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APPENDICES

Appendix A Life Cycle Inventory (LCI)

Table A1 Inventory results for energy consumption, emission, waste from 36,000 kg steel production

Steel 36,000 kg		
Fuel (MJ)	Coal (electricity)	389,033
	Fuel oil	121,320
	Coal	1,367,640
Atmospheric Emission (kg)	Dust	3,942.973
	CO	3,960
	CO_2	341,659.46
	SO_x	2,207.676
	NO_x	808.297
	HC	68.4
	CH_4	648.288
	H_2S	3.132
	HCl	31.464
Waterborne Waste (kg)	Suspended substance	4,339.44
	NH_4^+	35.64
	COD	10.152
	BOD	0.18
	Phenylic acid	0.18
	Na^+	13.68
Solid Waste (kg)	Slag	143,280
	Mixed solid waste	31,320
	Ash	10,620

Table A2 Inventory results for energy consumption, emission, waste from 24,000 kg copper production

Copper 24,000 kg		
Fuel (MJ)	Coal	151,200
	Coal (electricity)	372,000
Atmospheric Emissions (kg)	Fumes	496,512
	Dust	1,581.15
	CO_2	64,778.92
	SO_2	365.351
	NO_x	251.415
	CO	38.88
	HC	25.56
Waterborne Waste (kg)		24
Solid Waste (kg)	Acid mud	24
	Arsenic deposit	48
	Ash	720
	Gypsum	240

Table A3 Inventory results for energy consumption, emission, waste from 6,000 kg aluminum production

Aluminum 6,000 kg		
Fuel (MJ)	Coal	23,362
	Diesel oil	3,331
	Heavy oil	59,788
	Natural gas	65,767
	Coal (electricity)	789,346
Atmospheric Emission (kg)	Fluoride gaseous (as F)	3.42
	Fluoride particulate (as F)	3
	Particulate	101.4
	CO_2	94,266

Table A3 Inventory results for energy consumption, emission, waste from 6,000 kg aluminum production (cont.)

Aluminum 6,000 kg		
Atmospheric Emission (kg)	NO_x (NO_2)	488.13
	SO_2	902.328
	Total PAH	0.9
	Bap(Benzo-a-Pyrene)	0.031
	CF_4	1.32
	C_2F_6	0.126
	HCl	0.402
	Mercury	0.0012
	Dust	4,713.3
Waterborne Waste (kg)	Fresh water	80.4
	Sea water	165
	Fluoride(as F)	1.2
	Oil/grease	0.9
	PAH(6 Borneff components)	0.023
	Suspendèd solids	9.96
	Mercury	0.0108
Solid Waste (kg)	Bauxite residue(red mud)	11,430
	Carbon waste	42
	Dross-landfill	46.2
	Filter dust-landfill	2.4
	Other landfill wastes	4,572
	Refractory waste-landfill	26.4
	Scrubber sludges	87
	SPL-landfill	103.8
	Waste alumina	28.2

Table A4 Inventory results for energy consumption, emission, waste from 153,000 kg glass production

Glass 153,000 kg		
Fuel (MJ)	Coal (electricity)	1,398,515
	Coal	1,395,825
	Heavy oil	1,592,483
Atmospheric Emission (kg)	CO_2	167,282.86
	SO_2	2,102.95
	NO_x	1,130.67
	CO	41.31
	Dust	8568
Waterborne Waste (kg)	COD	76.194
	SS	709.92
	Oil	14.382
Solid Waste (kg)		1,839.06

Table A5 Inventory results for energy consumption, emission, waste from 3,000 kg polyethylene (PE) production

Polyethylene (PE) 3,000 kg		
Fuel (MJ)	Coal	97,640
Atmospheric Emission (kg)	CO_2	19,225.50
	SO_2	127.59
	NO_x	0.516
	C_2H_4	6.051
	CH_4	39
Waterborne Waste (kg)		45,669
Solid Waste (kg)		1,467.81

Table A6 Inventory results for energy consumption, emission, waste from 10,500 kg polyvinyl chloride (PVC) production

Polyvinyl chloride (PVC) 10,500 kg		
Fuel (MJ)	Coal	587,402
Atmospheric Emission (kg)	CO_2	91,230.25
	SO_2	778.89
	NO_x	1.806
	EDC	51.77
	CO	10.82
	VCM	3.57
	PVC	0.105
	CH_4	136.5
	Cl_2	0.001
Waterborne Waste (kg)	Waste water	389,791.50
Solid Waste (kg)		12,425.18

