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APPENDICES

Appendix A Life Cycle Inventory (LCI)

Table A1 Results of the inventory analysis of one ton of cassava root (Khongsiri, 2009)

Input			Output		
Type	**Quantity**	**Unit**	**Type**	**Quantity**	**Unit**
Raw material			**Products**		
Cassava stems	345	pieces	cassava root	1000	kg
cassava peel	1076	kg	cassava residue	555.048	kg
chicken manure	2580	kg	Cassava stems	872	piece
N-fertilizer	1.249	kg	**Air emissions**		
P-fertilizer	0.7	kg	carbondioxide	8.315	kg
K-fertilizer	1.336	kg	nitrogenoxide	0.171	kg
Alachlor	0.096	kg	sulfurdioxide	0.011	kg
Paraquat	0.15	kg	nitrousoxide	0.044	kg
Glyphosate	0.292	kg	ammonia	0.264	kg
Zinc	0.086	kg	volatile organic compound	0.058	kg
Fuel					
Diesel	2.475	kg			

Table A2 Results of the inventory analysis of one ton of cassava starch (Khongsiri, 2009)

Input			Output		
Type	**Quantity**	**Unit**	**Type**	**Quantity**	**Unit**
Raw material			**Product**		
cassava root	4,803.101	kg	cassava starch	1000.000	kg
sulfur	0.951	kg	**By products**		
water	12,435.76	kg	cassava peel	135.994	kg
Fuel/Electricity			Rhizome	68.224	kg
Fuel oil	34.504	L	cassava residue	1457.275	kg
Electricity	176.769	Kwh	sand	20.000	kg
			Waste		
			starch losses	121.582	kg
			Air emissions		
			carbondioxide	61.530	kg
			nitrogenoxide	252.270	g
			sulfurdioxide	330.960	g
			vapor	212.638	kg
			Water emissions		
			Waste water	13664.654	kg
			BOD	127.570	kg
			COD	265.131	kg
			total nitrogen	6.503	kg
			total phosphorus	0.400	kg
			Suspended solids	90.048	kg

Table A3 Results of the inventory analysis of one ton of cassava starch with biogas production line

Input			Output		
Item	**Quantity**	**Unit**	**Item**	**Quantity**	**Unit**
Raw material			**Product**		
cassava root	4,500	kg	cassava starch	1000.000	kg
sulfur	0.554	kg	**By products**		
water	12.67	m^3	cassava peel	248.6	kg
Fuel/Electricity			Rhizome	24.836	kg
Electricity	121.065	Kwh	cassava residue	460.47	kg
Fuel oil	1.189214	kg	sand	17.71	kg
			Air emissions		
			carbondioxide	4.126	kg
			nitrogenoxide	0.036	kg
			carbonmonoxide	0.0044	kg
			sulfur oxide	0.0073	kg
			Water emissions		
			Waste water	19.628	m^3
			BOD	0.927	kg
			COD	4.17	kg
			suspended solids	3.326	kg
			TDS	65.661	kg
			Oil & grease	0.216	kg

Table A4 Results of the inventory analysis of one ton of sugar

Input			Output		
Item	**Quantity**	**Unit**	**Item**	**Quantity**	**Unit**
Raw material			**Product**		
cassava starch	1.05	ton	Sugar(D-glucose)	1	ton
Sulfuric acid (100%)	1.207173913	kg	**Water emissions**		
Sodium hydroxide (50%)	0.756495652	kg	waste water	6.89	m^3
water	27	m^3			
Fuel/Electricity					
Fuel oil	6.67	L			
Electricity	144	kWh			

Table A5 Results of the inventory analysis of one kilogram Cassava-based PLA res-in

Input			Output		
Type	**Quantity**	**Unit**	**Type**	**Quantity**	**Unit**
Raw material			**Product**		
Sugar	1.34673	kg	PLLA resin	1	kg
Lime	0.513893	kg	**Water emissions**		
Sulfuric acid	0.644928	kg	waste water	0.00008	kg
$(NH_4)_2SO_4$	0.03	kg			
ammonia	0.01027	kg			
phosphoric acid	0.01973	kg			
Fuel/Electricity					
Diesel for inbound transportation	0.024742	L			
Electricity	1.087344	kWh			
Steam	0.651537	kg			

Table A6 Results of the inventory analysis of sugarcane plantation in Thailand

Input			Output		
Type	**Unit**	**Amount**	**Type**	**Unit**	**Amount**
Fuel			***Product***		
Diesel	liter	0.00142696	Sugarcane	kg	1
Chemical:			***Co-product***		
Fertilizer (N)	kg	0.00178048	Cane trash - 0% burning	kg	0.19999871
Fertilizer (P)	kg	0.00082918			
Fertilizer (K)	kg	0.00073919			
Paraquat	kg	1.2855E-05			
Atrazine	kg	4.4994E-05			
Ametryne	kg	3.2139E-05			
2,4-D	kg	1.2855E-05			

Table A7 Results of the inventory analysis of sugarcane milling in Thailand

Input Inventory			Output Inventory		
Type	**Unit**	**Amount**	**Type**	**Unit**	**Amount**
Raw material			***Product***		
Sugarcane plant	kg	128.3630363	Raw sugar	kg	10.1757
Energy			White sugar	kg	1
Production of Electricity & Steam Bagasse mainly & other	kg	35.73267327	Pure white sugar	kg	2.88944
			Co-product		
-Electricity from bagasse	kWh	2.23019802	Molasses	kg	4.65759
-Steam from bagasse	kg	57.7169967	Surplus bagasse and others	kg	11.8028
Chemical			Electricity for sale	kWh	0.57508
Lime	kg	0.270627063			
Sodium chloride	kg	0.100660066			
Hydrochloric acid	kg	5.77558E-05			
SiO_2	kg	0.00029703			
Biocide	kg	0.000470297			
Aluminium sulfate	kg	0.000478548			
Caustic soda flake	kg	0.000148515			
Flocculants	kg	0.004950495			
Miscellaneous	kg	0.000734323			

Table A8 Results of the inventory analysis of PLA garbage bag production from company based on one kg of bioplastic product

Transportation of PLA resin					
Input Inventory			**Output Inventory**		
Description	**Unit**	**Amount**	**Description**	**Unit**	**Amount**
Resource			***Product***		
Diesel	kg	0.00311	Cassava-based PLA resin	kg	1.1
			Emissions to air		
			Carbon dioxide (CO_2)	g	9.76954
			Carbon monoxide (CO)	g	0.033469
			Nitrogen oxides (NO_x)	g	0.100599
			Particulate matter (PM)	g	0.00755
			Hydrocarbons (HC)	g	0.008736
			Methane (CH_4)	g	0.000218
			Benzene (C_2H_6)	g	0.000166
			Toluene (C_7H_8)	g	6.99E-05
			Xylene (C_8H_{10})	g	6.99E-05
			Non – methane volatile organic compounds (NMVOCs)	g	0.016674
			Sulfur oxides (SO_x)	g	0.002105
			Nitrous Oxide (N_2O)	g	0.000387
			Cadmium	g	3.00E-08
			Copper	g	5.11E-06
			Chromium	g	1.50E-07
			Nickel	g	2.10E-07
			Selenium	g	3.00E-08
			Zinc	g	3.00E-06
			Lead	g	3.32E-10
			Mercury	g	6.00E-11

Drying					
Input Inventory			**Output Inventory**		
Description	**Unit**	**Amount**	**Description**	**Unit**	**Amount**
Resource			***Product***		
PLA resin	kg	1.1	Dried PLA resin	kg	1.1
Utilities					
Electricity	kWh	0.03652			
Blowing & Printing					
Input Inventory			**Output Inventory**		
Description	**Unit**	**Amount**	**Description**	**Unit**	**Amount**
Resources			***Product***		
Virgin PLA resin	kg	1.1	Uncut bag	kg	1.07692308
Recycle PLA resin	kg	0.05384615	***Solid Waste***		
Printing color A	kg	0.06153846	Scrap	kg	0.07692308
Utilities					
Electricity for blowing	kWh	0.27692308			
Electricity for printing	kWh	0.08076923			
Cutting					
Input Inventory			**Output Inventory**		
Description	**Unit**	**Amount**	**Description**	**Unit**	**Amount**
Resource			***Product***		
Printed bag	kg	1.07692308	Garbage bag	kg	1
Utility			***Solid Waste***		
Electricity	kWh	0.11769231	Scrap	kg	0.07692308
Recycling					
Input Inventory			**Output Inventory**		
Description	**Unit**	**Amount**	**Description**	**Unit**	**Amount**
Resource			***Product***		
Scrap	kg	0.05384615	Recycle PLA resin	kg	0.05384615
Utility					
Electricity	kWh	0.0125641			

Transportation of PLA product					
Input Inventory			**Output Inventory**		
Descriptioin	**Unit**	**Amount**	**Description**	**Unit**	**Amount**
Resources			***Product***		
Diesel	kg	0.003084	PLA Garbage bag	kg	1
Barge	kgkm	6.5	***Emissions to air***		
			Carbon dioxide (CO_2)	g	9.6888
			Carbon monoxide (CO)	g	0.033192
			Nitrogen oxides (NO_x)	g	0.099768
			Particulate matter (PM)	g	0.007488
			Hydrocarbons (HC)	g	0.008664
			Methane (CH_4)	g	0.000216
			Benzene (C_2H_6)	g	0.000165
			Toluene (C_7H_8)	g	6.94E-05
			Xylene (C_8H_{10})	g	6.94E-05
			Non – methane volatile organic compounds (NMVOCs)	g	0.016536
			Sulfur oxides (SO_x)	g	0.002088
			Nitrous Oxide (N_2O)	g	0.000384
			Cadmium	g	2.98E-08
			Copper	g	5.06E-06
			Chromium	g	1.49E-07
			Nickel	g	2.09E-07
			Selenium	g	2.98E-08
			Zinc	g	2.98E-06
			Lead	g	3.29E-10
			Mercury	g	5.95E-11

Table A9 Results of the inventory analysis of PBS garbage bag production based on one kg of bioplastic product

Transportation of PLA resin					
Input Inventory			Output Inventory		
Description	Unit	Amount	Description	Unit	Amount
Resource			***Product***		
Diesel	kg	0.00311	PBS resin	kg	1.1
			Emissions to air		
			Carbon dioxide (CO_2)	g	9.76954
			Carbon monoxide (CO)	g	0.033469
			Nitrogen oxides (NO_x)	g	0.100599
			Particulate matter (PM)	g	0.00755
			Hydrocarbons (HC)	g	0.008736
			Methane (CH_4)	g	0.000218
			Benzene (C_2H_6)	g	0.000166
			Toluene (C_7H_8)	g	6.99E-05
			Xylene (C_8H_{10})	g	6.99E-05
			Non – methane volatile organic compounds (NMVOCs)	g	0.016674
			Sulfur oxides (SO_x)	g	0.002105
			Nitrous Oxide (N_2O)	g	0.000387
			Cadmium	g	3.00E-08
			Copper	g	5.11E-06
			Chromium	g	1.50E-07
			Nickel	g	2.10E-07
			Selenium	g	3.00E-08
			Zinc	g	3.00E-06
			Lead	g	3.32E-10
			Mercury	g	6.00E-11

Drying					
Input Inventory			Output Inventory		
Description	**Unit**	**Amount**	**Description**	**Unit**	**Amount**
Resource			***Product***		
PBS resin	kg	1.1	Dried PBS resin	kg	1.1
Utility					
Electricity	kWh	0.03652			

Blowing & Printing					
Input Inventory			Output Inventory		
Description	**Unit**	**Amount**	**Description**	**Unit**	**Amount**
Resources			***Producs***		
Virgin PBS resin	kg	1.1	Uncut bag	kg	1.07692308
Recycle PBS resin	kg	0.05384615	***Solid Waste***		
Printing color A	kg	0.06153846	Scrap	kg	0.07692308
Utilities					
Electricity for blowing	kWh	0.27692308			
Electricity for printing	kWh	0.08076923			

Cutting					
Input Inventory			Output Inventory		
Description	**Unit**	**Amount**	**Description**	**Unit**	**Amount**
Resource			***Product***		
Printed bag	kg	1.07692308	Garbage bag	kg	1
Utility			***Solid Waste***		
Electricity	kWh	0.11769231	Scrap	kg	0.07692308

Recycling					
Input Inventory			Output Inventory		
Description	**Unit**	**Amount**	**Description**	**Unit**	**Amount**
Resource			***Product***		
Scrap	kg	0.05384615	Recycle PBS resin	kg	0.05384615
Utility					
Electricity	kWh	0.0125641			

