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APPENDICES

Appendix A Raw Data Collecting of Energy Consumption

Table A1 Raw data collecting of energy consumption in polyurethane foam production in mixing process

Electricity used in mixing process			
Equipment	Power (Hp)	Power (kW)	Operating time
Blender 20 MT	25	18.643	12 hrs/day
Blender 10 MT	15	11.186	12 hrs/day
Blender 10 MT	15	11.186	12 hrs/day
Blender 2 MT	5	3.728	12 hrs/day
Pump #1	25	18.643	12 hrs/day
Pump #2	25	18.643	12 hrs/day
Pump #3	25	18.643	12 hrs/day
Pump #4	25	18.643	12 hrs/day

Table A2 Raw data collecting of energy consumption in polyurethane foam production in injection process

Electricity used in injection process			
Equipment	Power (Hp)	Power (kW)	Operating time
Injection machine	194.89	145.3294	12 hrs/day

Table A3 Raw data collecting of energy consumption in polystyrene (GPPS) Pellet production

Electricity used in polystyrene (GPPS) Pellet producing			
Process	Power (Hp)	Power (kW)	Operating time
Raw Material Acquisition and Preparation	3750.05	2796.412	24 hrs/day
Polymerization	1221	39.41	24 hrs/day
Devolatilization	3983.22	2970.287	24 hrs/day
SM Recovery	1232.69	919.2168	24 hrs/day
Extrusion and Finishing	345.51	257.6468	24 hrs/day
Packaging	326.21	243.2548	24 hrs/day
Injection	-	88.2	24 hrs/day

Table A4 Raw data collecting of energy consumption in polystyrene (HIPS) Pellet production

Electricity used in polystyrene (HIPS) Pellet producing			
Process	Power (Hp)	Power (kW)	Operating time
Raw Material Acquisition and Preparation	3901.15	2929.087	24 hrs/day
Polymerization	1221	39.41	24 hrs/day
Devolatilization	3983.22	2970.287	24 hrs/day
SM Recovery	1232.69	919.2168	24 hrs/day
Extrusion and Finishing	345.51	257.6468	24 hrs/day
Packaging	326.21	243.2548	24 hrs/day
Injection	-	15.4055	24 hrs/day

The calculation example of energy consumption in mixing process of PU foam producing

Solution

Convert Hp to kW,

$$1 \text{ Hp} = 0.7456999 \text{ kW}$$

$$160 \text{ Hp} = 160 \times 0.7456999 = 119.312 \text{ kW}$$

Convert kW to kWh,

$$119.312 \text{ kW} \times 12 \text{ hrs/day} = 1{,}431.744 \text{ kWh/day}$$

From 1 day produces 28,409.09 kg

1 kg polyurethane foam has to use product (formulated polyol) in this process as 0.3553 kg

So, 1,431.744 kWh/day / 28,409.09 kg/day = 0.0504 kWh/kg

For 0.3553 kg,

$$0.0504 \text{ kWh/kg} \times 0.3553 \text{ kg} = 0.0179 \text{ kWh}$$

Appendix B Raw Data Collecting of Emission to Water

Table B1 Raw data collecting of emission to water in polyurethane foam production in mixing process

Wastewater	
Type	Amount /unit
TOC	13 mg/l
TDS	703 mg/l
SS	13 mg/l
COD	52 mg/l
BOD	5.5 mg/l
Oil & Grease	1 mg/l

Remarks: GPPS and HIPS Pellet have not emission to water

The calculation example of emission to water in mixing process of PU foam producing

Solution

Convert mg/l to mg/day,

Where flow rate of water is 32.75 kg/day

$$TOC = 13\frac{mg}{l} \times 32.75\frac{kg}{day} \times \frac{l}{1000}\frac{m^3}{kg} \times 1000\frac{l}{m^3}$$

$$= 425.75\frac{mg}{day}$$

Convert mg /day to mg TOC /kg Formulated polyol,

1 day produce Formulated polyol 28,409.09 kg

$$= 425.75\frac{mg}{day} \times \frac{1}{28{,}409.09}\frac{day}{kg\ Formulated\ polyol}$$

$$= 0.01499\frac{mg}{kg\ Formulated\ polyol}$$

1 kg polyurethane foam has to use product (formulated polyol) in this process as 0.3553 kg

$$\text{So, for } 0.3553 \text{ kg} = 0.01499 \frac{\text{mg TOC}}{\text{kg Formulated polyol}} \times 0.3553 \text{ kg Formulated polyol}$$

$$= 5.33\,E^{-3} \text{ mg}$$

Appendix C Raw Data Collecting of Emission to Air

Table C1 Raw data collecting of emission to air in polyurethane foam production in injection process

