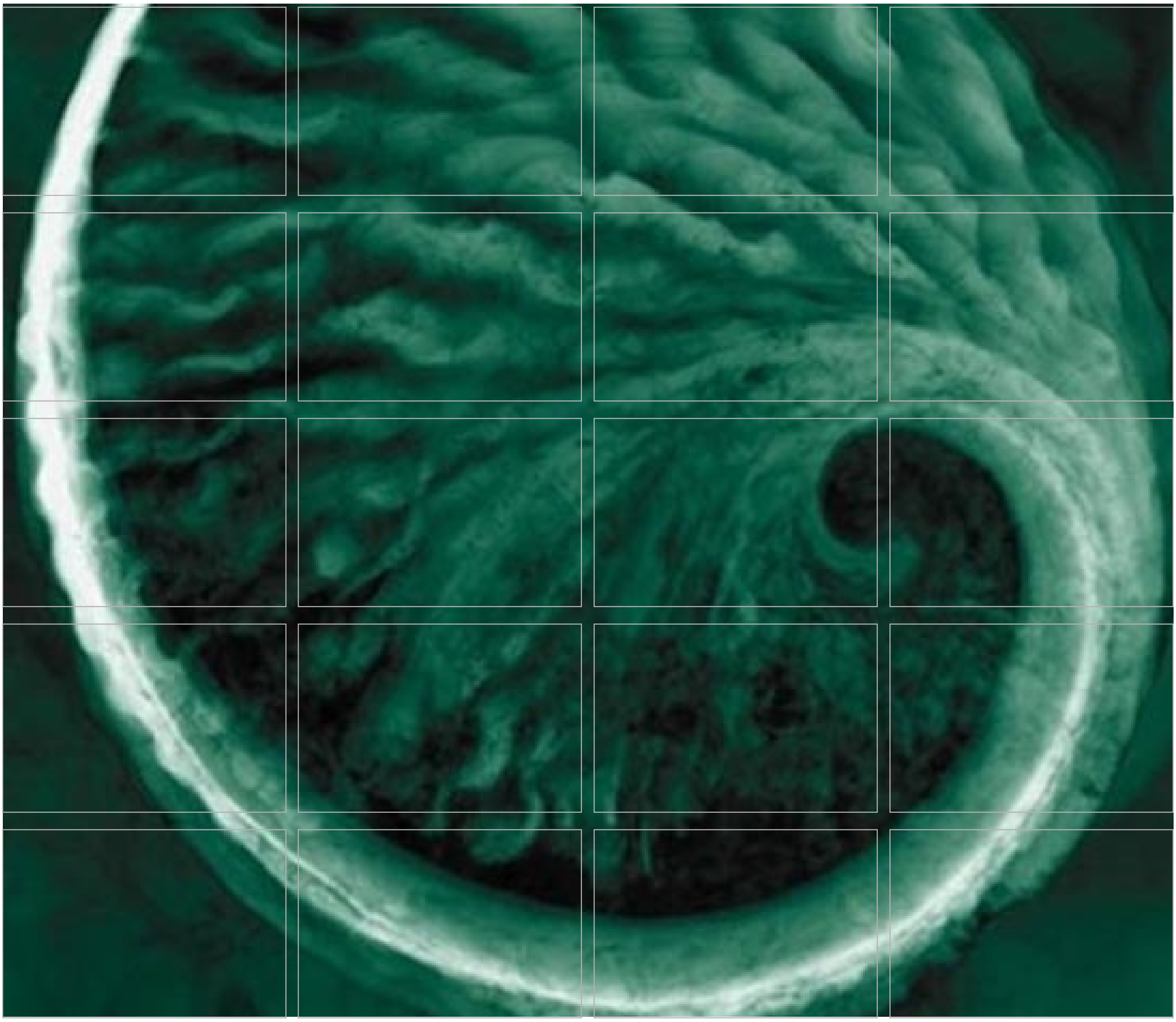

Battery Waste Management Life Cycle Assessment

Final Report for Publication

18 October 2006

Delivering sustainable solutions in a more competitive world

ERM

Defra

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Final Report for Publication

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For and on behalf of Environmental Resources Management
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Position: Partner
Date: 18 October 2006

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Executive Summary

1 EXECUTIVE SUMMARY

1.1 INTRODUCTION

At the end of 2004, the EU Council of Ministers reached agreement on a draft *Directive on Batteries and Accumulators*. This Common Position text includes a number of requirements:

- a partial ban on portable nickel-cadmium batteries (with some exclusions);
- a collection target of 25% of all spent portable batteries 4 years after transposition of the Directive;
- a collection target of 45% of all spent portable batteries 8 years after transposition of the Directive; and
- recycling targets for collected portable batteries of between 50% and 75%.

The aim of this study is to inform readers of the costs and benefits of various options for implementing these collection and recycling requirements in the UK. The study uses a life cycle assessment (LCA) approach with a subsequent economic valuation of the options. The LCA methods undertaken comply with those laid down in international standards (ISO14040).

The study has been commissioned by the UK Department for Environment Food and Rural Affairs (Defra). Its intended purpose is to assist policy by estimating the financial cost of different collection and recycling routes and to estimate the environmental return for that expenditure. Findings will be used to inform the development of a regulatory impact assessment (RIA) for the implementation of the proposed Directive in the UK.

The study, in accordance with the international standard for LCA, ISO14040, has been critically reviewed by a third party, Dr Anders Schmidt from FORCE Technology.

1.2 COMPARING SCENARIOS FOR DIRECTIVE IMPLEMENTATION

To compare options for implementing the proposed Batteries Directive, the study considered the environmental impacts associated with the management of forecast consumer portable battery waste arisings in the UK between 2006 and 2030. This included the collection and recycling of all portable battery chemistries, with the exception of industrial and automotive batteries.

The scope of the assessment has included the collection, sorting, recycling and residual waste management of the waste batteries. Impacts relating to the production and use of batteries were excluded from the study. Therefore, the options compared differ only in method of collection and subsequent treatment or recycling. Three collection scenarios were assessed, as follows:

- **Collection Scenario 1** where kerbside collection schemes are favoured;
- **Collection Scenario 2** where CA site collection schemes are favoured; and
- **Collection Scenario 3** where bring receptacle collection schemes, located in business/school/public/WEEE dismantler premises, are favoured.

These were matched with three scenarios describing the main alternative options for recycling alkaline and saline batteries (these account for more that 80% of battery sales in the UK) which were as follows:

- **Recycling Scenario 1** - UK provision of hydrometallurgical recycling;
- **Recycling Scenario 2** - UK and EU provision of hydrometallurgical recycling (50:50); and
- **Recycling Scenario 3** - EU provision of pyrometallurgical recycling.

In combination, a total of nine implementation scenarios were created (for example collection scenario 1 plus recycling scenario 1 etc.). These were compared with a tenth, baseline, scenario that assumed all batteries are managed as residual waste (89% landfill, 11% incineration).

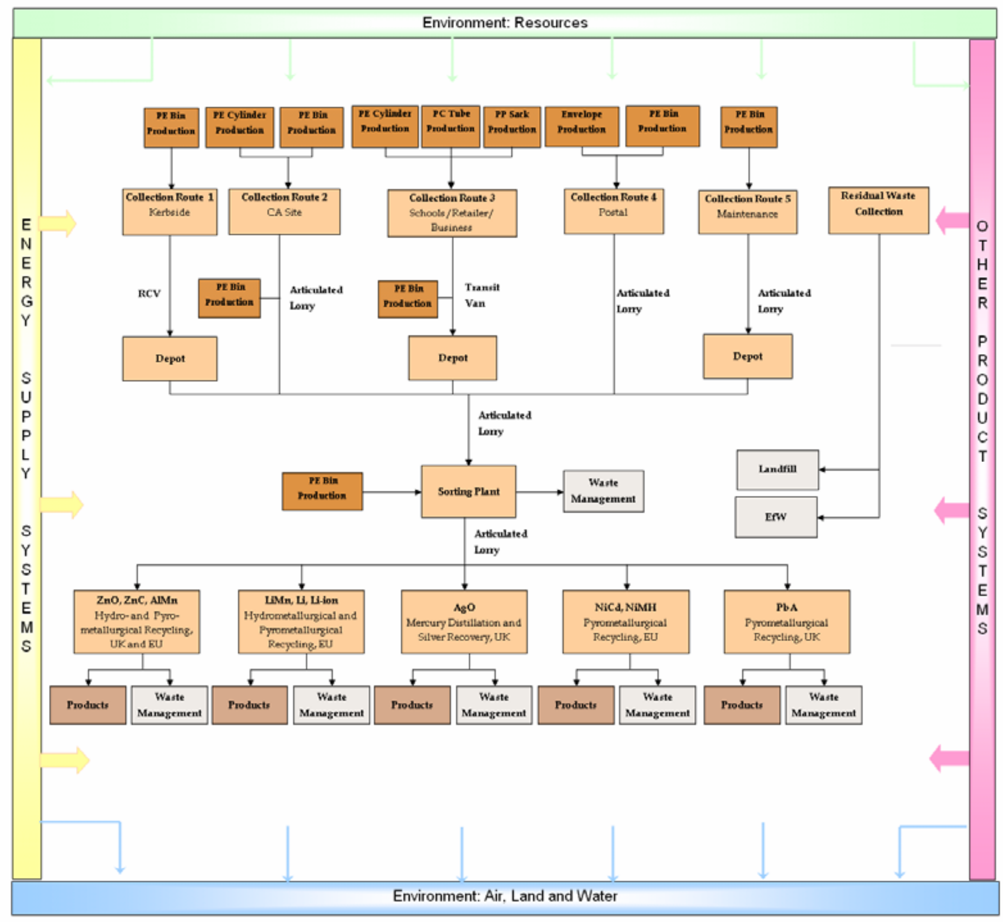
For each scenario, all of the materials, chemicals and energy consumed during the manufacture of collection containers, sorting of batteries into separate chemistries and processing for recycling or disposal were identified, together with all of the emissions to the environment at each stage. All these 'flows' were quantified and traced back to the extraction of raw materials that were required to supply them. For example, polymer materials used in collection containers were linked to the impacts associated with crude oil extraction. Any 'avoided' flows resulting from the recovery of metals in recycling processes (and reducing the need for virgin metals production) were also quantified.

Figure 1.1 shows the system that was studied for each implementation scenario.

The total flows of each substance were compiled for each stage of the life cycle and used to assess the environmental impacts of each system. For example, flows of methane, carbon dioxide and other greenhouse gases were aggregated for each system in total. Internationally agreed equivalents that quantify the relative global warming effect of each gas were then used to assess the overall global warming impact of each implementation scenario. This 'impact assessment' was carried out for a number of categories of environmental impact, for which there are well-described methods: abiotic resource depletion; global warming; ozone layer depletion; human, aquatic and terrestrial toxicity; acidification; and eutrophication.

Key players in the battery waste management industry provided data on the materials and energy requirements of collection, sorting and recycling operations shown in *Figure 1.1* (including materials recovery). Published life cycle inventory data were, in turn, used to describe the production (and avoided production) of these material and energy inputs. It is acknowledged that a key limitation of the study was the use of secondary data in this way. However, it was not within the scope of the project to collect primary data for these processes. The increasing age of secondary data suggest a need for a Europe wide programme to maintain and to improve LCI data for use in studies such as this.

Figure 1.1 *System Boundary of Scenarios*



1.3 THE STUDY FINDINGS

The study shows that increasing recycling of batteries is beneficial to the environment, due to the recovery of metals and avoidance of virgin metal production. However, it is achieved at significant financial cost when compared with disposal.

Table 1.1 displays the net environmental benefit associated with implementation scenarios (1-9), over and above the baseline scenario (10). *Table 1.2* displays the waste management and average environmental and social costs that have been estimated for each implementation scenario.

Estimates show that implementation of the proposed Directive will result in a significant increase in battery waste management costs, with some savings in the financial costs quantified for environmental and social aspects [1]. At the same time, the CO_2 savings that can be achieved amount to between 198kg and 248kg CO_2-equivalents avoided per tonne of battery waste arisings, in comparison with current management.

Table 1.1 Environmental Benefit of Implementation Scenarios (net Benefit in Comparison with Baseline)

Implementation Scenario	Abiotic depletion	Global warming (GWP100)	Ozone layer depletion (ODP)	Human toxicity	Fresh water aquatic ecotoxicity	Terrestrial ecotoxicity	Acidification	Eutro-phication
Unit	*t Sb eq*	*t CO_2 eq*	*t CFC-11 eq*	*t 1,4-DB eq*	*T 1,4-DB eq*	*t 1,4-DB eq*	*t SO_2 eq*	*t PO_4- eq*
Scenario 1	1751	133,764	26	1,908,108	2,224,908	26,750	1659	310
Scenario 2	1894	153,764	24	1,914,538	2,224,775	26,762	1718	310
Scenario 3	1525	135,064	16	2,051,248	2,240,745	261,128	2152	309
Scenario 4	1744	133,164	26	1,908,028	2,224,885	26,697	1654	310
Scenario 5	1887	153,164	23	1,914,458	2,224,752	26,760	1713	310
Scenario 6	1518	134,464	16	2,051,168	2,240,722	261,125	2147	308
Scenario 7	1672	123,044	25	1,902,468	2,223,758	26,656	1620	306
Scenario 8	1815	143,044	22	1,908,898	2,223,625	26,719	1679	306
Scenario 9	1446	124,344	15	2,045,608	2,239,595	261,085	2113	305

Note: all the scenarios show a net benefit over the baseline for all environmental impacts.

Table 1.2 Total Financial Costs of Implementation Scenarios

Scenario	Waste Management Costs (Million £)	Coverage	Environmental and Social Costs (Million £)	Coverage	Total Scenario Cost (Million £)
Scenario 1	235.2	Collection, sorting and recycling service charges. Landfill and incineration gate fees	-34.6	Effect of NOx, SO_2, NMVOC and particulate emissions on human health (human toxicity). Climate change costs of carbon (CO_2 and CH_4 emissions only). Abiotic depletion, ozone depletion, aquatic ecotoxicity, acidification (with the exception of damage to buildings) and eutrophication impacts have not been quantified.	200.6
Scenario 2	235.2		-35.4		199.8
Scenario 3	235.2		-30.5		204.7
Scenario 4	235.2		-34.5		200.7
Scenario 5	235.2		-35.4		199.8
Scenario 6	235.2		-30.5		204.7
Scenario 7	233.5		-33.9		199.6
Scenario 8	233.5		-34.7		198.8
Scenario 9	233.5		-30.1		203.4
Scenario 10	28.1		1.8		29.9

We found that the relative performance of different scenarios is mainly dictated by the choice of recycling scenario. Scenarios sharing the same recycling scenario (eg scenarios 1, 4 and 7) show more similarity in profile than those with the same collection scenario (eg scenarios 1, 2 and 3). Different recycling scenarios are favoured in each impact category, with no clear overall high performer.

Although making relatively little contribution in terms of overall benefit/burden, it is evident that scenarios utilising collection scenario 3

(1) It should be noted, however, that a number of external benefits associated implementation scenarios have not been quantified in terms of financial cost.

perform relatively less well than those utilising collection scenarios 1 and 2 in the majority of impact categories. This is predominantly due to additional fuel consumption and CO_2 emissions through the collection transportation network.

1.4 CRITICAL REVIEW SUMMARY

Dr Schmidt in his critical review (*Annex E*) concluded the following:

- 'The methods employed for the study are consistent with the international standards ISO 14040ff;
- The methods considered for the study are scientifically valid and reflect the international state of the art for LCA;
- Considering the goals of the study, the used data are justified to be adequate, appropriate and consistent;
- The consistency of the interpretations with regard to the goals and the limitations of the study is regarded to be fully fulfilled;
- The report is certified to have a good transparency and consistency; and
- Overall the critical review concludes that the study is in accordance with the requirements of the international standards ISO 14040ff.'

Main Report

1 *BATTERY WASTE MANAGEMENT LIFE CYCLE ASSESSMENT*

1.1 *ACKNOWLEDGEMENTS*

ERM would like to thank the following organisations for their help in collating data and information for this study: Batrec; Campine; Citron; G&P Batteries; Indaver Relight; Recupyl; SNAM and Valdi. Their contribution to the project has been invaluable in compiling the most up-to-date information for current battery collection and recycling processes.

1.2 *INTRODUCTION*

The European Commission adopted the proposed *Directive on Batteries and Accumulators* in November 2003. In response to these proposals, the Dutch presidency put forward a number of revisions in September 2004. Shortly afterwards, an extended impact assessment report was produced to support the Presidency's proposals.

Subsequently, at the end of 2004, the EU Council of Ministers reached political agreement on the draft Directive. This Common Position text includes a number of requirements:

- a partial ban on portable nickel-cadmium batteries with some exclusions;
- a collection target of 25% of all spent portable batteries 4 years after transposition of the Directive;
- a collection target of 45% of all spent portable batteries 8 years after transposition of the Directive; and
- recycling targets for collected portable batteries of between 50% and 75%.

These proposals will now be returned to the European Parliament for its second reading.

The objective of this study is to inform readers of the costs and benefits of various options for implementing these collection and recycling requirements in the UK. The study uses a life-cycle assessment (LCA) approach with a subsequent economic valuation of the options (*Section 6*).

A monetary valuation assessment was conducted, using up-to-date monetary valuation techniques to assess each of the implementation scenarios developed.

Due to uncertainties associated with battery arisings, with the collection and recycling routes that will be developed, and with the implementation dates for the Directive, a number of scenarios have been examined and sensitivity analyses conducted. The assessment of the scenarios and the sensitivity analyses provide information on the environmental benefits that will be achieved through implementation of the Directive.

1.3 *ISO 14040: GOAL AND SCOPE REQUIREMENTS*

Clear specification of goal and scope is of paramount importance for the credibility and successful conclusion of an LCA study.

The scope determines the method that will be used to collect and to collate data, to produce life cycle inventories, to conduct the impact assessment and to compare the different options.

In order to conform with ISO14041, the goal and scope of the study needs to address the following issues:

- the goal of the LCA study;
- the functions of the product systems;
- the functional unit;
- the systems to be studied;
- systems boundaries and reasoning for any excluded life cycle stages;
- allocation procedures;
- the format of the inventory and subsequent inventory analysis;
- types of impact and impact assessment method and subsequent interpretation to be employed;
- data and data quality requirements;
- assumptions;
- limitations;
- type of critical review; and
- type and format of the report required for the study.

It is the nature of LCA studies that, as they progress, the scope of the study may need to change as information becomes available.

1.4 *GOAL OF STUDY*

The international standard for LCA, ISO 14041, requires that the goal of an LCA study shall unambiguously state the intended application, the reasons for carrying out the study and the intended audience.

This study has been commissioned by the UK Department for Environment Food and Rural Affairs (Defra). Its intended purpose is to assist policy by estimating the financial cost of different collection and recycling routes and to estimate the environmental return for that expenditure. Findings will be used to inform the development of a regulatory impact assessment (RIA) for the implementation of the proposed *Directive on Batteries and Accumulators* in the UK.

The goal of the study is therefore twofold:

1. to determine the environmental impacts associated with the UK meeting the collection and recycling targets in the proposed *Directive on Batteries and Accumulators,* and to compare these with the impacts that would occur if batteries were disposed via residual waste management routes in the UK (ie if they were not collected for recycling); and
2. to estimate the financial cost of alternative scenarios for implementing the requirements of the proposed Directive.

Results will be used to inform policy makers of the consumption of resources and releases to the environment that result from different collection and recycling processes and the scale of benefits associated with recyclate produced.

The timeframe for the study to reflect is 25 years from 2006. However, the study will not consider changes in the design and operation of technologies over this period. The results of the study will reflect the performance technologies and designs that are currently in operation for the processing of batteries.

1.5 FUNCTION AND FUNCTIONAL UNIT

The function of systems assessed was the management of consumer portable battery waste arisings in the UK between 2006 and 2030.

The scope of the assessment has included the collection and recycling of portable battery waste arisings, including rechargeables and NiCds. Industrial and automotive batteries were not included in the scope of the study.

Table 1.1 Battery Sales 2003

Battery Type	**Typical Use**	**Class**	**2003 Weight (Tonnes)**	**2003 % by Weight**
Silver Oxide (AgO)	Cameras, pocket calculators	Primary	5	0.02%
Zinc Air (ZnO)	Hearing aids and pocket paging devices	Primary	12	0.05%
Lithium Manganese (LiMn)	Pocket calculators	Primary	11	0.04%
Lithium (Li)	Photographic equipment, remote controls and electronics	Primary	107	0.43%
Zinc Carbon (ZnC)	Torches, toys, clocks, flashing warning-lamps	Primary	4628	18.62%
Alkaline Manganese (AlMn)	Radios, torches, cassette players, cameras, toys	Primary	14,899	59.96%
Lithium Ion (Li-ion)	Cellular phones, lap- and palm-tops	Secondary	1064	4.28%
Nickel Cadmium (NiCd)	Emergency lighting	Secondary	1024	4.12%
Nickel Cadmium (NiCd)	Cordless phones, power tools	Secondary	1261	5.07%
Nickel Metal Hydride (NiMH)	Cellular and cordless phones	Secondary	1300	5.23%
Lead Acid (PbA)	Hobby applications	Secondary	538	2.17%
Total			**24,850**	

1.5.1 *Predicted Battery Arisings*

Predicting battery sales, and subsequently future waste arisings, can not be carried out with absolute precision because of uncertainty in the sources of data. Hence the absolute results are open to debate. For the purposes of this study, we have maintained 2003 levels of battery sales (*Table 1.1*, the most recent complete set of sales figures) and tested in sensitivity analysis different growth rates in battery sales and the reduction in NiCd battery use that may result from increased policy pressure for their replacement.

The battery sales data for 2003 were obtained from various sources. The main source of sales data for primary batteries in the UK was the British Battery Manufacturer's Association (BBMA). The main source of sales data for secondary batteries was EU sales data from Recharge. No UK data were available for secondary batteries. Therefore, a UK estimate was obtained by using 80% of the German data (based on the difference in population between the UK and Germany). This was done for the lithium-ion, nickel metal hydride and lead acid chemistries.

For the nickel cadmium power tool category, an estimate of sales was made by taking 17% of EU sales, again provided by Recharge. The nickel cadmium sales for emergency lightning were based on an estimate provided by ICEL for 2004 (Industry Committee for Emergency Lightning) and the average weight per unit by Recharge. In order to estimate the 2003 sales figure, the range of sales between 2001 and 2004 provided by Recharge for emergency lightning was used.

Total battery sales and waste arisings between 2006 and 2030 are therefore 621,259 tonnes.

1.5.2 *Directive Implementation*

We have assumed that the proposed Battery Directive will be implemented in 2008. This means that the 25% collection target for portable battery waste arisings will need to be met in 2012, and the 45% collection target will need to be met in 2016. It has been assumed that the collection rates from 2006 on will increase linearly up to the 25% target in 2012. Between the 2012 and 2016 target we have also assumed a linear increase in collection rate. Once the 2016 target is achieved, the 45% rate will be maintained until 2030. Based on the assumptions above with regard to battery sales growth and collection rate development, the UK will collect an aggregate 35.2% of portable battery waste arisings between 2006 and 2030.

Variations on the Battery Directive implementation year and in target levels were assessed through sensitivity analysis. By modelling variations in the quantity of batteries collected we were able to test variations in implementation, target years and collection targets.

Waste Battery Management Scenarios

We modelled a total of nine implementation scenarios combining three different collection mixes and three different recycling mixes.

These nine scenarios were assessed for the period 2006 to 2030. The collection levels were assumed to increase linearly from 2006 to 2012 and from 2012 to 2016, with no increases assumed post 2016. A linear relationship was applied as there is no evidence to suggest an alternative rate of change. These nine scenarios were compared with a tenth scenario, the baseline scenario, that assumed the Directive is not implemented and that batteries are disposed of as part of the MSW stream.

The composition and quantity of battery waste arisings was the same for all scenarios.

1.6 SYSTEMS TO BE STUDIED

The systems compared differ in method of collection and the management routes assumed for collected consumer portable batteries. We developed three collection scenarios which were matched with three different recycling scenarios – creating a total of nine implementation scenarios. These were compared with a tenth scenario that assumes all batteries are managed as residual waste.

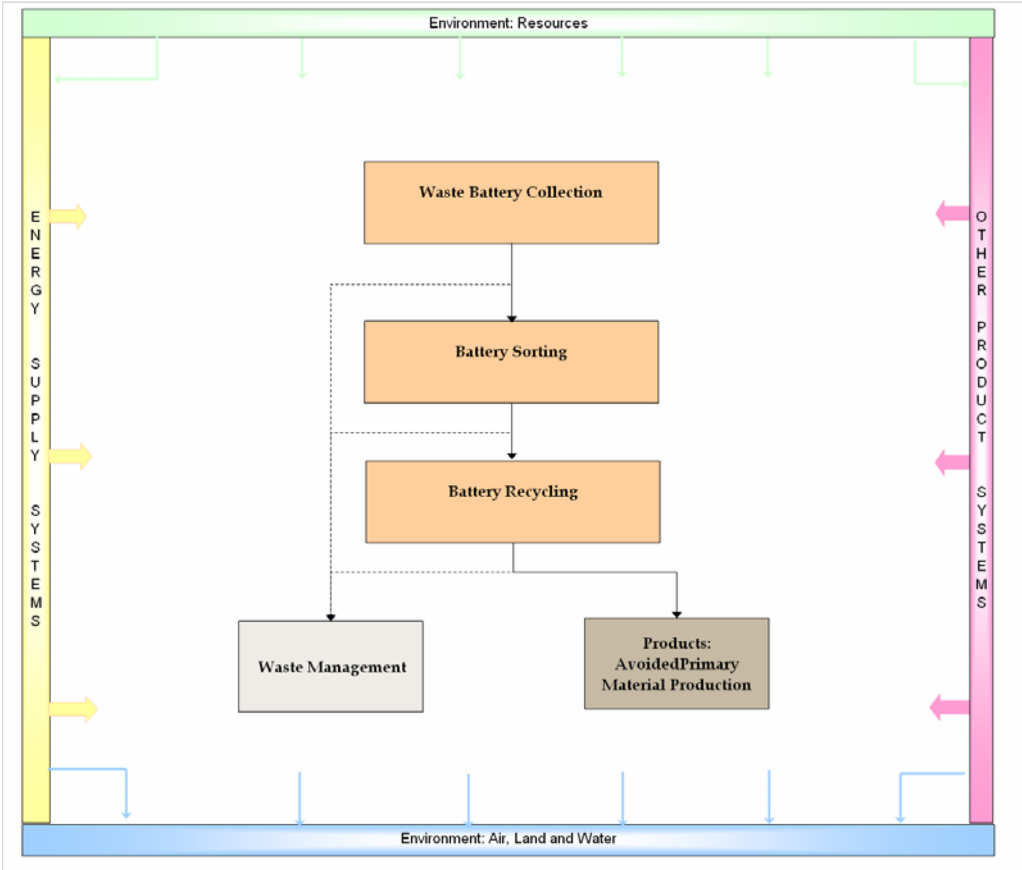
1.6.1 *Life Cycle Stages Included*

The scope of the assessment has included the collection, sorting, recycling and residual waste management of the battery arisings identified in *Section 1.5*. To this end, the study addressed flows to and from the environment from the point of battery collection to the ultimate fate of recycled or disposed batteries and secondary products. Flows relating to the production and use of batteries were excluded from the study as the assessment of these life cycle stages is beyond the scope and requirements of the study's goal.

The environmental burdens (inputs and outputs) associated with each life cycle stage were quantified and an 'offset' benefit was attributed to the recovery of secondary materials as a result of recycling processes. The recovery of materials has environmental benefits through offsetting the requirement for virgin materials. An estimation of the magnitude of this benefit was made by quantifying the avoided burdens (input and outputs) of producing an equivalent quantity of virgin material.

An overview of the life cycle stages included in the assessment is shown in *Figure 1.1* and *Section 1.11* provides further detail of the key processes contributing to each.

Figure 1.1 Study Boundary: Life Cycle Stages Included in the Assessment



1.7 COLLECTION SCENARIOS

Different combinations of battery collection methods were needed as there is limited knowledge as to how batteries will be collected in the UK to meet the targets. In the UK and Europe there are examples of battery collection being undertaken by three main routes: through deposit at civic amenity (CA) sites; via retailer/institutional take back and through kerbside collection. Unlike the UK, where kerbside is considered the most favoured route for batteries, based on limited experience, mainland Europe shows a preference for CA type recycling centres and collection points in public buildings and retail points.

Table 1.2 to *Table 1.6* detail the three collection scenarios assessed:

- **Collection Scenario 1** where kerbside collection schemes are favoured;
- **Collection Scenario 2** where CA site collection schemes are favoured; and
- **Collection Scenario 3** where bring receptacle collection schemes, located in business/school/public/WEEE dismantler premises, are favoured.

In determining realistic collection scenarios, we split the battery arisings by battery chemistries and application. Collection routes for each battery type were based on the nature of the battery use and the attitude of consumers to recycling, with kerbside recycling being the most preferred, due to ease of use and the minimal effort required to achieve separation.

All of the collection scenarios included a mix of collection routes, described in more detail in *Section 1.7.1*:

- **Collection Route 1** - involves collection from households through a bin or bag system by a local authority;
- **Collection Route 2** - involves the collection of batteries from battery collection bins provided at CA sites/household waste recycling centres and bring sites;
- **Collection Route 3** - involves collection from retail stores, schools or public buildings, business premises and WEEE dismantlers;
- **Collection Route 4** - involves the collection of batteries via the postal system through return envelopes; and
- **Collection Route 5** – involves the collection of batteries used in emergency lighting from facility maintenance companies. These batteries are officially classed as consumer batteries and latest data suggest that these represent a significant proportion (around a third) of the weight of all secondary batteries. We believe that these will be mainly discarded as business-to-business WEEE and will, in practice, be removed by a maintenance contractor. As a result, a fifth collection route has been included in the tables below.

Table 1.2 Collection Scenario 1: High Collection Route 1 (Proportion of Batteries Collected to be Collected via Each Route)

Battery Type	Typical Use	Class	Format	Collection Drivers	Collect. Route 1	Collect. Route 2	Collect. Route 3	Collect. Route 4	Collect. Route 5
Silver Oxide (AgO)	Cameras, pocket calculators	Primary	Button	Infrequent change. Very small batteries. Some specialist change. Products are expected to out-last battery. A proportion of consumers are likely to take the battery to a retail outlet to obtain replacement. Due to the size and nature of the batteries consumers may not treat as with other household waste.	15%	5%	80%	0%	0%
Zinc Air (ZnO)	Hearing aids and pocket paging devices	Primary	Button						
Lithium Manganese (LiMn)	Pocket calculators	Primary	Button						
Lithium (Li)	Photographic equipment, remote controls and electronics	Primary	Portable	Frequent change. Small batteries. Routine change. Products are expected to out-last battery. Consumer is likely to change in use and regularly, disposal choice by consumer is likely to mimic other recyclable household waste.	60%	10%	30%	0%	0%
Zinc Carbon (ZnC)	Torches, toys, clocks, flashing warning-lamps	Primary	Portable						
Alkaline Manganese (AlMn)	Radios, torches, cassette players, cameras, toys	Primary	Portable						
Lithium Ion (Li-ion)	Cellular phones, lap- and palm-tops	Secondary	Portable	Infrequent/No change. Medium/Large in size. A proportion of these batteries will be collected as WEEE, through WEEE collection schemes, and extracted by WEEE dismantlers. Consumers are expected to see these batteries as distinct and requiring instruction and specialist disposal through provision of specific collection modes.	45%	10%	40%	5%	0%
Nickel Cadmium (NiCd)	Cordless phones, power tools	Secondary	Portable						
Nickel Metal Hydride (NiMH)	Cellular and cordless phones	Secondary	Portable						
Lead Acid (PbA)	Hobby applications	Secondary	Portable						
Nickel Cadmium (NiCd)	Emergency lighting	Secondary	Portable	Infrequent/No Change. Batteries will be collected through removal or maintenance of the lighting.	0%	0%	0%	0%	100%

Table 1.3 Collection Scenario 2: High Collection Route 2 (Proportion of Batteries Collected to be Collected via Each Route)

Battery Type	Typical Use	Class	Format	Collection Drivers	Collect. Route 1	Collect. Route 2	Collect. Route 3	Collect. Route 4	Collect. Route 5
Silver Oxide (AgO)	Cameras, pocket calculators	Primary	Button	Infrequent change. Very small batteries. Some specialist change. Products are expected to out-last battery. A proportion of consumers are likely to take the battery to a retail outlet to obtain replacement. Due to the size and nature of the batteries consumers may not treat as with other household waste.	5%	15%	80%	0%	0%
Zinc Air (ZnO)	Hearing aids and pocket paging devices	Primary	Button						
Lithium Manganese (LiMn)	Pocket calculators	Primary	Button						
Lithium (Li)	Photographic equipment, remote controls and electronics	Primary	Portable	Frequent change. Small batteries Routine change. Products are expected to out-last battery. Consumer is likely to change in use and regularly, disposal choice by consumer is likely to mimic other recyclable household waste.	10%	60%	30%	0%	0%
Zinc Carbon (ZnC)	Torches, toys, clocks, flashing warning-lamps	Primary	Portable						
Alkaline Manganese (AlMn)	Radios, torches, cassette players, cameras, toys	Primary	Portable						
Lithium Ion (Li-ion)	Cellular phones, lap- and palm-tops	Secondary	Portable	Infrequent/No change. Medium/Large in size. A proportion of these batteries will be collected as WEEE, through WEEE collection schemes, and extracted by WEEE dismantlers. Consumers are expected to see these batteries as distinct and requiring instruction and specialist disposal through provision of specific collection modes.	10%	45%	40%	5%	0%
Nickel Cadmium (NiCd)	Cordless phones, power tools	Secondary	Portable						
Nickel Metal Hydride (NiMH)	Cellular and cordless phones	Secondary	Portable						
Lead Acid (PbA)	Hobby applications	Secondary	Portable						
Nickel Cadmium (NiCd)	Emergency lighting	Secondary	Portable	Infrequent/No Change. Batteries will be collected through removal or maintenance of the lighting.	0%	0%	0%	0%	100%

Table 1.4 Collection Scenario 3: High Collection Route 3 (Proportion of Batteries Collected to be Collected via Each Route)

Battery Type	Typical Use	Class	Format	Collection Drivers	Collect. Route 1	Collect. Route 2	Collect. Route 3	Collect. Route 4	Collect. Route 5
Silver Oxide (AgO)	Cameras, pocket calculators	Primary	Button	Infrequent change. Very small batteries. Some specialist change. Products are expected to out-last battery. A proportion of consumers are likely to take the battery to a retail outlet to obtain replacement. Due to the size and nature of the batteries consumers may not treat as with other household waste.	5%	5%	90%	0%	0%
Zinc Air (ZnO)	Hearing aids and pocket paging devices	Primary	Button						
Lithium Manganese (LiMn)	Pocket calculators	Primary	Button						
Lithium (Li)	Photographic equipment, remote controls and electronics	Primary	Portable	Frequent change. Small batteries. Routine change. Products are expected to out-last battery. Consumer is likely to change in use and regularly, disposal choice by consumer is likely to mimic other recyclable household waste.	30%	10%	60%	0%	0%
Zinc Carbon (ZnC)	Torches, toys, clocks, flashing warning-lamps	Primary	Portable						
Alkaline Manganese (AlMn)	Radios, torches, cassette players, cameras, toys	Primary	Portable						
Lithium Ion (Li-ion)	Cellular phones, lap- and palm-tops	Secondary	Portable	Infrequent/No change. Medium/Large in size. A proportion of these batteries will be collected as WEEE, through WEEE collection schemes, and extracted by WEEE dismantlers. Consumers are expected to see these batteries as distinct and requiring instruction and specialist disposal through provision of specific collection modes.	20%	10%	65%	5%	0%
Nickel Cadmium (NiCd)	Cordless phones, power tools	Secondary	Portable						
Nickel Metal Hydride (NiMH)	Cellular and cordless phones	Secondary	Portable						
Lead Acid (PbA)	Hobby applications	Secondary	Portable						
Nickel Cadmium (NiCd)	Emergency lighting	Secondary	Portable	Infrequent/No Change. Batteries will be collected through removal or maintenance of the lighting.	0%	0%	0%	0%	100%

Table 1.5 Collection Scenario 1: High Collection Route 1 (Tonnage of Batteries Collected via Each Route over 25-Year Period)

Battery Type	Typical Use	Class	Format	Collection Route 1 (tonnes)	Collection Route 2 (tonnes)	Collection Route 3 (tonnes)	Collection Route 4 (tonnes)	Collection Route 5 (tonnes)
Silver Oxide (AgO)	Cameras, pocket calculators	Primary	Button	7	2	39	0	0
Zinc Air (ZnO)	Hearing aids and pocket paging devices	Primary	Button	16	5	86	0	0
Lithium Manganese (LiMn)	Pocket calculators	Primary	Button	15	5	79	0	0
Lithium (Li)	Photographic equipment, remote controls and electronics	Primary	Portable	565	94	283	0	0
Zinc Carbon (ZnC)	Torches, toys, clocks, flashing warning-lamps	Primary	Portable	24,435	4072	12,217	0	0
Alkaline Manganese (AlMn)	Radios, torches, cassette players, cameras, toys	Primary	Portable	78,668	13,111	39,334	0	0
Lithium Ion (Li-ion)	Cellular phones, lap- and palm-tops	Secondary	Portable	4214	937	3746	468	0
Nickel Cadmium (NiCd)	Cordless phones, power tools	Secondary	Portable	4994	1110	4439	555	0
Nickel Metal Hydride (NiMH)	Cellular and cordless phones	Secondary	Portable	5148	1144	4576	572	0
Lead Acid (PbA)	Hobby applications	Secondary	Portable	2132	474	1895	237	0
Nickel Cadmium (NiCd)	Emergency lighting	Secondary	Portable	0	0	0	0	9009
Total				**120,194**	**20,955**	**66,693**	**1832**	**9009**

Table 1.6 Collection Scenario 2: High Collection Route 2 (Tonnage of Batteries Collected via Each Route over 25-Year Period)

Battery Type	Typical Use	Class	Format	Collection Route 1 (tonnes)	Collection Route 2 (tonnes)	Collection Route 3 (tonnes)	Collection Route 4 (tonnes)	Collection Route 5 (tonnes)
Silver Oxide (AgO)	Cameras, pocket calculators	Primary	Button	2	7	39	0	0
Zinc Air (ZnO)	Hearing aids and pocket paging devices	Primary	Button	5	16	86	0	0
Lithium Manganese (LiMn)	Pocket calculators	Primary	Button	5	15	79	0	0
Lithium (Li)	Photographic equipment, remote controls and electronics	Primary	Portable	94	565	283	0	0
Zinc Carbon (ZnC)	Torches, toys, clocks, flashing warning-lamps	Primary	Portable	4072	24,435	12,217	0	0
Alkaline Manganese (AlMn)	Radios, torches, cassette players, cameras, toys	Primary	Portable	13,111	78,668	39,334	0	0
Lithium Ion (Li-ion)	Cellular phones, lap- and palm-tops	Secondary	Portable	937	4214	3746	468	0
Nickel Cadmium (NiCd)	Cordless phones, power tools	Secondary	Portable	1110	4994	4439	555	0
Nickel Metal Hydride (NiMH)	Cellular and cordless phones	Secondary	Portable	1144	5148	4576	572	0
Lead Acid (PbA)	Hobby applications	Secondary	Portable	474	2132	1895	237	0
Nickel Cadmium (NiCd)	Emergency lighting	Secondary	Portable	0	0	0	0	9009
Total				**20,955**	**120,194**	**66,693**	**1832**	**9009**

Table 1.7 Collection Scenario 3: High Collection Route 3 (Tonnage of Batteries Collected via Each Route over 25-Year Period)

Battery Type	Typical Use	Class	Format	Collection Route 1 (tonnes)	Collection Route 2 (tonnes)	Collection Route 3 (tonnes)	Collection Route 4 (tonnes)	Collection Route 5 (tonnes)
Silver Oxide (AgO)	Cameras, pocket calculators	Primary	Button	2	2	44	0	0
Zinc Air (ZnO)	Hearing aids and pocket paging devices	Primary	Button	5	5	97	0	0
Lithium Manganese (LiMn)	Pocket calculators	Primary	Button	5	5	88	0	0
Lithium (Li)	Photographic equipment, remote controls and electronics	Primary	Portable	283	94	565	0	0
Zinc Carbon (ZnC)	Torches, toys, clocks, flashing warning-lamps	Primary	Portable	12,217	4072	24,435	0	0
Alkaline Manganese (AlMn)	Radios, torches, cassette players, cameras, toys	Primary	Portable	39,334	13,111	78,668	0	0
Lithium Ion (Li-ion)	Cellular phones, lap- and palm-tops	Secondary	Portable	1873	937	6087	468	0
Nickel Cadmium (NiCd)	Cordless phones, power tools	Secondary	Portable	2219	1110	7213	555	0
Nickel Metal Hydride (NiMH)	Cellular and cordless phones	Secondary	Portable	2288	1144	7436	572	0
Lead Acid (PbA)	Hobby applications	Secondary	Portable	947	474	3079	237	0
Nickel Cadmium (NiCd)	Emergency lighting	Secondary	Portable	0	0	0	0	9009
Total				**59,175**	**20,955**	**127,713**	**1832**	**9009**

1.7.1 *Collection Routes*

We investigated the details of a number of UK battery collection schemes (see *Annex A*) in order to develop models of collection activities for each of the collection scenarios. Details of the collection routes were developed in conjunction with G & P Batteries, the UK market leader in the collection and management of waste batteries, and these were supplemented with additional information from current practitioners where appropriate.

Consideration was given to future developments in battery collection, including expansion of collection networks and the potential to optimise bulking and sorting systems. Other UK battery collection companies, Loddon Holdings and Bleep Batteries, were also contacted for further information, verification of collection routes and discussion of future developments.
As such, it is considered that the collection routes outlined below provide a reasonable characterisation of UK practices over the study period.

Collection Route 1

Collection Route 1 involves collection from households through a bin or bag system by a local authority. Householders can generally place their waste batteries in a plastic bag, or other receptacle, in their usual kerbside collection box, or bag. These will be collected as part of the kerbside recyclables round, emptied into a separate compartment in the refuse collection vehicle (RCV) and transported to a central depot. A typical collection round will visit between 800 and 1800 households.

At the depot, batteries are stockpiled in one-tonne polyethylene bins, until they reach capacity and collection by a battery waste management specialist is arranged.

The batteries are collected from centralised depots as part of an optimised collection network, using a fleet of articulated lorries. Each lorry contains an on-board, diesel-powered forklift that manoeuvres bins to load the lorries. Batteries are transported to a sorting plant located centrally. An average collection round is approximately 250 miles, with all vehicles collecting to capacity.

Collection Route 2

Collection Route 2 involves the collection of batteries from battery collection bins provided at CA sites/household waste recycling centres and bring sites. There are two types of collection bin provided on sites:

- polyethylene cylinders for non-lead acid batteries; and
- polyethylene bins for lead acid batteries.

Typically, one of each container type is provided per site and collections by battery waste management specialists are made as and when required.

The batteries are collected from sites as part of an optimised collection network, using a fleet of articulated lorries. Non-lead acid batteries from the cylinders are emptied into one-tonne bins on the lorry, using a manually-powered sack truck. Lead acid battery bins are loaded using on-board forklifts. The batteries are then transported to a sorting plant located centrally. An average collection round is approximately 250 miles, with all vehicles collecting to capacity.

Collection Route 3

Collection Route 3 involves collection from retail stores, schools or public buildings, business premises and WEEE dismantlers. Potentially a number of containers are used for this collection route:

- polycarbonate tubes;
- polypropylene sacks (primarily for consolidation); and
- polyethylene cylinders.

Collections from sites gathering smaller quantities of batteries such as these are made by transit van, typically making numerous collections in one area over a period and delivering its payload of approximate one tonne to a satellite site for consolidation each day. Tubes and sacks are emptied into one-tonne bins in the transit vehicle, which are deposited at the satellite storage sites. Larger, articulated lorries will pick up the batteries for delivery to a centrally-located sorting plant when an appropriate tonnage has been consolidated.

A typical transit collection route is approximately 100 miles, and satellite sites are planned to be an average distance of approximately 250 miles from centrally-located sorting plants. They will be established as and when required.

As with collection routes 1 and 2, all vehicles collect to capacity and transport networks are optimised to enable economic efficiency.

Collection Route 4

Collection Route 4 involves the collection of batteries via the postal system through return envelopes. Few batteries are currently collected via this route in the UK. Most battery manufacturers provide a FREEPOST address and will consolidate posted batteries at a central depot. The modelling of this collection route assumed that the delivery of batteries to the central depot, via the postal system, is equivalent to personal travel and has therefore been excluded from the assessment.

At the depot, batteries are consolidated in one-tonne polyethylene bins, until they reach capacity and collection by a battery waste management specialist is arranged.

The batteries are collected from centralised depots as part of an optimised collection network, using a fleet of articulated lorries. Each lorry contains an on-board, diesel-powered forklift that manoeuvres bins to load the lorries. Batteries are transported to a sorting plant centrally located. An average collection round is approximately 250 miles, with all vehicles collecting to capacity.

Collection Route 5

Collection Route 5 involves the collection of batteries used in emergency lighting from facility maintenance companies. Batteries are tested periodically and replaced as and when required. Spent batteries are consolidated in a centralised depot, typically in a one-tonne polyethylene bin, until they reach capacity and collection by a battery waste management specialist is arranged.

The batteries are collected from centralised depots as part of an optimised collection network, using a fleet of articulated lorries. Each lorry contains an on-board, diesel-powered forklift that manoeuvres bins to load the lorries. Batteries are transported to a sorting plant located centrally. An average collection round is approximately 250 miles, with all vehicles collecting to capacity.

1.7.2 *Collection Points*

Scenarios were modelled on the basis that:

- there are 197 coordinating waste authorities in the UK (1) , each of which could potentially introduce a kerbside collection of batteries;
- there are currently 1065 CA sites in the UK (2) that could potentially collect waste batteries;
- it is likely that up to 69,500 institutional points (retail outlets, schools etc.) could operate as battery collection points;
- there are 73 postal depots in the UK (3) that could act as consolidation points for postal collection systems; and
- there are in the region of 50 lighting maintenance companies operating in the UK (4). Each is likely to recover NiCd batteries through emergency lighting maintenance and provide for their consolidation and collection.

A full list of assumptions regarding the number of schemes that will be required to meet the Directive's targets under each of the collection scenarios can be found in *Section 2*, Inventory Analysis.

(1) Network Recycling
(2) Network Recycling
(3) Royal Mail
(4) Kellysearch

1.7.3 *Sorting Plant Operations*

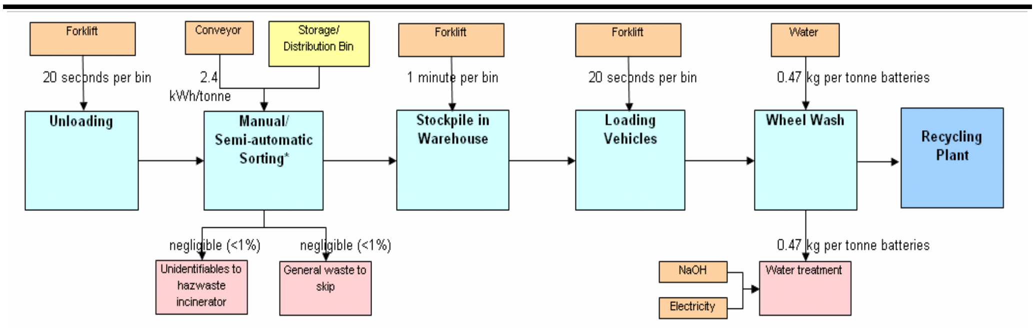
At the sorting plant, batteries are unloaded, using an on-site forklift, and are passed on to a warehouse for sorting. Currently all sorting is manual, but an increasing degree of automation is expected, with an associated increase in throughput. This is likely to be in the form of a conveyor, running at approximately 2.4 kWh per tonne of batteries sorted. Any further level of automation is not considered to be cost-effective, in terms of the rate of return that is achievable.