Transportation of PLA product					
Input Inventory			Output Inventory		
Descriptioin	Unit	Amount	Description	Unit	Amount
Resources			***Product***		
Diesel	kg	0.003084	PBS Garbage bag	kg	1
Barge	kgkm	6.5	***Emissions to air***		
			Carbon dioxide (CO_2)	g	9.6888
			Carbon monoxide (CO)	g	0.033192
			Nitrogen oxides (NO_x)	g	0.099768
			Particulate matter (PM)	g	0.007488
			Hydrocarbons (HC)	g	0.008664
			Methane (CH_4)	g	0.000216
			Benzene (C_2H_6)	g	0.000165
			Toluene (C_7H_8)	g	6.94E-05
			Xylene (C_8H_{10})	g	6.94E-05
			Non – methane volatile organic compounds (NMVOCs)	g	0.016536
			Sulfur oxides (SO_x)	g	0.002088
			Nitrous Oxide (N_2O)	g	0.000384
			Cadmium	g	2.98E-08
			Copper	g	5.06E-06
			Chromium	g	1.49E-07
			Nickel	g	2.09E-07
			Selenium	g	2.98E-08
			Zinc	g	2.98E-06
			Lead	g	3.29E-10
			Mercury	g	5.95E-11

Table A10 Results of the inventory analysis of garbage bag production from poly-ethylene based on one kg of garbage bag

Transportation of HDPE,LDPE and LLDPE resin					
Input Inventory			**Output Inventory**		
Descriptioin	**Unit**	**Amount**	**Description**	**Unit**	**Amount**
Resource			***Products***		
Diesel	kg	0.002781	HDPE & LDPE and LLDPE resin	kg	0.98357143
			Emissions to air		
			Carbon dioxide (CO_2)	g	8.735491
			Carbon monoxide (CO)	g	0.029926
			Nitrogen oxides (NO_x)	g	0.089952
			Particulate matter (PM)	g	0.006751
			Hydrocarbons (HC)	g	0.007812
			Methane (CH_4)	g	0.000195
			Benzene (C_2H_6)	g	0.000148
			Toluene (C_7H_8)	g	6.25E-05
			Xylene (C_8H_{10})	g	6.25E-05
			Non – methane volatile organic compounds (NMVOCs)	g	0.014909
			Sulfur oxides (SO_x)	g	0.001883
			Nitrous Oxide (N_2O)	g	0.000346
			Cadmium	g	2.68E-08
			Copper	g	4.57E-06
			Chromium	g	1.34E-07
			Nickel	g	1.88E-07
			Selenium	g	2.68E-08
			Zinc	g	2.68E-06
			Lead	g	2.96E-10
			Mercury	g	5.37E-11

Mixing					
Input Inventory			**Output Inventory**		
Description	**Unit**	**Amount**	**Description**	**Unit**	**Amount**
Resources			***Product***		
HDPE	kg	0.67678571	Mixed resin	kg	1.07142857
LDPE	kg	0.21475			
LLDPE	kg	0.09203571			
Recycle resin	kg	0.05357143			
Master batch	kg	0.03428571			
Utilities					
Electricity	kWh	0.00178571			

Blowing & Printing					
Input Inventory			**Output Inventory**		
Description	**Unit**	**Amount**	**Description**	**Unit**	**Amount**
Resources			***Product***		
Mixed resin	kg	1.07142857	Uncut bag	kg	1.02142857
Printing color A	kg	0.00137363	***Solid Waste***		
Toluene	kg	0.04201007	Scrap	kg	0.05
Isopropanol	kg	0.02106227			
Ethanol 99.7 %	kg	0.0069826			
Utilities					
Electricity for blowing	kWh	0.36285714			
Electricity for printing	kWh	0.075			

Cutting					
Input Inventory			**Output Inventory**		
Description	**Unit**	**Amount**	**Description**	**Unit**	**Amount**
Resource			***Product***		
Printed bag	kg	1.02142857	Garbage bag	kg	1
Utility			***Solid Waste***		
Electricity	kWh	0.11714286	Scrap	kg	0.02142857

Recycling					
Input Inventory			**Output Inventory**		
Description	**Unit**	**Amount**	**Description**	**Unit**	**Amount**
Resource			***Product***		
Scrap	kg	0.05357143	Recycle resin	kg	0.05357143
Utility					
Electricity	kWh	0.025			

Transportation of PLA product					
Input Inventory			**Output Inventory**		
Descriptioin	**Unit**	**Amount**	**Description**	**Unit**	**Amount**
Resource			***Product***		
Diesel	kg	0.003084	Garbage bag	kg	1
Barge	kgkm	6.5	***Emissions to air***		
			Carbon dioxide (CO_2)	g	9.6888
			Carbon monoxide (CO)	g	0.033192
			Nitrogen oxides (NO_x)	g	0.099768
			Particulate matter (PM)	g	0.007488
			Hydrocarbons (HC)	g	0.008664
			Methane (CH_4)	g	0.000216
			Benzene (C_2H_6)	g	0.000165
			Toluene (C_7H_8)	g	6.94E-05
			Xylene (C_8H_{10})	g	6.94E-05
			Non – methane volatile organic compounds (NMVOCs)	g	0.016536
			Sulfur oxides (SO_x)	g	0.002088
			Nitrous Oxide (N_2O)	g	0.000384
			Cadmium	g	2.98E-08
			Copper	g	5.06E-06
			Chromium	g	1.49E-07
			Nickel	g	2.09E-07
			Selenium	g	2.98E-08
			Zinc	g	2.98E-06
			Lead	g	3.29E-10
			Mercury	g	5.95E-11

Table A11 Emissions from transportation for waste collection

Transportation of PLA resin					
Input Inventory			Output Inventory		
Descriptioin	**Unit**	**Amount**	**Description**	**Unit**	**Amount**
Resource			***Product***		
Diesel	kg	0.000212	Plastic waste	kg	1
			Emissions to air		
			Carbon dioxide (CO_2)	g	0.6667
			Carbon monoxide (CO)	g	0.001402
			Nitrogen oxides (NO_x)	g	0.002685
			Particulate matter (PM)	g	0.000139
			Hydrocarbons (HC)	g	0.000324
			Methane (CH_4)	g	7.78E-06
			Benzene (C_2H_6)	g	6.16E-06
			Toluene (C_7H_8)	g	2.59E-06
			Xylene (C_8H_{10})	g	2.59E-06
			Non – methane volatile organic compounds (NMVOCs)	g	0.000993
			Sulfur oxides (SO_x)	g	0.000143
			Nitrous Oxide (N_2O)	g	2.57E-05
			Cadmium	g	2.04E-09
			Copper	g	3.47E-07
			Chromium	g	1.02E-08
			Nickel	g	1.43E-08
			Selenium	g	2.04E-09
			Zinc	g	2.04E-07
			Lead	g	2.25E-11
			Mercury	g	4.09E-12

Table A12 Results of the inventory analysis of landfill scenario (without energy recovery) based on one kg of PLA bioplastic waste

Landfill scenario (without energy recovery)					
Input Inventory			Output Inventory		
Descriptioin	Unit	Amount	Description	Unit	Amount
Resources			**Emissions to Air**		
Bioplastic waste	kg	1	CO	g	0.099
Diesel	kg	0.00513	CO_2 (fossil)	g	16.34
Electricity	kWh	0.00225	CH_4	g	0.022
Tap water	kg	0.00493	NO_x	g	0.327
Wire	kg	0.00164	N_2O	g	0.0004
			SO_x	g	0.027
			CH_4 (biogenic)	g	600
			Emissions to Water		
			BOD	g	0.0658
			COD	g	0.1088

Table A13 Results of the inventory analysis of recycling scenario based on one kg of PLA bioplastic waste

Recycling scenario					
Input Inventory			Output Inventory		
Descriptioin	Unit	Amount	Description	Unit	Amount
Resources			***Product***		
Bioplastic waste	kg	1	PLA resin	kg	0.81
Water	m^3	0.005	***Emission to Air***		
Utilities			CO_2	kg	0.325
Electricity	MJ	2.1	***Solid Waste***		
			Plastic waste	kg	0.19

Table A14 Results of the inventory analysis of landfill scenario (with energy recovery) based on one kg of PLA bioplastic waste

Landfill scenario (with energy recovery)					
Input Inventory			**Output Inventory**		
Descriptioin	**Unit**	**Amount**	**Description**	**Unit**	**Amount**
Resources			Product		
Bioplastic waste	kg	1	Electricity	kWh	1.5
Diesel	kg	0.00513	**Emissions to Air**		
Electricity	kWh	0.00225	CO	g	0.099
Water	kg	0.00493	CO_2 (fossil)	g	16.34
Wire	kg	0.00164	CH_4	g	0.022
			NO_x	g	0.327
			N_2O	g	0.0004
			SO_x	g	0.027
			CH_4 (biogenic)	g	300
			Emissions to Water		
			BOD	g	0.0658
			COD	g	0.1088

Table A15 Results of the inventory analysis of composting scenario based on one kg of bioplastic (PLA) waste

Composting scenario					
Input Inventory			**Output Inventory**		
Descriptioin	**Unit**	**Amount**	**Description**	**Unit**	**Amount**
Resources			***Product***		
Bioplastic waste	kg	1	Soil container	kg	0.13
Electricity	kWh	0.0006	***Emissions to Air***		
Water	l	0.0082	CO_2 (fossil)	kg	6.89E-06
Diesel	kg	2.55E-05	CO	kg	4.96E-07
			CH_4	kg	1.10E-07
			NO_x	kg	1.63E-06
			SO_x	kg	2.18E-09
			CO_2 (biogenic)	kg	1.414

Table A16 Results of the inventory analysis of incineration with energy recovery scenario based on one kg of bioplastic (PLA) product

Incineration scenario							
Input Inventory				**Output Inventory**			
Description	**Unit**	**Amount**	**Remark**	**Description**	**Unit**	**Amount**	**Remark**
Resources				***Products***			
Bioplastic product	kg	1		Electricity	kWh	1.5	
HCl 35%	l	0.000036					
NaOH 50%	l	0.000037		***Emission to Air***			
Lime	kg	0.00466		CO_2 (biotic)	kg	1.8	
Electricity	kWh	0.0429		CH_4 (biotic)	kg	0.0002	
Diesel	kg	0.000185		N_20 (biotic)	kg	0.00006	
Water	kg	0.00254		NO_x	kg	0.0008	
Lubricating oil	kg	0.000019		CO	kg	0.00025	
				SO_x	kg	0.00002	
				CH_4	kg	0.00198	
				Emissionto Soil			
				Ash	kg	0.01	
				Emission to Water			
				Wastewater	kg	0.02	

Table A17 Results of the inventory analysis of landfill scenario (without energy recovery) based on one kg of PBS bioplastic waste

Landfill scenario (without energy recovery)					
Input Inventory			Output Inventory		
Descriptioin	**Unit**	**Amount**	**Description**	**Unit**	**Amount**
Resources			**Emissions to Air**		
Bioplastic waste	kg	1	CO	g	0.099
Diesel	kg	0.00513	CO_2 (fossil)	g	16.34
Electricity	kWh	0.00225	CH_4	g	0.022
Tap water	kg	0.00493	NO_x	g	0.327
Wire	kg	0.00164	N_2O	g	0.0004
			SO_x	g	0.027
			CH_4 (biogenic)	g	669.31
			Emissions to Water		
			BOD	g	0.0658
			COD	g	0.1088

Table A18 Results of the inventory analysis of composting scenario based on one kg of bioplastic (PBS) waste

Composting scenario					
Input Inventory			Output Inventory		
Descriptioin	**Unit**	**Amount**	**Description**	**Unit**	**Amount**
Resources			***Product***		
Bioplastic waste	kg	1	Soil container	kg	0.13
Electricity	kWh	0.0006	***Emissions to Air***		
Water	l	0.0082	CO_2 (fossil)	kg	6.89E-06
Diesel	kg	2.55E-05	CO	kg	4.96E-07
			CH_4	kg	1.10E-07
			NO_x	kg	1.63E-06
			SO_x	kg	2.18E-09
			CO_2	kg	0.835

Table A19 Results of the inventory analysis of landfill scenario (with energy recovery) based on one kg of PBS bioplastic waste

