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APPENDICES

Appendix A Life Cycle Inventory (LCI)

Table A1 Results of the inventory analysis of sugarcane cultivation in Thailand (MTEC, 2012)

Inventory of sugarcane cultivation					
Input			Output		
Type	Amount	Unit	Type	Amount	Unit
Chemical			Product		
Fertilizer (N)	1.78E-03	kg	Sugarcane	1	kg
Fertilizer (P)	8.29E-04	kg			
Fertilizer (K)	7.39E-04	kg	Co-product		
Paraquat	1.29E-05	kg	Cane trash - 0% burning	0.199	kg
Atrazine	4.50E-05	kg			
Ametryne	3.21E-05	kg	Air emissions		
2,4-D	1.29E-05	kg	Carbon monoxide	8.84E-07	kg
			Nitrogen oxide	1.04E-06	kg
Fuel/Electricity			PM10	1.72E-07	kg
Diesel	1.21E-03	kg	sulfur dioxide	3.38E-07	kg
			Methane	4.31E-09	kg
			Nitrogen dioxide	1.92E-08	kg
			Carbon dioxide	3.96E-03	kg

Table A2 Results of the inventory analysis of sugarcane ethanol conversion (Ometto et al., 2010)

Inventory of sugarcane ethanol conversion					
Input			Output		
Type	Quantity	Unit	Type	Quantity	Unit
Raw material			Product		
Sugarcane	14.706	kg	Ethanol (96%)	1	kg
Water	118.613	kg	Co-product		
Chemical			Vinasse	20.625	kg
Sulfuric acid	1.13E-02	kg	Bagasse	4.265	kg
Fuel/Electricity			Water emissions		
Steam	2.75	kg	Sulfuric acid	1.13E-02	kg
Electricity	0.344	kWh			

Table A3 Results of the inventory analysis of ethanol dehydration

Inventory of ethanol dehydration					
Input			Output		
Type	Quantity	Unit	Type	Quantity	Unit
Raw material			Product		
Ethanol (96%)	1.04	kg	Ethanol (99.5%)	1	kg
Make up cooling water	2.79	kg	Air emission		
Fuel/Electricity			Water	4.12E-02	kg
Electricity	1.10E-02	kWh			

Table A4 Results of the inventory analysis of sugar milling in Thailand (MTEC, 2012)

Inventory of sugar milling					
Input			Output		
Type	Amount	Unit	Type	Amount	Unit
Raw material			Product		
Sugarcane plant	1000	kg	Raw sugar	109.57	kg
Energy			Co-product		
Steam	450	kg	Molasses	36.28	kg
Electricity	17.37	kWh	Bagasse	290	kg
Chemical					
Lime	2.11	kg			
Sodium chloride	0.78	kg			
Hydrochloric acid	4.50E-04	kg			
SiO ₂	2.31E-03	kg			
Biocide	3.66E-03	kg			
Aluminium sulfate	3.73E-03	kg			
Caustic soda flake	1.16E-03	kg			
Flocculants	0.0386	kg			
Miscellaneous	5.72E-03	kg			

Table A5 Results of the inventory analysis of molasses ethanol conversion (KAPI, 2008)

Inventory of molasses ethanol conversion					
Input		Output			
Type	Quantity	Unit	Type	Quantity	Unit
Raw material			Product		
Molasses	4500	kg	Ethanol	1000	kg
Water	15.838	m ³	Co-product		
Fuel/Electricity			Biogas recovery	208.75	m ³
Stream	3112.5	kg	Yeast residue	11.088	kg
Electricity	362.5	kWh			

Table A6 Results of the inventory analysis of cassava cultivation (Khongsiri, 2009).

Inventory of cassava cultivation					
Input			Output		
Type	Quantity	Unit	Type	Quantity	Unit
Raw material			Products		
Cassava stems	345	piece	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			
P-fertilizer	0.7	kg	Air emissions		
K-fertilizer	1.336	kg	Carbon dioxide	8.315	kg
Alachlor	0.096	kg	Nitrogen oxide	0.171	kg
Paraquat	0.15	kg	Sulfur dioxide	0.011	kg
Glyphosate	0.292	kg	Nitrous oxide	0.044	kg
Zinc	0.086	kg	Ammonia	0.264	kg
			Volatile organic compound	0.058	kg
Fuel					
Diesel	2.475	kg			

Table A7 Results of the inventory analysis of cassava chips production (Silalertruksa and Gheewala, 2011)