Following manual sorting, batteries are stockpiled in one-tonne polyethylene bins until an economic unit for transportation to recycling facilities has been collected. When this quantity has been reached, bins are loaded onto vehicles using on-site forklifts. Recycling destinations differ according to battery chemistry and recycling scenario, as detailed in *Section 1.8*.

All vehicles leaving the sorting plant must pass through a wheel wash prior to exiting the site. The water recovered from this washing process is dosed with sodium hydroxide to neutralise acidic residues that may have leached from lead acid batteries (1).

The processes that will be modelled as part of the sorting plant's operations are shown in *Figure 1.2*

Figure 1.2 ***Sorting Plant Operations***



Source: G&P Batteries

1.8 RECYCLING SCENARIOS

1.8.1 *Current Recycling Routes*

There two main categories of recycling route that can achieve a greater than 50% recycling rate, the hydrometallurgical process route, where metals are recovered via chemical methods, and the pyrometallurgical process route,

(1) Only a proportion of this process was allocated to the sorting of the portable consumer batteries that are considered under the scope of this study, based on the ratio between the quantity of post consumer lead acid batteries handled and the total quantity of lead acid batteries handled on site over the same time period.

where a furnace is used to recover the metals. These processes are described further in *Section 1.8.4*.

With the exception of silver oxide and lead acid batteries, there is currently no battery recycling capacity in the UK. The main recycling routes currently used are shown in *Table 1.8*. *Table 1.8* further shows that UK compliance with the Directive is reliant on the recycling of ZnC and AlMn batteries, as these contribute 79% of portable battery sales.

Table 1.8 Current Battery Recycling Routes

Battery Type	% of 2003 Sales	Current Recycling Route
Silver Oxide (AgO)	0.02%	Mercury distillation and silver recovery UK
Zinc Air (ZnO)	0.05%	Pyrometallurgical and Hydrometallurgical EU
Lithium Manganese (LiMn)	0.04%	Cryogenic North America. Pyrometallurgical and Hydrometallurgical processes recently developed in Europe
Lithium (Li)	0.43%	Cryogenic North America. Pyrometallurgical and Hydrometallurgical processes recently developed in Europe
Zinc Carbon (ZnC)	18.62%	Pyrometallurgical and Hydrometallurgical EU
Alkaline Manganese (AlMn)	59.96%	Pyrometallurgical and Hydrometallurgical EU
Lithium Ion (Li-ion)	4.28%	Cryogenic North America. Pyrometallurgical and Hydrometallurgical processes recently developed in Europe
Nickel Cadmium (NiCd)	9.19%	Pyrometallurgical EU
Nickel Metal Hydride (NiMH)	5.23%	Pyrometallurgical EU
Lead Acid (PbA)	2.17%	Pyrometallurgical UK

1.8.2 Future Developments

Currently the significant market unknown is whether the UK will develop its own capacity to reprocess waste batteries or whether they will continue to be exported for reprocessing via the routes shown in *Table 1.8*.

G&P Batteries is currently developing a hydrometallurgical recycling process for ZnC, ZnO and AlMn portable batteries in the UK. This process is described further in *Section 1.8.4.*

For the other battery types, it is unlikely that the routes identified will change as the quantities of these batteries are small and economies of scale would suggest that further provision in the UK is unlikely.

1.8.3 Scenario Development

Three recycling scenarios were developed, based on considerations of available recycling processes, current recycling routes and potential future developments, as discussed above. The scenarios that were assessed are as follows:

1. UK provision of hydrometallurgical recycling for ZnO, ZnC and AlMn batteries;
2. UK and EU provision of hydrometallurgical recycling (50:50) for ZnO, ZnC and AlMn batteries; and
3. EU provision of pyrometallurgical processing for ZnO, ZnC and AlMn batteries.

These three scenarios provide an indication of the significance of recycling route choice for 80% of battery arisings and the significance of transport post-sorting.

1.8.4 Recycling Processes

Battery recycling processes can be broadly grouped into the following categories, according to process methodology:

- hydrometallurgical;
- pyrometallurgical; and
- mercury distillation.

There are a number of specific processes that fall within these categories, as summarised in *Table 1.9.*

Table 1.9 Battery Recycling Processors

Company/ Processor	Location	Process Category	Batteries Types Treated
Recupyl	EU	Hydrometallurgical	AlMn, ZnC, ZnO, Li, LiMn, Li-ion
G&P	UK	Hydrometallurgical (mechanical stage only)	AlMn, ZnC, ZnO
Citron	EU	Pyrometallurgical	AlMn, ZnC, ZnO
Batrec	EU	Pyrometallurgical	AlMn, AnC, ZnO, Li, LiMn, Li-ion
Valdi	EU	Pyrometallurgical	AlMn, ZnC, ZnO
Indaver Relight	EU	Mercury distillation	AgO
SNAM	EU	Pyrometallurgical and mercury distillation	NiCd, NiMH
Campine	EU	Pyrometallurgical	PbA

Data were collected for each of these processes, with the aim of generating an average dataset for each battery type and process category, where possible. These form the basis of the recycling scenarios modelled during the assessment. Where data for a specific battery type/process category are sufficiently different so as to prevent averaging, the most complete dataset available was used.

Further details of each recycling process can be found in the following sections.

Hydrometallurgical Processes (AlMn, ZnC, ZnO, Li-ion Batteries)

Hydrometallurgy refers to the aqueous processing of metals. Hydrometallurgical processing of waste batteries involves a mechanical step and a chemical step. In the mechanical phase, the batteries are shredded in order to separate the metals, paper, plastic and the black mass. The black mass is further chemically processed to produce a solution, which undergoes electrolysis, or other treatment, in order to separate out the dissolved metals.

There are several EU companies currently carrying out hydrometallurgical processing of AlMn, ZnC and ZnO batteries. Recupyl (France) (1) , Eurodieuze (France) and Revatech (Belgium) and have also developed a process that can treat Li-ion batteries.

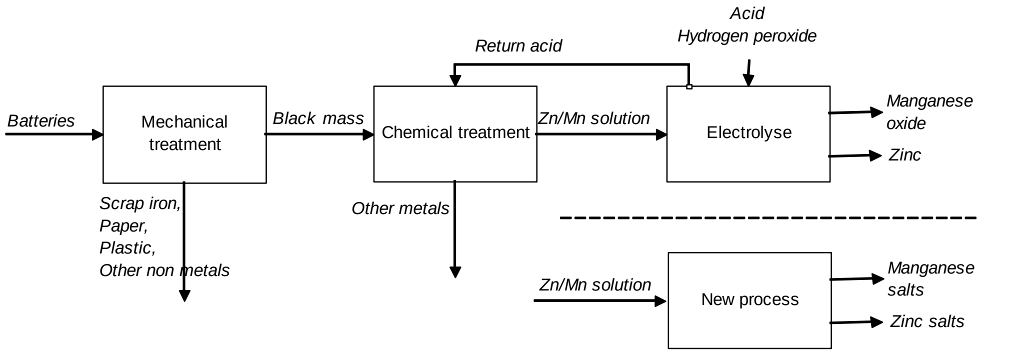
In the UK, G&P Batteries has recently commissioned a facility that has capacity to carry out the mechanical step of the Recupyl process for AlMn, ZnC and ZnO batteries.

Both Recupyl and G&P have participated in this study by providing data for their recycling processes.

Recupyl (AlMn, ZnC and ZnO Batteries)

Recupyl is a development process company located outside Grenoble, France. Different types of patents for recycling of special wastes have been developed by Recupyl. They have patented their alkaline and saline (AlMn, ZnC, ZnO) battery recycling process, called the RECUPYL™ process. The process uses hydrometallurgy for processing batches of mixed batteries and the Recupyl industrial recycling plant is authorised to handle all kinds of used battery. The process is shown diagrammatically in *Figure 1.3*.

Figure 1.3 **Recupyl Recycling Process**



(1) Recupyl is a development process company and does not recycle on a commercial basis.

Initially, batteries are sorted by size and shredded. The mechanical treatment step that follows sifts and magnetically separates steel, paper and plastics from the shredded batteries, leaving a 'black mass'. The black mass is subsequently treated with acid, resulting in a Zn/Mn solution and the separation of mercury and other (non ferrous) metals. Two alternative steps can then be used to purify the ZnMn solution. Using the traditional electrolysis step, zinc is separated from manganese using acid and electricity. Another, newly developed, purification step enables the separation of zinc and manganese salts.

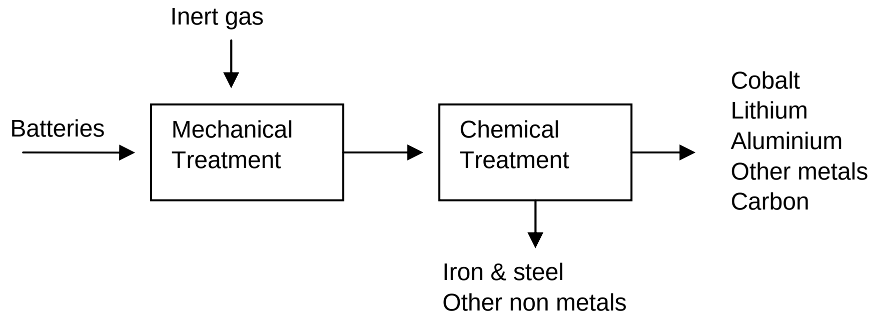
The flexibility of the Recupyl process allows for various end products, the relative production of which is determined by local demand. The three different end products are:

- zinc manganese solution via chemical treatment;
- zinc and manganese oxide via electrolysis; and
- zinc and manganese salts via the 'new' process step.

Recupyl (Li-ion Batteries)

A variant of the Recupyl process, called Valibat, is used to recycle Li-ion batteries. This process includes treating the batteries with inert gas once they are shredded. The products obtained include lithium salts and a number of metals. The process is shown diagrammatically in *Figure 1.4.*

Figure 1.4 Recupyl's Valibat Process for Recycling Lithium Batteries



G&P Batteries (AlMn, ZnC and ZnO Batteries)

G&P Batteries is a battery collection company based in Darlaston in the West Midlands, and is the first company to have started recycling alkaline and saline (AlMn, ZnC, ZnO) batteries in the UK. They have obtained a patent from Recupyl to carry out the mechanical treatment stage of the Recupyl process (*Figure 1.3*), which produces black mass, scrap iron, paper, plastic and other, non-ferrous metals.

The black mass product is still currently exported to Europe for further processing. However, the intention is that G&P will have a complete recycling facility, including the chemical stages of the hydrometallurgical process, once UK demand for manganese and zinc compounds has been established.

Pyrometallurgy (AlMn, ZnC, ZnO, NiMH, NiCd and Li-ion Batteries)

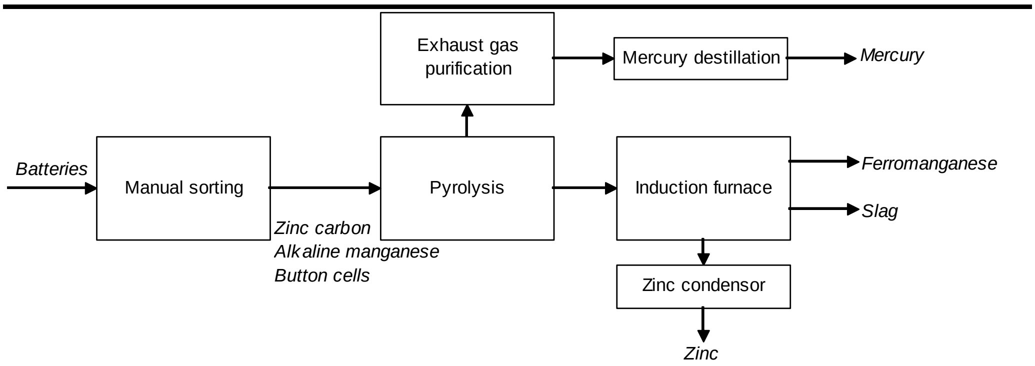
Pyrometallurgy uses high temperatures to transform metals. There is no generic method for recycling batteries pyrometallurgically and each of the existing methods is unique. For alkaline and saline batteries (AlMn, ZnC, ZnO), Batrec (Switzerland), Citron (France) and Valdi (France) carry out a pyrometallurgic process. Batrec has also developed a pyrometallurgic process that can treat Li-ion batteries. For NiCd and NiMH secondary batteries, SNAM (France) apply a high temperature process to recover cadmium and other metals. Similarly, Campine (Belgium) uses a high temperature process to recover lead from lead acid batteries.

Batrec, Citron, Valdi, SNAM and Campine have all participated in this study by providing data for their recycling processes.

Batrec (AlMn, ZnC, ZnO Batteries)

The core business of the Swiss company Batrec is the recycling of used batteries and materials containing heavy metals. Their recycling process is based on a pyrolysis plant and is shown diagrammatically in *Figure 1.5*.

Figure 1.5 Batrec Recycling Process



AlMn, ZnC, and ZnO batteries are manually sorted before being fed into a shaft furnace, where they are pyrolised at temperatures of up to 700° C.

In the furnace, water and mercury are vaporised and pass into the afterburner, together with carbonised organic components (paper, plastic, cardboard etc). The exhaust gases are then led into the exhaust gas purification plant. Here, gases are washed with circulating water. Solid materials are washed out and mercury condenses in metallic form.

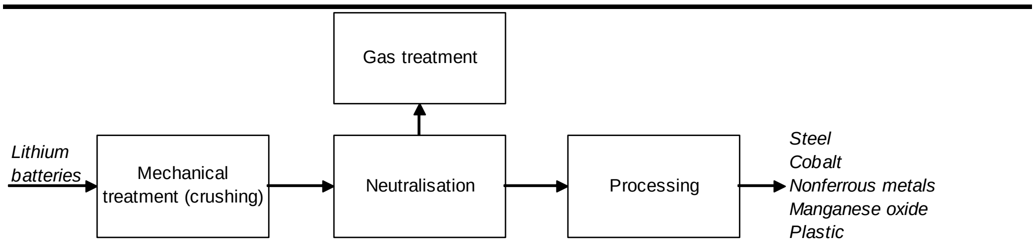
The metallic components arising through pyrolysis are passed to the induction furnace, where they are reduced through smelting at a temperature of 1500° C. Iron and manganese remain in the melt and combine to form ferro-manganese. Zinc vaporises and is recovered in the zinc condenser.

Batrec (Li-ion Batteries)

Batrec use an alternative process to treat Li-ion batteries, where the main safety concern is to render the highly flammable batteries inert. The process is shown diagrammatically in *Figure 1.6*.

The Li-ion batteries are fed to a crushing unit, where they are crushed in a controlled atmosphere. The released lithium is neutralised and other products (chrome-nickel steel, cobalt, non-ferrous metals, manganese oxide and plastic) are separated in a multistage separating plant.

Figure 1.6 ***Batrec's Recycling Process for Lithium Batteries***



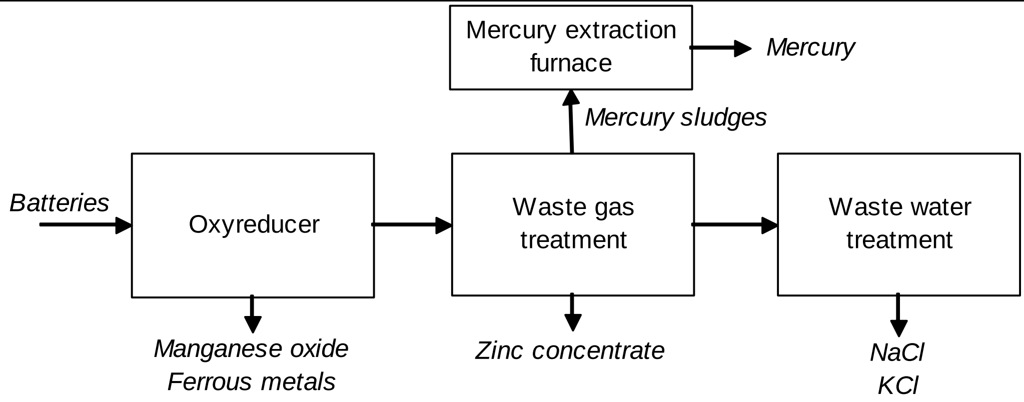
Citron (AlMn, ZnC and ZnO Batteries)

Citron's battery recycling facility is based in Rogersville, near La Havre in France. The plant recovers metals from alkaline and saline (AlMn, ZnC, ZnO) household batteries, automobile shredding residues, hydroxide sludges, grinding sludges and catalysts.

These waste streams are processed in a patented pyrometallurgical process called Oxyreducer™. This process can extract metals from all types of waste containing heavy metals. In 2003, 71,000 tonnes were recycled at the plant, of which 4400 tonnes were alkaline and saline batteries (approximately 6%) [1]. The process is shown diagrammatically in *Figure 1.7*.

(1) http://www.citron.ch/e/e2/documents/RAPPORTF.pdf

Figure 1.7 Citron Recycling Process



Batteries are sorted and fed into Oxyreducer, a rotary hearth furnace where zinc, mercury, organic materials and salts are vaporised. These gaseous emissions pass on to the waste gas treatment plant, where a number of processes occur:

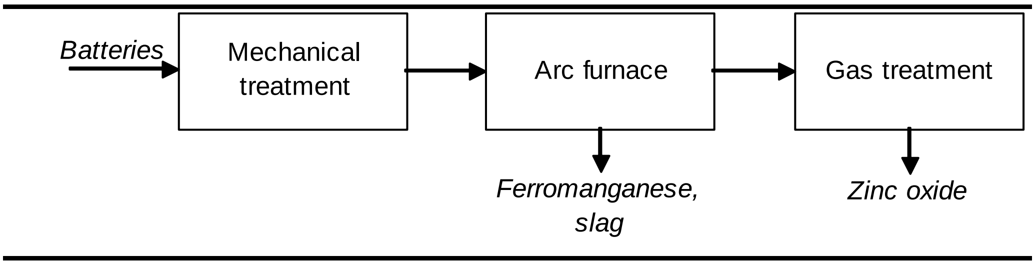
- oxidised zinc is settled out in a gravity chamber as a concentrate of zinc hydroxide;
- mercury is washed from the gaseous emission and discharged directly out of the water sumps as mercury-containing sludges. These are then further treated in the mercury extraction furnace, to yield mercury;
- all organic materials, such as paper and plastics, are completely oxidised in the Oxyreducer and over 50 % of the yielded energy is recovered. This energy is used to dry the zinc hydroxide sludges; and
- evaporated salts are washed out in the gas treatment system. They are reduced mainly to sodium chloride (NaCl) and potassium chloride (KCl) and leave the plant with the treated waste water.

Iron and manganese are not evaporated due to their high boiling points. These metals are discharged together with the carbon electrodes. The manganese oxide (MnO_2) is screened and sold for different applications, and the ferrous metals are sold as scrap. The carbon electrodes are re-introduced into the process as a reducing agent.

Valdi (AlMn, ZnC and ZnO Batteries)

Valdi is a France-based recycling company, specialising in refining ferrous alloys and recycling alkaline and saline batteries. A pyrometallurgical process is used for battery recycling, shown diagrammatically in *Figure 1.8*.

Figure 1.8 ***Valdi Recycling Process***

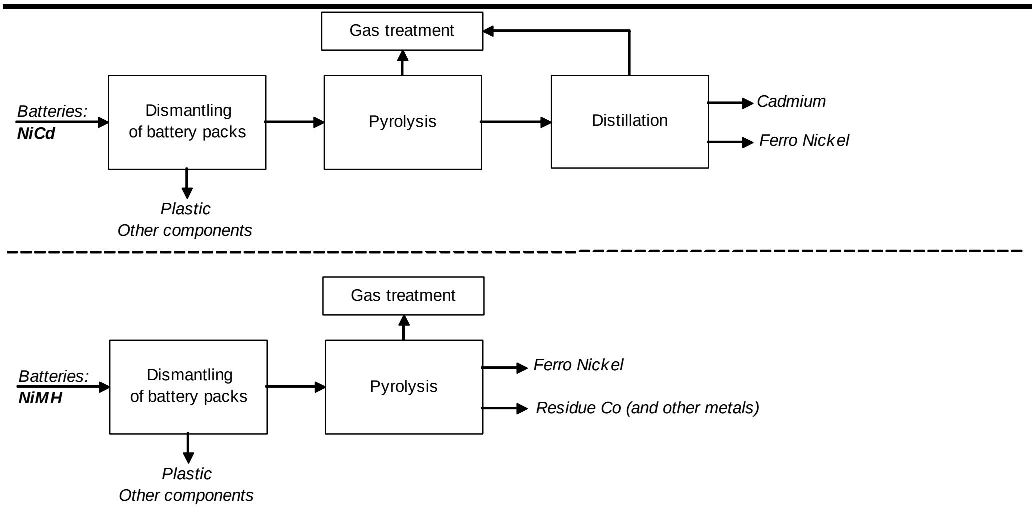


Batteries are ground and dried in a mechanical pre-treatment stage before being fed in to an arc furnace. At high temperatures, ferromanagese is obtained from the furnace and is cast into ingots. This process also produces a slag and gaseous emissions. The gases are treated with active carbon to yield zinc oxide dust.

SNAM (NiCd and NiMH Batteries)

Société Nouvelle d'Affinage des Métaux (SNAM) is a recycling company with facilities based in Lyon and Viviez, France. The company processes portable and industrial NiCd and NiMH batteries, cadmium-containing waste (powders, slag, etc.) and other streams containing cadmium. The processes used to recycle NiCd and NiMH batteries are shown diagrammatically in *Figure 1.9*.

Figure 1.9 ***SNAM Process for Recycling NiCd and NiMH Batteries***



Firstly, power packs are dismantled, separating the cells from the plastic cover. The cells are, together with other portable rechargeable batteries, transferred into a static pyrolysis reactor. At a temperature of 500˚C (1) , the waste batteries are held in the reactor for 16 hours.

(1) At this temperature, no cadmium is released.

Traces of mercury, present as a consequence of incomplete sorting of the battery feedstock, evaporate in the pyrolysis reactor. Active carbon is used for its removal, and is the only additive to the process.

The treatment of NiMH batteries ends at this stage, and the residues of ferro-nickel that are yielded are used in steel production.

The treatment of NiCd batteries involves an additional step. After pyrolysis, residues are placed in steel distillation ovens, which are tightly sealed off. Each batch is electrically heated at 900˚C for 16 hours and is subsequently cooled for eight hours. At these temperatures, a combination of distillation of metallic cadmium and sublimation of cadmium-oxides and –hydroxides takes place. Cadmium is condensed from the gaseous phase and is further purified, by means of continuous distillation.

Campine (Lead Acid Batteries)

Campine is a leading non-ferrous metal reprocessor, based in Belgium.
At the Campine reprocessing site, spent lead acid batteries are shredded in a covered storage area and escaping sulphuric acid is captured in a pit. The acid is pumped through a filter press and is stored in tanks. This recovered acid is then collected on a regular basis and transported for re-use.

The shredded lead acid batteries are mixed with other materials before passing to the furnace (coke, iron scraps, limestone and reusable slags from the process itself). The plastic casing of the batteries (predominantly polypropylene) is also added, as it serves as both a fuel and a reducing agent. The mix is sent to furnace in batches and melted at a temperature of 1200-1300°C.

The main outputs from the furnace are lead (86-87% pure and in need of refining to remove antimony and calcium), slags (approximately 78% of which can be re-used in the lead furnace as carrier material and the remainder of which is sent to landfill) and waste gases.

Waste gases are quenched, filtered and cooled with cold air, which prevents the formation of dioxins. Any carbon-containing air emissions are completely oxidised in the after-burner.

The lead refinery step involves the removal of antimony and calcium through oxidation. The oxide that is formed is removed by mechanical means.

Mercury Distillation and Silver Recovery (Button Cells)

During mercury distillation processes, mercury is recovered from mercury-containing wastes. Button cells, mercuric oxide cells in particular, are just one of the waste types that undergo mercury distillation.

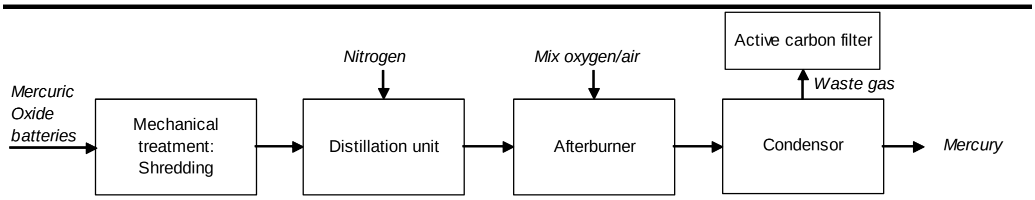
The process is a vacuum-based thermal treatment, during which mercury vaporises. At a reduced temperature, the mercury then condenses, producing mercury in its metallic form.

This process is carried out by Indaver Relight (Belgium), Duclos (France) and Citron (France). Data for have been obtained from Indaver Relight.

Indaver Relight (Button cells)

Indaver Relight, located in Flanders, Belgium, carries out a mercury distillation, as shown in *Figure 1.10*. The distillation unit can process a number of mercury containing waste streams, such as fluorescent lamps, thermometers, dentist's amalgam, mercury switches and button cells.

Figure 1.10 Indaver Relight Mercury Distillation Process



Around 200 kg of button cells are processed in each batch. Cells are firstly shredded and placed in the distillation unit. The temperature in the unit is raised to 600°C, at which the mercury is vaporised and becomes gaseous. The unit is continuously washed with nitrogen to remove the gases, which pass into the afterburn chamber. Here, a mixture of oxygen and air is injected and mixed with the gases at a temperature of 800°C. At this temperature, all organic substances are combusted.

Mercury is recovered from the waste gases via condensation at -6°C and the remaining gases are filtered via active carbon. The duration of the process is between 24 and 40 hours in total. The remaining residue is then available for further processing to recover the silver.

The residue is mixed with other silver bearing materials and the resultant mix is combined with lead and fluxes and charged into a shaft furnace. A lead/silver alloy with a silver purity of about 50% is produced. The lead is removed by preferential oxidation, to produce high grade silver (98+%) and lead oxide.

1.9 RESIDUAL WASTE MANAGEMENT SYSTEM

The baseline system assumes the collection of batteries as MSW for residual disposal, with no collection or recycling. In 2003-2004, 11% of residual MSW was incinerated with energy recovery and 89% was disposed to landfill

(*Environment Agency*). This split between landfilling and incineration is assumed to be constant for residual waste over the next 25 years.

1.10 *IMPLEMENTATION SCENARIOS*

Combining the three collection and three recycling scenarios described above results in a total of nine 'implementation' scenarios that were studied:

1. Collection Scenario 1 with Recycling Scenario 1
2. Collection Scenario 1 with Recycling Scenario 2
3. Collection Scenario 1 with Recycling Scenario 3
4. Collection Scenario 2 with Recycling Scenario 1
5. Collection Scenario 2 with Recycling Scenario 2
6. Collection Scenario 2 with Recycling Scenario 3
7. Collection Scenario 3 with Recycling Scenario 1
8. Collection Scenario 3 with Recycling Scenario 2
9. Collection Scenario 3 with Recycling Scenario 3

The tenth Scenario is the baseline scenario which involves batteries being disposed as residual waste.

The following section describes the system boundaries for each of the scenarios studied.

1.11 *SYSTEM BOUNDARIES*

System boundaries define the life cycle stages and unit processes studied, and the environmental releases (eg carbon dioxide, methane etc.) and inputs (eg coal reserves, iron ore etc.) included in an LCA. System boundaries should be defined in such a manner that the inputs and outputs from the system are elemental flows [(1)].

The aim of the study was to include all significant processes, tracing material and energy flows to the point where material and energy are extracted from, or emitted to, the natural environment.

The study aimed to be representative of expected battery collection and recycling systems in the UK between 2006 and 2030. We reflected the UK situation by assessing the average collection and recycling scenarios described in *Sections 1.7* and *1.8*. These scenarios take into account current UK practices, as well considering likely future developments in battery collection and recycling. This, unavoidably, involves prediction. The key assumptions

(1) An elemental flow is material or energy entering the system being studied, which has been drawn from the environment without previous human transformation, or it is a material or energy leaving the system being studied, which is discarded into the environment.

made, for example concerning transportation routes, were examined for their influence on their results during sensitivity analysis.

The study addressed flows to and from the environment for each implementation scenario, from the point of battery collection. Flows relating to the production and use of batteries were excluded from the study as the assessment of these life cycle stages is beyond the scope and requirements of the study's goal.

The diagrams shown in *Figure 1.11* to *Figure 1.14* detail the processes that were included in the assessment of each implementation scenario and the baseline scenario. The environmental burdens (inputs and outputs) associated with all of these activities have been quantified and a benefit has been attributed to the displacement of primary materials through recycling, where this occurs and on a mass-for-mass basis.

In short, inventories and impacts profiles generated for each of the implementation systems assessed represent the balance of impacts and benefits associated with:

- battery collection (container materials manufacture and processing, transport requirements);
- battery sorting (energy/fuel requirements of sorting process);
- battery transportation to reprocessor;
- battery recycling (process material and energy/fuel requirements);
- avoided burdens through the recovery of secondary materials and displaced production of equivalent quantities of primary material; and
- management of residual batteries and other wastes (via landfill or incineration).

Figure 1.11 Outline System Diagram: Implementation Scenario 1, 2 & 3

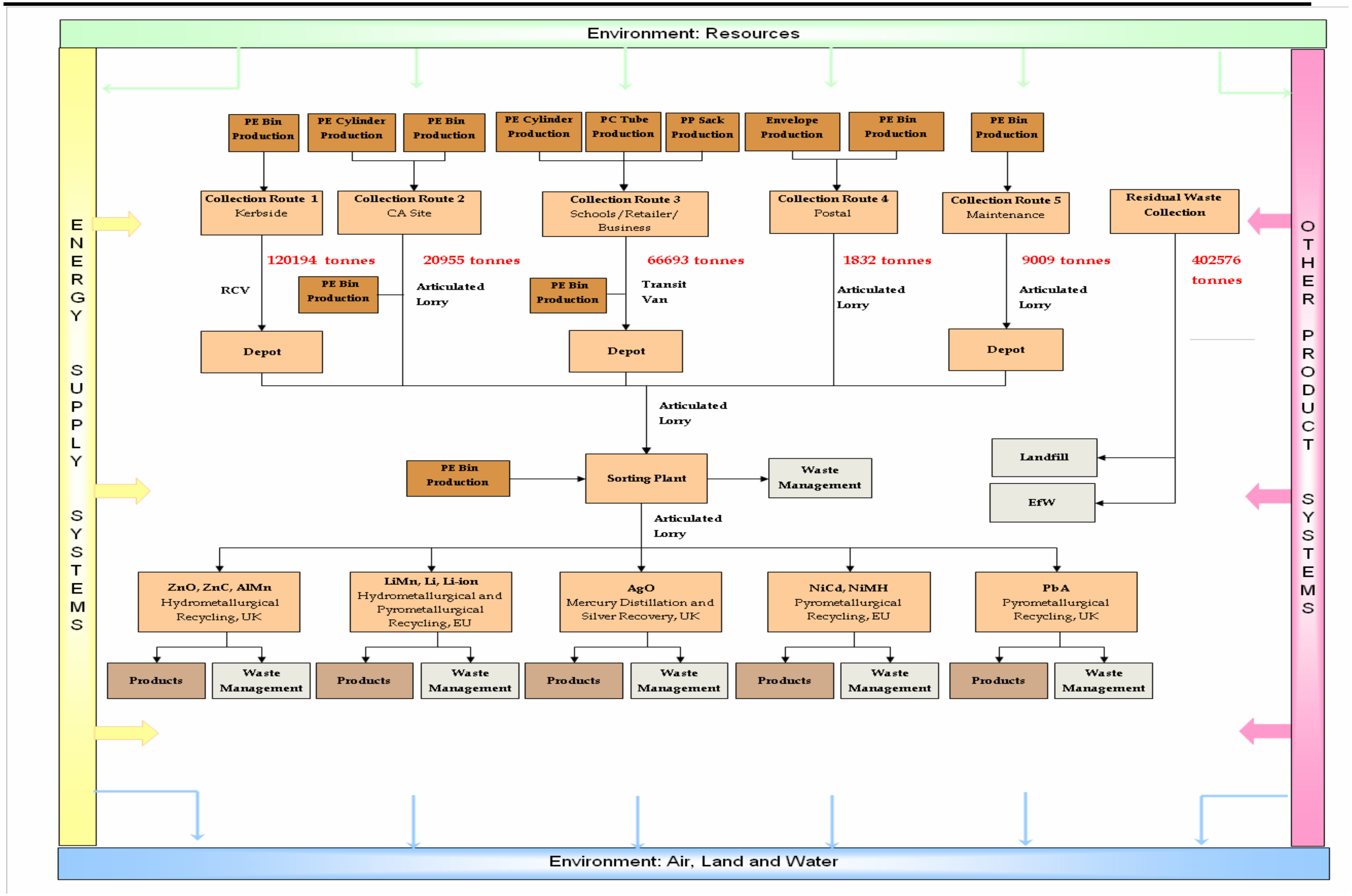


Figure 1.12 Outline System Diagram: Implementation Scenario 4, 5 & 6

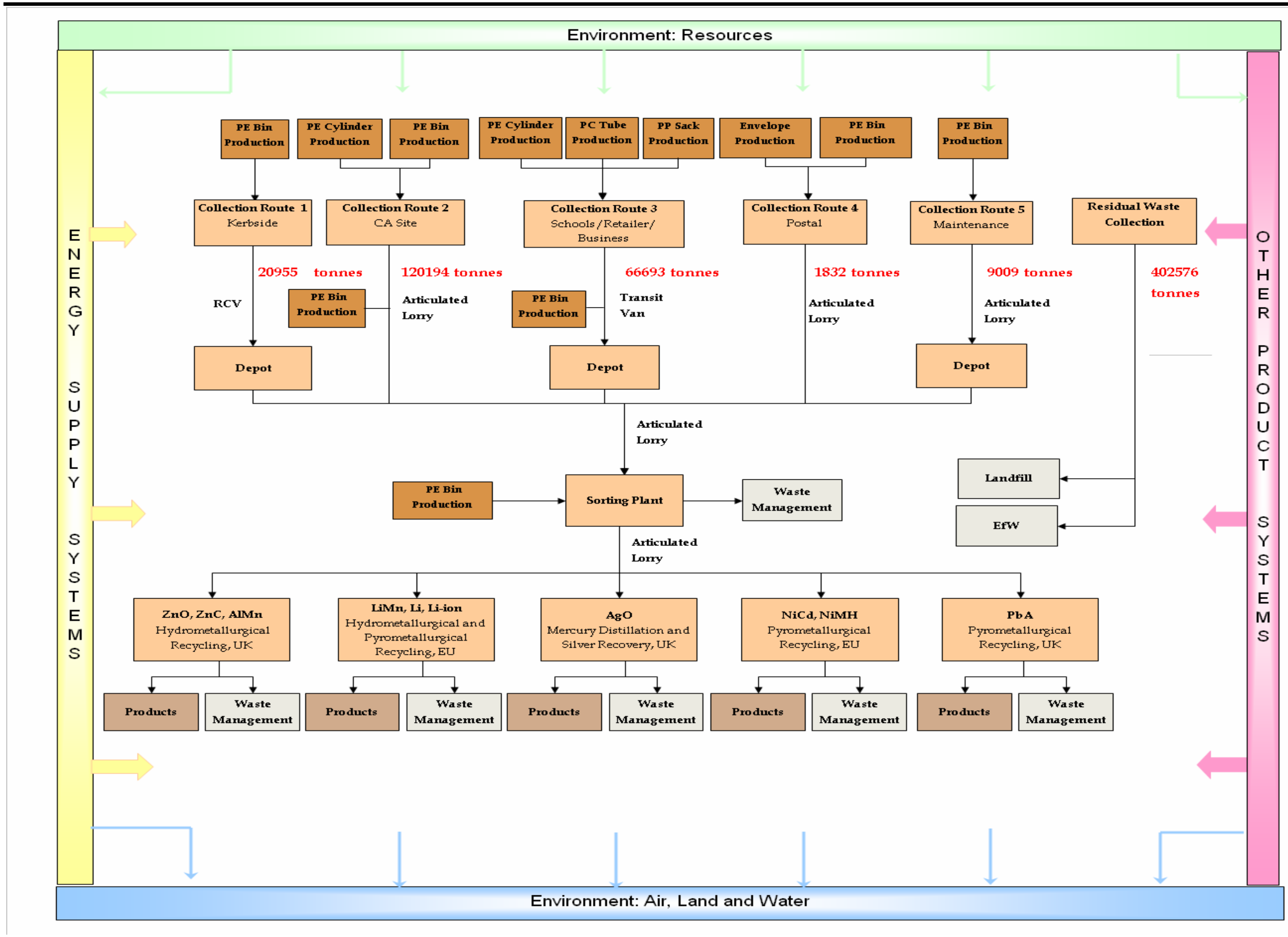


Figure 1.13 Outline System Diagram: Implementation Scenario 7, 8 & 9

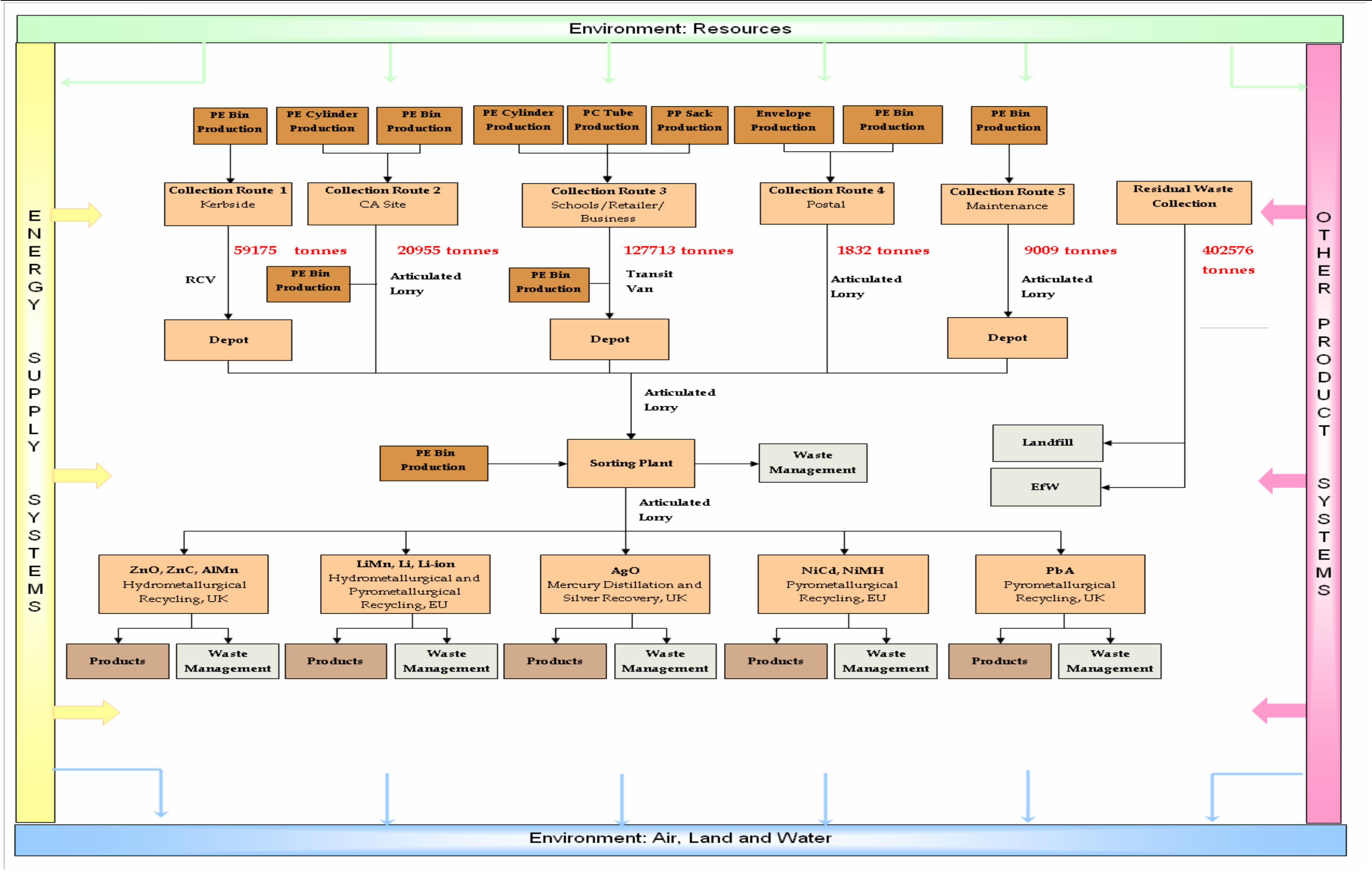
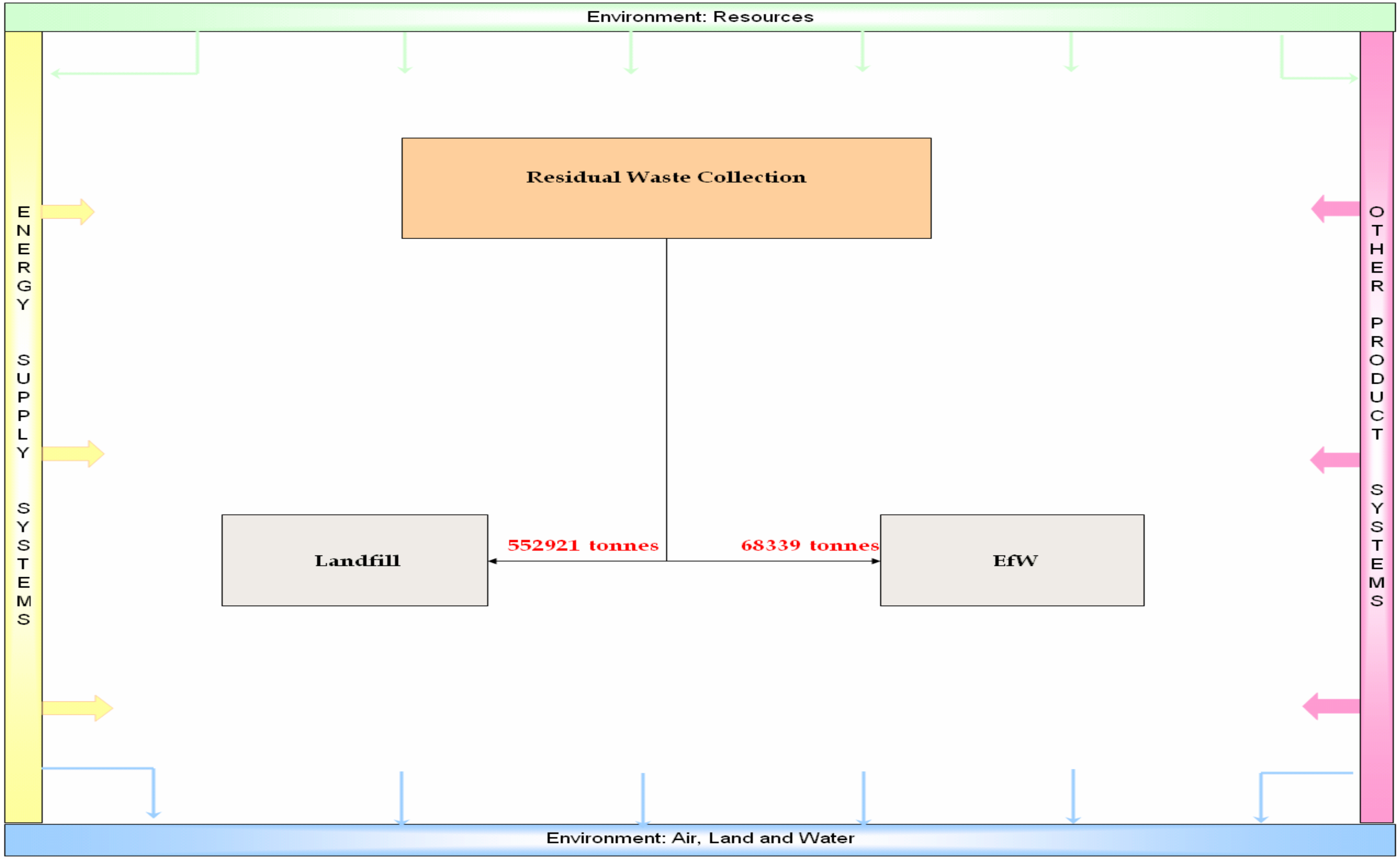


Figure 1.14 Outline System Diagram: Baseline Scenario 10



1.11.1 *Temporal, Spatial and Technological Boundaries*

The geographical coverage of the study was the collection of batteries within the UK and the recycling of these batteries within the UK and Europe. The location of recycling was determined by current recycling locations and planned recycling capacity within the UK. The temporal scope of the study was the collection of battery wastes between 2006 and 2030, however the data that were used to reflect collection and reprocessing activities were selected to represent technology currently in use.

A further discussion of data and quality requirements is presented in *Section 1.16*.

1.11.2 *Capital Equipment*

All equipment necessary for any process involved in the collection and recycling of batteries is referred to as capital equipment. Examples of capital equipment include collection vehicles and process equipment, eg boilers, fans, pumps, pipes etc.

Capital equipment for recycling processes and energy systems was excluded from the study boundary. The majority of the LCI data used to model impacts associated with other processes include capital burdens. However, on analysis of these datasets it was found that capital burdens contributed an insignificant proportion of the total impact.

All collection containers were considered to be consumables, as opposed to capital burdens, and were included in the scope of the assessment.

In the UK, G&P Batteries have just built a dedicated plant for battery recycling, and recycling at this plant is included in this study. The initial environmental impact for the construction of this plant is likely to be significant (as with the construction of buildings in general). However, for the envisaged life time of the plant, the impact per processed tonne of batteries will be insignificant. The impact from the plant construction is excluded from the scope of the study.

1.11.3 *Workforce Burdens*

It is not common practice when conducting LCAs to include an assessment of human labour burdens, due to difficulties in allocation, drawing boundaries, obtaining data and differentiating between labour and capital equipment.

We have excluded human labour as being outside the scope and resources of this project.

1.12 *ALLOCATION PROCEDURES*

Some processes may yield more than one product and they may also recycle intermediate products or raw materials. When this occurs, the LCA study has to allocate material and energy flows, as well as environmental releases, to the different products in a logical and reasonable manner.

Where the need for allocation presented itself, then the inputs and outputs of the inter-related processes was apportioned in a manner that reflected the underlying physical relationships between them. There are certain circumstances where this is not appropriate or possible when carrying out an LCA study. In such cases, alternative allocation methods were documented in the inventory analysis.

1.13 *INVENTORY ANALYSIS*

Inventory analysis involves data collection and calculation procedures to quantify the relevant inputs and outputs of a system.

Data sources included both specific and representative data. Specific data relating to battery collection and recycling scenarios were collected. Proprietary life cycle databases were used for common processes, materials, transport steps and electricity generation. Where data were missing, estimates based on literature and previous studies were made. All data gaps and substitutions were recorded.

For each of the implementation systems assessed, inventories of all environmental flows to and from the environment were produced.
The inventories that were generated provide data on hundreds of internal and elemental flows for each implementation scenario. As such, these inventories are annexed and summary inventory data for the ten scenarios is provided.

1.14 *IMPACT ASSESSMENT*

The impact assessment phase of an LCA assigns the results of the inventory analysis to different impact categories. The following steps are mandatory:

- selection of impact categories and characterisation models;
- classification - the assignment of LCI results; and
- characterisation - the calculation of inventory burdens' potential contribution to impacts.

Selection of appropriate impact categories is an important step in an LCA. We assessed the contribution of each system to the following impact indicators, which we believe address the breadth of environmental issues and for which thorough methodologies have been developed. The study employed the problem oriented approach for the impact assessment, which focuses on:

- depletion of abiotic resources;
- global warming;
- ozone layer depletion;
- human toxicity;
- aquatic and terrestrial toxicity measures;
- acidification; and
- eutrophication.