Landfill scenario (with energy recovery)					
Input Inventory			**Output Inventory**		
Descriptioin	**Unit**	**Amount**	**Description**	**Unit**	**Amount**
Resources			Product		
Bioplastic waste	kg	1	Electricity	kWh	1.5
Diesel	kg	0.00513	**Emissions to Air**		
Electricity	kWh	0.00225	CO	g	0.099
Water	kg	0.00493	CO_2 (fossil)	g	16.34
Wire	kg	0.00164	CH_4	g	0.022
			NO_x	g	0.327
			N_2O	g	0.0004
			SO_x	g	0.027
			CH_4 (biogenic)	g	334.655
			Emissions to Water		
			BOD	g	0.0658
			COD	g	0.1088

Table A20 Results of the inventory analysis of incineration with energy recovery scenario based on one kg of bioplastic (PBS) product

Incineration scenario							
Input Inventory				**Output Inventory**			
Description	**Unit**	**Amount**	**Remark**	**Description**	**Unit**	**Amount**	**Remark**
Resources				***Products***			
Bioplastic product	kg	1		Electricity	kWh	1.5	
HCl 35%	l	0.000036					
NaOH 50%	l	0.000037		***Emission to Air***			
Lime	kg	0.00466		CO_2 (biotic)	kg	1.08	
Electricity	kWh	0.0429		CO_2 (abiotic)	kg	0.96	
Diesel	kg	0.000185		CH_4 (biotic)	kg	0.0002	
Water	kg	0.00254		N_20 (biotic)	kg	0.00006	
Lubricating oil	kg	0.000019		NO_x	kg	0.0008	
				CO	kg	0.00025	
				SO_x	kg	0.00002	
				CH_4	kg	0.00198	
				Emissionto Soil			
				Ash	kg	0.01	
				Emission to Water			
				Wastewater	kg	0.02	

Table A21 Results of the inventory analysis of landfill scenario (without energy recovery) based on one kg of PE plastic waste

Landfill scenario (without energy recovery)					
Input Inventory			**Output Inventory**		
Descriptioin	**Unit**	**Amount**	**Description**	**Unit**	**Amount**
Resources			**Emissions to Air**		
PE garbage bag waste	kg	1	CO	g	0.099
Diesel	kg	0.00513	CO_2 (fossil)	g	17.61
Electricity	kWh	0.00225	CH_4	g	42.91
Tap water	kg	0.00493	NO_x	g	0.327
Wire	kg	0.00164	N_2O	g	0.0004
			SO_x	g	0.027
			Emissions to Water		
			Waste water	m^3	4.25E-05
			BOD	g	0.0658
			COD	g	0.1088

Table A22 Results of the inventory analysis of incineration (open burning) scenario based on one kg of PE plastic waste

Incineration scenario (open burning)					
Input Inventory			**Output Inventory**		
Descriptioin	**Unit**	**Amount**	**Description**	**Unit**	**Amount**
Resources			***Emissions to Air***		
PE garbage bag waste	kg	1	PM	g	7.92
			SO_X	g	0.49
			NO_X	g	2.97
			CO	g	42.06
			CO_2	g	455.06
			CH_4	g	6.43
			Emissions to Soil		
			Ash	kg	0.01

Table A23 Results of the inventory analysis of recycling scenario based on one kg of PE plastic waste

Recycling scenario					
Input Inventory			**Output Inventory**		
Descriptioin	**Unit**	**Amount**	**Description**	**Unit**	**Amount**
Resources			***Product***		
PE garbage bag waste	kg	1	PE resin	kg	0.81
Water	m^3	0.005	***Emission to Air***		
Utilities			CO_2	kg	0.325
Electricity	MJ	2.1	***Solid Waste***		
			Plastic waste	kg	0.19

Appendix B Life Cycle Impact Assessment (LCIA)

Table B1 Results of the impact assessment 1 kg cassava root by using CML 2 baseline 2000 V2.03 / World, 1995

Impact category	Unit	Total
abiotic depletion	kg Sb eq	0.000183013
global warming (GWP100)	kg CO2 eq	-3.27E-02
ozone layer depletion (ODP)	kg CFC-11 eq	1.13E-09
human toxicity	kg 1,4-DB eq	0.003732568
fresh water aquatic ecotox.	kg 1,4-DB eq	0.000492251
marine aquatic ecotoxicity	kg 1,4-DB eq	3.687316
terrestrial ecotoxicity	kg 1,4-DB eq	1.21E-04
photochemical oxidation	kg C2H4	4.32E-06
acidification	kg SO2 eq	6.37E-04
eutrophication	kg PO4--- eq	0.000125512

Table B2 Results of the impact assessment 1 kg cassava root by using Eco-indicator 95 V2.03 / Europe e

Impact category	Unit	Total
greenhouse	kg CO2	-3.38E-02
ozone layer	kg CFC11	1.32E-09
acidification	kg SO2	7.44E-04
eutrophication	kg PO4	1.20E-04
heavy metals	kg Pb	9.46E-08
carcinogens	kg B(a)P	4.03E-10
winter smog	kg SPM	7.63E-05
summer smog	kg C2H4	2.86E-05
pesticides	kg act.subst	0
energy resources	MJ LHV	0.40776617
solid waste	kg	1.16E-05

Table B3 Results of the impact assessment 1 kg cassava starch production without biogas by using CML 2 baseline 2000 V2.03 / World, 1995

Impact category	Unit	Total
abiotic depletion	kg Sb eq	1.04E-03
global warming (GWP100)	kg CO2 eq	1.52E-02
ozone layer depletion (ODP)	kg CFC-11 eq	6.79E-08
human toxicity	kg 1,4-DB eq	0.017279
fresh water aquatic ecotox.	kg 1,4-DB eq	0.003362
marine aquatic ecotoxicity	kg 1,4-DB eq	1.59E+01
terrestrial ecotoxicity	kg 1,4-DB eq	0.000259
photochemical oxidation	kg C2H4	2.20E-05
acidification	kg SO2 eq	0.001543
eutrophication	kg PO4--- eq	0.003906

Table B4 Results of the impact assessment 1 kg cassava starch production without biogas by using Eco-indicator 95 V2.03 / Europe e

Impact category	Unit	Total
greenhouse	kg CO2	1.25E-02
ozone layer	kg CFC11	9.01E-08
acidification	kg SO2	0.001734
eutrophication	kg PO4	3.90E-03
heavy metals	kg Pb	2.55E-07
carcinogens	kg B(a)P	9.33E-10
winter smog	kg SPM	3.90E-04
summer smog	kg C2H4	1.01E-04
pesticides	kg act.subst	0.00E+00
energy resources	MJ LHV	1.990098
solid waste	kg	7.41E-05

Table B5 Results of the impact assessment 1 kg cassava starch production with bio-gas by using CML 2 baseline 2000 V2.03 / World, 1995

Impact category	Unit	Total
abiotic depletion	kg Sb eq	0.000914
global warming (GWP100)	kg CO2 eq	-3.63E-02
ozone layer depletion (ODP)	kg CFC-11 eq	6.38E-09
human toxicity	kg 1,4-DB eq	0.010307
fresh water aquatic ecotox.	kg 1,4-DB eq	0.001396
marine aquatic ecotoxicity	kg 1,4-DB eq	9.966501
terrestrial ecotoxicity	kg 1,4-DB eq	0.000313
photochemical oxidation	kg C2H4	1.45E-05
acidification	kg SO2 eq	0.001771
eutrophication	kg PO4--- eq	0.000389

Table B6 Results of the impact assessment 1 kg cassava starch production with bio-gas by using Eco-indicator 95 V2.03 / Europe e

Impact category	Unit	Total
greenhouse	kg CO2	-0.03922
ozone layer	kg CFC11	8.02E-09
acidification	kg SO2	0.002056
eutrophication	kg PO4	0.000375
heavy metals	kg Pb	2.49E-07
carcinogens	kg B(a)P	1.08E-09
winter smog	kg SPM	0.000274
summer smog	kg C2H4	7.86E-05
pesticides	kg act.subst	0
energy resources	MJ LHV	1.714274
solid waste	kg	8.58E-05

Table B7 Results of the impact assessment 1 kg sugar production from cassava without biogas by using CML 2 baseline 2000 V2.03 / World, 1995

Impact category	Unit	Total
abiotic depletion	kg Sb eq	0.002128
global warming (GWP100)	kg CO2 eq	0.112685
ozone layer depletion (ODP)	kg CFC-11 eq	7.14E-08
human toxicity	kg 1,4-DB eq	0.019069
fresh water aquatic ecotox.	kg 1,4-DB eq	0.003628
marine aquatic ecotoxicity	kg 1,4-DB eq	17.41673
terrestrial ecotoxicity	kg 1,4-DB eq	0.000293
photochemical oxidation	kg C2H4	3.21E-05
acidification	kg SO2 eq	0.001954
eutrophication	kg PO4--- eq	0.004132

Table B8 Results of the impact assessment 1 kg sugar production from cassava without biogas by using Eco-indicator 95 V2.03 / Europe e

Impact category	Unit	Total
greenhouse	kg CO2	0.109607
ozone layer	kg CFC11	9.48E-08
acidification	kg SO2	0.002166
eutrophication	kg PO4	0.004121
heavy metals	kg Pb	2.97E-07
carcinogens	kg B(a)P	1.15E-09
winter smog	kg SPM	0.000614
summer smog	kg C2H4	1.29E-04
pesticides	kg act.subst	0
energy resources	MJ LHV	3.704846
solid waste	kg	0.000301

Table B9 Results of the impact assessment 1 kg sugar production from cassava with biogas by using CML 2 baseline 2000 V2.03 / World, 1995

Impact category	Unit	Total
abiotic depletion	kg Sb eq	0.00199
global warming (GWP100)	kg CO2 eq	0.058597
ozone layer depletion (ODP)	kg CFC-11 eq	6.86E-09
human toxicity	kg 1,4-DB eq	1.17E-02
fresh water aquatic ecotox.	kg 1,4-DB eq	0.001564
marine aquatic ecotoxicity	kg 1,4-DB eq	11.22664
terrestrial ecotoxicity	kg 1,4-DB eq	0.00035
photochemical oxidation	kg C2H4	2.42E-05
acidification	kg SO2 eq	2.19E-03
eutrophication	kg PO4--- eq	0.000439

Table B10 Results of the impact assessment 1 kg sugar production from cassava with biogas by using Eco-indicator 95 V2.03 / Europe e

Impact category	Unit	Total
greenhouse	kg CO2	0.055321
ozone layer	kg CFC11	8.61E-09
acidification	kg SO2	0.002503
eutrophication	kg PO4	0.000424
heavy metals	kg Pb	2.91E-07
carcinogens	kg B(a)P	1.30E-09
winter smog	kg SPM	0.000492
summer smog	kg C2H4	0.000105
pesticides	kg act.subst	0
energy resources	MJ LHV	3.415231
solid waste	kg	0.000313

Table B11 Results of the impact assessment 1 kg Cassava-based PLA resin production in Thailand based on PURAC (without biogas system) by using CML 2 baseline 2000 V2.03 / World, 1995

Impact category	Unit	Total
abiotic depletion	kg Sb eq	1.41E-02
global warming (GWP100)	kg CO2 eq	1.80E+00
ozone layer depletion (ODP)	kg CFC-11 eq	1.43E-07
human toxicity	kg 1,4-DB eq	0.191315
fresh water aquatic ecotox.	kg 1,4-DB eq	0.066756
marine aquatic ecotoxicity	kg 1,4-DB eq	198.546
terrestrial ecotoxicity	kg 1,4-DB eq	0.002385
photochemical oxidation	kg C2H4	0.000515
acidification	kg SO2 eq	0.01499
eutrophication	kg PO4--- eq	0.006278

Table B12 Results of the impact assessment 1 kg Cassava-based PLA resin production in Thailand based on PURAC (without biogas system) by using Eco-indicator 95 V2.03 / Europe e

Impact category	Unit	Total
greenhouse	kg CO2	1.78E+00
ozone layer	kg CFC11	1.78E-07
acidification	kg SO2	0.013982
eutrophication	kg PO4	6.26E-03
heavy metals	kg Pb	5.24E-06
carcinogens	kg B(a)P	4.30E-08
winter smog	kg SPM	0.01034
summer smog	kg C2H4	0.000349
pesticides	kg act.subst	0
energy resources	MJ LHV	24.12874
solid waste	kg	0.114438

Table B13 Results of the impact assessment 1 kg Cassava-based PLA resin production in Thailand based on PURAC (with biogas system) by using CML 2 baseline 2000 V2.03 / World, 1995