Inventory of cassava chips production					
Input			Output		
Type	Quantity	Unit	Type	Quantity	Unit
Raw material			Product		
Cassava roots	2100	kg	Cassava chips	1000	kg
			Rhizome	11.59	kg
Fuel/Electricity			Sand	8.26	kg
Diesel	11.0552	kg			
			Air emissions		
			Carbon monoxide	0.00804882	kg
			Nitrogen oxide	0.0094692	kg
			PM10	0.00156242	kg
			sulfur dioxide	0.00307749	kg
			Methane	3.9297E-05	kg
			Nitrogen dioxide	0.00017518	kg
			Carbon dioxide	36.077652	kg

Table A8 Results of the inventory analysis of cassava ethanol conversion (KAPI, 2008)

Inventory of cassava ethanol conversion					
Input			Output		
Type	Quantity	Unit	Type	Quantity	Unit
Raw material			Product		
Cassava chips	3083.75	kg	Ethanol	1000	kg
Water	10.9375	m ³	Co-product		
Fuel/Electricity			Biogas recovery	100	m ³
Electricity	262.5	kWh	DDGS production	250	kg
Steam	3375	kg	Yeast residue	11.0875	kg
			Carbon dioxide	916.67	kg

Table A9 Results of the inventory analysis of one ton of cassava starch with biogas production line (MTEC, 2012)

Inventory 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	kg
Sulfur	0.554	kg			
Water	12.665	m ³	By products		
Fuel/Electricity			Cassava peel	248.6	kg
Electricity	201.775	kWh	Rhizome	24.836	kg
Fuel oil	1.189	kg	Cassava residue	460.47	kg
			Sand	17.71	kg
			Biogas	79.492	m ³
			Air emissions		
			Carbon monoxide	0.0007569	kg
			Nitrogen oxide	0.0025735	kg
			PM10	0.0002927	kg
			sulfur dioxide	0.0075691	kg
			Methane	0.0001564	kg
			Nitrogen dioxide	1.716E-05	kg
			Carbon dioxide	3.9561028	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 A10 Results of the inventory analysis of cassava sugar production (MTEC, 2012)

Inventory of sugar from cassava sugar production					
Input			Output		
Item	Quantity	Unit	Item	Quantity	Unit
Raw material			Product		
cassava starch	1050	kg	Sugar(D-glucose)	1000	kg
Sulfuric acid (100%)	1.207	kg	Air emissions		
Sodium hydroxide	0.756	kg	Carbon monoxide	0.003979	kg
Water	27	m ³	Nitrogen oxide	0.0135286	kg
Fuel/Electricity			PM10	0.0015385	kg
Fuel oil	6.250457	kg	sulfur dioxide	0.0397899	kg
Electricity	144	kWh	Methane	0.0008223	kg
			Nitrogen dioxide	9.019E-05	kg
			Carbon dioxide	20.796847	kg
			Water emissions		
			Waste water	6.89	m ³

Table A11 Results of the inventory analysis of PLA resin production (Groot and Boren, 2010)

Inventory of PLA resin production					
Input			Output		
Type	Quantity	Unit	Type	Quantity	Unit
Raw material			Product		
Sugar	1000	kg	PLLA resin	742.5393	kg
Lime	381.5858	kg	Air emissions		
Sulfuric acid	478.8844	kg	Carbon monoxide	0.0113748	kg
(NH ₄) ₂ SO ₄	22.27618	kg	Nitrogen oxide	0.0133821	kg
Ammonia	7.625879	kg	PM10	0.002208	kg
phosphoric acid	14.6503	kg	sulfur dioxide	0.0043492	kg
Fuel/Electricity			Methane	5.554E-05	kg
Diesel for inbound transportation	15.62347	kg	Nitrogen dioxide	0.0002476	kg
Electricity	807.3957	kWh	Carbon dioxide	50.985793	kg
Steam	483.7919	kg	Water emissions		
			Waste water	0.059403	kg

Table A12 Results of the inventory analysis of electrical energy cogeneration

Inventory of electrical energy cogeneration					
Input			Output		
Type	Quantity	Unit	Type	Quantity	Unit
Raw material			Product		
Bagasse	27815	kg	Electrical energy	6033.448	kWh
Water	108000	kg	Steam	60000	kg
Fuel			Air emissions		
Diesel	387	kg	Carbon monoxide	108.9553	kg
			Nitrogen oxide	32.90117	kg
			PM10	171.0623	kg
			PM2.5	97.63065	kg
			Polycyclic hydrocarbons	0.013908	kg
			Sulfur dioxide	12.3896	kg
			Carbon dioxide	1374.856	

Table A13 Results of The inventory data of feedstocks transportation for 1 ton-kilometer (tkm) for 10-wheel truck at full load 16 tons (MTEC, 2012)