Emission to Air	
Type	Amount/Unit
CN^-	0.001 mg/m^3
VOCs	0.001 mg/m^3
CO_2	750 ppm
CO	1.38 ppm
NO_2	0.096 mg/m^3
SO_2	0.001 mg/m^3

Table C2 Raw data collecting of emission to air in polystyrene (GPPS) Pellet production

Emission to air in polystyrene (GPPS) Pellet producing		
Process	Type	Amount /unit
Raw Material Acquisition and Preparation	None	None
Polymerization	None	None
Devolatilization	TSP NO_2	0.5525 mg/m^3 8.1 ppm
SM Recovery	TSP NO_2 CO THC	83.375 mg/m^3 10.275 ppm 2 ppm 1.55 ppm

Emission to air in polystyrene (GPPS) Pellet producing		
Process	Type	Amount /unit
Extrusion and Finishing	TSP	1.275 mg/m^3
	THC	2.06 ppm
	Sb	$5E^{-3}$ mg/m^3
Injection	TSP	0.916 mg/m^3
	SO_2	0.001 mg/m^3
	NO_2	0.012 mg/m^3
	CO	0.14 ppm
	CO_2	700 ppm
	VOCs	0.001 ppm

Table C3 Raw data collecting of emission to air in polystyrene (HIPS) Pellet production

Emission to air in polystyrene (HIPS) Pellet producing		
Process	Type	Amount /unit
Raw Material Acquisition and Preparation	None	None
Polymerization	None	None
Devolatilization	TSP	1.547 mg/m^3
	NO_2	22.68 ppm
SM Recovery	TSP	223.45 mg/m^3
	NO_2	28.77 ppm
	CO	5.6 ppm
	THC	4.34 ppm
Extrusion and Finishing	TSP	4.557 mg/m^3
	THC	5.775 ppm
	Sb	0.014^3 mg/m^3

Emission to air in polystyrene (HIPS) Pellet producing		
Process	Type	Amount /unit
Packaging	None	None
Injection	TSP	0.916 mg/m^3
	SO_2	0.001 mg/m^3
	NO_2	0.012 mg/m^3
	CO	0.14 ppm
	CO_2	700 ppm
	VOCs	0.001 ppm

The calculation example of emission to air in Devolatilization Process of polystyrene (GPPS) Pellet producing

Solution

Convert mg/l to mg/m^3,

$$TSP = 1.547 \text{ mg/m}^3$$

$$NO_2 = 22.68\frac{mg}{l} \times 1{,}000\frac{l}{m^3}$$

$$= 22{,}680\frac{mg}{m^3}$$

Convert mg/m^3 to mg/day by multiply by gas flow rate

Where gas flow rate is 3,310m^3/hr

$$TSP = 1.547\frac{mg}{m^3} \times 3{,}310\frac{m^3}{hr} \times 24\frac{hr}{day}$$

$$= 122{,}893.68\frac{mg}{day}$$

$$NO_2 = 22{,}680\frac{mg}{m^3} \times 3{,}310\frac{m^3}{hr} \times 24\frac{hr}{day}$$

$$= 1{,}801{,}699{,}200\frac{mg}{day}$$

Convert mg/day to mg/kg,

1 day produce GPPS 83,333.33 kg

$$\text{TSP} = 122{,}893.68 \frac{\text{mg}}{\text{day}} \times \frac{1}{83{,}333.33} \frac{\text{day}}{\text{kg}}$$

$$= 1.4747 \text{ mg}$$

$$NO_2 = 1{,}801{,}699{,}200 \frac{\text{mg}}{\text{day}} \times \frac{1}{83{,}333.33} \frac{\text{day}}{\text{kg}}$$

$$= 21{,}620.39 \text{ mg}$$

Appendix D Ratio of Raw Materials in Polyurethane Foam Production

Table D1 Ratio of raw materials in formulated polyol production

Name	Amount (kg)	Average(kg)	%
Polyol	100	100	93.677
Silicons surfactant	2-6	4	3.747
Amine Catalyst	0.5-2.0	1.25	1.171
Water	1-2	1.5	1.405
Total		106.75	100

Table D2 Ratio of raw materials in polyurethane foam production

Name	Amount (kg)	%
Formulated polyol	100	35.34
HCFC 141 b	30	10.6
Papi 27(isocyanate)	153	54.06
Total	283	100

Collection quantity of raw material used in 1 kg PU foam production

Basis % yield of PU foam = 99.5 %

If get PU 1 kg,

$$\text{Total input} = 1\,\text{kg} \times \frac{100}{99.5}\ 100/99.5 = 1.005\ \text{kg}$$

