1-0.5) \times 0.499 \times (-9.75 \text{ kg} \times 5\text{yrs}/5\text{yrs}) = -2.43 \text{ kg}$ $(E^*_{V_polymer_HDPE_5\text{years}})$</p> <p>Total $E^*_v = -2.43 \text{ kg}$</p> <p>If polymer pots have durability of 5 years, then the secondary fencing product system is to be</p>	<p>(39 litres x 0.47 x 0.5 x 0.5 kg/litre = 4.71 kg ceramic)</p> <p>$(1-0.5) \times 0.499 \times (-4.71 \text{ kg} \times 5\text{yrs}/5\text{yrs}) = -1.18 \text{ kg}$ $(E^*_{V_ceramic_5\text{years}})$</p> <p>(39 litres x 0.47 x 0.5 x 0.5 kg/litre = 4.71 kg concrete)</p>	<p>(39 litres x 0.47 x 0.5 x 0.5 kg/litre = 4.71 kg ceramic)</p> <p>$(1-0.5) \times 0.499 \times (-4.71 \text{ kg} \times 5\text{yrs}/10\text{yrs}) = -0.59 \text{ kg}$ $(E^*_{V_ceramic_10\text{years}})$</p> <p>(39 litres x 0.47 x 0.5 x 0.5 kg/litre = 4.71 kg concrete)</p> <p>$(1-0.5) \times 0.499 \times (-4.71 \text{ kg} \times 5\text{yrs}/10\text{yrs}) = -0.59 \text{ kg}$ $(E^*_{V_concrete_10\text{years}})$</p> <p>(39 litres x 0.31 x 0.25 kg/litre = 2.98 kg polymer/HDPE/)</p>

			credited at EoL with 2.43 kg of primary HDPE pots production (per FU 1 m ² of fencing).	$(1-0.5) \times 0.499 \times (-4.71 \text{ kg} \times 5\text{yrs}/5\text{yrs}) = -1.18 \text{ kg}$ $(E^*V_{\text{concrete_5years}})$ $(39 \text{ litres} \times 0.31 \times 0.25 \text{ kg/litre} = 2.98 \text{ kg polymer/HDP E/})$ $(1-0.5) \times 0.499 \times (-2.98 \text{ kg} \times 5\text{yrs}/5\text{yrs}) = -0.74 \text{ kg}$ $(E^*V_{\text{polymer_HDPE_5years}})$ $(39 \text{ litres} \times 0.13 \times 1.99 \text{ kg/litre} = 10.32 \text{ kg metal/steel/})$ $(1-0.5) \times 0.499 \times (-10.32 \text{ kg} \times 5\text{yrs}/10\text{yrs}) = -1.29 \text{ kg}$ $(E^*V_{\text{metal_steel_10years}})$ $(39 \text{ litres} \times 0.09 \times 0.18 \text{ kg/litre} = 0.63 \text{ kg wood})$ $(1-0.5) \times 0.499 \times (-0.63 \text{ kg} \times 5\text{yrs}/8\text{yrs}) = -0.01 \text{ kg}$ $(E^*V_{\text{wood_8years}})$ Total E*v = -3.31 kg <p>If pots have the same durability, then the secondary fencing product system is to be credited at EoL with 3.31 kg of primary pots production (per FU 1 m² of fencing).</p>	$(1-0.5) \times 0.499 \times (-2.98 \text{ kg} \times 5\text{yrs}/5\text{yrs}) = -0.74 \text{ kg}$ $(E^*V_{\text{polymer_HDPE_5years}})$ $(39 \text{ litres} \times 0.13 \times 1.99 \text{ kg/litre} = 10.32 \text{ kg metal/steel/})$ $(1-0.5) \times 0.499 \times (-10.32 \text{ kg} \times 5\text{yrs}/10\text{yrs}) = -1.29 \text{ kg}$ $(E^*V_{\text{metal_steel_10years}})$ $(39 \text{ litres} \times 0.09 \times 0.18 \text{ kg/litre} = 0.63 \text{ kg wood})$ $(1-0.5) \times 0.499 \times (-0.63 \text{ kg} \times 5\text{yrs}/8\text{yrs}) = -0.01 \text{ kg}$ $(E^*V_{\text{wood_8years}})$ Total E*v = -3.31 kg <p>If pots have the same durability, then the secondary fencing product system is to be credited at EoL with 3.31 kg of primary pots production (per FU 1 m² of fencing).</p>
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				$(-0.63 \text{ kg} \times 5\text{yrs}/5\text{yrs}) = -0.16 \text{ kg}$ $(E^*_{V_wood_5\text{years}})$ Total $E^*_v = -5.84 \text{ kg}$ If pots have the same durability, then the secondary fencing product system is to be credited at EoL with 5.84 kg of primary pots production (per FU 1 m ² of fencing).	
What amount of waste secondary board is sent for landfill? (99%) (E_D)	$25 \text{ kg} \times 0.99 = 24.75 \text{ kg}$	Excluded	$(25 \text{ kg} - 25 \text{ kg} \times 0.5) \times 0.99 = \mathbf{12.375 \text{ kg}}$		
What amount of waste secondary board is sent for incineration) per FU? (1%) (R₃)	$25 \text{ kg} \times 0.01 = 0.2475 \text{ kg}$	Excluded	$(25 \text{ kg} - 25 \text{ kg} \times 0.5) \times 0.01 = \mathbf{0.125 \text{ kg}}$		