Inventory of feedstocks transportation					
Input			Output		
Type	Amount	Unit	Type	Amount	Unit
Fuel Diesel	1.51E-02	kg	Emission to Air		
			Carbon dioxide	47.37	g
			Carbon monoxide	1.62E-01	g
			Nitrogen oxides	4.88E-01	g
			Particulate matter	3.66E-02	g
			Hydrocarbons	4.24E-02	g
			Methane	1.00E-03	g
			Benzene	8.05E-04	g
			Toluene	3.39E-04	g
			Xylene	3.39E-04	g
			Non – methane volatile organic compounds	8.09E-02	g
			Sulfur oxides	1.02E-02	g
			Nitrous Oxide	1.80E-03	g
			Cadmium	1.46E-07	g
			Copper	2.48E-05	g
			Chromium	7.29E-07	g
			Nickel	1.02E-06	g
			Selenium	1.46E-07	g
			Zinc	1.46E-05	g
			Lead	1.60E-09	g
Mercury	2.91E-10	g			

Appendix B Life Cycle Impact Assessment (LCIA)

Table B1 Results of the impact assessment 1 kg sugarcane by using CML 2 baseline 2000 V2.03 / World, 1990

Impact category	Unit	Total
abiotic depletion	kg Sb eq	8.48E-05
global warming (GWP100)	kg CO2 eq	0.020016
ozone layer depletion (ODP)	kg CFC-11 eq	1.19E-10
human toxicity	kg 1,4-DB eq	0.000401
fresh water aquatic ecotox.	kg 1,4-DB eq	4.58E-05
marine aquatic ecotoxicity	kg 1,4-DB eq	0.287016
terrestrial ecotoxicity	kg 1,4-DB eq	8.74E-06
photochemical oxidation	kg C2H4	2.10E-06
acidification	kg SO2 eq	7.88E-05
eutrophication	kg PO4--- eq	9.28E-06

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

Impact category	Unit	Total
greenhouse	kg CO2	1.89E-02
ozone layer	kg CFC11	1.39E-10
acidification	kg SO2	8.39E-05
eutrophication	kg PO4	9.09E-06
heavy metals	kg Pb	8.31E-09
carcinogens	kg B(a)P	3.73E-11
winter smog	kg SPM	3.48E-05
summer smog	kg C2H4	2.26E-06
pesticides	kg act.subst	0.00E+00
energy resources	MJ LHV	1.74E-01
solid waste	kg	4.75E-06

Table B3 Results of the impact assessment 1 kg sugarcane based ethanol (96%) by using CML 2 baseline 2000 V2.03 / World, 1990

Impact category	Unit	Total
abiotic depletion	kg Sb eq	-0.01317
global warming (GWP100)	kg CO2 eq	-0.79663
ozone layer depletion (ODP)	kg CFC-11 eq	-1.83E-07
human toxicity	kg 1,4-DB eq	-0.35669
fresh water aquatic ecotox.	kg 1,4-DB eq	-0.0279
marine aquatic ecotoxicity	kg 1,4-DB eq	-261.924
terrestrial ecotoxicity	kg 1,4-DB eq	-0.008
photochemical oxidation	kg C2H4	3.66E-04
acidification	kg SO2 eq	0.001653
eutrophication	kg PO4--- eq	4.87E-04

Table B4 Results of the impact assessment 1 kg sugarcane based ethanol (96%) by using Eco-indicator 95 V2.03 / Europe e

Impact category	Unit	Total
greenhouse	kg CO2	-0.80202
ozone layer	kg CFC11	-1.71E-07
acidification	kg SO2	2.49E-03
eutrophication	kg PO4	0.000484
heavy metals	kg Pb	-7.90E-06
carcinogens	kg B(a)P	-1.02E-07
winter smog	kg SPM	0.040577
summer smog	kg C2H4	-4.06E-05
pesticides	kg act.subst	0
energy resources	MJ LHV	-25.548955
solid waste	kg	-1.21E-04

Table B5 Results of the impact assessment 1 kg sugarcane based ethanol (99.5%) by using CML 2 baseline 2000 V2.03 / World, 1990

Impact category	Unit	Total
abiotic depletion	kg Sb eq	-0.01363
global warming (GWP100)	kg CO2 eq	-0.82073
ozone layer depletion (ODP)	kg CFC-11 eq	-1.89E-07
human toxicity	kg 1,4-DB eq	-0.37072
fresh water aquatic ecotox.	kg 1,4-DB eq	-0.02894
marine aquatic ecotoxicity	kg 1,4-DB eq	-271.042
terrestrial ecotoxicity	kg 1,4-DB eq	-0.00829
photochemical oxidation	kg C2H4	3.82E-04
acidification	kg SO2 eq	1.75E-03
eutrophication	kg PO4--- eq	5.10E-04

