# Appendix E

**Perturbation analysis – detailed results**

Detailed results of the perturbation analysis undertaken to test the sensitivity of calculated results to the market substitution ratio parameter are presented in Table E1.

**Table E1**

Market substitution parameter sensitivity ratios (SR) of the material recycling systems investigated – detailed results.

| Material type | Secondary material | Avoided primary material | Initial market substitution rate | Initial result | Parameter contribution | Test market substitution rate | ∆Parameter | Test result | Test parameter contribution | ∆Result | SR |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| kg CO2-eq. | kg CO2-eq. | kg CO2-eq. | kg CO2-eq. | kg CO2-eq. |
| Green glass | Glass | Glass | 1 | -314 | -709 | 0.9 | 0.10 | -243 | -638 | 71 | -2.26 |
| Brown glass | Glass | Glass | 1 | -314 | -709 | 0.9 | 0.10 | -243 | -638 | 71 | -2.26 |
| Clear glass | Glass | Glass | 1 | -314 | -709 | 0.9 | 0.10 | -243 | -638 | 71 | -2.26 |
| Mixed glass | Glass | Glass | 1 | -314 | -709 | 0.9 | 0.10 | -243 | -638 | 71 | -2.26 |
| Paper | Newsprint | Newsprint | 1 | -459 | -2033 | 0.9 | 0.10 | -255 | -1830 | 203 | -4.43 |
| Card | Testliner | Kraftliner | 1 | -120 | -320 | 0.9 | 0.10 | -88 | -288 | 32 | -2.66 |
| Wellenstoff | SCF | 1 | -120 | -358 | 0.9 | 0.10 | -85 | -322 | 36 | -2.97 |
| Total avoided production | | 1 | -120 | -678 | 0.9 | 0.10 | -53 | -610 | 68 | -5.63 |
| Books | Testliner | Kraftliner | 1 | -117 | -320 | 0.9 | 0.10 | -85 | -288 | 32 | -2.72 |
| Wellenstoff | SCF | 1 | -117 | -358 | 0.9 | 0.10 | -82 | -322 | 36 | -3.04 |
| Total avoided production | | 1 | -117 | -678 | 0.9 | 0.10 | -50 | -610 | 68 | -5.77 |
| Mixed paper & card | Testliner | Kraftliner | 1 | -123 | -320 | 0.9 | 0.10 | -91 | -288 | 32 | -2.61 |
| Wellenstoff | SCF | 1 | -123 | -358 | 0.9 | 0.10 | -87 | -322 | 36 | -2.92 |
| Total avoided production | | 1 | -123 | -678 | 0.9 | 0.10 | -55 | -610 | 68 | -5.52 |
| Yellow Pages | Testliner | Kraftliner | 1 | -117 | -320 | 0.9 | 0.10 | -85 | -288 | 32 | -2.72 |
| Wellenstoff | SCF | 1 | -117 | -358 | 0.9 | 0.10 | -82 | -322 | 36 | -3.04 |
| Total avoided production | | 1 | -117 | -678 | 0.9 | 0.10 | -50 | -610 | 68 | -5.77 |
| Steel cans | Steel | Steel | 1 | -862 | -1391 | 0.9 | 0.10 | -723 | -1252 | 139 | -1.61 |
| Aluminium cans | Aluminium | Aluminium | 1 | -8143 | -9256 | 0.9 | 0.10 | -7218 | -8330 | 926 | -1.14 |
| Mixed cans | Steel | Steel | 1 | -3577 | -766 | 0.9 | 0.10 | -3500 | -690 | 77 | -0.21 |
| Aluminium | Aluminium | 1 | -3577 | -3693 | 0.9 | 0.10 | -3208 | -3324 | 369 | -1.03 |
| Total avoided production | | 1 | -3577 | -4460 | 0.9 | 0.10 | -3131 | -4014 | 446 | -1.25 |