Table S3 Inventory results for *Production of secondary fence board* (Recycling process I)
- results per FU, 1 m² of fence board

PRODUCTION OF SECONDARY FENCE BOARD (RECYCLING PROCESS I)		
Ecoinvent dataset (https://ecoinvent.org/database/ (accessed on 12 February 24))	Amount	Unit
<i>Inputs</i>		
Polypropylene, granulate {GLO} market for Cut-off, U	0.06	Kg
Injection moulding {GLO} market for Cut-off, U	0.06	Kg
Steel, chromium steel 18/8 {GLO} market for Cut-off, U	1.89	G
Silicone product {RER} market for silicone product Cut-off, U	0.45	G
Ethylene glycol {GLO} market for Cut-off, U	0.4	G
Lubricating oil {RER} market for lubricating oil Cut-off, U	1.71	G
Liquefied petroleum gas {GLO} market group for liquefied petroleum gas Cut-off, U	0.08	Kg
Electricity, low voltage {PL} market for Cut-off, U	48.65	kWh
<i>Outputs</i>		
Mixed plastics (waste treatment) {GLO} recycling of mixed plastics Cut-off, U	0.06	Kg
Hazardous waste, for incineration {Europe without Switzerland} market for hazardous waste, for incineration Cut-off, U	2.11	G
Waste plastic, mixture {RoW} treatment of waste plastic, mixture, municipal incineration Cut-off, U	0.45	G
Steel and iron (waste treatment) {GLO} recycling of steel and iron Cut-off, U	1.89	G

Source: own elaboration based in calculations SimaPro software

Table S4 Inventory results for *Production of secondary garden pots* (Recycling process II)
- results per FU, 1 m² of fence board

PRODUCTION OF SECONDARY GARDEN POTS (RECYCLING PROCESS II)		
Ecoinvent dataset (https://ecoinvent.org/database/ (accessed on 12 February 24))	Amount	Unit
<i>Inputs</i>		
Steel, low-alloyed {GLO} market for Cut-off, U	0.008668	Kg
Waste preparation facility {GLO} market for waste preparation facility Cut-off, U	2.21E-09	P
Wire drawing, steel {RER} processing Cut-off, U	0.008668	Kg
Thermoforming of plastic sheets {GLO} market for Cut-off, U	1	Kg
Diesel, burned in building machine {GLO} market for Cut-off, U	0.068825	MJ
Electricity, low voltage {Europe without Switzerland} market group for Cut-off, U	0.017383	kWh
Heat, district or industrial, natural gas {Europe without Switzerland} market for heat, district or industrial, natural gas Cut-off, U	8.6E-05	MJ
Propane, burned in building machine {GLO} market for Cut-off, U	0.018145	MJ
<i>Outputs</i>		
Waste plastic, mixture {Europe without Switzerland} market group for waste plastic, mixture Cut-off, U	0.104972	Kg

Source: own elaboration based in calculations SimaPro software

Table S5 Inventory results for life cycle stage *Materials & production – secondary fence board for options 1,2,3 and 4* - results per FU, 1 m² of fence board
(based on calculations with the CFF formula, $R_{1_fence_board} = 1.0$ and $A_{_fence_board} = 0.5$)