Table B6 Results of the impact assessment 1 kg sugarcane based ethanol (99.5%) by using Eco-indicator 95 V2.03 / Europe e

Impact category	Unit	Total
greenhouse	kg CO2	-0.82638
ozone layer	kg CFC11	-1.76E-07
acidification	kg SO2	2.63E-03
eutrophication	kg PO4	0.000507
heavy metals	kg Pb	-8.21E-06
carcinogens	kg B(a)P	-1.07E-07
winter smog	kg SPM	0.042269
summer smog	kg C2H4	-4.14E-05
pesticides	kg act.subst	0.00E+00
energy resources	MJ LHV	-26.465001
solid waste	kg	-1.17E-04

Table B7 Results of the impact assessment 1 kg molasses by using CML 2 baseline 2000 V2.03 / World, 1990

Impact category	Unit	Total
abiotic depletion	kg Sb eq	-2.97E-03
global warming (GWP100)	kg CO2 eq	-2.17E-01
ozone layer depletion (ODP)	kg CFC-11 eq	-3.29E-08
human toxicity	kg 1,4-DB eq	-0.05248
fresh water aquatic ecotox.	kg 1,4-DB eq	-4.70E-03
marine aquatic ecotoxicity	kg 1,4-DB eq	-46.766265
terrestrial ecotoxicity	kg 1,4-DB eq	-1.44E-03
photochemical oxidation	kg C2H4	2.22E-04
acidification	kg SO2 eq	0.001649
eutrophication	kg PO4--- eq	2.79E-04

Table B8 Results of the impact assessment 1 kg molasses by using Eco-indicator 95 V2.03 / Europe e

Impact category	Unit	Total
greenhouse	kg CO2	-0.22947
ozone layer	kg CFC11	-3.03E-08
acidification	kg SO2	1.98E-03
eutrophication	kg PO4	2.78E-04
heavy metals	kg Pb	-1.39E-06
carcinogens	kg B(a)P	-1.87E-08
winter smog	kg SPM	0.019577
summer smog	kg C2H4	4.89E-05
pesticides	kg act.subst	0
energy resources	MJ LHV	-5.0721688
solid waste	kg	-8.98E-05

Table B9 Results of the impact assessment 1 kg molasses based ethanol (99.5%) by using CML 2 baseline 2000 V2.03 / World, 1990

Impact category	Unit	Total
abiotic depletion	kg Sb eq	-0.00667
global warming (GWP100)	kg CO2 eq	-0.02245
ozone layer depletion (ODP)	kg CFC-11 eq	-4.67E-08
human toxicity	kg 1,4-DB eq	-3.77E-02
fresh water aquatic ecotox.	kg 1,4-DB eq	-0.00669
marine aquatic ecotoxicity	kg 1,4-DB eq	-71.741
terrestrial ecotoxicity	kg 1,4-DB eq	-0.00236
photochemical oxidation	kg C2H4	0.00109
acidification	kg SO2 eq	0.0094
eutrophication	kg PO4--- eq	4.49E-02

Table B10 Results of the impact assessment 1 kg molasses based ethanol (99.5%) by using Eco-indicator 95 V2.03 / Europe e

Impact category	Unit	Total
greenhouse	kg CO2	-0.09623
ozone layer	kg CFC11	-4.06E-08
acidification	kg SO2	1.08E-02
eutrophication	kg PO4	4.49E-02
heavy metals	kg Pb	-2.28E-06
carcinogens	kg B(a)P	-3.40E-08
winter smog	kg SPM	0.088945
summer smog	kg C2H4	3.40E-04
pesticides	kg act.subst	0.00E+00
energy resources	MJ LHV	-9.1783667
solid waste	kg	-3.10E-04

Table B11 Results of the impact assessment 1 kg cassava roots by using CML 2 baseline 2000 V2.03 / World, 1990

Impact category	Unit	Total
abiotic depletion	kg Sb eq	8.38E-05
global warming (GWP100)	kg CO2 eq	0.019134
ozone layer depletion (ODP)	kg CFC-11 eq	7.38E-10
human toxicity	kg 1,4-DB eq	0.002449
fresh water aquatic ecotox.	kg 1,4-DB eq	3.28E-04
marine aquatic ecotoxicity	kg 1,4-DB eq	2.497483
terrestrial ecotoxicity	kg 1,4-DB eq	7.75E-05
photochemical oxidation	kg C2H4	2.78E-06
acidification	kg SO2 eq	4.06E-04
eutrophication	kg PO4--- eq	7.99E-05

Table B12 Results of the impact assessment 1 kg cassava roots by using Eco-indicator 95 V2.03 / Europe e

