Is prolonging the lifetime of passive durable products a low hanging fruit of a circular economy? A multiple case study

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Supplementary Information

This document contains the detailed lifecycle inventory data used in the LCA, and the assumptions done in the sensitivity analysis. The data used for the LCC is deemed confidential by the companies, and thus cannot be shared. The document also includes the datasets used to model different materials/processes. The last section contains the results for the life cycle impact assessment.

The repair/refurbish phase was mainly cleaning with water, production of spare parts (which the inventory data of is already mentioned in the BOM), and collection and redistribution distances (also similar to distribution distances). Thus, this phase is not repeated again here.

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1 Bill of material and inbound transportation

Tables S1-5 include an overview of the bill of material of the five products, represented per functional unit. They also show the datasets used in modelling the materials.

Table S1 Overview of materials used and upstream logistics for the beach flag.

Beach flag						
Component	**Material**	**weight (kg)**	**Dataset used**	**Transport distance (km)**	**Transport mode**	**Dataset used**
Pole	Fiber glass	1.5	glass fibre production | glass fibre | APOS, S – RoW (ecoinvent)	23000	Ship	transport, freight, sea, transoceanic ship | transport, freight, sea, transoceanic ship | APOS, S – GLO (ecoinvent)
Textile	Polyester	0.125	(Roos et al., 2015)			
Bag for pole		0.5				
Cross base	Steel	4	steel production, converter, chromium steel 18/8 | steel, chromium steel 18/8 | APOS, S – RoW (ecoinvent)			

Table S2 Overview of materials used and upstream logistics for the event tent.

Event tent						
Component	**Material**	**weight (kg)**	**Dataset used**	**Transport distance (km)**	**Transport mode**	**Dataset used**
Frame	Aluminum	29	market for aluminium, cast alloy | aluminium, cast alloy | APOS, S – GLO (ecoinvent)	23000	Ship	transport, freight, sea, transoceanic ship | transport, freight, sea, transoceanic ship | APOS, S – GLO (ecoinvent)
Frame weights	Steel	60	steel production, converter, chromium steel 18/8 | steel, chromium steel 18/8 | APOS, S – RoW (ecoinvent)			
Textile	Polyester	15	(Roos et al., 2015)			

Table S3 Overview of materials used and upstream logistics for the recycling bin

Recycling bin						
Component	**Material**	**weight (kg)**	**Dataset used**	**Transport distance (km)**	**Transport mode**	**Dataset used**
body	Steel	37.12	steel production, converter, chromium steel 18/8 | steel, chromium steel 18/8 | APOS, S – RER (ecoinvent)	405	train	transport, freight train, electricity | transport, freight train | APOS, S - Europe without Switzerland (ecoinvent)
		9.28	steel production, low-alloyed, hot rolled | steel, low-alloyed, hot rolled | APOS, S – RER (ecoinvent)			
Body coating	Powder coating	0.8	coating powder production | coating powder | APOS, S – RER (ecoinvent)	100	LCV[2]	Transport, freight, light commercial vehicle | transport, freight, light commercial vehicle | APOS, S - Europe without Switzerland (ecoinvent)
Lid	MDF[3]	4.4	medium density fibre board production, uncoated | medium density fibreboard | APOS, S – RER (ecoinvent)	1000	lorry	transport, freight, lorry 16-32 metric ton, EURO5 | transport, freight, lorry 16-32 metric ton, EURO5 | APOS, S – RER (ecoinvent)
Lid coating	foil	0.4	(Gislaved-Folie-AB, 2018)	100	LCV	Transport, freight, light commercial vehicle | transport, freight, light commercial vehicle | APOS, S - Europe without Switzerland (ecoinvent)

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[2] Light commercial vehicle
[3] Medium Density Fiberboard, with a density of 770 kg/m^3, imported from Romania

Table S4 Overview of materials used and upstream logistics for the storage locker

