Life Cycle Assessment Data for Computer Products, Mobile Phones and Mixed Waste

Energy consumption data for product manufacturing				
Parameter	**Value**	**Units**	**Reference**	**Notes**
CPU, LEDs, CRTs and Notebooks:				
Energy for manufacturing CRT	18300.00	MJ/CRT	Socolof et al., 2001.	
Conversion factor	3.60	MJ/kWh		
Mass of CRT	21.16	kg/CRT	Socolof et al., 2001.	
Energy for production of CRT	240.23	kWh/kg	Calculated.	Calculated (Socolof MJ/CRT divided by Socolof kg/CRT, converted to kWh/kg using 3.6 MJ/kWh)
Energy for production of CPU	117.95	kWh/kg	SimaPro, 2015.	425 MJ/kg CPU from SimaPro model, converted to kWh/kg using 3.6 MJ/kWh
Energy for manufacturing LED	4655.83	MJ/LCD	SimaPro, 2015.	
Mass of LED	5.09	kg/LCD	SimaPro, 2015.	
Energy for production of LED monitor	254.03	kWh/kg	SimaPro, 2015.	915 MJ/kg monitor from SimaPro model, converted to equivalent kWh/kg using 3.6 MJ/kWh
Energy for production of notebook	232.58	kWh/kg ntbk	SimaPro, 2015.	837 MJ/kg notebook from SimaPro model, converted to equivalent kWh/kg using 3.6 MJ/kWh
Average (weighted) production energy	207.99	kWh/kg	SimaPro, 2015.	Calculated; kWh per kg of product weighted by FEC 2012 product distribution (used in longevity calc for energy).
Mobile phones:				
Energy for manufacturing mobile phone	150.00	MJ/phone	Frey et al., 2006; Nokia, 2005.	
Mass of phone	0.09	kg/phone	Frey et al., 2006; Nokia, 2005.	
Energy for production of mobile phone	462.96	kWh/kg	Calculated.	
Mixed waste:				
Recycling energy (shredding and copper smelting)	0.91	MJ/kg e-waste	Derived from primary data collected for the EPA Lead-Free Solder Project (Geibig and Socolof, 2005).	Shredding data are primary data provided by three electronic waste demanufacturing facilities, and copper smelting data are primary data collected from two electronic waste copper smelters. The energy for copper smelting derived from Geibig and Socolof, 2005, p. 2-40, using the following conversion factors: 13.4 g of SnPb solder/kg of PWB; 0.051 kg PWB/kg of e-waste; 8.4 g SnPb solder/cc of SnPb solder. Assume PWBs reaching end of life still have leaded solder.

LIFE CYCLE IMPACT DATA

LCI production data

Process	Emissions to air (kg)	Emissions to water (kg)	Total energy demand (MJ/kg)	Material inputs (kg)	GWP, 100 yr (kg CO2-equiv./kg or MJ)	Reference	Nation
For product materials:							
ABS co-polymer (ABS)	3.54	0.08	100.78	2.56	4.12	Average of two plastic data sources. Ecoinvent, 2012; US LCI Database, 2012.	Europe, US
Polycarbonate granulate (PC)	6.19	1.09	105.58	3.25	7.77	Ecoinvent, 2012. Plastics, Europe data.	Europe
Polystyrene high impact gran. (HIPS)	2.83	0.03	90.15	2.01	3.36	Average of two plastic data sources. Ecoinvent, 2012; US LCI Database, 2012.	Europe, US
Plastics (average) per kg material production	4.19	0.40	98.84	2.61	5.08		
Copper mix	1.78	8.35	32.19	2.27	1.71	Ecoinvent, 2012. Copper at regional storage.	European mix, from global sources
Copper (average) per kg material production	1.78	8.35	32.19	2.27	1.71		
Silver	98.1	144	1,459	93	95	Ecoinvent, 2012. Silver at regional storage.	European mix, from global sources
Gold	12,490	37,311	214,334	7,448	12,621	Ecoinvent, 2012. Gold at regional storage.	European mix, from global sources
Palladium	14,588	4,898	183,737	5,859	9,297	Ecoinvent, 2012. Palladium at regional storage.	European mix, from global sources
Precious Metals (weighted average) per kg material production	2,601.73	5,945.73	41,528.19	1,453.90	2,385.87		
Chromium steel (average) per kg material production	4.17	1.04	79.97	3.97	4.33	Ecoinvent, 2012. Chromium steel at regional storage.	European mix, from global sources
Aluminum (average) per kg material production	6.65	0.77	139.58	4.44	8.31	Ecoinvent, 2012. Aluminium production mix at plant.	Global
CRT Glass (average) per kg material production	0.14	0.22	853.17		8.39	Socolof et al., 2001.	US & Japan
Mobile Phone LCD Glass (average) per kg material production	11.31	0.21			41.88	Socolof et al., 2001.	US & Japan
For packaging:							
Low-density polyethylene (LDPE)	1.74	0.02	78.56	1.65	2.14	Average of U.S. and European plastic data. Ecoinvent, 2012; US LCI Database, 2012.	Europe, US
High-density polyethylene (HDPE)	1.55	0.02	74.82	1.59	1.91	Average of U.S. and European plastic data. Ecoinvent, 2012; US LCI Database, 2012.	Europe, US

