Using new spare parts for repair of WEEE? The Material Footprint of individual components

Supplementary Materials

Supplementary Materials A: Specification of Products

Table S1: Choice of equipment

Device	Specification
Washing machine	Front loader washing machine, capacity of 6kg, Siemens, year of construction 2005
Flat-screen monitor	17 inch flat screen monitor, Samsung, model 171 N S, year of construction 2003
Loudspeaker box	2-way passive loudspeaker box of a Kenwood RXD M33 stereo system
Coffee machine	a filter coffee machine with a glass jug and a capacity of 10 cups (Braun, type 3073) and a coffee pad machine (Senseo, type HD 7810)

Supplementary Materials B: Assignment of Characterisation Factors

Nine elementary flows do not appear in Mostert's and Bringezu's [28] list of elementary flows (Ecoinvent database 3.1) but these elementary flows are abiotic and process-linked in the Ecoinvent database 3.3. For these elementary flows, raw material is assigned; the values for the characterisation factors of the assigned raw materials are also based on Mostert and Bringezu [28].

Table S2: Elementary flows, assigned raw materials and characterization factors

No.	Elementary flow (Ecoinvent database 3.3)	Assigned raw material	Value for characterisation factor according to Mostert and Bringezu [28], kg/kg	
			CF RMI	CF TMR
1	Cobalt, Co 5.0E-2%, in mixed ore, in ground	Cobalt	115.0	115.0
2	Copper, Cu 6.8E-1%, in mixed ore, in ground	Copper	143.0	157.0
3	Gold, Au 1.0E-7%, in mixed ore, in ground	Gold	943,610.0	2,906,316.0
4	Nickel, Ni 2.5E+0%, in mixed ore, in ground	Nickel	63.0	101.0

5	Palladium, Pd 1.6E-6%, in mixed ore, in ground	Palladium	66,063.0	107,683.0
6	Platinum, Pt 4.7E-7%, in mixed ore, in ground	Platinum	274,186.0	274,186.0
7	Rhodium, Rh 1.6E-7%, in mixed ore, in ground	Rhodium	520,571.0	572,628.0
8	Silver, Ag 1.8E-6%, in mixed ore, in ground	Silver	10,561.0	17,954.0
9	Strontium	Strontium	1.0	1.0

Supplementary Materials C: Material Compositions per Appliance and Data Origin of Life Cycle Inventory Data

Table S3: Material composition of flat-screen monitor at component level

Component	Description of materials	Determination method of material		Weight in grams	
		Composition	Type	Total of measured values	Measured values
Stand incl. height lock	Sheet steel (69%), plastic casting (29%), steel springs (3%)	SZ (springs of the height lock account for 6% of the component weight, assumption: 80% steel sheet and 20% steel wire), M (rest)	SA	1,706	1,092 457 98 35 24
Back panel	ABS casting	-	K	365	365
Frame incl. control panel	ABS casting	-	K	94	94
Inner housing	Steel sheet (85%), aluminium sheet (13%), plastic film (2%)	M	SA	813	689 58 44 14 5 3
LC display	LC Display	-	SA	410	410
Backlight (CCFL, foils, diffusing panel, back panel and frame)	Backlight	-	SA	1,564	913 234 66 34 191 126
Loudspeaker	Permanent magnet (79%), plastic	M	SA	58	46 12

	casting (21%), paper (<< 1%), textile (<< 1%)				
Main board	Assembled board, SMD (95%), Assembled board, THT (5%)	SZ	SA	78	78
Power board	Assembled board, THT	-	SA	186	186
Circuit board, LCD	Assembled board, SMD	-	SA	32	32
Circuit board, CCFL	Assembled board, SMD (50%), Assembled board, THT (50%)	SZ	SA	66	66
Circuit board, control element	Assembled board, SMD	-	SA	3	3
Circuit board, loudspeaker	Assembled board, THT	-	SA	60	60
Toggle switch, power board	Toggle switch	-	SA	4	4
Internal cables	Cables	-	SA	50	31 19
Power cable	Cable (30%), power plug (70%)	SZ	SA	170	170
Screws	Steel wire	M	SA	53	28 10 7 4 4
Total	-	-	-	5,712	-

Determination method of material composition: M = measured value, SZ = estimated value.