MATERIALS & PRODUCTION – SECONDARY FENCE BOARD – OPTION 1 (primary production of packaging debited)		
Ecoinvent dataset (https://ecoinvent.org/database/ (accessed on 12 February 24)	Amount	Unit
<i>Inputs</i>		
Production of secondary fence board (Recycling process I)	3.75	Kg
Polyethylene, high density, granulate {GLO} market for Cut-off, U (debit)	3.375	Kg
Injection moulding {GLO} market for Cut-off, U (debit)	3.375	Kg
Production of secondary fence board (Recycling process I)	3.75	Kg
Polypropylene, granulate {GLO} market for Cut-off, U (debit)	3.375	Kg
Injection moulding {GLO} market for Cut-off, U (debit)	3.375	Kg
Production of secondary fence board (Recycling process I)	1.25	Kg
Polycarbonate {GLO} market for Cut-off, U (debit)	1.125	Kg
Injection moulding {GLO} market for Cut-off, U (debit)	1.125	Kg
Production of secondary fence board (Recycling process I)	1.25	Kg
Nylon 6-6 {RER} market for nylon 6-6 Cut-off, U (debit)	1.125	Kg
Injection moulding {GLO} market for Cut-off, U (debit)	1.125	Kg
Production of secondary fence board (Recycling process I)	1.25	Kg
Acrylonitrile-butadiene-styrene copolymer {GLO} market for Cut-off, U (debit)	1.125	Kg
Injection moulding {GLO} market for Cut-off, U (debit)	1.125	Kg
Production of secondary fence board (Recycling process I)	0.5	Kg
Aluminium, primary, liquid {GLO} market for Cut-off, U (debit)	0.5	Kg
Total Production of secondary fence board (Recycling process I):	11.75	Kg
Total debited primary production:	10.625	Kg
MATERIALS & PRODUCTION – SECONDARY FENCE BOARD – OPTION 2 (primary production of market fence debited, PVC panel, equal durability of fencing)		
Name	Amount	Unit
<i>Inputs</i>		
Production of secondary fence board (Recycling process I)	12.5	Kg
Polyvinylchloride, bulk polymerised {GLO} market for Cut-off, U (debit)	14	Kg
Thermoforming of plastic sheets {GLO} market for Cut-off, U (debit, processing)		
Total Production of secondary fence board (Recycling process I):	12.5	Kg
Total debited primary production:	14	Kg
MATERIALS & PRODUCTION – SECONDARY FENCE BOARD – OPTION 3 (primary production of market fence debited, materials mix, equal durability of fencing)		
Name	Amount	Unit
<i>Inputs</i>		

Production of secondary fence board (Recycling process I)	12.5	Kg
Steel, low-alloyed {GLO} market for Cut-off, U (debit)	41.04	Kg
Sheet rolling, steel {GLO} market for Cut-off, U (debit)		
Sawnwood, beam, softwood, dried (u=10%), planed {Europe without Switzerland} market for sawnwood, beam, softwood, dried (u=10%), planed Cut-off, U (debit)	0.0028	m3
Polyvinylchloride, bulk polymerised {GLO} market for Cut-off, U (debit)	1.49	Kg
Thermoforming of plastic sheets {GLO} market for Cut-off, U (debit)		
Concrete block {RoW} production Cut-off, U (debit)	1.76	Kg
Total Production of secondary fence board (Recycling process I):	12.5	Kg
Total debited primary production:	46.39	Kg
MATERIALS & PRODUCTION – SECONDARY FENCE BOARD – OPTION 4 (primary production of market fence debited, materials mix, different durability of fencing)		
Name	Amount	Unit
<i>Inputs</i>		
Production of secondary fence board (Recycling process I)	12.5	Kg
Steel, low-alloyed {GLO} market for Cut-off, U (debit)	5.77	Kg
Sheet rolling, steel {GLO} market for Cut-off, U (debit)		
Sawnwood, beam, softwood, dried (u=10%), planed {Europe without Switzerland} market for sawnwood, beam, softwood, dried (u=10%), planed Cut-off, U (debit)	0.000701	m3
Polyvinylchloride, bulk polymerised {GLO} market for Cut-off, U (debit)	1.49	Kg
Thermoforming of plastic sheets {GLO} market for Cut-off, U (debit)		
Concrete block {RoW} production Cut-off, U (debit)	0.25	Kg
Total Production of secondary fence board (Recycling process I):	12.5	Kg
Total debited primary production:	8.04	Kg

Source: own elaboration based in calculations SimaPro software

Table S6 Inventory results for life cycle stage *Materials – auxiliary materials*
- results per FU, 1 m² of fence board

