Supplementary Materials: Application of Eco-Design and Life Cycle Assessment Standards for Environmental Impact Reduction of an Industrial Product

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Table S1. PET Recycling Summarized Inventory Data from Perugini *et al*. [1].

INPUTS		OUTPUTS	
Diesel	0.197 kg	PET Recycled Granules	1 kg
Electricity	1.55 MJ	Plastic waste	0.908 kg
Natural Gas	2.5 MJ		
Sodium Hydroxide	0.003 kg		
PET	2.36 kg		
Water	2.96 kg		

Table S2. PET Recycling Summarized Inventory Data from Arena *et al*. [2].

INPUTS		OUTPUTS	
Diesel	0.0622 kg	PET Recycled Granules	1 kg
Electricity	2.54 MJ	Waste paper	0.08 kg
Natural Gas	2.76 MJ	Iron scraps	0.009 kg
Sodium Hydroxide (50%)	0.01 kg	PVC waste	0.1 kg
PET	1.76 kg	Waste water	2.96 kg
Water	2.96 kg		

Table S3. Environmental indicators used, LCIA method used for its calculation, and units of the indicator [3]

Environmental Indicator	Calculation Method	Unit	Classification
Global Warming Potential (GWP)	IPPC2007 [4]	kg CO_2 Eq.	I
Ozone Depletion Potential (ODP)	WMO1999 [5]	kg CFC-11 Eq.	I
Human Toxicity Potential, Cancer Effects (HTCP)	USEtox [6]	Comparative Toxic Unit for Human Health (CTUh)	II/III
Human Toxicity Potential, Non Cancer Effects (HTCNP)	UseTox [6]	CTUh	II/III
Ecotoxicity freshwater (FWETP)	USEtox [6]	Comparative Toxic Unit for ecosystems (CTUe)	II/III
Particulate matters (PMP)	RiskPoll model [7,8]	kg PM2,5 Eq.	I
Ionising radiation, human health effect model (IRP)	ReCiPe2008 (v1.05) [9]	kg U235 Eq.	Interim.*
Photochemical ozone formation (POCP)	ReCiPe 2008 [10]	kg NMVOC	II
Acidification Potential (AP), accumulated exceedance.	[11,12]	Mole of H+ Eq.	II
Terrestial Eutrophication (TEP), accumulated exceedance	[11,12]	Mole of N Eq.	II
Aquatic freshwater Eutrophication (FEP)	ReCiPe2008 [13]	kg of N Eq.	II

Aquatic marine Eutrophication (MEP)	ReCiPe2008 [13]	kg of N Eq.	II
Resource Depletion (RD)	CML 2002 [14]	kg Sb Eq.	II

* The classification “interim” indicates that a method was considered to be the best among the analyzed methods for the impact category, but still not developed enough so to be able to recommend it.

Table S4. Life Cycle Impact Assessment data for the glass syrup packaging life cycle.