Appendix E Data Collecting of Packaging

Table E1 Raw data collecting of packaging in polyurethane foam production

Type	Size	Disposal
Stock		
- Tank	200-500 Tons	
Polyol Packaging		
- Drum (Steel) 200L (18, 21 kg)	210 Kg	Press and Recycle /incineration/landfill
- Bulk	12 & 16 Ton	Reuse and Landfill
- Tote	1 Ton	Reuse and Recycle/Landfill
Formulation Polyol Packaging		
- Drum (Steel)	210 Kg	Press and Recycle /incineration/landfill
- Tote	1 Ton	Reuse and Recycle/Landfill
PAPI (Isocyanate), Amine Cat., Silicone Surfactant, and HCFC 141b Packaging		
- Drum (Steel)	210 Kg	Press and Recycle /incineration/landfill

Remarks: The packagings of all chemicals which send to SUE are steel drum

Table E2 Raw data collecting of packaging in polystyrene production

Type	Size	Disposal
Polyethylene	0.0044 kg/1 kg PS	Incineration
Polypropylene	3 g/piece	Incineration

The calculation example of packaging in mixing process of Formulation Polyol producing

Solution

Substance 210 kg contained by steel drum 21 kg

So, raw material input (except water) in mixing process 0.352 kg contained by steel

$$\text{Drum} = 0.352\ \text{kg} \times \frac{21\,\text{kg}}{210\text{kg}} = 0.0352\ \text{kg}$$

Appendix F Data Collecting of Transportation

Table F1 Raw data collecting of transportation in polyurethane foam production

Type	distance	Transport by	Remarks
Formulated Polyol	200 Km	10 wheel	
Polyol (20%)	50 m	Pipe	
Polyol (80%)	1689 miles	Shipment	2718.182 km
Silicone Surfactant	3238 miles	Shipment	5211.056 km
Amine Catalyst	1476 miles	Shipment	2375.392 km
HCFC 141b (50%)	1449 miles	Shipment	2331.939 km
HCFC 141b (50%)	587 miles	Shipment	944.6849 km
Papi 27 (Isocyanate)	7720 miles	Shipment	12424.14 km

Table F2 Raw data collecting of transportation in GPPS production

Type	distance	Transport by	Remarks
Polyethylene	251 Km	10 wheel	
Styrene Monomer	2 Km	Pipe	
Ethyl benzene	2 Km	Shipment	
Initiator	9858 Mile	Shipment	15864.91 km
Mineral Oil	1680 Mile	Shipment	2703.698 km

Table F3 Raw data collecting of transportation in HIPS production

Type	distance	Transport by	Remarks
Polyethylene	251 km	10 Wheel	
Styrene Monomer	2 km	Pipe	
Ethyl benzene	2 km	Pipe	
Polybutadiene Rubber	9858 mile	Shipment	15864.91 km
Initiator	9858 mile	Shipment	15864.91 km
Mineral Oil	1680 mile	Shipment	2703.698 km

The calculation example of transportation in mixing process of PU foam production

Solution

Convert km to kgkm,

For Polyol

Polyol used in mixing process for produce 1 kg PU foam = 0.3344 kg

$$\text{Transport by pipe (20\%)} = 0.3344\,\text{kg} \times \frac{20}{100} \times 50\,\text{m} \times \frac{1\,\text{km}}{1000\,\text{m}} = 3.344\text{E}^{-3}\,\text{kgkm}$$

$$\text{Transport by Shipment (80\%)} = 0.3344\,\text{kg} \times \frac{80}{100} \times 2{,}718.182\,\text{km} = 727.17\ \text{kgkm}$$

For Silicone Surfactant

Silicone Surfactant used in mixing process for produce 1 kg PU foam = 0.0134 kg

Transport by Shipment = $0.0134\,\text{kg} \times 5{,}211.056\,\text{km} = 69.83$ kgkm

For Amine Catalyst

Amine Catalyst used in mixing process for produce 1 kg PU foam = 0.0042 kg

Transport by Shipment = $0.0042\,\text{kg} \times 2{,}375.392$ km = 9.98 kgkm

Appendix G Characterization Factor of Eco-indicator 99

Table G1 Characterization factor of greenhouse gas (kg CO_2 Equivalent) in Eco-indicator 95