Impact category	Unit	Total
greenhouse	kg CO2	1.84E-02
ozone layer	kg CFC11	8.62E-10
acidification	kg SO2	4.74E-04
eutrophication	kg PO4	7.64E-05
heavy metals	kg Pb	6.31E-08
carcinogens	kg B(a)P	2.65E-10
winter smog	kg SPM	4.85E-05
summer smog	kg C2H4	1.65E-05
pesticides	kg act.subst	0.00E+00
energy resources	MJ LHV	1.91E-01
solid waste	kg	5.54E-05

Table B13 Results of the impact assessment 1 kg cassava chips by using CML 2 baseline 2000 V2.03 / World, 1990

Impact category	Unit	Total
abiotic depletion	kg Sb eq	4.13E-04
global warming (GWP100)	kg CO2 eq	7.79E-02
ozone layer depletion (ODP)	kg CFC-11 eq	1.52E-09
human toxicity	kg 1,4-DB eq	0.005114
fresh water aquatic ecotox.	kg 1,4-DB eq	0.000675
marine aquatic ecotoxicity	kg 1,4-DB eq	5.14E+00
terrestrial ecotoxicity	kg 1,4-DB eq	1.60E-04
photochemical oxidation	kg C2H4	7.04E-06
acidification	kg SO2 eq	0.000883
eutrophication	kg PO4--- eq	1.70E-04

Table B14 Results of the impact assessment 1 kg cassava chips by using Eco-indicator 95 V2.03 / Europe e

Impact category	Unit	Total
greenhouse	kg CO2	7.64E-02
ozone layer	kg CFC11	1.77E-09
acidification	kg SO2	1.03E-03
eutrophication	kg PO4	0.000163
heavy metals	kg Pb	1.31E-07
carcinogens	kg B(a)P	5.47E-10
winter smog	kg SPM	1.27E-04
summer smog	kg C2H4	4.66E-05
pesticides	kg act.subst	0
energy resources	MJ LHV	8.93E-01
solid waste	kg	1.65E-04

Table B15 Results of the impact assessment 1 kg cassava based ethanol (99.5%) by using CML 2 baseline 2000 V2.03 / World, 1990

Impact category	Unit	Total
abiotic depletion	kg Sb eq	0.006784
global warming (GWP100)	kg CO2 eq	0.89399
ozone layer depletion (ODP)	kg CFC-11 eq	8.68E-08
human toxicity	kg 1,4-DB eq	1.81E-01
fresh water aquatic ecotox.	kg 1,4-DB eq	0.013844
marine aquatic ecotoxicity	kg 1,4-DB eq	128.2073
terrestrial ecotoxicity	kg 1,4-DB eq	0.003868
photochemical oxidation	kg C2H4	1.04E-04
acidification	kg SO2 eq	0.003927
eutrophication	kg PO4--- eq	0.010199

Table B16 Results of the impact assessment 1 kg cassava based ethanol (99.5%) by using Eco-indicator 95 V2.03 / Europe e

Impact category	Unit	Total
greenhouse	kg CO2	0.875279
ozone layer	kg CFC11	8.27E-08
acidification	kg SO2	4.20E-03
eutrophication	kg PO4	1.02E-02
heavy metals	kg Pb	3.70E-06
carcinogens	kg B(a)P	4.41E-08
winter smog	kg SPM	0.001712
summer smog	kg C2H4	2.20E-04
pesticides	kg act.subst	0
energy resources	MJ LHV	13.92056
solid waste	kg	0.000495

Table B17 Results of the impact assessment 1 kg sugar from sugarcane by using CML 2 baseline 2000 V2.03 / World, 1990

Impact category	Unit	Total
abiotic depletion	kg Sb eq	-2.97E-03
global warming (GWP100)	kg CO2 eq	-2.17E-01
ozone layer depletion (ODP)	kg CFC-11 eq	-3.29E-08
human toxicity	kg 1,4-DB eq	-0.052478
fresh water aquatic ecotox.	kg 1,4-DB eq	-4.70E-03
marine aquatic ecotoxicity	kg 1,4-DB eq	-4.68E+01
terrestrial ecotoxicity	kg 1,4-DB eq	-1.44E-03
photochemical oxidation	kg C2H4	2.22E-04
acidification	kg SO2 eq	0.001649
eutrophication	kg PO4--- eq	2.79E-04

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

Impact category	Unit	Total
greenhouse	kg CO2	-2.29E-01
ozone layer	kg CFC11	-3.03E-08
acidification	kg SO2	1.98E-03
eutrophication	kg PO4	2.78E-04
heavy metals	kg Pb	-1.39E-06
carcinogens	kg B(a)P	-1.87E-08
winter smog	kg SPM	1.96E-02
summer smog	kg C2H4	4.89E-05
pesticides	kg act.subst	0
energy resources	MJ LHV	-5.0721688
solid waste	kg	-8.98E-05