Impact category	Unit	Total
abiotic depletion	kg Sb eq	0.013086
global warming (GWP100)	kg CO2 eq	1.473007
ozone layer depletion (ODP)	kg CFC-11 eq	6.93E-08
human toxicity	kg 1,4-DB eq	1.71E-01
fresh water aquatic ecotox.	kg 1,4-DB eq	0.066152
marine aquatic ecotoxicity	kg 1,4-DB eq	188.3187
terrestrial ecotoxicity	kg 1,4-DB eq	0.002395
photochemical oxidation	kg C2H4	0.000556
acidification	kg SO2 eq	0.015277
eutrophication	kg PO4--- eq	0.001292

Table B14 Results of the impact assessment 1 kg Cassava-based PLA resin production in Thailand based on PURAC (with biogas system) by using Eco-indicator 95 V2.03 / Europe e

Impact category	Unit	Total
greenhouse	kg CO2	1.454755
ozone layer	kg CFC11	7.93E-08
acidification	kg SO2	0.014366
eutrophication	kg PO4	0.001272
heavy metals	kg Pb	5.38E-06
carcinogens	kg B(a)P	3.20E-08
winter smog	kg SPM	0.010269
summer smog	kg C2H4	0.000327
pesticides	kg act.subst	0
energy resources	MJ LHV	22.72889
solid waste	kg	0.001398

Table B15 Results of the impact assessment 1 kg sugarcane plantation by using CML 2 baseline 2000 V2.03 / World, 1995

Impact category	Unit	Total
Abiotic depletion	kg Sb eq	8.64E-05
Acidification	kg SO2 eq	7.93E-05
Eutrophication	kg PO4--- eq	9.33E-06
Global warming (GWP100)	kg CO2 eq	-0.17201
Ozone layer depletion (ODP)	kg CFC-11 eq	6.84E-10
Human toxicity	kg 1,4-DB eq	0.000684
Fresh water aquatic ecotox.	kg 1,4-DB eq	8.17E-05
Marine aquatic ecotoxicity	kg 1,4-DB eq	0.382739
Terrestrial ecotoxicity	kg 1,4-DB eq	1.13E-05
Photochemical oxidation	kg C2H4	2.28E-06

Table B16 Results of the impact assessment 1 kg sugarcane plantation by using Eco-indicator 95 V2.03 / Europe e

Impact category	Unit	Total
Greenhouse	kg CO2	-0.17314
Ozone layer	kg CFC11	8.9E-10
Acidification	kg SO2	8.39E-05
Eutrophication	kg PO4	9.14E-06
Heavy metals	kg Pb	1.32E-08
Carcinogens	kg B(a)P	6.32E-11
Pesticides	kg act.subst	0
Summer smog	kg C2H4	2.05E-06
Winter smog	kg SPM	3.56E-05
Energy resources	MJ LHV	0.182307
Solid waste	kg	0

Table B17 Results of the impact assessment 1 kg sugar production from sugarcane by using CML 2 baseline 2000 V2.03 / World, 1995

Impact category	Unit	Total
Abiotic depletion	kg Sb eq	0.000193
Acidification	kg SO2 eq	0.000393
Eutrophication	kg PO4--- eq	4.69E-05
Global warming (GWP100)	kg CO2 eq	-1.10114
Ozone layer depletion (ODP)	kg CFC-11 eq	4.33E-09
Human toxicity	kg 1,4-DB eq	0.005391
Fresh water aquatic ecotox.	kg 1,4-DB eq	0.000744
Marine aquatic ecotoxicity	kg 1,4-DB eq	2.693525
Terrestrial ecotoxicity	kg 1,4-DB eq	7.97E-05
Photochemical oxidation	kg C2H4	1.2E-05

Table B18 Results of the impact assessment 1 kg sugar production from sugarcane by using Eco-indicator 95 V2.03 / Europe e

Impact category	Unit	Total
Greenhouse	kg CO2	-1.10815
Ozone layer	kg CFC11	5.61E-09
Acidification	kg SO2	0.000414
Eutrophication	kg PO4	4.56E-05
Heavy metals	kg Pb	1.23E-07
Carcinogens	kg B(a)P	6.41E-10
Pesticides	kg act.subst	0
Summer smog	kg C2H4	1.08E-05
Winter smog	kg SPM	0.000166
Energy resources	MJ LHV	0.633174
Solid waste	kg	-4.6E-05

Table B19 Results of the impact assessment 1 kg succinic acid production by using CML 2 baseline 2000 V2.03 / World, 1995

Impact category	**Unit**	**Total**
Abiotic depletion	kg Sb eq	0.032299
Acidification	kg SO2 eq	0.023216
Eutrophication	kg PO4--- eq	0.000846
Global warming (GWP100)	kg CO2 eq	2.382442
Ozone layer depletion (ODP)	kg CFC-11 eq	3.66E-07
Human toxicity	kg 1,4-DB eq	1.250947
Fresh water aquatic ecotox.	kg 1,4-DB eq	0.124059
Marine aquatic ecotoxicity	kg 1,4-DB eq	573.4995
Terrestrial ecotoxicity	kg 1,4-DB eq	0.021214
Photochemical oxidation	kg C2H4	0.001012

Table B20 Results of the impact assessment 1 kg succinic acid production by using Eco-indicator 95 V2.03 / Europe e

Impact category	**Unit**	**Total**
Greenhouse	kg CO2	2.278024
Ozone layer	kg CFC11	3.61E-07
Acidification	kg SO2	0.020866
Eutrophication	kg PO4	0.000845
Heavy metals	kg Pb	2.98E-05
Carcinogens	kg B(a)P	2.47E-07
Pesticides	kg act.subst	0
Summer smog	kg C2H4	0.000569
Winter smog	kg SPM	0.017985
Energy resources	MJ LHV	63.88254
Solid waste	kg	0.011197

Table B21 Results of the impact assessment 1 kg PBS resin production by using CML 2 baseline 2000 V2.03 / World, 1995

Impact category	Unit	Total
Abiotic depletion	kg Sb eq	0.066295865
Acidification	kg SO2 eq	0.026698459
Eutrophication	kg PO4--- eq	0.00160897
Global warming (GWP100)	kg CO2 eq	5.383490678
Ozone layer depletion (ODP)	kg CFC-11 eq	5.6531E-07
Human toxicity	kg 1,4-DB eq	1.70210886
Fresh water aquatic ecotox.	kg 1,4-DB eq	0.237517268
Marine aquatic ecotoxicity	kg 1,4-DB eq	767.9451464
Terrestrial ecotoxicity	kg 1,4-DB eq	0.023881168
Photochemical oxidation	kg C2H4	0.001459353

Table B22 Results of the impact assessment 1 kg PBS resin production by using Eco-indicator 95 V2.03 / Europe e

Impact category	Unit	Total
Greenhouse	kg CO2	5.205678682
Ozone layer	kg CFC11	5.42868E-07
Acidification	kg SO2	0.025039145
Eutrophication	kg PO4	0.001607374
Heavy metals	kg Pb	4.0709E-05
Carcinogens	kg B(a)P	3.92342E-07
Pesticides	kg act.subst	0
Summer smog	kg C2H4	0.001652097
Winter smog	kg SPM	0.019794755
Energy resources	MJ LHV	130.3678819
Solid waste	kg	0.056527574

Table B23 Results of the impact assessment 1 kg HDPE resin production by using CML 2 baseline 2000 V2.03 / World, 1995

Impact category	Unit	Total
Abiotic depletion	kg Sb eq	0.033282667
Global warming (GWP100)	kg CO2 eq	1.921212
Ozone layer depletion (ODP)	kg CFC-11 eq	1.98E-10
Human toxicity	kg 1,4-DB eq	0.07747427
Fresh water aquatic ecotox.	kg 1,4-DB eq	0.02409699
Marine aquatic ecotoxicity	kg 1,4-DB eq	92.473122
Terrestrial ecotoxicity	kg 1,4-DB eq	0.000114479
Photochemical oxidation	kg C2H4	0.000618446
Acidification	kg SO2 eq	0.006516918
Eutrophication	kg PO4--- eq	0.000515856

Table B24 Results of the impact assessment 1 kg HDPE resin production by using Eco-indicator 95 V2.03 / Europe e

Impact category	Unit	Total
Greenhouse	kg CO2	1.73E+00
Ozone layer	kg CFC11	2.54E-10
Acidification	kg SO2	0.006406157
Eutrophication	kg PO4	0.000515852
Heavy metals	kg Pb	2.43E-05
Carcinogens	kg B(a)P	4.00E-09
Winter smog	kg SPM	0.004520741
Summer smog	kg C2H4	0.001957833
Pesticides	kg act.subst	0
Energy resources	MJ LHV	76.673994
Solid waste	kg	0

Table B25 Results of the impact assessment 1 kg LDPE resin production by using CML 2 baseline 2000 V2.03 / World, 1995

Impact category	Unit	Total
abiotic depletion	kg Sb eq	0.033107
global warming (GWP100)	kg CO2 eq	2.07433
ozone layer depletion (ODP)	kg CFC-11 eq	2.58E-10
human toxicity	kg 1,4-DB eq	0.107663
fresh water aquatic ecotox.	kg 1,4-DB eq	0.029438
marine aquatic ecotoxicity	kg 1,4-DB eq	129.063
terrestrial ecotoxicity	kg 1,4-DB eq	0.000163
photochemical oxidation	kg C2H4	0.000416
acidification	kg SO2 eq	0.007941
eutrophication	kg PO4--- eq	0.000624

Table B26 Results of the impact assessment 1 kg LDPE resin production by using Eco-indicator 95 V2.03 / Europe e

Impact category	Unit	Total
greenhouse	kg CO2	1.874338
ozone layer	kg CFC11	3.35E-10
acidification	kg SO2	0.007756
eutrophication	kg PO4	0.000624
heavy metals	kg Pb	3.36E-05
carcinogens	kg B(a)P	1.84E-09
winter smog	kg SPM	0.005509
summer smog	kg C2H4	0.002137
pesticides	kg act.subst	0
energy resources	MJ LHV	78.57551
solid waste	kg	0

Table B27 Results of the impact assessment 1 kg LLDPE resin production by using CML 2 baseline 2000 V2.03 / World, 1995

Impact category	Unit	Total
abiotic depletion	kg Sb eq	0.032725
global warming (GWP100)	kg CO2 eq	1.819984
ozone layer depletion (ODP)	kg CFC-11 eq	1.24E-10
human toxicity	kg 1,4-DB eq	0.04769
fresh water aquatic ecotox.	kg 1,4-DB eq	0.0149
marine aquatic ecotoxicity	kg 1,4-DB eq	64.80005
terrestrial ecotoxicity	kg 1,4-DB eq	6.90E-05
photochemical oxidation	kg C2H4	0.000321
acidification	kg SO2 eq	0.005713
eutrophication	kg PO4--- eq	0.000445

Table B28 Results of the impact assessment 1 kg LLDPE resin production by using Eco-indicator 95 V2.03 / Europe e

Impact category	Unit	Total
greenhouse	kg CO2	1.647735
ozone layer	kg CFC11	1.58E-10
acidification	kg SO2	0.005632
eutrophication	kg PO4	0.000445
heavy metals	kg Pb	1.43E-05
carcinogens	kg B(a)P	1.20E-09
winter smog	kg SPM	0.004313
summer smog	kg C2H4	0.001363
pesticides	kg act.subst	0
energy resources	MJ LHV	74.21346
solid waste	kg	0

Table B29 Results of the impact assessment 1 kg resin production (bioplastic and conventional plastic resins) by using CML 2 baseline 2000 V2.03 / World, 1995

Impact category	Unit	PLA without biogas	PLA with biogas	HDPE	LDPE	LLDPE	PBS
abiotic depletion	kg Sb eq	0.0141	0.0131	0.0333	0.0331	0.0327	0.0663
global warming (GWP100)	kg CO2 eq	1.8023	1.4730	1.9212	2.0743	1.8200	5.3835
ozone layer depletion (ODP)	kg CFC-11 eq	1.43E-07	6.93E-08	1.98E-10	2.58E-10	1.24E-10	5.65E-07
human toxicity	kg 1,4-DB eq	0.1913	0.1706	0.0775	0.1077	0.0477	1.7021
fresh water aquatic ecotox.	kg 1,4-DB eq	0.0668	0.0662	0.0241	0.0294	0.0149	0.2375
marine aquatic ecotoxicity	kg 1,4-DB eq	198.5460	188.3187	92.4731	129.0630	64.8000	767.9451
terrestrial ecotoxicity	kg 1,4-DB eq	0.0024	0.0024	0.0001	0.0002	0.0001	0.0239
photochemical oxidation	kg C2H4	0.0005	0.0006	0.0006	0.0004	0.0003	0.0015
acidification	kg SO2 eq	0.0150	0.0153	0.0065	0.0079	0.0057	0.0267
eutrophication	kg PO4--- eq	0.0063	0.0013	0.0005	0.0006	0.0004	0.0016

