**Appendix C**

**Foreground system and avoided production data sources and data quality**

An overview of foreground system process and avoided production data used and, for each, data source, the results of a data quality assessment are presented in Tables C1 and C2, respectively.

**Table C1**

Recycled material foreground system process data used and data quality rating.

| Waste material group | Waste material type | Name of dataset used | Data source | Geographic coverage | Reference year | Data quality rating |
| --- | --- | --- | --- | --- | --- | --- |
| Glass | Green glass | “Glass cullets, sorted, at sorting plant” | Hischier (2007) | Europe | 1998 | Poor quality |
| Container glass manufacture using recycled glass | Enviros Consulting Ltd (2003) | Europe | 2003 | Fair quality |
| Glass production using glass waste as cullet | Larsen *et al.* (2009) | Europe | 2009 | Fair quality |
| Brown glass | “Glass cullets, sorted, at sorting plant” | Hischier (2007) | Europe | 1998 | Poor quality |
| Container glass manufacture using recycled glass | Enviros Consulting Ltd (2003) | Europe | 2003 | Fair quality |
| Glass production using glass waste as cullet | Larsen *et al.* (2009) | Europe | 2009 | Fair quality |
| Clear glass | “Glass cullets, sorted, at sorting plant” | Hischier (2007) | Europe | 1998 | Poor quality |
| Container glass manufacture using recycled glass | Enviros Consulting Ltd (2003) | Europe | 2003 | Fair quality |
| Glass production using glass waste as cullet | Larsen *et al.* (2009) | Europe | 2009 | Fair quality |
| Mixed glass | “Glass cullets, sorted, at sorting plant” | Hischier (2007) | Europe | 1998 | Poor quality |
| Container glass manufacture using recycled glass | Enviros Consulting Ltd (2003) | Europe | 2003 | Fair quality |
| Glass production using glass waste as cullet | Larsen *et al.* (2009) | Europe | 2009 | Fair quality |
| Paper & card | Paper | “Paper, newsprint, DIP containing, at plant” | Hischier (2007) | Europe | 2000 | Poor quality |
| Card | “Corrugated board base paper, testliner, at plant” | Hischier (2007) | Europe | 2005 | Fair quality |
| “Corrugated board base paper, wellenstoff, at plant” | Hischier (2007) | Europe | 2005 | Fair quality |
| Books | “Corrugated board base paper, testliner, at plant” | Hischier (2007) | Europe | 2005 | Fair quality |
| “Corrugated board base paper, wellenstoff, at plant” | Hischier (2007) | Europe | 2005 | Fair quality |
| Mixed paper & card | “Corrugated board base paper, testliner, at plant” | Hischier (2007) | Europe | 2005 | Fair quality |
| “Corrugated board base paper, wellenstoff, at plant” | Hischier (2007) | Europe | 2005 | Fair quality |
| Yellow pages | “Corrugated board base paper, testliner, at plant” | Hischier (2007) | Europe | 2005 | Fair quality |
| “Corrugated board base paper, wellenstoff, at plant” | Hischier (2007) | Europe | 2005 | Fair quality |
| Metal | Steel cans | Crude steel production, electric arc furnace | Burchart-Korol (2013) | Poland | 2010 | Fair quality |
| Aluminium cans | “Scrap metal sorting and preparation” | EAA (2008) | Europe | 2002 | Fair quality |
| “Aluminium, secondary production” | Classen *et al.* (2009) | Europe | 2002 | Fair quality |
| Mixed cans\* | “Scrap metal sorting and preparation” | EAA (2008) | Europe | 2002 | Poor quality |
| Other scrap metal\* | “Scrap metal sorting and preparation” | EAA (2008) | Europe | 2002 | Poor quality |
| Aluminium foil | “Scrap metal sorting and preparation” | EAA (2008) | Europe | 2002 | Poor quality |
| “Aluminium, secondary production” | Classen *et al.* (2009) | Europe | 2002 | Poor quality |