Resource depletion: is an important concern because it is considered impossible to sustain current rates of economic growth given the associated consumption of resources. Many of the resources that drive our economies are limited (non-renewable) and will therefore one day be exhausted, if we continue to use them at current rates. An indication of resource depletion is provided by considering the proportion of the available resource (in years) for each raw material consumed by the activities in question, and summing their contributions to depletion of known stocks, giving a measure of total depletion in years. Raw materials extracted that contribute to resource depletion are aggregated according to their impact on resource depletion compared with antimony reserves as a reference.

Global warming: human activities have altered the chemical composition of the atmosphere through the build-up of greenhouse gases, primarily carbon dioxide, methane, and nitrous oxide. As the world becomes more industrialised, the higher concentration of these gases increases the heat trapping capability of the earth's atmosphere. As a result, temperatures and sea levels are rising annually. Gases contributing to the greenhouse effect are aggregated according to their impact on radiative warming compared to carbon dioxide as the reference gas.

Ozone layer depletion: ozone is a naturally occurring gas that filters out the sun's ultraviolet (UV) radiation in the stratosphere. Its depletion is caused by the release of chlorofluorocarbons (CFCs) and other ozone-depleting substances into the atmosphere. Over exposure to UV rays can lead to skin cancer, cataracts, and weakened immune systems. For gases that contribute to the depletion of the ozone layer (eg chlorofluorocarbons), ozone depletion potentials have been developed using CFC-11 as a reference substance.

Human toxicity: the anthropogenic release of chemical compounds to the environment is a major environmental concern due to the potential for harm to humans and the natural environment. For this reason, methods have been developed which estimate the potential harm that may result from emissions of chemical compounds to the environment. The impact assessment method used in this tool is based on calculated human toxicity *potentials* and is not related to *actual* impact. These Human Toxicity Potentials (HTP) are a calculated index that reflect the potential harm of a unit of chemical released into the environment. Characterisation factors, expressed as HTPs, are calculated with USES-LCA, describing fate, exposure and effects of toxic substances for an infinite time horizon. For each toxic substance, HTPs are expressed as 1,4-dichlorobenzene equivalents/kg emission.

Eco-toxicity: is the potential for substances released to the environment through human activities to exert toxic effects on organisms within the natural environment. Eco-toxicity potentials for the aquatic and terrestrial environments are calculated with USES-LCA, describing fate, exposure and effects of toxic substances. Characterisation factors are expressed as 1,4-dichlorobenzene equivalents/ kg emission.

Acidification: is the process whereby air pollution, mainly ammonia, sulphur dioxide and nitrogen oxides, results in the deposition of acid substances. 'Acid rain' is best known for the damage it causes to forests and lakes. Less well known are the many ways it affects freshwater and coastal ecosystems, soils and even ancient historical monuments. The heavy metals whose release into groundwater these acids facilitate are also not well studied. Gases contributing to air acidification are aggregated according to their acidification potential. These potentials have been developed for potentially acidifying gases such as SO_2, NOx, HCl, HF and NH_3 on the basis of the number of hydrogen ions that can be produced per mole of a substance, using SO_2 as the reference substance.

Eutrophication: the overloading of seas, lakes, rivers and streams with nutrients (particularly nitrogen and phosphorus) can result in a series of adverse effects known collectively as eutrophication. Phosphorus is the key nutrient for eutrophication in freshwater and nitrate is the key substance for saltwater. Those substances that have the potential for causing nutrification are aggregated using nutrification potentials, which are a measure of the capacity to form biomass compared to phosphate (PO_4).

For some impact categories, particularly human toxicity and aquatic and terrestrial eco-toxicity, a number of simplifying assumptions were made in the modelling used to derive characterisation factors. As a result, their adequacy in representing impacts is still the subject of some scientific discussion. However, they are still widely used and we therefore included them in the assessment as issues of interest, accompanied by caveats describing their deficiencies. The impact assessment reflects potential, not actual, impacts and it takes no account of the local receiving environment.

The method that was used is that developed and advocated by CML (Centre for Environmental Science, Leiden University) and which is incorporated into the SimaPro (1) LCA software tool. The version contained in the software is based on the CML spreadsheet version 2.02 (September 2001), as published on the CML web site.

(1) PRé Consultants bv Plotterweg 12 3821 BB Amersfoort The Netherlands

The method used for each impact category for classification and characterisation is described in *Annex B*.

According to ISO 14042, the following additional steps may be included in impact assessment, but are not mandatory:

- normalisation;
- grouping;
- weighting; and
- valuation.

None of these were performed in the study, instead, and in a separate exercise, ERM conducted monetary valuation assessment using up-to-date monetary valuation techniques to assess each of the implementation scenarios. This drew upon the report prepared for Defra by Enviros Consulting Ltd. and EFTEC (1).

1.15 *SENSITIVITY ANALYSIS*

Key variables and assumptions were tested to determine their influence on the results of the inventory analysis and the impact assessment.

Key areas that were identified for sensitivity analysis included battery waste arisings, NiCd battery displacement, collection targets and Directive implementation years. Due to the permutations associated with battery arisings, collection levels and recycling routes, sensitivity analysis formed a significant proportion of the work for this study.

Sensitivities included:

1. battery sales growth in line with treasury economic growth predictions;
2. displacement of NiCd batteries with NiMH batteries;
3. increases in proposed collection targets (30% in 2012 and 50% in 2016; 35% in 2012 and 55% in 2016; 40% in 2012 and 60% in 2016);
4. collection and recycling levels in line with proposed voluntary agreement levels (23.5% collection from 2012 to 2030); and
5. key collection target years brought forward by 2 years.

Conclusions made in the study drew on both the primary results for the systems assessed and on the variations that result through the sensitivity analysis.

(1) '*Valuation of external costs and benefits to health and environment of waste management options*' (2004)

1.16 DATA REQUIREMENTS

In addition to collecting data describing the collection and recycling operations assessed, the following were identified as key elements for which inventory data were required:

- electricity generation;
- container materials production;
- container manufacture;
- offset material production; and
- vehicle operation.

1.16.1 *Data Quality Requirements*

Primary versus secondary data

It was considered a requirement of the study that primary data relating to the collection, sorting and reprocessing of waste batteries be collected. However, it was not within the scope of the study to collect primary data relating to the production of ancillary and offset primary materials, or for energy production and residual waste management systems. As such, secondary data were sourced, using the following hierarchy of preferred sources:

1. existing, critically reviewed life cycle data from published studies or from proprietary packages;
2. estimates based on other data sources, such as books, publications, internet sources etc; and
3. substitute data, for example substituting materials with similar manufacturing processes.

Time-related coverage

All primary data collected were sought to be representative of current UK or EU practices, as appropriate (2003/04 data collected as the latest available at the time of study).

All secondary data were sought to be less than 15 years in age.

Geographical coverage

The geographical coverage of the study was the collection and recycling of batteries according to expected UK practice between 2006 and 2030.

Some recycling processes occur outside the UK and, in these cases, the technologies assessed were sought to be representative of the countries in which they are located.

Secondary data were sought to be representative for Europe, except for electricity used in the recycling processes. The electricity mix should represent the country where the process is located. If certain processes, such as mining of metals, do not take place in Europe, global data was sought.

Technology coverage

For primary data, current UK or EU practices were sought. Primary data relating to the performance of plant currently processing batteries, and that are considered likely management routes for UK batteries, were required. For secondary data, technologies representative/indicative of European conditions were used.

It was not within the scope of the study to consider in any detail the potential for future change in technology.

Representativeness

The data used were considered to be representative for the system if geographical coverage, time period and technology coverage requirements, as defined above, were met.

1.17 KEY ASSUMPTIONS AND LIMITATIONS

All assumptions and limitations were recorded and are reported in this study report. All key assumptions were tested through sensitivity analysis. For example, the assumption made as to year-on-year increases in battery collection levels influences the results, and so was examined in more detail.

A key limitation of the study was the use of secondary data to quantify the avoided burdens of primary material production through recycling, and the associated assumption that these presented a reasonable representation of overall recycling benefits. However, it was not possible within the scope of the study to collect alternative data for these processes. The increasing age of secondary data and limitations found with regard to meta data suggest a need for a Europe-wide programme to maintain and improve LCI data for use in studies such as this. The value of LCA going forward is dependant on the quality and availability of secondary data.

The potential for future changes in technology is not included in the scope of the study. It is likely that recycling processes for batteries will become more efficient over time, which potentially will lead to a decrease in environmental impact. However, it was not possible within the scope of this study to investigate potential technological improvement. The level of technology is assumed to be steady for the time coverage of the study.

1.18 CRITICAL REVIEW

In accordance with ISO14040, the study was peer reviewed by an external reviewer. In accordance with the standard, the reviewer addressed the issues below and provided a review report. This report, together with ERMs response, can be found in *Annex E*.

For the goal and scope:

- Review of the scope of the study to ensure it is consistent with the goal of the study and that both are consistent with ISO 14041

For the inventory:

- Review of the inventory for transparency and consistency with the goal and scope and ISO14041; and
- Check data validation and that the data used are consistent with the system boundaries (we do not expect the reviewer to check data and calculations, other than samples).

For the impact assessment:

- Review of the impact assessment for appropriateness and conformity to ISO14042.

For the draft final report:

- Review of the report for consistency with reporting guidelines in ISO 14040.

2 INVENTORY ANALYSIS: LIFE CYCLE INVENTORY DATA

Inventory analysis involves data collection and calculation procedures to quantify the relevant inputs to, and outputs from, a system. For each of the implementation systems assessed, inventories of significant environmental flows to and from the environment, and internal material and energy flows, were produced.

Data sources included both primary and secondary data. Primary data relating to battery collection and recycling process inputs and outputs were sourced. Secondary data from life cycle databases were used for common processes, materials, transport steps and electricity generation.

Sections 2.1 to *2.4* describe the assumptions, data and inventories used to generate the life cycle inventories for each collection, recycling and implementation scenario. *Section 2.5* provides further detail of the all secondary datasets used in the assessment, together with an evaluation of their quality and appropriateness for use.

2.1 COLLECTION SYSTEMS

A number of key assumptions were required to determine the number of collection points and containers that were required to meet the needs of the three collection scenarios under assessment:

- **Collection Scenario 1** where kerbside collection schemes are favoured;
- **Collection Scenario 2** where CA site collection schemes are favoured; and
- **Collection Scenario 3** where bring receptacle collection schemes, located in institutional premises (business/school/public/WEEE dismantlers etc.), are favoured.

The methods used to make these estimates are documented below. The following sections also describe the data and assumptions used to model these scenarios with regard to the manufacture of containers, transport of batteries to bulking and sorting points, sorting plant operations and onwards transport to recycling facilities.

2.1.1 Collection Points

Collection points fall into five categories, in accordance with the five possible routes for battery collection and consolidation. The estimated maximum number of each collection point available in the UK over the study period was discussed in *Section 1.7.2* and is summarised in *Table 2.1*.

Table 2.1 Battery Collection Points

Collection Route	Collection Point	Estimated No. in UK	Source
1	Waste authority bulking point for kerbside collection	197	Number of coordinating waste authorities in the UK taken from: Cameron-Beaumont, Bridgewater & Seabrook (2004). *National Assessment of Civic Amenity Sites: Civic Amenity Sites in the UK – Current Status*. Future West, Network Recycling. Chapter 2.2, Current CA Site Provision. It was assumed that each authority will operate one bulking point/transfer station for the consolidation of kerbside collected materials.
2	Civic Amenity (CA) site	1065	Number of civic amenity sites in the UK taken from: Cameron-Beaumont, Bridgewater & Seabrook (2004). *National Assessment of Civic Amenity Sites: Civic Amenity Sites in the UK – Current Status*. Future West, Network Recycling. Chapter 2.2, Current CA Site Provision. It was assumed that each CA site will potentially house a collection point. Alternatively, local Authorities may use bring sites for the collection of household batteries. As such, the number of collection points assumed for this collection route may have been underestimated. There will be some overlap with collection route 3, however, as bring sites may be located at supermarkets, or other institutional points, and so it is considered that the potential for underestimation is not significant.
3	Institutional bring site, eg school, electrical equipment retailer, supermarket, hospital	69,500	Estimate based on the relative number of institutional points and performance of collection systems in Belgium (Bebat) and the Netherlands (Stibat). The Belgium system houses a network of 19,500 schools, shops and other institutional sites for its approximate 10.4 million population (0.0019 sites/head) and generates a collection rate of 56%. The Dutch system supports a network of 10,710 sites at schools and shops for its approximate 16.3 million population (0.00068 sites/head) and generates a collection rate of 37%. The number of sites/head required to achieve a 45% collection rate via both of these systems was calculated (in Belgium = (0.0019/56)*45, in the Netherlands = (0.00068/37)*45). An average of these was taken and multiplied by UK population (59.6 million, ONS 2003 estimate) to result in an estimated number of institutional sites for the UK.
4	Mail sorting centre	73	Royal Mail operates 73 Inward Mail Centres, through which all incoming mail must pass. It was assumed that these will act as a consolidation points for the collection of batteries via the postal system.

Collection Route	Collection Point	Estimated No. in UK	Source
5	Lighting maintenance operator bulking site	50	An internet search through Kelly's Industrial Product and Service Information Service (http://www.kellysearch.com) was performed with criteria set to retrieve facilities and emergency lighting maintenance providers. In excess of 50 were listed but many were small companies, without focus on maintenance provision. Approximately 50 provided either facilities maintenance to businesses, or had particular focus on emergency lighting service and maintenance provision. It was assumed that each would collect and consolidate spent batteries when performing routine maintenance and inspections of emergency lighting fittings.

It was assumed that, throughout the study period, each of the postal and maintenance collection points will be used for battery consolidation. The postal system is an interdependent network of collection, sorting and delivery centres and, as such, a collection point would be required at each regional sorting centre to enable a UK-wide postal scheme to operate.

It is a mandatory requirement for employers to carry out routine inspection and maintenance of emergency lighting fittings, under Work Place Regulations 1997 and Employers Guide, Fire and Safety 1999. Maintenance operators are then required to dispose of them in a safe manner, in general through a licensed distribution office. This maintenance system operates independently of the proposed Directive's collection targets and so it was assumed that each maintenance company will house a consolidation/collection point.

For kerbside, CA and institutional collection routes, an estimate of the number of schemes/collection points required to meet the proposed collection targets was made. This was determined by:

- Calculating the potential arisings of batteries per person each year, a function of waste battery arisings (1), coupled with the high participation and capture rates required to achieve a 45% collection rate (2).
- Maximum proportion of waste batteries to be collected via each route was then factored in (3), resulting in a maximum amounted potentially collected for that route.
- Multiplied by the average number of people served by a collection point (4) to determine the maximum amount of batteries potentially collected via each kerbside, CA and institutional collection point each year.

(1) Based on 2003 battery sales data, detailed in *Table 1.1* of the *Goal and Scope*

(2) 70% participation and 70% capture were assumed (totalling 49%), allowing for the unlikelihood that 100% capture will be achieved.

(3) based on the battery collection scenarios described in *Section 1.6* of the *Goal and Scope*

(4) assuming an even distribution of population and collection points

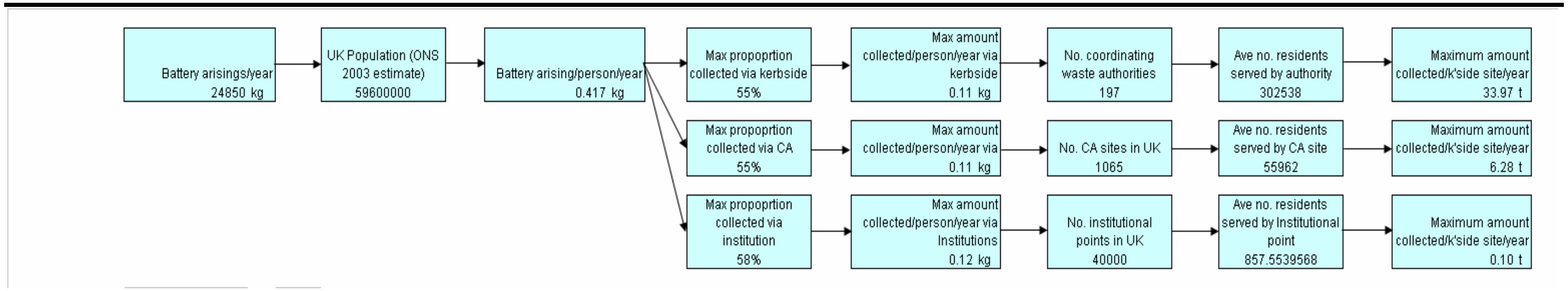
This process is summarised in *Figure 2.1*.

The number of collection points required to fulfil the collection requirements of each scenario (detailed in *Tables 1.2 to 1.7*) was then determined by dividing the required quantity by the maximum quantity collected at each point. The results of this exercise are shown in *Table 2.2*.

Table 2.2 Number of Collection Points Required to Meet Directive Targets over Study Period

	No. Kerbside Collection Points			**No. CA Collection Points**			**No. Institutional Collection Points**		
Scenario	***1***	***2***	***3***	***1***	***2***	***3***	***1***	***2***	***3***
Year									
2006	14	3	7	14	78	14	2645	2645	5066
2007	29	5	14	27	155	27	5291	5291	10,131
2008	43	8	21	41	233	41	7936	7936	15,197
2009	57	10	28	54	310	54	10,581	10,581	20,262
2010	72	13	35	68	388	68	13,227	13,227	25,328
2011	86	15	42	81	466	81	15,872	15,872	30,394
2012	101	18	49	95	543	95	18,517	18,517	35,459
2013	121	21	59	114	652	114	22,221	22,221	42,551
2014	141	25	69	133	761	133	25,924	25,924	49,643
2015	161	28	79	152	869	152	29,628	29,628	56,735
2016	181	32	89	171	978	171	33,331	33,331	63,827
2017	181	32	89	171	978	171	33,331	33,331	63,827
2018	181	32	89	171	978	171	33,331	33,331	63,827
2019	181	32	89	171	978	171	33,331	33,331	63,827
2020	181	32	89	171	978	171	33,331	33,331	63,827
2021	181	32	89	171	978	171	33,331	33,331	63,827
2022	181	32	89	171	978	171	33,331	33,331	63,827
2023	181	32	89	171	978	171	33,331	33,331	63,827
2024	181	32	89	171	978	171	33,331	33,331	63,827
2025	181	32	89	171	978	171	33,331	33,331	63,827
2026	181	32	89	171	978	171	33,331	33,331	63,827
2027	181	32	89	171	978	171	33,331	33,331	63,827
2028	181	32	89	171	978	171	33,331	33,331	63,827
2029	181	32	89	171	978	171	33,331	33,331	63,827
2030	181	32	89	171	978	171	33,331	33,331	63,826

Figure 2.1 Assumptions Regarding the Number of Batteries Potentially Collected via each Collection Route/Year



Note: 70% participation and 70% capture rates were assumed to calculate battery arisings/person/year

2.1.2 *Collection Containers Requirements*

G&P Batteries, the UK market leaders in battery waste management, were consulted in order to determine the number/type of containers needed to fulfil capacity requirements at each collection point, and for each collection route. This information is summarised in *Table 2.3*. For further information on collection container specifications, refer to *Table 2.5*.

Table 2.3 On-site Collection Container Requirements

Collection Route	Collection Point	Collection containers on site							Comments
		Mini tube	Mid tube	Large tube	Cylin -der	Sack	Large bin	Small bin	
1	Kerbside bulking point						3		Up to 33t/year/site collected, max collection freq = 12/year. Thus 3 large bins/site required
2	CA site				1		0.9	0.1	1 cylinder plus consolidation bin/site (approx 10% small bins where space limited)
3	Institutional site	0.25	0.3	0.3	0.15	1			1 receptacle plus consolidation sack/site. Receptacle requirement split according to % likelihood of use
4	Mail centre						0.9	0.1	1 consolidation bin/site (approx 10% small bins where space limited)
5	Maintenance bulking point						0.9	0.1	1 consolidation bin/site (approx 10% small bins where space is limited)

Each collection container is assumed to have an average lifespan of four years. This figure has been determined by G&P Batteries on the basis of past experience.

By multiplying the number of collection points required over the study period (*Table 2.2*) by the collection container requirements at each site (*Table 2.3*), it was possible to determine the total number of collection containers needed at collection points over the 25-year study period. Totals for each scenario are shown in *Table 2.4*. These take into account the assumed four year lifespan of each container.

Table 2.4 Collection Scenario Container Requirements (at Collection Points)

Container Type	Number Required for Collection Scenario (at Collection Points)
Scenario 1	
Mini tube	40,738
Mid tube	48,886
Large tube	48,886
Cylinder	25,276
Sack	81,476
Large bin	4096
Small bin	160
Total	**249,518**
Scenario 2	
Mini tube	40,738
Mid tube	48,886
Large tube	48,886
Cylinder	29,224
Sack	81,476
Large bin	5458
Small bin	555
Total	**255,223**
Scenario 3	
Mini tube	78,010
Mid tube	93,612
Large tube	93,612
Cylinder	47,640
Sack	156,020
Large bin	2749
Small bin	160
Total	**471,803**

The large, one-tonne collection bins ('large bin') form a key part of the collection systems and are used not only for on-site consolidation, but also for transporting, sorting and storing batteries. These bins are therefore re-used many times over their four-year lifespan were allocated in the study to reflect this.

The number of times bins are reused is dependent on the number of bins that are pooled in the collection system. This figure is, in turn, dependent on the number of tonnes that are required to be collected each day, as a bin is required to transport each tonne of batteries collected. One-tonne bins will also be kept in stock at the sorting plant for sorting and storage operations (approx 20 per chemistry (1)) and a number of bins will be located at recycling facilities (approx 20 per chemistry (2)), awaiting pick-up. On this basis, and assuming that each bin has an approximate 4 year lifespan, it was estimated that 129 tonnes of batteries would be managed by each bin in the pool. This

(1) Michael Green, pers comm.

(2) Michael Green, pers comm.

allocation was applied to the use of one-tonne bins for transport, sorting and storage purposes.

Such an allocation is not required for other collection containers, and one-tonne bins located at collection points, as it was assumed that they remain at the collection point for four years before being replaced.

2.1.3 *Collection Container Manufacturing*

Container manufacturers were contacted in order to determine the quantities and types of materials used to manufacture the collection containers, together with the production processes used. These data are summarised in *Table 2.5*. The Life Cycle Inventory (LCI) data used to model the manufacture of containers are detailed in *Table 2.6*.

Table 2.5 Collection Container Specifications

Container	Compatible Batteries	Average Capacity (kg)	Empty Weight (kg)	Material Composition	Key Manufacturing process/es
Mini tube	Non-PbA	5	0.7	Polycarbonate (approx 60%), ABS (approx 40%)	Polycarbonate tube extrusion, moulding of ABS base parts
Mid tube	Non-PbA	20	1.5	Polycarbonate (approx 80%), ABS (approx 20%)	Polycarbonate tube extrusion, moulding of ABS base parts
Large tube	Non-PbA	40	8.2	Steel (approx 85%), Polycarbonate (approx 15%)	Polycarbonate tube extrusion, moulding of steel base parts
Cylinder	Non-PbA	80	7.1	Polyethylene (6.5kg) (approx 10% with a steel inner (6kg))	Rota moulding from polyethylene powder
Sack	Non-PbA	40	0.3	Woven polypropylene	Polypropylene extrusion followed by weaving
Large bin	All	1000	45	High density polyethylene	Injection moulding
Small bin	All	500	19	High density polyethylene	Injection moulding

Table 2.6 Life Cycle Inventory Data for Collection Containers

Container	Inventory Data Input	Quantity	Inventory Data Source	Time coverage	Geographic Coverage	Comment
Mini Tube	Polycarbonate (PC)	0.4 kg	Ecoinvent	1992-1996	Europe	-
	Extrusion, plastic pipes	0.40 kg	Ecoinvent	1993-1997	Europe	Extrusion of PC tube. Includes estimated process efficiency
	ABS	0.2 kg	Ecoinvent	1995	Europe	-
	Injection moulding	0.201 kg	Ecoinvent	1993-1997	Europe	Moulding of ABS base parts. Includes estimated process efficiency
Mid Tube	Polycarbonate	1.2 kg	Ecoinvent	1992-1996	Europe	-
	Extrusion, plastic pipes	1.21 kg	Ecoinvent	1993-1997	Europe	Extrusion of PC tube. Includes estimated process efficiency
	ABS	0.3 kg	Ecoinvent	1995	Europe	-
	Injection moulding	0.30 kg	Ecoinvent	1993-1997	Europe	Moulding of ABS base parts. Includes estimated process efficiency
Large Tube	Polycarbonate	0.95 kg	Ecoinvent	1992-1996	Europe	-
	Extrusion, plastic pipes	0.90 kg	Ecoinvent	1993-1997	Europe	Extrusion of PC tube. Includes estimated process efficiency
	Steel, low alloyed	6.8 kg	Ecoinvent	2001	Europe	-
	Forging steel	6.8 kg	Kemna	1989	Europe	Moulding of steel base parts.
Cylinder	Polyethylene, HDPE	6.5 kg	Ecoinvent	1993	Europe	-
	Blow moulding	6.52 kg	Ecoinvent	1993-1997	Europe	Substitute for rota moulding as most similar plastics processing method in terms of energy demand. Includes estimated process efficiency
	Steel, low alloyed	0.6 kg	Ecoinvent	2001	Europe	-
	Electroplating steel with zinc	0.34 m^2	Idemat	1994	Europe	Steel inner specifications = 86cm x 36cm
	Cold transforming steel	0.6 kg	Kemna	1989	Europe	Machining of rolled steel to produce bucket. Electricity requirement only.
Sack	Polypropylene	0.3 kg	Ecoinvent	1992-1993	Europe	-
	Extrusion, plastic film	0.31 kg	Ecoinvent	1993-1997	Europe	Extrusion of polypropylene film. Includes estimated process efficiency

Container	Inventory Data Input	Quantity	Inventory Data Source	Time coverage	Geographic Coverage	Comment
Large Bin	Polyethylene, HDPE	45 kg	Ecoinvent	1992-1993	Europe	-
	Injection moulding	45.27 kg	Ecoinvent	1993-1997	Europe	Moulding of bin. Includes estimated process efficiency
Small Bin	Polyethylene, HDPE	19 kg	Ecoinvent	1992-1993	Europe	-
	Injection moulding	19.11 kg	Ecoinvent	1993-1997	Europe	Moulding of bin. Includes estimated process efficiency

Refer to *Section 2.5* for further description of secondary datasets

2.1.4 *Collection Container Maintenance*

G&P Batteries further supplied data regarding typical maintenance requirements for collection containers, both at collection points and at depot or sorting plant. This information is summarised in *Table 2.7*.

Table 2.7 Collection Container Maintenance Requirements

Container	Maintenance Requirements	Life Cycle Inventory Data	Inventory Data Source
Mini tube	None	-	-
Mid tube	None	-	-
Large tube	None	-	-
Cylinder	Occasional manual wash, 1 x year	Soap – 5g per wash Tap water – 5kg per wash	Ecoinvent (1992-1995, Europe) Ecoinvent (2000, Europe)
Sack	None	-	-
Large bin	Mechanical wash at sorting plant every use	Soap – 5g per wash Tap water – 5kg per wash	Ecoinvent (1992-1995, Europe) Ecoinvent (2000, Europe)
Small bin	Mechanical wash at sorting plant every use	Soap – 5g per wash Tap water – 5kg per wash	Ecoinvent (1992-1995, Europe) Ecoinvent (2000, Europe)

Refer to *Section 2.5* for further description of secondary datasets

2.1.5 *Transport to Depot/Sorting Plant*

G&P Batteries were also contacted to provide estimated average transport distances for each collection route. These take into consideration the optimisation of collection routes to minimise costs and the likely future expansion of UK collection networks to a hub-spoke based system as collection tonnages increase. It is assumed that collection trucks will operate to 50% capacity, travelling out empty and returning full.

A summary of the estimated transport requirements for each collection route is provided in *Table 2.8*. Distances refer to the distance batteries travel from the point at which they enter the collection system to the point at which they reach the central sorting plant. The delivery of batteries via the postal system and via maintenance operators is assumed to be equivalent to personal travel and is excluded from the assessment. The LCI data used to model transport requirements are detailed in *Table 2.11*.

Table 2.8 ***Transport from Collection to Sorting Plants***

Collection Route	Refuse Collection Vehicle (km/tonne)	Transit Van (km)	Articulated lorry – (km)	Packing Requirements
1	1.5		400	1 x large bin per tonne batteries
2			400	1 x large bin per tonne batteries
3		161	400	1 x large bin per tonne batteries
4			400	1 x large bin per tonne batteries
5			400	1 x large bin per tonne batteries

2.1.6 Sorting Plant

Table 2.9 details the inputs and outputs for the G&P Batteries sorting plant, the largest waste battery sorting plant in the UK. Data take into account the future development of this process, in terms of levels of process automation. Currently sorting is predominantly manual, but with increasing throughput, automation is likely to be introduced in order to increase efficiency. The process will remain predominantly manual, however, as research has shown that automation can only be increased to a certain level before increased rates of sorting error become prohibitive (1). It has been assumed that a conveyer will be introduced early in the study period, to address increased tonnages collected.

The water treatment step of sorting plant operations (see *Figure 1.2*) has been excluded from the assessment as it is required predominantly for the treatment of effluent resulting from industrial PbA battery washings. PbA batteries arising through hobby applications are likely to comprise <1% of the PbA batteries being sorted at plant. As such, the impacts associated with this process in relation to the study scope are assumed to be minimal.

(1) Michael Green, pers comm.

Table 2.9 Sorting Plant: Input/Output Data per Tonne of Batteries

INPUTS	Inventory Data/Source	Quantity	Unit	Outputs	Inventory Data/Source	Quantity	Unit
Feedstock				*Output Product*			
Mixed waste batteries	-	1	tonne	Sorted batteries	-	1	tonne
Container/packaging				*Container/packaging*			
Polyethylene (large bin)	See *Table 1.6*	1.25	kg*	Polyethylene (large bin)	See *Table 1.6*	1.25	kg*
Water Consumption				*Solid Wastes*			
Mains water (washing)	Tap Water (Ecoinvent, Europe, 2000)	0.47	kg	Negligible general waste and unidentifiable hazardous waste (<1%)			
Electricity consumption				*Water emissions*			
Grid electricity (conveyor)	Electricity MV (BUWAL, GB, 2005)	2.4	kWh	Wastewater to sewer	Wastewater to sewage treatment works (Ecoinvent, CH, 2000)	0.47	kg
Fuel consumption				*Gaseous emissions*			
Diesel (forklift)	Diesel (Ecoinvent, Europe, 1989-2000)	0.17	litres	NOx	-	0.0039	kg
				PM10	-	0.00025	kg
				CO	-	0.0024	kg
				NMVOC	-	0.00077	kg
				SO_2	-	0.00029	kg
				CO_2	-	0.46	kg
				Dioxins and Furans	-	negligible	

* This figure takes into account the reuse of containers throughout the collection system
Refer to *Section 2.5* for further description of secondary datasets

2.1.7 *Transport to Recycling Plant*

The final step in each collection system is the transport of sorted batteries from the sorting plant to recycling facilities. Average distances to recycling facilities were calculated for each recycling scenario, using web-based route mapping tools (1), and are shown in *Table 2.10*, together with assumed packaging and vehicle requirements. The LCI data used to model transportation are detailed in *Table 2.11*.

(1) www.multimap.com

Table 2.10 Transport to Recycling Facilities

Battery Type	Destination: Recycling Scenario 1	Destination: Recycling Scenario 2	Destination: Recycling Scenario 3	Vehicle used	Additional Packing Requirements
Alkaline and saline (AlMn, ZnC, ZnO)	UK (10km)	50% UK (10km), 50% France (1250km)	Switzerland (1200km)	25-tonne truck (haulier) for transport to continent, 15-tonne truck for transport to dedicated facility in UK	None
Primary Lithium (Li, LiMn)	Switzerland (1200km)	Switzerland (1200km)	Switzerland (1200km)	25-tonne truck (to transport 15t batteries) - (haulier)	10 tonnes sand
Li-ion	50% France (1250km), 50% Switzerland (1200km)	50% France (1250km), 50% Switzerland (1200km)	50% France (1250km), 50% Switzerland (1200km)	25-tonne truck (haulier)	None
NiCd, NiMH	France (1250km)	France (1250km)	France (1250km)	25-tonne truck (haulier)	None
AgO	UK (150km)	UK (150km)	UK (150km)	25-tonne truck (haulier)	None
PbA	UK (150km)	UK (150km)	UK (150km)	25-tonne truck (haulier)	None

Table 2.11 Life Cycle Inventory Data for Transportation

Vehicle	Inventory Data	Inventory Data Source	Age of Data	Geographic Coverage	Comment
Refuse Collection Vehicle	RCV, 21 tonne	Ecoinvent	2005	Switzerland/ Europe	Adapted with Euro IV emissions standards
Transit van	Van, 3.5 tonne	Ecoinvent	2005	Switzerland/ Europe	Adapted with Euro IV emissions standards
15-tonne truck	Lorry, 15 tonne	Ecoinvent	2005	Switzerland/ Europe	Adapted with Euro IV emissions standards
25-tonne truck	Lorry, 25 tonne	Ecoinvent	2005	Switzerland/ Europe	Adapted with Euro IV emissions standards

Refer to *Section 2.5* for further description of secondary datasets

2.1.8 Inventory Compilation

An inventory for each collection scenario was compiled by combining collection container requirements, transportation to sorting plant, sorting plant operations and onward transport to recycling facilities.

2.2 BATTERY MATERIAL COMPOSITION

The assumed composition of collected batteries is detailed in *Table 2.12* to *Table 2.23*. These have important implications in particular for the fate of materials on disposal (discussed further in *Section 2.4*).

Primary Batteries

Table 2.12 Alkaline Manganese Battery Composition

Component	Percentage
Iron & Steel	24.8%
Manganese	22.3%
Nickel	0.5%
Zinc	14.9%
Other metals	1.3%
Alkali	5.4%
Carbon	3.7%
Paper	1.0%
Plastics	2.2%
Water	10.1%
Other non metals	14.0%

Table 2.13 Zinc Carbon Battery Composition

Component	Percentage
Iron & Steel	16.8%
Manganese	15.0%
Lead	0.1%
Zinc	19.4%
Other metals	0.8%
Alkali	6.0%
Carbon	9.2%
Paper	0.7%
Plastics	4.0%
Water	12.3%
Other non metals	15.2%

Table 2.14 Mercuric Oxide (button) Battery Composition

Components	Percentage
Iron steel	37%
Mercury	31%
Manganese	1%
Nickel	1%
Zinc	14%
KOH	2%
Carbon	1%
Plastics	3%
Water	3%
Other material	7%

Table 2.15 Zinc Air (button) Battery Composition

Components	Percentage
Iron & Steel	42%
Mercury	1%
Zinc	35%
Alkali	4%
Carbon	1%
Plastics	4%
Water	10%
Other non metals	3%

Table 2.16 Lithium (button) Battery Composition

Components	Percentage
Iron & Steel	60%
Lithium	3%
Manganese	18%
Nickel	1%
Carbon	2%
Plastics	3%
Other non metals	13%

Table 2.17 Alkaline (button) Battery Composition

Components	Percentage
Iron & Steel	37%
Mercury	0.6%
Manganese	23%
Nickel	1%
Zinc	11%
Alkali	2%
Carbon	2%
Plastics	6%
Water	6%
Other non metals	14%

Table 2.18 Silver Oxide (button) Battery Composition

Components	Percentage
Silver	31%
Iron & Steel	42%
Mercury	0.4%
Manganese	2%
Nickel	2%
Zinc	9%
Other metals	4%
Alkali	1%
Carbon	0.5%
Plastics	2%
Water	2%
Other non metals	4%

Table 2.19 Lithium Manganese Battery Composition

Components	Percentage
Iron & Steel	50%
Lithium	2%
Manganese	19%
Nickel	1%
Carbon	2%
Plastics	7%
Other non metals	19%

Secondary Batteries

Table 2.20 Nickel Cadmium Battery Composition

Components	Percentage
Cadmium	15.0%
Iron & Steel	35.0%
Nickel	22.0%
Alkali	2.0%
Plastics	10.0%
Water	5.0%
Other non metals	11.0%

Table 2.21 Nickel Metal Hydride Battery Composition

Components	Percentage
Cobalt	4.0%
Iron & Steel	20.0%
Manganese	1.0%
Nickel	35.0%
Zinc	1.0%
Other metals	10.0%
Alkali	4.0%
Plastics	9.0%
Water	8.0%
Other non metals	8.0%

Table 2.22 Lithium Ion Battery Composition

Components	Percentage
Iron & Steel	22.0%
Aluminium	5.0%
Cobalt	18.0%
Lithium	3.0%
Other metals	11.0%
Carbon	13.0%
Other non metals	28.0%

Table 2.23 Lead Acid Battery Composition

Components	Percentage
Lead	65%
Other metals	4%
H2SO4	16%
Plastics	10%
Other material	5%

2.3 RECYCLING SYSTEMS

The following sections describe the data and assumptions used to model the processing requirements of the three recycling scenarios, as detailed in *Table 2.24*.

Table 2.24 Recycling Scenario Summary

Battery Type	Recycling Scenario 1	Recycling Scenario 2	Recycling Scenario 3
AlMn, ZnC, ZnO	UK hydrometallurgical	UK and EU hydrometallurgical	EU pyrometallurgical
Li-ion	EU hydro- and pyrometallurgical	EU hydro- and pyrometallurgical	EU hydro- and pyrometallurgical
Lithium primary (Li, LiMn)	EU pyrometallurgical	EU pyrometallurgical	EU pyrometallurgical
NiMH, NiCd	EU pyrometallurgical	EU pyrometallurgical	EU pyrometallurgical
AgO (button cells)	UK mercury distillation/ electrolysis	UK mercury distillation/ electrolysis	UK mercury distillation/ electrolysis
PbA	UK pyrometallurgical	UK pyrometallurgical	UK pyrometallurgical

Information regarding recycling systems for different battery chemistries was obtained from various recyclers, by means of questionnaires and personal contact with individual processors.

2.3.1 Alkaline and Saline Batteries (AlMn, ZnC, ZnO)

In general, alkaline and saline battery recycling processes treat a mixture of waste batteries, such that ERM was unable to allocate inputs and emissions to the specific battery chemistries. Two options were presented:

1. to use combined data, representative of recycling processes for mixed alkaline and saline batteries; or
2. to allocate inputs and outputs to specific chemistries based on the composition of each.

The latter option is limited, as the battery composition data available to ERM are generic and, as such, are not directly related to the composition of batteries undergoing treatment. This makes allocation ineffectual and so the former option was employed.

Hydrometallurgical Processing

Data for the hydrometallurgical processing of alkaline and saline batteries were obtained from Recupyl (France), and are representative of 2004 production. *Table 2.25* details the inputs and outputs per tonne of batteries recycled for this process.

The same inputs and outputs were assumed for hydrometallurgical processing in the UK, as G&P Batteries, the only UK company to process waste batteries, have obtained a patent from Recupyl to carry out the mechanical treatment stage of their process. Black mass resulting from this will then be transported to other plant in Europe for further treatment. With increasing tonnages requiring treatment in the UK, G&P are likely to expand the treatment facility to incorporate further treatment of the black mass in the UK.

Table 2.25 Hydrometallurgical Processing of Alkaline and Saline Batteries: Input/Output Data per Tonne of Batteries

Flow	Quantity	Unit	Data Quality Indicator	Inventory Data/Source
INPUTS				
Raw material inputs				
Waste batteries	1000	kg		-
H_2SO_4 (92%)	168	l		284.2 kg of 100% Sulphuric Acid (assumed density 1.83 kg/l). Ecoinvent, Europe, 2000
H_2O_2 (30%)	126	l		75.6 kg of 50% Hydrogen Peroxide (assumed density 1 kg/l). Ecoinvent, Europe, 1995
Antifoam	0.86	l		0.8645 kg generic organic chemicals (assumed density 1 kg/l). Ecoinvent, global average, 2000
Electricity consumption				
Electricity, national grid (UK/France)	959.4	kWh	M	Grid Electricity, Medium Voltage, UK/France. Derived from BUWAL data, 2002.
Water consumption				
Industrial water. Use in waste gas treatment	569.61	l	M/C	Tap Water, used as substitute for mains water. Ecoinvent, Europe, 2000
OUTPUTS				
Product output				
Zinc – to non ferrous metals industry/ galvanisation	205	kg	M	Zinc, for coating. Ecoinvent, Europe, 1994-2003

Flow	Quantity	Unit	Data Quality Indicator	Inventory Data/Source
Manganese dioxide - to non ferrous metals industry	317	kg		228 kg Manganese. Ecoinvent, Europe, 2003
- of which pure manganese	*228*	kg	M	
Iron and steel – to steel production	180	kg	M	Recycling iron and steel. Ecoinvent, Europe, 2002
Emissions to air				
NH_3	0.005	kg	M	-
Dust	0.0015	kg	M	-
Hg + Cd	0.00003	kg	M	-
Acid	0.000084	kg	M	-
H_2, O_2, water	29.61	kg	C	-
Zn + Mn	0.00001316	kg	M	-
O_2	39			-
Emissions to water (sewer)				
Solid suspension	0.0119	kg	M	-
Hg	0.0000028	kg	M	-
Cd	0.000007	kg	M	-
Zn	0.0028	kg	M	-
Mn	0.00224	kg	M	-
Water + Acid (recycled within process)	768	kg	M	Reused within process
Water release	99	kg	M	Sewage treatment at wastewater treatment plant, class 3. Ecoinvent, Switzerland, 2000
Solid wastes				
Paper/plastic to landfill/incineration	120	kg	M	Packaging paper/mixed plastics to sanitary landfill/municipal incineration. Ecoinvent, Switzerland, 1995
Residue of leaching (chemical treatment) to landfill	97	kg	M	Waste disposal in residual material landfill, process –specific burdens only. Ecoinvent, Switzerland, 1995
Mixed heavy metals to disposal	10	kg		Waste disposal in residual material landfill, process –specific burdens only. Ecoinvent, Switzerland, 1995

Source: Recupyl. M = measured, C = calculated, E = estimated
Refer to *Section 2.5* for further description of secondary datasets

There is a discrepancy of approximately 7 % between the raw material inputs and process outputs provided and, for this process, input exceeds output. The data have been checked by Recupyl and confirmed as representative for the processing of one tonne of batteries. The difference in mass between process inputs and outputs is considered to be due to the water content in alkaline and saline batteries (*Table 2.12* and *Table 2.13* show alkaline and saline batteries to have a water content of approximately 10%).

Pyrometallurgical Processing

Data for the pyrometallurgical recycling of alkaline and saline batteries were obtained from three recyclers: Batrec (Switzerland); Citron (France); and Valdi (France). It was not possible to obtain specific data for the recycling of batteries at the Citron plant, however, and batteries make only approximately 5 % of the total waste treated. As such, the data were not considered to be representative of battery recycling processes and were not included in the assessment.

The most complete data were obtained from Batrec and so this dataset was used to model the potential impacts associated with the recycling of alkaline and saline batteries via the pyrometallurgical route. *Table 2.26* details inputs and outputs for the Batrec recycling process. The data are representative of plant activities in 2004.

Data for the Valdi pyrometallurgical process was used in the sensitivity analyses to determine the significance of this choice.

Table 2.26 Pyrometallurgical Processing of Alkaline and Saline Batteries: Input/Output Data per Tonne of Batteries

Flow	Quantity	Unit	Data Quality Indicator	Inventory Data/Source
INPUTS				
Raw material inputs				
Waste batteries, alkaline and saline batteries	1000	kg		-
Electricity consumption				
Electricity, national grid (Switzerland)	1690	kWh	M	Grid Electricity, Medium Voltage, Switzerland. Derived from BUWAL data, 2002.
Fuel usage				
Fuel oil for pyrolysis	58	kg	M	Light fuel oil. Ecoinvent, Switzerland, 2000
Propane for safety burner	6	kg	M	Propane/butane. Ecoinvent, Switzerland, 2000
Water consumption				
Process water - mains supply	400	l	M	Tap Water, used as substitute for mains water. Ecoinvent, EU, 2000
Cooling water - main supply	1000	l	M	Tap Water, used as substitute for mains water. Ecoinvent, EU, 2000
OUTPUTS				
Product output				
Ferromanganese (55% Fe,	290	kg	M	Ferromanganese. Ecoinvent,

Flow	Quantity	Unit	Data Quality Indicator	Inventory Data/Source
40% Mn, 5% Cu & Ni) to cast iron foundry				Europe, 1994-2003
Zinc to metal market	200	kg	M	Zinc, for coating. Ecoinvent, Europe, 1994-2003
Mercury to metal market	0.3	kg	M	Mercury, liquid. Ecoinvent, global average, 2000
Emissions to air (process gas)				
Cd	0.000006	kg	M	-
CO	0.52	kg	M	-
HCl	0.0004	kg	M	-
Hg	0.000001	kg	M	-
HF	0.0004	kg	M	-
N_2O	0.82	kg	M	-
Particulates	0.001	kg	M	-
Pb	0.00008	kg	M	-
SO_2	0.001	kg	M	-
Zn	0.0002	kg	M	-
Emissions to water (sewer)				
Zn	0.00000035	kg	M	-
Cd	6E-09	kg	M	-
Hg	3E-09	kg	M	-
CN	0.00000001	kg	M	-
F	0.00018	kg	M	-
Cl (from electrolyte)	44	kg	C	-
K (from electrolyte)	50	kg	C	-
Water to sewer	1400	l	C	Sewage treatment at wastewater treatment plant, class 3. Ecoinvent, Switzerland, 2000
Solid wastes				
Slags to landfill	146	kg	M	Disposal of inert waste to in inert landfill. Ecoinvent, Switzerland, 1995.

Source: Batrec. M = measured, C = calculated, E = estimated
Refer to *Section 2.5* for further description of secondary datasets

There is a discrepancy of approximately 27% between raw material inputs and process outputs provided and, for this process, input exceeds output. The data have been checked by Batrec and confirmed as representative for the processing of one tonne of batteries. The difference in mass between process inputs and outputs is considered to be due to the water, paper, plastics and carbon content of input batteries. Water and carbon each comprise 10% of the battery composition and both are released during the pyrolysis process. Furthermore, taking account of the oxidation of paper (1%) and plastics (2%) in the process, this reduces overall mass discrepancy to 4%. This is considered to be reasonable within the likely variation in composition of input batteries.

2.3.2 *Lithium Batteries (Li-ion, Li, LiMn)*

Lithium batteries can alternatively be classified as primary (Li and LiMn) or secondary (Li-ion) cells. Secondary, Li-ion batteries can be treated via both hydrometallurgic and pyrometallurgic process routes, whereas technology currently only exists that can process primary lithium batteries via the pyrometallurgical route.

Hydrometallurgical Processing (Li-ion)

A variant of the Recupyl process, Valibat, is available for recycling Li-ion batteries via the hydrometallurgical route. Data for this process were obtained from Recupyl (France), and represent recycling activities during 2004. *Table 2.27* details the inputs and outputs for the Valibat recycling process.