MATERIALS - AUXILIARY MATERIALS (wooden fence posts, wood preservative, steel screws, and steel bolts)		
Ecoinvent dataset (https://ecoinvent.org/database/ (accessed on 12 February 24))	Amount	Unit
<i>Inputs</i>		
Sawnwood, beam, softwood, dried (u=10%), planed {Europe without Switzerland} market for sawnwood, beam, softwood, dried (u=10%), planed Cut-off, U	0.004762	m3
Wood preservative, creosote {RER} market for wood preservative, creosote Cut-off, U	0.037278	kg
Steel, chromium steel 18/8 {GLO} market for Cut-off, U	0.42	kg

Source: own elaboration based in calculations SimaPro software

Table S7 Inventory results for life cycle stage *Transport to the installation place*
- results per FU, 1 m² of fence board

TRANSPORT TO THE INSTALLATION PLACE		
Ecoinvent dataset (https://ecoinvent.org/database/ (accessed on 12 February 24))	Amount	Unit
<i>Inputs</i>		
Transport, freight, lorry 3.5-7.5 metric ton, euro6 {RER} market for transport, freight, lorry 3.5-7.5 metric ton, EURO6 Cut-off, U	8125.5 (Load: 70 kg board + 11.25 kg auxiliary materials Distance: 100 km)	Kgkm

Source: own elaboration based in calculations SimaPro software

Table S8 Inventory results for life cycle stage *Installation and maintenance* (15 years of lifetime) - results per FU, 1 m² of fence board

INSTALATION AND MAINTENANCE (drilling and screwing, maintenance of wooden posts, cleaning)		
Ecoinvent dataset (https://ecoinvent.org/database/ (accessed on 12 February 24))	Amount	Unit
<i>Inputs</i>		
Wood preservative, creosote {RER} market for wood preservative, creosote Cut-off, U	0.104	Kg
Tap water {Europe without Switzerland} market for Cut-off, U	56	Kg
Electricity, low voltage {PL} market for Cut-off, U	0.058	kWh
Wastewater, unpolluted {RoW} market for wastewater, unpolluted Cut-off, U	56	L

Source: own elaboration based in calculations SimaPro software

Table S9 Inventory results for life cycle stage *End of life - auxiliary materials*
- results per FU, 1 m² of fence board

(based on calculations with the CFF formula, $R_{2_wood} = 0.38$, $A_{_wood} = 0.8$, $R_{2_steel} = 0.85$, $A_{_steel} = 0.2$, the fraction of the waste not sent for recycling is to be disposed of as follows: 99% landfilled and 1% incinerated)

END OF LIFE - AUXILIARY MATERIALS		
Ecoinvent dataset (https://ecoinvent.org/database/ (accessed on 12 February 24))	Amount	Unit
<i>Inputs</i>		
Transport, freight, lorry 7.5-16 metric ton, euro6 {RER} market for transport, freight, lorry 7.5-16 metric ton, EURO6 Cut-off, U	402 (Load: 4.2 kg Distance: 100 km)	kgkm
Sawnwood, beam, softwood, dried (u=10%), planed {Europe without Switzerland} market for sawnwood, beam, softwood, dried (u=10%), planed Cut-off, U (credit)	-0.00036	m3
Steel, chromium steel 18/8 {GLO} market for Cut-off, U (credit)	-0.286	kg
<i>Outputs</i>		
Waste bulk iron, excluding reinforcement {Europe without Switzerland} treatment of waste bulk iron, excluding reinforcement, sorting plant Cut-off, U	0.286	kg

Waste brick {Europe without Switzerland} treatment of waste brick, sorting plant Cut-off, U (used as proxy)	0.274	kg
Waste wood, untreated {RoW} treatment of, sanitary landfill Cut-off, U	2.21	kg
Waste building wood, chrome preserved {RoW} treatment of, municipal incineration Cut-off, U	0.022	kg
Inert waste {Europe without Switzerland} treatment of inert waste, sanitary landfill Cut-off, U	0.062	kg
Scrap steel {Europe without Switzerland} treatment of scrap steel, municipal incineration Cut-off, U	0.001	kg

Source: own elaboration based in calculations SimaPro software

Table S10 Inventory results for life cycle stage *End of life – secondary fence board*
- results per FU, 1 m² of fence board

(based on calculations with the CFF formula, $R_{2_fence_board} = 0.499$, $A_{fence_board} = 0.5$

the fraction of the waste not sent for recycling is to be disposed of as follows: 99% landfilled and 1% incinerated)