Compartment	Substance	Factor	Unit
Airborne emission	1,1,1-trichloroethane	100	kg
Airborne emission	CFC-11	3400	kg
Airborne emission	CFC-113	4500	kg
Airborne emission	CFC-114	7000	kg
Airborne emission	CFC-115	7000	kg
Airborne emission	CFC-116	6200	kg
Airborne emission	CFC-12	7100	kg
Airborne emission	CFC-13	13000	kg
Airborne emission	CFC-14	4500	kg
Airborne emission	CFC (hard)	7100	kg
Airborne emission	CFC (soft)	1600	kg
Airborne emission	CO_2	1	kg
Airborne emission	CO_2 (soft)	1	kg
Airborne emission	dichloromethane	15	kg
Airborne emission	HOLON-1211	4900	kg
Airborne emission	HOLON-1301	4900	kg
Airborne emission	HCFC-123	90	kg
Airborne emission	HCFC-124	440	kg
Airborne emission	HCFC-141b	580	kg
Airborne emission	HCFC-142b	1800	kg
Airborne emission	HCFC-22	1600	kg
Airborne emission	HFC-125	3400	kg
Airborne emission	HFC-134a	1200	kg
Airborne emission	HFC-143a	3800	kg

Compartment	Substance	Factor	Unit
Airborne emission	HFC-152a	150	kg
Airborne emission	methane	11	kg
Airborne emission	N_2O	270	kg
Airborne emission	tetrachloromethane	1300	kg
Airborne emission	trichloromethane	25	kg

Table G2 Characterization factor of ozone layer depletion (kg CFC11) in Eco-indicator 95

Compartment	Substance	Factor	Unit
Airborne emission	1,1,1-trichloroethane	0.12	kg
Airborne emission	CFC-11	1	kg
Airborne emission	CFC-113	1.07	kg
Airborne emission	CFC-114	0.8	kg
Airborne emission	CFC-115	0.5	kg
Airborne emission	CFC-12	1	kg
Airborne emission	CFC-13	1	kg
Airborne emission	CFC (hard)	1	kg
Airborne emission	CFC (soft)	0.055	kg
Airborne emission	HOLON-1201	1.4	kg
Airborne emission	HOLON-1202	1.25	kg
Airborne emission	HOLON-1211	4	kg
Airborne emission	HOLON-1301	16	kg
Airborne emission	HOLON-2311	0.14	kg
Airborne emission	HOLON-2401	0.25	kg
Airborne emission	HOLON-2402	7	kg
Airborne emission	HCFC-123	0.02	kg
Airborne emission	HCFC-124	0.022	kg
Airborne emission	HCFC-141b	0.11	kg

Compartment	Substance	Factor	Unit
Airborne emission	HCFC-142b	0.065	kg
Airborne emission	HCFC-22	0.055	kg
Airborne emission	HCFC-225ca	0.025	kg
Airborne emission	HCFC-225cb	0.033	kg
Airborne emission	Methyl bromide	0.6	kg
Airborne emission	tetrachloromethane	1.08	kg

Table G3 Characterization factor of acidification (kg SO_2) effect in Eco-indicator 95

Compartment	Substance	Factor	Unit
Airborne emission	ammonia	1.88	kg
Airborne emission	HCl	0.88	kg
Airborne emission	HF	1.6	kg
Airborne emission	NOx	0.7	kg
Airborne emission	NOx (as NO_2)	0.7	kg
Airborne emission	SO_2	1	kg
Airborne emission	SOx	1	kg
Airborne emission	NO	1.07	kg
Airborne emission	NO_2	0.7	kg
Airborne emission	SOx	1	kg

Table G4 Characterization factor of carcinogen (kg B(a)) affect in Eco-indicator 95

Compartment	Substance	Factor	Unit
Airborne emission	benzene	0.000044	kg
Airborne emission	CxHy aromatic	0.000044	kg
Airborne emission	metals	0.0001786	kg
Airborne emission	Ni	0.0044	kg
Airborne emission	PAH's	0.4792	kg

Compartment	Substance	Factor	Unit
Airborne emission	Acrylonitrile	0.00022	kg
Airborne emission	As	0.044	kg
Airborne emission	Benzo(a)pyrene	1	kg
Airborne emission	Cr(VI)	0.44	kg
Airborne emission	Ethylbenzene	0.000044	kg
Airborne emission	floranthene	1	kg
Airborne emission	tar	0.000044	kg
Airborne emission	vinyl chloride	0.000011	kg

Table G5 Characterization factor of energy resources depletion (MJ LHV) in Eco-indicator 95

Compartment	Substance	Factor	Unit
Raw Material	coal ETH	18	kg
Raw Material	crude oil ETH	42.6	kg
Raw Material	lignite ETH	8	kg
Raw Material	natural gas (vol)	36.6	m^3
Raw Material	natural gas ETH	35	m^3
Raw Material	pot.energy hydropower	1	MJ
Raw Material	unspecified energy	1	MJ
Raw Material	uranium (in ore)	451000	kg
Raw Material	wood.	15.3	kg
Raw Material	wood (feedstock)	15.3	kg
Raw Material	crude oil (feed stock)	41	kg
Raw Material	energy (undef.)	1	MJ
Raw Material	energy from hydro power	1	MJ
Raw Material	natural gas (feedstock)	35	m^3
Raw Material	steam from waste incineration	1	MJ
Raw Material	barrage water	0.01	kg