Table A7 Inventory results for energy consumption, emission, waste from 18,000 kg polystyrene (PS) production

Polystyrene (PS) 18,000 kg		
Fuel (MJ)	Heavy oil	299,775
	Light oil	82,229
	Coal(electric)	192,174
Atmospheric Emission (kg)	CO_2	84,313.64
	NO_x	278.386
	SO_x	510.873
	Dust	1,147.50
Solid Waste (kg)		793.636

Table A8 Inventory results for energy consumption, emissions, waste from color TV sets manufacturing

TV 10,000 set (300,000 kg)		
Fuel (MJ)	Coal (electricity)	701,791
Atmospheric Emission (kg)	CO_2	448,363.048
	SO_2	2,710.29
	NO_x	2,995.288
	Dust	4,190.5
Solid Waste (kg)		28,028

Table A9 CRT-television production in Thailand from year 2000 to 2013 in unit TV set (OIE, 2013)

Year	**CRT-TV Production (unit)**
2000	5,236,000
2001	4,633,000
2002	5,595,000
2003	5,627,000
2004	5,763,000
2005	5,984,000
2006	5,478,000
2007	4,612,000
2008	3,393,000
2009	2,186,000
2010	1,778,000
2011	1,156,000
2012	575,000
2013	139,000

Table A10 Discarded CRT-television in Thailand from 2000 to 2013 in unit TV sets (Pollution Control Department, 2011)

Year	CRT-TV Waste (unit)
2012	2,000,000
2013	2,400,000

Table A11 Percentage of dismantling and treatment of CRT-TV parts based on current waste management (base case)

Component of CRT-TV	% Dismantling	%Landfill	%Recycling	%Incineration
Cathode Ray Tube	80			
- Funnel Glass		100	0	0
- Panel Glass		100	0	0
Metal Parts	80	50	50	0
Cabinet (Plastics)	80	50	50	0
Cable	80	50	0	50
Electronic Parts	80	50	50	0
Others (Waste)	100	100	0	0
*Remaining (Dismantling)	20	100	0	0

Table A12 Percentage of dismantling and treatment of CRT-TV parts based on improved current waste management (case 1)

Component of CRT-TV	% Dismantling	%Landfill	%Recycling
Cathode Ray Tube	80		
- Funnel Glass		70	30
- Panel Glass		20	80
Metal Parts	80	20	80
Cabinet (Plastics)	80	20	80
Cable	80	20	80
Electronic Parts	80	20	80
Others (Waste)	100	100	0
*Remaining (Dismantling)	20	100	0

Table A13 Percentage of dismantling and treatment of CRT-TV parts based on possible best waste management (case 2)

Component of CRT-TV	% Dismantling	%Landfill	%Recycling
Cathode Ray Tube	100		
- Funnel Glass		0	100
- Panel Glass		0	100
Metal Parts	100	0	100
Cabinet (Plastics)	100	0	100
Cable	100	0	100
Electronic Parts	100	0	100
Others (Waste)	100	100	0

Table A14 Percentage of dismantling and treatment of CRT-TV parts based on modified technology from China waste management (case 3)

Component of CRT-TV	% Dismantling	%Landfill	%Recycling
Cathode Ray Tube	80		
- Funnel Glass		0	100
- Panel Glass		70	30
Metal Parts	80	20	80
Cabinet (Plastics)	80	20	80
Cable	80	20	80
Electronic Parts	80	20	80
Others (Waste)	100	100	0
*Remaining (Waste)	20	100	0

Table A15 Percentage of dismantling and treatment of CRT-TV parts based on modified technology from Japan waste management (case 4)

Component of CRT-TV	% Dismantling	%Landfill	%Recycling
Cathode Ray Tube	100		
- Funnel Glass		10	90
- Panel Glass		10	90
Metal Parts	100	20	80
Cabinet (Plastics)	100	20	80
Cable	100	20	80
Electronic Parts	100	20	80
Others (Waste)	100	100	0

Appendix B Calculations

Table B1 The all data related to energy consumption, emissions, waste, etc. base on the transportation in Thailand