	Cardboard box	Aluminun cap	Polypropilene dispenser	Glass container	Transport	End of Life
GWP [kg CO2 Eq.]	$1.40{\times}10^{-2}$	$4.73{\times}10^{-3}$	$1.50{\times}10^{-2}$	$1.14{\times}10^{-1}$	$7.80{\times}10^{-4}$	$7.51{\times}10^{-3}$
ODP [kg CFC-11 Eq.]	$1.58{\times}10^{-13}$	$2.26{\times}10^{-12}$	$4.82{\times}10^{-10}$	$1.34{\times}10^{-11}$	$5.34{\times}10^{-15}$	$8.90{\times}10^{-12}$
PMP [kg PM2,5 Eq.]	1.5410^{-6}	$1.27{\times}10^{-6}$	$3.88{\times}10^{-6}$	$4.14{\times}10^{-4}$	$2.10{\times}10^{-7}$	$4.09{\times}10^{-7}$
POCP [kg NMVOC Eq.]	$4.50{\times}10^{-5}$	$9.76{\times}10^{-6}$	$3.63{\times}10^{-5}$	$1.97{\times}10^{-4}$	$1.15{\times}10^{-6}$	$8.57{\times}10^{-6}$
AP [Mol H+ Eq.]	$4.53{\times}10^{-5}$	$2.26{\times}10^{-5}$	$7.21{\times}10^{-5}$	$8.45{\times}10^{-4}$	$7.05{\times}10^{-6}$	$7.80{\times}10^{-6}$
TEP [kg N Eq.]	$1.87{\times}10^{-4}$	$3.45{\times}10^{-5}$	$1.30{\times}10^{-4}$	$2.43{\times}10^{-3}$	$3.75{\times}10^{-5}$	$2.31{\times}10^{-5}$
MEP [kg N Eq.]	$8.04{\times}10^{-6}$	$9.30{\times}10^{-8}$	$1.20{\times}10^{-5}$	$1.67{\times}10^{-4}$	$3.35{\times}10^{-6}$	$6.47{\times}10^{-7}$
FEP [kg P Eq.]	$6.04{\times}10^{-7}$	$3.19{\times}10^{-9}$	$3.30{\times}10^{-7}$	$6.27{\times}10^{-8}$	$5.27{\times}10^{-9}$	$4.32{\times}10^{-7}$
RD [kg Sb Eq.]	$2.37{\times}10^{-8}$	$5.40{\times}10^{-8}$	$3.62{\times}10^{-9}$	$3.44{\times}10^{-7}$	$2.18{\times}10^{-10}$	$1.29{\times}10^{-8}$
HTCP [CTUh]	$6.90{\times}10^{-12}$	$2.00{\times}10^{-12}$	$1.62{\times}10^{-13}$	$2.57{\times}10^{-11}$	$2.04{\times}10^{-10}$	$5.87{\times}10^{-10}$
HTNCP [CTUh]	$2.29{\times}10^{-9}$	$2.12{\times}10^{-10}$	$1.11{\times}10^{-11}$	$3.07{\times}10^{-9}$	$6.21{\times}10^{-13}$	$5.13{\times}10^{-12}$
FWETP [CTUe]	$3.22{\times}10^{-3}$	$1.28{\times}10^{-4}$	$2.24{\times}10^{-5}$	$1.80{\times}10^{-3}$	$1.46{\times}10^{-4}$	$1.34{\times}10^{-4}$
IRP [kg U235 Eq.]	$6.64{\times}10^{-5}$	$5.05{\times}10^{-4}$	$0.00{\times}10^{-00}$	$3.85{\times}10^{-3}$	$1.73{\times}10^{-6}$	$4.62{\times}10^{-5}$

Table S5. Domestic inventory for EU + 27 and Overall robustness of the data and normalization method related with [15].

Environmental Indicator	Unit	Normalized	Overall Robustness
Global Warming Potential (GWP)	kg CO_2 Eq.	$4.60{\times}10^{12}$	Very High
Particulate matters/Respiratory Inorganics (PMP)	kg PM2,5 Eq.	$1.90{\times}10^{9}$	Very High
Acidification Potential (AP), accumulated exceedance.	Mole of H+ Eq.	$2.36{\times}10^{10}$	High
Ozone Depletion Potential (ODP)	kg CFC-11 Eq.	$1.08{\times}10^{7}$	Medium
Ionising radiation, human health effect model (IRP)	kg U235 Eq.	$5.64{\times}10^{11}$	Medium
Photochemical ozone formation (POCP)	kg NMVOC	$1.58{\times}10^{10}$	Medium
Terrestial Eutrophication (TEP), accumulated exceedance	Mole of N Eq.	$8.76{\times}10^{10}$	Medium
Resource Depletion (RD)	kg Sb Eq.	$5.03{\times}10^{7}$	Medium
Aquatic freshwater Eutrophication (FEP)	kg of N Eq.	$7.41{\times}10^{8}$	Medium to Low
Aquatic marine Eutrophication (MEP)	kg of N Eq.	$8.44{\times}10^{9}$	Medium to Low
Ecotoxicity freshwater (FWETP)	Comparative Toxic Unit for ecosystems (CTUe)	$4.36{\times}10^{12}$	Low
Human Toxicity Potential, Cancer Effects (HTCP)	Comparative Toxic Unit for Human Health (CTUh)	$1.84{\times}10^{4}$	Low
Human Toxicity Potential, Non Cancer Effects (HTCNP)	CTUh	$2.66{\times}10^{5}$	Low

Table S6. Normalized data for the glass container syrup packaging life cycle.