Compartment	Substance	Factor	Unit
Raw Material	biomass (feedstock)	1	MJ
Raw Material	coal	29.3	kg
Raw Material	coal FAL	26.4	kg
Raw Material	crude oil	41	kg
Raw Material	crude oil FAL	42	kg
Raw Material	crude oil IDEMAT	42.7	kg
Raw Material	energy from coal	1	MJ
Raw Material	energy from lignite	1	MJ
Raw Material	energy from natural gas	1	MJ
Raw Material	energy from oil	1	MJ
Raw Material	energy from uranium	1	MJ
Raw Material	energy from wood	1	MJ
Raw Material	energy recovery	1	MJ
Raw Material	gas from oil production	40.9	m^3
Raw Material	lignite	10	kg
Raw Material	methane (kg)	35.9	kg
Raw Material	natural gas	30.3	kg
Raw Material	natural gas FAL	46.8	kg
Raw Material	uranium (ore)	1110	kg
Raw Material	uranium FAL	2291	g
Raw Material	wood and wood wastes FAL	9.5	kg
Raw Material	natural gas (feedstock) FAL	46.8	kg
Raw Material	crude oil (feedstock) FAL	42	kg
Raw Material	coal (feedstock) FAL	26.4	kg
Raw Material	petroleum gas ETH	35	m^3

Table G6 Normalization and weighting factor of Eco-indicator 95

Impact Category	Normalization	Weighting
Greenhouse	0.0000765	2.5
Ozone layer	1.08	100
Acidification	0.00888	10
Eutrophication	0.0262	5
Heavy metal	18.4	5
Carcinogens	92	10
Winter smog	0.0106	5
Summer smog	0.0558	2.5
Pesticides	1.04	25
Energy resources	0.00000629	0
Solid waste	0	0

Table G7 Correlated effect to type of damage of eco-indicator 95

Type of Damage	Effect Contributing to This Damage
Factor of fatalities as a consequence of the effect	Ozone Layer Airborne Heavy Metal Pesticides Carcinogenic Substances
Nuisance and number of non-fatal casualties as a result of occurrence of smog period	Winter Smog Summer Smog
Damage to parts of ecosystem	Greenhouse Effect Acidification Eutrophication Waterborne Heavy Metals Pesticides

Appendix H Characterization Factor of Eco-indicator 99

Table H1 Characterization factor of climate change (DALY) in Eco-indicator 99

Compartment	Substance	Factor	Unit
Airborne emission	CO_2	2.1E-7	kg
Airborne emission	CO_2 (non-fossil)	2.1E-7	kg
Airborne emission	HOLON-1301	-0.0071	kg
Airborne emission	methane	4.4E-6	kg
Airborne emission	N_2O	6.9E-5	kg
Airborne emission	CFC-14	1.4E-3	kg
Airborne emission	1,1,1-trichloroethane	-0.000043	kg
Airborne emission	CF3I	2.1E-7	kg
Airborne emission	CFC-11	2.2E-4	kg
Airborne emission	CFC-113	6.3E-4	kg
Airborne emission	CFC-116	2.0E-3	kg
Airborne emission	CFC-12	1.4E-3	kg
Airborne emission	CO_2 (fossil)	2.1E-7	kg
Airborne emission	dichloromethane	1.9E-6	kg
Airborne emission	HCFC-123	6.6E-6	kg
Airborne emission	HCFC-124	8.5E-5	kg
Airborne emission	HCFC-141b	5.2E-5	kg
Airborne emission	HCFC-142b	3.4E-4	kg
Airborne emission	HCFC-22	2.8E-4	kg
Airborne emission	HFC-125	5.7E-4	kg
Airborne emission	HFC-134	2.1E-4	kg
Airborne emission	HFC-134a	2.7E-4	kg
Airborne emission	HFC-143	6.3E-5	kg
Airborne emission	HFC-143a	7.8E-4	kg
Airborne emission	HFC-152a	2.9E-5	kg