| Aerosols\* | “Scrap metal sorting and preparation” | EAA (2008) | Europe | 2002 | Poor quality |
| Fire extinguishers\* | “Scrap metal sorting and preparation” | EAA (2008) | Europe | 2002 | Poor quality |
| Gas bottles\* | “Scrap metal sorting and preparation” | EAA (2008) | Europe | 2002 | Poor quality |
| Bicycles | - | - | - | - |  |
| Plastic | Mixed plastics | Stadler plastic film separation & Titech NIR sorting | Shonfield (2008) | UK | 2008 | Fair quality |
| "Plastic (HDPE) recycling, Linpac" | EA (2010) | UK | 2003 | Poor quality |
| Mixed plastic bottles | Stadler plastic film separation & Titech NIR sorting | Shonfield (2008) | UK | 2008 | Fair quality |
| "Plastic (HDPE) recycling, Linpac" | EA (2010) | UK | 2003 | Poor quality |
| PET | “Plastics (PET) recycling, Delleve” | EA (2010) | UK | 2004 | Fair quality |
| HDPE | "Plastic (HDPE) recycling, Linpac" | EA (2010) | UK | 2003 | Poor quality |
| PVC | "Plastic (HDPE) recycling, Linpac" | EA (2010) | UK | 2003 | Poor quality |
| LDPE | “Agricultural film recycling, BPI Poly” | EA (2010) | UK | 2003 | Poor quality |
| PP | "Plastic (HDPE) recycling, Linpac" | EA (2010) | UK | 2003 | Poor quality |
| Wood | Wood | Composite wood materials recycling, microrelease process | Mitchell and Stevens (2009) | UK | 2008 | Poor quality |
| Chipboard & MDF | Composite wood materials recycling, microrelease process | Mitchell and Stevens (2009) | UK | 2008 | Poor quality |
| Composite wood materials | Composite wood materials recycling, microrelease process | Mitchell and Stevens (2009) | UK | 2008 | Poor quality |
| WEEE | LDAs\* | “Shredding, electrical and electronic scrap” | Hischier *et al.* (2007) | Europe | 2005 | Fair quality |
| Recycling of WEEE appliances | Crowe *et al.* (2003) | Europe | 2000 | Poor quality |
| “Disposal, treatment of printed wiring boards” | Hischier *et al.* (2007) | Global | 2005 | Poor quality |
| SDAs\* | “Shredding, electrical and electronic scrap” | Hischier *et al.* (2007) | Europe | 2005 | Fair quality |
| Recycling of WEEE appliances | Crowe *et al.* (2003) | Europe | 2000 | Poor quality |
| CRTs\* | “Manual depollution, CRT screen” | Hischier *et al.* (2007) | Global | 2005 | Fair quality |
| “Mechanical treatment, shredding, CRT screen” | Hischier *et al.* (2007) | Global | 2005 | Fair quality |
| “Copper, secondary, at refinery” | Classen *et al.* (2009) | Europe | 2003 | Poor quality |
| Pyrometallurgical processing of CRT funnel glass | Xu *et al.* (2013) | USA | 2013 | Fair quality |
| Fluorescent tubes & other light bulbs\* | “Disposal, fluorescent lamps” | Hischier *et al.* (2007) | Switzerland | 2005 | Fair quality |
| Fridges & freezers\* | “Shredding, electrical and electronic scrap” | Hischier *et al.* (2007) | Europe | 2005 | Fair quality |
| Recycling of WEEE appliances | Crowe *et al.* (2003) | Europe | 2000 | Poor quality |
| Batteries | Automotive batteries | Mixed waste batteries sorting | Fisher *et al.* (2006) | UK | 2006 | Fair quality |
| Lead acid battery recycling, Campine | Fisher *et al.* (2006) | Belgium | 2004 | Fair quality |
| Post-consumer, non-automotive batteries | Mixed waste batteries sorting | Fisher *et al.* (2006) | UK | 2006 | Fair quality |
| Hydrometallurgical processing (RECUPYLTM process) of spent alkaline batteries, Recupyl | Fisher *et al.* (2006) | France | 2004 | Fair quality |
| Pyrometallurgical processing of spent alkaline batteries, Batrec | Fisher *et al.* (2006) | Switzerland | 2004 | Fair quality |