Table B19 Results of the impact assessment 1 kg sugarcane based PLA resin by using CML 2 baseline 2000 V2.03 / World, 1990

Impact category	Unit	Total
abiotic depletion	kg Sb eq	0.006203
global warming (GWP100)	kg CO2 eq	1.138909
ozone layer depletion (ODP)	kg CFC-11 eq	1.26E-08
human toxicity	kg 1,4-DB eq	7.27E-02
fresh water aquatic ecotox.	kg 1,4-DB eq	0.057085
marine aquatic ecotoxicity	kg 1,4-DB eq	103.3776
terrestrial ecotoxicity	kg 1,4-DB eq	-0.000276
photochemical oxidation	kg C2H4	0.000817
acidification	kg SO2 eq	0.014426
eutrophication	kg PO4--- eq	0.001078

Table B20 Results of the impact assessment 1 kg sugarcane based PLA resin by using Eco-indicator 95 V2.03 / Europe e

Impact category	Unit	Total
greenhouse	kg CO2	1.108075
ozone layer	kg CFC11	2.36E-08
acidification	kg SO2	1.36E-02
eutrophication	kg PO4	1.08E-03
heavy metals	kg Pb	2.82E-06
carcinogens	kg B(a)P	2.95E-09
winter smog	kg SPM	0.035874
summer smog	kg C2H4	0.000244
pesticides	kg act.subst	0
energy resources	MJ LHV	10.83499
solid waste	kg	0.000839

Table B21 Results of the impact assessment 1 kg cassava starch with biogas by using CML 2 baseline 2000 V2.03 / World, 1990

Impact category	Unit	Total
abiotic depletion	kg Sb eq	0.000606
global warming (GWP100)	kg CO2 eq	0.091057
ozone layer depletion (ODP)	kg CFC-11 eq	1.90E-09
human toxicity	kg 1,4-DB eq	0.00654
fresh water aquatic ecotox.	kg 1,4-DB eq	0.000846
marine aquatic ecotoxicity	kg 1,4-DB eq	6.466363
terrestrial ecotoxicity	kg 1,4-DB eq	0.0002
photochemical oxidation	kg C2H4	1.07E-05
acidification	kg SO2 eq	0.001171
eutrophication	kg PO4--- eq	0.000273

Table B22 Results of the impact assessment 1 kg cassava starch with biogas by using Eco-indicator 95 V2.03 / Europe e

Impact category	Unit	Total
greenhouse	kg CO2	0.089153
ozone layer	kg CFC11	2.22E-09
acidification	kg SO2	1.36E-03
eutrophication	kg PO4	0.000264
heavy metals	kg Pb	1.64E-07
carcinogens	kg B(a)P	7.14E-10
winter smog	kg SPM	0.000232
summer smog	kg C2H4	4.53E-05
pesticides	kg act.subst	0
energy resources	MJ LHV	1.081065
solid waste	kg	2.09E-04

Table B23 Results of the impact assessment 1 kg sugar from cassava starch by using CML 2 baseline 2000 V2.03 / World, 1990

Impact category	Unit	Total
abiotic depletion	kg Sb eq	1.68E-03
global warming (GWP100)	kg CO2 eq	2.13E-01
ozone layer depletion (ODP)	kg CFC-11 eq	2.08E-09
human toxicity	kg 1,4-DB eq	0.007954
fresh water aquatic ecotox.	kg 1,4-DB eq	0.001018
marine aquatic ecotoxicity	kg 1,4-DB eq	7.83E+00
terrestrial ecotoxicity	kg 1,4-DB eq	2.34E-04
photochemical oxidation	kg C2H4	2.04E-05
acidification	kg SO2 eq	0.001578
eutrophication	kg PO4--- eq	0.00032

Table B24 Results of the impact assessment 1 kg sugar from cassava starch by using Eco-indicator 95 V2.03 / Europe e

Impact category	Unit	Total
greenhouse	kg CO2	2.10E-01
ozone layer	kg CFC11	2.43E-09
acidification	kg SO2	1.79E-03
eutrophication	kg PO4	0.00031
heavy metals	kg Pb	1.96E-07
carcinogens	kg B(a)P	9.37E-10
winter smog	kg SPM	4.54E-04
summer smog	kg C2H4	5.79E-05
pesticides	kg act.subst	0
energy resources	MJ LHV	2.779169
solid waste	kg	4.97E-04

Table B25 Results of the impact assessment 1 kg cassava based PLA resin by using CML 2 baseline 2000 V2.03 / World, 1990