List	Type of Transportation	
	No Load	**Full Load**
Fuel (L/tkm)		
Diesel	0.2133	0.018
Atmospheric Emission (g/tkm)		
Carbon dioxide (CO_2)	519.97	47.37
Carbon monoxide (CO)	1.7813	0.1623
Nitrogen oxides (NO_x)	5.3549	0.4879
Particulate matter (PM)	0.4014	0.0366
Hydrocarbons (HC)	0.465	0.0424
Methane (CH_4)	0.0112	0.001
Benzene (C_2H_6)	8.84E-03	8.05E-04
Toluene (C_7H_8)	3.72E-03	3.39E-04
Xylene (C_8H_{10})	3.72E-03	3.39E-04
Non – methane volatile organic compounds (NMVOCs)	0.9586	0.0809
Sulfur oxides (SO_x)	0.1209	0.0102
Nitrous Oxide (N_2O)	0.0218	0.0018
Cadmium	1.73E-06	1.46E-07
Copper	2.94E-04	2.48E-05
Chromium	8.64E-06	7.29E-07
Nickel	1.21E-05	1.02E-06
Selenium	1.73E-06	1.46E-07
Zinc	1.73E-04	1.46E-05
Lead	1.90E-08	1.60E-09
Mercury	3.46E-09	2.91E-10

The Assumption of Transportation:

- Truck 10 wheels with capacity of 16 ton
- Diesel engine truck (base on SAE J-313C)
- Total distance 150 km from Bangkok to Samutprakarn (37.5 km), transport raw material (75 km) and TV set (75 km)
- Limited speed 60-90 km/hr
- The one unit of television set and the raw material for production are transported.
- Two types of transportation : No load (return) and Full load (carry)

Example Calculation of Transportation

Fuel: Diesel

- The unit diesel consumption is 0.018 L/tkm (full load)
- Distance is 75 km
- The weight was 50,000 ton of televise waste (TV waste in Thailand in 2012)

So, diesel consume (L) = 0.018 × 75 ×50,000

= 67,500 L

And, diesel consume (kg) = 67,500 L × 0.84 kg/L (density of diesel = 0.84 kg/L)

= 56,700 kg

Atmospheric emission: Carbon dioxide (CO_2)

- The unit CO_2 release is 519.97 g/tkm
- Distance is 75 km
- The weight was 50,000 ton of televise waste (TV waste in Thailand in 2012)

So, CO_2 release = 519.97 × 75 ×50,000

= 1,949,887.5 kg

Table B2 The all data related to energy consumption, emissions, waste, etc. in transportation phase

List	Type of Transportation		Total
	No Load	Full Load	
Fuel (L/tkm)			
Diesel	799,875	67,500	867,375
Atmospheric Emission (g/tkm)			
Carbon dioxide (CO_2)	1,949,887.5	177,637.5	2,127,525
Carbon monoxide (CO)	6,679.875	608.625	7,288.5
Nitrogen oxides (NO_x)	20,080.875	1,829.625	21,910.5
Particulate matter (PM)	1,505.25	137.25	1642.5
Hydrocarbons (HC)	1,743.75	159	1,902.75
Methane (CH_4)	42	3.75	45.75
Benzene (C_2H_6)	33.15	3.01875	36.16875
Toluene (C_7H_8)	13.95	1.27125	15.22125
Xylene (C_8H_{10})	13.95	1.27125	15.22125
Non – methane volatile organic compounds	3,594.75	303.375	3,898.125
Sulfur oxides (SO_x)	453.375	38.25	491.625
Nitrous Oxide (N_2O)	81.75	6.75	88.5
Cadmium	0.0064875	0.0005475	0.007035
Copper	1.1025	0.093	1.1955
Chromium	0.0324	0.00273375	0.03513375
Nickel	0.045375	0.003825	0.0492
Selenium	0.0064875	0.0005475	0.007035
Zinc	0.64875	0.05475	0.7035
Lead	0.00007125	0.000006	0.00007725
Mercury	0.00001297	1.09125E-06	1.40663E-05

Appendix C The Electricity in Thailand

Table C1 The electricity in Thailand was consumed by television set base on electricity Thailand in 2007

Source Electricity Generation	**%**
Lignite Power Plant	22.29
Combine Power Plant	54.07
Diesel Power Plant	0.02
Gas Power Plant	0.70
Hydro Power Plant	6.3
Thermal Power Plant	16.62
Total	**100**