| Tyres | Car tyres\* | Tyre recycling, multi-function plant | Eldan Recycling (2014) | UK | 2014 | Poor quality |
| Recycling of end of life tyres | Baeyens *et al.* (2010) | Global | 2010 | Poor quality |
| Van tyres\* | Tyre recycling, multi-function plant | Eldan Recycling (2014) | UK | 2014 | Poor quality |
| Recycling of end of life tyres | Baeyens *et al.* (2010) | Global | 2010 | Poor quality |
| Large vehicle tyres\* | Tyre recycling, multi-function plant | Eldan Recycling (2014) | UK | 2014 | Poor quality |
| Recycling of end of life tyres | Baeyens *et al.* (2010) | Global | 2010 | Poor quality |
| Mixed tyres\* | Tyre recycling, multi-function plant | Eldan Recycling (2014) | UK | 2014 | Poor quality |
| Recycling of end of life tyres | Baeyens *et al.* (2010) | Global | 2010 | Poor quality |
| Furniture | Furniture | Composite wood materials recycling, microrelease process | Mitchell and Stevens (2009) | UK | 2008 | Poor quality |
| Rubble | Rubble\* | “Buiding rubble recycling, Tarmac” | EA (2010) | UK | 2004 | Poor quality |
| Soil | Soil | - | Boldrin *et al.* (2009) | Europe | 2009 | Fair quality |
| - | Bruun *et al.* (2006) | Denmark | 2006 | Poor quality |
| - | Hansen (2006) | Europe | 2006 | Poor quality |
| Plasterboard | Plasterboard\* | Plasterboard recycling | WRAP (2008) | UK | 2007 | Fair quality |
| Oil | Vegetable oil | Biodiesel production, alkali-catalysed transesterification processing of waste vegetable oil | Morais *et al.* (2010) | Europe | 2010 | Fair quality |
| Mineral oil | Biodiesel production, alkali-catalysed transesterification processing of waste vegetable oil | Morais *et al.* (2010) | Europe | 2010 | Poor quality |
| Composite | Composite food & beverage cartons\* | “Waste paper, sorted, for further treatment” | Hischier (2007) | Europe | 2007 | Poor quality |
| Composite packaging waste recycling | Xie *et al.* (2012) | China | 2013 | Poor quality |
| Mattresses\* | Textiles recovery, reclamation and processing, Jmp Wilcox & Co Ltd | EA (2010) | UK | 2005 | Fair quality |
| Paint | Paint\* | “Scrap metal sorting and preparation” | EAA (2008) | Europe | 2002 | Poor quality |
| “Treatment, sewage, to wastewater treatment, class 5” | Doka (2009) | Switzerland | 2000 | Poor quality |
| Textiles | Textiles & footwear | Textiles recovery, reclamation and processing, Jmp Wilcox & Co Ltd | EA (2010) | UK | 2005 | Fair quality |
| Textiles recycling, production of filling fibre, Edward Clay & Sons Ltd | EA (2010) | UK | 2005 | Fair quality |
| Textiles reprocessing, production of wiping cloths, Jmp Wilcox & Co Ltd | EA (2010) | UK | 2005 | Fair quality |
| Textiles only | Textiles recovery, reclamation and processing, Jmp Wilcox & Co Ltd | EA (2010) | UK | 2005 | Fair quality |
| Textiles recycling, production of filling fibre, Edward Clay & Sons Ltd | EA (2010) | UK | 2005 | Fair quality |
| Textiles reprocessing, production of wiping cloths, Jmp Wilcox & Co Ltd | EA (2010) | UK | 2005 | Fair quality |
| Footwear only | Textiles recovery, reclamation and processing, Jmp Wilcox & Co Ltd | EA (2010) | UK | 2005 | Fair quality |
| Textiles recycling, production of filling fibre, Edward Clay & Sons Ltd | EA (2010) | UK | 2005 | Poor quality |
| Textiles reprocessing, production of wiping cloths, Jmp Wilcox & Co Ltd | EA (2010) | UK | 2005 | Poor quality |
| Carpets\* | Carpet recycling, Blackwater Ltd. | WRAP (no date) | UK | Unknown | Poor quality |
| Other | AHPs\* | “Waste paper, sorted, for further treatment” | Hischier (2007) | Europe | 2007 | Poor quality |
| Nappy recycling, Knowaste | Freyberg (2012) | UK | 2012 | Fair quality |