Determination method of material type: K = according to label, SA = estimation.

Table S4: Material composition of loudspeaker box at component level

Component	Description of materials	Determination method of material		Weight in grams (volume in cm^3)	
		Composition	Type	Total of measured values	Measured values
Housing	Chipboard coated	-	SA	1,491 (2,449)	1.491 (562) (562) (330) (330) (383) (284)
Loudspeaker cover	ABS (94%), textile (6%), cast rubber (< 1%)	M	K (ABS), SA (rest)	49	46 3
Subwoofer	Permanent magnet (82%), sheet steel (14%), plastic casting (4%), copper wire (< 1%), aluminium sheet (< 1%), paper (< 1%), textile (< 1%)	M (basket, magnet, frame ≥ 99% of component weight), SZ (rest)	SA	534	437 75 22
Tweeter	Permanent magnet (85%), plastic casting (14%), plastic foil (< 1%), copper wire (< 1%), aluminium sheet (< 1%)	M (dome cover accounts for 12% of component weight), SZ (remainder)	SA	132	116 16
Capacitor incl. cable	Cable (80%), electronic component, passive (20%)	SZ	SA	33	33

Damping material	Textile	-	SA	21	21
Bass reflex tube	Cardboard	-	SA	31	31
Screws	Steel wire	-	SA	7	7
Total	-	-	-	2,298	-

Determination method of material composition: M = measured value, SZ = estimated value.

Determination method of material type: K = according to label, SA = estimation.

Table S5: Material composition of filter coffee machine at component level

Component	Description of materials	Determination method of material		Weight in grams	
		Composition	Type	Total of measured values	Measured values
Top cover	PP casting	-	K	53	53
Base	PP casting	-	K	120	120
Feet	Rubber casting	-	SA	-	-
Housing incl. water tank, filter device and elements of the water duct (without base and top cover)	PP casting	-	K	554	554
Hot plate incl. fixing element for heater	Sheet steel, plastic casting (< 1%), sheet copper (< 1%)	SZ	SA	114	1113
Control panel on/off	Plastic casting	-	SA	3	3
Insert for filter device incl. coffee spout	PP casting, plastic casting (<< 1%), rubber casting (<<	SZ	K (PP), SA (rest)	62	62

	1%), steel wire (<< 1%)				
Water hoses	Rubber casting	-	SA	32	18 14
Water pipe from water tank to filter	PP casting, steel wire (<< 1%)	M	K	17	17
Check valve	Plastic casting	-	SA	-	-
Coffee pot	Glass (84%), plastic casting (15%), aluminium sheet (1%)	M	SA	313	262 24 22 4
Heating element incl. water pipe	Die-cast aluminium, insulating material (< 1%), heat conductor (< 1%)	SZ	SA	82	82
Temperature switch incl. fuse	Electronic component, passive	-	SA	10	10
On/off switch with LED	Electronic component, passive (67%), LED (33%)	SZ	SA	3	3
Cable	Cable	-	SA	3	3
Power cable	Cable (30%), power plug (70%)	SZ	SA	103	103
Screws	Steel wire	-	SA	3	3
Total	-	-	-	1.472	-

Determination method of material composition: M = measured value, SZ = estimated value.

Determination method of material type: K = according to label, SA = estimation.

Table S6: Material composition of coffee pad machine at component level

Component	Description of materials	Determination method of material	Weight in grams

		Composition	Type	Total of measured values	Measured values
Top cover	PP casting	-	K	98	98
Base	PP casting	-	K	142	142
Back panel	PP casting	-	K	59	59
Housing (without base, top cover and back panel)	PP casting	-	K	215	215
Control panel/knobs	ABS casting	-	K	3	3
Cup tray	Sheet steel	-	SA	69	69
Drip tray	PP casting	-	K	15	15
Feet	Rubber casting	-	SA	-	-
Pad holder	Stainless steel (82%), POM casting (9%), PP casting (9%)	M	K (POM, PP), SA (rest)	34	28 3 3
Water tank	PP casting	-	K	132	132
Float	Plastic casting (80%), permanent magnet (20%)	SZ	SA	3	3
Hose water tank – pump	Rubber casting	-	SA	9	9
Hose pump – heating chamber	Rubber casting	-	SA	9	9
Hose heating chamber – brewing chamber	Rubber casting	-	SA	6	6
Water level sensor	Reed switch	-	SA	-	-
Pump	Electric steel sheet (49%), permanent magnet (6%), plastic casting (26%), copper wire (19%),	SZ (parts of stator & rotor composition, account for 51% of weight), M (remainder)	SA	324	124 122 42 36