END OF LIFE – SECONDARY FENCE BOARD – OPTION A (no recycling at the EoL)		
Ecoinvent dataset (https://ecoinvent.org/database/ (accessed on 12 February 24))	Amount	Unit
<i>Inputs</i>		
Transport, freight, lorry 7.5-16 metric ton, euro6 {RER} market for transport, freight, lorry 7.5-16 metric ton, EURO6 Cut-off, U	2502 (Load: 25.025 kg Distance: 100 km)	kgkm
<i>Outputs</i>		
Waste polyethylene {RoW} treatment of waste polyethylene, sanitary landfill Cut-off, U	7.45	kg
Waste polyethylene {RoW} treatment of waste polyethylene, municipal incineration Cut-off, U	0.05	kg
Waste polypropylene {RoW} treatment of waste polypropylene, sanitary landfill Cut-off, U	7.45	kg
Waste polypropylene {RoW} treatment of waste polypropylene, municipal incineration Cut-off, U	0.05	kg
Waste plastic, mixture {RoW} treatment of waste plastic, mixture, sanitary landfill Cut-off, U	2.483	kg
Waste plastic, mixture {RoW} treatment of waste plastic, mixture, municipal incineration Cut-off, U	0.017	kg
Waste plastic, mixture {RoW} treatment of waste plastic, mixture, sanitary landfill Cut-off, U	2.483	kg
Waste plastic, mixture {RoW} treatment of waste plastic, mixture, municipal incineration Cut-off, U	0.017	kg
Waste plastic, mixture {RoW} treatment of waste plastic, mixture, sanitary landfill Cut-off, U	2.483	kg
Waste plastic, mixture {RoW} treatment of waste plastic, mixture, municipal incineration Cut-off, U	0.017	kg
Waste aluminium {RoW} treatment of, sanitary landfill Cut-off, U	2.483	kg

Scrap aluminium {Europe without Switzerland} treatment of scrap aluminium, municipal incineration Cut-off, U	0.017	kg
Total Production of secondary garden pots (Recycling process II):	n.a.	
Total credited primary production:	n.a	
Total landfilling:	24.75	kg
Total incineration:	0.245	kg
END OF LIFE – SECONDARY FENCE BOARD – OPTION B (primary production of market HDPE pots credited)		
Inputs		
Transport, freight, lorry 7.5-16 metric ton, euro6 {RER} market for transport, freight, lorry 7.5-16 metric ton, EURO6 Cut-off, U	2502 (Load: 25.025 kg Distance: 100 km)	kgkm
Production of secondary garden pots (Recycling process II)	12.48	kg
Polyethylene, high density, granulate {GLO} market for Cut-off, U (credit)	-2.43	kg
Blow moulding {GLO} market for Cut-off, U (credit)		
Outputs		
Waste polyethylene {RoW} treatment of waste polyethylene, sanitary landfill Cut-off, U	3.7125	kg
Waste polyethylene {RoW} treatment of waste polyethylene, municipal incineration Cut-off, U	0.0375	kg
Waste polypropylene {RoW} treatment of waste polypropylene, sanitary landfill Cut-off, U	3.7125	kg
Waste polypropylene {RoW} treatment of waste polypropylene, municipal incineration Cut-off, U	0.0375	kg
Waste plastic, mixture {RoW} treatment of waste plastic, mixture, sanitary landfill Cut-off, U	1.2375	kg
Waste plastic, mixture {RoW} treatment of waste plastic, mixture, municipal incineration Cut-off, U	0.0125	kg
Waste plastic, mixture {RoW} treatment of waste plastic, mixture, sanitary landfill Cut-off, U	1.2375	kg
Waste plastic, mixture {RoW} treatment of waste plastic, mixture, municipal incineration Cut-off, U	0.0125	kg
Waste plastic, mixture {RoW} treatment of waste plastic, mixture, sanitary landfill Cut-off, U	1.2375	kg
Waste plastic, mixture {RoW} treatment of waste plastic, mixture, municipal incineration Cut-off, U	0.0125	kg
Waste aluminium {RoW} treatment of, sanitary landfill Cut-off, U	1.2375	kg
Scrap aluminium {Europe without Switzerland} treatment of scrap aluminium, municipal incineration Cut-off, U	0.0125	kg
Total Production of secondary garden pots (Recycling process II):	12.48	kg
Total credited primary production:	-2.43	kg
Total landfilling:	12.375	kg
Total incineration:	0.125	kg