\*For composite materials, only data sources used for material pre-processing (e.g. dismantlement, disassembly, and sorting) and the recycling (reprocessing) of components particular to that composite material are presented. Data sources used for the recycling of component material types are detailed individually.

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

**Table C2**

Avoided primary production process data used and data quality rating.

| Secondary product | Avoided primary product | Name of primary production data set used | Data source | Geographic coverage | Reference year | Data quality rating |
| --- | --- | --- | --- | --- | --- | --- |
| Secondary container glass | Primary container glass | Container glass manufacture using recycled glass | Enviros Consulting Ltd (2003) | Europe | 2003 | Fair quality |
| Glass production using glass waste as cullet | Larsen *et al.* (2009) | Europe | 2009 | Fair quality |
| Secondary newsprint | Primary newsprint | “Paper, newsprint, 0% DIP, at plant” | Hischier (2007) | Europe | 2000 | Poor quality |
| Testliner | Kraftliner | "Corrugated board base paper, kraftliner, at plant" | Hischier (2007) | Europe | 2005 | Fair quality |
| Wellenstoff | Semi-chemical fluting | "Corrugated board base paper, semichemical fluting, at plant" | Hischier (2007) | Europe | 2005 | Fair quality |
| Crude steel | Steel | "Steel, converter, unalloyed, at plant" | Classen *et al.* (2009) | Europe | 2001 | Fair quality |
| Aluminium | Aluminium | "Aluminium, primary, at plant" | Classen *et al.* (2009) | Europe | 2002 | Fair quality |
| PET flakes | PET flakes | "Polyethylene terephthalate, granulate, amorphous, at plant" | Hischier (2007) | Europe | 2003 | Fair quality |
| HDPE granulate | HDPE granulate | "Polyethylene, HDPE, granulate, at plant" | Hischier (2007) | Europe | 2001 | Fair quality |
| PVC pellets | PVC pellets | " Polyvinylchloride, suspension polymerised, at plant" | Hischier (2007) | Europe | 2001 | Fair quality |
|  |  | "Polyvinylchloride, emulsion polymerised, at plant" | Hischier (2007) | Europe | 2001 | Fair quality |
| PP granulate | PP granulate | "Polypropylene granulate (PP), production mix, at plant" | JRC (2008) | Europe | 2001 | Fair quality |
| LDPE pellets | LDPE pellets | "Polyethylene, LDPE, granulate, at plant" | Hischier (2007) | Europe | 2001 | Fair quality |
| Recycled MDF | Virgin MDF fibre | - | Shonfield (2008) | UK | 2008 | Fair quality |
| Zinc | Zinc | "Zinc, primary, at regional storage" | Classen *et al.* (2009) | Europe | 2003 | Fair quality |
| Manganese | Manganese | "Manganese, at regional storage" | Classen *et al.* (2009) | Europe | 2003 | Poor quality |
| Mercury | Mercury | "Mercury, liquid, at plant" | Classen *et al.* (2009) | Global | 2000 | Poor quality |
| Ferromanganese | Ferromanganese | "Ferromanganese, high-coal, 74/5% Mn, at regional storage" | Classen *et al.* (2009) | Europe | 2003 | Poor quality |
| Lead | Lead | "Lead, primary, at plant" | Classen *et al.* (2009) | Global | 2005 | Fair quality |
| Copper | Copper | "Copper, primary, at refinery" | Classen *et al.* (2009) | Europe | 2003 | Fair quality |
| Rubber granulate <3 mm | Bitumen | "Bitumen, at refinery" | Jungbluth (2007) | Europe | 2000 | Poor quality |
| Rubber crumb <20 mm | Synthetic rubber | "Synthetic rubber, at plant" | Hischier (2007) | Europe | 2003 | Poor quality |
| Aggregate | Gravel | "Gravel, unspecified, at mine" | Kellenberger *et al.* (2007) | Switzerland | 2001 | Poor quality |
| Gypsum | Mineral gypsum | "Gypsum, mineral, at mine" | Kellenberger *et al.* (2007) | Switzerland | 2003 | Poor quality |
| - | WRAP (2008) | UK | 2007 | Fair quality |
| Biodiesel | Fossil diesel | - | DEFRA *et al.* (2014) | UK | 2013 | High quality |
| Mattress filling fibre | Flocking material | "Polyurethane, flexible foam, at plant" | Hischier (2007) | Europe | 1997 | Poor quality |
| Natural fibre wiping cloths | Paper wiping cloths | "Kraft paper, bleached, at plant" | Hischier (2007) | Europe | 1993 | Poor quality |
| Artificial fibre wiping cloths | Artificial wiping cloths | - | DEFRA *et al.* (2014) | UK | 2013 | High quality |