| Other scrap metal | Steel | Steel | 1 | -3577 | -766 | 0.9 | 0.10 | -3500 | -690 | 77 | -0.21 |
| Aluminium | Aluminium | 1 | -3577 | -3693 | 0.9 | 0.10 | -3208 | -3324 | 369 | -1.03 |
| Total avoided production | | 1 | -3577 | -4460 | 0.9 | 0.10 | -3131 | -4014 | 446 | -1.25 |
| Aluminium foil | Aluminium | Aluminium | 1 | -8143 | -9256 | 0.9 | 0.10 | -7218 | -8330 | 926 | -1.14 |
| Aerosols | Steel | Steel | 1 | -3577 | -766 | 0.9 | 0.10 | -3500 | -690 | 77 | -0.21 |
| Aluminium | Aluminium | 1 | -3577 | -3693 | 0.9 | 0.10 | -3208 | -3324 | 369 | -1.03 |
| Total avoided production | | 1 | -3577 | -4460 | 0.9 | 0.10 | -3131 | -4014 | 446 | -1.25 |
| Fire extinguishers | Steel | Steel | 1 | -673 | -1324 | 0.9 | 0.10 | -541 | -1192 | 132 | -1.97 |
| Gas bottles | Steel | Steel | 1 | -673 | -1324 | 0.9 | 0.10 | -541 | -1192 | 132 | -1.97 |
| Bicycles | Steel | Steel | 1 | -3577 | -766 | 0.9 | 0.10 | -3500 | -690 | 77 | -0.21 |
| Aluminium | Aluminium | 1 | -3577 | -3693 | 0.9 | 0.10 | -3208 | -3324 | 369 | -1.03 |
| Total avoided production | | 1 | -3577 | -4460 | 0.9 | 0.10 | -3131 | -4014 | 446 | -1.25 |
| Mixed plastics | HDPE | HDPE | 1 | -1024 | -339 | 0.9 | 0.10 | -990 | -305 | 34 | -0.33 |
| PVC | PVC | 1 | -1024 | -62 | 0.9 | 0.10 | -1018 | -56 | 6 | -0.06 |
| PP | PP | 1 | -1024 | -114 | 0.9 | 0.10 | -1012 | -103 | 11 | -0.11 |
| Total avoided production | | 1 | -1024 | -1363 | 0.9 | 0.10 | -888 | -1227 | 136 | -1.33 |
| Mixed plastic bottles | PET | PET | 1 | -1084 | -814 | 0.9 | 0.10 | -1003 | -732 | 81 | -0.75 |
| HDPE | HDPE | 1 | -1084 | -574 | 0.9 | 0.10 | -1027 | -516 | 57 | -0.53 |
| PVC | PVC | 1 | -1084 | -15 | 0.9 | 0.10 | -1083 | -13 | 1 | -0.01 |
| PP | PP | 1 | -1084 | -18 | 0.9 | 0.10 | -1083 | -16 | 2 | -0.02 |
| Total avoided production | | 1 | -1084 | -1420 | 0.9 | 0.10 | -942 | -1278 | 142 | -1.31 |
| PET | PET | PET | 1 | -2192 | -2347 | 0.9 | 0.10 | -1957 | -2112 | 235 | -1.07 |
| HDPE | HDPE | HDPE | 1 | -1149 | -1528 | 0.9 | 0.10 | -996 | -1375 | 153 | -1.33 |
| PVC | PVC | PVC | 1 | -1549 | -1928 | 0.9 | 0.10 | -1356 | -1735 | 193 | -1.24 |
| LDPE | LDPE | LDPE | 1 | -972 | -1001 | 0.9 | 0.10 | -872 | -901 | 100 | -1.03 |
| PP | PP | PP | 1 | -1184 | -1563 | 0.9 | 0.10 | -1027 | -1407 | 156 | -1.32 |
| Wood | rMDF | vMDF | 1 | -351 | -981 | 0.9 | 0.10 | -253 | -883 | 98 | -2.79 |
| Chipboard and MDF | rMDF | vMDF | 1 | -351 | -981 | 0.9 | 0.10 | -253 | -883 | 98 | -2.79 |
| Composite wood materials | rMDF | vMDF | 1 | -177 | -785 | 0.9 | 0.10 | -98 | -706 | 78 | -4.44 |
| WEEE - large domestic appliances | Steel | Steel | 1 | -866 | -716 | 0.9 | 0.10 | -795 | -645 | 72 | -0.83 |
| Aluminium | Aluminium | 1 | -866 | -566 | 0.9 | 0.10 | -810 | -509 | 57 | -0.65 |