END OF LIFE – SECONDARY FENCE BOARD – OPTION C (primary production of market pots credited, materials mix, equal durability of pots)		
<i>Inputs</i>		
Transport, freight, lorry 7.5-16 metric ton, euro6 {RER} market for transport, freight, lorry 7.5-16 metric ton, EURO6 Cut-off, U	2502 (Load: 25.025 kg Distance: 100 km)	kgkm
Production of secondary garden pots (Recycling process II)	12.48	kg
Ceramic tile {GLO} market for Cut-off, U (credit)	-1.18	kg
Concrete roof tile {GLO} market for Cut-off, U (credit)	-1.18	kg
Polyethylene, high density, granulate {GLO} market for Cut-off, U (credit)	-0.74	kg
Blow moulding {GLO} market for Cut-off, U (credit)	-2.58	kg
Steel, low-alloyed {GLO} market for Cut-off, U (credit)		
Hot rolling, steel {GLO} market for Cut-off, U (credit)		
Sawnwood, beam, softwood, dried (u=10%), planed {Europe without Switzerland} market for sawnwood, beam, softwood, dried (u=10%), planed Cut-off, U (credit)	-0.0002	m3
<i>Outputs</i>		
Waste polyethylene {RoW} treatment of waste polyethylene, sanitary landfill Cut-off, U	3.7125	kg
Waste polyethylene {RoW} treatment of waste polyethylene, municipal incineration Cut-off, U	0.0375	kg
Waste polypropylene {RoW} treatment of waste polypropylene, sanitary landfill Cut-off, U	3.7125	kg
Waste polypropylene {RoW} treatment of waste polypropylene, municipal incineration Cut-off, U	0.0375	kg
Waste plastic, mixture {RoW} treatment of waste plastic, mixture, sanitary landfill Cut-off, U	1.2375	kg
Waste plastic, mixture {RoW} treatment of waste plastic, mixture, municipal incineration Cut-off, U	0.0125	kg
Waste plastic, mixture {RoW} treatment of waste plastic, mixture, sanitary landfill Cut-off, U	1.2375	kg
Waste plastic, mixture {RoW} treatment of waste plastic, mixture, municipal incineration Cut-off, U	0.0125	kg
Waste plastic, mixture {RoW} treatment of waste plastic, mixture, sanitary landfill Cut-off, U	1.2375	kg
Waste plastic, mixture {RoW} treatment of waste plastic, mixture, municipal incineration Cut-off, U	0.0125	kg
Waste aluminium {RoW} treatment of, sanitary landfill Cut-off, U	1.2375	kg
Scrap aluminium {Europe without Switzerland} treatment of scrap aluminium, municipal incineration Cut-off, U	0.0125	kg
Total Production of secondary garden pots (Recycling process II):	12.48	kg
Total credited primary production:	-5.84	kg
Total landfilling:	12.375	kg
Total incineration:	0.125	kg

END OF LIFE – SECONDARY FENCE BOARD – OPTION D (primary production of market pots credited, materials mix, different durability of pots)		
<i>Inputs</i>		
Transport, freight, lorry 7.5-16 metric ton, euro6 {RER} market for transport, freight, lorry 7.5-16 metric ton, EURO6 Cut-off, U	2502 (Load: 25.025 kg Distance: 100 km)	kgkm
Production of secondary garden pots (Recycling process II)	12.48	kg
Ceramic tile {GLO} market for Cut-off, U (credit)	-0.59	kg
Concrete roof tile {GLO} market for Cut-off, U (credit)	-0.59	kg
Polyethylene, high density, granulate {GLO} market for Cut-off, U (credit)	-0.74	kg
Blow moulding {GLO} market for Cut-off, U (credit)	-1.29	kg
Steel, low-alloyed {GLO} market for Cut-off, U (credit)		
Hot rolling, steel {GLO} market for Cut-off, U (credit)		
Sawnwood, beam, softwood, dried (u=10%), planed {Europe without Switzerland} market for sawnwood, beam, softwood, dried (u=10%), planed Cut-off, U (credit)	-0.000013	m3
<i>Outputs</i>		
Waste polyethylene {RoW} treatment of waste polyethylene, sanitary landfill Cut-off, U	3.7125	kg
Waste polyethylene {RoW} treatment of waste polyethylene, municipal incineration Cut-off, U	0.0375	kg
Waste polypropylene {RoW} treatment of waste polypropylene, sanitary landfill Cut-off, U	3.7125	kg
Waste polypropylene {RoW} treatment of waste polypropylene, municipal incineration Cut-off, U	0.0375	kg
Waste plastic, mixture {RoW} treatment of waste plastic, mixture, sanitary landfill Cut-off, U	1.2375	kg
Waste plastic, mixture {RoW} treatment of waste plastic, mixture, municipal incineration Cut-off, U	0.0125	kg
Waste plastic, mixture {RoW} treatment of waste plastic, mixture, sanitary landfill Cut-off, U	1.2375	kg
Waste plastic, mixture {RoW} treatment of waste plastic, mixture, municipal incineration Cut-off, U	0.0125	kg
Waste plastic, mixture {RoW} treatment of waste plastic, mixture, sanitary landfill Cut-off, U	1.2375	kg
Waste plastic, mixture {RoW} treatment of waste plastic, mixture, municipal incineration Cut-off, U	0.0125	kg
Waste aluminium {RoW} treatment of, sanitary landfill Cut-off, U	1.2375	kg
Scrap aluminium {Europe without Switzerland} treatment of scrap aluminium, municipal incineration Cut-off, U	0.0125	kg
Total Production of secondary garden pots (Recycling process II):	12.48	kg
Total credited primary production:	-3.31	kg
Total landfilling:	12.375	kg
Total incineration:	0.125	kg