Table 2.27 Hydrometallurgical Processing of Li-ion Batteries: Input/Output Data per Tonne of Batteries

Flow	Quantity	Unit	Data Quality Indicator	Inventory Data/Source
INPUTS				
Raw material inputs				
Waste batteries	1	tonne		
Reagent	25	kg		Generic inorganic chemicals. Ecoinvent, global average, 2000
Electricity consumption				
Electricity, national grid (France)	140	kWh	M	Grid Electricity, Medium Voltage, France. Derived from BUWAL data, 2002.
Water consumption				
Industrial water	0.72	m^3	M	Tap Water, used as substitute for mains water. Ecoinvent, EU, 2000
H_2SO_4 (92%)	126	l	M	213.2 kg of 100% Sulphuric Acid (assumed density 1.83 kg/l). Ecoinvent, Europe, 2000
Lime	116	kg	M	Hydrated lime. Ecoinvent, EU, 2000
OUTPUTS				
Product output				
Cobalt salt *(as C_oCO3)* to cobalt producer	340 *(Co =180)*	kg kg	M	180kg Cobalt. Ecoinvent, global average, 2000
Lithium salt *(as Li_2CO_3)* to lithium producer	198 *(Li = 30)*	kg kg	M	198 kg Li_2CO_3 (production in South America). ESU, 2000.
Iron and steel to steel industry	165	kg	M	Recycling iron and steel. Ecoinvent, Europe, 2002
Non-ferrous metals to reprocessor	150	kg	M	Recycling aluminium. Ecoinvent, Europe, 2002

Flow	Quantity	Unit	Data Quality Indicator	Inventory Data/Source
Emissions to air				
SO_2	4.5	g	M	-
VOC	2.5	g	M	-
Emissions to water (sewer)				
Solid suspension	12	g	M	-
Chemical oxygen	30	g	M	-
Total hydrocarbon	0.01	g	M	-
Cu+Co+Ni	0.05	g	M	-
Fluoride	0.03	g	M	-
Water to sewer	*337*	kg	M	Sewage treatment at wastewater treatment plant, class 3. Ecoinvent, Switzerland, 2000
Solid wastes				
Paper and plastic to refining	130	kg	M	Recycling paper/mixed plastic. Ecoinvent, Switzerland, 1995
Residue to landfill	202	kg	M	Disposal of inert waste to in inert landfill. Ecoinvent, Switzerland, 1995.
Gypsum (as $CaSO_4$, H_2O) to landfill	339	kg	M	Disposal of gypsum to in inert landfill. Ecoinvent, Switzerland, 1995.

Source: Recupyl. M = measured, C = calculated, E = estimated
Refer to *Section 2.5* for further description of secondary datasets

There is a discrepancy of approximately 13% between raw material inputs and process outputs provided and, for this process, output exceeds input. The data have been checked by Recupyl and confirmed as representative for the processing of one tonne of batteries. The difference in mass between process inputs and outputs is considered to be due to water use within the process. Apart from the direct emission to sewer, the water input ends up in various output fractions, such as cobalt salts, lithium salts, residues and gypsum.

Pyrometallurgical Processing (Li-ion, Li, LiMn)

Pyrometallurgical lithium battery recycling processes treat a mixture of waste lithium batteries, such that ERM was unable to allocate inputs and emissions to the specific battery chemistries. A similar limitation to the allocation of flows to specific chemistries resulted in combined datasets being modelled for lithium batteries via the pyrometallurgical route.

Data for the pyrometallurgical recycling of lithium batteries were obtained from Batrec and are representative of recycling in 2004. *Table 2.28* details the inputs and outputs for the Batrec lithium battery recycling process.

Table 2.28 Pyrometallurgical Processing of Lithium Batteries: Input/Output Data per Tonne of Batteries

Flow	Quantity	Unit	Data Quality Indicator	Inventory Data/Source
INPUTS				
Raw material inputs				
Waste batteries:	1000	kg		-
NaOH (30 %)	350	kg	C	210 kg 50% NaOH. Ecoinvent, Europe, 2000
Electricity consumption				
Electricity, national grid (Switzerland)	800	kWh	C	Grid Electricity, Medium Voltage, Switzerland. Derived from BUWAL data, 2002.
Water consumption				
Process water - main supply	1000	l	C	Tap Water, used as substitute for mains water. Ecoinvent, EU, 2000
OUTPUTS				
Product output				
Steel to steel industry	270	kg	C	Recycling iron and steel. Ecoinvent, Europe, 2002
Co-Powder (cobalt oxide 60% and carbon 40 %) to cobalt industry	192	kg	C	74.9 kg Cobalt (60% cobalt oxide, assuming Co content of C_oO_2 = 65% (stoichiometric calculation). Ecoinvent, global average, 2000
Non ferrous metals to metal industry	240	kg	C	Primary aluminium avoided Recycling Aluminium. Ecoinvent, Europe, 2002
M_nO_2-powder to recycler	10	kg	C	6.3 kg Manganese (assuming Mn content of M_nO_2 = 63% (stoichiometric calculation). Ecoinvent, Europe, 2003
Emissions to air				
Dust	0.208	kg	M/C	-
SO_2	0.048	kg	M/C	-
Emissions to water				
Water to sewer	1000	l		Sewage treatment at wastewater treatment plant, class 3. Ecoinvent, Switzerland, 2000
SO_2	40	kg		-
Cl	40	kg		-
Solid wastes				
Plastics to incinerator	200	kg	C	Mixed plastics to municipal incineration. Ecoinvent, Switzerland, 1995

Source: Batrec. M = measured, C = calculated, E = estimated
Refer to *Section 2.5* for further description of secondary datasets

There is a discrepancy of approximately 9% between raw material inputs and process outputs provided and, for this process, input exceeds output. The data have been checked by Batrec and confirmed as representative for the processing of one tonne of batteries. The difference in mass between process inputs and outputs is considered to be due to losses of salts and oxygen, which leave the system with the waste water and the waste gas scrubber.

2.3.3 *NiCd and NiMH Batteries*

NiCd and NiMH batteries are most commonly recycled via pyrometallurgy. Data for the pyrometallurgical recycling of NiCd and NiMH batteries were obtained from SNAM and are representative of plant activities in 2003.

Table 2.29 and *Table 2.30* detail inputs to and outputs from the SNAM NiCd and NiMH recycling processes.

Table 2.29 Pyrometallurgical Processing of NiCd Batteries: Input/Output Data per Tonne of Batteries

Flow	Quantity	Unit	Data Quality Indicator	Inventory Data/Source
INPUTS				
Raw material inputs				
NiCd batteries	1	tonne		-
Active carbon	1.67	kg	C	Carbon black, used as substitute for active carbon. ETH, Europe, 1994
Electricity consumption				
Electricity, national grid (France)	1545	kWh	C	Grid Electricity, Medium Voltage, France. Derived from BUWAL data, 2002.
Fuel usage				
Natural gas and propane for heating and pyrolysis	170.6	kg	C	Propane/butane, used as substitute for natural gas and propane. Ecoinvent, Switzerland, 2000
Water consumption				
Process water (surface)	240	kg	C	Tap Water, used as substitute for mains water. Ecoinvent, Europe, 2000
OUTPUTS				
Product output				
Pure cadmium for use in industrial batteries	135.4	kg	C	Cadmium. Idemat, EU, 1990-1994
Nickel-Iron residues to stainless steel producer	543	kg	C	Recycling iron and steel. Ecoinvent, Europe, 2002
Emissions to air				
NOx	0.47	kg	M	-
SO_2	0.016	kg	M	-

Flow	Quantity	Unit	Data Quality Indicator	Inventory Data/Source
VOC	1.003	kg	M	-
Dust – total	10	g	C	-
Cd	0.682	g	C	-
Hg	0.582	g	C	-
Emissions to water (sewer)				
Water to sewer	240	kg	C	Sewage treatment at wastewater treatment plant, class 3. Ecoinvent, Switzerland, 2000
BOD	8.5	g	M	-
COD	26	g	M	-
Suspended solids	1.24	g	M	-
Oil & grease	2	g	M	-
Heavy metals: Cd + Ni	0.062	g	M	-
Zinc	0.01	g	M	-
Solid wastes				
KOH to neutralisation	44.8	kg	C	Sewage treatment at wastewater treatment plant, class 3, used as proxy for neutralisation process. Ecoinvent, Switzerland, 2000
Plastic waste to landfill	147	kg	C	Mixed plastics to sanitary landfill. Ecoinvent, Switzerland, 1995
Iron residues to recycling	62	kg	C	Recycling iron and steel. Ecoinvent, Europe, 2004

Source: SNAM. M = measured, C = calculated, E = estimated
Refer to *Section 2.5* for further description of secondary datasets

There is a discrepancy of approximately 7% between raw material inputs and process outputs provided. For this process, input exceeds output. The data have been checked by SNAM and confirmed as representative for the processing of one tonne of batteries. The difference in mass between process inputs and outputs is considered to be due to the water content of nickel cadmium batteries (approximately 5%, *Table 2.20*), which evaporates in the process. The loss of this water reduces the mass discrepancy to 2%, considered to be reasonable within the likely variation in composition of input batteries.

Table 2.30 Pyrometallurgical Processing of NiMH Batteries: Input/Output Data per Tonne of Batteries

Flow	Quantity	Unit	Data Quality Indicator	Inventory Data/Source
INPUTS				
Raw material inputs				
NiMH batteries	1	tonne		-
Active carbon	1.67	kg	C	Carbon black, used as substitute for active carbon. ETH, Europe, 1994
Electricity consumption				
Electricity, national grid (France)	310	kWh	C	Grid Electricity, Medium Voltage, France. Derived from BUWAL data, 2002.
Fuel usage				
Natural gas and propane used in pyrolysis	94.7	kg	C	Propane/butane, used as substitute for natural gas and propane. Ecoinvent, Switzerland, 2000
Water consumption				
Process water (surface)	240	kg	C	Tap Water, used as substitute for mains water. Ecoinvent, Europe, 2000
OUTPUTS				
Product output				
Nickel-Cobalt-Iron residues to stainless steel producer	730	kg	C	Recycling iron and steel. Ecoinvent, Europe, 2002
Emissions to air				
NOx	0.47	kg	M	-
SO_2	0.016	kg	M	-
VOC	1.003	kg	M	-
Dust – total	4.89	g	C	-
Hg	0.53	g	C	-
Emissions to water				
Water to sewer	240	kg		Sewage treatment at wastewater treatment plant, class 3. Ecoinvent, Switzerland, 2000
BOD	8.5	g	M	-
COD	26	g	M	-
Suspended solids	1.24	g	M	-
Oil & grease	2	g	M	-
Heavy metals: Cd + Ni	0.062	g	M	-
Zinc	0.01	g	M	-
Solid wastes				
Plastic to landfill	147	kg	C	Mixed plastics to sanitary landfill. Ecoinvent, Switzerland, 1995

Source: SNAM. M = measured, C = calculated, E = estimated

Refer to *Section 2.5* for further description of secondary datasets

There is a discrepancy of approximately 12 % between raw material inputs and process outputs provided. For this process, input exceeds output. The data have been checked by SNAM and confirmed as representative for the processing of one tonne of batteries. The difference in mass between process inputs and outputs is considered to be due to the water content of nickel metal hydride batteries (approximately 8%, *Table 2.21*), which evaporates in the process. The loss of this water reduces the mass discrepancy to approximately 4%, considered to be reasonable within the likely variation in composition of input batteries.

2.3.4 AgO Batteries

Data for the recycling of AgO batteries could not be obtained from current processors in the UK. In general, AgO batteries are treated through undergoing a mercury decontamination process, with residues then sent for silver extraction.

Data for the mercury distillation step of battery (button cell) recycling were obtained from Indaver Relight in Belgium and are representative of processing in 2004. These data were used as a proxy for the mercury decontamination of AgO button cells and are shown in *Table 2.31*. The quantities of mercury and residues recovered from the process have been scaled according the average mercury content of AgO batteries (0.4%, *Table 2.18*). Mercury emissions to air were provided in terms of concentration in exhaust gases. The total quantity of gaseous emissions could not be determined, however and so it was assumed that 1% of the input mercury content would be released as gaseous emissions (1).

Silver recovery is most commonly undertaken using an electrolytic process, where the silver is recovered from solution by electroplating it on a cathode. Data for this electrolytic step could not be obtained and so substitute data, describing the material and energy requirements for the electrowinning of zinc from ore were used to represent this process (2). The use of substitute data in this case is unlikely to have a significant impact on results, due to the relatively small quantity of AgO batteries under study (0.02% by weight).

Table 2.31 details the inputs and outputs for the mercury decontamination and electrolysis stages of AgO battery recycling.

(1) ERM estimate.

(2) 3200 kWh/tonne of Zinc. Norgate, T. E. & Rankin, W. J (2002). An Environmental Assessment of Lead and Zinc Production Processes. *Proceedings, Green Processing 2002, International Conference on the Sustainable Processing of Minerals, May 2002, pp 177-184*. http://www.minerals.csiro.au/sd/CSIRO_Paper_LCA_PbZn.pdf. This was scaled to reflect the average silver content of AgO batteries (31%, *Table 2.18*)

Table 2.31 ***Mercury Distillation and Electrolysis of AgO Batteries: Input/Output Data per Tonne of Batteries***

Flow	Quantity	Unit	Data Quality Indicator	Inventory Data/Source
Mercury Distillation*				
INPUTS				
Raw material inputs				
Mercuric oxide batteries	1	tonne	M	-
Nitrogen gas	0.15	M^3	C	0.188 kg Nitrogen, assuming density 1.25 kg/m^3. ETH, Europe, 1994
Oxygen	0.15	m^3	C	0.214 kg Oxygen, assuming density 1.43 kg/m^3. ETH, Europe, 1994
Active carbon	3	g	C	Carbon black, used as substitute for active carbon. ETH, Europe1994
Electricity consumption				
Electricity, Grid	75	kWh	C	Grid Electricity, Medium Voltage, GB. Derived from BUWAL data, 2002.
OUTPUTS				
Product output				
Mercury	3.96	kg	C	Mercury, liquid. Ecoinvent, global average, 2000
Residues to silver recovery	996	kg	C	n/a
Emissions to air				
Mercury	0.04	kg	E	-
Silver Recovery (Electrolysis)**				
INPUTS				
Electricity consumption , National Grid	992	kWh	E/C	Grid Electricity, Medium Voltage, GB. Derived from BUWAL data, 2002.
OUTPUTS				
Product output				
Silver	310	kg	E/C	Assumed platinum group metals are analogous to silver. Ecoinvent, global average, 2002
Wastes				
Residues to landfill	682	kg	E/C	Waste disposal in residual material landfill, process – specific burdens only. Ecoinvent, Switzerland, 1995

* Indaver Relight. ** Norgate, TE and Rankin, WJ (2002).
M = measured, C = calculated, E = estimated
Refer to *Section 2.5* for further description of secondary datasets

2.3.5 *PbA Batteries*

Data for the recycling of lead acid batteries were obtained from Campine and are representative of plant activities in 2004.

Table 2.32 details inputs to and outputs from the Campine lead acid recycling process.

Table 2.32 ***Lead Acid***

Flow	Quantity	Unit	Data Quality Indicator	Inventory Data/Source
INPUTS				
Raw material inputs				
Lead acid batteries	1000	kg		-
Limestone	5.8	kg		Limestone, milled. Ecoinvent, Switzerland, 2002
Iron scrap	4.0	kg		Iron scrap. Ecoinvent, Europe, 2002
NaOH	350	kg	C	50% NaOH. Ecoinvent, Europe, 2000
Sodium nitrate	0.4	kg	C	Generic inorganic chemicals. Ecoinvent, global average, 2000
Sulphur	0.9	kg		Sulphur. BUWAL, Europe, 1998
Iron chloride	0.9	kg		Iron (III) chloride (30%). Ecoinvent, Switzerland, 2000
Slag	150	kg		Reused from process
Electricity consumption				
Electricity	35.2	kWh		Grid Electricity, Medium Voltage, GB. Derived from BUWAL data, 2002.
Fuel usage				
Natural gas	16.2	kg		Natural Gas. BUWAL, Europe, 1996
Coke	20.0	kg		Petroleum coke, used as substitute for coke. Ecoinvent, Europe, 1980-2000
Water consumption				
Process water	770	kg	C	Treated rainwater, reused through process
OUTUTS				
Product outputs				
Lead to processor	650	kg		Lead. Ecoinvent, Europe, 1994-2003
Flue dust for internal reuse	13.6	kg		Reused in process
Return slag for internal reuse	150	kg		Reused in process
Sulphuric acid for internal reuse	71.0	kg		Sulphuric acid. Ecoinvent, Europe, 2000

Flow	Quantity	Unit	Data Quality Indicator	Inventory Data/Source
Emissions to air				
SO_2	7.1	kg		-
CO_2 (fuel combustion)	500	kg		-
Pb	0.00127	kg		-
Sb	0.0000056	kg		-
Solid waste				
Excess slag to landfill	44.0	kg		Disposal of inert waste to in inert landfill. Ecoinvent, Switzerland, 1995.

Source: European Commission. M = measured, C = calculated, E = estimated
Refer to *Section 2.5* for further description of secondary datasets

There is a discrepancy of approximately 8% between raw material inputs and process outputs provided. For this process, input exceeds output. The data have been checked by Campine and confirmed as representative for the processing of one tonne of batteries. As with the pyrometallurgical processing of alkaline and saline batteries, the difference in mass between process inputs and outputs is considered to be due to the presence of plastic and other combustible materials in the input batteries. Plastics comprise approximately 10% of the battery material content (*Table 2.23*). Taking account of the oxidation of these materials in the process (and assuming an ash content of around 10%) reduces the discrepancy to approximately 2%. This is considered to be reasonable within the likely variation in composition of input batteries.

2.3.6 *Life Cycle Inventory Compilation*

Each of the datasets presented in *Table 2.24* to *Table 2.32* relates to the inputs and outputs associated with the processing of one tonne of waste batteries of a specific chemistry, or group of chemistries. Appropriate datasets were multiplied by the total numbers of batteries collected over the study period, as applicable, to generate an inventory for each recycling scenario.

2.4 *RESIDUAL WASTE MANAGEMENT*

In 2003/2004, 11% of residual MSW in the UK was incinerated with energy recovery and 89% was landfilled (*Environment Agency*).

The disposal of batteries in MSW to landfill or incineration is seen as a route for the metals they contain to be released to the environment, although there are limited data on their fate. It is the potential emission of heavy metals from battery wastes that is of greatest environmental concern. Process control of landfills and incinerators, alongside mineralization mechanisms in landfills, limit the quantity of metals that are released to the environment.

The *WISARD* software tool requires the specification of waste on the basis of the components of municipal waste. We have therefore designated carbon and paper components (see *Table 2.12* to *Table 2.23*) as being biodegradable waste and the remainder as being non-degradable.

Although no specific data is available describing the leaching potential of the heavy metals in spent batteries, we have assumed that 5% of these metals in batteries are leached to the environment, the remainder remaining locked in landfills either as non-compromised batteries or as mineralised compounds resistant to leaching.

For the incineration of batteries MSW, we have used LCI data, supplied by the Environment Agency and describing a modern MSW EfW plant. As with the landfill inventories, we have not been able to allocate the emissions to air that arise from the incineration of a tonne of MSW to the spent batteries it contains. However, we have amended heavy metals and CO_2 emissions to reflect battery composition.

We have assumed that 0.5% of the heavy metals in batteries are emitted to air from the EfW plant and the remaining 99.5% are removed through flue gas treatment and bottom ash. We have assumed that EfW residues are disposed to landfill. We have assumed that 2.5% of the heavy metal content landfilled is leached to water, lower than that for raw MSW as the residues are considered to be more inert. No energy recovery benefit has been attributed to batteries contained in EfW as they are considered to be of low calorific value.

The modelling described above has required a number of subjective assumptions but is aimed to estimate the impact from disposal. It takes into account the potential for battery components to escape to the environment, but also reflects the view that batteries pose limited potential to pollute the environment through MSW management in the UK.

2.5 SECONDARY DATASETS

Secondary data have been used for common processes, materials, transport steps and electricity generation. The key life cycle databases used to describe these processes were:

- **Ecoinvent (updated, version 1.2)** - Ecoinvent is a peer-reviewed database, containing life cycle inventory data for over 2500 processes in the energy, transport, building materials, chemicals, paper/board, agriculture and waste management sectors. It aims to provide a set of unified and generic LCI data of high quality. The data are mainly investigated for Swiss and Western European conditions;
- **ETH (ETH-ESU 96)** - The ETH database contains inventory data for the Swiss and Western European energy supply situation, including raw material production, production of intermediate, auxiliary and working materials, supply of transport and waste treatment services, construction of infrastructure and energy conversion and transmission.

The data relate to Swiss and Western European production and are often used to approximate an average European situation;

- **BUWAL (BUWAL 250)** - Inventory of packaging materials for the Swiss Packaging Institute, made by EMPA. The inventory includes emissions from raw material production, energy production, production of intermediate and auxiliary materials, transport and material production processes. Energy systems are based on ETH data, without capital goods; and
- **IDEMAT (IDEMAT 2001)** - This database was developed at Delft University of Technology, department of industrial design engineering, under the IDEMAT project. The focus is on the production of materials and data are mostly original (not taken from other LCA databases), deriving from a wide variety of sources.

When selecting which database to use, a hierarchy has been followed, with the aim of using the most complete and up-to-date information. Databases were selected in the order:

1. Ecoinvent;
2. ETH;
3. BUWAL; and
4. IDEMAT.

A move down the hierarchy was instigated where no appropriate LCI data were available for the material of concern. For secondary data relating to electricity production, the BUWAL database was the preferred source, as it does not include capital burdens for electricity generation.

Generic datasets relate predominantly to Western European process technologies and, as such, will confer some differences from equivalent UK systems. Assuming that technologies will not differ, the most significant difference is likely to be with respect to energy mix. It was not possible within the scope of the assessment to manipulate all datasets used to represent UK electricity mix (or French/Swiss mix, as appropriate). However, care has been taken that direct inputs of electricity, for example to sorting and recycling processes, reflect appropriate geographies. Further, it is reasonable to consider that a number of the ancillary material and fuel inputs to processes, for which generic data have been used, will be produced across Europe and, as such, average European or global technologies are applicable.

Details of all secondary datasets used in the assessment are summarised in *Table 2.33* to *Table 2.36*. Commentary on their quality and representativeness for the assessment is further provided in *Section 2.5.1*.

Table 2.33 Datasets used to Model Fuel/Energy Production Processes

Fuel/Energy Source	Database	Geography	Year	Technology	Reference
Diesel	Ecoinvent	Europe	1989-2000	Average technology	Ecoinvent-Report No. 6
Electricity MV - mix	BUWAL	Great Britain		Average technology	BUWAL 250 for energy production, ERM internal for energy mix
Grid Electricity, Medium Voltage	BUWAL	France		Average technology	BUWAL 250 for energy production, ERM internal for energy mix
Grid Electricity, Medium Voltage	BUWAL	Switzerland		Average technology	BUWAL 250 for energy production, ERM internal for energy mix
Grid Electricity, Medium Voltage	BUWAL	UK/France		Average technology	BUWAL 250 for energy production, ERM internal for energy mix
Light fuel oil	Ecoinvent	Switzerland	2000	Average technology	Ecoinvent-Report No. 6
Natural Gas	BUWAL	Europe	1996 -	Average technology	BUWAL 250 for energy production, ERM internal for energy mix
Petroleum coke, used as substitute for coke	Ecoinvent	Europe	1980-2000	Average technology	Ecoinvent-Report No. 6
Propane/butane	Ecoinvent	Switzerland	1980-2000	Average technology	Ecoinvent-Report No. 6

Table 2.34 Datasets used to Model Other Collection Scenario Inputs

Material/Process	Database	Geography	Year	Technology	Reference
ABS plastic	Ecoinvent	Europe	1995	Production by emulsion polymerization out of its three monomers	Ecoinvent-Report No. 11
Cold transforming steel	Kemna	W Europe	1989	Average technology	KEMNA (1) 1981
Electroplating steel with zinc	Idemat	W Europe	1994	Mixed technology	SPIN Galvanic Treatment 1992
Forging steel	Kemna	W Europe	1989	Average technology	KEMNA (1) 1981
Polycarbonate (PC)	Ecoinvent	Europe	1992-1996	Representative for European production	Ecoinvent-Report No.
Polyethylene, HDPE	Ecoinvent	Europe	1992-1993	Polymerization out of ethylene under normal pressure and temperature.	Ecoinvent-Report No. 11
Polypropylene	Ecoinvent	Europe	1992-1993	Polymerization out of propylene.	Ecoinvent-Report No. 11
Soap	Ecoinvent	Europe	1992-1995	Average technology for the production of soap out of a blend of fatty acids from palm and coconut oil, representing typical European production mix in the mid 90s.	Ecoinvent-Report No. 12
Steel, low alloyed	Ecoinvent	Europe	2001	EU technology mix	Ecoinvent-Report No. 10
Tap water	Ecoinvent	Europe	2000	Example of a waterworks in Switzerland.	Ecoinvent-Report No. 8
Blow moulding	Ecoinvent	Europe	1993-1997	Present technologies.	Ecoinvent-Report No. 11
Extrusion, plastic film	Ecoinvent	Europe	1993-1997	Present technologies.	Ecoinvent-Report No. 11
Extrusion, plastic pipes	Ecoinvent	Europe	1993-1997	Present technologies.	Ecoinvent-Report No. 11
Injection moulding	Ecoinvent	Europe	1993-1997	Present technologies.	Ecoinvent-Report No. 11

Material/Process	Database	Geography	Year	Technology	Reference
Sewage treatment at wastewater treatment plant, class 3	Ecoinvent	Switzerland	2000	Specific to the technology mix encountered in Switzerland in 2000. Well applicable to modern treatment practices in Europe, North America or Japan.	Ecoinvent-Report No. 13
Transport by lorry (15 tonne, 25 tonne), RCV (21 tonne) and van (3.5 tonne)	Ecoinvent	Switzerland/ Europe	2005	For vehicle operation all technologies are included in the average data. Road construction comprises bitumen and concrete roads. For the manufacturing of vehicles, the data reflects current modern technologies	Ecoinvent-Report No. 14

Table 2.35 Datasets used to Model Recycling Process Inputs

Material/Process	Database	Geography	Year	Technology	Reference
Carbon black	ETH	Europe	1990-1994	Average technology.	ETH-ESU (1996)
Generic inorganic chemicals	Ecoinvent	Global	2000	Present technology for the production of several inorganic chemicals	Ecoinvent-Report No. 8
Generic organic chemicals	Ecoinvent	Global	2000	Based on information from two chemical plant sites in Germany.	Ecoinvent-Report No. 8
Hydrogen Peroxide	Ecoinvent	Europe	1995	Average technology.	Ecoinvent-Report No. 8
Iron (III) chloride (30%).	Ecoinvent	Switzerland	1995-2001	Inventory refers to technology used for production in Switzerland.	Ecoinvent-Report No. 8
Iron scrap	Ecoinvent	Europe	2002	Assumed technology of medium sized plant.	Ecoinvent-Report No. 10
Limestone, milled	Ecoinvent	Switzerland	2000-2002	High technical level.	Ecoinvent-Report No. 7
NaOH	Ecoinvent	Europe	2000	Present state of technology used in Europe.	Ecoinvent-Report No. 8
Nitrogen	ETH	Europe	1994	Average technology.	ETH-ESU (1996)
Oxygen	ETH	Europe	1994	Average technology.	ETH-ESU (1996)

Material/Process	Database	Geography	Year	Technology	Reference
Sulphur	BUWAL	Europe	1998	Average technology.	BUWAL 250 (1996)
Sulphuric Acid	Ecoinvent	Europe	2000	Mix of average and state-of-the-art.	Ecoinvent-Report No. 8
Tap water	Ecoinvent	Europe	2000	Example of a waterworks in Switzerland.	Ecoinvent-Report No. 8
Disposal of gypsum to in inert landfill	Ecoinvent	Switzerland	1995	Landfill with renaturation after closure. 50% of the sites feature a base seal and leachate collection system. Well applicable to modern treatment practices in Europe, North America or Japan.	Ecoinvent-Report No. 13
Disposal of inert waste to in inert landfill	Ecoinvent	Switzerland.	1995	Landfill with renaturation after closure. 50% of the sites feature a base seal and leachate collection system. Well applicable to modern treatment practices in Europe, North America or Japan.	Ecoinvent-Report No. 13
Mixed plastics to municipal incineration	Ecoinvent	Switzerland.	1995	Average Swiss MSWI plants in 2000 with electrostatic precipitator for fly ash (ESP), wet flue gas scrubber and 29.4% SNCR , 32.2% SCR-high dust , 24.6% SCR-low dust -DeNOx facilities and 13.8% without Denox (by burnt waste, according to Swiss average). Well applicable to modern treatment practices in Europe, North America or Japan.	Ecoinvent-Report No. 13
Packaging paper/mixed plastics to sanitary landfill/municipal incineration	Ecoinvent	Switzerland.	1995	Average Swiss MSWI plants in 2000. Well applicable to modern treatment practices in Europe, North America or Japan.	Ecoinvent-Report No. 13
Sewage treatment at wastewater treatment plant, class 3	Ecoinvent	Switzerland.	2000	Specific to the technology mix encountered in Switzerland in 2000. Well applicable to modern treatment practices in Europe, North America or Japan.	Ecoinvent-Report No. 13
Waste disposal in residual material landfill, process –specific burdens only	Ecoinvent	Switzerland	1995	Landfill with renaturation after closure. 50% of the sites feature a base seal and leachate collection system.	Ecoinvent-Report No. 13

Table 2.36 Datasets used to Model Offset/Avoided Material Production

Material	Database	Geography	Year	Technology	Reference
Cadmium	Idemat	Europe	1990-1994	Average technology for Cadmium production	Metals and minerals (1989); Metal resources (1983)
Cobalt	Ecoinvent	Global	2000	Data approximated with data from nickel mining and benefication. For further treatment the process "reduction of oxides" is approximated by stoechiometric calculation - assuming a yield of 95% - and approximations for energy consumption from other chemical plants. No emissions are assumed for this treatment process.	Ecoinvent-Report No. 11
Copper, primary, from platinum group metal production in South Africa	Ecoinvent	South Africa	1995-2002	In South Africa an electric arc furnace with a Søderberg electrode system and a Pierce-Smith-Converter is used. Sulphur dioxide in the off-gas is recovered producing sulphuric acid. The separation of non ferrous metals is done hydrometallurgically, the refining by selective precipitation. Although electricity production in South Africa is mainly coal based, the UCTE production mix is inventoried.	Ecoinvent-Report No. 10
Ferromanganese	Ecoinvent	Europe	1994-2003	The ore is processed in blast furnaces (20%), electric arc furnaces without flux (27%), electric arc furnaces with calcareous flux (53%).	Ecoinvent-Report No. 10
Lead	Ecoinvent	Europe	1994-2003	A mix of 56% direct smelting and 44% sinter/blast furnace (ISP) is chosen. For emission control 56% improved and 44% limited control is chosen.	Ecoinvent-Report No. 10
Li_2CO_3	ESU	South America	2000	No information provided in reference source	*Life Cycle Inventory and Assessment of the Energy Use and CO_2 Emissions for Lithium and Lithium Compounds* (2000), ESU-services

Material	Database	Geography	Year	Technology	Reference
Manganese	Ecoinvent	Europe	2003	The metal is won by electrolysis (assumption: 25%) and electrothermic processes (assumption: 75%). No detailed information available, mainly based on rough estimates.	Ecoinvent-Report No. 10
Mercury, liquid	Ecoinvent	Global	2000	Data approximated with data from lime mining, crushing and milling plus estimation of the additional furnace operation step, based on information in literature and own assumptions.	Ecoinvent-Report No. 8
Recycling aluminium	Ecoinvent	Europe	2002	Average technology for the aluminium recycled/consumed in Europe. Includes collecting, sorting and preparing of post consumer aluminium scrap. Offset includes cast aluminium ingot production, transport of materials to the plant and the disposal of wastes.	Ecoinvent-Report No. 10
Recycling iron and steel	Ecoinvent	Europe	2002	Assumed technology of medium sized plant for recycling. Collecting of new and old iron scrap, transport to scrap-yard, sorting and pressing to blocks. Offset iron produced by blast furnace process.	Ecoinvent-Report No. 10
Sulphuric Acid	Ecoinvent	Europe	2000	Considers the average technology used in European sulphuric acid production plants.	Ecoinvent-Report No. 8
Zinc, for coating	Ecoinvent	Europe	1994-2003	A mix of 80% hydrometallurgical and 20% pyrometallurgical production is chosen. For emission control 80% improved and 20% limited control is chosen.	Ecoinvent-Report No. 10

2.5.1 *Data Quality Assessment*

Primary and secondary data quality has been assessed, using the data quality requirements defined in *Section 1.16.1*. *Table 2.37* shows the results of this assessment. A tick indicates that the dataset meets the requirements set out in *Section 1.16.1*. A cross indicates that it does not.

The majority of primary and secondary datasets used fulfil data quality requirements for temporal, geographical and technology coverage. Since representativeness is a combination of these three, this criterion is, for the most part, also fulfilled. It has been difficult to assess generic LCI databases with regards to completeness and precision as the databases used generally did not contain enough specific information to allow evaluation at this level.

The following materials did not fulfil all data quality requirements. However, each has been reviewed with regard to its suitability for use:

- steel production (input to collection container manufacture);
- cold transforming/forging steel (input to collection container manufacture);
- tap water production (input to sorting plant and recycling processes);
- generic chemicals production (input to recycling processes);
- iron (III) chloride production (input to recycling processes);
- light fuel oil (input to pyrometallurgical processing);
- propane/butane (input to pyrometallurgical processing);
- disposal of gypsum in inert landfill (waste from recycling processes);
- waste disposal in residual material landfill (waste from recycling processes);
- cobalt production (offset material process);
- copper production (offset material process); and
- mercury production (offset material process).

A number of other processes were difficult to assess, due to lack of information.

In the absence of more specific data, these datasets were deemed appropriate for use as a surrogate. Wherever data or assumptions were found to be significant, they have been addressed in sensitivity analysis. However, analysis of results found these datasets not to contribute significantly.

Table 2.37 Data Quality Assessment of Primary and Secondary Data

Activity/Data Category	Primary/Secondary Dataset	Geographical coverage	Time-related coverage	Technology coverage	Representativeness
Collection activities including physical parameters of bins	*Primary data*	√	√	√	√
Collection Inputs/Outputs	*Secondary datasets*				
	ABS plastic	√	√	No information	(√) – incomplete information
	Cold transforming steel	√	X	√	X
	Electroplating steel with zinc	√	√	√	√
	Forging steel	√	X	√	X
	Polycarbonate	√	√	√	√
	Polyethylene, HDPE	√	√	No information	(√) – incomplete information
	Polypropylene	√	√	No information	(√) – incomplete information
	Soap	√	√	√	√
	Steel, low alloyed	√	√	√	√
	Tap water	√	√	X	X
	Blow moulding	√	√	√	√
	Extrusion, plastic film	√	√	√	√
	Extrusion, plastic pipes	√	√	√	√
	Injection moulding	√	√	√	√
	Sewage treatment at wastewater treatment plant	√	√	√	√
	Lorry, 15 tonne	√	√	√	√
	Lorry, 25 tonne	√	√	√	√
	RCV, 21 tonne	√	√	√	√
	Van, 3.5 tonne	√	√	√	√
Recycling Processes	*Primary data*	√	√	√	√
Recycling Process Inputs/Outputs	*Secondary datasets*				
	Carbon black	√	√	√	√
	Generic inorganic chemicals	X	√	√	X
	Generic organic chemicals	X	√	X	X
	Hydrogen Peroxide	√	√	√	√
	Iron (III) chloride (30%).	X	√	X	X
	Iron scrap	√	√	√	√
	Limestone, milled	X	√	√	X
	NaOH	√	√	√	√

Activity/Data Category	Primary/Secondary Dataset	Geographical coverage	Time-related coverage	Technology coverage	Representativeness
	Nitrogen	√	√	√	√
	Oxygen	√	√	√	√
	Sulphur	√	√	√	√
	Sulphuric Acid	√	√	√	√
	Tap water	√	√	X	X
	Disposal of gypsum to in inert landfill	X	√	No information	X
	Disposal of inert waste to in inert landfill	√	√	No information	(√) – incomplete information
	Mixed plastics to municipal incineration	√	√	No information	(√) – incomplete information
	Packaging paper/mixed plastics to sanitary landfill/municipal incineration	√	√	X	X
	Sewage treatment at wastewater treatment plant	√	√	√	√
	Waste disposal in residual material landfill	X	√	X	X
Offset Materials	*Secondary datasets*				
	Cadmium	√	√	√	√
	Cobalt	X	√	No information	X
	Copper, primary, from platinum group metal production in South Africa	South Africa	√	No information	(√) – incomplete information
	Ferromanganese	√	√	No information	(√) – incomplete information
	Lead	√	√	No information	(√) – incomplete information
	Li_2CO_3	South America	√	No information	(√) – incomplete information
	Manganese	√	√	No information	(√) – incomplete information
	Mercury, liquid	X	√	No information	X
	Recycling aluminium	√	√	√	√
	Recycling iron and steel	√	√	√	√
	Sulphuric Acid	√	√	√	√
	Zinc, for coating	√	√	√	√
Energy systems	*Secondary datasets*				
	Diesel	√	√	√	√
	Grid Electricity, Medium Voltage	√	√	√	√
	Light fuel oil	X	√	√	X
	Natural Gas	√	√	√	√
	Petroleum coke, used as substitute for coke	√	√	√	√
	Propane/butane	X	√	√	X

√ - dataset meets the requirements set out in *Section 1.16.1*. X – dataset does not meet the requirements set out in *Section 1.16.1*

2.6 *IMPLEMENTATION SYSTEMS*

Combining inventories for the three collection and three recycling scenarios described above resulted in the generation of life cycle inventories for the nine implementation scenarios assessed:

- **Implementation Scenario 1** - Collection Scenario 1 with Recycling Scenario 1;
- **Implementation Scenario 2 -** Collection Scenario 1 with Recycling Scenario 2;
- **Implementation Scenario 3 -** Collection Scenario 1 with Recycling Scenario 3;
- **Implementation Scenario 4 -** Collection Scenario 2 with Recycling Scenario 1;
- **Implementation Scenario 5 -** Collection Scenario 2 with Recycling Scenario 2;
- **Implementation Scenario 6 -** Collection Scenario 2 with Recycling Scenario 3;
- **Implementation Scenario 7 -** Collection Scenario 3 with Recycling Scenario 1;
- **Implementation Scenario 8 -** Collection Scenario 3 with Recycling Scenario 2; and
- **Implementation Scenario 9 -** Collection Scenario 3 with Recycling Scenario 3.

The 10th Scenario is the baseline scenario, which involves batteries being disposed as residual waste.

3 LIFE CYCLE INVENTORY ANALYSIS: RESULTS

The inventories that have been generated provide information on hundreds of internal and elemental flows for each implementation system. Complete inventories of all environmental interventions (material inputs and emissions to air, water and soil) are presented in *Annex D*.

A number of flows have been analysed in further detail. These were selected following impact assessment. Results were analysed to investigate the key contributors, in terms of both impact and benefit, to each impact category. Those flows contributing the most to overall environmental impacts in each category have been included in the summary tables presented below.

Analyses of these selected interventions show that, with the exception of a small number of flows (eg methane, oil and gas for some scenarios), each of the implementation scenarios, 1-9, result in an overall reduction in materials consumption and pollutant emissions, through offset benefits associated with materials recycling.

Methane emissions arise predominantly through the landfill of the biodegradable fraction of waste batteries and electricity generation processes (with coal or gas feedstock). Scenarios 1, 4 and 7 emit a relatively higher quantity of methane over the study period due to recycling processing capacity being located entirely in the UK and dependent on UK grid electricity, with its relatively higher proportion of coal and gas in the production mix. This also has an influence on flows of natural gas, such that scenarios 1, 4 and 7 consume significantly higher quantities of this fossil fuel than other scenarios, through electricity generation and input to processing.

Flows of oil are influenced predominantly by transport requirements. Those scenarios whereby batteries are transported to France (2, 5 and 8) or Switzerland (3, 6 and 9) for processing result in increased fuel, and therefore oil, consumption.

Emissions of heavy metals to air, water and soil arise mainly from the disposal of residual batteries and, predominantly in the case of lead and mercury, are further reduced through metals recovery (and avoiding the burdens of primary metal production).

The relative contribution of alternative elements of scenario life cycles is investigated further during impact assessment. However, it is clear that the relative performance of scenarios is predominantly dictated by alternative recycling scenarios, as collection scenarios contribute relatively less to the flows analysed, and sorting and disposal requirements are the same for each scenario.

Table 3.1 Inventory Analysis of Selected Flows – Comparison between Implementation Scenarios

Emission	Unit	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7	Scenario 8	Scenario 9	Scenario 10
Coal	kg	-6.6E+07	-7.8E+07	-5.6E+07	-6.6E+07	-7.8E+07	-5.6E+07	-6.5E+07	-7.7E+07	-5.5E+07	463000
Gas	kg	865000	-2380000	-5660000	968000	-2280000	-5560000	1330000	-1920000	-5200000	521000
Oil	kg	974000	5830000	20400000	1180000	6040000	20600000	3750000	8600000	23200000	1740000
Cadmium, in ore	kg	-2860000	-2860000	-2860000	-2860000	-2860000	-2860000	-2860000	-2860000	-2860000	x
Lead, in ore	kg	-7770000	-7690000	-7610000	-7770000	-7690000	-7610000	-7760000	-7680000	-7600000	1830
Zinc, in ore	kg	-5.6E+07	-5.6E+07	-5.4E+07	-5.6E+07	-5.6E+07	-5.4E+07	-5.6E+07	-5.6E+07	-5.4E+07	183
CO_2	kg	-7.2E+07	-9E+07	-8.3E+07	-7.1E+07	-9E+07	-8.3E+07	-6.2E+07	-8E+07	-7.3E+07	43300000
CH_4	kg	907000	794000	449000	907000	794000	449000	908000	795000	450000	675000
NOx	kg	-845000	-849000	-631000	-842000	-847000	-629000	-826000	-830000	-613000	166000
SOx	kg	-813000	-868000	-1320000	-810000	-865000	-1320000	-790000	-844000	-1300000	45200
NH_3	kg	-73000	-72600	-68600	-73000	-72600	-68600	-72700	-72300	-68200	773
Cd (air)	kg	2880	2880	2880	2880	2880	2880	2880	2880	2880	4710
Ni (air)	kg	9120	9100	9060	9120	9100	9060	9120	9110	9070	14200
Pb (air)	kg	-20800	-20800	-20100	-20800	-20800	-20100	-20800	-20800	-20100	4900
Co (air)	kg	2160	2160	2160	2160	2160	2160	2160	2160	2160	3350
Hg (air)	kg	-819	-820	-9100	-819	-820	-9100	-819	-819	-9100	2.94
Cd (water/soil)	kg	254000	255000	255000	254000	255000	255000	255000	255000	255000	405000
Ni (water/soil)	kg	791000	791000	792000	791000	791000	792000	791000	791000	792000	1220000
Pb (water/soil)	kg	222000	222000	220000	222000	222000	220000	222000	222000	220000	422000
Co (water/soil)	kg	187000	187000	186000	187000	187000	186000	187000	187000	186000	288000
Hg (water/soil)	kg	-5.4	-3.51	20.1	-5.35	-3.45	20.2	-4.8	-2.9	20.7	262
PAH (water/soil)	kg	-3090	-3080	-3240	-3090	-3080	-3240	-3080	-3080	-3240	1.19
Phosphate (water)	kg	76600	75800	75600	76600	75800	75700	77100	76300	76100	122000

Table 3.2 Inventory Analysis of Selected Flows – Implementation Scenario 1

Emission	Unit	Total (all life cycle stages)	Collection (container use)	Collection (transport)	Sorting	Recycling (process)	Recycling (transport)	Disposal
Coal	kg	-6.6E+07	538000	1590000	136000	-6.9E+07	347000	300000
Gas	kg	865000	416000	662000	72900	-820000	197000	337000
Oil	kg	974000	555000	7780000	136000	-1.1E+07	2560000	1130000
Cadmium, in ore	kg	-2860000	-6.7E-12	-7.2E-10	2.45E-11	-2860000	1.8E-10	x
Lead, in ore	kg	-7770000	268	120000	35.3	-7940000	44700	1190
Zinc, in ore	kg	-5.6E+07	402	2870	9.33	-5.6E+07	1290	118
CO_2	kg	-7.2E+07	2440000	25100000	608000	-1.4E+08	7930000	28100000
CH_4	kg	907000	198	28.8	896	469000	15.4	437000
NOx	kg	-845000	8990	90400	3360	-1090000	37000	108000
SOx	kg	-813000	10300	42200	2200	-908000	10600	29300
NH_3	kg	-73000	85.3	930	3.74	-74900	282	501
Cd (air)	kg	2880	0.0347	1.63	0.00496	-174	0.387	3050
Ni (air)	kg	9120	1.17	11.6	0.236	-107	2.59	9210
Pb (air)	kg	-20800	2.14	38.9	0.064	-24000	12.9	3170
Co (air)	kg	2160	0.339	0.832	0.00742	-10.2	0.148	2170
Hg (air)	kg	-819	0.527	0.988	0.0384	-823	0.364	1.91
Cd (water/soil)	kg	254000	2.45	128	0.0585	-7920	47.6	262000
Ni (water/soil)	kg	791000	112	152	1.28	-2400	44.6	793000
Pb (water/soil)	kg	222000	8.94	864	1.32	-53000	321	273000
Co (water/soil)	kg	187000	23.4	22.7	0.164	188	4.9	186000
Hg (water/soil)	kg	-5.4	0.384	2.74	0.0237	-179	1.01	170
PAH (water/soil)	kg	-3090	0.45	2.7	0.0203	-3090	0.796	0.769
Phosphate (water)	kg	76600	396	490	13.8	-3820	172	79300

Table 3.3 Inventory Analysis of Selected Flows – Implementation Scenario 2

Emission	Unit	Total (all life cycle stages)	Collection (container use)	Collection (transport)	Sorting	Recycling (process)	Recycling (transport)	Disposal
Coal	kg	-7.8E+07	538000	1590000	136000	-8.1E+07	1020000	300000
Gas	kg	-2380000	416000	662000	72900	-4440000	577000	337000
Oil	kg	5830000	555000	7780000	136000	-1.1E+07	7500000	1130000
Cadmium, in ore	kg	-2860000	2.12E-10	-8E-10	1.37E-11	-2860000	-7.1E-10	7.28E-14
Lead, in ore	kg	-7690000	268	120000	35.3	-7940000	130000	1190
Zinc, in ore	kg	-5.6E+07	402	2870	9.33	-5.6E+07	3820	118
CO_2	kg	-9E+07	2440000	25100000	608000	-1.7E+08	23200000	28100000
CH_4	kg	794000	198	28.8	896	356000	27.5	437000
NOx	kg	-849000	8990	90400	3360	-1170000	108000	108000
SOx	kg	-868000	10300	42200	2200	-983000	31000	29300
NH_3	kg	-72600	85.3	930	3.74	-75000	823	501
Cd (air)	kg	2880	0.0347	1.63	0.00496	-175	1.13	3050
Ni (air)	kg	9100	1.17	11.6	0.236	-124	7.6	9210
Pb (air)	kg	-20800	2.14	38.9	0.064	-24000	37.4	3170
Co (air)	kg	2160	0.339	0.832	0.00742	-10.2	0.433	2170
Hg (air)	kg	-820	0.527	0.988	0.0384	-824	1.07	1.91
Cd (water/soil)	kg	255000	2.45	128	0.0585	-7930	138	262000
Ni (water/soil)	kg	791000	112	152	1.28	-2490	131	793000
Pb (water/soil)	kg	222000	8.94	864	1.32	-53000	932	273000
Co (water/soil)	kg	187000	23.4	22.7	0.164	188	14.4	186000
Hg (water/soil)	kg	-3.51	0.384	2.74	0.0237	-179	2.95	170
PAH (water/soil)	kg	-3080	0.45	2.7	0.0203	-3090	2.33	0.769
Phosphate (water)	kg	75800	396	490	13.8	-4980	505	79300