Table B30 Results of the impact assessment 1 kg resin production (bioplastic and conventional plastic resins) by using Eco-indicator 95 V2.03 / Europe e

Impact category	Unit	PLA without biogas	PLA with biogas	HDPE	LDPE	LLDPE	PBS
greenhouse	kg CO2	1.784027	1.454755	1.731814	1.874338	1.647735	5.205679
ozone layer	kg CFC11	1.78E-07	7.93E-08	2.54E-10	3.35E-10	1.58E-10	5.43E-07
acidification	kg SO2	0.013982	0.014366	0.006406	0.007756	0.005632	0.025039
eutrophication	kg PO4	0.006264	0.001272	0.000516	0.000624	0.000445	0.001607
heavy metals	kg Pb	5.24E-06	5.38E-06	2.43E-05	3.36E-05	1.43E-05	4.07E-05
carcinogens	kg B(a)P	4.30E-08	3.20E-08	4.00E-09	1.84E-09	1.20E-09	3.92E-07
winter smog	kg SPM	0.01034	0.010269	0.004521	0.005509	0.004313	0
summer smog	kg C2H4	0.000349	0.000327	0.001958	0.002137	0.001363	0.001652
pesticides	kg act.subst	0	0	0	0	0	0.019795
energy resources	MJ LHV	24.12874	22.72889	76.67399	78.57551	74.21346	130.3679
solid waste	kg	0.114438	0.001398	0	0	0	0.056528

Table B31 Results of the impact assessment 1 kg cassava-based PLA garbage bag without disposal phase by using CML 2 baseline 2000 V2.03 / World, 1995

Impact category	Unit	Total
abiotic depletion	kg Sb eq	0.020182
global warming (GWP100)	kg CO2 eq	2.3332
ozone layer depletion (ODP)	kg CFC-11 eq	2.33E-07
human toxicity	kg 1,4-DB eq	1.42109
fresh water aquatic ecotox.	kg 1,4-DB eq	0.09937
marine aquatic ecotoxicity	kg 1,4-DB eq	358.7911
terrestrial ecotoxicity	kg 1,4-DB eq	0.003373
photochemical oxidation	kg C2H4	0.00293
acidification	kg SO2 eq	0.124104
eutrophication	kg PO4--- eq	0.027992

Table B32 Results of the impact assessment 1 kg cassava-based PLA garbage bag without disposal phase by using Eco-indicator 95 V2.03 / Europe e

Impact category	Unit	Total
greenhouse	kg CO2	2.191508
ozone layer	kg CFC11	2.79E-07
acidification	kg SO2	0.162447
eutrophication	kg PO4	0.02797
heavy metals	kg Pb	1.23E-05
carcinogens	kg B(a)P	6.59E-08
winter smog	kg SPM	0.016706
summer smog	kg C2H4	0.021437
pesticides	kg act.subst	0
energy resources	MJ LHV	35.62266
solid waste	kg	0.020843

Table B33 Results of the impact assessment 1 kg PBS garbage bag without PBS resin and disposal phase by using CML 2 baseline 2000 V2.03 / World, 1995

Impact category	Unit	Total
abiotic depletion	kg Sb eq	0.005787
global warming (GWP100)	kg CO2 eq	0.712893
ozone layer depletion (ODP)	kg CFC-11 eq	1.57E-07
human toxicity	kg 1,4-DB eq	1.233391
fresh water aquatic ecotox.	kg 1,4-DB eq	0.026603
marine aquatic ecotoxicity	kg 1,4-DB eq	151.6406
terrestrial ecotoxicity	kg 1,4-DB eq	0.000739
photochemical oxidation	kg C2H4	0.002318
acidification	kg SO2 eq	0.1073
eutrophication	kg PO4--- eq	0.02657

Table B34 Results of the impact assessment 1 kg PBS garbage bag without PBS resin and disposal phase by using Eco-indicator 95 V2.03 / Europe e

Impact category	Unit	Total
greenhouse	kg CO2	0.591278
ozone layer	kg CFC11	1.92E-07
acidification	kg SO2	0.146645
eutrophication	kg PO4	0.02657
heavy metals	kg Pb	6.37E-06
carcinogens	kg B(a)P	3.07E-08
winter smog	kg SPM	0.00541
summer smog	kg C2H4	0.021078
pesticides	kg act.subst	0
energy resources	MJ LHV	10.62089
solid waste	kg	0.019305

Table B35 Results of the impact assessment 1 kg mixed PE garbage bag without disposal phase by using CML 2 baseline 2000 V2.03 / World, 1995

Impact category	Unit	Total
abiotic depletion	kg Sb eq	0.039948
global warming (GWP100)	kg CO2 eq	2.704281
ozone layer depletion (ODP)	kg CFC-11 eq	1.19E-08
human toxicity	kg 1,4-DB eq	1.03503
fresh water aquatic ecotox.	kg 1,4-DB eq	0.041599
marine aquatic ecotoxicity	kg 1,4-DB eq	215.0681
terrestrial ecotoxicity	kg 1,4-DB eq	0.000855
photochemical oxidation	kg C2H4	0.002702
acidification	kg SO2 eq	0.108505
eutrophication	kg PO4--- eq	0.025629

Table B36 Results of the impact assessment 1 kg mixed PE garbage bag without disposal phase by using Eco-indicator 95 V2.03 / Europe e

Impact category	Unit	Total
greenhouse	kg CO2	2.396835
ozone layer	kg CFC11	1.51E-08
acidification	kg SO2	0.145639
eutrophication	kg PO4	0.025629
heavy metals	kg Pb	3.10E-05
carcinogens	kg B(a)P	2.77E-08
winter smog	kg SPM	0.009918
summer smog	kg C2H4	0.021881
pesticides	kg act.subst	0
energy resources	MJ LHV	89.13035
solid waste	kg	0.015511

Table B37 Comparison of the impact assessment 1 kg garbage bag production without disposal phase by using CML 2 baseline 2000 V2.03 / World, 1995

Impact category	Unit	PE garbage bag	cassava-based PLA garbage bag
abiotic depletion	kg Sb eq	0.039948	0.020182
global warming (GWP100)	kg CO2 eq	2.704281	2.3332
ozone layer depletion (ODP)	kg CFC-11 eq	1.19E-08	2.33E-07
human toxicity	kg 1,4-DB eq	1.03503	1.42109
fresh water aquatic ecotox.	kg 1,4-DB eq	0.041599	0.09937
marine aquatic ecotoxicity	kg 1,4-DB eq	215.0681	358.7911
terrestrial ecotoxicity	kg 1,4-DB eq	0.000855	0.003373
photochemical oxidation	kg C2H4	0.002702	0.00293
acidification	kg SO2 eq	0.108505	0.124104
eutrophication	kg PO4--- eq	0.025629	0.027992

Table B38 Comparison of the impact assessment 1 kg garbage bag production without disposal phase by using Eco-indicator 95 V2.03 / Europe e

Impact category	Unit	PE garbage bag	cassava-based PLA garbage bag
greenhouse	kg CO2	2.396835	2.191508
ozone layer	kg CFC11	1.51E-08	2.79E-07
acidification	kg SO2	0.145639	0.162447
eutrophication	kg PO4	0.025629	0.02797
heavy metals	kg Pb	3.10E-05	1.23E-05
carcinogens	kg B(a)P	2.77E-08	6.59E-08
winter smog	kg SPM	0.009918	0.016706
summer smog	kg C2H4	0.021881	0.021437
pesticides	kg act.subst	0	0
energy resources	MJ LHV	89.13035	35.62266
solid waste	kg	0.015511	0.020843

Table B39 LCIA results of PLA landfill (without energy recovery) based on 1 kg of bioplastic waste by using CML 2 baseline 2000 V2.03 / World, 1995

Impact category	Unit	Total
abiotic depletion	kg Sb eq	0.000145
global warming (GWP100)	kg CO2 eq	13.82193
ozone layer depletion (ODP)	kg CFC-11 eq	5.32E-12
human toxicity	kg 1,4-DB eq	0.000842
fresh water aquatic ecotox.	kg 1,4-DB eq	7.40E-06
marine aquatic ecotoxicity	kg 1,4-DB eq	0.064517
terrestrial ecotoxicity	kg 1,4-DB eq	3.59E-06
photochemical oxidation	kg C2H4	0.003616
acidification	kg SO2 eq	0.000236
eutrophication	kg PO4--- eq	4.89E-05

Table B40 LCIA results of PLA landfill (without energy recovery) based on 1 kg of bioplastic waste by using Eco-indicator 95 V2.03 / Europe e

Impact category	Unit	Total
greenhouse	kg CO2	6.621421
ozone layer	kg CFC11	7.10E-12
acidification	kg SO2	0.000298
eutrophication	kg PO4	4.90E-05
heavy metals	kg Pb	3.04E-08
carcinogens	kg B(a)P	9.60E-10
winter smog	kg SPM	5.23E-05
summer smog	kg C2H4	0.004207
pesticides	kg act.subst	0
energy resources	MJ LHV	0.292348
solid waste	kg	4.20E-05

Table B41 LCIA results of PLA landfill (with energy recovery) based on 1 kg of bioplastic waste by using CML 2 baseline 2000 V2.03 / World, 1995

Impact category	Unit	Total
abiotic depletion	kg Sb eq	0.000233
global warming (GWP100)	kg CO2 eq	6.846981
ozone layer depletion (ODP)	kg CFC-11 eq	5.38E-12
human toxicity	kg 1,4-DB eq	0.000879
fresh water aquatic ecotox.	kg 1,4-DB eq	7.56E-06
marine aquatic ecotoxicity	kg 1,4-DB eq	0.065799
terrestrial ecotoxicity	kg 1,4-DB eq	3.79E-06
photochemical oxidation	kg C2H4	0.001816
acidification	kg SO2 eq	0.000262
eutrophication	kg PO4--- eq	5.17E-05

Table B42 LCIA results of PLA landfill (with energy recovery) based on 1 kg of bioplastic waste by using Eco-indicator 95 V2.03 / Europe e

Impact category	Unit	Total
greenhouse	kg CO2	3.246465
ozone layer	kg CFC11	7.18E-12
acidification	kg SO2	0.000326
eutrophication	kg PO4	5.19E-05
heavy metals	kg Pb	3.07E-08
carcinogens	kg B(a)P	9.67E-10
winter smog	kg SPM	6.71E-05
summer smog	kg C2H4	0.002108
pesticides	kg act.subst	0
energy resources	MJ LHV	0.421942
solid waste	kg	5.34E-05

Table B43 LCIA results of PBS landfill (without energy recovery) based on 1 kg of bioplastic waste by using CML 2 baseline 2000 V2.03 / World, 1995

Impact category	Unit	Total
abiotic depletion	kg Sb eq	0.000145
global warming (GWP100)	kg CO2 eq	15.41606
ozone layer depletion (ODP)	kg CFC-11 eq	5.32E-12
human toxicity	kg 1,4-DB eq	0.000842
fresh water aquatic ecotox.	kg 1,4-DB eq	7.40E-06
marine aquatic ecotoxicity	kg 1,4-DB eq	0.064517
terrestrial ecotoxicity	kg 1,4-DB eq	3.59E-06
photochemical oxidation	kg C2H4	0.004031
acidification	kg SO2 eq	0.000236
eutrophication	kg PO4--- eq	4.89E-05

Table B44 LCIA results of PBS landfill (without energy recovery) based on 1 kg of bioplastic waste by using Eco-indicator 95 V2.03 / Europe e

Impact category	Unit	Total
greenhouse	kg CO2	7.383831
ozone layer	kg CFC11	7.10E-12
acidification	kg SO2	0.000298
eutrophication	kg PO4	4.90E-05
heavy metals	kg Pb	3.04E-08
carcinogens	kg B(a)P	9.60E-10
winter smog	kg SPM	5.23E-05
summer smog	kg C2H4	0.004693
pesticides	kg act.subst	0
energy resources	MJ LHV	0.292348
solid waste	kg	4.20E-05

Table B45 LCIA results of PBS landfill (with energy recovery) based on 1 kg of bioplastic waste by using CML 2 baseline 2000 V2.03 / World, 1995