Compartment	Substance	Factor	Unit
Airborne emission	HFC-227ea	5.9E-4	kg
Airborne emission	HFC-23	2.6E-3	kg
Airborne emission	HFC-236fa	1.4E-3	kg
Airborne emission	HFC-245ca	1.2E-4	kg
Airborne emission	HFC-32	1.4E-4	kg
Airborne emission	HFC-41	3.1E-5	kg
Airborne emission	HFC-4310mee	2.7E-4	kg
Airborne emission	perfluorbutane	1.5E-3	kg
Airborne emission	perfluorcyclobutane	1.9E-3	kg
Airborne emission	perfluorhexane	1.6E-3	kg
Airborne emission	perfluorpentane	1.7E-3	kg
Airborne emission	perfluorpropane	1.5E-3	kg
Airborne emission	SF6	5.3E-3	kg
Airborne emission	tetrachloromethane	-0.00026	kg
Airborne emission	trichloromethane	8.3E-7	kg

Table H2 Characterization factor of ozone layer depletion (DALY) in Eco-indicator 99

Compartment	Substance	Factor	Unit
Airborne emission	HOLON-1301	1.26E-2	kg
Airborne emission	1,1,1-trichloroethane	1.26E-4	kg
Airborne emission	CFC-11	1.05E-3	kg
Airborne emission	CFC-113	9.48E-4	kg
Airborne emission	CFC-114	8.95E-4	kg
Airborne emission	CFC-115	4.21E-4	kg
Airborne emission	CFC-12	8.63E-4	kg
Airborne emission	HOLON-1201	1.47E-3	kg
Airborne emission	HOLON-1202	1.32E-3	kg

Compartment	Substance	Factor	Unit
Airborne emission	HOLON-1211	5.37E-3	kg
Airborne emission	HOLON-2311	1.47E-4	kg
Airborne emission	HOLON-2401	2.63E-4	kg
Airborne emission	HOLON-2402	7.37E-3	kg
Airborne emission	HCFC-123	1.47E-5	kg
Airborne emission	HCFC-124	3.16E-5	kg
Airborne emission	HCFC-141b	1.05E-4	kg
Airborne emission	HCFC-142b	5.26E-5	kg
Airborne emission	HCFC-22	4.21E-5	kg
Airborne emission	HCFC-225ca	2.11E-5	kg
Airborne emission	HCFC-225cb	2.11E-5	kg
Airborne emission	Methyl bromide	6.74E-4	kg
Airborne emission	Methyl chloride	2.11E-5	kg
Airborne emission	tetrachloromethane	1.26E-3	kg

Table H3 Characterization factor of acidification effect (PDF*m) in Eco-indicator 99

Compartment	Substance	Factor	Unit
Airborne emission	ammonia	15.57	kg
Airborne emission	NOx	5.713	kg
Airborne emission	NOx (as NO_2)	5.713	kg
Airborne emission	SO_2	1.041	kg
Airborne emission	Sox (as SO_2)	1.041	kg
Airborne emission	NO	8.789	kg
Airborne emission	NO_2	5.713	kg
Airborne emission	SO_3	0.8323	kg
Airborne emission	SOx	1.041	kg

Table H4 Characterization factor of carcinogen affect (DALY) in Eco-indicator 99

Compartment	Substance	Factor	Unit
Airborne emission	1,2-dibromoethane	2.6E-4	kg
Airborne emission	1,2-dichloroethane	2.9E-5	kg
Airborne emission	1,3-butadiene	1.58E-5	kg
Airborne emission	1,4-dioxane	1.39E-7	kg
Airborne emission	2,4,6-trichlorophenol	2.05E-6	kg
Airborne emission	acetaldehyde	2.16E-7	kg
Airborne emission	acrylonitrile	1.69E-5	kg
Airborne emission	Alpha-HCH	3.00E-4	kg
Airborne emission	As	2.46E-2	kg
Airborne emission	BCME	7.48E-3	kg
Airborne emission	benzene	2.50E-6	kg
Airborne emission	benzo(a)anthracene	5.86E-2	kg
Airborne emission	benzo(a)pyrene	3.98E-3	kg
Airborne emission	benzotrichloride	6.6E-3	kg
Airborne emission	benzylchloride	1.04E-5	kg
Airborne emission	Beta-HCH	9.99E-5	kg
Airborne emission	bromodichlromethane	8.76E-6	kg
Airborne emission	Cd	1.35E-1	kg
Airborne emission	Cr(VI)	1.75	kg
Airborne emission	di(2-ethylhexyl)phthalate	3.38E-5	kg
Airborne emission	dibenz(a)anthracene	3.1E1	kg
Airborne emission	dichlromethane	4.36E-7	kg
Airborne emission	Dichlrvos	3.15E-5	kg
Airborne emission	Dioxin(TEQ)	1.79E2	kg
Airborne emission	epichlorohydrin	3.02E-7	kg
Airborne emission	ethylene oxide	1.83E-4	kg
Airborne emission	formadehyde	9.91E-7	kg