Table 3.4 Inventory Analysis of Selected Flows – Implementation Scenario 3

Emission	Unit	Total (all life cycle stages)	Collection (container use)	Collection (transport)	Sorting	Recycling (process)	Recycling (transport)	Disposal
Coal	kg	-5.6E+07	538000	1590000	136000	-6E+07	1630000	300000
Gas	kg	-5660000	416000	662000	72900	-8080000	926000	337000
Oil	kg	20400000	555000	7780000	136000	-1190000	12000000	1130000
Cadmium, in ore	kg	-2860000	-3.1E-10	-4.4E-09	-1E-10	-2860000	-8.3E-09	x
Lead, in ore	kg	-7610000	268	120000	35.3	-7940000	208000	1190
Zinc, in ore	kg	-5.4E+07	402	2870	9.33	-5.4E+07	6130	118
CO_2	kg	-8.3E+07	2440000	25100000	608000	-1.8E+08	37300000	28100000
CH_4	kg	449000	198	28.8	896	10900	38.6	437000
NOx	kg	-631000	8990	90400	3360	-1020000	174000	108000
SOx	kg	-1320000	10300	42200	2200	-1460000	49700	29300
NH_3	kg	-68600	85.3	930	3.74	-71400	1320	501
Cd (air)	kg	2880	0.0347	1.63	0.00496	-175	1.81	3050
Ni (air)	kg	9060	1.17	11.6	0.236	-171	12.2	9210
Pb (air)	kg	-20100	2.14	38.9	0.064	-23400	59.9	3170
Co (air)	kg	2160	0.339	0.832	0.00742	-10.6	0.695	2170
Hg (air)	kg	-9100	0.527	0.988	0.0384	-9110	1.71	1.91
Cd (water/soil)	kg	255000	2.45	128	0.0585	-8050	222	262000
Ni (water/soil)	kg	792000	112	152	1.28	-1670	210	793000
Pb (water/soil)	kg	220000	8.94	864	1.32	-55600	1490	273000
Co (water/soil)	kg	186000	23.4	22.7	0.164	-76.1	23.1	186000
Hg (water/soil)	kg	20.1	0.384	2.74	0.0237	-157	4.73	170
PAH (water/soil)	kg	-3240	0.45	2.7	0.0203	-3250	3.74	0.769
Phosphate (water)	kg	75600	396	490	13.8	-5410	811	79300

Table 3.5 Inventory Analysis of Selected Flows – Implementation Scenario 4

Emission	Unit	Total (all life cycle stages)	Collection (container use)	Collection (transport)	Sorting	Recycling (process)	Recycling (transport)	Disposal
Coal	kg	-6.6E+07	589000	1640000	136000	-6.9E+07	347000	300000
Gas	kg	968000	468000	712000	72900	-820000	197000	337000
Oil	kg	1180000	668000	7880000	136000	-1.1E+07	2560000	1130000
Cadmium, in ore	kg	-2860000	6.32E-11	3E-10	6.71E-13	-2860000	-1.5E-10	x
Lead, in ore	kg	-7770000	302	120000	35.3	-7940000	44700	1190
Zinc, in ore	kg	-5.6E+07	462	2870	9.33	-5.6E+07	1290	118
CO_2	kg	-7.1E+07	2730000	25300000	608000	-1.4E+08	7930000	28100000
CH_4	kg	907000	212	31.2	896	469000	15.4	437000
NOx	kg	-842000	10200	91300	3360	-1090000	37000	108000
SOx	kg	-810000	12000	43700	2200	-908000	10600	29300
NH_3	kg	-73000	88.8	933	3.74	-74900	282	501
Cd (air)	kg	2880	0.0376	1.63	0.00496	-174	0.387	3050
Ni (air)	kg	9120	1.24	11.6	0.236	-107	2.59	9210
Pb (air)	kg	-20800	2.19	38.9	0.064	-24000	12.9	3170
Co (air)	kg	2160	0.348	0.837	0.00742	-10.2	0.148	2170
Hg (air)	kg	-819	0.565	1.02	0.0384	-823	0.364	1.91
Cd (water/soil)	kg	254000	2.51	128	0.0585	-7920	47.6	262000
Ni (water/soil)	kg	791000	113	153	1.28	-2400	44.6	793000
Pb (water/soil)	kg	222000	9.52	865	1.32	-53000	321	273000
Co (water/soil)	kg	187000	23.7	22.8	0.164	188	4.9	186000
Hg (water/soil)	kg	-5.35	0.414	2.77	0.0237	-179	1.01	170
PAH (water/soil)	kg	-3090	0.456	2.7	0.0203	-3090	0.796	0.769
Phosphate (water)	kg	76600	426	493	13.8	-3820	172	79300

Table 3.6 Inventory Analysis of Selected Flows – Implementation Scenario 5

Emission	Unit	Total (all life cycle stages)	Collection (container use)	Collection (transport)	Sorting	Recycling (process)	Recycling (transport)	Disposal
Coal	kg	-7.8E+07	589000	1640000	136000	-8.1E+07	1020000	300000
Gas	kg	-2280000	468000	712000	72900	-4440000	577000	337000
Oil	kg	6040000	668000	7880000	136000	-1.1E+07	7500000	1130000
Cadmium, in ore	kg	-2860000	1.64E-10	1.05E-09	2.57E-11	-2860000	1.5E-09	-6.8E-15
Lead, in ore	kg	-7690000	302	120000	35.3	-7940000	130000	1190
Zinc, in ore	kg	-5.6E+07	462	2870	9.33	-5.6E+07	3820	118
CO_2	kg	-9E+07	2730000	25300000	608000	-1.7E+08	23200000	28100000
CH_4	kg	794000	212	31.2	896	356000	27.5	437000
NOx	kg	-847000	10200	91300	3360	-1170000	108000	108000
SOx	kg	-865000	12000	43700	2200	-983000	31000	29300
NH_3	kg	-72600	88.8	933	3.74	-75000	823	501
Cd (air)	kg	2880	0.0376	1.63	0.00496	-175	1.13	3050
Ni (air)	kg	9100	1.24	11.6	0.236	-124	7.6	9210
Pb (air)	kg	-20800	2.19	38.9	0.064	-24000	37.4	3170
Co (air)	kg	2160	0.348	0.837	0.00742	-10.2	0.433	2170
Hg (air)	kg	-820	0.565	1.02	0.0384	-824	1.07	1.91
Cd (water/soil)	kg	255000	2.51	128	0.0585	-7930	138	262000
Ni (water/soil)	kg	791000	113	153	1.28	-2490	131	793000
Pb (water/soil)	kg	222000	9.52	865	1.32	-53000	932	273000
Co (water/soil)	kg	187000	23.7	22.8	0.164	188	14.4	186000
Hg (water/soil)	kg	-3.45	0.414	2.77	0.0237	-179	2.95	170
PAH (water/soil)	kg	-3080	0.456	2.7	0.0203	-3090	2.33	0.769
Phosphate (water)	kg	75800	426	493	13.8	-4980	505	79300

Table 3.7 Inventory Analysis of Selected Flows – Implementation Scenario 6

Emission	Unit	Total (all life cycle stages)	Collection (container use)	Collection (transport)	Sorting	Recycling (process)	Recycling (transport)	Disposal
Coal	kg	-5.6E+07	589000	1640000	136000	-6E+07	1630000	300000
Gas	kg	-5560000	468000	712000	72900	-8080000	926000	337000
Oil	kg	20600000	668000	7880000	136000	-1190000	12000000	1130000
Cadmium, in ore	kg	-2860000	-8.3E-11	-4.7E-09	-6.9E-11	-2860000	-5.2E-09	x
Lead, in ore	kg	-7610000	302	120000	35.3	-7940000	208000	1190
Zinc, in ore	kg	-5.4E+07	462	2870	9.33	-5.4E+07	6130	118
CO_2	kg	-8.3E+07	2730000	25300000	608000	-1.8E+08	37300000	28100000
CH_4	kg	449000	212	31.2	896	10900	38.6	437000
NOx	kg	-629000	10200	91300	3360	-1020000	174000	108000
SOx	kg	-1320000	12000	43700	2200	-1460000	49700	29300
NH_3	kg	-68600	88.8	933	3.74	-71400	1320	501
Cd (air)	kg	2880	0.0376	1.63	0.00496	-175	1.81	3050
Ni (air)	kg	9060	1.24	11.6	0.236	-171	12.2	9210
Pb (air)	kg	-20100	2.19	38.9	0.064	-23400	59.9	3170
Co (air)	kg	2160	0.348	0.837	0.00742	-10.6	0.695	2170
Hg (air)	kg	-9100	0.565	1.02	0.0384	-9110	1.71	1.91
Cd (water/soil)	kg	255000	2.51	128	0.0585	-8050	222	262000
Ni (water/soil)	kg	792000	113	153	1.28	-1670	210	793000
Pb (water/soil)	kg	220000	9.52	865	1.32	-55600	1490	273000
Co (water/soil)	kg	186000	23.7	22.8	0.164	-76.1	23.1	186000
Hg (water/soil)	kg	20.2	0.414	2.77	0.0237	-157	4.73	170
PAH (water/soil)	kg	-3240	0.456	2.7	0.0203	-3250	3.74	0.769
Phosphate (water)	kg	75700	426	493	13.8	-5410	811	79300

Table 3.8 Inventory Analysis of Selected Flows – Implementation Scenario 7

Emission	Unit	Total (all life cycle stages)	Collection (container use)	Collection (transport)	Sorting	Recycling (process)	Recycling (transport)	Disposal
Coal	kg	-6.5E+07	911000	2390000	136000	-6.9E+07	347000	300000
Gas	kg	1330000	662000	877000	72900	-820000	197000	337000
Oil	kg	3750000	779000	10300000	136000	-1.1E+07	2560000	1130000
Cadmium, in ore	kg	-2860000	1.14E-10	6.94E-10	1.54E-11	-2860000	1.12E-10	x
Lead, in ore	kg	-7760000	413	128000	35.3	-7940000	44700	1190
Zinc, in ore	kg	-5.6E+07	737	3580	9.33	-5.6E+07	1290	118
CO_2	kg	-6.2E+07	3970000	33800000	608000	-1.4E+08	7930000	28100000
CH_4	kg	908000	369	40.5	896	469000	15.4	437000
NOx	kg	-826000	14300	104000	3360	-1090000	37000	108000
SOx	kg	-790000	15700	60500	2200	-908000	10600	29300
NH_3	kg	-72700	156	1210	3.74	-74900	282	501
Cd (air)	kg	2880	0.0598	2.37	0.00496	-174	0.387	3050
Ni (air)	kg	9120	2.08	17.6	0.236	-107	2.59	9210
Pb (air)	kg	-20800	4	46.9	0.064	-24000	12.9	3170
Co (air)	kg	2160	0.633	1.33	0.00742	-10.2	0.148	2170
Hg (air)	kg	-819	0.918	1.24	0.0384	-823	0.364	1.91
Cd (water/soil)	kg	255000	4.55	137	0.0585	-7920	47.6	262000
Ni (water/soil)	kg	791000	213	216	1.28	-2400	44.6	793000
Pb (water/soil)	kg	222000	15.7	926	1.32	-53000	321	273000
Co (water/soil)	kg	187000	44.3	35.1	0.164	188	4.9	186000
Hg (water/soil)	kg	-4.8	0.665	3.06	0.0237	-179	1.01	170
PAH (water/soil)	kg	-3080	0.852	3.78	0.0203	-3090	0.796	0.769
Phosphate (water)	kg	77100	742	649	13.8	-3820	172	79300

Table 3.9 Inventory Analysis of Selected Flows – Implementation Scenario 8

Emission	Unit	Total (all life cycle stages)	Collection (container use)	Collection (transport)	Sorting	Recycling (process)	Recycling (transport)	Disposal
Coal	kg	-7.7E+07	911000	2390000	136000	-8.1E+07	1020000	300000
Gas	kg	-1920000	662000	877000	72900	-4440000	577000	337000
Oil	kg	8600000	779000	10300000	136000	-1.1E+07	7500000	1130000
Cadmium, in ore	kg	-2860000	3.33E-11	-1.6E-09	7.13E-12	-2860000	-5E-10	-1.5E-13
Lead, in ore	kg	-7680000	413	128000	35.3	-7940000	130000	1190
Zinc, in ore	kg	-5.6E+07	737	3580	9.33	-5.6E+07	3820	118
CO_2	kg	-8E+07	3970000	33800000	608000	-1.7E+08	23200000	28100000
CH_4	kg	795000	369	40.5	896	356000	27.5	437000
NOx	kg	-830000	14300	104000	3360	-1170000	108000	108000
SOx	kg	-844000	15700	60500	2200	-983000	31000	29300
NH_3	kg	-72300	156	1210	3.74	-75000	823	501
Cd (air)	kg	2880	0.0598	2.37	0.00496	-175	1.13	3050
Ni (air)	kg	9110	2.08	17.6	0.236	-124	7.6	9210
Pb (air)	kg	-20800	4	46.9	0.064	-24000	37.4	3170
Co (air)	kg	2160	0.633	1.33	0.00742	-10.2	0.433	2170
Hg (air)	kg	-819	0.918	1.24	0.0384	-824	1.07	1.91
Cd (water/soil)	kg	255000	4.55	137	0.0585	-7930	138	262000
Ni (water/soil)	kg	791000	213	216	1.28	-2490	131	793000
Pb (water/soil)	kg	222000	15.7	926	1.32	-53000	932	273000
Co (water/soil)	kg	187000	44.3	35.1	0.164	188	14.4	186000
Hg (water/soil)	kg	-2.9	0.665	3.06	0.0237	-179	2.95	170
PAH (water/soil)	kg	-3080	0.852	3.78	0.0203	-3090	2.33	0.769
Phosphate (water)	kg	76300	742	649	13.8	-4980	505	79300

Table 3.10 Inventory Analysis of Selected Flows – Implementation Scenario 9

Emission	Unit	Total (all life cycle stages)	Collection (container use)	Collection (transport)	Sorting	Recycling (process)	Recycling (transport)	Disposal
Coal	kg	-5.5E+07	911000	2390000	136000	-6E+07	1630000	300000
Gas	kg	-5200000	662000	877000	72900	-8080000	926000	337000
Oil	kg	23200000	779000	10300000	136000	-1190000	12000000	1130000
Cadmium, in ore	kg	-2860000	1.15E-10	-3.9E-09	1.33E-12	-2860000	-4.2E-09	x
Lead, in ore	kg	-7600000	413	128000	35.3	-7940000	208000	1190
Zinc, in ore	kg	-5.4E+07	737	3580	9.33	-5.4E+07	6130	118
CO_2	kg	-7.3E+07	3970000	33800000	608000	-1.8E+08	37300000	28100000
CH_4	kg	450000	369	40.5	896	10900	38.6	437000
NOx	kg	-613000	14300	104000	3360	-1020000	174000	108000
SOx	kg	-1300000	15700	60500	2200	-1460000	49700	29300
NH_3	kg	-68200	156	1210	3.74	-71400	1320	501
Cd (air)	kg	2880	0.0598	2.37	0.00496	-175	1.81	3050
Ni (air)	kg	9070	2.08	17.6	0.236	-171	12.2	9210
Pb (air)	kg	-20100	4	46.9	0.064	-23400	59.9	3170
Co (air)	kg	2160	0.633	1.33	0.00742	-10.6	0.695	2170
Hg (air)	kg	-9100	0.918	1.24	0.0384	-9110	1.71	1.91
Cd (water/soil)	kg	255000	4.55	137	0.0585	-8050	222	262000
Ni (water/soil)	kg	792000	213	216	1.28	-1670	210	793000
Pb (water/soil)	kg	220000	15.7	926	1.32	-55600	1490	273000
Co (water/soil)	kg	186000	44.3	35.1	0.164	-76.1	23.1	186000
Hg (water/soil)	kg	20.7	0.665	3.06	0.0237	-157	4.73	170
PAH (water/soil)	kg	-3240	0.852	3.78	0.0203	-3250	3.74	0.769
Phosphate (water)	kg	76100	742	649	13.8	-5410	811	79300

4 LIFE CYCLE IMPACT ASSESSMENT

Table 4.1 details impact assessment results for the ten implementation scenarios. The contribution of individual life cycle stages to the total for each implementation scenario is further presented in *Table 4.2* to *Table 4.10*.

Analyses show that implementation scenarios 1-9 present opportunities for overall benefit in the categories: abiotic depletion; global warming potential; human toxicity; terrestrial ecotoxicity; and acidification, through offset benefits associated with materials recycling. The scenarios also show reduced impacts in comparison with the baseline (scenario 10) for the categories ozone layer depletion, freshwater ecotoxicity and eutrophication.

Relative performance is again predominantly dictated by the recycling scenario chosen, as combinations with equivalent recycling components (eg 1, 4 and 7) show more similarity in profile than those with equivalent collection components (eg 1, 2 and 3). Different recycling scenarios are favoured in each impact category, with no clear overall high performer.

Further analysis of the processes contributing to the potential impacts and benefits in each category shows that the majority of benefits occur as a result of avoiding the need to produce virgin materials, in particular metals. Given the predominance of zinc carbon and alkaline manganese chemistries among collected batteries, it follows that the avoided impacts of raw material extraction, energy and fuel consumption and transport during primary zinc and manganese production contribute the greatest benefit to all impact categories.

The greatest burdens in categories occur as a result of fuel and electricity inputs to recycling processes (this is true for abiotic depletion, global warming potential and acidification) and through disposal of residual batteries (this is the case for ozone layer depletion, the toxicity categories and eutrophication).

The majority of differences between potential impacts and benefits for alternative implementation scenarios result from the following two key factors.

- The relative quantity of zinc and manganese recovered from the recycling of alkaline and saline batteries. *Table 2.25* and *Table 2.26* show that comparable quantities of zinc are recovered from pyrometallurgical and hydrometallurgical processing, but that less manganese is recovered from the pyrometallurgical process (recovered as ferromanganese). As a result, for the majority of categories, less offset burden is awarded.
- The fuel/energy requirements of the recycling facility, location of recycling facilities and associated energy mix. Recycling scenarios 1, 2 and 3 differ in terms of the location at which batteries are processed. Scenario

1 assumes UK recycling, scenario 2 models the impact of sending 50% of alkaline and saline batteries to France for processing and scenario 3 assumes these batteries are processed in Switzerland (where current pyrometallurgical capacity exists). The electricity mix in the UK comprises a high proportion of coal and gas-derived energy, compared to a high proportion of nuclear in France and hydro-electric power in Switzerland. The generation of electricity via nuclear and hydro-electric power has relatively lower environmental burdens across a number or impact categories as fewer resources are consumed in the process.

The balance of importance between these factors differs between impact categories.

As an example, with respect to global warming potential results for scenarios 1 to 9 are dominated by the avoided impacts of primary zinc and manganese/ ferromanganese production. These are greater than the impacts associated with battery collection, sorting, transport, disposal and energy consumption during processing, such that an overall benefit is seen. Results show implementation scenarios utilising recycling scenario 2 (scenarios 2, 5 and 8) to perform favourably. Despite an increase in greenhouse gases from battery transport to France, this scenario is favoured due to significantly reduced burdens of consuming 50% of electricity generated according to the average (and current) French mix (44,800,000 kg CO_2-eq compared to 89,100,000 kg CO_2-eq where all electricity input to alkaline and saline battery recycling is from the UK).

Implementation scenarios utilising recycling scenario 3 (scenarios 3, 6 and 9) perform relatively well in the global warming category, again due to the importance of electricity generation and the low burdens associated with the hydro-dominated Swiss generation mix. However, the reduced recovery of manganese from this process results in these scenarios performing less well than might be expected in this impact category.

The baseline scenario (10) shows an overall impact across all categories, as the burdens of waste treatment (landfill and incineration) are incurred and no offset benefits of avoided materials are awarded. For the toxicity categories, these burdens come predominantly in the form of releases of heavy metals to the environment. For other categories, such as global warming potential, the landfill of biodegradable elements of the waste batteries (paper etc) and the incineration of waste batteries generates significant burden.

Although making relatively little contribution in terms of overall benefit/burden, it is evident that scenarios utilising collection scenario 3 perform relatively less well than those utilising collection scenarios 1 and 2 in the majority of impact categories. For example, with respect to global warming potential, implementation scenario 7 (collection scenario 3, recycling scenario 1) delivers significantly less benefit over the 25-year period than implementation scenarios 1 and 4 (collection scenarios 1 and 2 respectively, recycling scenario 1). Further analysis of results shows that this is predominantly due to additional fuel consumption and CO_2 emissions through the collection transportation network.

Table 4.1 Life Cycle Impact Assessment - Comparison between Implementation Scenarios

Impact Category	Unit	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7	Scenario 8	Scenario 9	Scenario 10
abiotic depletion	kg Sb eq	-1698230	-1841130	-1472130	-1691030	-1833930	-1464930	-1619130	-1762030	-1393030	53200
global warming (GWP100)	kg CO_2 eq	-86864000.0	-106864000	-88164000	-86264000	-106264000	-87564000	-76144000	-96144000	-77444000	46900000
ozone layer depletion (ODP)	kg CFC-11 eq	5	7	15	5	8	15	6	9	16	31
human toxicity	kg 1,4-DB eq	-48108000	-54538000	-191248000	-48028000	-54458000	-191168000	-42468000	-48898000	-185608000	1860000000
fresh water aquatic ecotox.	kg 1,4-DB eq	3725092300	3725225300	3709255300	3725115300	3725248300	3709278300	3726242300	3726375300	3710405300	5950000000
terrestrial ecotoxicity	kg 1,4-DB eq	-23050390	-23062290	-257428190	-22996690	-23059590	-257425490	-22956290	-23019190	-257385090	3700000
acidification	kg SO_2 eq	-1519970	-1578970	-2012570	-1515070	-1574070	-2007670	-1481070	-1540070	-1973670	139000
eutrophication	kg PO_4^{---} eq	133507	133897	135297	133797	134187	135587	137647	138037	139437	444000

Table 4.2 Impact Profile – Implementation Scenario 1

Impact Category	Unit	Total (all life cycle stages)	Collection (container use)	Collection (transport)	Collection (total)	Sorting	Recycling (transport)	Recycling (process)	Recycling (total)	Disposal
abiotic depletion	kg Sb eq	-1698230	28000	192000	220000	6370	60900	-2020000	-1959100	34500
	%	100%	-2%	-11%	-13%	-0.4%	-4%	119%	115%	-2%
global warming (GWP100)	kg CO_2 eq	-86864000	2590000	26200000	28790000	646000	8300000	-155000000	-146700000	30400000
	%	100%	-3%	-30%	-33%	-0.7%	-10%	178%	169%	-35%
ozone layer depletion (ODP)	kg CFC-11 eq	5	0.2	4	4	0.1	1	-21	-19	20
	%	100%	4%	80%	84%	1%	28%	-423%	-395%	411%
human toxicity	kg 1,4-DB eq	-48108000	1660000	8260000	9920000	112000	1860000	-1260000000	-1258140000	1200000000
	%	100%	-3.5%	-17%	-21%	-0.2%	-4%	2619%	2615%	-2494%
fresh water aquatic ecotox.	kg 1,4-DB eq	3725092300	630000	1860000	2490000	15300	587000	-128000000	-127413000	3850000000
	%	100%	0.0%	0%	0.1%	0.0004%	0.0%	-3%	-3%	103%
terrestrial ecotoxicity	kg 1,4-DB eq	-23050390	19200	19200	38400	2010	19200	-25500000	-25480800	2390000
	%	100%	-0.1%	-0.1%	-0.2%	-0.01%	-0.1%	111%	111%	-10%
acidification	kg SO_2 eq	-1519970	17000	97300	114300	4330	31600	-1760000	-1728400	89800
	%	100%	-1%	-6%	-8%	-0.3%	-2%	116%	114%	-6%
eutrophication	kg PO_4^{---} eq	133507	1820	15300	17120	477	5910	-178000	-172090	288000
	%	100%	1%	11%	13%	0.4%	4%	-133%	-129%	216%

Table 4.3 Impact Profile – Implementation Scenario 2

Impact Category	Unit	Total (all life cycle stages)	Collection (container use)	Collection (transport)	Collection (total)	Sorting	Recycling (transport)	Recycling (process)	Recycling (total)	Disposal
abiotic depletion	kg Sb eq	-1841130	28000	192000	220000	6370	178000	-2280000	-2102000	34500
	%	100%	-2%	-10%	-12%	-0.3%	-10%	124%	114%	-2%
global warming (GWP100)	kg CO_2 eq	-106864000	2590000	26200000	28790000	646000	24300000	-191000000	-166700000	30400000
	%	100%	-2%	-25%	-27%	-1%	-23%	179%	156%	-28%
ozone layer depletion (ODP)	kg CFC-11 eq	7	0.2	4	4	0.1	4	-21	-17	20
	%	100%	2%	53%	56%	1%	55%	-284%	-229%	274%
human toxicity	kg 1,4-DB eq	-54538000	1660000	8260000	9920000	112000	5430000	-1270000000	-1264570000	1200000000
	%	100%	-3%	-15%	-18%	-0.2%	-10%	2329%	2319%	-2200%
fresh water aquatic ecotox.	kg 1,4-DB eq	3725225300	630000	1860000	2490000	15300	1720000	-129000000	-127280000	3850000000
	%	100%	0.02%	0.0%	0.1%	0.0004%	0.05%	-3%	-3%	103%
terrestrial ecotoxicity	kg 1,4-DB eq	-23062290	19200	70200	89400	2010	56300	-25600000	-25543700	2390000
	%	100%	-0.1%	-0.3%	-0.4%	-0.01%	-0.2%	111%	111%	-10%
acidification	kg SO_2 eq	-1578970	17000	97300	114300	4330	92600	-1880000	-1787400	89800
	%	100%	-1%	-6%	-7%	-0.3%	-6%	119%	113%	-6%
eutrophication	kg PO_4^{---} eq	133897	1820	15300	17120	477	17300	-189000	-171700	288000
	%	100%	1%	11%	13%	0.4%	13%	-141%	-128%	215%

Table 4.4 Impact Profile – Implementation Scenario 3

Impact Category	Unit	Total (all life cycle stages)	Collection (container use)	Collection (transport)	Collection (total)	Sorting	Recycling (transport)	Recycling (process)	Recycling (total)	Disposal
abiotic depletion	kg Sb eq	-1472130	28000	192000	220000	6370	287000	-2020000	-1733000	34500
	%	100%	-2%	-13%	-15%	0%	-19%	137%	118%	-2%
global warming (GWP100)	kg CO_2 eq	-88164000	2590000	26200000	28790000	646000	39000000	-187000000	-148000000	30400000
	%	100%	-3%	-30%	-33%	-1%	-44%	212%	168%	-34%
ozone layer depletion (ODP)	kg CFC-11 eq	15	0.2	4	4	0.1	7	-16	-9	20
	%	100%	1%	26%	28%	0.5%	44%	-107%	-63%	135%
human toxicity	kg 1,4-DB eq	-191248000	1660000	8260000	9920000	112000	8720000	-1410000000	-1401280000	1200000000
	%	100%	-1%	-4%	-5%	-0.1%	-5%	737%	733%	-627%
fresh water aquatic ecotox.	kg 1,4-DB eq	3709255300	630000	1860000	2490000	15300	2750000	-146000000	-143250000	3850000000
	%	100%	0.02%	0.1%	0.1%	0.0004%	0.1%	-4%	-4%	104%
terrestrial ecotoxicity	kg 1,4-DB eq	-257428190	19200	70200	89400	2010	90400	-260000000	-259909600	2390000
	%	100%	-0.01%	-0.03%	-0.03%	-0.001%	0.0%	101%	101%	-1%
acidification	kg PO_4^{---} eq	-2012570	17000	97300	114300	4330	149000	-2370000	-2221000	89800
	%	100%	-1%	-5%	-6%	-0.2%	-7%	118%	110%	-4%
eutrophication	kg PO4--- eq	135297	1820	15300	17120	477	27700	-198000	-170300	288000
	%	100%	1%	11%	13%	0.4%	20%	-146%	-126%	213%

Table 4.5 Impact Profile – Implementation Scenario 4

Impact Category	Unit	Total (all life cycle stages)	Collection (container use)	Collection (transport)	Collection (total)	Sorting	Recycling (transport)	Recycling (process)	Recycling (total)	Disposal
abiotic depletion	kg Sb eq	-1691030	32200	195000	227200	6370	60900	-2020000	-1959100	34500
	%	100%	-2%	-12%	-13%	0%	-4%	119%	116%	-2%
global warming (GWP100)	kg CO_2 eq	-86264000	2890000	26500000	29390000	646000	8300000	-155000000	-146700000	30400000
	%	100%	-3%	-31%	-34%	-1%	-10%	180%	170%	-35%
ozone layer depletion (ODP)	kg CFC-11 eq	5	0.2	4	4	0.1	1	-21	-19	20
	%	100%	4%	79%	83%	1%	28%	-410%	-382%	398%
human toxicity	kg 1,4-DB eq	-48028000	1710000	8290000	10000000	112000	1860000	-1260000000	-1258140000	1200000000
	%	100%	-4%	-17%	-21%	-0.2%	-4%	2623%	2620%	-2499%
fresh water aquatic ecotox.	kg 1,4-DB eq	3725115300	643000	1870000	2513000	15300	587000	-128000000	-127413000	3850000000
	%	100%	0.02%	0.1%	0.1%	0.0004%	0.02%	-3%	-3%	103%
terrestrial ecotoxicity	kg 1,4-DB eq	-22996690	20700	71400	92100	2010	19200	-25500000	-25480800	2390000
	%	100%	-0.1%	-0.3%	-0.4%	-0.01%	-0.1%	111%	111%	-10%
acidification	kg SO_2 eq	-1515070	19600	99600	119200	4330	31600	-1760000	-1728400	89800
	%	100%	-1%	-7%	-8%	-0.3%	-2%	116%	114%	-6%
eutrophication	kg PO_4^{---} eq	133797	2010	15400	17410	477	5910	-178000	-172090	288000
	%	100%	2%	12%	13%	0.4%	4%	-133%	-129%	215%

Table 4.6 Impact Profile – Implementation Scenario 5

Impact Category	Unit	Total (all life cycle stages)	Collection (container use)	Collection (transport)	Collection (total)	Sorting	Recycling (transport)	Recycling (process)	Recycling (total)	Disposal
abiotic depletion	kg Sb eq	-1833930	32200	195000	227200	6370	178000	-2280000	-2102000	34500
	%	100%	-2%	-11%	-12%	-0.3%	-10%	124%	115%	-2%
global warming (GWP100)	kg CO_2 eq	-106264000	2890000	26500000	29390000	646000	24300000	-191000000	-166700000	30400000
	%	100%	-3%	-25%	-28%	-1%	-23%	180%	157%	-29%
ozone layer depletion (ODP)	kg CFC-11 eq	8	0.2	4	4	0.1	4	-21	-17	20
	%	100%	3%	53%	56%	1%	54%	-278%	-224%	267%
human toxicity	kg 1,4-DB eq	-54458000	1710000	8290000	10000000	112000	5430000	-1270000000	-1264570000	1200000000
	%	100%	-3%	-15%	-18%	-0.2%	-10%	2332%	2322%	-2204%
fresh water aquatic ecotox.	kg 1,4-DB eq	3725248300	643000	1870000	2513000	15300	1720000	-129000000	-127280000	3850000000
	%	100%	0.02%	0.1%	0.1%	0.0004%	0.05%	-3%	-3%	103%
terrestrial ecotoxicity	kg 1,4-DB eq	-23059590	20700	71400	92100	2010	56300	-25600000	-25543700	2390000
	%	100%	-0.1%	-0.3%	-0.4%	-0.01%	-0.2%	111%	111%	-10%
acidification	kg SO_2 eq	-1574070	19600	99600	119200	4330	92600	-1880000	-1787400	89800
	%	100%	-1%	-6%	-8%	-0.3%	-6%	119%	114%	-6%
eutrophication	kg PO_4^{---} eq	134187	2010	15400	17410	477	17300	-189000	-171700	288000
	%	100%	1%	11%	13%	0.4%	13%	-141%	-128%	215%

Table 4.7 Impact Profile – Implementation Scenario 6

Impact Category	Unit	Total (all life cycle stages)	Collection (container use)	Collection (transport)	Collection (total)	Sorting	Recycling (transport)	Recycling (process)	Recycling (total)	Disposal
abiotic depletion	kg Sb eq	-1464930	32200	195000	227200	6370	287000	-2020000	-1733000	34500
	%	100%	-2%	-13%	-16%	-0.4%	-20%	138%	118%	-2%
global warming (GWP100)	kg CO_2 eq	-87564000	2890000	26500000	29390000	646000	39000000	-187000000	-148000000	30400000
	%	100%	-3%	-30%	-34%	-1%	-45%	214%	169%	-35%
ozone layer depletion (ODP)	kg CFC-11 eq	15	0.2	4	4	0.1	7	-16	-9	20
	%	100%	1%	27%	28%	0.5%	43%	-106%	-63%	134%
human toxicity	kg 1,4-DB eq	-191168000	1710000	8290000	10000000	112000	8720000	-1410000000	-1401280000	1200000000
	%	100%	-1%	-4%	-5%	-0.1%	-5%	738%	733%	-628%
fresh water aquatic ecotox.	kg 1,4-DB eq	3709278300	643000	1870000	2513000	15300	2750000	-146000000	-143250000	3850000000
	%	100%	0.02%	0.1%	0.1%	0.0004%	0.1%	-4%	-4%	104%
terrestrial ecotoxicity	kg 1,4-DB eq	-257425490	20700	71400	92100	2010	90400	-260000000	-259909600	2390000
	%	100%	-0.01%	-0.03%	-0.04%	-0.001%	-0.04%	101%	101%	-1%
acidification	kg SO_2 eq	-2007670	19600	99600	119200	4330	149000	-2370000	-2221000	89800
	%	100%	-1%	-5%	-6%	-0.2%	-7%	118%	111%	-4%
eutrophication	kg PO_4^{---} eq	135587	2010	15400	17410	477	27700	-198000	-170300	288000
	%	100%	1%	11%	13%	0.4%	20%	-146%	-126%	212%

Table 4.8 Impact Profile – Implementation Scenario 7

Impact Category	Unit	Total (all life cycle stages)	Collection (container use)	Collection (transport)	Collection (total)	Sorting	Recycling (transport)	Recycling (process)	Recycling (total)	Disposal
abiotic depletion	kg Sb eq	-1619130	43100	256000	299100	6370	60900	-2020000	-1959100	34500
	%	100%	-3%	-16%	-18%	-0.4%	-4%	125%	121%	-2%
global warming (GWP100)	kg CO_2 eq	-76144000	4210000	35300000	39510000	646000	8300000	-155000000	-146700000	30400000
	%	100%	-6%	-46%	-52%	-1%	-11%	204%	193%	-40%
ozone layer depletion (ODP)	kg CFC-11 eq	6	0.2	5	5	0.1	1	-21	-19	20
	%	100%	3%	83%	86%	1%	23%	-339%	-317%	330%
human toxicity	kg 1,4-DB eq	-42468000	3060000	12500000	15560000	112000	1860000	-1260000000	-1258140000	1200000000
	%	100%	-7%	-29%	-37%	-0.3%	-4%	2967%	2963%	-2826%
fresh water aquatic ecotox.	kg 1,4-DB eq	3726242300	1180000	2460000	3640000	15300	587000	-128000000	-127413000	3850000000
	%	100%	0.03%	0.1%	0.1%	0.0004%	0.02%	-3%	-3%	103%
terrestrial ecotoxicity	kg 1,4-DB eq	-22956290	33300	99200	132500	2010	19200	-25500000	-25480800	2390000
	%	100%	-0.1%	-0.4%	-0.6%	-0.01%	-0.1%	111%	111%	-10%
acidification	kg SO_2 eq	-1481070	26200	127000	153200	4330	31600	-1760000	-1728400	89800
	%	100%	-2%	-9%	-10%	-0.3%	-2%	119%	117%	-6%
eutrophication	kg PO_4^{---} eq	137647	3060	18200	21260	477	5910	-178000	-172090	288000
	%	100%	2%	13%	15%	0.3%	4%	-129%	-125%	209%

Table 4.9 Impact Profile – Implementation Scenario 8

Impact Category	Unit	Total (all life cycle stages)	Collection (container use)	Collection (transport)	Collection (total)	Sorting	Recycling (transport)	Recycling (process)	Recycling (total)	Disposal
abiotic depletion	kg Sb eq	-1762030	43100	256000	299100	6370	178000	-2280000	-2102000	34500
	%	100%	-2%	-15%	-17%	-0.4%	-10%	129%	119%	-2%
global warming (GWP100)	kg CO_2 eq	-96144000	4210000	35300000	39510000	646000	24300000	-191000000	-166700000	30400000
	%	100%	-4%	-37%	-41%	-1%	-25%	199%	173%	-32%
ozone layer depletion (ODP)	kg CFC-11 eq	9	0.2	5	5	0.1	4	-21	-17	20
	%	100%	2%	59%	61%	1%	47%	-244%	-197%	235%
human toxicity	kg 1,4-DB eq	-48898000	3060000	12500000	15560000	112000	5430000	-1270000000	-1264570000	1200000000
	%	100%	-6%	-26%	-32%	-0.2%	-11%	2597%	2586%	-2454%
fresh water aquatic ecotox.	kg 1,4-DB eq	3726375300	1180000	2460000	3640000	15300	1720000	-129000000	-127280000	3850000000
	%	100%	0.03%	0.1%	0.1%	0.0004%	0.05%	-3%	-3%	103%
terrestrial ecotoxicity	kg 1,4-DB eq	-23019190	33300	99200	132500	2010	56300	-25600000	-25543700	2390000
	%	100%	-0.1%	-0.4%	-0.6%	-0.01%	-0.2%	111%	111%	-10%
acidification	kg SO_2 eq	-1540070	26200	127000	153200	4330	92600	-1880000	-1787400	89800
	%	100%	-2%	-8%	-10%	-0.3%	-6%	122%	116%	-6%
eutrophication	kg PO_4^{---} eq	138037	3060	18200	21260	477	17300	-189000	-171700	288000
	%	100%	2%	13%	15%	0.3%	13%	-137%	-124%	209%

Table 4.10 Impact Profile – Implementation Scenario 9

Impact Category	Unit	Total (all life cycle stages)	Collection (container use)	Collection (transport)	Collection (total)	Sorting	Recycling (transport)	Recycling (process)	Recycling (total)	Disposal
abiotic depletion	kg Sb eq	-1393030	43100	256000	299100	6370	287000	-2020000	-1733000	34500
	%	100%	-3%	-18%	-21%	-0.5%	-21%	145%	124%	-2%
global warming (GWP100)	kg CO_2 eq	-77444000	4210000	35300000	39510000	646000	39000000	-187000000	-148000000	30400000
	%	100%	-5%	-46%	-51%	-1%	-50%	241%	191%	-39%
ozone layer depletion (ODP)	kg CFC-11 eq	16	0.2	5	5	0.1	7	-16	-9	20
	%	100%	1%	31%	33%	0.4%	41%	-99%	-59%	126%
human toxicity	kg 1,4-DB eq	-185608000	3060000	12500000	15560000	112000	8720000	-1410000000	-1401280000	1200000000
	%	100%	-2%	-7%	-8%	-0.1%	-5%	760%	755%	-647%
fresh water aquatic ecotox.	kg 1,4-DB eq	3710405300	1180000	2460000	3640000	15300	2750000	-146000000	-143250000	3850000000
	%	100%	0.0%	0.1%	0.1%	0.0%	0.1%	-4%	-4%	104%
terrestrial ecotoxicity	kg 1,4-DB eq	-257385090	33300	99200	132500	2010	90400	-260000000	-259909600	2390000
	%	100%	-0.01%	-0.04%	-0.1%	-0.001%	-0.04%	101%	101%	-1%
acidification	kg SO_2 eq	-1973670	26200	127000	153200	4330	149000	-2370000	-2221000	89800
	%	100%	-1%	-6%	-8%	-0.2%	-8%	120%	113%	-5%
eutrophication	kg PO_4^{---} eq	139437	3060	18200	21260	477	27700	-198000	-170300	288000
	%	100%	2%	13%	15%	0.3%	20%	-142%	-122%	207%

5 *SENSITIVITY ANALYSIS*

The section describes the sensitivity analyses undertaken as part of the study. Sensitivity analysis is a process whereby key input parameters about which there may be uncertainty, or for which a range of values may exist, are tested.

Key areas that have been identified for sensitivity analysis include battery waste arisings, collection targets and Directive implementation years. Sensitivity analyses were also carried out in order to investigate the impact of assumptions regarding the number of institution collection points utilised in collection route 3.

5.1 *BATTERY WASTE ARISINGS*

Battery waste arisings were assumed to remain static over the 25-year assessment period. Sensitivity analyses were carried out to:

- investigate the implications of a growth in battery sales, and thus waste arisings, in line with treasury economic growth predictions (1); and
- investigate the implications of a growth in battery arisings in line with economic predictions, and assuming that the market for NiCd batteries remains static due to increased policy pressure for their replacement and sales of NiMH increase to fill the market gap.

Figure 5.1 shows the impact of this change on the impact profile of implementation scenario 1. A growth in battery arisings increases the environmental impact in three of the studied categories: ozone layer depletion; fresh water ecotoxicity; and eutrophication.

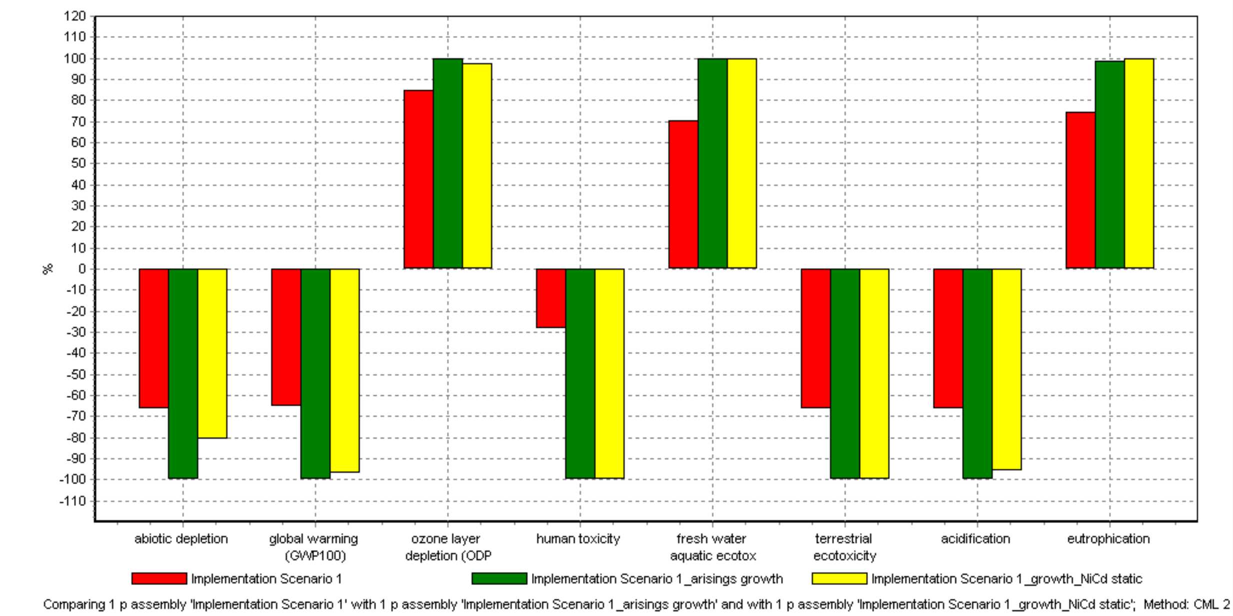
In five of the categories (abiotic depletion, global warming potential, human toxicity, terrestrial ecotoxicity and acidification), battery growth appears to yield a decrease in environmental impact. This is explained by the benefits that occur from recycling, and avoiding the need to produce virgin materials. It is important to stress that only the waste management part of the battery's life cycle is included in this study, however. If the whole life cycle was investigated, including the production of the battery, the result of the comparison would be that the environmental impact increases as the battery arisings increase.

The difference between the two investigated battery arisings scenarios is insignificant for most categories. The biggest difference is seen in the abiotic depletion category, where the use of NiCd batteries compares favourably to

(1) 2.1% in 2005, increasing to 2.7% in 2008 and 2.6% in 2009 (http://www.hm-treasury.gov.uk/media/0CA/24/forecasts_ukeconomy_310805.pdf). A rate of 2.6% growth per annum was then assumed for the period 2009 to 2030.

the use of NiMH batteries. Again this is explained by the avoided production of virgin materials. For NiCd batteries, recycling is assumed to offset cadmium, and for NiMH the offset used is production of iron and steel (see *Table 2.29*). The production of cadmium has a higher contribution to abiotic depletion than the production of iron and steel.

Figure 5.1 ***Comparing the Impact of Growth in Battery Arisings on the Impact Profile for Implementation Scenario 1***



A full analysis of the environmental and cost implications of a further two alternative growth predictions was carried out to inform Regulatory Impact Assessment evaluations (growth in waste battery arisings at a constant rate of 2.5% and growth in line with historic trends for individual chemistries). Results of this analysis are presented in *Annex C*.

5.2 *COLLECTION TARGETS*

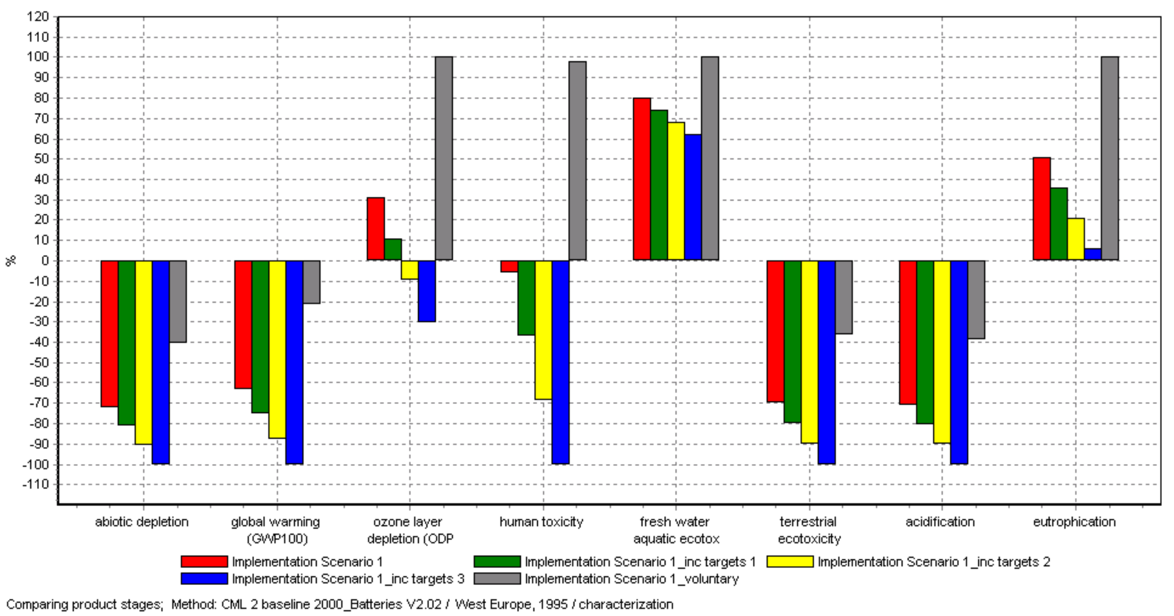
Sensitivity analyses were carried out to investigate the implications of an increase in the proposed collection targets on the impact profile of implementation scenarios. Three alternative collection targets were assessed:

1. 30% in 2012 and 50% in 2016;
2. 35% in 2012 and 55% in 2016; and
3. 40% in 2012 and 60% in 2016.

A scenario with collection and recycling levels in line with proposed voluntary agreement levels was also assessed. This modelled the implications of the UK reaching a collection level of 23.5% in 2012 and continuing to achieve this collection rate year-on-year for the remainder of the study period (2013-2030).

Figure 5.2 shows the impact of these alternative rates of collection. For all impact categories, an increase in collection rates results in an improved environmental profile. Conversely, the scenario modelling voluntary agreement rates shows that a decrease in collection rates results in increased environmental impact.