Appendix D Life Cycle Impact Assessment (LCIA)

Table D1 Results of the impact assessment 1 TV set in production of manufacturing materials by using CML 2 baseline 2000 V2.03 / World, 1990

Impact Category	Unit	Total	Steel	Copper	Aluminum	PE	PS	PVC	Glass
Abiotic Depletion	kg Sb eq	0.934384	0.298515	0.065501	0.132113	0.004633	0.030629	0.027873	0.37512
Global Warming (GWP100)	kg CO_2 eq	224.134	90.23726	17.53299	32.50512	2.181074	9.27961	10.45427	61.94368
Ozone Layer Depletion (ODP)	kg CFC-11 eq	1.21E-07	1.29E-08	2.71E-09	5.74E-09	0	9E-08	0	1.02E-08
Human Toxicity	kg 1,4-DB eq	99.25567	0.497968	45.7204	52.35685	0.002693	0.124248	0.013837	0.539672
Fresh Water Aquatic Ecotox.	kg 1,4-DB eq	0.93839	0.084374	0.661052	0.118744	1.29E-05	0.006775	7.77E-05	0.067355
Marine Aquatic Ecotoxicity	kg 1,4-DB eq	822.2889	159.2444	403.5052	71.70016	3.14E-06	62.17875	1.89E-05	125.6604
Terrestrial Ecotoxicity	kg 1,4-DB eq	16.04171	0.002002	16.0324	0.005345	1.47E-06	0.00041	8.83E-06	0.001543
Photochemical Oxidation	kg C_2H_4	0.071314	0.030798	0.003815	0.009752	0.001288	0.002763	0.004132	0.018766
Acidification	kg SO_2 eq	1.771093	0.616465	0.120611	0.268695	0.015679	0.080829	0.095614	0.573201
Eutrophication	kg PO_4^{---} eq	0.103019	0.037731	0.008481	0.017339	3.86E-05	0.003903	0.000215	0.035312

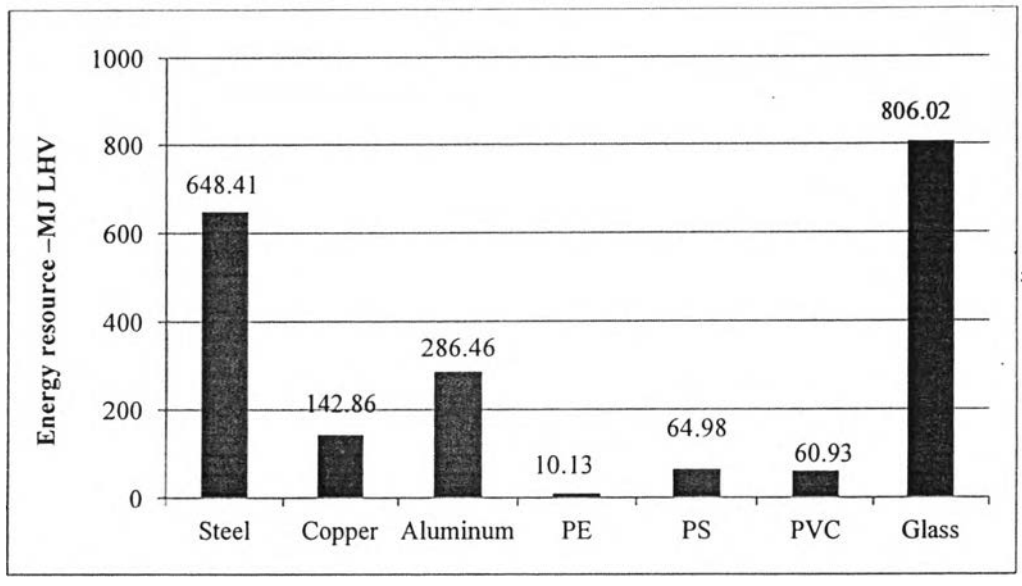

Figure D1 Results of the energy resources 1 TV set in production of each material by using CML 2 baseline 2000 V2.03 / World, 1990

Table D2 Results of the impact assessment 1 TV set based TV set manufacturing by using CML 2 baseline 2000 V2.03 / World, 1990