	Cardboard box	Aluminun cap	Polypropilene dispenser	Glass container	Transport	End of Life
GWP [kg CO2 Eq.]	386.2	130.1	413.0	3131.6	21.5	206.7
PMP [kg PM2,5 Eq.]	79.8	65.9	201.8	21512.2	10.9	21.3
AP [Mol H+ Eq.]	240.5	119.8	382.7	4484.2	37.4	41.4
ODP [kg CFC-11 Eq.]	0.0	0.0	5.6	0.2	0.0	0.1
IRP [kg U235 Eq.]	14.7	112.1	0.0	854.3	0.4	10.3
POCP [kg NMVOC Eq.]	354.4	76.9	285.6	1549.5	9.0	67.5
TEP [kg N Eq.]	268.5	49.4	186.0	3489.5	53.8	33.2
RD [kg Sb Eq.]	58.9	134.4	9.0	855.9	0.5	32.0
FEP [kg P Eq.]	102.1	0.5	55.8	10.6	0.9	72.9
MEP [kg N Eq.]	119.6	1.4	177.8	2482.2	49.8	9.6
FWETP [CTUe]	92.5	3.7	0.6	51.8	4.2	3.8
HTCP [CTUh]	46.9	13.6	1.1	175.1	4.2	34.9
HTNCP [CTUh]	1080.1	99.9	5.2	1445.9	96.1	276.5

Table S7. Life Cycle Impact Assessment data for the PET syrup packaging life cycle.

	Cardboard Box	Aluminum cap	Polypropilene dispenser	PET container	Transport	End of life
GWP [kg CO2 Eq.]	1.40×10^{-2}	4.70×10^{-3}	1.50×10^{-2}	6.41×10^{-2}	2.79×10^{-4}	1.14×10^{-2}
ODP [kg CFC-11 Eq.]	1.58×10^{-13}	2.24×10^{-12}	4.82×10-10	2.08×10^{-7}	1.15×10^{-15}	9.96×10^{-12}
PMP [kg PM2,5 Eq.]	1.54×10^{-6}	1.26×10^{-6}	3.88×10^{-6}	1.42×10^{-5}	7.59×10^{-8}	1.56×10^{-6}
POCP [kg NMVOC Eq.]	4.50×10^{-5}	9.69×10^{-6}	3.63×10^{-5}	2.18×10^{-4}	4.01×10^{-7}	1.77×10^{-5}
AP [Mol H+ Eq.]	4.53×10^{-5}	2.24×10^{-5}	7.21×10^{-5}	3.29×10^{-4}	2.64×10^{-6}	2.92×10^{-5}
TEP [kg N Eq.]	1.87×10^{-4}	3.42×10^{-5}	1.30×10^{-4}	5.60×10^{-4}	1.41×10^{-5}	5.50×10^{-5}
MEP [kg N Eq.]	8.04×10^{-6}	9.25×10^{-8}	1.20×10^{-5}	1.77×10^{-6}	1.27×10^{-6}	1.14×10^{-6}
FEP [kg P Eq.]	6.04×10^{-7}	3.17×10^{-9}	3.30×10^{-7}	1.18×10^{-6}	1.91×10^{-9}	1.12×10^{-6}
RD [kg Sb Eq.]	2.37×10^{-8}	5.35×10^{-8}	3.62×10^{-9}	4.29×10^{-6}	7.26×10^{-11}	1.68×10^{-8}
HTCP [CTUh]	6.90×10^{-12}	1.99×10^{-12}	1.62×10^{-13}	1.07×10^{-10}	2.20×10^{-13}	7.04×10^{-12}
HTNCP [CTUh]	2.29×10^{-9}	2.11×10^{-10}	1.11×10^{-11}	3.28×10^{-9}	7.35×10^{-11}	1.26×10^{-9}
FWETP [CTUe]	3.22×10^{-3}	1.27×10^{-4}	2.24×10^{-5}	4.18×10^{-2}	5.15×10^{-5}	6.60×10^{-4}
IRP [kg U235 Eq.]	6.64×10^{-5}	5.02×10^{-4}	0.00×10^{-0}	6.88×10^{-3}	4.05×10^{-7}	5.18×10^{-4}

Table S8. Normalized data for the PET syrup packaging life cycle.