PET, polyethylene terephthalate; LDPE, low-density polyethylene; HDPE, high-density polyethylene; PVC, polyvinyl chloride; PP, polypropylene; MDF, medium-density fibreboard

## References

Baeyens, J., Brems, A. and Dewil, R. (2010) Recovery and recycling of post-consumer waste materials. Part 2. Target wastes (glass beverage bottles, plastics, scrap metal and steel cans, end-of-life tyres, batteries and household hazardous waste). *International Journal of Sustainable Engineering,* 3 (4), 232-245.

Boldrin, A., Andersen, J.K., Moller, J., Christensen, T.H. and Favoino, E. (2009) Composting and compost utilization: Accounting of greenhouse gases and global warming contributions. *Waste Management & Research,* 27 (8), 800-812.

Bruun, S., Hansen, T.L., Christensen, T.H., Magid, J. and Jensen, L.S. (2006) Application of processed organic municipal solid waste on agricultural land – a scenario analysis. *Environmental Modeling & Assessment,* 11 (3), 251-265.

Burchart-Korol, D. (2013) Life cycle assessment of steel production in Poland: a case study. *Journal of Cleaner Production,* 54, 235-243.

Classen, M., Althaus, H.-J., Balaser, S., Scharnhorst, W., Tuchschmid, M., Jungbluth, N. and Emmenegger, L. (2009) *Life cycle inventories of metals. Final report ecoinvent report No. 10*. Dübendorf, Switzerland: Swiss Centre for Life Cycle Inventories.

Crowe, M., Elser, A., Göpfert, B., Mertins, L., Meyer, T., Schmid, J., Spillner, A. and Ströbel, R. (2003) *Waste from electrical and electronic equipment (WEEE) - quantities, dangerous substances and treatment methods*. Copenhagen, Denmark: European Environment Agency.

Department for Environment, Food & Rural Affairs (Defra), Ricardo-AEA and Carbon Smart (2014) *Greenhouse gas conversion factor repository*. Available from: http://www.ukconversionfactorscarbonsmart.co.uk/ [Accessed 10/06/2015].

Doka, G. (2009) *Life cycle inventories of waste treatment services. ecoinvent report No. 13*. Dübendorf, Switzerland: Swiss Centre for Life Cycle Inventories.

EAA (2008) *Environmental profile report for the European aluminium industry*. Brussels, Belgium: European Aluminium Association.

Eldan Recycling (2014) *Multi Function Plant (Tyre/Cable/WEEE)*. Available from: http://www.eldan-recycling.com/content/multi-function-plant-tyrecableweee-1 [Accessed 11/06/2015].