| PP | PP | 1 | -866 | -12 | 0.9 | 0.10 | -865 | -11 | 1 | -0.01 |
| Total avoided production | | 1 | -866 | -1294 | 0.9 | 0.10 | -737 | -1165 | 129 | -1.49 |
| WEEE - small domestic appliances | Steel | Steel | 1 | -1350 | -542 | 0.9 | 0.10 | -1295 | -488 | 54 | -0.40 |
| Aluminium | Aluminium | 1 | -1350 | -1223 | 0.9 | 0.10 | -1227 | -1101 | 122 | -0.91 |
| PP | PP | 1 | -1350 | -34 | 0.9 | 0.10 | -1346 | -31 | 3 | -0.03 |
| Zinc (from batteries) | Zinc | 1 | -1350 | -7 | 0.9 | 0.10 | -1349 | -6 | 1 | -0.01 |
| Manganese (from batteries) | Manganese | 1 | -1350 | -3 | 0.9 | 0.10 | -1349 | -3 | 0 | 0.00 |
| Mercury (from batteries) | Mercury | 1 | -1350 | 0 | 0.9 | 0.10 | -1350 | 0 | 0 | 0.00 |
| Mercury (from batteries) | Ferromanganese | 1 | -1350 | -1 | 0.9 | 0.10 | -1349 | -1 | 0 | 0.00 |
| Steel (from batteries) | Steel | 1 | -1350 | -3 | 0.9 | 0.10 | -1349 | -2 | 0 | 0.00 |
| Total avoided production | | 1 | -1350 | -1812 | 0.9 | 0.10 | -1168 | -1631 | 181 | -1.34 |
| WEEE - CRTs | Steel | Steel | 1 | -228 | -133 | 0.9 | 0.10 | -214 | -120 | 13 | -0.59 |
| Aluminium | Aluminium | 1 | -228 | -151 | 0.9 | 0.10 | -213 | -136 | 15 | -0.66 |
| Copper | Copper | 1 | -228 | -13 | 0.9 | 0.10 | -226 | -12 | 1 | -0.06 |
| Lead | Lead | 1 | -228 | -198 | 0.9 | 0.10 | -208 | -178 | 20 | -0.87 |
| Copper (from cables) | Copper | 1 | -228 | -3 | 0.9 | 0.10 | -227 | -2 | 0 | -0.01 |
| Total avoided production | | 1 | -228 | -499 | 0.9 | 0.10 | -178 | -449 | 50 | -2.19 |
| WEEE - fluorescent tubes & other light bulbs | Steel | Steel | 1 | -779 | -33 | 0.9 | 0.10 | -776 | -30 | 3 | -0.04 |
| Aluminium | Aluminium | 1 | -779 | -518 | 0.9 | 0.10 | -728 | -467 | 52 | -0.66 |
| Glass | Glass | 1 | -779 | -745 | 0.9 | 0.10 | -705 | -671 | 75 | -0.96 |
| Total avoided production | | 1 | -779 | -1297 | 0.9 | 0.10 | -650 | -1167 | 130 | -1.66 |
| WEEE - fridges & freezers | Steel | Steel | 1 | -853 | -851 | 0.9 | 0.10 | -768 | -766 | 85 | -1.00 |
| Aluminium | Aluminium | 1 | -853 | -459 | 0.9 | 0.10 | -807 | -413 | 46 | -0.54 |
| PP | PP | 1 | -853 | -13 | 0.9 | 0.10 | -852 | -11 | 1 | -0.01 |
| Total avoided production | | 1 | -853 | -1322 | 0.9 | 0.10 | -721 | -1190 | 132 | -1.55 |
| Automotive batteries | Lead | Lead | 1 | -435 | -1373 | 0.9 | 0.10 | -298 | -1236 | 137 | -3.15 |
| Post-consumer, non-automotive batteries | Zinc | Zinc | 1 | -204 | -682 | 0.9 | 0.10 | -136 | -614 | 68 | -3.35 |
| Manganese | Manganese | 1 | -204 | -294 | 0.9 | 0.10 | -174 | -265 | 29 | -1.45 |
| Mercury | Mercury | 1 | -204 | -2 | 0.9 | 0.10 | -204 | -2 | 0 | -0.01 |
| Ferromanganese | Ferromanganese | 1 | -204 | -104 | 0.9 | 0.10 | -193 | -94 | 10 | -0.51 |