Impact category	Unit	Total
abiotic depletion	kg Sb eq	0.012459
global warming (GWP100)	kg CO2 eq	1.717079
ozone layer depletion (ODP)	kg CFC-11 eq	5.97E-08
human toxicity	kg 1,4-DB eq	1.54E-01
fresh water aquatic ecotox.	kg 1,4-DB eq	0.06479
marine aquatic ecotoxicity	kg 1,4-DB eq	176.9009
terrestrial ecotoxicity	kg 1,4-DB eq	0.001985
photochemical oxidation	kg C2H4	0.000545
acidification	kg SO2 eq	0.01433
eutrophication	kg PO4--- eq	0.001133

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

Impact category	Unit	Total
greenhouse	kg CO2	1.7004
ozone layer	kg CFC11	6.77E-08
acidification	kg SO2	1.33E-02
eutrophication	kg PO4	1.12E-03
heavy metals	kg Pb	4.96E-06
carcinogens	kg B(a)P	2.94E-08
winter smog	kg SPM	0.01012
summer smog	kg C2H4	0.000256
pesticides	kg act.subst	0
energy resources	MJ LHV	21.40862
solid waste	kg	0.00163

Table B27 Results of the impact assessment of feedstock transportation phase for produce 1 kg sugarcane based ethanol (99.5%) by using CML 2 baseline 2000 V2.03 / World, 1990

Impact category	Unit	Total
abiotic depletion	kg Sb eq	0.000514
global warming (GWP100)	kg CO2 eq	0.079525
ozone layer depletion (ODP)	kg CFC-11 eq	0
human toxicity	kg 1,4-DB eq	0.003626
fresh water aquatic ecotox.	kg 1,4-DB eq	1.09E-05
marine aquatic ecotoxicity	kg 1,4-DB eq	0.050394
terrestrial ecotoxicity	kg 1,4-DB eq	1.89E-06
photochemical oxidation	kg C2H4	1.01E-05
acidification	kg SO2 eq	0.000476
eutrophication	kg PO4--- eq	0.000106

Table B28 Results of the impact assessment of feedstock transportation phase for produce 1 kg sugarcane based ethanol (99.5%) by using Eco-indicator 95 V2.03 / Europe e

Impact category	Unit	Total
greenhouse	kg CO2	0.079063
ozone layer	kg CFC11	0
acidification	kg SO2	0.000627
eutrophication	kg PO4	0.000106
heavy metals	kg Pb	1.23E-08
carcinogens	kg B(a)P	6.52E-11
winter smog	kg SPM	6.51E-05
summer smog	kg C2H4	1.05E-04
pesticides	kg act.subst	0
energy resources	MJ LHV	1.065237
solid waste	kg	0.000109

Table B29 Results of the impact assessment of feedstock transportation phase for produce 1 kg molasses based ethanol (99.5%) by using CML 2 baseline 2000 V2.03 / World, 1990

Impact category	Unit	Total
abiotic depletion	kg Sb eq	1.03E-03
global warming (GWP100)	kg CO2 eq	0.160245
ozone layer depletion (ODP)	kg CFC-11 eq	0.00E+00
human toxicity	kg 1,4-DB eq	0.007307
fresh water aquatic ecotox.	kg 1,4-DB eq	2.20E-05
marine aquatic ecotoxicity	kg 1,4-DB eq	0.101544
terrestrial ecotoxicity	kg 1,4-DB eq	3.81E-06
photochemical oxidation	kg C2H4	2.04E-05
acidification	kg SO2 eq	0.000959
eutrophication	kg PO4--- eq	2.13E-04

Table B30 Results of the impact assessment of feedstock transportation phase for produce 1 kg molasses based ethanol (99.5%) by using Eco-indicator 95 V2.03 / Europe

Impact category	Unit	Total
greenhouse	kg CO2	0.159676
ozone layer	kg CFC11	0
acidification	kg SO2	0.001266
eutrophication	kg PO4	0.000214
heavy metals	kg Pb	2.49E-08
carcinogens	kg B(a)P	1.32E-10
winter smog	kg SPM	1.32E-04
summer smog	kg C2H4	2.11E-04
pesticides	kg act.subst	0
energy resources	MJ LHV	2.151361
solid waste	kg	0.00022

Table B31 Results of the impact assessment of feedstock transportation phase for produce 1 kg cassava based ethanol (99.5%) by using CML 2 baseline 2000 V2.03 / World, 1990