EA (2010) *Waste and Resources Assessment Tool for the Environment (WRATE) LCA model*. Rotherham, UK: Environment Agency.

Enviros Consulting Ltd (2003) *Glass recycling - life cycle carbon dioxide emissions*. Sheffield, UK: British Glass Manufacturers Confederation.

Fisher, K., Wallén, E., Laenen, P.P. and Collins, M. (2006) *Battery waste management life cycle assessment*. London, UK: Department for Environment, Food & Rural Affairs.

Freyberg, T. (2012) Nappy recycling is the UK ready to run walk or crawl? *Waste Management World,* 13 (5).

Hansen, T.L. (2006) Environmental modelling of use of treated organic waste on agricultural land: a comparison of existing models for life cycle assessment of waste systems. *Waste Management & Research,* 24 (2), 141-152.

Hischier, R. (2007) *Life cycle inventories of packagings and graphical papers. ecoinvent report No. 11*. Dübendorf, Switzerland: Swiss Centre for Life Cycle Inventories.

Hischier, R., Classen, M., Lehmann, M. and Scharnhorst, W. (2007) *Life cycle inventories of electric and electronic equipment - production, use & disposal. ecoinvent report No. 18*. Dübendorf, Switzerland: Swiss Centre for Life Cycle Inventories.

Joint Research Centre (JRC) (2008) *European reference life cycle database, version 2.0*. European Commission. Available from: http://eplca.jrc.ec.europa.eu/ELCD3/ [Accessed 11/06/2015].

Jungbluth, N. (2007) Erdӧl IN: Dones, R. (ed.) *Sachbilanzen von Energiesystemen: Grundlagen für den ӧkologischen Vergleich von Energiesystemen und den Einbezug von Energiesystemen in Ökobilanzen für die Schweiz. ecoinvent report No. 6-IV*. Dübendorf, Switzerland: Swiss Centre for Life Cycle Inventories.

Kellenberger, D., Althaus, H.-J., Künniger, T., Lehmann, M., Jungbluth, N. and Thalmann, P. (2007) *Life cycle inventories of building products. ecoinvent report No. 7*. Dübendorf, Switzerland: Swiss Centre for Life Cycle Inventories.

Larsen, A.W., Merrild, H. and Christensen, T.H. (2009) Recycling of glass: Accounting of greenhouse gases and global warming contributions. *Waste Management & Research,* 27 (8), 754-762.

Mitchell, A. and Stevens, G. (2009) *Life cycle assessment of closed loop MDF recycling: Microrelease trial*. Banbury, UK: Waste & Resources Action Programme.

Morais, S., Mata, T.M., Martins, A.A., Pinto, G.A. and Costa, C.A.V. (2010) Simulation and life cycle assessment of process design alternatives for biodiesel production from waste vegetable oils. *Journal of Cleaner Production,* 18 (13), 1251-1259.

Shonfield, P. (2008) *LCA of Management Options for Mixed Waste Plastics*. Banbury, UK: Waste & Resources Action Programme.

WRAP (2008) *Life Cycle Assessment of plasterboard. Quantifying the environmental impacts throughout the product life cycle, building the evidence base in sustainable construction*. Banbury, UK: Waste & Resources Action Programme.

WRAP (no date) *Collecting and shredding carpets from Household Waste Recycling Centres*. Banbury, UK: Waste & Resources Action Programme.

Xie, M., Qiao, Q., Sun, Q. and Zhang, L. (2012) Life cycle assessment of composite packaging waste management—a Chinese case study on aseptic packaging. *The International Journal of Life Cycle Assessment,* 18 (3), 626-635.

Xu, Q., Yu, M., Kendall, A., He, W., Li, G. and Schoenung, J.M. (2013) Environmental and economic evaluation of cathode ray tube (CRT) funnel glass waste management options in the United States. *Resources, Conservation and Recycling,* 78, 92-104.