Impact category	Unit	Total
abiotic depletion	kg Sb eq	0.000233
global warming (GWP100)	kg CO2 eq	7.644046
ozone layer depletion (ODP)	kg CFC-11 eq	5.38E-12
human toxicity	kg 1,4-DB eq	0.000879
fresh water aquatic ecotox.	kg 1,4-DB eq	7.56E-06
marine aquatic ecotoxicity	kg 1,4-DB eq	0.065799
terrestrial ecotoxicity	kg 1,4-DB eq	3.79E-06
photochemical oxidation	kg C2H4	0.002024
acidification	kg SO2 eq	0.000262
eutrophication	kg PO4--- eq	5.17E-05

Table B46 LCIA results of PBS landfill (with energy recovery) based on 1 kg of bioplastic waste by using Eco-indicator 95 V2.03 / Europe e

Impact category	Unit	Total
greenhouse	kg CO2	3.62767
ozone layer	kg CFC11	7.18E-12
acidification	kg SO2	0.000326
eutrophication	kg PO4	5.19E-05
heavy metals	kg Pb	3.07E-08
carcinogens	kg B(a)P	9.67E-10
winter smog	kg SPM	6.71E-05
summer smog	kg C2H4	0.002351
pesticides	kg act.subst	0
energy resources	MJ LHV	0.421942
solid waste	kg	5.34E-05

Table B47 LCIA results of PE landfill (without energy recovery) based on 1 kg of plastic waste by using CML 2 baseline 2000 V2.03 / World, 1995

Impact category	Unit	Total
abiotic depletion	kg Sb eq	0.000145
global warming (GWP100)	kg CO2 eq	1.168197
ozone layer depletion (ODP)	kg CFC-11 eq	5.32E-12
human toxicity	kg 1,4-DB eq	0.000842
fresh water aquatic ecotox.	kg 1,4-DB eq	7.40E-06
marine aquatic ecotoxicity	kg 1,4-DB eq	0.064517
terrestrial ecotoxicity	kg 1,4-DB eq	3.59E-06
photochemical oxidation	kg C2H4	0.000273
acidification	kg SO2 eq	0.000236
eutrophication	kg PO4--- eq	4.89E-05

Table B48 LCIA results of PE landfill (without energy recovery) based on 1 kg of plastic waste by using Eco-indicator 95 V2.03 / Europe e

Impact category	Unit	Total
greenhouse	kg CO2	0.652983
ozone layer	kg CFC11	7.10E-12
acidification	kg SO2	0.000298
eutrophication	kg PO4	4.90E-05
heavy metals	kg Pb	3.04E-08
carcinogens	kg B(a)P	9.60E-10
winter smog	kg SPM	5.23E-05
summer smog	kg C2H4	0.000308
pesticides	kg act.subst	0
energy resources	MJ LHV	0.292348
solid waste	kg	4.20E-05

Table B49 LCIA results of PE landfill (with energy recovery) based on 1 kg of plastic waste by using CML 2 baseline 2000 V2.03 / World, 1995

Impact category	Unit	Total
abiotic depletion	kg Sb eq	-0.00196
global warming (GWP100)	kg CO2 eq	0.475372
ozone layer depletion (ODP)	kg CFC-11 eq	3.84E-12
human toxicity	kg 1,4-DB eq	-2.88E-05
fresh water aquatic ecotox.	kg 1,4-DB eq	3.66E-06
marine aquatic ecotoxicity	kg 1,4-DB eq	0.033654
terrestrial ecotoxicity	kg 1,4-DB eq	-1.13E-06
photochemical oxidation	kg C2H4	0.000135
acidification	kg SO2 eq	-0.00039
eutrophication	kg PO4--- eq	-2.02E-05

Table B50 LCIA results of PE landfill (with energy recovery) based on 1 kg of plastic waste by using Eco-indicator 95 V2.03 / Europe e

Impact category	Unit	Total
greenhouse	kg CO2	0.206292
ozone layer	kg CFC11	5.12E-12
acidification	kg SO2	-0.00037
eutrophication	kg PO4	-2.01E-05
heavy metals	kg Pb	2.22E-08
carcinogens	kg B(a)P	7.93E-10
winter smog	kg SPM	-0.0003
summer smog	kg C2H4	0.000151
pesticides	kg act.subst	0
energy resources	MJ LHV	-2.82701
solid waste	kg	-0.00023

Table B51 LCIA results of PLA incineration (with energy recovery) based on 1 kg of bioplastic waste by using CML 2 baseline 2000 V2.03 / World, 1995

Impact category	Unit	Total
abiotic depletion	kg Sb eq	-0.00899
global warming (GWP100)	kg CO2 eq	1.318154
ozone layer depletion (ODP)	kg CFC-11 eq	6.93E-11
human toxicity	kg 1,4-DB eq	0.023534
fresh water aquatic ecotox.	kg 1,4-DB eq	9.17E-05
marine aquatic ecotoxicity	kg 1,4-DB eq	0.394927
terrestrial ecotoxicity	kg 1,4-DB eq	-9.96E-06
photochemical oxidation	kg C2H4	0.000114
acidification	kg SO2 eq	0.002888
eutrophication	kg PO4--- eq	0.001099

Table B52 LCIA results of PLA incineration (with energy recovery) based on 1 kg of bioplastic waste by using Eco-indicator 95 V2.03 / Europe e

Impact category	Unit	Total
greenhouse	kg CO2	1.076544
ozone layer	kg CFC11	7.00E-11
acidification	kg SO2	0.004801
eutrophication	kg PO4	0.001099
heavy metals	kg Pb	8.46E-08
carcinogens	kg B(a)P	1.27E-10
winter smog	kg SPM	-0.00135
summer smog	kg C2H4	0.000631
pesticides	kg act.subst	0
energy resources	MJ LHV	-13.2858
solid waste	kg	-0.00017

Table B53 LCIA results of PBS incineration (with energy recovery) based on 1 kg of bioplastic waste by using CML 2 baseline 2000 V2.03 / World, 1995

Impact category	Unit	Total
abiotic depletion	kg Sb eq	-0.00899
global warming (GWP100)	kg CO2 eq	1.558154
ozone layer depletion (ODP)	kg CFC-11 eq	6.93E-11
human toxicity	kg 1,4-DB eq	0.023534
fresh water aquatic ecotox.	kg 1,4-DB eq	9.17E-05
marine aquatic ecotoxicity	kg 1,4-DB eq	0.394927
terrestrial ecotoxicity	kg 1,4-DB eq	-9.96E-06
photochemical oxidation	kg C2H4	0.000114
acidification	kg SO2 eq	0.002888
eutrophication	kg PO4--- eq	0.001099

Table B54 LCIA results of PBS incineration (with energy recovery) based on 1 kg of bioplastic waste by using Eco-indicator 95 V2.03 / Europe e

Impact category	Unit	Total
greenhouse	kg CO2	1.316544
ozone layer	kg CFC11	7.00E-11
acidification	kg SO2	0.004801
eutrophication	kg PO4	0.001099
heavy metals	kg Pb	8.46E-08
carcinogens	kg B(a)P	1.27E-10
winter smog	kg SPM	-0.00135
summer smog	kg C2H4	0.000631
pesticides	kg act.subst	0
energy resources	MJ LHV	-13.2858
solid waste	kg	-0.00017

Table B55 LCIA results of PE incineration (open burning) based on 1 kg of plastic waste by using CML 2 baseline 2000 V2.03 / World, 1995

Impact category	Unit	Total
abiotic depletion	kg Sb eq	0
global warming (GWP100)	kg CO2 eq	0.667302
ozone layer depletion (ODP)	kg CFC-11 eq	0
human toxicity	kg 1,4-DB eq	0.003611
fresh water aquatic ecotox.	kg 1,4-DB eq	0
marine aquatic ecotoxicity	kg 1,4-DB eq	0
terrestrial ecotoxicity	kg 1,4-DB eq	0
photochemical oxidation	kg C2H4	0.001198
acidification	kg SO2 eq	0.002073
eutrophication	kg PO4--- eq	0.000386

Table B56 LCIA results of PE incineration (open burning) based on 1 kg of plastic waste by using Eco-indicator 95 V2.03 / Europe e

Impact category	Unit	Total
greenhouse	kg CO2	0.52579
ozone layer	kg CFC11	0
acidification	kg SO2	0.002569
eutrophication	kg PO4	0.000386
heavy metals	kg Pb	0
carcinogens	kg B(a)P	0
winter smog	kg SPM	0.00049
summer smog	kg C2H4	4.50E-05
pesticides	kg act.subst	0
energy resources	MJ LHV	0
solid waste	kg	0

Table B57 LCIA results of PLA compost based on 1 kg of bioplastic waste by using CML 2 baseline 2000 V2.03 / World, 1995

Impact category	Unit	Total
abiotic depletion	kg Sb eq	-0.00328
global warming (GWP100)	kg CO2 eq	-1.17898
ozone layer depletion (ODP)	kg CFC-11 eq	8.83E-12
human toxicity	kg 1,4-DB eq	0.013658
fresh water aquatic ecotox.	kg 1,4-DB eq	9.60E-05
marine aquatic ecotoxicity	kg 1,4-DB eq	0.527546
terrestrial ecotoxicity	kg 1,4-DB eq	1.17E-05
photochemical oxidation	kg C2H4	-1.75E-05
acidification	kg SO2 eq	-0.00204
eutrophication	kg PO4--- eq	-0.00024

Table B58 LCIA results of PLA compost based on 1 kg of bioplastic waste by using Eco-indicator 95 V2.03 / Europe e

Impact category	Unit	Total
greenhouse	kg CO2	-1.09266
ozone layer	kg CFC11	1.18E-11
acidification	kg SO2	-2.05E-03
eutrophication	kg PO4	-0.00022
heavy metals	kg Pb	1.52E-07
carcinogens	kg B(a)P	1.83E-09
winter smog	kg SPM	-7.57E-04
summer smog	kg C2H4	5.05E-04
pesticides	kg act.subst	0
energy resources	MJ LHV	-6.42414
solid waste	kg	2.82E-05

Table B59 LCIA results of PBS compost based on 1 kg of bioplastic waste by using CML 2 baseline 2000 V2.03 / World, 1995

Impact category	Unit	Total
abiotic depletion	kg Sb eq	-0.00328
global warming (GWP100)	kg CO2 eq	-0.34398
ozone layer depletion (ODP)	kg CFC-11 eq	8.83E-12
human toxicity	kg 1,4-DB eq	0.013658
fresh water aquatic ecotox.	kg 1,4-DB eq	9.60E-05
marine aquatic ecotoxicity	kg 1,4-DB eq	0.527546
terrestrial ecotoxicity	kg 1,4-DB eq	1.17E-05
photochemical oxidation	kg C2H4	-1.75E-05
acidification	kg SO2 eq	-0.00204
eutrophication	kg PO4--- eq	-0.00024

Table B60 LCIA results of PBS compost based on 1 kg of bioplastic waste by using Eco-indicator 95 V2.03 / Europe e

Impact category	Unit	Total
greenhouse	kg CO2	-0.25766
ozone layer	kg CFC11	1.18E-11
acidification	kg SO2	-0.00205
eutrophication	kg PO4	-0.00022
heavy metals	kg Pb	1.52E-07
carcinogens	kg B(a)P	1.83E-09
winter smog	kg SPM	-0.00076
summer smog	kg C2H4	0.000505
pesticides	kg act.subst	0
energy resources	MJ LHV	-6.42414
solid waste	kg	2.82E-05

Table B61 LCIA results of PLA recycle based on 1 kg of bioplastic waste by using CML 2 baseline 2000 V2.03 / World, 1995

Impact category	Unit	Total
abiotic depletion	kg Sb eq	0.010692
global warming (GWP100)	kg CO2 eq	1.399935
ozone layer depletion (ODP)	kg CFC-11 eq	-5.08E-08
human toxicity	kg 1,4-DB eq	0.282073
fresh water aquatic ecotox.	kg 1,4-DB eq	-0.04631
marine aquatic ecotoxicity	kg 1,4-DB eq	-88.2713
terrestrial ecotoxicity	kg 1,4-DB eq	0.001422
photochemical oxidation	kg C2H4	0.001336
acidification	kg SO2 eq	0.005812
eutrophication	kg PO4--- eq	0.000588

Table B62 LCIA results of PLA recycle based on 1 kg of bioplastic waste by using Eco-indicator 95 V2.03 / Europe e

Impact category	Unit	Total
greenhouse	kg CO2	1.339919
ozone layer	kg CFC11	-5.71E-08
acidification	kg SO2	0.00709
eutrophication	kg PO4	0.000756
heavy metals	kg Pb	2.61E-05
carcinogens	kg B(a)P	9.44E-07
winter smog	kg SPM	0.003993
summer smog	kg C2H4	0.000997
pesticides	kg act.subst	0
energy resources	MJ LHV	22.83172
solid waste	kg	0.205581