Figure 5.2 ***Comparing the Impact of Alternative Collection Rates on the Impact Profile for Implementation Scenario 1***

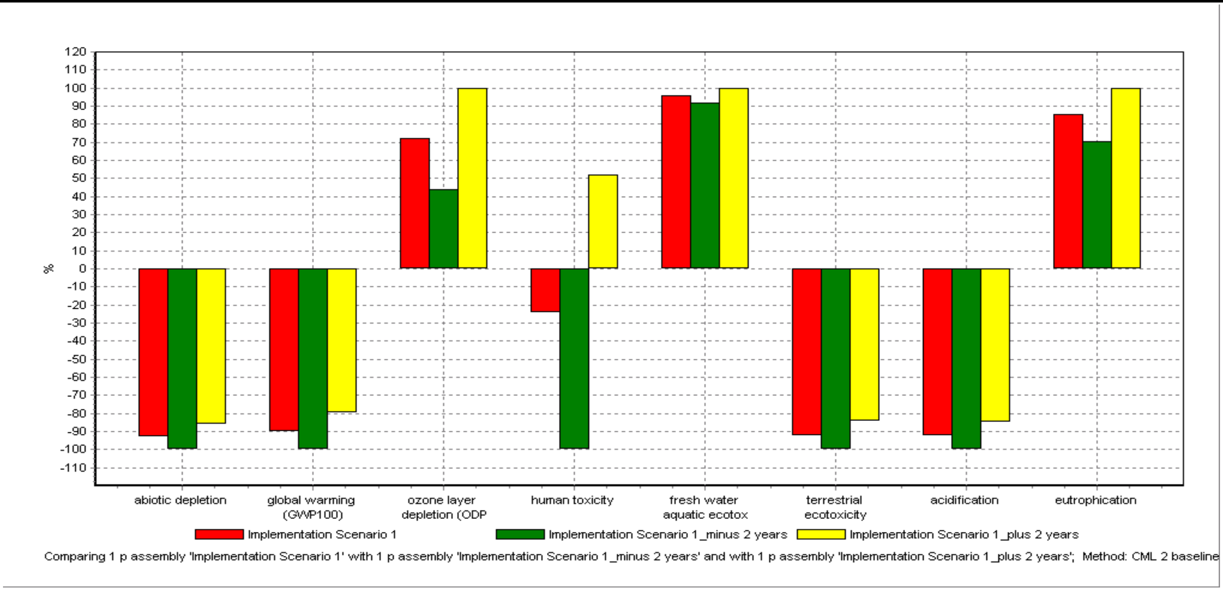


5.3 DIRECTIVE IMPLEMENTATION YEAR

The assessment of scenarios assumes that the proposed Battery Directive will be implemented in 2008, the 25% collection target is met in 2012 and the 45% collection target is met in 2016. Sensitivity analyses were carried to investigate the impact in implementation scenarios should the implementation year be moved forward to 2006 or postponed to 2010.

Figure 5.3 shows that environmental impact decreases if the implementation year is moved forward, and increases if the implementation year is postponed. This is relevant for all the investigated environmental impact categories.

Figure 5.3 *Comparing the Impact of Alternative Implementation Years on the Impact Profile for Implementation Scenario 1*



5.4 *DISPOSAL ASSUMPTIONS*

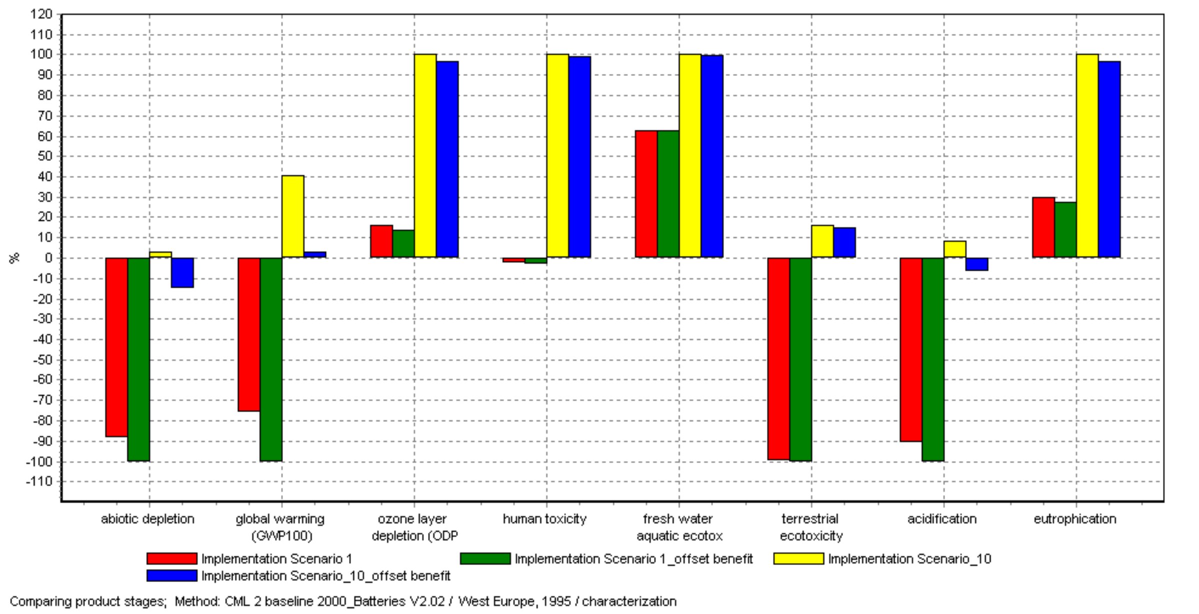
There is no definitive evidence that allows us to accurately reflect the transfer of battery components to the environment, our current assumption is that a maximum of 5% of battery heavy metal components are released to the environment through disposal operations. Should it be proved that this is an underestimate then the environmental impacts assessed for landfilling wastes, in particular the toxicity impacts, would be higher and would increase proportionally with the increased metal emission. As all the implementation scenarios perform better than the baseline for toxicity impacts then we can expect the benefit of recycling to increase the greater the proportion of the metals that escape to the environment. Similarly, if metals are released to the environment at a lower rate, the relative benefits of recycling would decrease.

The assessment awards no offset benefit of energy recovery to battery incineration, as the paper, plastic and carbon components are not in a great enough quantity to provide a calorific value above 8MJ/kg, a level at which waste can be considered a useful fuel. However, there is enough uncertainty with uncharacterised material in the batteries that would suggest this level could be achieved. Sensitivity analyses were carried out to investigate the impact of assuming an offset benefit of recovering 2.12MJ of electricity (1) through the incineration of 1kg of batteries (energy recovery benefit of the MSW incinerator modelled). *Figure 5.4* shows the impact of this assumption.

(1) Offset inventory: marginal electricity assumed

The assumption to include an offset for generated electricity results in lower environmental impact for all the included environmental impact categories. This is valid for both of the assessed scenarios.

Figure 5.4 ***Comparing the Impact of an Offset Benefit of Energy Recovery for Battery Incineration on the Impact Profile for Implementation Scenarios 1 and 10***



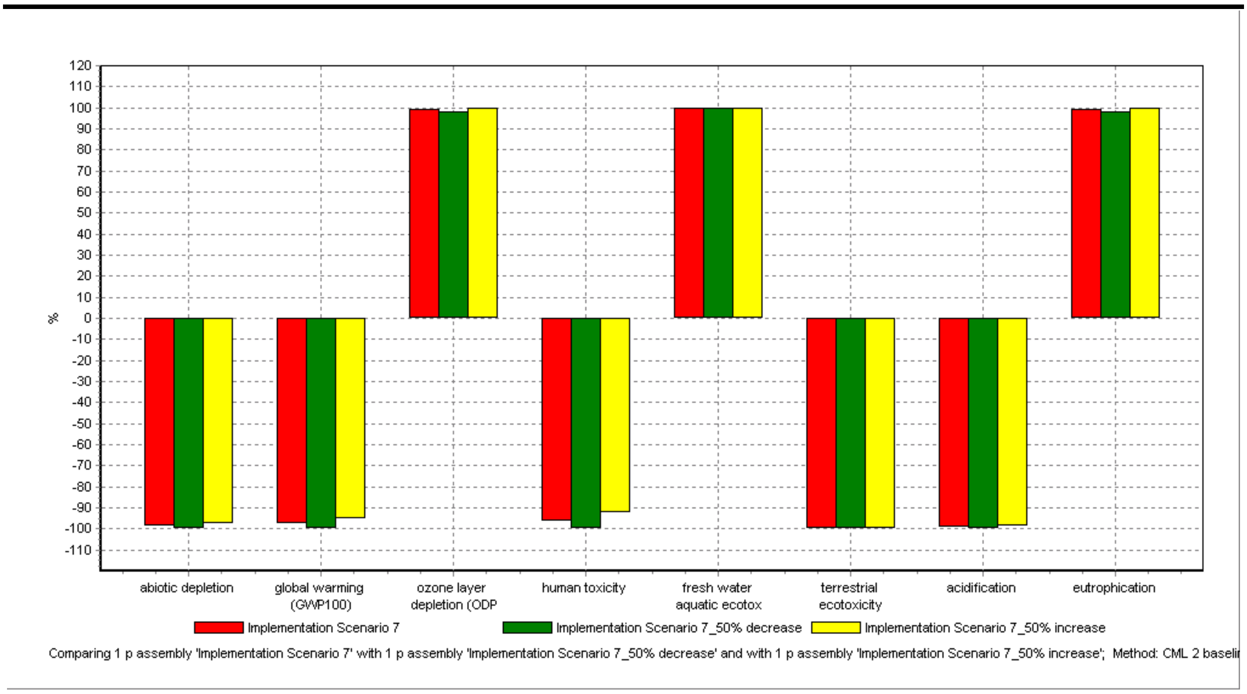
5.5 *INSTITUTIONAL COLLECTION POINTS*

For the purposes of modelling collection route 3, 69,500 institutional bring sites (schools, supermarkets, electrical equipment retailers etc.) were assumed to be operational across the UK. Sensitivity analyses were carried out to test this assumption, by alternatively modelling a 50% increase and a 50% decrease in the number of sites.

Figure 5.5 shows the impact of this change on the impact profile of implementation scenario 7 (1). The minimal change in profile shows that the number of bring sites modelled has a very limited impact on the results. As mentioned previously, it is the fuel and electricity input to the recycling processes, the disposal of residual batteries, and the materials avoided through recycling that dominate the results.

(1) This scenario was chosen for analysis as it is based on collection scenario 3, which utilises a high proportion of collection route 3.

Figure 5.5 ***Comparing the Impact of Number of Institutional Collection Points on the Impact Profile for Implementation Scenario 7***



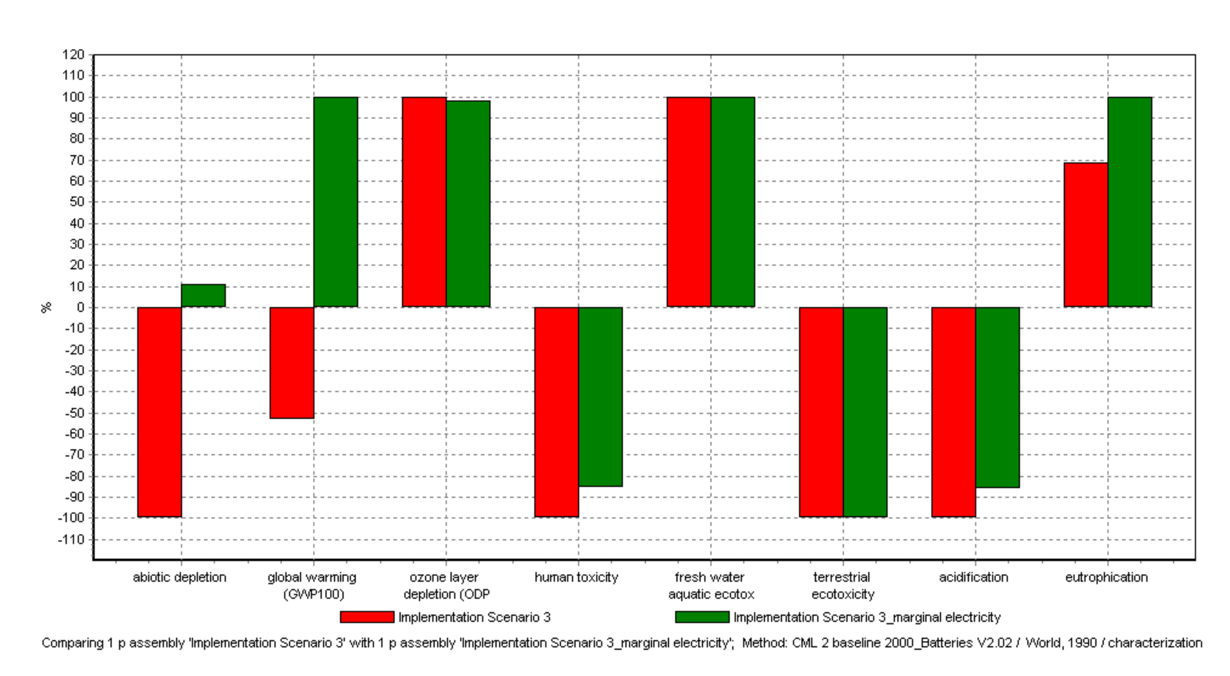
5.6 *ELECTRICITY INPUT TO RECYCLING*

Life cycle inventory analysis and impact assessment highlighted the strong influence that the fuel/energy requirements of recycling facilities, the location of recycling facilities and associated energy mix had on comparative results between scenarios. A sensitivity analysis was carried out to investigate the scale of this influence and impact on results should the increasing demands of plant be supplied by the marginal energy source. It was assumed that marginal electricity across Europe would derive from combined cycle gas turbine (CCGT) plant.

Figure 5.6 shows the impact of this change on the impact profile of implementation scenario 3 (1). The main differences are seen in the impact categories abiotic depletion and global warming. The Swiss geography and electricity mix assumed for pyrometallurgical processing of alkaline and saline batteries in recycling (and implementation) scenario 3 is comprised a high proportion of hydro power. Hydro power has a very low impact on abiotic resource depletion and global warming, compared to electricity generated from gas.

(1) This scenario was chosen for analysis as it is based on recycling scenario 3, which was found to perform favourably in a number of categories as a result of processing in Switzerland, with its high proportion of hydro-derived power in grid electricity mix.

Figure 5.6 Comparing the Impact of Marginal (Gas) Electricity Input on the Impact Profile for Implementation Scenario 3



6 FINANCIAL COSTS

An estimation of the financial costs of implementing each scenario was made as an additional element of the study. This included both an assessment of indicative collection and recycling costs and an evaluation of the potential environmental impacts associated with each scenario.

A problem commonly associated with data on the financial costs of waste management activities is the acquisition of detailed, reliable and up-to-date information, and the necessity of relying on small and dated data sets in forecasting future costs. In addition, some technologies are not as well established as others, resulting in additional difficulties in making accurate cost predictions. All assumptions made in calculating cost estimates are outlined in the following sections.

6.1 COLLECTION COSTS

Collection costs vary depending on the tonnage of batteries that can be collected within an operational time period. This is, in turn, dependent on both the size and frequency of collections made. Battery collection volumes increase significantly over the study time period (2006 - 2030) and so it was assumed that collection costs will decrease at a similar rate.

ERM estimates of current collection charges, based on discussions with industry, are shown in *Table 6.1*, together with assumptions regarding how collection costs may change over the study period.

Table 6.1 Collection Charges

Quantity Collected	Current Charge/ Tonne	Estimated Charge/Tonne with Increased Collection Tonnages
<0.5 tonnes	£200	It is envisaged that collections from sites gathering smaller quantities of batteries will be by small vehicles, making numerous collections in one area over a time period and delivering its approximate one tonne payload to a regional depot for consolidation each day. As tonnages increase, the network of depots will expand and the number of collections made/day will increase, reducing the cost of collection. With this infrastructure in place, up to 20-30 collections could be made per day, significantly reducing collection costs to an estimated £25/tonne. It was assumed that this point would be reached in 2016 when the 45% collection rate is achieved. Intermediate collection costs of £100/tonne and £50/tonne have been set for 2012 and 2014 respectively, when collection rates of 25% and 35% are reached.
0.5 – 1 tonne	£125	It was assumed that collections from sites consolidating an intermediate quantity of batteries would be made using the optimised network of regional depots as described above. For this reason, the same decrease in collection costs over time has been assumed: £100/tonne from 2012; £50 from 2014; and £25/tonne from 2016.
>1 tonne	£75	No change. It was assumed that collections of more than one tonne are unlikely to be collected via the network of regional depots as transit vans have a restricted payload.

The quantity of batteries to be collected via each collection route for each of the study's collection scenarios was discussed in *Section 1.6* and is summarised in *Table 6.2*. This further details the average size of collection that was assumed for each collection route.

Table 6.2 Quantity of Batteries Collected

Collection Route	Tonnes Collected over 25-year Period	Average Collection Size
1 – Kerbside collection, consolidation at MRF/transfer station	Scenario 1 – 120,194 Scenario 2 – 20,955 Scenario 3 – 59,175	Calculations presented in *Section 2.1* involved a quantification of the quantity of batteries collected via each kerbside collection point per year. This figure was calculated to be in excess of 33t (*Figure 1.1*). Collections are unlikely to be made to a given site more than once/month and so it was estimated that approximately 3 tonnes (ie > 1 tonne) of batteries would be collected at any one time via this collection route.
2 – CA site	Scenario 1 – 20,955 Scenario 2 – 120,194 Scenario 3 – 20,955	It was assumed that one tonne of batteries would be consolidated at a CA site before a collection is made. Collections of household batteries are also likely to be made in conjunction with car batteries that are commonly collected at CA sites across the UK. Although these batteries fall outside the scope of this study, the likely combined collection of household and car batteries impacts on collection costs, as greater tonnages will be collected. As a result, it was assumed that collections made via this route will fall into the category, '> 1 tonne', with associated collection costs.
3 – Institutional bring site, eg supermarket, school, retailer	Scenario 1 – 66,693 Scenario 2 – 66,693 Scenario 3 – 127,713	Collections made via this route are likely to be small in tonnage and have been assumed to fall into the category '<0.5 tonnes', with associated collection costs.
4 – Postal return, consolidation at Royal Mail sorting depot	Scenario 1 – 1832 Scenario 2 – 1832 Scenario 3 – 1832	It was assumed that one tonne of batteries would be consolidated at a Royal Mail sorting depot before a collection is made. Depots are likely to house a single, one-tonne bin and so collections in excess one one-tonne are unlikely, however. Collections via this route have therefore been assumed to fall into the category '05 -1 tonne', with associated collection costs.
5 – Emergency Lighting refurbishment, consolidation at maintenance operator bulking site	Scenario 1 – 9009 Scenario 2 – 9009 Scenario 3 – 9009	It was assumed that one tonne of batteries would be consolidated at a maintenance operator bulking site before a collection is made. Sites are likely to house a single, one-tonne bin and so collections in excess of one-tonne are unlikely. Collections via this route have therefore been assumed to fall into the category '05 -1 tonne', with associated collection costs.

Estimated costs for each collection scenario were quantified by applying the collection costs listed in *Table 6.1* to the quantity of batteries detailed in *Table 6.2*. Results are shown in *Table 6.3*.

Table 6.3 Estimated Scenario Collection Costs

Year	Collection Scenario 1 Costs (Million £)	Collection Scenario 2 Costs (Million £)	Collection Scenario 3 Costs (Million £)
2006	0.1	0.1	0.1
2007	0.2	0.2	0.3
2008	0.3	0.3	0.4
2009	0.4	0.4	0.5
2010	0.5	0.5	0.7
2011	0.6	0.6	0.8
2012	0.5	0.5	0.6
2013	0.6	0.6	0.7
2014	0.6	0.6	0.5
2015	0.7	0.7	0.6
2016	0.6	0.6	0.5
2017	0.6	0.6	0.5
2018	0.6	0.6	0.5
2019	0.6	0.6	0.5
2020	0.6	0.6	0.5
2021	0.6	0.6	0.5
2022	0.6	0.6	0.5
2023	0.6	0.6	0.5
2024	0.6	0.6	0.5
2025	0.6	0.6	0.5
2026	0.6	0.6	0.5
2027	0.6	0.6	0.5
2028	0.6	0.6	0.5
2029	0.6	0.6	0.5
2030	0.6	0.6	0.5
Total	**14.1**	**14.1**	**12.4**

6.2 SORTING COSTS

Manual sorting constitutes a labour-intensive element of the waste management life cycle and discussions with industry representatives suggest costs in the order of £0.50 per kg of mixed batteries. It was assumed that batteries arising via each of the collection routes will require sorting, with the exception of collection route 5, through which only NiCds from emergency lighting are collected. The cost of sorting was assumed to remain the same throughout the study period as sorting practices are unlikely to change significantly. Sorting charges are equivalent for each scenario, 1-9, as the same quantity of batteries are collected and require sorting. Total costs are shown in *Table 6.4*.

The implications of the 'producer responsibility' nature of the proposed Directive are such that there is significant incentive for manufacturers to introduce measures to simplify sorting and thus reduce costs. For example, design considerations could potentially ease consumer identification of alternative battery chemistries and allow a degree of pre-sorting. *Table 6.10* examines the cost implications of such mechanisms reducing sorting costs by 50%.

Table 6.4 Estimated Sorting Costs (Scenarios 1 to 9)

Year	Sorting Costs - All Scenarios (Million £)
2006	0.4
2007	0.9
2008	1.3
2009	1.7
2010	2.1
2011	2.6
2012	3.0
2013	3.6
2014	4.2
2015	4.8
2016	5.4
2017	5.4
2018	5.4
2019	5.4
2020	5.4
2021	5.4
2022	5.4
2023	5.4
2024	5.4
2025	5.4
2026	5.4
2027	5.4
2028	5.4
2029	5.4
2030	5.4
Total	**104.8**

6.3 *RECYCLING COSTS*

Scenario recycling costs have been determined on the basis of the charges likely to made by a collection service provider. These include both gate fees for recycling facilities and the costs of logistical arrangements, together with service provision charges. The sale of secondary materials is embodied in the gate fee element of these costs, as is the capital costs associated with the development of new facilities. It has been assumed that these are borne by the service provider and are thus incorporated in the calculation of the gate fee, together with operating costs and profit.

In a similar way to collection costs, recycling costs are likely to decrease with increasing volumes of batteries collected, through economies of scale. ERM estimates of current recycling charges, based on discussions with industry, are shown in *Table 6.5*. The estimated costs of recycling should battery volumes increase are also indicated. These have been approximated, based on known economies of scale and a consideration of how metal markets might develop.

It should be noted that uncertainties surrounding changes in metal markets and thus sale of secondary materials are such that the costs presented in *Table 6.5* can only represent broad estimates.

Table 6.5 Recycling Charges

Battery Type	Current Charge/Tonne	Potential Charge/Tonne at Increased Collection Volume
AgO	Zero (can be a rebate)	No change
ZnC	£850*	£600 at 1000 tonnes, £400 at 5000 tonnes*
AlMn	£850*	£600 at 1000 tonnes, £400 at 5000 tonnes*
ZnO	£850*	£600 at 1000 tonnes, £400 at 5000 tonnes*
Li-ion	Zero (can be a rebate)	No change
LiMn	£2050**	Would only start to decrease if >100 tonnes are collected (not required for implementation)
Li	£2050**	Would only start to decrease if >100 tonnes are collected (not required for implementation)
NiCd (dry)	£570	No change
NiMH	£250	At 1000 tonnes could reach zero charge
PbA	Zero (can be a rebate)	No change

* These figures are independent of recycling scenario as they represent a service charge estimated by industry representatives and are not significantly influenced by the different gate fees incurred by recycling processes. Any future economies of scale are also assumed to have similar influence on each recycling route.
** Gate fee only. Does not include transport and other logistical costs.

Estimated recycling costs were quantified by applying the costs listed in *Table 6.5* to the quantity of batteries handled throughout the study period. Results are shown in *Table 6.6*.

Table 6.6 Estimated Scenario Recycling Costs (all Recycling Scenarios)

Year	AgO/ Li-ion/ PbA Costs	ZnO Recycling (Million £)	AlMn Recycling (Million £)	ZnC Recycling (Million £)	Primary Lithium (Li, LiMn) Recyc. (Million £)	NiCd Recycling (Million £)	NiMH Recycling (Million £)	Total (Million £)
2006	n/a	0.0004	0.5	0.1	0.02	0.05	0.01	0.7
2007	n/a	0.001	0.6	0.3	0.03	0.1	0.02	1.1
2008	n/a	0.001	1.0	0.4	0.05	0.1	0.03	1.6
2009	n/a	0.001	1.3	0.6	0.07	0.2	0.05	2.1
2010	n/a	0.002	1.6	0.7	0.09	0.2	0.1	2.7
2011	n/a	0.002	1.9	0.8	0.10	0.3	0.1	3.2
2012	n/a	0.003	2.2	0.7	0.12	0.3	0.1	3.5
2013	n/a	0.003	2.7	0.8	0.15	0.4	0.1	4.2
2014	n/a	0.004	2.1	1.0	0.17	0.5	0.1	3.8
2015	n/a	0.004	2.4	1.1	0.19	0.5	0.1	4.3
2016	n/a	0.005	2.7	1.2	0.22	0.6	0.1	4.9
2017	n/a	0.005	2.7	1.2	0.22	0.6	0.1	4.9
2018	n/a	0.005	2.7	1.2	0.22	0.6	0.1	4.9
2019	n/a	0.005	2.7	1.2	0.22	0.6	0.1	4.9
2020	n/a	0.005	2.7	1.2	0.22	0.6	0.1	4.9
2021	n/a	0.005	2.7	1.2	0.22	0.6	0.1	4.9
2022	n/a	0.005	2.7	1.2	0.22	0.6	0.1	4.9
2023	n/a	0.005	2.7	1.2	0.22	0.6	0.1	4.9
2024	n/a	0.005	2.7	1.2	0.22	0.6	0.1	4.9
2025	n/a	0.005	2.7	1.2	0.22	0.6	0.1	4.9
2026	n/a	0.005	2.7	1.2	0.22	0.6	0.1	4.9
2027	n/a	0.005	2.7	1.2	0.22	0.6	0.1	4.9
2028	n/a	0.005	2.7	1.2	0.22	0.6	0.1	4.9
2029	n/a	0.005	2.7	1.2	0.22	0.6	0.1	4.9
2030	n/a	0.005	2.7	1.2	0.22	0.6	0.1	4.9
Total	**n/a**	**0.1**	**56.5**	**25.3**	**4.26**	**11.5**	**2.9**	**100.4**

6.4 DISPOSAL COSTS

Average costs for the disposal of municipal solid waste via landfill (£12.29/tonne disposal fee (1), plus landfill tax increasing to £35/tonne by 2011) and incineration (£42/tonne (2)) were used to model the financial costs associated with the disposal of batteries not separately collected. Total costs for each implementation scenario, 1 – 9, are the same, as the same quantity of batteries is collected, and the same disposed. These are presented in *Table 6.7* and are compared with the total disposal costs for the baseline, 'do nothing' scenario (10) in *Table 6.8*.

(1) *Costs for Municipal Waste Management in the EU* (2002). Eunomia Research & Consulting.

(2) *EfW: A Good Practice Guide* (2003). The Chartered Institute of Waste Management.

Table 6.7 Estimated Disposal Costs (Scenarios 1 to 9)

Year	Landfill Costs (Million £)	Incineration Costs (Million £)	Total Disposal Cost (Million £)
2006	0.7	0.1	0.8
2007	0.7	0.1	0.9
2008	0.8	0.1	0.9
2009	0.8	0.1	0.9
2010	0.8	0.1	0.9
2011	0.8	0.1	0.9
2012	0.8	0.1	0.9
2013	0.7	0.1	0.8
2014	0.7	0.1	0.8
2015	0.6	0.1	0.7
2016	0.6	0.1	0.6
2017	0.6	0.1	0.6
2018	0.6	0.1	0.6
2019	0.6	0.1	0.6
2020	0.6	0.1	0.6
2021	0.6	0.1	0.6
2022	0.6	0.1	0.6
2023	0.6	0.1	0.6
2024	0.6	0.1	0.6
2025	0.6	0.1	0.6
2026	0.6	0.1	0.6
2027	0.6	0.1	0.6
2028	0.6	0.1	0.6
2029	0.6	0.1	0.6
2030	0.6	0.1	0.6
Total	**16.1**	**1.9**	**18.0**

Table 6.8 Estimated Disposal Costs (Baseline Scenario 10)

Year	Total Disposal Cost (Million £) for Baseline Scenario 10
2006	0.9
2007	0.9
2008	1.0
2009	1.1
2010	1.1
2011	1.2
2012	1.2
2013	1.2
2014	1.2
2015	1.2
2016	1.2
2017	1.2
2018	1.2
2019	1.2
2020	1.2
2021	1.2
2022	1.2
2023	1.2
2024	1.2
2025	1.2

Year	Total Disposal Cost (Million £) for Baseline Scenario 10
2026	1.2
2027	1.2
2028	1.2
2029	1.2
2030	1.2
Total	**28.1**

6.5 TOTAL COSTS FOR IMPLEMENTATION SCENARIOS

Collection, sorting and recycling costs were combined to calculate a total cost for each implementation scenario, as shown in *Table 6.9*. The potential impact of a reduction in sorting costs, as discussed in *Section 6.2*, is further shown in *Table 6.10*.

Table 6.9 Total Implementation Scenario Collection, Sorting, Recycling and Disposal Costs

Year	Implementation Scenario 1	Implementation Scenario 2	Implementation Scenario 3	Implementation Scenario 4	Implementation Scenario 5	Implementation Scenario 6	Implementation Scenario 7	Implementation Scenario 8	Implementation Scenario 9	Implementation Scenario 10
2006	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	0.9
2007	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	0.9
2008	4.0	4.0	4.0	4.0	4.0	4.0	4.1	4.1	4.1	1.0
2009	5.1	5.1	5.1	5.1	5.1	5.1	5.2	5.2	5.2	1.0
2010	6.2	6.2	6.2	6.2	6.2	6.2	6.3	6.3	6.3	1.1
2011	7.2	7.2	7.2	7.2	7.2	7.2	7.4	7.4	7.4	1.2
2012	7.8	7.8	7.8	7.8	7.8	7.8	7.8	7.8	7.8	1.2
2013	9.1	9.1	9.1	9.1	9.1	9.1	9.1	9.1	9.1	1.2
2014	9.2	9.2	9.2	9.2	9.2	9.2	9.2	9.2	9.2	1.2
2015	10.4	10.4	10.4	10.4	10.4	10.4	10.3	10.3	10.3	1.2
2016	11.4	11.4	11.4	11.4	11.4	11.4	11.3	11.3	11.3	1.2
2017	11.4	11.4	11.4	11.4	11.4	11.4	11.3	11.3	11.3	1.2
2018	11.4	11.4	11.4	11.4	11.4	11.4	11.3	11.3	11.3	1.2
2019	11.4	11.4	11.4	11.4	11.4	11.4	11.3	11.3	11.3	1.2
2020	11.4	11.4	11.4	11.4	11.4	11.4	11.3	11.3	11.3	1.2
2021	11.4	11.4	11.4	11.4	11.4	11.4	11.3	11.3	11.3	1.2
2022	11.4	11.4	11.4	11.4	11.4	11.4	11.3	11.3	11.3	1.2
2023	11.4	11.4	11.4	11.4	11.4	11.4	11.3	11.3	11.3	1.2
2024	11.4	11.4	11.4	11.4	11.4	11.4	11.3	11.3	11.3	1.2
2025	11.4	11.4	11.4	11.4	11.4	11.4	11.3	11.3	11.3	1.2
2026	11.4	11.4	11.4	11.4	11.4	11.4	11.3	11.3	11.3	1.2
2027	11.4	11.4	11.4	11.4	11.4	11.4	11.3	11.3	11.3	1.2
2028	11.4	11.4	11.4	11.4	11.4	11.4	11.3	11.3	11.3	1.2
2029	11.4	11.4	11.4	11.4	11.4	11.4	11.3	11.3	11.3	1.2
2030	11.4	11.4	11.4	11.4	11.4	11.4	11.3	11.3	11.3	1.2
Total (Mill £)	**235.23**	**235.23**	**235.23**	**235.23**	**235.23**	**235.23**	**233.50**	**233.50**	**233.50**	**28.1**

Table 6.10 Total Implementation Scenario Collection, Sorting, Recycling and Disposal Costs with 50% Reduction in Sorting Costs

Year	Implementation Scenario 1	Implementation Scenario 2	Implementation Scenario 3	Implementation Scenario 4	Implementation Scenario 5	Implementation Scenario 6	Implementation Scenario 7	Implementation Scenario 8	Implementation Scenario 9	Implementation Scenario 10
2006	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	0.9
2007	2.5	2.5	2.5	2.5	2.5	2.5	2.6	2.6	2.6	0.9
2008	3.4	3.4	3.4	3.4	3.4	3.4	3.5	3.5	3.5	1.0
2009	4.3	4.3	4.3	4.3	4.3	4.3	4.4	4.4	4.4	1.0
2010	5.1	5.1	5.1	5.1	5.1	5.1	5.3	5.3	5.3	1.1
2011	6.0	6.0	6.0	6.0	6.0	6.0	6.2	6.2	6.2	1.2
2012	6.3	6.3	6.3	6.3	6.3	6.3	6.3	6.3	6.3	1.2
2013	7.3	7.3	7.3	7.3	7.3	7.3	7.4	7.4	7.4	1.2
2014	7.1	7.1	7.1	7.1	7.1	7.1	7.1	7.1	7.1	1.2
2015	8.0	8.0	8.0	8.0	8.0	8.0	7.9	7.9	7.9	1.2
2016	8.7	8.7	8.7	8.7	8.7	8.7	8.6	8.6	8.6	1.2
2017	8.7	8.7	8.7	8.7	8.7	8.7	8.6	8.6	8.6	1.2
2018	8.7	8.7	8.7	8.7	8.7	8.7	8.6	8.6	8.6	1.2
2019	8.7	8.7	8.7	8.7	8.7	8.7	8.6	8.6	8.6	1.2
2020	8.7	8.7	8.7	8.7	8.7	8.7	8.6	8.6	8.6	1.2
2021	8.7	8.7	8.7	8.7	8.7	8.7	8.6	8.6	8.6	1.2
2022	8.7	8.7	8.7	8.7	8.7	8.7	8.6	8.6	8.6	1.2
2023	8.7	8.7	8.7	8.7	8.7	8.7	8.6	8.6	8.6	1.2
2024	8.7	8.7	8.7	8.7	8.7	8.7	8.6	8.6	8.6	1.2
2025	8.7	8.7	8.7	8.7	8.7	8.7	8.6	8.6	8.6	1.2
2026	8.7	8.7	8.7	8.7	8.7	8.7	8.6	8.6	8.6	1.2
2027	8.7	8.7	8.7	8.7	8.7	8.7	8.6	8.6	8.6	1.2
2028	8.7	8.7	8.7	8.7	8.7	8.7	8.6	8.6	8.6	1.2
2029	8.7	8.7	8.7	8.7	8.7	8.7	8.6	8.6	8.6	1.2
2030	8.7	8.7	8.7	8.7	8.7	8.7	8.6	8.6	8.6	1.2
Total (Mill £)	**182.81**	**182.81**	**182.81**	**182.81**	**182.81**	**182.81**	**181.08**	**181.08**	**181.08**	**28.1**

6.6 *EVALUATING THE EXTERNAL COST OF ENVIRONMENTAL IMPACTS*

An estimation of the financial cost of the potential environmental damage associated with implementing each of the scenarios was made using environmental costs factors per tonne of pollutant. These have been estimated through Defra research into the health effects of waste management (1) (*Table 6.11*). Comparative results for each implementation scenario are shown in *Table 6.12* to *Table 6.14*.

Table 6.11 Cost Factors

Pollutant	Cost Factor (Central Low Estimate)	Cost Factor (Central High Estimate)	Cost Factor (Average Estimate)	Coverage	Source
Particulates (PM_{10})	£5257.3/tonne	£33 166.7/ tonne	£19 212/ tonne	Health effects only	Average cost/tonne for mobile (transport) and stationary (waste management, electricity supply) sources calculated from Defra figures
NOx	£163.5/ tonne	£1037.5/ tonne	£600.5/ tonne	Health effects only	Average cost/tonne for mobile (transport) and stationary (waste management, electricity supply) sources calculated from Defra figures
SO_2	£643/ tonne	£2941/ tonne	£1792/ tonne	Effects on health and materials	Defra health effects report
VOC (except methane)	£263/ tonne	£665/ tonne	£464/ tonne	Health effects and crop damage	Defra health effects report
CO_2	£16/ tonne	£49/ tonne	£27/ tonne	Climate change only	Calculated directly from estimates relating to the social cost of carbon. 2000 estimates (£35/tonne, £70/tonne and £140/tonne for respective estimates) have been increased by £1/tonne carbon/year, based on Defra recommendations. An average cost/tonne carbon dioxide was taken for the period 2006-2030.
CH_4	£340/ tonne	£1020/ tonne	£566/ tonne	Climate change only	Calculated as derived CO_2 factors multiplied by the global warming potential (GWP) of methane, = 21 (IPCC, 2001). An average cost/tonne methane was taken for the period 2006-2030.

Notes overleaf

(1) *Valuation of external costs and benefits to health and environment of waste management options* (2004). Prepared for Defra by Enviros Consulting Ltd. and EFTEC. To be updated December 2005 (interim values used).

Notes from Table:

1. Numbers relate to costs for emissions that occur in the UK – (this is not the case for the study, we have assumed the cost values to be the same across Europe)
2. Values for NO_X and SO_2 include secondary particulate (PM_{10}) formation (nitrates and sulphates)
3. Values for VOC include ozone formation and effects
4. Values for NO_X do NOT include ozone formation and effects
5. The analysis assumes no threshold of effects
6. Future life years lost have been discounted using agreed 1.5% discount rate
7. Central low assumes £3100 for death brought forward and £31500 per life year lost, with future life years discounted (1.5%).
8. Central high assumes £110000 for death brought forward and £65000 per life year lost, with future life years discounted (1.5%)
9. All chronic mortality impacts use original $PM_{2.5}$ functions for PM_{10} pollution data.
10. External costs of air pollution vary according to a variety of environmental factors, including overall levels of pollution, geographic location of emission sources, height of emission source, local and regional population density, meteorology and so on. These numbers take these issues into account to a certain degree only.
11. The numbers exclude several categories of impact. They are therefore a sub-total of overall costs. The key areas excluded are:

- Effects of NO_X on ozone formation (note ozone effects from NO_X could positive as well as negative, due to issues with local NO + ozone reactions, and regional precursor levels)
- Effects on ecosystems (acidification, eutrophication, etc)
- Effects on cultural or historic buildings from air pollution
- Chronic mortality health effects from PM_{10} on children
- Chronic morbidity health effects from PM_{10}
- Morbidity and mortality health effects from chronic (long-term) exposure to ozone
- Change in visibility (visual range)
- Effects of ozone on materials, particularly rubber
- Non-ozone effects on agriculture

Table 6.12 Cost of Pollutant Emissions – Central High Estimate

Pollutant	Unit	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7	Scenario 8	Scenario 9	Scenario 10
NOx	Million £	-0.85	-0.86	-0.63	-0.85	-0.86	-0.63	-0.84	-0.84	-0.61	0.21
SO_2	Million £	-3.07	-3.01	-4.08	-3.06	-3.00	-4.07	-3.00	-2.94	-4.01	0.02
NMVOC	Million £	-0.09	-0.08	-0.06	-0.09	-0.08	-0.05	-0.09	-0.07	-0.05	0.02
Particulates	Million £	-52.10	-52.70	-44.00	-52.10	-52.60	-44.00	-51.60	-52.20	-43.60	0.82
CO_2	Million £	-4.22	-5.11	-4.31	-4.20	-5.09	-4.29	-3.72	-4.61	-3.82	1.49
CH_4	Million £	0.71	0.59	0.46	0.71	0.59	0.46	0.71	0.59	0.46	0.69
Total	**Million £**	**-59.63**	**-61.17**	**-52.62**	**-59.60**	**-61.04**	**-52.59**	**-58.54**	**-60.07**	**-51.63**	**3.24**

Table 6.13 Cost of Pollutant Emissions - Central Low Estimate

Pollutant	Unit	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7	Scenario 8	Scenario 9	Scenario 10
NOx	Million £	-0.14	-0.14	-0.10	-0.13	-0.14	-0.10	-0.13	-0.13	-0.10	0.03
SO_2	Million £	-0.67	-0.66	-0.89	-0.67	-0.66	-0.89	-0.66	-0.64	-0.88	0.00
NMVOC	Million £	-0.04	-0.03	-0.02	-0.04	-0.03	-0.02	-0.03	-0.03	-0.02	0.01
Particulates	Million £	-8.25	-8.35	-6.98	-8.25	-8.34	-6.98	-8.18	-8.28	-6.91	0.13
CO_2	Million £	-1.38	-1.67	-1.41	-1.37	-1.66	-1.40	-1.22	-1.51	-1.25	0.49
CH_4	Million £	0.24	0.20	0.15	0.24	0.20	0.15	0.24	0.20	0.15	0.23
Total	**Million £**	**-10.24**	**-10.65**	**-9.25**	**-10.23**	**-10.63**	**-9.24**	**-9.99**	**-10.40**	**-9.00**	**0.89**

Table 6.14 Cost of Pollutant Emissions – Average Estimate

Pollutant	Unit	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7	Scenario 8	Scenario 9	Scenario 10
NOx	Million £	-0.49	-0.50	-0.37	-0.49	-0.50	-0.37	-0.48	-0.49	-0.36	0.12
SO_2	Million £	-1.87	-1.83	-2.48	-1.86	-1.83	-2.48	-1.83	-1.79	-2.44	0.01
NMVOC	Million £	-0.07	-0.06	-0.04	-0.07	-0.06	-0.04	-0.06	-0.05	-0.03	0.01
Particulates	Million £	-30.20	-30.50	-25.50	-30.20	-30.50	-25.50	-29.90	-30.20	-25.30	0.48
CO_2	Million £	-2.33	-2.82	-2.38	-2.31	-2.80	-2.36	-2.05	-2.54	-2.10	0.82
CH_4	Million £	0.39	0.33	0.25	0.39	0.33	0.25	0.39	0.33	0.26	0.38
Total	**Million £**	**-34.57**	**-35.38**	**-30.51**	**-34.54**	**-35.35**	**-30.49**	**-33.93**	**-34.74**	**-29.97**	**1.82**

The assessment shows that there is a net environmental benefit associated with the implementation of the proposed Directive on batteries and accumulators when compared with disposal (implementation scenario 10). *Table 7.1* displays the net environmental benefit associated with implementation scenarios (1-9), over and above the baseline scenario (10).

Little difference is shown between scenarios 1-9, in terms of net environmental benefit. However, it is evident that scenarios utilising collection scenario 3 perform relatively less well than those utilising collection scenarios 1 and 2 in the majority of impact categories. This is evident through comparison of implementation scenarios with equivalent recycling scenarios, but alternative collection scenarios. For example, scenarios 1 and 4 (recycling scenario 1, collection scenarios 1 and 2 respectively) show a higher net environmental benefit than scenario 7 (recycling scenario 1, collection scenario 3). Further analysis of results showed this to be predominantly related to additional CO_2 emissions through the collection transportation network (1).

Table 7.1 Environmental Benefit of Implementation Scenarios (net Benefit in Comparison with Baseline)

Scenario	abiotic depletion	global warming (GWP100)	ozone layer depletion (ODP)	human toxicity	fresh water aquatic ecotox.	terrestrial ecotoxicity	acidification	eutrophication
Unit	kg Sb eq	kg CO_2 eq	kg CFC-11 eq	kg 1,4-DB eq	kg 1,4-DB eq	kg 1,4-DB eq	kg SO_2 eq	kg PO_4 --- eq
Implementation Scenario 1	1751430	133764000	26	1908108000	2224907700	26750390	1658970	310493
Implementation Scenario 2	1894330	153764000	24	1914538000	2224774700	26762290	1717970	310103
Implementation Scenario 3	1525330	135064000	16	2051248000	2240744700	261128190	2151570	308703
Implementation Scenario 4	1744230	133164000	26	1908028000	2224884700	26696690	1654070	310203
Implementation Scenario 5	1887130	153164000	23	1914458000	2224751700	26759590	1713070	309813
Implementation Scenario 6	1518130	134464000	16	2051168000	2240721700	261125490	2146670	308413
Implementation Scenario 7	1672330	123044000	25	1902468000	2223757700	26656290	1620070	306353
Implementation Scenario 8	1815230	143044000	22	1908898000	2223624700	26719190	1679070	305963
Implementation Scenario 9	1446230	124344000	15	2045608000	2239594700	261085090	2112670	304563

(1) Sensitivity analysis, presented in Section 5.4.5, further showed that the assumed number of institution collection points, and thus the number of collection container required at sites, had little influence on results.

All implementation scenarios show a significant benefit for toxicity emissions when compared with disposal (implementation scenario 10). This is a result of avoiding virgin material production and emissions from waste disposal. Further, all scenarios show aquatic toxicity impacts that are approximately proportional to the tonnage of batteries sent for disposal. This impact is a result of the assumptions with regard to the proportion of heavy metals that are released to the environment from batteries in the residual waste stream.

The CO_2 savings that can be achieved through implementation of the battery Directive amount to between 198kg and 248kg CO_2-equivalents avoided per tonne of battery waste arisings [1] (this reflects a recycling rate of 35.2% over the 25 years). The benefit is attributable to offset materials and is therefore reliant on markets for products from recycling being achieved.

Table 7.2 displays the waste management and average environmental and social costs that have been estimated for each implementation scenario. Estimates show that implementation of the proposed Directive will result in a significant increase in battery waste management costs, with some savings in the financial costs quantified for environmental and social aspects. It should be noted, however, that a number of external benefits associated implementation scenarios have not been quantified in terms of financial cost.

Table 7.2 Total Financial Costs of Implementation Scenarios

Scenario	Waste Management Costs (Million £)	Coverage	Environmental and Social Costs (Million £)	Coverage	Total Scenario Cost (Million £)
Implementation Scenario 1	235.2	Collection, sorting and recycling service charges. Landfill and incineration gate fees	-34.6	Effect of NOx, SO_2, NMVOC and particulate emissions on human health (human toxicity). Climate change costs of carbon (CO_2 and CH_4 emissions only). Abiotic depletion, ozone depletion, aquatic ecotoxicity, acidification (with the exception of damage to buildings) and eutrophication impacts have not been quantified.	200.6
Implementation Scenario 2	235.2		-35.4		199.8
Implementation Scenario 3	235.2		-30.5		204.7
Implementation Scenario 4	235.2		-34.5		200.7
Implementation Scenario 5	235.2		-35.4		199.8
Implementation Scenario 6	235.2		-30.5		204.7
Implementation Scenario 7	233.5		-33.9		199.6
Implementation Scenario 8	233.5		-34.7		198.8
Implementation Scenario 9	233.5		-30.1		203.4
Implementation Scenario 10	28.1		1.8		29.9

(1) Net benefit in comparison with baseline

Sensitivity analysis shows that earlier implementation of the Directive (brought forward two years) will increase the benefit to the environment but will cost an additional £17 million (based on implementation scenario 1).

The study shows that increasing recycling of batteries is beneficial to the environment. However, it is achieved at significant financial cost when compared with disposal.

A key limitation of the study was the use of secondary data to quantify the avoided burdens of primary material production through recycling. The increasing age of secondary data and limitations found with regard to meta data suggest a need for a Europe wide programme to maintain and improve LCI data for use in studies such as this.

8 REFERENCES

BUWAL 250. "Oekoinventare für Verpackungen", Schriftenreihe Umwelt Nr. 250, part 1+2, second edition, (German language), BUWAL, Bern, CH.

Ecoinvent-Report No. 6. Jungbluth N. (2003) Erdöl. In: Sachbilanzen von Energiesystemen: Grundlagen für den ökologischen Vergleich von Energiesystemen und den Einbezug von Energiesystemen in Ökobilanzen für die Schweiz (ed. Dones R.). Final report ecoinvent 2000 No. 6, Paul Scherrer Institut Villigen, Swiss Centre for Life Cycle Inventories, Duebendorf, CH.

Ecoinvent-Report No. 7. Kellenberger D., Althaus H.-J. and Jungbluth N. (2004) Life Cycle Inventories of Building Products. Final report ecoinvent 2000 No. 7, Swiss Centre for Life Cycle Inventories, Duebendorf, CH.

Ecoinvent-Report No. 8. Althaus H.-J., Chudacoff M., Hischier R., Jungbluth N., Primas A. and Osses M. (2004) Life Cycle Inventories of Chemicals. Final report ecoinvent 2000 No. 8, Swiss Centre for Life Cycle Inventories, Duebendorf, CH.

Ecoinvent-Report No. 10. Althaus H.-J., Blaser S., Classen M., Jungbluth N. (2004) Life Cycle Inventories of Metals. Final report ecoinvent 2000 No. 10, Swiss Centre for Life Cycle Inventories, Duebendorf, CH.