Storage locker						
Component	**Material**	**weight (kg)**	**Dataset used**	**Transport distance (km)**	**Transport mode**	**Dataset used**
Body[4]	Particle board	169.2	particle board production, for indoor use | particle board, for indoor use | APOS, S – RER (ecoinvent)	559	lorry	transport, freight, lorry 16-32 metric ton, EURO5 | transport, freight, lorry 16-32 metric ton, EURO5 | APOS, S – RER (ecoinvent)
Body cover	Veneer	8.9	market for sawlog and veneer log, hardwood, measured as solid wood under bark | sawlog and veneer log, hardwood, measured as solid wood under bark | APOS, S - Europe without Switzerland (ecoinvent)			
Door paint	paint	10.8	alkyd paint production, white, water-based, product in 60% solution state | alkyd paint, white, without water, in 60% solution state | APOS, S – RER (ecoinvent)	100		
Glue	Glue	0.34	epoxy resin production, liquid | epoxy resin, liquid | APOS, S – RER (ecoinvent)	100	LCV	Transport, freight, light commercial vehicle | transport, freight, light commercial vehicle | APOS, S - Europe without Switzerland (ecoinvent)
Lockers and hinges	steel	10	steel production, converter, chromium steel 18/8 | steel, chromium steel 18/8 | APOS, S – RER (ecoinvent)			

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[4] The particle board has a density 746 kg/m³, imported from Latvia. It is assumed that it is covered with a 1 mm layer of veneer

Table S5 Overview of materials used and upstream logistics for the waste inlet. For the circular offering, the weight is represented between parenthesis for the door.

Waste inlet						
Component	Material	weight (kg)	Dataset used	Transport distance (km)	Transport mode	Dataset used
Inlet (upper and lower part)	Steel	679.85	steel production, low-alloyed, hot rolled	steel, low-alloyed, hot rolled	APOS, S – RER (ecoinvent)	500	train	transport, freight train, electricity	transport, freight train	APOS, S - Europe without Switzerland (ecoinvent)
	Zinc coating	7.88	zinc coating, pieces	zinc coat, pieces	APOS, S - RER (ecoinvent)			
	powder coating	1.66	coating powder production	coating powder	APOS, S – RER (ecoinvent)			
	EPDM[5]	3.38	synthetic rubber production	synthetic rubber	APOS, S – RER (ecoinvent)			
Door		0.11 (0)				
	Steel	0.1 (0.58)	steel production, converter, chromium steel 18/8	steel, chromium steel 18/8	APOS, S – RER (ecoinvent)			
	PEHD[6]	0 (0.01)	Polyethylene high density granulate (PE-HD), production mix, at plant – RER (ecoinvent)			
	Aluminum	2.58 (2.64)	market for aluminium, cast alloy	aluminium, cast alloy	APOS, S – GLO (ecoinvent)			
Door handle		0 (0.34)				

[5] Ethylene Propylene Diene Monomer rubber
[6] Polyethylene, High Density

2 Manufacturing data

Table S6 includes the processes used for the manufacturing of the five products. All datasets used are from the ecoinvent 3.3 database.

Table S6 Overview of the manufacturing processes of the five products

Product	Process	Amount	Dataset used
Beach flag	Electricity	50 MJ	market group for electricity, low voltage | electricity, low voltage | APOS, S - CN
Event tent		50 MJ	
Recycling bin		288 MJ	market for electricity, low voltage | electricity, low voltage | APOS, S - SE
Storage locker		57.6 MJ	
Waste inlet	Aluminum drilling	0.03 kg	aluminium drilling, conventional | aluminium removed by drilling, conventional | APOS, U[7]
	Steel drilling	7 kg	steel drilling, conventional | steel removed by drilling, conventional | APOS, U[8]

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[7] This process was edited by removing "aluminium, cast alloy" and "aluminium, wrought alloy" flows from the input, since it is already accounted for in the input, and to avoid double counting.

[8] This process was edited by removing "steel, low-alloyed, hot rolled" flow from the input, since it is already accounted for in the input, and to avoid double counting.

3   Distribution

The distribution of the different products is summarized in table S7. All datasets used are from the ecoinvent 3.3 database.

Table S7 Overview of the distribution modes and distances for different products

Product	Transport distance (km)	Transport mode	Dataset used
Beach flag	200	Light commercial vehicle	Transport, freight, light commercial vehicle | transport, freight, light commercial vehicle | APOS, S - Europe without Switzerland
Event tent	200	Light commercial vehicle	Transport, freight, light commercial vehicle | transport, freight, light commercial vehicle | APOS, S - Europe without Switzerland
Recycling bin	356	lorry	transport, freight, lorry 7.5-16 metric ton, EURO6 | transport, freight, lorry 7.5-16 metric ton, EURO6 | APOS, S - RER
Storage locker	356	lorry	transport, freight, lorry 7.5-16 metric ton, EURO6 | transport, freight, lorry 7.5-16 metric ton, EURO6 | APOS, S - RER
Waste Inlet	62	lorry	transport, freight, lorry 3.5-7.5 metric ton, EURO6 | transport, freight, lorry 3.5-7.5 metric ton, EURO6 | APOS, S - RER