Polyethylene terephthalate (PET)	2.23	0.07	71.01	1.78	2.51	Average of U.S. and European plastic data. Ecoinvent, 2012; US LCI Database, 2012.	Europe, US
Polystyrene, general purpose (GPPS)	2.81	0.03	89.61	1.99	3.36	Average of U.S. and European plastic data. Ecoinvent, 2012; US LCI Database, 2012.	Europe, US
Plastics (average) per kg material production	2.08	0.03	78.50	1.75	2.48	calculated.	
Cardboard (average) per kg material production	2.32	0.04	30.67	2.52	1.26	Average of U.S. and European data. Ecoinvent, 2012; US Corrugated Packaging Alliance, 2009.	Europe, US
For electricity:							
Power grid mix (kg/MJ)	0.17	0.0004	2.97	0.08	0.18	Average US generation mix by fuel from EPA 2016, modeled in SimaPro 2017.	US
Power grid mix (kg/kWh) (converted)	0.62	0.00143	10.69	0.30	0.66	Converted kg/MJ to kg/kWh	
Note: All emissions are based on the production of 1 kg of product except power grid mix which is based on production of 1 MJ of power							

LCI recycling data

Process	Emissions to air (kg)	Emissions to water (kg)	Total energy demand (MJ/kg)	Material inputs (kg)	GWP, 100 yr (kg CO2-equiv./kg or MJ)	Reference	Nation
For product materials:							
ABS co-polymer (ABS)						N/A	
Polycarbonate granulate (PC)						N/A	
Polystyrene high impact gran. (HIPS)						N/A	
Plastics (average) per kg material processed							
E-waste shredding (for metals recovery)	0.19	0.0003	0.90	not used in calculations	0.20	Geibig and Socolof, 2005. Shredding data are primary data provided by three electronic waste demanufacturing facilities.	
Copper smelting (kg or MJ/kg e-waste)	0.0003	0.002	0.01	0.0003	0.71	Geibig and Socolof, 2005. Copper smelting data are primary data collected from two electronic waste copper smelters. The energy for copper smelting derived from Geibig and Socolof, 2005, p. 2-40, using the following conversion factors: 13.4 g of SnPb solder/kg of PWB; 0.051 kg PWB/kg of e-waste; 8.4 g SnPb solder/cc of SnPb solder. Assume PWBs reaching end of life still have leaded solder.	N. America and Europe
Metals recovery (average) per kg material processed	0.19	0.002	0.91		0.91	calculated	
Silver	20.77	3.64	138.92	28.21	21.52	Ecoinvent, 2012. Silver, secondary at precious metal refinery.	Swedish process data adapted to US

Gold	1212.60	212.32	8109.10	1646.53	1256.33	Ecoinvent, 2012. Gold, secondary at precious metal refinery.	Swedish process data adapted to US
Palladium	635.15	111.21	4247.46	862.43	658.05	Ecoinvent, 2012. Palladium, secondary at precious metal refinery.	Swedish process data adapted to US
Precious Metals (weighted average) per kg material processed	227.19	39.78	1519.31	308.49	235.38	wtd avg calculated based on relative wts of silver, gold, Pd in cell phone	
Steel (average) per kg material processed	0.35	0.001	5.70	0.18	0.38	Steel billet, electric furnace. Franklin Associates private database based on the U.S. LCI database.	North America
Aluminum (average) per kg material processed	0.35	0.001	5.70	0.18	0.38	Aluminum ingot, secondary. Aluminum Association, 2010.	US
CRT Glass (average) per kg material processed						N/A	
Mobile Phone LCD glass (average) per kg processed						N/A	
Note: All emissions are based on the recycling of 1 kg of product							

GHG Emissions Data

Parameter	Value	Units	Reference	Notes
Electricity Production				
GHG emissions from electricity	0.18	kgCE/kWh	EPA, 2016	eGRID 2014 kWh modeled in SimaPro, kg CO2 eq/kWh converted to kg C eq/kWh
Product Resins				
GHG emitted for product resins	1.39	kg CE/kg product resin	From LCI production data above, converted.	Average of ABS, PC, HIPS. Converted from CO2-equivalents in LCI production data. Used in EPEAT Material Use calculation for recycled content of resins for production of globally produced products.
Packaging Resins				
GHG emissions for packaging resins				
HDPE	0.44	kgCE/kg	EPA WARM, 2012. Plastic Products documentation, Exhibit 7.	Converted from MTCO2E/short ton.
LDPE	0.54	kgCE/kg	EPA WARM, 2012. Plastic Products documentation, Exhibit 7.	Converted from MTCO2E/short ton.
PET	0.67	kgCE/kg	EPA WARM, 2012. Plastic Products documentation, Exhibit 7.	Converted from MTCO2E/short ton.
PS (general purpose)	0.75	kgCE/kg	EPA WARM, 2012. Plastic Products documentation, Exhibit 7.	Converted from MTCO2E/short ton.
Average GHG emissions for packaging resins	0.60	kg CE/kg resin	Calculated.	Average for U.S. production of HDPE, LDPE, PET PS from WARM documentation. Used in calculations for reuse of packaging.