Impact Category	Unit	TV Set Manufacturing
Abiotic Depletion	kg Sb eq	0.158223373
Global Warming (GWP100)	kg CO_2 eq	80.06138664
Ozone Layer Depletion (ODP)	kg CFC-11 eq	5.32382E-07
Human Toxicity	kg 1,4-DB eq	1.952910157
Fresh Water Aquatic Ecotox.	kg 1,4-DB eq	0.006320259
Marine Aquatic Ecotoxicity	kg 1,4-DB eq	11974.53888
Terrestrial Ecotoxicity	kg 1,4-DB eq	0.023887657
Photochemical Oxidation	kg C_2H_4	0.023692167
Acidification	kg SO_2 eq	0.806802003
Eutrophication	kg PO_4^{---} eq	0.059005578

Table D3 Results of the impact assessment 1 TV set based transportation by using CML 2 baseline 2000 V2.03 / World, 1990

Impact Category	Unit	Transportation
Abiotic Depletion	kg Sb eq	0.009697482
Global Warming (GWP100)	kg CO_2 eq	1.408043289
Ozone Layer Depletion (ODP)	kg CFC-11 eq	0
Human Toxicity	kg 1,4-DB eq	0.064334115
Fresh Water Aquatic Ecotox.	kg 1,4-DB eq	0.000206218
Marine Aquatic Ecotoxicity	kg 1,4-DB eq	0.951902695
Terrestrial Ecotoxicity	kg 1,4-DB eq	3.57022E-05
Photochemical Oxidation	kg C_2H_4	0.00018166
Acidification	kg SO_2 eq	0.008505257
Eutrophication	kg PO_4^{---} eq	0.001874107

Table D4 Results of the impact assessment 1 TV set based use of TV set by using CML 2 baseline 2000 V2.03 / World, 1990

Impact Category	Unit	Use of TV Set
Abiotic Depletion	kg Sb eq	17.8045678
Global Warming (GWP100)	kg CO_2 eq	1870.673953
Ozone Layer Depletion (ODP)	kg CFC-11 eq	1.2553E-08
Human Toxicity	kg 1,4-DB eq	7.355816679
Fresh Water Aquatic Ecotox.	kg 1,4-DB eq	0.031571022
Marine Aquatic Ecotoxicity	kg 1,4-DB eq	260.6029822
Terrestrial Ecotoxicity	kg 1,4-DB eq	0.039914784
Photochemical Oxidation	kg C_2H_4	0.123844014
Acidification	kg SO_2 eq	5.278278793
Eutrophication	kg PO_4^{---} eq	0.583355875

Table D5 Results of the impact assessment 1 TV set based end-of-life of TV waste by using CML 2 baseline 2000 V2.03 / World, 1990

Impact Category	Unit	Base Case	Case 1	Case 2	Case 3	Case 4
Abiotic Depletion	kg Sb eq	0.080895	0.063273	0.028065	0.063664	0.034533
Global Warming (GWP100)	kg CO_2 eq	10.95859	7.843842	6.02298	7.876088	5.879346
Ozone Layer Depletion (ODP)	kg CFC-11 eq	3.81E-07	2.82E-07	1.79E-07	2.92E-07	1.9E-07
Human Toxicity	kg 1,4-DB eq	4.72296	3.245311	2.593389	3.25797	2.494792
Fresh Water Aquatic Ecotox.	kg 1,4-DB eq	44.9427	24.74631	37.52902	24.74749	30.21592
Marine Aquatic Ecotoxicity	kg 1,4-DB eq	15555.15	9523.915	11464.57	9528.212	9748.649
Terrestrial Ecotoxicity	kg 1,4-DB eq	0.032761	0.024219	0.019727	0.024279	0.018831
Photochemical Oxidation	kg C_2H_4	0.005021	0.003904	0.001442	0.003911	0.001945
Acidification	kg SO_2 eq	0.034943	0.027744	0.014622	0.027936	0.016598
Eutrophication	kg PO_4^{---} eq	0.007444	0.005652	0.002761	0.005691	0.003247

Table D6 Results of the impact assessment 1 TV set based end-of-life of TV waste

Phase	Impact Categories				
	Abiotic Depletion	Global Warming Potential	Human Toxicity	Acidification	Energy Resources
Base Case	29.57 %	28.20 %	28.77 %	28.30 %	29.00 %
Case 1	23.52 %	20.39 %	19.94 %	22.90 %	23.24 %
Case 2	10.43 %	15.65 %	15.94 %	12.06 %	11.14 %
Case 3	23.65 %	20.48 %	20.02 %	23.05 %	23.40 %
Case 4	12.83 %	15.28 %	15.33 %	13.69 %	13.22 %