4 End of life

Since the cut-off method was used for the end-of-life, the recycling of the metals at the final use is not modelled. Non-metal parts (textile, fiberglass, and wood) is sent into incineration with energy recovery. The burden of incineration was modelled, without giving credit to the energy recovery. All the EOL transports are assumed to be carried by a lorry ("transport, freight, lorry 3.5-7.5 metric ton, EURO6 | transport, freight, lorry 3.5-7.5 metric ton, EURO6 | APOS, S – RER" was used from ecoinvent) for a distance of 100 km. Table S8 shows the datasets used for different incineration processes, some are adjusted to include only the burden without the credit.

Table S8 Overview of the incineration processes used at the end-of-life

Process	Dataset used	DataBase
Textile incineration burden	Waste incineration of textile fraction in municipal solid waste (MSW), at plant, average European waste-to-energy plant, without collection, transport and pre-treatment - EU-27[9]	ELCD (ELCD, 2012)
Wood incineration burden	heat and power co-generation, wood chips, 6667 kW, state-of-the-art 2014	heat, district or industrial, other than natural gas	APOS, U - SE[10]	Ecoinvent 3.3
Fiberglass incineration burden	treatment of waste glass, municipal incineration	waste glass	APOS, U - Europe without Switzerland	Ecoinvent 3.3

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[9] This process was edited by removing the "process steam from waste incineration" and the "electricity from waste incineration" flows from the output, to exclude the credits of incineration.

[10] This process was edited by removing the "heat, district or industrial, other than natural gas" flow from the output, to exclude the credits of incineration.

5   Life Cycle Impact Assessment Results

Table S9 summarizes the results of the LCIA for both the BAU offering and the circular offerings (between parenthesis).

Table S9 Overview of the LCIA results for the various products

Impact Category	Beach flag	Event tent	Recycle bin	storage locker	Waste inlet
Acidification potential (kg SO_2 eq/functional unit)	0.27 (0.07)	5.65 (2.89)	1.38 (0.73)	2.03 (1.32)	11.49 (11.23)
Global warming potential (kg CO_2 eq/functional unit)	41.59 (11.51)	869.32 (477.86)	234.9 (124.02)	189.95 (118.34)	2786.61 (2748.36)
Eutrophication potential (kg SO_4^{3-} eq functional unit)	0.06 (0.02)	1.39 (0.6)	0.4 (0.21)	0.57 (0.35)	5.73 (5.64)
Ozone depletion potential (kg CFFC-11 eq functional unit)	2.3E-5 (6.9E-6)	5.7E-4 (5.2E-4)	1.8E-5 (1E-5)	4.6E-5 (2.6E-5)	3E-4 (2.9E-4)
Iron, 46% in ore (kg/functional unit)	4.74 (0.56)	74.76 (10.19)	48.02 (24.16)	5.15 (2.8)	-
Aluminum, 25% in Bauxite (kg/functional unit)	-	-	-	-	2.53E-3 (2.47E-3)
Intensive forest occupation (m^2.year/functional unit)	-	-	8.73 (13.1)	339.38 (169.69)	-

Table S10 shows the GWP results of the sensitivity analysis for company A, where the number of reuses was changed.

Table S10 GWP results (in kg CO_2 eq/functional unit) of the sensitivity analysis for company A

	Number of uses									
	1	2	3	4	5	6	7	8	9	10
Beach flag	41.59	23.82	18.07	15.33	13.79	12.85	12.26	11.88	11.64	11.51
Event tent	869.32	633.89	558.41	522.91	503.4	491.9	484.96	480.88	478.8	477.86

Table S11 shows the GWP results of the sensitivity analysis for company B, where the number of reuses was changed.

Table S11 GWP results (in kg CO_2 eq/functional unit) of the sensitivity analysis for company B

	Number of repairs/lifetime						
	1	2	3	4	5	34	35
Recycling bin	121.02	124.02	127.85	131.26	134.68	233.68	237.1
Storage locker	118.34	141.73	165.12	188.5	211.89	-	-

Table S12 shows the GWP results of the sensitivity analysis for company C, where the number of door damages was changed.

Table S12 GWP results (in kg CO_2 eq/functional unit) of the sensitivity analysis for company C

	Number of door changes					
	0	1	2	3	4	5
BAU	2738.72	2754.68	2770.65	2786.61	2802.57	2818.53
Circular	2742.33	2744.34	2746.35	2748.36	2750.36	2752.37

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