Average GHG emissions for packaging resins	0.676	kg CE/kg resin	From LCI production data above, converted.	Average of global packaging data for HDPE, LDPE, PET, PS. Used in calculations for production of packaging used to deliver globally produced products.
Paper Packaging				
GHG emissions from corrugated box production	0.26	kg CE/kg	EPA WARM, 2012. Paper Products documentation, Exhibit 12.	Converted from MTCO2E/short ton. Used in calculations for reuse of packaging.
Conversion factor (CO2-equiv to CE)				
Conversion factor CO2-equiv to CE	0.273	unitless	Periodic chart of elements.	Molecular weight of C (12 g/mol) / molecular weight of CO2 (44 g/mol).
GHG emissions factors for end-of-life of personal computers				
Baseline EOL Dispositions	**Value**	**Unit**	**Reference**	**Notes**
Source reduction (reuse)	-54.15	MTCE/short ton	SimaPro, 2015.	Source reduction GHG factors are based on avoided GHG emissions from SimaPro equipment production models.
Recycling	-2.35	MTCE/short ton	SimaPro, 2015.	Recycling GHG are based on the amounts of resins and metals recycled from each type of equipment and credits for virgin materials displaced by the recycled materials.
Source reduction converted	12.99	kgCE/kg	FEC, 2012; SimaPro, 2015.	FEC 2012 use-weighted avg of SimaPro production GWP for all 4 equip types
Recycling converted	0.89	kgCE/kg	FEC, 2012; SimaPro, 2015.	FEC 2012 use-weighted avg for recycling kg CE/kg from SimaPro model for CPU, monitor, and notebook (no data available for CRT and CRTs are only 0.1% of equipment used)
Energy factors for end-of-life of personal computers				
Baseline EOL Dispositions	**Value**	**Unit**	**Reference**	**Notes**
Source reduction converted	208.00	kWh/kg	FEC, 2012; SimaPro, 2015.	FEC 2012 use-weighted avg of SimaPro production GWP for all 4 equip types
Recycling converted	17.44	kWh/kg	FEC, 2012; SimaPro, 2015.	FEC 2012 use-weighted avg for recycling kg CE/kg from SimaPro model for CPU, monitor, and notebook (no data available for CRT and CRTs are only 0.1% of equipment used)

General Conversion Factors	
1000	g/kg
2.205	lb/kg
0.272727273	CE/CO2 equivalent

Recycling Assumptions - Efficiency Rate		
Material Type	**% of recycled material turned into reusable product**	**Reference**
Aluminum cans	93%	EPA WARM, 2016. Recycling document, Exhibit 2.1.
Steel cans	98%	EPA WARM, 2016. Recycling document, Exhibit 2.1.
Copper wire	81%	EPA WARM, 2016. Recycling document, Exhibit 2.1.
Glass	88%	EPA WARM, 2016. Recycling document, Exhibit 2.1.
Plastics	88%	EPA WARM, 2016. Recycling document, Exhibit 2.1.

Recycling Assumptions - CRT Glass		
Recycling Process	**% of Mass**	**Reference**
Glass-to-glass recycling	73.7%	EPA, 2008. Table 5.1, p. 29.
Lead Smelting	26.3%	EPA, 2008. Table 5.1, p. 29.

Mobile Phones EOL Impacts per Mobile Phone (Materials Based Approach)					
12a. Mass					
12b. Energy					
12c. GHG Emissions					
12d. Emissions to Air					
12e. Emissions to Water					
Mixed Electronics EOL Impacts per kg Mixed Electronic (Material Based Approach)					
13a. Mass					
13b. Energy					
13c. GWP					
13d. Emissions to Air					
13e. Emissions to Water					

These sections for mobile phones and mixed electronics are calculated from the assumptions shown on individual product PDFs. For example, mass of phones recycled = composition by weight of phone (Wu, et. al., 2008) x mass of phone (average weight of phone + battery from SWICO Recycling, 2010, minus average battery weight from MPPI, 2009) x percent of phones collected for recycling that are recycled (assumed to be 100%).

For energy and emissions savings calculations from recycling or reuse, the mass of individual materials (for example, copper) is multiplied by the production emissions per kg copper (from LCI production data).

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