Impact category	Unit	Total
abiotic depletion	kg Sb eq	2.17E-04
global warming (GWP100)	kg CO2 eq	0.033634
ozone layer depletion (ODP)	kg CFC-11 eq	0.00E+00
human toxicity	kg 1,4-DB eq	0.001534
fresh water aquatic ecotox.	kg 1,4-DB eq	4.62E-06
marine aquatic ecotoxicity	kg 1,4-DB eq	0.021313
terrestrial ecotoxicity	kg 1,4-DB eq	8.00E-07
photochemical oxidation	kg C2H4	4.28E-06
acidification	kg SO2 eq	0.000201
eutrophication	kg PO4--- eq	4.48E-05

Table B32 Results of the impact assessment of feedstock transportation phase for produce 1 kg cassava based ethanol (99.5%) by using Eco-indicator 95 V2.03 / Europe

Impact category	Unit	Total
greenhouse	kg CO2	3.35E-02
ozone layer	kg CFC11	0
acidification	kg SO2	2.65E-04
eutrophication	kg PO4	4.48E-05
heavy metals	kg Pb	5.22E-09
carcinogens	kg B(a)P	2.76E-11
winter smog	kg SPM	2.76E-05
summer smog	kg C2H4	4.43E-05
pesticides	kg act.subst	0
energy resources	MJ LHV	4.51E-01
solid waste	kg	4.60E-05

Table B33 Results of the impact assessment of feedstock transportation phase for produce 1 kg sugarcane based PLA resin by using CML 2 baseline 2000 V2.03 / World, 1990

Impact category	Unit	Total
abiotic depletion	kg Sb eq	3.10E-04
global warming (GWP100)	kg CO2 eq	0.047957
ozone layer depletion (ODP)	kg CFC-11 eq	0.00E+00
human toxicity	kg 1,4-DB eq	0.002187
fresh water aquatic ecotox.	kg 1,4-DB eq	6.58E-06
marine aquatic ecotoxicity	kg 1,4-DB eq	0.03039
terrestrial ecotoxicity	kg 1,4-DB eq	1.14E-06
photochemical oxidation	kg C2H4	6.10E-06
acidification	kg SO2 eq	0.000287
eutrophication	kg PO4--- eq	6.38E-05

Table B34 Results of the impact assessment of feedstock transportation phase for produce 1 kg sugarcane based PLA resin by using Eco-indicator 95 V2.03 / Europe e

Impact category	Unit	Total
greenhouse	kg CO2	4.77E-02
ozone layer	kg CFC11	0
acidification	kg SO2	3.78E-04
eutrophication	kg PO4	6.38E-05
heavy metals	kg Pb	7.43E-09
carcinogens	kg B(a)P	3.93E-11
winter smog	kg SPM	3.93E-05
summer smog	kg C2H4	6.31E-05
pesticides	kg act.subst	0
energy resources	MJ LHV	6.43E-01
solid waste	kg	6.56E-05

Table B35 Results of the impact assessment of feedstock transportation phase for produce 1 kg cassava based PLA resin by using CML 2 baseline 2000 V2.03 / World, 1990

Impact category	Unit	Total
abiotic depletion	kg Sb eq	0.000213
global warming (GWP100)	kg CO2 eq	0.033049
ozone layer depletion (ODP)	kg CFC-11 eq	0
human toxicity	kg 1,4-DB eq	0.001507
fresh water aquatic ecotox.	kg 1,4-DB eq	4.54E-06
marine aquatic ecotoxicity	kg 1,4-DB eq	0.020943
terrestrial ecotoxicity	kg 1,4-DB eq	7.86E-07
photochemical oxidation	kg C2H4	4.20E-06
acidification	kg SO2 eq	0.000198
eutrophication	kg PO4--- eq	4.40E-05

Table B36 Results of the impact assessment of feedstock transportation phase for produce 1 kg cassava based PLA resin by using Eco-indicator 95 V2.03 / Europe e

Impact category	Unit	Total
greenhouse	kg CO2	0.032865
ozone layer	kg CFC11	0
acidification	kg SO2	0.000261
eutrophication	kg PO4	4.40E-05
heavy metals	kg Pb	5.12E-09
carcinogens	kg B(a)P	2.71E-11
winter smog	kg SPM	2.71E-05
summer smog	kg C2H4	4.35E-05
pesticides	kg act.subst	0
energy resources	MJ LHV	4.43E-01
solid waste	kg	4.52E-05

CURRICULUM VITAE

Name: Mr. Rachasak Chinnawornrungrsee

Date of Birth: November 21, 1987

Nationality: Thai

University Education:

2005 – 2009 Bachelor Degree of Engineering (Petrochemical and Polymeric material), Faculty of Engineering, Silpakorn University, Nakhon Pathom, Thailand

Working Experience:

April-June 2009 Position: Student Internship in phrakhanong
 office and oil Terminal
 Company name: PTT Public Company Limited

Proceedings:

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