Compartment	Substance	Factor	Unit
Airborne emission	gamma-HCH(Lindane)	3.49E-4	kg
Airborne emission	heavy metals	0.0006969	kg
Airborne emission	hexachlorobenzene	8.25E-2	kg
Airborne emission	metals	0.0006969	kg
Airborne emission	Ni	2.35E-2	kg
Airborne emission	Ni-subsulfide	9.48E-2	kg
Airborne emission	Ni refinery dust	4.74E-2	kg
Airborne emission	PAH's	1.7E-4	kg
Airborne emission	particles diesel soot	9.78E-6	kg
Airborne emission	PCB's	1.97E-3	kg
Airborne emission	pentachlorophenol	7.21E-3	kg
Airborne emission	propyleneoxide	1.17E-5	kg
Airborne emission	styrene	2.44E-8	kg
Airborne emission	tetrachloroethane	4.82E-7	kg
Airborne emission	tetrachloromethane	8.38E-4	kg
Airborne emission	trichloromethane	2.63E-5	kg
Airborne emission	vinyl chloride	2.09E-7	kg
Emission to soil	1,2-dibromoethane(ind.)	3.81E-3	kg
Emission to soil	1,2-dichloroethane(ind.)	4.58E-4	kg
Emission to soil	1,3-butadiene(ind.)	1.2E-5	kg
Emission to soil	1,4-dioxane(ind.)	3.1E-7	kg
Emission to soil	2,4,6-trichlorophenol(ind.)	2.76E-6	kg
Emission to soil	acetaldehyde(ind.)	4.77E-7	kg
Emission to soil	acrylonitrile(ind.)	7.01E-5	kg
Emission to soil	Alpha-HCH(ind.)	2.32E-2	kg
Emission to soil	As(ind.)	1.32E-2	kg
Emission to soil	BCME	1.68E-2	kg
Emission to soil	Benzene (ind.)	1.33E-5	kg
Emission to soil	benzo(a)anthracene (ind.)	1.6E-1	kg

Compartment	Substance	Factor	Unit
Emission to soil	benzo(a)pyrene (ind.)	2.06E-3	kg
Emission to soil	benzotrichloride (ind.)	1.32E-1	kg
Emission to soil	Benzylchloride (ind.)	4.16E-5	kg
Emission to soil	Beta-HCH (arg.)	7.36E-3	kg
Emission to soil	Bromodichlromethane (ind.)	7.82E-5	kg
Emission to soil	Cd (ind.)	3.98E-3	kg
Emission to soil	Cr (VI) (ind.)	2.71E-1	kg
Emission to soil	di(2-ethylhexyl)phthalate (ind.)	3.18E-7	kg
Emission to soil	dibenz(a)anthracene (ind.)	2.44E1	kg
Emission to soil	Dichlromethane (ind.)	5.99E-6	kg
Emission to soil	Dichlrvos (arg)	2.25E-5	kg
Emission to soil	Dioxin(TEQ) (ind.)	7.06	kg
Emission to soil	Epichlorohydrin (ind.)	1.3E-6	kg
Emission to soil	ethylene oxide (ind.)	2.38E-3	kg
Emission to soil	Formaldehyde (ind.)	1.83E-6	kg
Emission to soil	gamma-HCH(Lindane) (agr.)	8.64E-3	kg
Emission to soil	Hexachlorobenzene (ind.)	1.47E-1	kg
Emission to soil	Ni-subsulfide (ind.)	1.27E-2	kg
Emission to soil	Ni	3.94E-3	kg
Emission to soil	Ni refinery dust (ind.)	6.37E-3	kg
Emission to soil	PCB's (ind.)	2.04E-2	kg
Emission to soil	Pentachlorophenol (ind.)	1.26E-5	kg
Emission to soil	Propylene oxide (ind.)	1.4E-4	kg
Emission to soil	Styrene (ind.)	2.09E-8	kg
Emission to soil	Tetrachloroethane (ind.)	6.0E-6	kg
Emission to soil	Tetrachloromethane (ind.)	3.99E-2	kg
Emission to soil	Trichloromethane (ind.)	4.12E-6	kg
Emission to soil	vinyl chloride (ind.)	7.67E-7	kg
Waterborne emission	1,2-dibromoethane	1.24E-3	kg