Table D7 Results of the energy resources TV set based end-of-life of TV waste

Phase	Unit	Energy Resources
Production of Manufacturing Materials	MJ LHV	2,019.79
TV Set Manufacturing	MJ LHV	312.62
Transportation	MJ LHV	20.13
Use of TV Set	MJ LHV	877.98
End-of-Life	MJ LHV	169.08

Table D8 The environmental impacts of life cycle of CRT-TV

Phase	Impact Categories			
	Abiotic Depletion (kg Sb eq)	**Global Warming Potential (kg CO_2 eq)**	**Human Toxicity (kg 1,4-DB eq)**	**Acidification (kg SO_2 eq)**
Production of Manufacturing Materials	0.9344	224.1340	99.2557	1.7711
TV set Manufacturing	0.1582	80.0610	1.9529	0.8068
Transportation	0.0097	1.4080	0.0643	0.0085
Use of TV Set	17.80465	1870.6740	7.3558	5.2782
End-of-Life (Base Case)	0.0809	10.959	4.723	0.0349

Table D9 The benefits of abiotic depletion and global warming potential of life cycle of CRT-TV

Component of CRT-TV	Mass of Waste (kg)	Disposal (End-of-Life)	Abiotic Depletion (kg Sb eq)	GWP (kg CO_2 eq)
Cathode Ray Tube				
- Funnel Glass	4.56	Landfill	-	-
- Panel Glass	9.12	Landfill	-	-
Metal Parts				
- Steel	1.20	Recycling	0.0995	30.0791
	1.20	Landfill	-	-
- Aluminum	0.24	Recycling	0.528	13.0020
	0.24	Landfill	-	-
- Copper	0.60	Recycling	0.164	4.3832
	0.60	Landfill	-	-
Cabinet (Plastics)				
- Polyethylene (PE)	0.12	Recycling	0.0019	0.8740
	0.12	Landfill	-	-
- Polyvinyl chloride	0.42	Recycling	0.0111	4.1817
(PVC)	0.42	Landfill	-	-
- Polystyrene (PS)	0.72	Recycling	0.0123	3.7118
	0.72	Landfill	-	-
Cable	0.54	Incineration	-	-
	0.54	Landfill	-	-
Electronic Parts	0.36	Recycling	-	-
	0.36	Landfill	-	-
Others (Waste)	2.40	Landfill	-	-
Remaining	5.52	Landfill	-	-
Total	**30.00**		**-0.1940**	**-56.2304**

Table D10 The benefits of human toxicity, acidification and energy resources of life cycle of CRT-TV

Component of CRT-TV	Mass of Waste (kg)	Disposal (End-of-Life)	HT (kg 1,4-DB eq)	Acidification (kg SO_2 eq)	Energy Resources (MJ LHV)
Cathode Ray Tube					
- Funnel Glass	4.56	Landfill	-	-	-
- Panel Glass	9.12	Landfill	-	-	-
Metal Parts					
- Steel	1.20	Recycling	0.1660	0.2055	216.00
	1.20	Landfill	-	-	-
- Aluminum	0.24	Recycling	20.9427	0.1075	115.00
	0.24	Landfill	-	-	-
- Copper	0.60	Recycling	11.4301	0.0302	35.70
	0.60	Landfill	-	-	-
Cabinet (Plastics)					
- Polyethylene (PE)	0.12	Recycling	0.0011	0.0063	4.05
	0.12	Landfill	-	-	-
- Polyvinyl chloride	0.42	Recycling	0.0055	0.0382	24.40
(PVC)	0.42	Landfill	-	-	-
- Polystyrene (PS)	0.72	Recycling	0.0497	0.0323	26.00
	0.72	Landfill	-	-	-
Cable	0.54	Incin.	-	-	-
	0.54	Landfill	-	-	-
Electronic Parts	0.36	Recycling	-	-	-
	0.36	Landfill	-	-	-
Others (Waste)	2.40	Landfill	-	-	-
Remaining	5.52	Landfill	-	-	-
Total	**30.00**		**-32.5951**	**-0.4200**	**-421.15**

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