	plastic film (<< 1%)				
Three-way valve	Plastic casting	-	SA	7	7
Brewing chamber	PA casting (44%), PA-GF casting (32%), PP casting (19%), rubber casting (5%)	M	K (PA, PA-GF, PP), SA (rest)	232	101 75 45 11
Strainer insert	Stainless steel	-	SA	14	14
Coffee collection chamber incl. coffee spout	POM casting	-	K	45	42 – 47
Heating chamber	Stainless steel (71%), plastic (18%), sheet steel (6%), electronic component, passive (5%), cable (< 1%)	M	SA	251	179 45 16 11
Circuit board with steel element	Sheet steel (60%), Assembled board, SMD (20%), Assembled board, THT (20%)	SZ	SA	56	56
Cable	Cable (30%), power plug (70%)	SZ	SA	125	125
Connecting elements e.g. screws, cable ties	Plastic casting (65%), steel wire (35%)	M	SA	17	11 6
Total	-	-	-	1.865	-

Determination method of material composition: M = measured value, SZ = estimated value.

Determination method of material type: K = according to label, SA = estimation.

Table S7: Material composition of washing machine at component level

Component	Description of materials	Determination method of material		Weight in grams	
		Composition	Type	Total of measured values	Measured values
Back panel & side walls	Sheet steel	-	SA	11,237	5,375* 5,270* 592
Cross braces for stabilization	Sheet steel	-	SA	828	828
Front wall	Sheet steel	-	SA	2,968	2,968
Sound insulation	Textile	-	SA	127	127
Cover	Chipboard (100%), plastic casting (< 1%), coating (< 1%)	SZ	SA	3,976 (7,200)	3,976** (7,200)
Faceplate (bottom)	PC-ABS casting	-	K	173	173
Door	Glass (67%), PCABS casting (16%), PP casting (11%), zinc die casting (6%), aluminium sheet (< 1%), steel wire (< 1%), plastic casting (< 1%)	M	K (PC-ABS, PP), SA (rest)	2,380	1,607 379 260 134
Door lock	Cast plastic, copper sheet (< 1%), steel sheet (< 1%), brass (< 1%)	SZ	SA	42	42

Door seal incl. clamping ring	EPDM casting (92%), steel wire (8%)	M	K (EPDM), SA (rest)	809	741 68
Detergent drawer	PP casting (63%), PC-ABS casting (37%)	M	K	331	210 121
Filter flap	PC-ABS casting	-	K	81	81
Control panel	PC-ABS casting (99%), foam (1%)	M	K (PCABS), SA (rest)	422	294 105 15 5 3
Feet	Steel wire, cast rubber (< 1%)	SZ	SA	150	150
Tub	PP casting	-	K	6,421	2,461 2,025 1,902 33*
Springs	Steel wire	-	SA	241	241
Shock absorber	Sheet steel (78%), cast plastic (16%), cast rubber (5%)	M	SA	278	216 46 16
Weights	Concrete (99%), steel sheet (1%), reinforcing steel (< 1%)	M	K (concrete), SA (rest)	22,200	4,727 (1,995)*** 3,974 (1,677)*** 3,319 (1,401)*** 2,668 (1,126)*** 2,655 (1,120)*** 2,491 (1,051)*** 676* (278)*** 662* (273)***