	Cardboard Box	Aluminu m cap	Polypropile ne Dosifier	PET container	Transport	End of Life
GWP [kg CO_2 Eq.]	386.2	129.2	413.0	1763.9	7.7	313.3
PMP [kg PM2,5 Eq.]	79.8	65.5	201.8	736.5	3.9	81.1
AP [Mol H+ Eq.]	240.5	118.9	382.7	1746.1	14.0	155.0
ODP [kg CFC-11 Eq.]	0.0	0.0	5.6	2415.9	0.0	0.1
IRP [kg U235 Eq.]	14.7	111.4	0.0	1527.0	0.1	115.0
POCP [kg NMVOC Eq.]	354.4	76.3	285.6	1714.5	3.2	139.4
TEP [kg N Eq.]	268.5	49.1	186.0	802.8	20.3	78.8
RD [kg Sb Eq.]	58.9	133.1	9.0	10690.0	0.2	41.9
FEP [kg P Eq.]	102.1	0.5	55.8	200.2	0.3	189.5
MEP [kg N Eq.]	119.6	1.4	177.8	26.3	18.8	16.9
HTCP [CTUh]	46.9	13.5	1.1	726.6	1.5	47.9
HTNCP [CTUh]	1080.1	99.1	5.2	1544.7	34.6	590.8
FWETP [CTUe]	92.5	3.7	0.6	1199.0	1.5	19.0

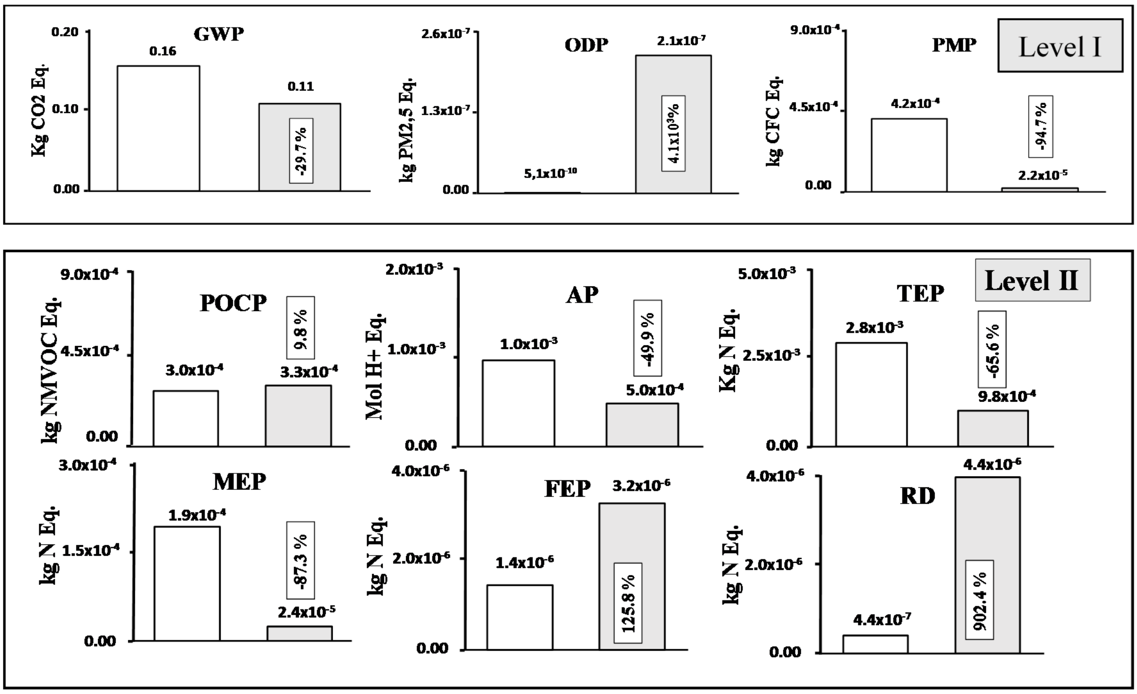

Figure S1. Overall values of the level I and II environmental indicators for glass (white) and PET (grey) containers life cycle.

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