Source: own elaboration based in calculations SimaPro software

Table S11 The environmental impact (single score) and results of identification of the most relevant impact categories and life cycle stages – scenarios 4C (the best), 4B, 4D, 4A, 2C, 2B, 2D and 1C

SCENARIOS	4C (the best)		4B		4D		4A		2C		2B		2D		1C	
	Life cycle of secondary fence board (scenario 4C)		Life cycle of secondary fence board (scenario 4B)		Life cycle of secondary fence board (scenario 4D)		Life cycle of secondary fence board (scenario 4A)		Life cycle of secondary fence board (scenario 2C)		Life cycle of secondary fence board (scenario 2B)		Life cycle of secondary fence board (scenario 2D)		Life cycle of secondary fence board (scenario 1C)	
	The total environmental impact (single score)															
Single score [mPt]	4.58		5.18		5.19		5.71		7.29		7.89		7.90		7.93	
	The most-relevant impact categories															
	ranking	share	ranking	share	ranking	share	ranking	share	ranking	share	ranking	share	ranking	share	ranking	share
Climate change	1	27.9%	1	25.1%	1	26.4%	1	23.3%	1	27.0%	1	25.2%	1	26.1%	1	30.7%
Resource use, fossils	4	14.6%	4	11.0%	3	13.9%	3	13.0%	2	20.4%	2	17.5%	2	19.4%	2	23.2%
Ecotoxicity, freshwater	2	15.8%	2	15.1%	2	14.9%	2	19.5%	3	12.1%	3	11.9%	3	11.7%	3	10.8%
Eutrophication, freshwater	3	15.1%	3	13.7%	4	13.8%	4	12.3%	4	10.9%	4	10.3%	4	10.4%	4	9.9%
Particulate matter			6	6.8%							6	6.2%				
Acidification	5	6.8%	7	6.1%	7	6.4%	6	5.6%	6	6.3%			6	6.0%	5	7.1%
Resource use, minerals and metals			5	7.1%	5	6.5%	5	6.8%	5	9.2%	5	9.7%	5	9.3%		
	The most-relevant life cycle stages															
Climate change	Materials & production - secondary board		Materials & production - secondary board		Materials & production - secondary board		Materials & production - secondary board		Materials & production - secondary board		Materials & production - secondary board		Materials & production - secondary board		Materials & production - secondary board	
Resource use, fossils	Materials & production - secondary board		Materials & production - secondary board End of life - secondary board		Materials & production - secondary board		Materials & production - secondary board		Materials & production - secondary board		Materials & production - secondary board		Materials & production - secondary board		Materials & production - secondary board	

Ecotoxicity, freshwater	Materials & production - secondary board End of life - secondary board	Materials & production - secondary board End of life - secondary board	Materials & production - secondary board End of life - secondary board	End of life - secondary board. Materials & production - secondary board.	Materials & production - secondary board End of life - secondary board	Materials & production - secondary board End of life - secondary board	Materials & production - secondary board End of life - secondary board	Materials & production - secondary board End of life - secondary board
Eutrophication, freshwater	Materials & production - secondary board	Materials & production - secondary board	Materials & production - secondary board	Materials & production - secondary board	Materials & production - secondary board	Materials & production - secondary board	Materials & production - secondary board	Materials & production - secondary board
Particulate matter	Materials & production - secondary board	Materials & production - secondary board End of life - secondary board				Materials & production - secondary board End of life - secondary board		.
Acidification	Materials & production - secondary board	Materials & production - secondary board	Materials & production - secondary board	Materials & production - secondary board	Materials & production - secondary board		Materials & production - secondary board	Materials & production - secondary board
Resource use, minerals and metals		Materials & production - secondary board Materials & production - auxiliary materials	Materials & production - secondary board Materials & production - auxiliary materials	Materials & production - secondary board	Materials & production - secondary board End of life - secondary board	Materials & production - secondary board	Materials & production - secondary board	.