					626* (258)*** 268* (111)*** 183
Washing drum	Stainless steel sheet	-	SA	3,524	3,424 100
Drum cross incl. shaft	Die-cast aluminium (60%), sheet steel (40%)	M	SA	1,928	1,157 771
Bearing	Sheet steel	-	SA	2,479	2,479
V-belt	Rubber casting	-	SA	40	40
Belt pulley	Aluminium sheet	-	K	366	366
Motor	Electrical steel sheet (61%), copper wire (21%), aluminium die casting (14%), plastic casting (2%), steel sheet (2%), rubber casting (< 1%), cable (< 1%), fiberglass (< 1%), electronic component, passive (< 1%)	SZ (rotor composition, accounts for 28% of the motor weight and consists of equal parts of copper wire and electrical steel sheet), M (rest)	SA	5,470	2,557 1,559* 746 391 88 87 35
Carbon brushes	Copper wire (56%), plastic casting (44%), graphite (< 1%), steel wire (< 1%)	M	SA	36	16 20
Inlet hose (incl. gasket)	Plastic casting	-	SA	235	235

Drain hose (incl. seal and clamps)	Plastic casting (96%), steel wire (4%)	M	SA	309	12 293 4
Hoses (internal) incl. ball valve and clamps	EPDM casting (67%), steel wire (24%), plastic casting (9%)	M	K (EPDM), SA (rest)	464	311 113 16 13 11
Rinse-in unit	PP	-	K	383	383
Magnet valve	Copper wire (37%), plastic casting (36%), electrical steel sheet (27%)	M	SA	161	59* 58* 44*
Water inlet control	PA-GF cast iron, copper sheet (< 1%), steel sheet (< 1%), brass sheet (< 1%)	SZ	K (PAGF), SA (rest)	35	35
Pump	Electrical steel sheet (40%), copper wire (28%), plastic casting (23%), permanent magnet (9%), rubber casting (< 1%), brass sheet (< 1%) electronic component, passive (< 1%)	M	SA	490	199 103 84 52 44 8
Lint filter	PP casting	-	K	38	38
Heating	Stainless steel sheet (86%),	SZ (heating element composition,	SA	284	243** 25

	steel sheet (9%), EPDM cast (5%), insulating material (< 1%), heating conductor (< 1%)	accounts for 86% of the weight), M (rest)			16
Temperature sensor	Electronic component, passive	-	SA	8	8
Control electronics	Assembled board, SMD (60 %), assembled board, THT (40%)	SZ	SA	186	186
Line filter	Steel sheet (35%), plastic casting (35%), electronic component, passive (25%), copper wire (5%)	SZ	SA	128	128**
Power cable	Cable (30%), power plug (70%)	SZ	SA	172	172
Cable harness with connectors	Cable (81%), electronic component, passive (19%)	M	SA	296	241 55
Cable duct	PP casting	-	K	54	54
Fragments	Cast plastic, sheet steel (< 1%)	SZ	SA	18	18
Screws	Steel wire (94%), stainless steel wire (6%)	M	SA	354	67 66 37 61 23 22

					20 20 16 16 3 3
Total	-	-	-	70,122	-

Determination method of material composition: M = measured value, SZ = estimated value. Determination method of material type: K = according to label, SA = estimation.

*(Partial) component was destroyed with saw/angle grinder.

**For visual estimation of material composition, the component or parts were destroyed, however, the total weight of the component was determined before destruction.

***Volume data is determined by measuring the weight. The volume-based values are therefore determined using a concrete density of 2,370kg/m3 and the weight-based values.

Table S8: Data origin of Life Cycle Inventory data, in %

Device	Material composition			Type of material	
	Measured value	Estimated value	Monomaterial	Marking on component	Estimated value
Flat-screen monitor	44	7	48	8	91
Loudspeaker box	26	6	67	2	97
Filter coffee machine	22	24	52	54	43

Coffee pad machine	36	18	43	49	48
Washing machine	49	9	42	45	54
Total	47	10	43	42	58

Supplementary Materials D: PMR Results per Appliance

Table S9: $TMR_{abiotic}$ and $RMI_{abiotic}$, manufacturing, flat-screen monitor by component

Component	$TMR_{abiotic}$, kg	$RMI_{abiotic}$, kg
LC Display	818.53	387.70
Main board	522.81	188.29
Circuit board, CCFL	264.16	99.11
Circuit board, LCD	223.85	80.44
Power board	180.96	88.61
Circuit board, loudspeaker	58.41	28.71
Backlight incl. foils etc.	51.84	36.53
Loudspeaker	22.64	21.64
Circuit board, control element	21.40	7.69
Stand incl. height lock	20.11	13.38
Power cable	18.45	14.81
Inner housing	14.59	9.95
Toggle switch, power board	5.52	2.01
Internal cables	5.36	4.31
Screws	5.09	4.06
Back panel	1.63	1.43
Frame incl. control panel	0.42	0.37
Total	2,235.77	989.04

