

Assessing the end of life options of biobased and fossil-based polyethylene terephthalate (PET) and high density polyethylene (HDPE) through anticipatory consequential life cycle assessment

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Table S1 Transport distances and selected ecoinvent processes. Countries are indicated for the supply chain of virgin biobased plastics HDPE and PET. Locations for the end of life options are generic and typical European distances were estimated.

Transport leg ^a	Distance (km)	Simapro
Consumer house – Retailer ¹	5	Transport, passenger car, EURO 5 {RER} market for Cut-off, S
Retailer – Consumer House ¹	5	Transport, passenger car, EURO 5 {RER} market for Cut-off, S
Consumer house - Collection plant	40	Transport, truck <10t, EURO5, 80%LF, empty return/GLO Economic
Collection plant - Reprocessing plant	100	Transport, truck >20t, EURO5, 80%LF, empty return/GLO Economic
Reprocessing plant - Shampoo plant	500	Transport, truck >20t, EURO5, 80%LF, empty return/GLO Economic
Shampoo plant – Retailer	500	Transport, truck >20t, EURO5, 80%LF, empty return/GLO Economic
Collection plant – Incineration plant	100	Transport, truck >20t, EURO5, 80%LF, empty return/GLO Economic
Bottle plant (NL) – Shampoo plant	426	Transport, truck >20t, EURO5, 80%LF, empty return/GLO Economic
Sugar field – Sugar Mill (Average, BR)	157	Transport, truck >20t, EURO3, 80%LF, empty return/GLO Economic
Sugar Mill – polyethylene plant (both BR)	1429	Transport, truck >20t, EURO3, 80%LF, empty return/GLO Economic
Polyethylene plant – Harbour (Both BR)	359	Transport, truck >20t, EURO3, 80%LF, empty return/GLO Economic
Harbour (BR) – Bottle plant (NL)	12308	Transport, freight, sea, container ship {GLO} transport, freight, sea, container ship Cut-off, S
Sugar Mill – Harbour (Both BR)	1545	Transport, truck >20t, EURO3, 80%LF, empty return/GLO Economic
Harbour (BR) – Harbour (IN)	7895	Transport, freight, sea, container ship {GLO} transport, freight, sea, container ship Cut-off, S
Harbour – BioMEG plant (Both IN)	20	Transport, truck >20t, EURO3, 80%LF, empty return/GLO Economic
Harbour (IN) – Bottle Plant (NL)	4547	Transport, freight, sea, container ship {GLO} transport, freight, sea, container ship Cut-off, S

¹ For this process it was assumed that each bottle of shampoo would be have around 300ml content for a total weight of 340 g and that each shopping load will have a weight of around 10 kg.

Table S1 Values and ranges for the uncertainty analysis for energy requirements during production and recycling. Unless units are reported, efficiencies are unitless and transport distances are in km.

Process	Amount	Source	Variation range			
			MIN	Source	MAX	Source
Energy required for ethanol to ethylene conversion	1.855 MJ kg ⁻¹ of ethanol	Assumption based on temperature requirements [1]	1.23 MJ kg ⁻¹	Assumptions based on expert opinion	2.45 MJ kg ⁻¹	Assumptions based on expert opinion
Energy required for pyrolysis HDPE	2.67 MJ kg ⁻¹ of HDPE	Assumption based on temperature requirements from IP [2]	1.782 MJ kg ⁻¹	Assumptions based on expert opinion	3.56 MJ kg ⁻¹	Assumptions based on expert opinion
Energy required for glycolysis PET	906 KJ kg ⁻¹ of PET	Assumption based on the temperature requirements from Donaj et al. (2012)	604 KJ kg ⁻¹	Assumptions based on expert opinion	1207 KJ kg ⁻¹	Assumptions based on expert opinion

Table S3 Values and ranges for the uncertainty analysis for efficiencies and transport distances. Efficiencies are unitless and transport distances are in km.

