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APPENDICES

Appendix A Characterization Factor of Eco-indicator 95

Table A1 Characterization factor of greenhouse gas (kg CO₂ 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 ₂ O	270	kg
Airborne emission	tetrachloromethane	1300	kg
Airborne emission	trichloromethane	25	kg

Table A2 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 A3 Characterization factor of acidification (kg SO₂) 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	NO _x	0.7	kg
Airborne emission	NO _x (as NO ₂)	0.7	kg
Airborne emission	SO ₂	1	kg
Airborne emission	SO _x	1	kg
Airborne emission	NO	1.07	kg
Airborne emission	NO ₂	0.7	kg
Airborne emission	SO _x	1	kg

Table A4 Characterization factor of carcinogen (kg B(a)) affect in Eco-indicator 95

Compartment	Substance	Factor	Unit
Airborne emission	benzene	0.000044	kg
Airborne emission	C _x H _y 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 A5 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 A6 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 A7 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 B Characterization Factor of Eco-indicator 99

Table B1 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 ₂ O	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	perfluorocyclobutane	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 B2 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 B3 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 B4 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	benzotrchloride	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	bromodichloromethane	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	dichloromethane	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 B5 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 B6 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 B7 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 B8 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 B9 Damage assessment factor of resources depletion in Eco-indicator 99

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

CURRICULUM VITAE

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Poster Presentation:

1. Meedeche, J., Nithitanakul, M., and Malakul, P. (2005, December 15-16) Life Cycle Assessment of Polyethylene Shopping Bag in Thailand. Poster Presentation at International Workshop "Capacity Building on Life Cycle Assessment in APEC Economies", Bangkok, Thailand.