Table B63 LCIA results of PE recycle based on 1 kg of plastic waste by using CML 2 baseline 2000 V2.03 / World, 1995

Impact category	Unit	Total
abiotic depletion	kg Sb eq	-0.00559
global warming (GWP100)	kg CO2 eq	1.017482
ozone layer depletion (ODP)	kg CFC-11 eq	5.22E-09
human toxicity	kg 1,4-DB eq	0.354453
fresh water aquatic ecotox.	kg 1,4-DB eq	-0.01249
marine aquatic ecotoxicity	kg 1,4-DB eq	-15.01
terrestrial ecotoxicity	kg 1,4-DB eq	0.003264
photochemical oxidation	kg C2H4	0.001344
acidification	kg SO2 eq	0.012717
eutrophication	kg PO4--- eq	0.001203

Table B64 LCIA results of PE recycle based on 1 kg of plastic waste by using Eco-indicator 95 V2.03 / Europe e

Impact category	Unit	Total
greenhouse	kg CO2	1.096668
ozone layer	kg CFC11	6.97E-09
acidification	kg SO2	0.013357
eutrophication	kg PO4	0.001355
heavy metals	kg Pb	9.90E-06
carcinogens	kg B(a)P	9.68E-07
winter smog	kg SPM	0.00849
summer smog	kg C2H4	-0.00031
pesticides	kg act.subst	0
energy resources	MJ LHV	-21.0136
solid waste	kg	0.206714

Table B65 LCIA results of comparison for all disposal of PLA waste based on 1 kg of bioplastic waste by using CML 2 baseline 2000 V2.03 / World, 1995

Impact category	Unit	landfill without energy recovery	landfill with energy recovery	incineration with energy recovery	compost	recycle
abiotic depletion	kg Sb eq	0.000145	0.000233	-0.00899	-0.00328	0.010692
global warming (GWP100)	kg CO2 eq	13.82193	6.846981	1.318154	-1.17898	1.399935
ozone layer depletion (ODP)	kg CFC-11 eq	5.32E-12	5.38E-12	6.93E-11	8.83E-12	-5.08E-08
human toxicity	kg 1,4-DB eq	0.000842	0.000879	0.023534	0.013658	0.282073
fresh water aquatic ecotox.	kg 1,4-DB eq	7.40E-06	7.56E-06	9.17E-05	9.60E-05	-0.04631
marine aquatic ecotoxicity	kg 1,4-DB eq	0.064517	0.065799	0.394927	0.527546	-88.2713
terrestrial ecotoxicity	kg 1,4-DB eq	3.59E-06	3.79E-06	-9.96E-06	1.17E-05	0.001422
photochemical oxidation	kg C2H4	0.003616	0.001816	0.000114	-1.75E-05	0.001336
acidification	kg SO2 eq	0.000236	0.000262	0.002888	-0.00204	0.005812
eutrophication	kg PO4--- eq	4.89E-05	5.17E-05	0.001099	-0.00024	0.000588

Table B66 LCIA results of comparison for all disposal of PLA waste based on 1 kg of bioplastic waste by using Eco-indicator 95 V2.03 / Europe e

Impact category	Unit	landfill without energy recovery	landfill with energy recovery	Incineration with energy recovery	compost	recycle
greenhouse	kg CO2	6.621421	3.246465	1.076544	-1.09266	1.339919
ozone layer	kg CFC11	7.10E-12	7.18E-12	7.00E-11	1.18E-11	-5.71E-08
acidification	kg SO2	0.000298	0.000326	0.004801	-0.00205	0.00709
eutrophication	kg PO4	4.90E-05	5.19E-05	0.001099	-0.00022	0.000756
heavy metals	kg Pb	3.04E-08	3.07E-08	8.46E-08	1.52E-07	2.61E-05
carcinogens	kg B(a)P	9.60E-10	9.67E-10	1.27E-10	1.83E-09	9.44E-07
winter smog	kg SPM	5.23E-05	6.71E-05	-0.00135	-0.00076	0.003993
summer smog	kg C2H4	0.004207	0.002108	0.000631	0.000505	0.000997
pesticides	kg act.subst	0	0	0	0	0
energy resources	MJ LHV	0.292348	0.421942	-13.2858	-6.42414	22.83172
solid waste	kg	4.20E-05	5.34E-05	-0.00017	2.82E-05	0.205581

Table B67 LCIA results of comparison for all disposal of PBS waste based on 1 kg of bioplastic waste by using CML 2 baseline 2000 V2.03 / World, 1995

Impact category	Unit	landfill without energy recovery	landfill with energy recovery	Incineration with energy recovery	compost
abiotic depletion	kg Sb eq	0.000145	0.000233	-0.00899	-0.00328
global warming (GWP100)	kg CO2 eq	15.41606	7.644046	1.558154	-0.34398
ozone layer depletion (ODP)	kg CFC-11 eq	5.32E-12	5.38E-12	6.93E-11	8.83E-12
human toxicity	kg 1,4-DB eq	0.000842	0.000879	0.023534	0.013658
fresh water aquatic ecotox.	kg 1,4-DB eq	7.40E-06	7.56E-06	9.17E-05	9.60E-05
marine aquatic ecotoxicity	kg 1,4-DB eq	0.064517	0.065799	0.394927	0.527546
terrestrial ecotoxicity	kg 1,4-DB eq	3.59E-06	3.79E-06	-9.96E-06	1.17E-05
photochemical oxidation	kg C2H4	0.004031	0.002024	0.000114	-1.75E-05
acidification	kg SO2 eq	0.000236	0.000262	0.002888	-0.00204
eutrophication	kg PO4--- eq	4.89E-05	5.17E-05	0.001099	-0.00024

Table B68 LCIA results of comparison for all disposal of PBS waste based on 1 kg of bioplastic waste by using Eco-indicator 95 V2.03 / Europe e

Impact category	Unit	landfill without energy recovery	landfill with energy recovery	Incineration with energy recovery	compost
greenhouse	kg CO2	7.383831	3.62767	1.316544	-0.25766
ozone layer	kg CFC11	7.10E-12	7.18E-12	7.00E-11	1.18E-11
acidification	kg SO2	0.000298	0.000326	0.004801	-0.00205
eutrophication	kg PO4	4.90E-05	5.19E-05	0.001099	-0.00022
heavy metals	kg Pb	3.04E-08	3.07E-08	8.46E-08	1.52E-07
carcinogens	kg B(a)P	9.60E-10	9.67E-10	1.27E-10	1.83E-09
winter smog	kg SPM	5.23E-05	6.71E-05	-0.00135	-0.00076
summer smog	kg C2H4	0.004693	0.002351	0.000631	0.000505
pesticides	kg act.subst	0	0	0	0
energy resources	MJ LHV	0.292348	0.421942	-13.2858	-6.42414
solid waste	kg	4.20E-05	5.34E-05	-0.00017	2.82E-05

Table B69 LCIA results of comparison for all disposal of PE waste based on 1 kg of plastic waste by using CML 2 baseline 2000 V2.03 / World, 1995

Impact category	Unit	landfill without energy recovery	Landfill with energy recovery	open burning	recycle
abiotic depletion	kg Sb eq	0.000145	-0.00196	0	-0.00559
global warming (GWP100)	kg CO2 eq	1.168197	0.475372	0.667302	1.017482
ozone layer depletion (ODP)	kg CFC-11 eq	5.32E-12	3.84E-12	0	5.22E-09
human toxicity	kg 1,4-DB eq	0.000842	-2.88E-05	0.003611	0.354453
fresh water aquatic ecotox.	kg 1,4-DB eq	7.40E-06	3.66E-06	0	-0.01249
marine aquatic ecotoxicity	kg 1,4-DB eq	0.064517	0.033654	0	-15.01
terrestrial ecotoxicity	kg 1,4-DB eq	3.59E-06	-1.13E-06	0	0.003264
photochemical oxidation	kg C2H4	0.000273	0.000135	0.001198	0.001344
acidification	kg SO2 eq	0.000236	-0.00039	0.002073	0.012717
eutrophication	kg PO4--- eq	4.89E-05	-2.02E-05	0.000386	0.001203

Table B70 LCIA results of comparison for all disposal of PE waste based on 1 kg of plastic waste by using Eco-indicator 95 V2.03 / Europe e

Impact category	Unit	landfill without energy recovery	landfill with energy recovery	open burning	recycle
greenhouse	kg CO2	0.652983	0.206292	0.52579	1.096668
ozone layer	kg CFC11	7.10E-12	5.12E-12	0	6.97E-09
acidification	kg SO2	0.000298	-0.00037	0.002569	0.013357
eutrophication	kg PO4	4.90E-05	-2.01E-05	0.000386	0.001355
heavy metals	kg Pb	3.04E-08	2.22E-08	0	9.90E-06
carcinogens	kg B(a)P	9.60E-10	7.93E-10	0	9.68E-07
winter smog	kg SPM	5.23E-05	-0.0003	0.00049	0.00849
summer smog	kg C2H4	0.000308	0.000151	4.50E-05	-0.00031
pesticides	kg act.subst	0	0	0	0
energy resources	MJ LHV	0.292348	-2.82701	0	-21.0136
solid waste	kg	4.20E-05	-0.00023	0	0.206714

Table B71 LCIA results of whole life cycle of PE garbage bag (old technology for waste management) based on 1 kg of garbage bag by using CML 2 baseline 2000 V2.03 / World, 1995

Impact category	Unit	Total
abiotic depletion	kg Sb eq	0.038891
global warming (GWP100)	kg CO2 eq	3.644416
ozone layer depletion (ODP)	kg CFC-11 eq	1.30E-08
human toxicity	kg 1,4-DB eq	1.121574
fresh water aquatic ecotox.	kg 1,4-DB eq	0.039177
marine aquatic ecotoxicity	kg 1,4-DB eq	212.4301
terrestrial ecotoxicity	kg 1,4-DB eq	0.001515
photochemical oxidation	kg C2H4	0.003597
acidification	kg SO2 eq	0.113183
eutrophication	kg PO4--- eq	0.026323

Table B72 LCIA results of whole life cycle of PE garbage bag (old technology for waste management) based on 1 kg of garbage bag by using Eco-indicator 95 V2.03 / Europe e

Impact category	Unit	Total
greenhouse	kg CO2	3.088327
ozone layer	kg CFC11	1.65E-08
acidification	kg SO2	0.151075
eutrophication	kg PO4	0.026353
heavy metals	kg Pb	3.31E-05
carcinogens	kg B(a)P	2.22E-07
winter smog	kg SPM	0.011948
summer smog	kg C2H4	0.022395
pesticides	kg act.subst	0
energy resources	MJ LHV	85.05236
solid waste	kg	0.056871

Table B73 LCIA results of whole life cycle of PLA garbage bag (new technology for waste management) based on 1 kg of garbage bag by using CML 2 baseline 2000 V2.03 / World, 1995

Impact category	Unit	Total
abiotic depletion	kg Sb eq	0.029614
global warming (GWP100)	kg CO2 eq	2.56E+00
ozone layer depletion (ODP)	kg CFC-11 eq	1.01E-07
human toxicity	kg 1,4-DB eq	1.277661
fresh water aquatic ecotox.	kg 1,4-DB eq	6.23E-02
marine aquatic ecotoxicity	kg 1,4-DB eq	2.70E+02
terrestrial ecotoxicity	kg 1,4-DB eq	0.002524
photochemical oxidation	kg C2H4	0.003563
acidification	kg SO2 eq	0.118211
eutrophication	kg PO4--- eq	0.027085

Table B74 LCIA results of whole life cycle of PLA garbage bag (new technology for waste management) based on 1 kg of garbage bag by using Eco-indicator 95 V2.03 / Europe e

Impact category	Unit	Total
greenhouse	kg CO2	2.307775
ozone layer	kg CFC11	1.22E-07
acidification	kg SO2	0.156457
eutrophication	kg PO4	0.027113
heavy metals	kg Pb	2.56E-05
carcinogens	kg B(a)P	2.37E-07
winter smog	kg SPM	0.014311
summer smog	kg C2H4	0.022188
pesticides	kg act.subst	0
energy resources	MJ LHV	60.96074
solid waste	kg	0.058998

Table B75 LCIA results of whole life cycle of PBS garbage bag without PBS resin (new technology for waste management) based on 1 kg of garbage bag by using CML 2 baseline 2000 V2.03 / World, 1995