Process	Amount	Source	Variation range			
			MIN	Source	MAX	Source
PET Collection Efficiency	0.77	[4]	0.28	[5]	0.77	[4]
PET Sorting Efficiency	0.31	[4]	0.31	[4]	0.37	[5]
PET mechanical Efficiency	0.86	[4]	0.47	[5]	0.86	[4]
PET chemical efficiency	0.87	[6,7]	0.78	-10%	0.96	+10%
HDPE Collection Efficiency	0.72	[4]	0.41	[5]	0.72	[4]
HDPE Sorting Efficiency	0.40	[4]	0.40	[4]	0.72	[5]
HDPE mechanical Efficiency	0.95	[4]	0.87	[5]	0.95	[4]
HDPE chemical efficiency	0.21	[3,6,8]	0.19	-10%	0.23	+10%
Reuse Efficiency	0.99	Assumption	0.9	Assumption	0.99	Assumption
Inclusion fraction recycled HDPE	0.16	[9]	0.14	-10%	0.18	+10%
Inclusion fraction PET	0.24	[9]	0.22	-10%	0.27	+10%
Bottle plant - Shampoo plant	426	Assumption	383	-10%	469	+10%
Shampoo plant - Retailer	500	Assumption	450	-10%	550	+10%
Retailer - Consumer house	5	Assumption	4.5	-10%	5.5	+10%
Consumer House - Retailer	5	Assumption	4.5	-10%	5.5	+10%
Collection plant - Reprocessing plant	100	Assumption	90	-10%	110	+10%
Reprocessing plant - Shampoo plant	500	Assumption	450	-10%	550	+10%
Collection plant - Incineration plant	100	Assumption	90	-10%	110	+10%
Consumer house- collection plant	40	Assumption	36	-10%	44	+10%

Table S4 Results of the uncertainty analysis. SD: Standard Deviation, CV: Coefficient of Variation, pct: percentile, SEM: Standard Error of the Mean, IC: Improvement Change. IC is the percentage change from the mean to 2.5 percentile. Results for Climate Change and Fossil Resource scarcity shown with 4 decimals to show at least 2 digits. Negative values indicate that the scenario causes a net reduction of the environmental impacts assessed. Scenario naming according to R=Reuse, M=mechanical recycling, C=chemical recycling, B=biobased virgin plastic, F=fossil virgin plastic, H=HDPE and P=PET