Ecoinvent-Report No. 11. Hischier R. (2004) Life Cycle Inventories of Packaging and Graphical Paper. Final report ecoinvent 2000 No. 11, Swiss Centre for Life Cycle Inventories, Duebendorf, CH.

Ecoinvent-Report No. 12. Zah R., Hischier R. (2004) Life Cycle Inventories of Detergents. Final report ecoinvent 2000 No. 12, Swiss Centre for Life Cycle Inventories, Duebendorf, CH.

Ecoinvent-Report No. 13. Doka G. (2003) Life Cycle Inventories of Waste Treatment Services. Final report ecoinvent 2000 No. 13, EMPA St. Gallen, Swiss Centre for Life Cycle Inventories, Duebendorf, CH.

Ecoinvent-Report No. 14. Spielmann M., Kägi T. and Tietje O. (2004) Life Cycle Inventories of Transport Services. Final report ecoinvent 2000 No. 14, Swiss Centre for Life Cycle Inventories, Duebendorf, CH.

ETH-ESU (1996). Frischknecht et al (1996), Ökoinventare von Energiesystemen, ETH Zurich/PSI Villigen, 3rd edition, ENET, Bern, CH.

KEMNA (1) 1981. Energiebewust ontwerpen. Kemna, RBJ. (1981). Energiebewust ontwerpen, Delft, Netherlands.

Metals and minerals (1989), Metal resources (1983). Available in the IDEMAT database. Data collection from various sources supervised by Dr. Han Remmerswaal, Faculty of Industrial Design Engineering, Delft Technical University, The Netherlands.

SPIN Galvanic Treatment 1992. Galvanische bewerkingen, SPIN rapport, RIVM, Bilthoven, Netherlands.

Annex A

UK Battery Collection Schemes

A1.1 UK BATTERY COLLECTION SCHEMES

ERM investigated the details of the following collection services to inform the development of the collection models outlined in the Goal and Scope document:

- The Bristol scheme (one year trial) saw batteries collected in paper bags through an existing multi material black box service operated for 160,000 households in the BS1 – BS16 area. The batteries had been sent for reprocessing at Avonmouth-based Britannia Zinc until February 2003 when the plant closed down. This left the UK with no remaining plants where battery recycling could be carried out, so a new deal was brokered with Wolverhampton-based G&P Batteries which saw the batteries sent to France for recycling.

- Bath and North East Somerset offer collection services for waste batteries as part of the council's existing multi-material kerbside recycling service. The council's waste management contractor ECT Recycling collect the batteries via the green box scheme, which are then sent to France for reprocessing.

- Barnet's kerbside recycling scheme collects all types of batteries. ECT Recycling collect the batteries.

- West Sussex county council has opened battery recycling points at 11 of its household waste recycling centres which are run by Viridor Waste Management. Each site is expected to take in 200-300kg of household batteries per year with householders placing these in 40kg capacity collection containers. Batteries from all the sites are then tipped into three larger containers at a Viridor site. These are then collected three times a year by battery reprocess or G&P Batteries Ltd and will be taken to the company's new facility at West Bromwich.

- In a similar scheme, Suffolk county council has introduced battery recycling containers at 18 civic amenity sites across the county. The sites are again run by Viridor Waste Management, who, in the same way, bulk the batteries in one-tonne bins at a central site, prior to collection by G&P Batteries.

- Lancashire Waste Partnership has introduced a household battery-recycling scheme for primary schools; 100 primary schools have been given two collections tubes in which to collect the used batteries in. These tubes hold approx 400 household batteries, the batteries will be collected every half term and recycled.

- Onyx, in partnership with Sheffield city council, has introduced battery facilities at the city's five household waste recycling centres, which will then be sent to G&P Batteries for recycling.

- G&P Batteries has been entering agreements with various cities and companies across the UK to collect batteries. As well as Sheffield and Bristol, G&P also has agreements with Bedford, Gloucester and parts of London, among others.

- Some regional based retailers have set up schemes, although these are few and far between. Businesses can contact RABBITT Recycling or G&P Batteries for further information on collections for recycling.

- Rechargeable batteries can also be recycled once they have reached the end of their useful lives. REBAT was set up in 1998 to manage and collect the main types of portable rechargeable batteries in the UK.

Annex B

Impact Assessment Method (Includes Characterisation Factors)

B1 INTRODUCTION

Extracted From Simapro

Name CML 2 baseline 2000 ERM Correction Acidification: NOx attributed a CF factor

Comment This method is an update from the CML 1992 method. This version is based on the spreadsheet version 2.02 (September 2001) as published on the CML web site and replaces the preliminary version.

The CML 2 baseline method elaborates the problem-oriented (midpoint) approach. The CML Guide provides a list of impact assessment categories grouped into
A: Obligatory impact categories (Category indicators used in most LCAs)
B: Additional impact categories (operational indicators exist, but are not often included in LCA studies)

C: Other impact categories (no operational indicators available, therefore impossible to include quantitatively in LCA)

In case several methods are available for obligatory impact categories, a baseline indicator is selected, based on the principle of best available practice. These baseline indicators are category indicators at "mid-point level" (problem oriented approach)". Baseline indicators are recommended for simplified studies. The guide provides guidelines for inclusion of other methods and impact category indicators in case of detailed studies and extended studies.
Only baseline indicators are available in the CML method in SimaPro (based on CML Excel spreadsheet with characterisation and normalisation factors). In general, these indicators do not deviate from the ones in the spreadsheet. In case the spreadsheet contained synonyms of substance names already available in the substance list of the SimaPro database, the existing names are used. A distinction is made for emissions to agricultural soil and industrial soil, indicated with respectively (agr.) or (ind.) behind substance names emitted to soil. Emissions to seawater are indicated with (sea), while emissions to fresh water have no addition behind their substance name (we assume that all emissions to water in existing process records are emissions to fresh water).

Depletion of abiotic resources
This impact category indicator is related to extraction of minerals and fossil fuels due to inputs in the system. The Abiotic Depletion Factor (ADF) is determined for each extraction of minerals and fossil fuels (kg antimony equivalents/kg extraction) based on concentration reserves and rate of deaccumulation.

Climate change
The characterisation model as developed by the Intergovernmental Panel on Climate Change (IPCC) is selected for development of characterisation factors. Factors are expressed as Global Warming Potential for time horizon 100 years (GWP100), in kg carbon dioxide/kg emission.

Stratospheric Ozone depletion
The characterisation model is developed by the World Meteorological Organisation (WMO) and defines ozone depletion potential of different gasses (kg CFC-11 equivalent/ kg emission).

Human toxicity
Characterisation factors, expressed as Human Toxicity Potentials (HTP), are calculated with USES-LCA, describing fate, exposure and effects of toxic substances for an infinite time horizon. For each toxic substance HTP's are expressed as 1,4-dichlorobenzene equivalents/ kg emission.

Fresh-water aquatic eco-toxicity
Eco-toxicity Potential (FAETP) are calculated with USES-LCA, describing fate, exposure and effects of toxic substances. Characterisation factors are expressed as 1,4-dichlorobenzene equivalents/ kg emission.

Marine aquatic ecotoxicity
Marine eco-toxicity refers to impacts of toxic substances on marine ecosystems (see description fresh water toxicity).

Terrestrial ecotoxicity

This category refers to impacts of toxic substances on terrestrial ecosystems (see description fresh water toxicity).

Photo-oxidant formation
Photochemical Ozone Creation Potential (POCP) (also known as summer smog) for emission of substances to air is calculated with the UNECE Trajectory model (including fate), and expressed in kg ethylene equivalents/kg emission. Acidification
Acidification Potentials (AP) is expressed as kg SO2 equivalents/ kg emission.

Eutrophication
Nutrification potential (NP) is based on the stoichiometric procedure of Heijungs (1992), and expressed as kg PO4 equivalents/ kg emission. Normalisation
For each baseline indicator, normalisation scores are calculated for the reference situations: the world in 1990, Europe in 1995 and the Netherlands in 1997. Normalisation data are described in the report: Huijbregts et al LCA normalisation data for the Netherlands (1997/1998), Western Europe (1995) and the World (1990 and 1995).

Grouping and weighting
Grouping and weighting are considered to be optional step. No baseline recommended rules or values are given for these steps. Based on the reports:
"Life Cycle Assessment. An operational Guide to ISO Standards" Centre of Environmental Science (CML), Leiden University, the Netherlands. Download from http://www.leidenuniv.nl/cml/lca2/index.html.

May 01 Characterisation for sum parameters metals added. October 2001 Version 2.02 update.

B1.1 ABIOTIC DEPLETION

Impact category	**Abiotic resource depletion**	**kg Sb eq**	
Raw	aluminium (in ore)	kg	0.00000001
Raw	argon	kg	0.000000471
Raw	bauxite	kg	2.1E-09
Raw	chromium (in ore)	kg	0.000858
Raw	chromium (ore)	kg	0.000257522
Raw	coal	kg	0.0134
Raw	coal ETH	kg	0.0134
Raw	coal FAL	kg	0.0134
Raw	cobalt (in ore)	kg	0.0000262
Raw	copper (in ore)	kg	0.00194
Raw	copper (ore)	kg	2.19642E-05
Raw	crude oil	kg	0.0201
Raw	crude oil (feedstock)	kg	0.0201
Raw	crude oil ETH	kg	0.0201
Raw	crude oil FAL	kg	0.0201
Raw	crude oil IDEMAT	kg	0.0201
Raw	energy from coal	MJ	0.000457
Raw	energy from lignite	MJ	0.000671
Raw	energy from natural gas	MJ	0.000534
Raw	energy from oil	MJ	0.00049
Raw	iron (in ore)	kg	8.43E-08
Raw	iron (ore)	kg	0.000000048
Raw	lead (in ore)	kg	0.0135
Raw	lead (ore)	kg	0.000676957
Raw	lignite	kg	0.00671
Raw	lignite ETH	kg	0.00671
Raw	magnesium (in ore)	kg	3.73E-09
Raw	manganese (in ore)	kg	0.0000138
Raw	manganese (ore)	kg	0.0000062
Raw	mercury (in ore)	kg	0.495
Raw	molybdene (in ore)	kg	0.0317
Raw	molybdenum (ore)	kg	3.16646E-05
Raw	natural gas	kg	0.0225
Raw	natural gas (feedstock)	m3	0.0187
Raw	natural gas (vol)	m3	0.0187
Raw	natural gas ETH	m3	0.0187
Raw	natural gas FAL	kg	0.0225
Raw	nickel (in ore)	kg	0.000108
Raw	nickel (ore)	kg	1.61394E-06
Raw	palladium (in ore)	kg	0.323
Raw	platinum (in ore)	kg	1.29
Raw	K	kg	3.13E-08
Raw	silicon	kg	2.99E-11
Raw	silver	kg	1.84
Raw	sulphur	kg	0.000358
Raw	tin (in ore)	kg	0.033
Raw	tin (ore)	kg	0.0000033
Raw	uranium (in ore)	kg	0.00287
Raw	uranium FAL	kg	0.00287
Raw	zinc (in ore)	kg	0.000992
Raw	zinc (ore)	kg	3.94812E-05
Raw	polonium (in ore)	kg	4.79E+14
Raw	krypton	kg	20.9

Impact category	Abiotic resource depletion	kg Sb eq	
Raw	protactinium (in ore)	kg	9770000
Raw	radon	kg	1.2E+20
Raw	xenon	kg	17500
Raw	radium (in ore)	kg	23600000
Raw	calcium (Ca)	kg	7.08E-10
Raw	actinium (in ore)	kg	6.33E+13
Raw	thulium (in ore)	kg	0.0000831
Raw	vanadium (in ore)	kg	0.00000116
Raw	erbium (in ore)	kg	0.00000244
Raw	praseodymium (in ore)	kg	0.000000285
Raw	niobium (in ore)	kg	0.0000231
Raw	holmium (in ore)	kg	0.0000133
Raw	lutetium (in ore)	kg	0.0000766
Raw	bismuth (in ore)	kg	0.0731
Raw	F	kg	0.00000296
Raw	thorium (in ore)	kg	0.000000208
Raw	lanthanum (in ore)	kg	2.13E-08
Raw	thallium (in ore)	kg	0.0000505
Raw	iridium (in ore)	kg	32.3
Raw	rubidium (in ore)	kg	2.36E-09
Raw	arsenic (in ore)	kg	0.00917
Raw	osmium (in ore)	kg	14.4
Raw	ruthenium (in ore)	kg	32.3
Raw	cadmium (in ore)	kg	0.33
Raw	ytterbium (in ore)	kg	0.00000213
Raw	Na	kg	8.24E-11
Raw	hafnium (in ore)	kg	0.000000867
Raw	tantalum (in ore)	kg	0.0000677
Raw	gadolinium (in ore)	kg	0.000000657
Raw	neon	kg	0.325
Raw	lithium (in ore)	kg	0.00000923
Raw	strontium (in ore)	kg	0.00000112
Raw	cesium (in ore)	kg	0.0000191
Raw	dysprosium (in ore)	kg	0.00000213
Raw	antimony (in ore)	kg	1
Raw	gallium (in ore)	kg	0.000000103
Raw	samarium (in ore)	kg	0.000000532
Raw	terbium (in ore)	kg	0.0000236
Raw	boron (in ore)	kg	0.00467
Raw	indium (in ore)	kg	0.00903
Raw	phosphor (in ore)	kg	0.0000844
Raw	helium	kg	148
Raw	germanium (in ore)	kg	0.00000147
Raw	titanium (in ore)	kg	0.000000044
Raw	scandium (in ore)	kg	3.96E-08
Raw	europium (in ore)	kg	0.0000133
Raw	barium (in ore)	kg	1.06E-10
Raw	tellerium (in ore)	kg	52.8
Raw	selenium (in ore)	kg	0.475
Raw	I	kg	0.0427
Raw	neodymium (in ore)	kg	1.94E-17
Raw	Cl	kg	4.86E-08
Raw	zirconium (in ore)	kg	0.0000186
Raw	beryllium (in ore)	kg	0.0000319
Raw	yttrium (in ore)	kg	0.000000334
Raw	tungsten (in ore)	kg	0.0117
Raw	gold (in ore)	kg	89.5
Raw	cerium (in ore)	kg	5.32E-09
Raw	Br	kg	0.00667
Raw	natural gas (feedstock) FAL	kg	0.0225
Raw	crude oil (feedstock) FAL	kg	0.0201
Raw	coal (feedstock) FAL	kg	0.0134
Raw	uranium (in ore) ETH	kg	0.00287
Raw	rhodium (in ore)	kg	32.3
Raw	rhenium (in ore)	kg	0.766

B1.2 GLOBAL WARMING POTENTIAL

Impact category	Global warming (GWP100)		kg CO2 eq
Air	1,1,1-trichloroethane	kg	110
Air	CFC-14	kg	6500
Air	CFC-11	kg	4000
Air	CFC-113	kg	5000
Air	CFC-114	kg	9300
Air	CFC-115	kg	9300
Air	CFC-116	kg	9200
Air	CFC-12	kg	8500
Air	CFC-13	kg	11700
Air	CO2	kg	1
Air	CO2 (fossil)	kg	1
Air	dichloromethane	kg	9
Air	HALON-1301	kg	5600
Air	HCFC-123	kg	93
Air	HCFC-124	kg	480
Air	HCFC-141b	kg	630
Air	HCFC-142b	kg	2000
Air	HCFC-22	kg	1700
Air	HCFC-225ca	kg	170
Air	HCFC-225cb	kg	530
Air	HFC-125	kg	2800
Air	HFC-134	kg	1000
Air	HFC-134a	kg	1300
Air	HFC-143	kg	300
Air	HFC-143a	kg	3800
Air	HFC-152a	kg	140
Air	HFC-227ea	kg	2900
Air	HFC-23	kg	11700
Air	HFC-236fa	kg	6300
Air	HFC-245ca	kg	560

Impact category	Global warming (GWP100)		kg CO2 eq
Air	HFC-32	kg	650
Air	HFC-41	kg	13000
Air	HFC-4310mee	kg	1300
Air	methane	kg	21
Air	N2O	kg	310
Air	perfluorbutane	kg	7000
Air	perfluorcyclobutane	kg	8700
Air	perfluorhexane	kg	7400
Air	perfluorpentane	kg	7500
Air	perfluorpropane	kg	7000
Air	SF6	kg	23900
Air	tetrachloromethane	kg	1400
Air	trichloromethane	kg	4

B1.3 *OZONE LAYER DEPLETION*

Impact category	Ozone layer depletion (ODP)	kg CFC-11 eq	
Air	1,1,1-trichloroethane	kg	0.11
Air	CFC-11	kg	1
Air	CFC-113	kg	0.9
Air	CFC-114	kg	0.85
Air	CFC-115	kg	0.4
Air	CFC-12	kg	0.82
Air	HALON-1201	kg	1.4
Air	HALON-1202	kg	1.25
Air	HALON-1211	kg	5.1
Air	HALON-1301	kg	12
Air	HALON-2311	kg	0.14
Air	HALON-2401	kg	0.25
Air	HALON-2402	kg	7
Air	HCFC-123	kg	0.012
Air	HCFC-124	kg	0.026
Air	HCFC-141b	kg	0.086
Air	HCFC-142b	kg	0.043
Air	HCFC-22	kg	0.034
Air	HCFC-225ca	kg	0.017
Air	HCFC-225cb	kg	0.017
Air	methyl bromide	kg	0.37
Air	methyl chloride	kg	0.02
Air	tetrachloromethane	kg	1.2

B1.4 *HUMAN TOXICITY*

Impact category	x Human toxicity	kg 1,4-DB eq	
Air	1,1,1-trichloroethane	kg	16
Air	1,2,3-trichlorobenzene	kg	130
Air	1,2,4-trichlorobenzene	kg	120
Air	1,2-dichloroethane	kg	6.8
Air	1,3,5-trichlorobenzene	kg	120
Air	1,3-butadiene	kg	2200
Air	2,4,6-trichlorophenol	kg	14000
Air	2,4-D	kg	6.6
Air	acrolein	kg	57
Air	acrylonitrile	kg	3400
Air	Aldrin	kg	19
Air	ammonia	kg	0.1
Air	As	kg	350000
Air	Atrazine	kg	4.5
Air	Azinphos-methyl	kg	14
Air	Ba	kg	760
Air	Be	kg	230000
Air	Bentazon	kg	2.1
Air	benzene	kg	1900
Air	benzylchloride	kg	3500
Air	Carbendazim	kg	19
Air	Cd	kg	150000
Air	cobalt	kg	17000
Air	Cr (III)	kg	650
Air	Cr (VI)	kg	3400000
Air	CS2	kg	2.4
Air	Cu	kg	4300
Air	di(2-ethylhexyl)phthalate	kg	2.6
Air	dibutylphthalate	kg	25
Air	dichloromethane	kg	2
Air	Dichlorvos	kg	100
Air	Dieldrin	kg	13000
Air	dioxin (TEQ)	kg	1900000000
Air	Diuron	kg	210
Air	DNOC	kg	160
Air	dust (PM10)	kg	0.82
Air	ethene	kg	0.64
Air	ethylbenzene	kg	0.97
Air	ethylene oxide	kg	14000
Air	Fentin-acetate	kg	2200
Air	formaldehyde	kg	0.83
Air	H2S	kg	0.22
Air	HCl	kg	0.5
Air	heavy metals	kg	1634
Air	hexachlorobenzene	kg	3200000
Air	HF	kg	2900
Air	Hg	kg	6000
Air	m-xylene	kg	0.027
Air	Malathion	kg	0.035
Air	Mecoprop	kg	120
Air	Metabenzthiazuron	kg	7.1
Air	metals	kg	1634
Air	Metamitron	kg	0.88
Air	methyl bromide	kg	350
Air	Mevinfos	kg	1
Air	Mo	kg	5400

Impact category	x Human toxicity	kg 1,4-DB eq	
Air	naphthalene	kg	8.1
Air	Ni	kg	35000
Air	NO2	kg	1.2
Air	NOx (as NO2)	kg	1.2
Air	o-xylene	kg	0.12
Air	p-xylene	kg	0.043
Air	PAH's	kg	570000
Air	Pb	kg	470
Air	pentachlorophenol	kg	5.1
Air	phenol	kg	0.52
Air	phthalic acid anhydride	kg	0.41
Air	propyleneoxide	kg	1300
Air	Sb	kg	6700
Air	Se	kg	48000
Air	Simazine	kg	33
Air	Sn	kg	1.7
Air	SO2	kg	0.096
Air	styrene	kg	0.047
Air	tetrachloroethene	kg	5.5
Air	tetrachloromethane	kg	220
Air	Thiram	kg	19
Air	Tl	kg	430000
Air	toluene	kg	0.33
Air	trichloroethene	kg	34
Air	trichloromethane	kg	13
Air	Trifluralin	kg	1.7
Air	V	kg	6200
Air	vinyl chloride	kg	84
Air	Zn	kg	100
Water	1,2,3-trichlorobenzene	kg	130
Water	1,2,4-trichlorobenzene	kg	120
Water	1,2-dichloroethane	kg	28
Water	1,3,5-trichlorobenzene	kg	120
Water	1,3-butadiene	kg	7000
Water	2,4,6-trichlorophenol	kg	9100
Water	2,4-D	kg	3.5
Water	acrylonitrile	kg	7100
Water	Aldrin	kg	6000
Water	As	kg	950
Water	Atrazine	kg	4.6
Water	Azinphos-methyl	kg	2.5
Water	Ba	kg	630
Water	Be	kg	14000
Water	Bentazon	kg	0.73
Water	benzene	kg	1800
Water	benzylchloride	kg	2400
Water	Carbendazim	kg	2.5
Water	Cd	kg	23
Water	Co	kg	97
Water	Cr (III)	kg	2.1
Water	Cr (VI)	kg	3.4
Water	Cu	kg	1.3
Water	di(2-ethylhexyl)phthalate	kg	0.91
Water	dibutylphthalate	kg	0.54
Water	dichloromethane	kg	1.8
Water	Dichlorvos	kg	0.34
Water	Dieldrin	kg	45000
Water	dioxins (TEQ)	kg	860000000
Water	Diuron	kg	53
Water	DNOC	kg	59
Water	ethyl benzene	kg	0.83
Water	ethylene oxide	kg	11000
Water	formaldehyde	kg	0.037
Water	hexachlorobenzene	kg	5600000
Water	Hg	kg	1400
Water	Malathion	kg	0.24
Water	Mecoprop	kg	200
Water	metallic ions	kg	3.511
Water	Metamitron	kg	0.16
Water	Mevinfos	kg	11
Water	Mo	kg	5500
Water	Ni	kg	330
Water	PAH's	kg	280000
Water	Pb	kg	12
Water	pentachlorophenol	kg	7.2
Water	phenol	kg	0.049
Water	propylene oxide	kg	2600
Water	Sb	kg	5100
Water	Se	kg	56000
Water	Simazine	kg	9.7
Water	Sn	kg	0.017
Water	styrene	kg	0.085
Water	tetrachloroethene	kg	5.7
Water	tetrachloromethane	kg	220
Water	Thiram	kg	3.3
Water	toluene	kg	0.3
Water	trichloroethene	kg	33
Water	trichloromethane	kg	13
Water	Trifluralin	kg	97
Water	V	kg	3200
Water	vinyl chloride	kg	140
Water	Zn	kg	0.58
Soil	1,2,3-trichlorobenzene (ind.)	kg	54
Soil	1,2,4-trichlorobenzene (ind.)	kg	43
Soil	1,2-dichloroethane (ind.)	kg	5.7
Soil	1,3,5-trichlorobenzene (ind.)	kg	52
Soil	1,3-butadiene (ind.)	kg	2200
Soil	2,4,6-trichlorophenol (ind.)	kg	170
Soil	2,4-D (agr.)	kg	47
Soil	acrylonitrile (ind.)	kg	1500
Soil	Aldrin (agr.)	kg	4700
Soil	As (ind.)	kg	1000
Soil	Atrazine (agr.)	kg	21
Soil	Azinphos-methyl (agr.)	kg	39
Soil	Bentazon (agr.)	kg	15
Soil	benzene (ind.)	kg	1600
Soil	benzylchloride (ind.)	kg	490

Impact category	x Human toxicity	kg 1,4-DB eq	
Soil	Carbendazim (agr.)	kg	140
Soil	Cd (agr.)	kg	20000
Soil	Cd (ind.)	kg	67
Soil	Cr (III) (ind.)	kg	300
Soil	Cr (VI) (ind.)	kg	500
Soil	Cu (ind.)	kg	1.3
Soil	di(2-ethylhexyl)phthalate(ind)	kg	0.0052
Soil	dibutylphthalate (ind.)	kg	0.013
Soil	dichloromethane (ind.)	kg	1.3
Soil	Dichlorvos (agr.)	kg	0.97
Soil	Dieldrin (agr.)	kg	7600
Soil	dioxin (TEQ) (ind.)	kg	10000000
Soil	Diuron (agr.)	kg	1300
Soil	DNOC (agr.)	kg	280
Soil	ethylene oxide (ind.)	kg	4600
Soil	formaldehyde (ind.)	kg	0.019
Soil	gamma-HCH (Lindane) (agr.)	kg	490
Soil	hexachlorobenzene (ind.)	kg	1300000
Soil	Hg (ind.)	kg	1100
Soil	Malathion (agr.)	kg	0.026
Soil	Mecoprop (agr.)	kg	740
Soil	Metamitron (agr.)	kg	6.5
Soil	Mevinfos (agr.)	kg	5.7
Soil	Ni (ind.)	kg	200
Soil	Pb (ind.)	kg	290
Soil	pentachlorophenol (ind.)	kg	0.039
Soil	propylene oxide (ind.)	kg	590
Soil	Simazine (agr.)	kg	210
Soil	styrene (ind.)	kg	0.018
Soil	tetrachloroethene (ind.)	kg	5.2
Soil	tetrachloromethane (ind.)	kg	220
Soil	Thiram (agr.)	kg	7.9
Soil	toluene (ind.)	kg	0.21
Soil	trichloroethene (ind.)	kg	32
Soil	trichloromethane (ind.)	kg	10
Soil	vinyl chloride (ind.)	kg	83
Soil	Zn (ind.)	kg	0.42
Soil	phenol (agr.)	kg	1.9
Soil	Bentazon (ind.)	kg	0.16
Water	Fentin chloride (sea)	kg	12
Water	dihexylphthalate	kg	14000
Soil	Zineb (ind.)	kg	0.1
Soil	Iprodione (ind.)	kg	0.0032
Water	Fentin acetate	kg	880
Soil	Metolachlor (ind.)	kg	0.11
Soil	diethylphthalate (agr.)	kg	0.057
Water	Aldicarb	kg	61
Soil	Fenitrothion (ind.)	kg	0.32
Air	DDT	kg	110
Water	carbon disulfide	kg	2.4
Water	Dichlorvos (sea)	kg	0.0023
Soil	1,3,5-trichlorobenzene (agr.)	kg	69
Soil	2-chlorophenol (agr.)	kg	8.3
Air	Propachlor	kg	12
Soil	Captan (agr.)	kg	0.097
Water	toluene (sea)	kg	0.039
Soil	2,4-dichlorophenol (ind.)	kg	1.9
Air	Parathion-ethyl	kg	3.3
Soil	styrene (agr.)	kg	0.48
Soil	barium (agr.)	kg	360
Water	m-xylene	kg	0.34
Water	Parathion-methyl	kg	100
Water	Trichlorfon	kg	0.37
Soil	Demeton (agr.)	kg	5700
Water	Cypermethrin	kg	5.5
Soil	ethylene (ind.)	kg	0.62
Water	1,4-dichlorobenzene	kg	1.1
Water	Acephate (sea)	kg	0.00051
Soil	1,3-dichlorobenzene (agr.)	kg	250
Soil	benzylchloride (agr.)	kg	5500
Soil	Oxamyl (agr.)	kg	10
Air	tributyltinoxide	kg	7500
Water	Pirimicarb (sea)	kg	0.0013
Water	Methomyl	kg	3.3
Water	dimethylphthalate	kg	7.2
Air	hexachloro-1,3-butadiene	kg	79000
Soil	As (agr.)	kg	32000
Soil	2,3,4,6-tetrachlorophenol (ind.)	kg	1.6
Water	Dinoseb (sea)	kg	0.63
Water	Folpet (sea)	kg	0.31
Soil	Metazachlor (agr.)	kg	49
Water	o-xylene (sea)	kg	0.026
Soil	anilazine (agr.)	kg	0.08
Soil	diisodecylphthalate (agr.)	kg	110
Soil	Dichlorvos (ind.)	kg	0.036
Water	Anilazine	kg	0.24
Water	Metobromuron	kg	8
Soil	Azinphos-ethyl (agr.)	kg	760
Water	Aldicarb (sea)	kg	0.24
Soil	carbon disulfide (ind.)	kg	2.2
Water	Oxamyl	kg	0.36
Water	Chlorpyriphos (sea)	kg	0.038
Soil	Metazachlor (ind.)	kg	0.16
Air	2-chlorophenol	kg	22
Water	Fenthion (sea)	kg	0.46
Air	Tolclophos-methyl	kg	0.06
Soil	pentachlorobenzene (ind.)	kg	140
Air	dihexylphthalate	kg	7000
Soil	MCPA (agr.)	kg	100
Soil	Chlorpyriphos (ind.)	kg	0.14
Soil	Parathion-ethyl (agr.)	kg	2.9
Soil	Cyanazine (ind.)	kg	0.35
Soil	Glyphosate (ind.)	kg	0.00065
Air	Carbaryl	kg	3.2

Impact category	x Human toxicity	kg 1,4-DB eq	
Soil	Pyrazophos (agr.)	kg	51
Water	hexachloro-1,3-butadiene	kg	80000
Soil	benzene (agr.)	kg	15000
Water	Chlordane (sea)	kg	1200
Water	Dimethoate (sea)	kg	0.0033
Water	Iprodione (sea)	kg	0.00012
Soil	dioxin (TEQ) (agr.)	kg	1300000000
Water	Carbaryl	kg	4.7
Soil	Desmetryn (agr.)	kg	650
Water	Bifenthrin (sea)	kg	0.75
Water	1,2,3,4-tetrachlorobenzene	kg	160
Water	Heptenophos (sea)	kg	0.0023
Soil	Dinoseb (ind.)	kg	97
Air	cypermethrin	kg	170
Soil	Heptenophos (ind.)	kg	0.02
Air	1-chloro-4-nitrobenzene	kg	1200
Soil	Malathion (ind.)	kg	0.00095
Soil	para-xylene (agr.)	kg	3
Water	1,4-dichlorobenzene (sea)	kg	0.47
Soil	acrolein (ind.)	kg	17
Air	Glyphosate	kg	0.0031
Water	Glyphosate	kg	0.066
Water	2,3,4,6-tetrachlorophenol (sea)	kg	0.26
Water	1,2,3-trichlorobenzene (sea)	kg	62
Soil	Chlorothalonil (ind.)	kg	1
Soil	Acephate (ind.)	kg	0.31
Soil	Methabenzthiazuron (ind.)	kg	0.36
Water	1,2-dichlorobenzene (sea)	kg	4.1
Soil	naphtalene (ind.)	kg	1.6
Water	2,4-D (sea)	kg	0.000067
Soil	Dinoseb (agr.)	kg	560
Soil	diisooctylphthalate (ind.)	kg	0.052
Soil	methylbromide (ind.)	kg	260
Water	Demeton	kg	720
Soil	Aldicarb (agr.)	kg	510
Soil	Endrin (agr.)	kg	8400
Air	Heptenophos	kg	23
Soil	Folpet (ind.)	kg	1.5
Air	Chlorpropham	kg	0.34
Water	2,4-dichlorophenol (sea)	kg	0.065
Soil	Diuron (ind.)	kg	7.2
Soil	Acephate (agr.)	kg	22
Soil	1,1,1-trichloroethane (agr.)	kg	16
Soil	chlorobenzene (agr.)	kg	7.1
Water	Triazophos	kg	320
Soil	dihexylphthalate (ind.)	kg	14
Water	Mo (sea)	kg	6800
Water	Sb (sea)	kg	8600
Soil	Fenthion (agr.)	kg	30
Water	Oxamyl (sea)	kg	0.000014
Water	Fenthion	kg	93
Water	ethene (sea)	kg	0.047
Water	Bentazon (sea)	kg	0.0022
Water	Fentin hydroxide (sea)	kg	4.1
Air	1,2,4,5-tetrachlorobenzene	kg	35
Water	Cu (sea)	kg	5.9
Soil	Mevinfos (ind.)	kg	0.055
Water	1,2,3,5-tetrachlorobenzene	kg	92
Water	Iprodione	kg	0.18
Water	Ethoprophos	kg	1800
Water	diisodecylphthalate (sea)	kg	3.2
Water	methyl-mercury	kg	15000
Air	dinoseb	kg	3600
Soil	2,4,5-T (ind.)	kg	0.18
Soil	Methomyl (ind.)	kg	0.69
Soil	Triazophos (agr.)	kg	1200
Water	diisodecylphthalate	kg	19
Soil	Cyromazine (agr.)	kg	280
Soil	Thiram (ind.)	kg	0.25
Water	Co (sea)	kg	60
Soil	ethylbenzene (ind.)	kg	0.5
Water	propylene oxide (sea)	kg	16
Soil	vanadium (agr.)	kg	19000
Water	Dichlorprop (sea)	kg	0.097
Water	thallium	kg	230000
Water	Chlorothalonil (sea)	kg	0.45
Water	Triazophos (sea)	kg	1.6
Air	3-chloroaniline	kg	17000
Soil	bifenthrin (ind.)	kg	0.3
Water	tetrachloromethane (sea)	kg	170
Water	4-chloroaniline (sea)	kg	4
Water	Parathion-ethyl	kg	31
Air	Chlorpyriphos	kg	21
Soil	ethylene (agr.)	kg	0.78
Soil	pentachloronitrobenzene (agr.)	kg	72
Soil	Folpet (agr.)	kg	13
Soil	anthracene (ind.)	kg	0.02
Air	Parathion-methyl	kg	53
Air	Lindane	kg	610
Water	trichloroethene (sea)	kg	14
Water	Phoxim (sea)	kg	0.29
Soil	Heptachlor (agr.)	kg	670
Soil	Dimethoate (agr.)	kg	320
Water	Glyphosate (sea)	kg	0.000015
Water	3,4-dichloroaniline (sea)	kg	1.5
Soil	Metolachlor (agr.)	kg	11
Soil	Dichlorprop (ind.)	kg	0.26
Soil	1,4-dichlorobenzene (ind.)	kg	0.74
Soil	Chlordane (agr.)	kg	2800
Water	Linuron (sea)	kg	0.65
Air	Metobromuron	kg	55
Soil	toluene (agr.)	kg	0.35
Water	styrene (sea)	kg	0.01
Air	Oxamyl	kg	1.4
Water	Chloridazon (sea)	kg	0.0021

Impact category	x Human toxicity	kg 1,4-DB eq	
Soil	Dichlorprop (agr.)	kg	4.5
Water	Ethoprophos (sea)	kg	13
Soil	phenol (ind.)	kg	0.006
Soil	Parathion-methyl (ind.)	kg	1.7
Air	Chlordane	kg	6700
Soil	Fentin acetate (agr.)	kg	72
Water	Metamitron (sea)	kg	0.000032
Water	Methabenzthiazuron	kg	2.6
Air	Permethrin	kg	0.85
Soil	Pyrazophos (ind.)	kg	1.2
Soil	4-chloroaniline (ind.)	kg	510
Air	4-chloroaniline	kg	260
Soil	thallium (agr.)	kg	2000000
Air	Acephate	kg	3.1
Water	naphtalene	kg	5.6
Air	Metolachlor	kg	2.6
Water	benzylchloride (sea)	kg	55
Soil	Ethoprophos (agr.)	kg	5700
Air	Deltamethrin	kg	1.6
Soil	anilazine (ind.)	kg	0.0003
Soil	Dinoterb (ind.)	kg	0.12
Soil	Coumaphos (agr.)	kg	11000
Water	Permethrin (sea)	kg	0.26
Air	anilazine	kg	0.072
Water	1,2-dichloroethane (sea)	kg	5.5
Soil	tetrachloromethane (agr.)	kg	220
Soil	tributyltinoxide (ind.)	kg	43
Water	Pb (sea)	kg	79
Water	dioxins (TEQ) (sea)	kg	420000000
Water	naphtalene (sea)	kg	0.19
Soil	Propoxur (ind.)	kg	0.27
Soil	dibutylphthalate (agr.)	kg	1.3
Air	Ethoprophos	kg	1100
Soil	diethylphthalate (ind.)	kg	0.0033
Soil	Pirimicarb (ind.)	kg	0.29
Water	Metazachlor (sea)	kg	0.0024
Air	Dichlorprop	kg	1.1
Water	3-chloroaniline (sea)	kg	2.1
Water	p-xylene	kg	0.35
Water	butylbenzylphthalate (sea)	kg	0.00085
Water	V (sea)	kg	6200
Water	Chlordane	kg	740
Water	Cd (sea)	kg	100
Soil	acrylonitrile (agr.)	kg	490000
Soil	Co (agr.)	kg	2400
Soil	butylbenzylphthalate (ind.)	kg	0.0018
Water	Thiram (sea)	kg	0.00066
Soil	Endrin (ind.)	kg	750
Water	methyl-mercury (sea)	kg	88000
Soil	Carbendazim (ind.)	kg	0.43
Air	2,4,5-trichlorophenol	kg	8.3
Water	ethylene oxide (sea)	kg	540
Soil	Propoxur (agr.)	kg	270
Water	DDT (sea)	kg	34
Water	Deltamethrin (sea)	kg	0.033
Water	benzene (sea)	kg	210
Soil	antimony (agr.)	kg	8900
Soil	diisooctylphthalate (agr.)	kg	32
Soil	Dieldrin (ind.)	kg	1500
Water	dioctylphthalate (sea)	kg	1.3
Water	Chlorpropham (sea)	kg	0.0043
Air	Pyrazophos	kg	25
Air	Triazophos	kg	210
Air	Oxydemethon-methyl	kg	120
Soil	dioctylphthalate (agr.)	kg	8.6
Soil	Oxamyl (ind.)	kg	0.068
Soil	pentachlorophenol (agr.)	kg	0.15
Soil	Linuron (ind.)	kg	9.4
Soil	Chloridazon (ind.)	kg	0.02
Water	Endosulfan (sea)	kg	0.042
Soil	propylene oxide (agr.)	kg	220000
Soil	Atrazine (ind.)	kg	0.88
Soil	Pb (agr.)	kg	3300
Soil	2,4-dichlorophenol (agr.)	kg	740
Water	Chlorfenvinphos (sea)	kg	3.8
Soil	Metamitron (ind.)	kg	0.012
Water	hexachlorobenzene (sea)	kg	3400000
Water	o-xylene	kg	0.42
Water	Fenitrothion (sea)	kg	0.09
Water	Coumaphos (sea)	kg	220
Water	Ni (sea)	kg	750
Soil	PAH (carcinogenic) (agr.)	kg	71000
Soil	Cyanazine (agr.)	kg	24
Soil	Zineb (agr.)	kg	20
Soil	ethylbenzene (agr.)	kg	0.75
Soil	hexachloro-1,3-butadiene (agr.)	kg	30000
Soil	Azinphos-methyl (ind.)	kg	0.099
Air	butylbenzylphthalate	kg	10
Water	Tri-allate (sea)	kg	1.2
Water	pentachlorophenol (sea)	kg	0.14
Water	Mecoprop (sea)	kg	0.84
Soil	dimethylphthalate (ind.)	kg	0.27
Water	1,2,3,4-tetrachlorobenzene (sea)	kg	30
Water	Methabenzthiazuron (sea)	kg	0.0082
Soil	Tolclophos-methyl (agr.)	kg	11
Soil	Aldicarb (ind.)	kg	13
Air	pentachloronitrobenzene	kg	190
Soil	hexachloro-1,3-butadiene (ind.)	kg	35000
Soil	hexachlorobenzene (agr.)	kg	33000000
Soil	vanadium (ind.)	kg	1700
Soil	bifenthrin (agr.)	kg	29
Soil	trichloroethene (agr.)	kg	32
Soil	DDT (agr.)	kg	270
Water	Captafol (sea)	kg	9.7

Impact category	x Human toxicity	kg 1,4-DB eq	
Water	Methomyl (sea)	kg	0.0014
Soil	Deltamethrin (ind.)	kg	0.03
Water	phthalic anhydride	kg	0.00011
Soil	1,2-dichloroethane (agr.)	kg	1300
Water	diethylphthalate	kg	0.14
Soil	Cu (agr.)	kg	94
Water	dimethylphthalate (sea)	kg	0.0084
Soil	Benomyl (ind.)	kg	0.0011
Water	Permethrin	kg	23
Soil	1,2,3,4-tetrachlorobenzene (agr.)	kg	80
Air	diazinon	kg	59
Water	Folpet	kg	8.6
Soil	Cr (III) (agr.)	kg	5100
Air	2,3,4,6-tetrachlorophenol	kg	290
Soil	Chloridazon (agr.)	kg	2.2
Soil	Fentin hydroxide (agr.)	kg	88
Water	Parathion-methyl (sea)	kg	0.54
Air	methomyl	kg	6.2
Water	Propoxur	kg	1.3
Soil	meta-xylene (ind.)	kg	0.019
Water	Deltamethrin	kg	2.8
Soil	Dimethoate (ind.)	kg	3
Water	1-chloro-4-nitrobenzene (sea)	kg	220
Water	methylbromide	kg	300
Water	PAH (sea)	kg	29000
Soil	Oxydemethon-methyl (ind.)	kg	3.8
Soil	Chlorothalonil (agr.)	kg	0.94
Water	1,2,4-trichlorobenzene (sea)	kg	56
Water	1,3-dichlorobenzene	kg	74
Soil	3,4-dichloroaniline (ind.)	kg	31
Water	thallium (sea)	kg	290000
Water	Dinoseb	kg	160
Air	anthracene	kg	0.52
Water	Mevinfos (sea)	kg	0.0018
Soil	Triazophos (ind.)	kg	37
Water	Isoproturon	kg	13
Water	tributyltinoxide (sea)	kg	55
Water	1,3-dichlorobenzene (sea)	kg	30
Water	HF (sea)	kg	3600
Water	Azinphos-methyl (sea)	kg	0.0057
Air	Bifenthrin	kg	19
Air	diethylphthalate	kg	0.32
Soil	Aldrin (ind.)	kg	160
Water	diethylphthalate (sea)	kg	0.00057
Water	2,4,5-T	kg	1.9
Water	Hg (sea)	kg	8200
Water	Cypermethrin (sea)	kg	0.026
Soil	trichloromethane (agr.)	kg	14
Water	Trichlorfon (sea)	kg	0.000031
Soil	Mecoprop (ind.)	kg	42
Air	Iprodione	kg	0.28
Water	Chlorpyriphos	kg	44
Soil	Benomyl (agr.)	kg	0.43
Soil	Chlordane (ind.)	kg	27
Soil	3-chloroaniline (agr.)	kg	30000
Soil	Ni (agr.)	kg	2700
Soil	Fenthion (ind.)	kg	1.5
Water	Lindane	kg	830
Soil	1,2,3-trichlorobenzene (agr.)	kg	56
Soil	tin (agr.)	kg	13
Water	Captafol	kg	500
Water	Cr (VI) (sea)	kg	17
Water	Chlorfenvinphos	kg	810
Air	tri-allate	kg	9.7
Soil	Trichlorfon (ind.)	kg	0.02
Air	pentachlorobenzene	kg	410
Air	2,4,5-T	kg	0.89
Soil	selenium (ind.)	kg	28000
Air	1,2,3,5-tetrachlorobenzene	kg	46
Water	dibutylphthalate (sea)	kg	0.003
Water	Cr (III) (sea)	kg	10
Air	chlorobenzene	kg	9.2
Soil	Fentin chloride (agr.)	kg	130
Soil	Simazine (ind.)	kg	2.2
Soil	1,2,3,5-tetrachlorobenzene (ind.)	kg	14
Soil	methylbromide (agr.)	kg	260
Water	Parathion-ethyl (sea)	kg	0.18
Soil	Pirimicarb (agr.)	kg	26
Water	Pyrazophos	kg	53
Soil	1,2,4-trichlorobenzene (agr.)	kg	42
Water	trichloromethane (sea)	kg	6
Air	Captafol	kg	87
Soil	Propachlor (ind.)	kg	0.14
Air	Endrin	kg	1200
Soil	Fentin chloride (ind.)	kg	13
Soil	thallium (ind.)	kg	120000
Air	Fentin hydroxide	kg	850
Soil	1,2,3,5-tetrachlorobenzene (agr.)	kg	180
Air	Desmetryn	kg	95
Soil	Iprodione (agr.)	kg	1.8
Air	Pirimicarb	kg	3.4
Air	MCPA	kg	15
Soil	Tri-allate (agr.)	kg	5.8
Soil	dioctylphthalate (ind.)	kg	0.0088
Water	1-chloro-4-nitrobenzene	kg	1700
Water	vinyl chloride (sea)	kg	43
Water	Fentin hydroxide	kg	870
Soil	gamma-HCH (Lindane) (ind.)	kg	52
Soil	butylbenzylphthalate (agr.)	kg	0.31
Air	coumaphos	kg	780
Soil	Isoproturon (ind.)	kg	2.8
Soil	Captafol (agr.)	kg	960

Impact category	x Human toxicity	kg 1,4-DB eq	
Water	phenol (sea)	kg	0.00008
Water	Diazinon (sea)	kg	0.27
Water	diisooctylphthalate	kg	18
Soil	antimony (ind.)	kg	2600
Water	Captan (sea)	kg	0.0000054
Water	Cyromazine (sea)	kg	0.0026
Air	3,4-dichloroaniline	kg	220
Water	Metobromuron (sea)	kg	0.076
Soil	Trichlorfon (agr.)	kg	33
Soil	Chlorpyriphos (agr.)	kg	14
Soil	Desmetryn (ind.)	kg	2.9
Water	pentachloronitrobenzene (sea)	kg	46
Soil	2,4,5-trichlorophenol (ind.)	kg	2.9
Water	Anilazine (sea)	kg	0.00082
Water	1,2,3,5-tetrachlorobenzene (sea)	kg	25
Air	dioctylphthalate	kg	19
Air	1,2,3,4-tetrachlorobenzene	kg	50
Water	Trifluralin (sea)	kg	6
Soil	1,2-dichlorobenzene (agr.)	kg	7.3
Soil	Diazinon (agr.)	kg	120
Soil	methyl-mercury (agr.)	kg	20000
Air	1,2-dichlorobenzene	kg	9.1
Water	Be (sea)	kg	16000
Soil	di(2-ethylhexyl)phthalate (agr.)	kg	1.8
Air	Metazachlor	kg	6.8
Soil	2-chlorophenol (ind.)	kg	1.4
Water	HF	kg	3600
Water	Tolclophos-methyl (sea)	kg	0.065
Soil	Chlorpropham (ind.)	kg	0.081
Soil	Co (ind.)	kg	59
Water	Metazachlor	kg	1.7
Soil	Fentin acetate (ind.)	kg	9.2
Water	Cyromazine	kg	5.4
Water	1,3,5-trichlorobenzene (sea)	kg	54
Soil	Dinoterb (agr.)	kg	0.36
Air	Disulfothon	kg	290
Water	phthalic anhydride (sea)	kg	0.0000001
Soil	methyl-mercury (ind.)	kg	11000
Soil	Tolclophos-methyl (ind.)	kg	0.04
Water	Desmetryn	kg	50
Water	Chlorothalonil	kg	6.7
Water	Pirimicarb	kg	1.7
Water	formaldehyde (sea)	kg	0.000028
Soil	Linuron (agr.)	kg	170
Soil	1-chloro-4-nitrobenzene (agr.)	kg	22000
Water	2,4,5-trichlorophenol	kg	45
Soil	tributyltinoxide (agr.)	kg	290
Water	Azinphos-ethyl (sea)	kg	1.6
Water	Chloridazon	kg	0.14
Water	Phoxim	kg	12
Air	Captan	kg	0.59
Soil	Phoxim (agr.)	kg	25
Water	Tri-allate	kg	83
Water	2,4,5-T (sea)	kg	0.0054
Soil	beryllium (ind.)	kg	7000
Soil	Carbaryl (agr.)	kg	21
Soil	Captan (ind.)	kg	0.00011
Soil	beryllium (agr.)	kg	13000
Soil	meta-xylene (agr.)	kg	3.8
Water	Endrin (sea)	kg	1600
Water	Metolachlor	kg	0.55
Water	Aldrin (sea)	kg	780
Soil	tetrachloroethene (agr.)	kg	6.4
Water	Se (sea)	kg	63000
Air	Chlorothalonil	kg	8.4
Soil	Propachlor (agr.)	kg	15
Air	cyromazine	kg	38
Soil	Parathion-ethyl (ind.)	kg	0.11
Water	ethene	kg	0.65
Water	1,1,1-trichloroethane (sea)	kg	9.6
Soil	ortho-xylene (agr.)	kg	5
Air	Propoxur	kg	37
Air	Fenitrothion	kg	5.9
Water	di(2-ethylhexyl)phthalate (sea)	kg	0.04
Water	Carbendazim (sea)	kg	0.002
Soil	Heptenophos (agr.)	kg	3.4
Air	Linuron	kg	14
Soil	Endosulfan (ind.)	kg	0.016
Soil	Coumaphos (ind.)	kg	1600
Soil	Phtalic anhydride (ind.)	kg	0.00000066
Air	Fentin chloride	kg	840
Water	acrylonitrile (sea)	kg	51
Water	Coumaphos	kg	10000
Soil	Cr (VI) (agr.)	kg	8500
Water	hexachloro-1,3-butadiene (sea)	kg	39000
Soil	Trifluarin (ind.)	kg	0.68
Soil	DDT (ind.)	kg	1.8
Water	Zineb (sea)	kg	0.00082
Water	Bifenthrin	kg	98
Water	Simazine (sea)	kg	0.016
Air	Aldicarb	kg	72
Soil	Cypermethrin (agr.)	kg	5200
Water	3,4-dichloroaniline	kg	130
Water	Disulfothon (sea)	kg	1.5
Soil	barium (ind.)	kg	320
Air	cyanazine	kg	3.5
Soil	Tri-allate (ind.)	kg	0.36
Soil	1,2,3,4-tetrachlorobenzene (ind.)	kg	5.2
Water	Metolachlor (sea)	kg	0.00085
Soil	Phtalic anhydride (agr.)	kg	0.01