Table S10: $TMR_{abiotic}$ and $RMI_{abiotic}$, packaging, flat-screen monitor

Packaging	$TMR_{abiotic}$, kg	$RMI_{abiotic}$, kg
Polystyrene and cardboard	3.30	2.81

Table S11: $TMR_{abiotic}$ and $RMI_{abiotic}$, manufacturing, loudspeaker box by component (per box)

Component	$TMR_{abiotic}$, kg	$RMI_{abiotic}$, kg
Subwoofer	214.64	205.03
Tweeter	57.07	54.54
Capacitor incl. cable	17.11	8,.0
Housing	1.45	1.18
Loudspeaker cover	0.22	0.19
Screws	0.11	0.07
Damping material	0.07	0.06
Bass reflex tube	0.05	0.04
Total	290.72	269.81

Table S12: $TMR_{abiotic}$ and $RMI_{abiotic}$, packaging, loudspeaker boxes

Packaging	$TMR_{abiotic}$, kg	$RMI_{abiotic}$, kg
Polystyrene and cardboard	3.30	2.81

Table S13: $TMR_{abiotic}$ and $RMI_{abiotic}$, manufacturing, filter coffee machine by component

Component	$TMR_{abiotic}$, kg	$RMI_{abiotic}$, kg
Temperature switch incl. fuse	21.71	13.93
Heating element incl. water pipe	16.47	9.80
Power cable	11.11	8.92
On/off switch with LED	3.34	1.77
Coffee pot	2.13	1.60
Housing incl. water tank, filter device and elements of the water duct (without base and top cover)	1.84	1.47
Hot plate incl. fixing element for heater	1.73	1.12
Base	0.40	0.35
Cable	0.32	0.25
Insert for filter device incl. coffee spout	0.21	0.18
Water hoses	0.20	0.17
Top cover	0.18	0.16

Water pipe from water tank to filter	0.06	0.05
Screws	0.05	0.03
Control panel on/off	0.01	0.01
Feet	-	-
Check valve	-	-
Total	59.76	39.81

Table S14: $TMR_{abiotic}$ and $RMI_{abiotic}$, packaging, coffee filter machine

Packaging	$TMR_{abiotic}$, kg	$RMI_{abiotic}$, kg
Polystyrene and cardboard	3.30	2.81

Table S15: $TMR_{abiotic}$ and $RMI_{abiotic}$, manufacturing, coffee pad machine by component

Component	$TMR_{abiotic}$, kg	$RMI_{abiotic}$, kg
Circuit board with steel element	89.27	33.70
Heating chamber	29.57	14.53
Pump	21.12	18.52
Cable	13.49	10.83
Brewing chamber	1.23	1.05
Cup tray	1.04	0.67
Pad holder	0.84	0.55
Housing	0.72	0.63
Base	0.48	0.41
Water tank	0.45	0.39
Strainer insert	0.41	0.27
Top cover	0.33	0.29
Float	0.30	0.29
Back panel	0.20	0.17
Coffee collection chamber incl. coffee spout	0.15	0.13
Connecting elements e.g. screws, cable ties	0.13	0.09
Hose pump - heating chamber	0.06	0.05
Hose water tank -pump	0.06	0.05
Drip tray	0.05	0.04
Hose heating chamber – brewing chamber	0.04	0.03

Three-way valve	0.02	0.02
Control panel/knobs	0.01	0.01
Feet	-	-
Water level sensor	-	-
Total	159.97	82.72

Table S16: $TMR_{abiotic}$ and $RMI_{abiotic}$, packaging, coffee pad machine

Packaging	$TMR_{abiotic}$, kg	$RMI_{abiotic}$, kg
Polystyrene and cardboard	3.30	2.81

Table S17: $TMR_{abiotic}$ and $RMI_{abiotic}$, manufacturing, washing machine by component