Scenario	Mean	Median	SD	CV	2.5 percentile	97.5 percentile	SEM	IF
Climate Change (kg CO₂ eq)								
R-B-H	-0.1160	-0.1159	0.0040	-3.4%	-0.1240	-0.1087	3.98E-05	-7%
R-F-H	-0.1144	-0.1144	0.0034	-2.9%	-0.1200	-0.1088	3.37E-05	-5%
M-B-H	-0.0038	-0.0038	0.0011	-29.6%	-0.0060	-0.0016	1.13E-05	-58%
M-F-H	-0.0045	-0.0045	0.0010	-22.0%	-0.0063	-0.0025	9.86E-06	-41%
C-B-H	-0.0098	-0.0098	0.0021	-21.7%	-0.0141	-0.0059	2.13E-05	-44%
C-F-H	-0.0105	-0.0104	0.0020	-19.3%	-0.0144	-0.0066	2.02E-05	-38%
R-B-P	-0.1479	-0.1478	0.0044	-3.0%	-0.1555	-0.1406	4.38E-05	-5%
R-F-P	-0.1492	-0.1491	0.0043	-2.9%	-0.1563	-0.1421	4.29E-05	-5%
M-B-P	-0.0155	-0.0155	0.0022	-14.3%	-0.0196	-0.0111	2.21E-05	-27%
M-F-P	-0.0158	-0.0158	0.0022	-14.0%	-0.0200	-0.0115	2.21E-05	-26%
C-B-P	-0.0045	-0.0045	0.0017	-37.5%	-0.0078	-0.0013	1.69E-05	-73%
C-F-P	-0.0048	-0.0048	0.0017	-35.2%	-0.0080	-0.0016	1.69E-05	-67%
Fossil Resource Scarcity (kg oil eq)								
R-B-H	-0.0368	-0.0368	0.0013	-3.6%	-0.0394	-0.0344	1.33E-05	-7%
R-F-H	-0.0760	-0.0760	0.0022	-2.8%	-0.0796	-0.0725	2.15E-05	-5%
M-B-H	-0.0013	-0.0013	0.0004	-28.8%	-0.0020	-0.0006	3.68E-06	-56%
M-F-H	-0.0082	-0.0082	0.0007	-8.0%	-0.0094	-0.0071	6.58E-06	-14%
C-B-H	-0.0091	-0.0090	0.0010	-11.4%	-0.0112	-0.0072	1.03E-05	-23%
C-F-H	-0.0160	-0.0159	0.0013	-8.2%	-0.0185	-0.0136	1.31E-05	-16%
R-B-P	-0.0654	-0.0654	0.0019	-2.9%	-0.0687	-0.0623	1.89E-05	-5%
R-F-P	-0.0733	-0.0733	0.0021	-2.8%	-0.0767	-0.0699	2.07E-05	-5%
M-B-P	-0.0095	-0.0095	0.0009	-9.7%	-0.0112	-0.0078	9.25E-06	-18%
M-F-P	-0.0115	-0.0115	0.0010	-8.9%	-0.0134	-0.0096	1.03E-05	-16%
C-B-P	-0.0036	-0.0036	0.0007	-19.9%	-0.0050	-0.0023	7.17E-06	-39%
C-F-P	-0.0056	-0.0056	0.0008	-14.1%	-0.0071	-0.0041	7.86E-06	-27%
Mineral Resource Scarcity (kg Cu eq)								
R-B-H	-3.47E-04	-3.47E-04	1.27E-06	-0.4%	-3.49E-04	-3.45E-04	1.27E-08	-1%
R-F-H	-2.07E-04	-2.07E-04	5.80E-06	-2.8%	-2.16E-04	-1.97E-04	5.80E-08	-5%
M-B-H	-3.90E-05	-3.90E-05	2.48E-06	-6.4%	-4.31E-05	-3.49E-05	2.48E-08	-11%
M-F-H	-1.79E-05	-1.79E-05	1.26E-06	-7.0%	-2.01E-05	-1.58E-05	1.26E-08	-12%
C-B-H	-6.72E-05	-6.72E-05	4.48E-06	-6.7%	-7.54E-05	-5.94E-05	4.48E-08	-12%
C-F-H	-4.61E-05	-4.60E-05	3.38E-06	-7.3%	-5.25E-05	-4.00E-05	3.38E-08	-14%
R-B-P	-5.69E-04	-5.69E-04	1.58E-05	-2.8%	-5.95E-04	-5.43E-04	1.58E-07	-5%
R-F-P	-5.42E-04	-5.42E-04	1.49E-05	-2.8%	-5.67E-04	-5.18E-04	1.49E-07	-5%
M-B-P	-1.21E-04	-1.21E-04	7.53E-06	-6.2%	-1.34E-04	-1.09E-04	7.53E-08	-10%
M-F-P	-1.14E-04	-1.14E-04	7.14E-06	-6.2%	-1.26E-04	-1.03E-04	7.14E-08	-10%
C-B-P	-8.97E-05	-8.96E-05	6.01E-06	-6.7%	-1.01E-04	-7.91E-05	6.01E-08	-12%
C-F-P	-8.28E-05	-8.28E-05	5.62E-06	-6.8%	-9.31E-05	-7.29E-05	5.62E-08	-12%

Figure S1 Environmental impacts of 8 recycling scenarios for A: Climate Change, B: Fossil Resource Scarcity, C: Mineral Resource Scarcity. On the left (A1-C1) absolute contributions are shown and on the right (A2-C2) the net effect is shown. Negative values indicate that the scenario causes a net reduction of the environmental impacts assessed. Scenario naming according to M=mechanical recycling, C=chemical recycling, B=biobased virgin plastic, F=fossil virgin plastic, H=HDPE and P=PET