Impact category	Unit	Total
abiotic depletion	kg Sb eq	0.023856
global warming (GWP100)	kg CO2 eq	2.242382
ozone layer depletion (ODP)	kg CFC-11 eq	7.10E-08
human toxicity	kg 1,4-DB eq	1.202582
fresh water aquatic ecotox.	kg 1,4-DB eq	0.033196
marine aquatic ecotoxicity	kg 1,4-DB eq	187.1599
terrestrial ecotoxicity	kg 1,4-DB eq	0.00147
photochemical oxidation	kg C2H4	0.003318
acidification	kg SO2 eq	0.11149
eutrophication	kg PO4--- eq	0.026516

Table B76 LCIA results of whole life cycle of PBS garbage bag without PBS resin (new technology for waste management) based on 1 kg of garbage bag by using Eco-indicator 95 V2.03 / Europe e

Impact category	Unit	Total
greenhouse	kg CO2	2.001683
ozone layer	kg CFC11	8.71E-08
acidification	kg SO2	0.150136
eutrophication	kg PO4	0.026553
heavy metals	kg Pb	2.33E-05
carcinogens	kg B(a)P	2.23E-07
winter smog	kg SPM	0.009792
summer smog	kg C2H4	0.022044
pesticides	kg act.subst	0
energy resources	MJ LHV	50.96003
solid waste	kg	0.058383

Appendix C Calculation

C1. Calculation of Methane Content from Landfill (45%)

Calculate methane emission rate from landfill by using First-order decay reaction

$$Q = L_0 R (e^{kc} - e^{-kt})$$

Where

Q = Methane content in the present (m^3/year)

L_0 = Methane generation potential of the waste (m^3/ton of waste) (170)

R = A certain amount of waste (ton/year) (2,431)

K = the rate constant of biodegradation (per year) (0.02)

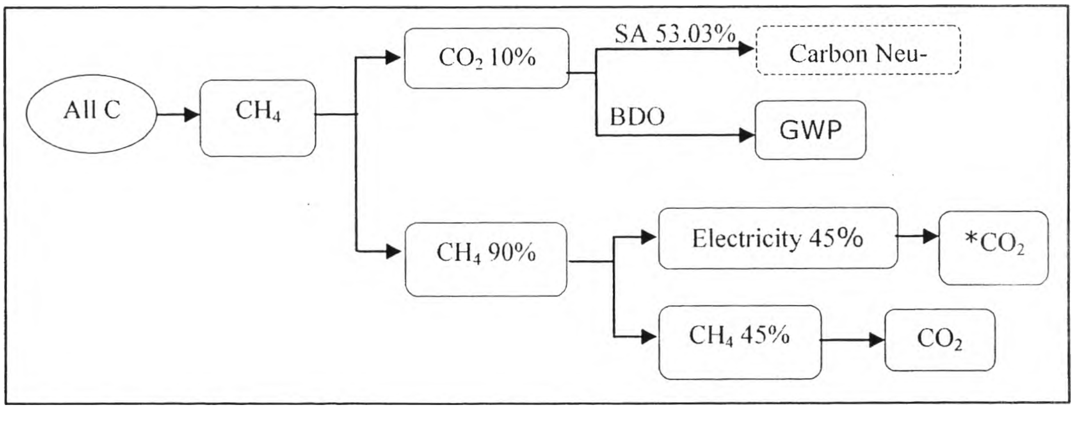
C = Time (year) (1)

T = The time elapsed since landfilling of the waste (year) (6)

Source: The default parameters are provided by US.EPA. For regulations under the Clean Air Act (CAA), a k of 0.02 yr^{-1} for dry landfill and an L_0 of 170 m^3/kg are used (Reinhart and et. al., 2005).

From this equation, methane content can be calculated 14,058,618.86 m^3/yr but it can be collected only 700 m^3/hr. When it is expressed in term of annual, it shows 6,132,000 m^3/yr. Therefore, it is calculated for being percentage about 45%.

C2. Emission Calculation of PBS Landfill



PBS compositions are divided into 2 major composition as following

- SA (Bio-base) 53.03%
- BDO (petroleum-base) 46.97%

Chemical formula: $C_8H_{12}O_4$ $(MW = 172)$

PBS 1 mol: 172 g

PBS 1 kg: $(1000/172) = 5.81$ mol

Assume PBS is biodegradable 100%

PBS 1 mol transforms to CH_4 100% = CH_4 8 mol

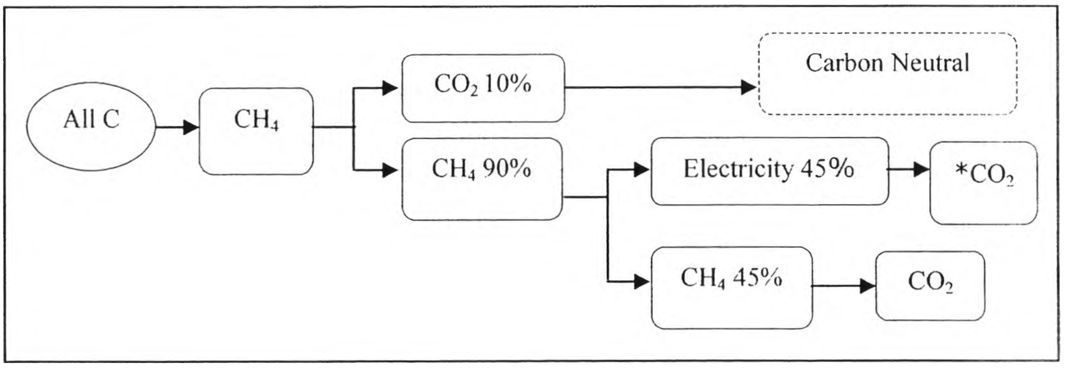
But assumption for Carbon content in PBS, which can be transformed to CH_4 90%

So PBS 1 mol has CH_4 7.2 mol

So PBS 5.81 mol can emit CH_4 (5.81 x 7.2) = 41.832 mol or $(41.832 \times 16) = 669$ g

<u>Conclusion</u>: PBS 1 kg is biodegraded, it can emit CH_4 669 g

C3. Emission Calculation of PLA Landfill



Chemical formula: $C_3H_4O_2$ $(MW = 72)$

PLA 1 mol: 72 g

PLA 1 kg: (1000/72) = 13.89 mol

Assume PLA is biodegradable 100%

PLA 1 mol transforms to CH_4 100% = CH_4 3 mol

but assumption for Carbon content in PLA, which can be transformed to CH_4 90%

So PLA 1 mol has CH_4 2.7 mol

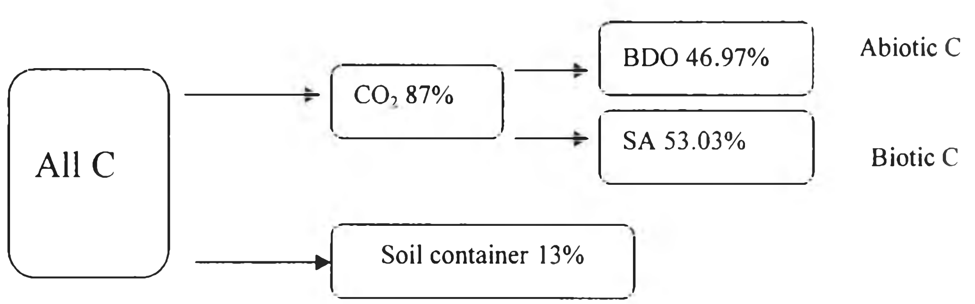
So PLA 13.89 mol can emit CH_4 (13.89 x 2.7) = 37.50 mol or (37.5 x 16) = 600 g

Conclusion: PLA 1 kg is biodegraded, it can emit CH_4 600 g

C4. Emission calculation of PBS and PLA Composting

PBS

Assumption



Chemical formula: $C_8H_{12}O_4$ (MW = 172)

PBS 1 mol: 172 g

PBS 1 kg: (1000/172) = 5.81 mol

Assume PBS is biodegradable 100%

PBS 1 mol transforms to CO_2 100% = CO_2 8 mol

but assumption for Carbon content in PBS, which can be transformed to CO_2 87%

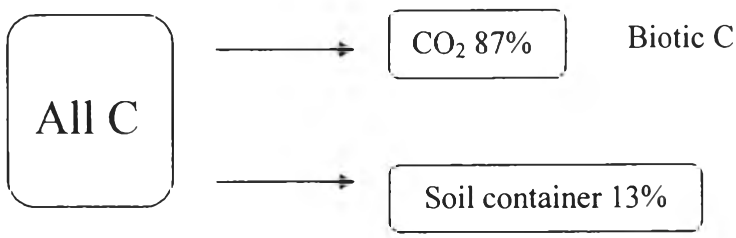
So PBS 1 mol has CO_2 6.96 mol

So PBS 5.81 mol can emit CO_2 (5.81 x 6.96) = 40.437 mol or (40.437 x 44) = 1,779.25 g

Conclusion: PBS 1 kg is biodegraded, it can emit CO_2 1,779.25 g → BDO 835.71 g CO_2 → SA 943.53 g CO_2

PLA

Assumption



Chemical formula: $C_3H_4O_2$ (MW = 72)

PLA 1 mol: 72 g

PLA 1 kg: (1000/72) = 13.89 mol

Assume PLA is biodegradable 100%

PLA 1 mol transforms to CO_2 100% = CO_2 3 mol

but assumption for Carbon content in PLA, which can be transformed to CO_2 87%

So PLA 1 mol has CO_2 2.61 mol

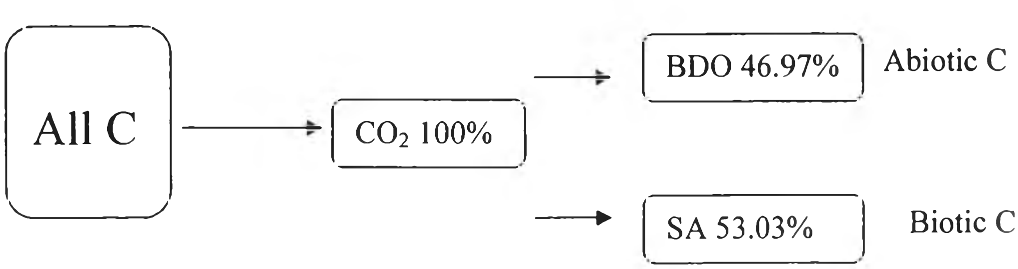
So PLA 13.89 mol can emit CO_2 (13.89 x 2.61) = 36.25 mol or (36.25 x 44) = 1,595.13 g

Conclusion: PLA 1 kg is biodegraded, it can emit CO_2 1,595.13 g

C5. Emission Calculation of PBS and PLA Incineration

PBS

Assumption



Chemical formula: $C_8H_{12}O_4$ (MW = 172)

PBS 1 mol:172 g

PBS 1 kg: (1000/172) = 5.81 mol

Assume PBS is biodegradable 100%

PBS 1 mol transforms to CH_4 100% = CO_2 8 mol

but assumption for Carbon content in PBS, which can be transformed to CO_2 100%

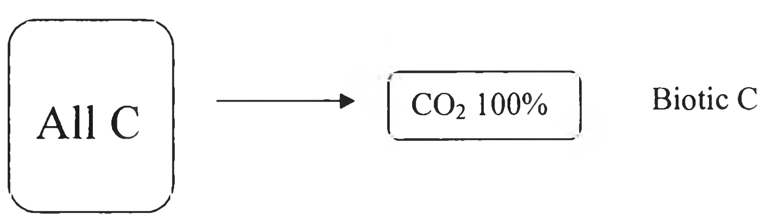
So PBS 1 mol has CO_2 8 mol

So PBS 5.81 mol can emit CO_2 (5.81 x 8) = 46.48 mol or (46.48 x 44) = 2,045.12 g

<u>Conclusion</u>: PBS 1 kg is biodegraded, it can emit CO_2 2,045.12 g → BDO 960.59 g CO_2 → SA 1,084.53 g CO_2

<u>PLA</u>

<u>Assumption</u>



Chemical formula: $C_3H_4O_2$ (MW = 72)

PLA 1 mol: 72 g

PLA 1 kg: (1000/72) = 13.89 mol

Assume PLA is biodegradable 100%

PLA 1 mol transforms to CO_2 100% = CO_2 3 mol

but assumption for Carbon content in PLA, which can be transformed to CO_2 100%

So PLA 1 mol has CO_2 3 mol

So PLA 13.89 mol can emit CO_2 (13.89 x 3) = 41.67 mol or (41.67 x 44) = 1,833 g

<u>Conclusion</u>: PLA 1 kg is biodegraded, it can emit CO_2 1,833 g

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Proceedings:

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