Component	$TMR_{abiotic}$, kg	$RMI_{abiotic}$, kg
Control electronics	851.74	315.77
Motor	350.66	287.04
Drum cross incl. shaft	245.52	205.12
Back panel & side walls	170.05	109.96
Cable harness with connectors	142.46	73.71
Washing drum	102.78	66.90
Line filter	71.09	32.38
Front wall	44.96	29.07
Pump	44.64	39.12
Bearing	37.54	24.28
Weights	27.69	25.42
Tub	21.70	18.83
Power cable	18.53	14.88
Temperature sensor	17.20	7.74
Door	14.41	12.34
Belt pulley	14.21	10.92
Cross braces for stabilization	12.53	8.10
Magnet valve	9.85	7.90
Heating	7.54	4.92
Screws	5.87	3.81
Door seal incl. clamping ring	5.69	4.47
Cover	4.40	3.57
Hoses (internal) incl. ball valve and clamps	3.85	2.86
Springs	3.80	2.47
Shock absorber	3.53	2.34

Carbon brushes	3.30	2.65
Feet	2.36	1.53
Control panel	2.06	1.80
Detergent drawer	1.30	1.14
Rinse-in unit	1.29	1.12
Drain hose (incl. seal and clamps)	1.19	0.99
Faceplate (bottom)	0.85	0.75
Inlet hose (incl. seal)	0.78	0.68
Sound insulation	0.43	0.36
Filter flap	0.40	0.35
V-belt	0.26	0.21
Water inlet control	0.20	0.17
Cable duct	0.18	0.16
Door lock	0.14	0.12
Lint filter	0.13	0.11
Fragments	0.06	0.05
Total	2,247.17	1,326.11

Table S18: $TMR_{abiotic}$ and $RMI_{abiotic}$, packaging, washing machine

Packaging	$TMR_{abiotic}$, kg	$RMI_{abiotic}$, kg
Coarse chipboard, polystyrene and cardboard	3.84	3.25

Supplementary Materials E: Sensitivity Analysis – Significance of the Results Depending on the Material Composition

The following table shows the considered literature to compare the materials compositions. For loudspeaker boxes no data was found in literature, therefore a producer of loudspeaker boxes was consulted. Derived from the comparison of material composition, the third column shows the striking differences. Based on this, the subject of the sensitivity analysis is chosen, the analysis conducted and results of the calculations displayed (see second half of the table).

Table S19: Relative sensitivities of influencing factors

Device	Sources considered	Striking differences in material composition	Influencing factor	Specific $TMR_{abiotic}$ and $RMI_{abiotic}$ with changed influencing factor	Percentage change of results of specific $TMR_{abiotic}$ and $RMI_{abiotic}$ per percentage change of influencing factor (absolute value)
Flat-screen monitor	Böni und Widmer [40];	Share of cable	Share of cable 1.1 % instead of 3.9 %	389 and 171 kg/kg	0.01 and 0.02

	Salhofer et al. [41]		(relative share of other components unchanged)		
Loudspeaker box	Interview with loudspeaker manufacturer (incl. repair workshop), conducted on 02/24/2017	Various*	Ferrite instead of neodymium magnets	23 and 13 kg/kg (for two boxes)	0.91 and 0.95
Coffee filter machine	Mudgal et al. [42]	Share of electronic parts and total weight of device	Mass of electronic 75 g instead of 13 g (material composition of other components is extrapolated, so that the total weight is 2.5 kg)	81 kg/kg and 45 kg/kg	0.21 and 0,14

Coffee pad machine	Mudgal et al. [42]	No	Ferrite instead of neodymium magnets	80 and 39 kg/kg	0.07 and 0.12
Washing mashine	Ebersberger [43]; Presutto et al. [44]; Boyano et al. [45]	Material of tub	Tub out of stainless steel instead of plastic	34 und 20 kg/kg	0.06 (both)

*Loudspeaker boxes can be made of varying materials. For example, the housing can be made of wood, plastic or aluminium. The materials used for the membrane range from paper, metal and plastics to fabric; AlNiCo, hard ferrite or neodymium magnets are generally used for the magnets. Due to the large number of possible material compositions and thus also weight proportions of the different materials, a sensitivity analysis can only be carried out as an example.