| Steel | Steel | 1 | -204 | -250 | 0.9 | 0.10 | -179 | -225 | 25 | -1.23 |
| Total avoided production | | 1 | -204 | -1333 | 0.9 | 0.10 | -70 | -1199 | 133 | -6.54 |
| Car tyres | Steel | Steel | 1 | -636 | -213 | 0.9 | 0.10 | -614 | -192 | 21 | -0.33 |
| Rubber crumb | Synthetic rubber | 1 | -636 | -419 | 0.9 | 0.10 | -594 | -377 | 42 | -0.66 |
| Rubber granulate | Bitumen | 1 | -636 | -209 | 0.9 | 0.10 | -615 | -188 | 21 | -0.33 |
| Total avoided production | | 1 | -636 | -841 | 0.9 | 0.10 | -551 | -757 | 84 | -1.32 |
| Van tyres | Steel | Steel | 1 | -671 | -188 | 0.9 | 0.10 | -653 | -169 | 19 | -0.28 |
| Rubber crumb | Synthetic rubber | 1 | -671 | -453 | 0.9 | 0.10 | -626 | -408 | 45 | -0.68 |
| Rubber granulate | Bitumen | 1 | -671 | -227 | 0.9 | 0.10 | -649 | -205 | 23 | -0.34 |
| Total avoided production | | 1 | -671 | -868 | 0.9 | 0.10 | -584 | -782 | 87 | -1.29 |
| Large vehicle tyres | Steel | Steel | 1 | -671 | -188 | 0.9 | 0.10 | -653 | -169 | 19 | -0.28 |
| Rubber crumb | Synthetic rubber | 1 | -671 | -453 | 0.9 | 0.10 | -626 | -408 | 45 | -0.68 |
| Rubber granulate | Bitumen | 1 | -671 | -227 | 0.9 | 0.10 | -649 | -205 | 23 | -0.34 |
| Total avoided production | | 1 | -671 | -868 | 0.9 | 0.10 | -584 | -782 | 87 | -1.29 |
| Mixed tyres | Steel | Steel | 1 | -640 | -210 | 0.9 | 0.10 | -619 | -189 | 21 | -0.33 |
| Rubber crumb | Synthetic rubber | 1 | -640 | -423 | 0.9 | 0.10 | -598 | -381 | 42 | -0.66 |
| Rubber granulate | Bitumen | 1 | -640 | -211 | 0.9 | 0.10 | -619 | -190 | 21 | -0.33 |
| Total avoided production | | 1 | -640 | -845 | 0.9 | 0.10 | -555 | -760 | 84 | -1.32 |
| Furniture | rMDF | vMDF | 1 | -177 | -785 | 0.9 | 0.10 | -98 | -706 | 78 | -4.44 |
| Rubble | Aggregate | Gravel | 1 | -2 | -3 | 0.9 | 0.10 | -1 | -2 | 0 | -1.65 |
| Steel | Steel | 1 | -2 | -14 | 0.9 | 0.10 | 0 | -13 | 1 | -8.81 |
| Total avoided production | | 1 | -2 | -17 | 0.9 | 0.10 | 0 | -15 | 2 | -10.45 |
| Soil | - | - | - | - | - | - | - | - | - | - | - |
| Plasterboard | Gypsum | Gypsum | 1 | 4 | -35 | 0.9 | 0.10 | 7 | -32 | 4 | 9.95 |
| Testliner | Kraftliner | 1 | 4 | -7 | 0.9 | 0.10 | 4 | -6 | 1 | 1.99 |
| Wellenstoff | SCF | 1 | 4 | -8 | 0.9 | 0.10 | 4 | -7 | 1 | 2.22 |
| Total avoided production | | 1 | 4 | -50 | 0.9 | 0.10 | 9 | -45 | 5 | 14.16 |
| Vegetable oil | Biodiesel | Fossil diesel | 1 | -2759 | -3406 | 0.9 | 0.10 | -2418 | -3065 | 341 | -1.23 |
| Mineral oil | Biodiesel | Fossil diesel | 1 | -2759 | -3406 | 0.9 | 0.10 | -2418 | -3065 | 341 | -1.23 |
| Composite food & beverage cartons | Testliner | Kraftliner | 1 | -242 | -189 | 0.9 | 0.10 | -223 | -170 | 19 | -0.78 |
| Wellenstoff | SCF | 1 | -242 | -212 | 0.9 | 0.10 | -220 | -191 | 21 | -0.88 |
| HDPE | HDPE | 1 | -242 | -199 | 0.9 | 0.10 | -222 | -179 | 20 | -0.82 |