Compartment	Substance	Factor	Unit
Waterborne emission	1,2-dichloroethane	2.98E-5	kg
Waterborne emission	1,3-butadiene	3.37E-4	kg
Waterborne emission	1,4-dioxane	9.21E-7	kg
Waterborne emission	2,4,6-trichlorophenol	1.05E-5	kg
Waterborne emission	acetaldehyde	9.23E-7	kg
Waterborne emission	acrylonitrile	4.16E-5	kg
Waterborne emission	Alpha-HCH	6.85E-3	kg
Waterborne emission	As	6.57E-2	kg
Waterborne emission	BCME	1.54E-2	kg
Waterborne emission	benzene	4.12E-6	kg
Waterborne emission	benzo(a)anthracene	6.58E-1	kg
Waterborne emission	benzo(a)pyrene	2.99	kg
Waterborne emission	benzotrichloride	9.46E-3	kg
Waterborne emission	benzylchloride	1.98E-5	kg
Waterborne emission	Beta-HCH	5.75E-3	kg
Waterborne emission	bromodichlromethane	9.36E-6	kg
Waterborne emission	Cd	7.12E-2	kg
Waterborne emission	Cr(VI)	3.43E-1	kg
Waterborne emission	di(2-ethylhexyl)phthalate	6.64E-4	kg
Waterborne emission	dibenz(a)anthracene	4.07E1	kg
Waterborne emission	dichlromethane	4.97E-7	kg
Waterborne emission	Dichlrvos	1.17E-5	kg
Waterborne emission	Dioxin(TEQ)	2.02E3	kg
Waterborne emission	epichlorohydrin	9.9E-7	kg
Waterborne emission	ethylene oxide	1.39E-4	kg
Waterborne emission	formadehyde	4.97E-6	kg
Waterborne emission	gamma-HCH(Lindane)	4.16E-3	kg
Waterborne emission	hexachlorobenzene	1.25E-1	kg
Waterborne emission	Metallic ions	4.272E-5	kg

Compartment	Substance	Factor	Unit
Waterborne emission	Ni	3.11E-2	kg
Waterborne emission	Ni-subsulfide	5.02E-3	kg
Waterborne emission	Ni refinery dust	1.00E-2	kg
Waterborne emission	PAH's	2.6E-3	kg
Waterborne emission	PCB's	3.91E-2	kg
Waterborne emission	pentachlorophenol	2.29E-2	kg
Waterborne emission	propyleneoxide	1.74E-5	kg
Waterborne emission	styrene	1.22E-6	kg
Waterborne emission	tetrachloroethane	4.27E-7	kg
Waterborne emission	tetrachloromethane	8.29E-4	kg
Waterborne emission	trichloromethane	2.6E-5	kg
Waterborne emission	vinyl chloride	2.84E-7	kg

Table H5 Characterization factor of energy resources depletion (MJ surplus) in Eco-indicator 99

Compartment	Substance	Factor	Unit
Raw Material	coal ETH	0.155	kg
Raw Material	crude oil ETH	6.13	kg
Raw Material	natural gas (vol)	5.49	m^3
Raw Material	natural gas ETH	5.25	m^3
Raw Material	crude oil (feed stock)	5.90	kg
Raw Material	natural gas (feedstock)	5.25	m^3
Raw Material	coal	0.252	kg
Raw Material	coal FAL	0.227	kg
Raw Material	crude oil	5.90	kg
Raw Material	crude oil FAL	6.04	kg
Raw Material	crude oil IDEMAT	6.15	kg
Raw Material	energy from coal	8.59E-3	MJ

Compartment	Substance	Factor	Unit
Raw Material	energy from natural gas	1.50E-1	MJ
Raw Material	energy from oil	0.144	MJ
Raw Material	natural gas	4.55	kg
Raw Material	natural gas FAL	7.02	kg
Raw Material	natural gas (feedstock) FAL	7.02	kg
Raw Material	crude oil (feedstock) FAL	6.04	kg
Raw Material	coal (feedstock) FAL	0.227	kg

Table H6 Normalization and weighting of Eco-indicator 99

Damage Category	Normalization	Weighting
Human health	65.1	400
Ecosystem quality	$1.95E^{-4}$	400
Resources	$1.19E^{-4}$	200

Table H7 Damage assessment factor of human health in Eco-indicator 99

Impact Category	Unit	Factor
Carcinogens	DALY	1
Resp.organics	DALY	1
Resp.inorganics	DALY	1
Climate change	DALY	1
Radiation	DALY	1
Ozone layer	DALY	1

Table H8 Damage assessment factor of ecosystem quality in Eco-indicator 99

Impact Category	Unit	Factor
Ecotoxicity	PAF*m2yr	0.1
Acidification/Eutrophication	PAF*m2yr	1
Land use	PAF*m2yr	1

Table H9 Damage assessment factor of resources depletion in Eco-indicator 99

Impact Category	Unit	Factor
Minerals	MJ surplus	1
Fossil Fuels	MJ surplus	1

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