Source: own elaboration based on calculations in SimaPro software

Table S12 The environmental impact (single score) and results of identification of the most relevant impact categories and life cycle stages – scenarios 2A, 1B, 1D, 1A (baseline), 3C, 3B, 3D and 3A (the worst)

SCENARIOS	2A		1B		1D		1A (baseline)		3C		3B		3D		3A (the worst)	
	Life cycle of secondary fence board (scenario 2A)		Life cycle of secondary fence board (scenario 1B)		Life cycle of secondary fence board (scenario 1D)		Life cycle of secondary fence board (scenario 1A)		Life cycle of secondary fence board (scenario 3C)		Life cycle of secondary fence board (scenario 3B)		Life cycle of secondary fence board (scenario 3D)		Life cycle of secondary fence board (scenario 3A)	
	The total environmental impact (single score)															
Single score [mPt]	8.42		8.52		8.53		9.05		14.36		14.96		15.0		15.48	
	The most-relevant impact categories															
	ranking	share	ranking	share	ranking	share	ranking	share	ranking	share	ranking	share	ranking	share	ranking	share
Climate change	1	24.0%	1	28.8%	1	29.6%	1	27.4%	1	24.1%	1	23.3%	1	23.8%	1	22.7%
Resource use, fossils	2	18.5%	2	20.4%	2	22.2%	2	21.1%	3	12.7%	3	11.5%	3	12.5%	3	12.2%
Ecotoxicity, freshwater	3	15.1%	3	10.8%	3	10.6%	3	13.8%	2	13.2%	2	13.0%	2	12.9%	2	14.7%
Eutrophication, freshwater	4	9.5%	4	9.5%	4	9.5%	4	8.8%	5	9.5%	6	9.2%	5	9.3%	5	8.8%
Particulate matter	7		5	7.5%	6	5.3%	5	6.6%	6	6.7%	5	9.2%	6	8.0%	6	8.7%
Acidification	6	5.5%	6	6.6%	5	6.8%	6	6.3%								
Resource use, minerals and metals	5	9.3%							4	9.6%	4	9.9%	4	9.7%	4	9.7%
Human toxicity, cancer									7	6.3%	7	6.4%	7	6.2%	7	6.2%

	The most-relevant life cycle stages							
Climate change	Materials & production - secondary board	Materials & production - secondary board	Materials & production - secondary board	Materials & production - secondary board	Materials & production - secondary board	Materials & production - secondary board	Materials & production - secondary board	Materials & production - secondary board
Resource use, fossils	Materials & production - secondary board	Materials & production - secondary board	Materials & production - secondary board	Materials & production - secondary board	Materials & production - secondary board	Materials & production - secondary board	Materials & production - secondary board	Materials & production - secondary board
Ecotoxicity, freshwater	End of life - secondary board Materials & production - secondary board	Materials & production - secondary board End of life - secondary board	Materials & production - secondary board End of life - secondary board	End of life - secondary board Materials & production - secondary board	Materials & production - secondary board End of life - secondary board	Materials & production - secondary board End of life - secondary board	Materials & production - secondary board End of life - secondary board	Materials & production - secondary board End of life - secondary board
Eutrophication, freshwater	Materials & production - secondary board	Materials & production - secondary board	Materials & production - secondary board	Materials & production - secondary board	Materials & production - secondary board	Materials & production - secondary board	Materials & production - secondary board	Materials & production - secondary board
Particulate matter	Materials & production - secondary board	Materials & production - secondary board End of life - secondary board	Materials & production - secondary board End of life - secondary board	Materials & production - secondary board	Materials & production - secondary board End of life - secondary board	Materials & production - secondary board	Materials & production - secondary board	Materials & production - secondary board
Acidification		Materials & production - secondary board	Materials & production - secondary board	Materials & production - secondary board				
Resource use, minerals, and metals	Materials & production - secondary board				Materials & production - secondary board	Materials & production - secondary board	Materials & production - secondary board	Materials & production - secondary board

Human toxicity, cancer					Materials & production - secondary board	Materials & production - secondary board	Materials & production - secondary board	Materials & production - secondary board
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Source: own elaboration based in calculations SimaPro software