| Aluminium | Aluminium | 1 | -242 | -454 | 0.9 | 0.10 | -196 | -408 | 45 | -1.88 |
| Total avoided production | | 1 | -242 | -1054 | 0.9 | 0.10 | -136 | -948 | 105 | -4.36 |
| Mattresses | Steel | Steel | 1 | -1241 | -661 | 0.9 | 0.10 | -1175 | -595 | 66 | -0.53 |
| Mattress filling fibre | PE foam | 1 | -1241 | -410 | 0.9 | 0.10 | -1200 | -369 | 41 | -0.33 |
| Synthetic cloths | Polyester cloths | 1 | -1241 | -551 | 0.9 | 0.10 | -1186 | -496 | 55 | -0.44 |
| Natural fibre cloths | Kraft paper | 1 | -1241 | -97 | 0.9 | 0.10 | -1231 | -87 | 10 | -0.08 |
| Total avoided production | | 1 | -1241 | -1718 | 0.9 | 0.10 | -1069 | -1546 | 172 | -1.38 |
| Paint | Steel | Steel | 1 | 86 | -278 | 0.9 | 0.10 | 114 | -250 | 28 | 3.24 |
| Textiles & footwear | Mattress filling fibre | PE foam | 1 | -3376 | -1463 | 0.9 | 0.10 | -3230 | -1317 | 146 | -0.43 |
| Synthetic cloths | Polyester cloths | 1 | -3376 | -1969 | 0.9 | 0.10 | -3179 | -1772 | 197 | -0.58 |
| Natural fibre cloths | Kraft paper | 1 | -3376 | -345 | 0.9 | 0.10 | -3342 | -311 | 35 | -0.10 |
| Total avoided production | | 1 | -3376 | -3777 | 0.9 | 0.10 | -2999 | -3399 | 378 | -1.12 |
| Textiles only | Mattress filling fibre | PE foam | 1 | -3376 | -1463 | 0.9 | 0.10 | -3230 | -1317 | 146 | -0.43 |
| Synthetic cloths | Polyester cloths | 1 | -3376 | -1969 | 0.9 | 0.10 | -3179 | -1772 | 197 | -0.58 |
| Natural fibre cloths | Kraft paper | 1 | -3376 | -345 | 0.9 | 0.10 | -3342 | -311 | 35 | -0.10 |
| Total avoided production | | 1 | -3376 | -3777 | 0.9 | 0.10 | -2999 | -3399 | 378 | -1.12 |
| Footwear only | Mattress filling fibre | PE foam | 1 | -3376 | -1463 | 0.9 | 0.10 | -3230 | -1317 | 146 | -0.43 |
| Synthetic cloths | Polyester cloths | 1 | -3376 | -1969 | 0.9 | 0.10 | -3179 | -1772 | 197 | -0.58 |
| Natural fibre cloths | Kraft paper | 1 | -3376 | -345 | 0.9 | 0.10 | -3342 | -311 | 35 | -0.10 |
| Total avoided production | | 1 | -3376 | -3777 | 0.9 | 0.10 | -2999 | -3399 | 378 | -1.12 |
| Carpets | PP | PP | 1 | -9 | -152 | 0.9 | 0.10 | 6 | -137 | 15 | -17.15 |
| AHPs | Testliner | Kraftliner | 1 | 14 | -13 | 0.9 | 0.10 | 15 | -11 | 1 | 0.93 |
| Wellenstoff | SCF | 1 | 14 | -14 | 0.9 | 0.10 | 15 | -13 | 1 | 1.04 |
| PET | PET | 1 | 14 | -9 | 0.9 | 0.10 | 14 | -8 | 1 | 0.65 |
| PP | PP | 1 | 14 | -14 | 0.9 | 0.10 | 15 | -13 | 1 | 1.06 |
| Total avoided production | | 1 | 14 | -50 | 0.9 | 0.10 | 19 | -45 | 5 | 3.68 |

PET, polyethylene terephthalate; HDPE, high-density polyethylene; PVC, polyvinyl chloride; LDPE, low-density polyethylene; PP, polypropylene; MDF, medium-density fibreboard; WEEE, waste electrical and electronic equipment; CRT, cathode-ray tube; AHP, absorbent hygiene product.