Impact category	x Human toxicity	kg 1,4-DB eq	
Water	Linuron	kg	110
Air	Chlorfenvinphos	kg	270
Water	Acephate	kg	2.1
Water	Tolclophos-methyl	kg	1
Soil	1,2,4,5-tetrachlorobenzene (agr.)	kg	84
Water	m-xylene (sea)	kg	0.01
Soil	1,3-dichlorobenzene (ind.)	kg	50
Water	Endosulfan	kg	17
Soil	Demeton (ind.)	kg	89
Air	Benomyl	kg	0.021
Soil	DNOC (ind.)	kg	2.8
Air	Chloridazon	kg	0.013
Water	Carbofuran (sea)	kg	0.21
Soil	3-chloroaniline (ind.)	kg	460
Soil	Zn (agr.)	kg	64
Air	Folpet	kg	2
Soil	Chlorfenvinphos (agr.)	kg	1200
Water	1,2,4,5-tetrachlorobenzene	kg	180
Water	2-chlorophenol (sea)	kg	0.35
Water	Benomyl (sea)	kg	0.00024
Air	Azinphos-ethyl	kg	200
Soil	Methabenzthiazuron (agr.)	kg	51
Air	1,3-dichlorobenzene	kg	62
Water	cyanazine	kg	6
Water	2-chlorophenol	kg	70
Soil	Endosulfan (agr.)	kg	0.26
Air	diisooctylphthalate	kg	310
Soil	Azinphos-ethyl (ind.)	kg	6.9
Water	Zn (sea)	kg	3.2
Air	methyl-mercury	kg	58000
Soil	Diazinon (ind.)	kg	3.2
Water	anthracene (sea)	kg	0.16
Water	acrolein	kg	59
Water	anthracene	kg	2.1
Air	Phoxim	kg	0.97
Air	1,4-dichlorobenzene	kg	1
Soil	Chlorfenvinphos (ind.)	kg	44
Soil	Trifluarin (agr.)	kg	120
Soil	hydrogen fluoride (agr.)	kg	1800
Water	Ba (sea)	kg	800
Soil	Permethrin (ind.)	kg	0.021
Soil	Fentin hydroxide (ind.)	kg	8.5
Air	zineb	kg	4.8
Soil	2,3,4,6-tetrachlorophenol (agr.)	kg	31
Water	Demeton (sea)	kg	0.3
Water	MCPA	kg	15
Water	2,3,4,6-tetrachlorophenol	kg	35
Soil	3,4-dichloroaniline (agr.)	kg	1700
Water	DDT	kg	37
Soil	selenium (agr.)	kg	29000
Water	Malathion (sea)	kg	0.00084
Soil	2,4-D (ind.)	kg	0.72
Soil	PAH (carcinogenic) (ind.)	kg	2700
Water	Heptachlor	kg	3400
Soil	Cyromazine (ind.)	kg	1.3
Water	chlorobenzene	kg	9.1
Soil	Carbofuran (ind.)	kg	8
Water	Heptachlor (sea)	kg	43
Water	Oxydemethon-methyl	kg	74
Water	Atrazine (sea)	kg	0.018
Soil	naphtalene (agr.)	kg	4.8
Soil	pentachlorobenzene (agr.)	kg	4500
Water	Sn (sea)	kg	0.11
Water	Propachlor	kg	1.6
Water	1,3-butadiene (sea)	kg	450
Water	2,4,5-trichlorophenol (sea)	kg	0.61
Air	dinoterb	kg	170
Water	pentachlorobenzene (sea)	kg	410
Water	DNOC (sea)	kg	0.0015
Water	Propachlor (sea)	kg	0.0026
Soil	Carbofuran (agr.)	kg	1400
Water	Fentin chloride	kg	860
Water	diisooctylphthalate (sea)	kg	9.7
Water	Fenitrothion	kg	22
Soil	Disulfoton (ind.)	kg	2
Soil	Fenitrothion (agr.)	kg	12
Soil	Captafol (ind.)	kg	79
Air	2,4-dichlorophenol	kg	95
Soil	Carbaryl (ind.)	kg	0.15
Air	diisodecylphthalate	kg	46
Soil	anthracene (agr.)	kg	0.51
Soil	1,2-dichlorobenzene (ind.)	kg	6.9
Water	2,4,6-trichlorophenol (sea)	kg	47
Soil	Permethrin (agr.)	kg	11
Soil	ethylene oxide (agr.)	kg	110000
Water	MCPA (sea)	kg	0.037
Water	pentachloronitrobenzene	kg	91
Air	Isoproturon	kg	130
Water	Disulfothon	kg	340
Soil	dichloromethane (agr.)	kg	2.4
Soil	diisodecylphthalate (ind.)	kg	0.038
Water	ethyl benzene (sea)	kg	0.07
Water	Propoxur (sea)	kg	0.00039
Water	Diuron (sea)	kg	0.19
Soil	Parathion-methyl (agr.)	kg	24
Water	Dichlorprop	kg	24
Water	dioctylphthalate	kg	6.3
Soil	Isoproturon (agr.)	kg	960
Soil	formaldehyde (agr.)	kg	2.3
Soil	Methomyl (agr.)	kg	43
Water	Zineb	kg	1.7
Water	Heptenophos	kg	1.3
Soil	hydrogen fluoride (ind.)	kg	1800
Soil	dihexylphthalate (agr.)	kg	1200
Soil	2,4,5-T (agr.)	kg	5.8

Impact category	x Human toxicity	kg 1,4-DB eq	
Water	pentachlorobenzene	kg	1200
Soil	chlorobenzene (ind.)	kg	6.8
Soil	ortho-xylene (ind.)	kg	0.076
Soil	Heptachlor (ind.)	kg	4.4
Soil	Glyphosate (agr.)	kg	0.015
Water	Dimethoate	kg	18
Water	As (sea)	kg	2400
Water	3-chloroaniline	kg	3500
Soil	1,2,4,5-tetrachlorobenzene (ind.)	kg	5.4
Water	p-xylene (sea)	kg	0.013
Water	acrolein (sea)	kg	0.8
Water	Benomyl	kg	0.14
Soil	tin (ind.)	kg	0.52
Soil	para-xylene (ind.)	kg	0.025
Soil	Oxydemethon-methyl (agr.)	kg	610
Soil	1,4-dichlorobenzene (agr.)	kg	2.9
Soil	dimethylphthalate (agr.)	kg	28
Water	tetrachloroethene (sea)	kg	2.8
Water	Carbaryl (sea)	kg	0.0019
Air	dimethylphthalate	kg	210
Water	Desmetryn (sea)	kg	0.12
Air	Demeton	kg	71
Soil	carbon disulfide (agr.)	kg	3.6
Soil	Ethoprophos (ind.)	kg	380
Water	Azinphos-ethyl	kg	460
Water	chlorobenzene (sea)	kg	5.2
Soil	1,1,1-trichloroethane (ind.)	kg	16
Soil	Chlorpropham (agr.)	kg	2.1
Water	dichloromethane (sea)	kg	0.3
Air	Carbofuran	kg	200
Air	dimethoate	kg	44
Air	Endosulfan	kg	6.7
Soil	1-chloro-4-nitrobenzene (ind.)	kg	460
Soil	4-chloroaniline (agr.)	kg	35000
Water	Isoproturon (sea)	kg	0.029
Water	Dinoterb	kg	2.5
Soil	2,4,5-trichlorophenol (agr.)	kg	5.3
Soil	1,3-butadiene (agr.)	kg	3100
Soil	Metobromuron (agr.)	kg	410
Water	1,1,1-trichloroethane	kg	16
Soil	pentachloronitrobenzene (ind.)	kg	4.3
Water	Lindane (sea)	kg	6.1
Water	Chlorpropham	kg	1
Water	tributyltinoxide	kg	3400
Soil	Mo (ind.)	kg	3100
Water	Diazinon	kg	66
Water	Captan	kg	0.0053
Soil	Hg (agr.)	kg	5900
Water	cyanazine (sea)	kg	0.0096
Soil	vinyl chloride (agr.)	kg	520
Soil	Cypermethrin (ind.)	kg	1.8
Water	Fentin acetate (sea)	kg	4.1
Water	dihexylphthalate (sea)	kg	370
Water	methylbromide (sea)	kg	25
Water	1,2-dichlorobenzene	kg	8.9
Water	1,2,4,5-tetrachlorobenzene (sea)	kg	30
Air	Heptachlor	kg	40
Soil	Phoxim (ind.)	kg	0.38
Water	Dieldrin (sea)	kg	5500
Soil	Metobromuron (ind.)	kg	1.9
Water	Pyrazophos (sea)	kg	0.23
Soil	Deltamethrin (agr.)	kg	0.16
Soil	Mo (agr.)	kg	6200
Water	Endrin	kg	6000
Air	Trichlorfon	kg	4.4
Soil	2,4,6-trichlorophenol (agr.)	kg	1800
Water	Carbofuran	kg	56
Air	Fenthion	kg	63
Water	4-chloroaniline	kg	2900
Soil	acrolein (agr.)	kg	230
Soil	MCPA (ind.)	kg	0.97
Water	carbon disulfide (sea)	kg	0.48
Water	Dinoterb (sea)	kg	0.0029
Water	Oxydemethon-methyl (sea)	kg	0.01
Water	2,4-dichlorophenol	kg	16
Soil	Disulfoton (agr.)	kg	170
Air	dust (PM10) stationary	kg	0.82
Air	dust (PM10) mobile	kg	0.82
Water	butylbenzylphthalate	kg	0.086

B1.5 FRESH WATER AQUATIC ECOTOXICITY

Impact category	x Fresh water aquatic ecotox.	kg 1,4-DB eq	
Air	1,1,1-trichloroethane	kg	0.00012
Air	1,2,3-trichlorobenzene	kg	0.0085
Air	1,2,4-trichlorobenzene	kg	0.0099
Air	1,2-dichloroethane	kg	0.00012
Air	1,3,5-trichlorobenzene	kg	0.016
Air	1,3-butadiene	kg	0.00000033
Air	2,4,6-trichlorophenol	kg	5.9
Air	2,4-D	kg	39
Air	acrolein	kg	520
Air	acrylonitrile	kg	0.41
Air	Aldrin	kg	2.7
Air	As	kg	50
Air	Atrazine	kg	360
Air	Azinphos-methyl	kg	420
Air	Ba	kg	43
Air	Be	kg	17000

Impact category	x Fresh water aquatic ecotox.	kg 1,4-DB eq	
Air	Bentazon	kg	5.6
Air	benzene	kg	0.000084
Air	benzo(a)anthracene	kg	42
Air	benzo(a)pyrene	kg	88
Air	benzylchloride	kg	0.76
Air	Carbendazim	kg	3000
Air	Cd	kg	290
Air	cobalt	kg	640
Air	Cr (III)	kg	1.9
Air	Cr (VI)	kg	7.7
Air	CS2	kg	0.033
Air	Cu	kg	220
Air	di(2-ethylhexyl)phthalate	kg	0.35
Air	dibutylphthalate	kg	0.56
Air	dichloromethane	kg	0.000033
Air	Dichlorvos	kg	510
Air	Dieldrin	kg	200
Air	dioxin (TEQ)	kg	2100000
Air	Diuron	kg	530
Air	DNOC	kg	3.4
Air	ethene	kg	1.4E-11
Air	ethylbenzene	kg	0.00013
Air	ethylene oxide	kg	0.099
Air	Fentin-acetate	kg	4300
Air	fluoranthene	kg	18
Air	formaldehyde	kg	8.3
Air	heavy metals	kg	21.43
Air	hexachlorobenzene	kg	1.3
Air	HF	kg	4.6
Air	Hg	kg	320
Air	m-xylene	kg	0.000044
Air	Malathion	kg	1800
Air	Mecoprop	kg	37
Air	Metabenzthiazuron	kg	70
Air	metals	kg	21.43
Air	Metamitron	kg	0.93
Air	methyl bromide	kg	0.033
Air	Mevinfos	kg	9300
Air	Mo	kg	97
Air	naphthalene	kg	0.5
Air	Ni	kg	630
Air	o-xylene	kg	0.000093
Air	p-xylene	kg	0.000061
Air	PAH's	kg	170
Air	Pb	kg	2.4
Air	pentachlorophenol	kg	11
Air	phenol	kg	1.5
Air	phthalic acid anhydride	kg	0.0082
Air	propyleneoxide	kg	0.037
Air	Sb	kg	3.7
Air	Se	kg	550
Air	Simazine	kg	2100
Air	Sn	kg	2.5
Air	styrene	kg	0.000051
Air	tetrachloroethene	kg	0.00041
Air	tetrachloromethane	kg	0.00025
Air	Thiram	kg	2700
Air	Tl	kg	1600
Air	toluene	kg	0.00007
Air	trichloroethene	kg	0.000038
Air	trichloromethane	kg	0.000095
Air	Trifluralin	kg	9.9
Air	V	kg	1700
Air	vinyl chloride	kg	0.0000029
Air	Zn	kg	18
Water	1,2,3-trichlorobenzene	kg	4
Water	1,2,4-trichlorobenzene	kg	3.5
Water	1,2-dichloroethane	kg	0.023
Water	1,3,5-trichlorobenzene	kg	5
Water	1,3-butadiene	kg	3
Water	2,4,6-trichlorophenol	kg	290
Water	2,4-D	kg	400
Water	acrylonitrile	kg	79
Water	Aldrin	kg	12000
Water	As	kg	210
Water	Atrazine	kg	5000
Water	Azinphos-methyl	kg	52000
Water	Ba	kg	230
Water	Be	kg	91000
Water	Bentazon	kg	51
Water	benzene	kg	0.091
Water	benzo(a)anthracene	kg	110000
Water	benzo(a)pyrene	kg	250000
Water	benzylchloride	kg	200
Water	Carbendazim	kg	38000
Water	Cd	kg	1500
Water	Co	kg	3400
Water	Cr (III)	kg	6.9
Water	Cr (VI)	kg	28
Water	Cu	kg	1200
Water	di(2-ethylhexyl)phthalate	kg	79
Water	dibutylphthalate	kg	79
Water	dichloromethane	kg	0.012
Water	Dichlorvos	kg	120000
Water	Dieldrin	kg	79000
Water	dioxins (TEQ)	kg	170000000
Water	Diuron	kg	9400
Water	DNOC	kg	110
Water	ethyl benzene	kg	0.55
Water	ethylene oxide	kg	9.8
Water	fluoranthene	kg	13000
Water	formaldehyde	kg	280
Water	hexachlorobenzene	kg	150
Water	Hg	kg	1700
Water	Malathion	kg	210000
Water	Mecoprop	kg	380

Impact category	x Fresh water aquatic ecotox.	kg 1,4-DB eq	
Water	metallic ions	kg	3.659
Water	Metamitron	kg	23
Water	Mevinfos	kg	590000
Water	Mo	kg	480
Water	Ni	kg	3200
Water	PAH's	kg	28000
Water	Pb	kg	9.6
Water	pentachlorophenol	kg	710
Water	phenol	kg	240
Water	propylene oxide	kg	4
Water	Sb	kg	20
Water	Se	kg	2900
Water	Simazine	kg	27000
Water	Sn	kg	10
Water	styrene	kg	0.44
Water	tetrachloroethene	kg	0.7
Water	tetrachloromethane	kg	0.21
Water	Thiram	kg	98000
Water	toluene	kg	0.29
Water	trichloroethene	kg	0.097
Water	trichloromethane	kg	0.042
Water	Trifluralin	kg	27000
Water	V	kg	9000
Water	vinyl chloride	kg	0.028
Water	Zn	kg	92
Soil	1,2,3-trichlorobenzene (ind.)	kg	0.03
Soil	1,2,4-trichlorobenzene (ind.)	kg	0.032
Soil	1,2-dichloroethane (ind.)	kg	0.00075
Soil	1,3,5-trichlorobenzene (ind.)	kg	0.066
Soil	1,3-butadiene (ind.)	kg	0.000057
Soil	2,4,6-trichlorophenol (ind.)	kg	4.8
Soil	2,4-D (agr.)	kg	29
Soil	acrylonitrile (ind.)	kg	8.1
Soil	Aldrin (agr.)	kg	280
Soil	As (ind.)	kg	130
Soil	Atrazine (agr.)	kg	340
Soil	Azinphos-methyl (agr.)	kg	190
Soil	Bentazon (agr.)	kg	8.3
Soil	benzene (ind.)	kg	0.00072
Soil	benzo(a)pyrene (ind.)	kg	530
Soil	benzylchloride (ind.)	kg	3.2
Soil	Carbendazim (agr.)	kg	2000
Soil	Cd (agr.)	kg	780
Soil	Cd (ind.)	kg	780
Soil	Cr (III) (ind.)	kg	5.3
Soil	Cr (VI) (ind.)	kg	21
Soil	Cu (ind.)	kg	590
Soil	di(2-ethylhexyl)phthalate(ind)	kg	0.006
Soil	dibutylphthalate (ind.)	kg	0.31
Soil	dichloromethane (ind.)	kg	0.00016
Soil	Dichlorvos (agr.)	kg	74
Soil	Dieldrin (agr.)	kg	600
Soil	dioxin (TEQ) (ind.)	kg	490000
Soil	Diuron (agr.)	kg	350
Soil	DNOC (agr.)	kg	1.2
Soil	ethylene oxide (ind.)	kg	0.98
Soil	fluoranthene (ind.)	kg	76
Soil	formaldehyde (ind.)	kg	44
Soil	gamma-HCH (Lindane) (agr.)	kg	97
Soil	hexachlorobenzene (ind.)	kg	4.3
Soil	Hg (ind.)	kg	850
Soil	Malathion (agr.)	kg	160
Soil	Mecoprop (agr.)	kg	30
Soil	Metamitron (agr.)	kg	0.41
Soil	Mevinfos (agr.)	kg	350
Soil	Ni (ind.)	kg	1700
Soil	Pb (ind.)	kg	6.5
Soil	pentachlorophenol (ind.)	kg	1.3
Soil	propylene oxide (ind.)	kg	0.48
Soil	Simazine (agr.)	kg	2300
Soil	styrene (ind.)	kg	0.0026
Soil	tetrachloroethene (ind.)	kg	0.0022
Soil	tetrachloromethane (ind.)	kg	0.00056
Soil	Thiram (agr.)	kg	690
Soil	toluene (ind.)	kg	0.0011
Soil	trichloroethene (ind.)	kg	0.00046
Soil	trichloromethane (ind.)	kg	0.00047
Soil	vinyl chloride (ind.)	kg	0.000064
Soil	Zn (ind.)	kg	48
Soil	phenol (agr.)	kg	3.5
Soil	Bentazon (ind.)	kg	11
Water	Fentin chloride (sea)	kg	18
Water	dihexylphthalate	kg	110
Soil	Zineb (ind.)	kg	1400
Soil	Iprodione (ind.)	kg	1.9
Water	Fentin acetate	kg	270000
Soil	Metolachlor (ind.)	kg	5800
Soil	diethylphthalate (agr.)	kg	0.16
Water	Aldicarb	kg	440000
Soil	Fenitrothion (ind.)	kg	3000
Air	DDT	kg	320
Water	carbon disulfide	kg	110
Water	Dichlorvos (sea)	kg	0.011
Soil	1,3,5-trichlorobenzene (agr.)	kg	0.054
Soil	2-chlorophenol (agr.)	kg	7.9
Air	Propachlor	kg	20
Soil	Captan (agr.)	kg	0.4
Water	toluene (sea)	kg	0.0000083
Soil	2,4-dichlorophenol (ind.)	kg	9.2
Air	Parathion-ethyl	kg	2800
Soil	styrene (agr.)	kg	0.0015
Soil	barium (agr.)	kg	110
Water	m-xylene	kg	0.6
Water	Parathion-methyl	kg	290000

Impact category	x Fresh water aquatic ecotox.	kg 1,4-DB eq	
Water	Trichlorfon	kg	410000
Soil	Demeton (agr.)	kg	800
Water	Cypermethrin	kg	7900000
Soil	ethylene (ind.)	kg	1.1E-09
Water	1,4-dichlorobenzene	kg	1
Water	Acephate (sea)	kg	0.00000006
Soil	1,3-dichlorobenzene (agr.)	kg	0.018
Soil	benzylchloride (agr.)	kg	0.92
Soil	Oxamyl (agr.)	kg	30
Air	tributyltinoxide	kg	7700
Water	Pirimicarb (sea)	kg	0.00089
Water	Methomyl	kg	140000
Water	dimethylphthalate	kg	3.1
Air	hexachloro-1,3-butadiene	kg	46
Soil	As (agr.)	kg	130
Soil	2,3,4,6-tetrachlorophenol (ind.)	kg	120
Water	Dinoseb (sea)	kg	0.11
Water	Folpet (sea)	kg	16
Soil	Metazachlor (agr.)	kg	3.9
Water	o-xylene (sea)	kg	0.000015
Soil	anilazine (agr.)	kg	0.21
Soil	diisodecylphthalate (agr.)	kg	0.0046
Soil	Dichlorvos (ind.)	kg	300
Water	Anilazine	kg	1100
Water	Metobromuron	kg	430
Soil	Azinphos-ethyl (agr.)	kg	2800
Water	Aldicarb (sea)	kg	0.12
Soil	carbon disulfide (ind.)	kg	0.34
Water	Oxamyl	kg	650
Water	Chlorpyriphos (sea)	kg	0.23
Soil	Metazachlor (ind.)	kg	14
Air	2-chlorophenol	kg	13
Water	Fenthion (sea)	kg	0.26
Air	Tolclophos-methyl	kg	0.15
Soil	pentachlorobenzene (ind.)	kg	1.1
Air	dihexylphthalate	kg	0.5
Soil	MCPA (agr.)	kg	0.46
Soil	Chlorpyriphos (ind.)	kg	1400
Soil	Parathion-ethyl (agr.)	kg	500
Soil	Cyanazine (ind.)	kg	3000
Soil	Glyphosate (ind.)	kg	3.7
Air	Carbaryl	kg	110
Soil	Pyrazophos (agr.)	kg	250
Water	hexachloro-1,3-butadiene	kg	45000
Air	phenanthrene	kg	1.3
Soil	benzene (agr.)	kg	0.00072
Soil	chrysene (ind.)	kg	290
Water	Chlordane (sea)	kg	31
Water	Dimethoate (sea)	kg	0.0000074
Water	Iprodione (sea)	kg	3.8E-09
Soil	dioxin (TEQ) (agr.)	kg	120000
Soil	phenanthrene (ind.)	kg	1.2
Water	Carbaryl	kg	4500
Soil	Desmetryn (agr.)	kg	3
Water	fluoranthene (sea)	kg	0.87
Water	Bifenthrin (sea)	kg	0.055
Water	1,2,3,4-tetrachlorobenzene	kg	16
Water	Heptenophos (sea)	kg	0.0013
Soil	Dinoseb (ind.)	kg	58000
Air	cypermethrin	kg	84000
Soil	Heptenophos (ind.)	kg	120
Air	1-chloro-4-nitrobenzene	kg	11
Soil	Malathion (ind.)	kg	650
Soil	para-xylene (agr.)	kg	0.0014
Water	1,4-dichlorobenzene (sea)	kg	0.0011
Air	chrysene	kg	39
Soil	acrolein (ind.)	kg	45000
Air	Glyphosate	kg	22
Water	Glyphosate	kg	1400
Water	2,3,4,6-tetrachlorophenol (sea)	kg	0.0013
Water	1,2,3-trichlorobenzene (sea)	kg	0.0039
Soil	Chlorothalonil (ind.)	kg	3.7
Soil	Acephate (ind.)	kg	160
Soil	Methabenzthiazuron (ind.)	kg	140
Water	1,2-dichlorobenzene (sea)	kg	0.0013
Soil	naphtalene (ind.)	kg	12
Water	2,4-D (sea)	kg	1.1E-10
Soil	Dinoseb (agr.)	kg	20000
Soil	diisooctylphthalate (ind.)	kg	0.0025
Soil	methylbromide (ind.)	kg	0.14
Water	Demeton	kg	22000
Soil	Aldicarb (agr.)	kg	96000
Soil	Endrin (agr.)	kg	21000
Air	Heptenophos	kg	120
Soil	Folpet (ind.)	kg	13000
Air	Chlorpropham	kg	2.3
Water	2,4-dichlorophenol (sea)	kg	0.00029
Soil	Diuron (ind.)	kg	1100
Soil	Acephate (agr.)	kg	51
Soil	1,1,1-trichloroethane (agr.)	kg	0.00037
Soil	chlorobenzene (agr.)	kg	0.0032
Water	Triazophos	kg	170000
Soil	dihexylphthalate (ind.)	kg	0.074
Water	Mo (sea)	kg	6.6E-19
Soil	fluoranthene (agr.)	kg	19
Water	Sb (sea)	kg	7.6E-21
Soil	Fenthion (agr.)	kg	3500
Water	Oxamyl (sea)	kg	0.00000045
Water	Fenthion	kg	910000
Water	ethene (sea)	kg	1E-12
Water	Bentazon (sea)	kg	7.4E-09
Water	Fentin hydroxide (sea)	kg	0.029
Air	1,2,4,5-tetrachlorobenzene	kg	0.073
Water	Cu (sea)	kg	4.1E-20

Impact category	x Fresh water aquatic ecotox.	kg 1,4-DB eq	
Soil	Mevinfos (ind.)	kg	1500
Soil	chrysene (agr.)	kg	74
Water	1,2,3,5-tetrachlorobenzene	kg	14
Water	Iprodione	kg	160
Water	Ethoprophos	kg	150000
Water	diisodecylphthalate (sea)	kg	0.038
Water	methyl-mercury	kg	39000
Air	dinoseb	kg	10000
Soil	2,4,5-T (ind.)	kg	1.5
Soil	Methomyl (ind.)	kg	28000
Soil	Triazophos (agr.)	kg	5800
Water	diisodecylphthalate	kg	86
Soil	Cyromazine (agr.)	kg	6500
Soil	Thiram (ind.)	kg	4400
Water	Co (sea)	kg	1.2E-18
Soil	ethylbenzene (ind.)	kg	0.0018
Water	propylene oxide (sea)	kg	0.00044
Soil	vanadium (agr.)	kg	4700
Water	Dichlorprop (sea)	kg	1.6E-12
Water	chrysene	kg	19000
Water	thallium	kg	8000
Water	Chlorothalonil (sea)	kg	0.14
Water	Triazophos (sea)	kg	0.079
Air	3-chloroaniline	kg	100
Water	phenanthrene	kg	520
Soil	bifenthrin (ind.)	kg	410
Water	tetrachloromethane (sea)	kg	0.00019
Water	4-chloroaniline (sea)	kg	0.011
Water	Parathion-ethyl	kg	1200000
Soil	benzo[a]anthracene (agr.)	kg	62
Air	Chlorpyriphos	kg	520
Soil	ethylene (agr.)	kg	1.1E-09
Soil	pentachloronitrobenzene (agr.)	kg	15
Soil	Folpet (agr.)	kg	4500
Soil	anthracene (ind.)	kg	320
Air	Parathion-methyl	kg	990
Air	Lindane	kg	52
Water	trichloroethene (sea)	kg	0.000016
Water	Phoxim (sea)	kg	0.033
Soil	Heptachlor (agr.)	kg	2.3
Soil	Dimethoate (agr.)	kg	8.9
Water	Glyphosate (sea)	kg	2.1E-11
Water	3,4-dichloroaniline (sea)	kg	0.0012
Soil	benzo[ghi]perylene (agr.)	kg	61
Soil	Metolachlor (agr.)	kg	1900
Soil	Dichlorprop (ind.)	kg	0.051
Soil	1,4-dichlorobenzene (ind.)	kg	0.014
Soil	Chlordane (agr.)	kg	94
Water	Linuron (sea)	kg	0.06
Air	Metobromuron	kg	49
Soil	toluene (agr.)	kg	0.0011
Water	styrene (sea)	kg	0.00001
Air	Oxamyl	kg	56
Water	Chloridazon (sea)	kg	0.0035
Soil	Dichlorprop (agr.)	kg	0.013
Water	Ethoprophos (sea)	kg	1
Soil	phenol (ind.)	kg	13
Soil	Parathion-methyl (ind.)	kg	4400
Air	Chlordane	kg	270
Soil	Fentin acetate (agr.)	kg	380
Water	Metamitron (sea)	kg	6.8E-10
Water	Methabenzthiazuron	kg	1100
Air	Permethrin	kg	16000
Soil	Pyrazophos (ind.)	kg	990
Soil	4-chloroaniline (ind.)	kg	490
Air	4-chloroaniline	kg	2
Soil	thallium (agr.)	kg	4200
Air	Acephate	kg	79
Water	naphtalene	kg	660
Air	Metolachlor	kg	1500
Water	benzylchloride (sea)	kg	0.011
Soil	Ethoprophos (agr.)	kg	11000
Air	Deltamethrin	kg	1800
Soil	anilazine (ind.)	kg	0.86
Soil	Dinoterb (ind.)	kg	1300
Soil	Coumaphos (agr.)	kg	1000000
Water	Permethrin (sea)	kg	10
Air	anilazine	kg	14
Water	1,2-dichloroethane (sea)	kg	0.000088
Soil	tetrachloromethane (agr.)	kg	0.00056
Soil	tributyltinoxide (ind.)	kg	4200
Water	Pb (sea)	kg	5.6E-23
Water	dioxins (TEQ) (sea)	kg	130000
Water	naphtalene (sea)	kg	0.011
Soil	Propoxur (ind.)	kg	54000
Soil	dibutylphthalate (agr.)	kg	0.079
Air	Ethoprophos	kg	2400
Soil	diethylphthalate (ind.)	kg	0.63
Soil	Pirimicarb (ind.)	kg	5200
Water	Metazachlor (sea)	kg	0.000003
Air	Dichlorprop	kg	0.099
Water	3-chloroaniline (sea)	kg	0.0000037
Water	p-xylene	kg	0.55
Water	butylbenzylphthalate (sea)	kg	0.000032
Water	V (sea)	kg	2.4E-18
Water	Chlordane	kg	90000
Water	Cd (sea)	kg	2.5E-20
Soil	acrylonitrile (agr.)	kg	6.5
Soil	Co (agr.)	kg	1700
Soil	butylbenzylphthalate (ind.)	kg	0.1
Water	Thiram (sea)	kg	0.026
Soil	Endrin (ind.)	kg	71000
Water	benzo(ghi)perylene	kg	52000
Water	methyl-mercury (sea)	kg	160
Soil	Carbendazim (ind.)	kg	6100

Impact category	x Fresh water aquatic ecotox.	kg 1,4-DB eq	
Air	2,4,5-trichlorophenol	kg	15
Water	ethylene oxide (sea)	kg	0.0038
Soil	Propoxur (agr.)	kg	20000
Water	DDT (sea)	kg	15
Water	Deltamethrin (sea)	kg	3.2
Water	benzene (sea)	kg	0.0000092
Soil	antimony (agr.)	kg	10
Soil	diisooctylphthalate (agr.)	kg	0.00062
Soil	Dieldrin (ind.)	kg	2300
Water	dioctylphthalate (sea)	kg	0.00014
Water	Chlorpropham (sea)	kg	0.000028
Air	Pyrazophos	kg	180
Air	Triazophos	kg	3300
Air	Oxydemethon-methyl	kg	2400
Soil	dioctylphthalate (agr.)	kg	0.000042
Soil	Oxamyl (ind.)	kg	120
Soil	pentachlorophenol (agr.)	kg	0.33
Soil	Linuron (ind.)	kg	2400
Soil	Chloridazon (ind.)	kg	3.9
Water	Endosulfan (sea)	kg	0.021
Soil	propylene oxide (agr.)	kg	0.42
Soil	Atrazine (ind.)	kg	930
Soil	Pb (agr.)	kg	6.5
Soil	2,4-dichlorophenol (agr.)	kg	2.5
Water	benzo(k)fluoranthrene	kg	1200000
Water	Chlorfenvinphos (sea)	kg	0.000056
Soil	Metamitron (ind.)	kg	1.5
Water	hexachlorobenzene (sea)	kg	1.1
Water	o-xylene	kg	0.56
Water	Fenitrothion (sea)	kg	0.0099
Water	Coumaphos (sea)	kg	110
Water	Ni (sea)	kg	6.1E-19
Soil	indeno[1,2,3-cd]pyrene (agr.)	kg	90
Soil	PAH (carcinogenic) (agr.)	kg	58
Soil	Cyanazine (agr.)	kg	810
Soil	Zineb (agr.)	kg	370
Soil	ethylbenzene (agr.)	kg	0.0018
Soil	hexachloro-1,3-butadiene (agr.)	kg	70
Soil	Azinphos-methyl (ind.)	kg	800
Air	butylbenzylphthalate	kg	0.4
Water	Tri-allate (sea)	kg	1.1
Water	pentachlorophenol (sea)	kg	0.000012
Water	Mecoprop (sea)	kg	3.8E-10
Soil	dimethylphthalate (ind.)	kg	0.029
Water	1,2,3,4-tetrachlorobenzene (sea)	kg	0.038
Water	Methabenzthiazuron (sea)	kg	0.000092
Soil	Tolclophos-methyl (agr.)	kg	3.1
Soil	Aldicarb (ind.)	kg	96000
Air	pentachloronitrobenzene	kg	47
Soil	hexachloro-1,3-butadiene (ind.)	kg	84
Soil	hexachlorobenzene (agr.)	kg	3.2
Soil	vanadium (ind.)	kg	4700
Soil	bifenthrin (agr.)	kg	100
Soil	trichloroethene (agr.)	kg	0.00046
Soil	DDT (agr.)	kg	87
Water	Captafol (sea)	kg	0.00005
Water	Methomyl (sea)	kg	0.0085
Soil	Deltamethrin (ind.)	kg	96
Water	phthalic anhydride	kg	0.55
Soil	1,2-dichloroethane (agr.)	kg	0.00075
Water	diethylphthalate	kg	34
Soil	Cu (agr.)	kg	590
Water	dimethylphthalate (sea)	kg	0.00000038
Soil	Benomyl (ind.)	kg	18
Water	Permethrin	kg	5000000
Soil	1,2,3,4-tetrachlorobenzene (agr.)	kg	0.028
Air	diazinon	kg	230
Air	indeno[1,2,3-cd]pyrene	kg	170
Water	Folpet	kg	82000
Soil	Cr (III) (agr.)	kg	5.3
Air	2,3,4,6-tetrachlorophenol	kg	80
Soil	Chloridazon (agr.)	kg	1.8
Soil	benzo[k]fluoranthrene (ind.)	kg	20000
Soil	Fentin hydroxide (agr.)	kg	380
Water	Parathion-methyl (sea)	kg	0.12
Air	methomyl	kg	14000
Water	Propoxur	kg	260000
Soil	meta-xylene (ind.)	kg	0.0019
Water	Deltamethrin	kg	650000
Soil	Dimethoate (ind.)	kg	28
Water	1-chloro-4-nitrobenzene (sea)	kg	1.9
Water	methylbromide	kg	19
Water	PAH (sea)	kg	0.12
Soil	Oxydemethon-methyl (ind.)	kg	3600
Soil	Chlorothalonil (agr.)	kg	1
Water	1,2,4-trichlorobenzene (sea)	kg	0.0044
Water	1,3-dichlorobenzene	kg	1.2
Soil	benzo[k]fluoranthrene (agr.)	kg	5200
Soil	3,4-dichloroaniline (ind.)	kg	4000
Water	thallium (sea)	kg	7.9E-18
Water	Dinoseb	kg	320000
Air	anthracene	kg	140
Water	Mevinfos (sea)	kg	0.000069
Soil	Triazophos (ind.)	kg	19000
Water	Isoproturon	kg	1900
Water	tributyltinoxide (sea)	kg	3
Water	1,3-dichlorobenzene (sea)	kg	0.0011
Water	HF (sea)	kg	0.0022
Water	Azinphos-methyl (sea)	kg	0.00011
Air	Bifenthrin	kg	820

Impact category	x Fresh water aquatic ecotox.	kg 1,4-DB eq	
Air	diethylphthalate	kg	0.42
Soil	Aldrin (ind.)	kg	290
Water	diethylphthalate (sea)	kg	0.000079
Water	2,4,5-T	kg	17
Water	Hg (sea)	kg	6.8
Water	Cypermethrin (sea)	kg	2.4
Soil	trichloromethane (agr.)	kg	0.00047
Water	Trichlorfon (sea)	kg	0.0000053
Soil	Mecoprop (ind.)	kg	78
Air	Iprodione	kg	2.8
Water	Chlorpyriphos	kg	640000
Soil	Benomyl (agr.)	kg	4.6
Soil	Chlordane (ind.)	kg	370
Soil	3-chloroaniline (agr.)	kg	74
Soil	Ni (agr.)	kg	1700
Soil	Fenthion (ind.)	kg	14000
Water	Lindane	kg	6500
Soil	1,2,3-trichlorobenzene (agr.)	kg	0.023
Soil	tin (agr.)	kg	6.9
Water	Captafol	kg	540000
Water	Cr (VI) (sea)	kg	3.5E-22
Soil	benzo[a]anthracene (ind.)	kg	250
Water	Chlorfenvinphos	kg	1100
Water	indeno[1,2,3-cd]pyrene (sea)	kg	0.00074
Air	tri-allate	kg	61
Soil	Trichlorfon (ind.)	kg	18000
Air	pentachlorobenzene	kg	0.37
Air	2,4,5-T	kg	0.85
Soil	selenium (ind.)	kg	1500
Air	1,2,3,5-tetrachlorobenzene	kg	0.073
Water	dibutylphthalate (sea)	kg	0.000029
Water	Cr (III) (sea)	kg	8.8E-23
Water	benzo(a)pyrene (sea)	kg	0.28
Air	chlorobenzene	kg	0.00047
Soil	Fentin chloride (agr.)	kg	250
Soil	Simazine (ind.)	kg	5600
Water	chrysene (sea)	kg	0.26
Soil	1,2,3,5-tetrachlorobenzene (ind.)	kg	0.19
Soil	methylbromide (agr.)	kg	0.14
Water	Parathion-ethyl (sea)	kg	0.2
Soil	Pirimicarb (agr.)	kg	1700
Water	Pyrazophos	kg	49000
Soil	1,2,4-trichlorobenzene (agr.)	kg	0.02
Water	trichloromethane (sea)	kg	0.000045
Air	Captafol	kg	20000
Soil	Propachlor (ind.)	kg	64
Air	Endrin	kg	1100
Soil	Fentin chloride (ind.)	kg	990
Soil	thallium (ind.)	kg	4200
Air	Fentin hydroxide	kg	4200
Soil	1,2,3,5-tetrachlorobenzene (agr.)	kg	0.083
Air	Desmetryn	kg	6.8
Soil	Iprodione (agr.)	kg	0.23
Air	Pirimicarb	kg	2400
Air	MCPA	kg	1.1
Soil	Tri-allate (agr.)	kg	50
Soil	dioctylphthalate (ind.)	kg	0.00017
Water	1-chloro-4-nitrobenzene	kg	860
Water	vinyl chloride (sea)	kg	0.0000014
Water	Fentin hydroxide	kg	270000
Soil	gamma-HCH (Lindane) (ind.)	kg	370
Soil	butylbenzylphthalate (agr.)	kg	0.025
Air	coumaphos	kg	240000
Soil	Isoproturon (ind.)	kg	400
Soil	Captafol (agr.)	kg	27000
Water	phenol (sea)	kg	0.000017
Water	Diazinon (sea)	kg	0.064
Water	diisooctylphthalate	kg	21
Soil	antimony (ind.)	kg	10
Water	Captan (sea)	kg	0.00000065
Water	Cyromazine (sea)	kg	0.00000081
Air	3,4-dichloroaniline	kg	1700
Water	Metobromuron (sea)	kg	0.0016
Soil	Trichlorfon (agr.)	kg	3300
Soil	Chlorpyriphos (agr.)	kg	360
Soil	Desmetryn (ind.)	kg	11
Water	pentachloronitrobenzene (sea)	kg	11
Soil	2,4,5-trichlorophenol (ind.)	kg	99
Water	Anilazine (sea)	kg	0.00000011
Water	1,2,3,5-tetrachlorobenzene (sea)	kg	0.03
Air	dioctylphthalate	kg	0.016
Air	1,2,3,4-tetrachlorobenzene	kg	0.1
Water	Trifluralin (sea)	kg	1.8
Soil	1,2-dichlorobenzene (agr.)	kg	0.019
Soil	Diazinon (agr.)	kg	1300
Soil	methyl-mercury (agr.)	kg	19000
Air	1,2-dichlorobenzene	kg	0.0029
Water	Be (sea)	kg	1.6E-16
Soil	di(2-ethylhexyl)phthalate (agr.)	kg	0.0015
Air	Metazachlor	kg	7.4
Soil	2-chlorophenol (ind.)	kg	31
Water	HF	kg	19
Water	Tolclophos-methyl (sea)	kg	0.029
Soil	Chlorpropham (ind.)	kg	6.4
Soil	Co (ind.)	kg	1700
Water	Metazachlor	kg	150
Soil	Fentin acetate (ind.)	kg	1500
Water	Cyromazine	kg	26000
Water	1,3,5-trichlorobenzene (sea)	kg	0.007

Impact category	x Fresh water aquatic ecotox.	kg 1,4-DB eq	
Soil	Dinoterb (agr.)	kg	330
Air	Disulfothon	kg	27
Water	phthalic anhydride (sea)	kg	4.6E-11
Soil	methyl-mercury (ind.)	kg	19000
Soil	Tolclophos-methyl (ind.)	kg	9.2
Water	Desmetryn	kg	190
Water	Chlorothalonil	kg	370
Water	Pirimicarb	kg	36000
Water	formaldehyde (sea)	kg	0.00021
Soil	Linuron (agr.)	kg	690
Soil	1-chloro-4-nitrobenzene (agr.)	kg	150
Water	2,4,5-trichlorophenol	kg	1600
Soil	tributyltinoxide (agr.)	kg	1100
Water	Azinphos-ethyl (sea)	kg	0.041
Water	Chloridazon	kg	31
Water	Phoxim	kg	2600
Air	Captan	kg	16
Soil	Phoxim (agr.)	kg	4.4
Water	Tri-allate	kg	49000
Air	benzo(k)fluoranthrene	kg	3900
Water	2,4,5-T (sea)	kg	1.7E-10
Soil	beryllium (ind.)	kg	46000
Soil	Carbaryl (agr.)	kg	23
Soil	Captan (ind.)	kg	4.7
Soil	beryllium (agr.)	kg	46000
Soil	meta-xylene (agr.)	kg	0.0019
Water	Endrin (sea)	kg	6.1
Water	Metolachlor	kg	38000
Water	Aldrin (sea)	kg	1.3
Soil	tetrachloroethene (agr.)	kg	0.0022
Water	Se (sea)	kg	7.4E-18
Air	Chlorothalonil	kg	2.5
Soil	Propachlor (agr.)	kg	17
Air	cyromazine	kg	3500
Soil	Parathion-ethyl (ind.)	kg	1900
Water	ethene	kg	0.022
Water	1,1,1-trichloroethane (sea)	kg	0.000071
Soil	ortho-xylene (agr.)	kg	0.0025
Air	Propoxur	kg	25000
Air	Fenitrothion	kg	2500
Water	di(2-ethylhexyl)phthalate (sea)	kg	0.0016
Water	Carbendazim (sea)	kg	0.000000024
Soil	Heptenophos (agr.)	kg	31
Air	Linuron	kg	40
Soil	Endosulfan (ind.)	kg	9
Soil	Coumaphos (ind.)	kg	3100000
Soil	Phtalic anhydride (ind.)	kg	0.000031
Air	Fentin chloride	kg	1800
Water	acrylonitrile (sea)	kg	0.006
Water	Coumaphos	kg	20000000
Soil	Cr (VI) (agr.)	kg	21
Water	hexachloro-1,3-butadiene (sea)	kg	23
Soil	Trifluarin (ind.)	kg	160
Soil	DDT (ind.)	kg	340
Water	Zineb (sea)	kg	0.0036
Water	Bifenthrin	kg	240000
Water	Simazine (sea)	kg	0.0045
Air	Aldicarb	kg	51000
Soil	Cypermethrin (agr.)	kg	200000
Water	3,4-dichloroaniline	kg	19000
Water	Disulfothon (sea)	kg	0.013
Soil	barium (ind.)	kg	110
Air	cyanazine	kg	1900
Soil	Tri-allate (ind.)	kg	200
Soil	1,2,3,4-tetrachlorobenzene (ind.)	kg	0.1
Water	Metolachlor (sea)	kg	0.07
Soil	Phtalic anhydride (agr.)	kg	0.000048
Water	Linuron	kg	31000
Air	Chlorfenvinphos	kg	32
Water	Acephate	kg	1100
Water	Tolclophos-methyl	kg	500
Soil	1,2,4,5-tetrachlorobenzene (agr.)	kg	0.025
Water	m-xylene (sea)	kg	0.0000072
Soil	1,3-dichlorobenzene (ind.)	kg	0.018
Water	Endosulfan	kg	28000
Soil	Demeton (ind.)	kg	2600
Air	Benomyl	kg	30
Water	benzo(k)fluoranthrene (sea)	kg	9.1
Soil	DNOC (ind.)	kg	4.5
Air	Chloridazon	kg	0.026
Water	Carbofuran (sea)	kg	0.00018
Soil	3-chloroaniline (ind.)	kg	250
Soil	Zn (agr.)	kg	48
Air	Folpet	kg	410
Soil	Chlorfenvinphos (agr.)	kg	16
Water	1,2,4,5-tetrachlorobenzene	kg	13
Water	2-chlorophenol (sea)	kg	0.0067
Water	Benomyl (sea)	kg	0.000000089
Air	Azinphos-ethyl	kg	290
Soil	Methabenzthiazuron (agr.)	kg	44
Air	1,3-dichlorobenzene	kg	0.0024
Water	cyanazine	kg	54000
Water	2-chlorophenol	kg	1600
Soil	Endosulfan (agr.)	kg	2.2
Air	diisooctylphthalate	kg	0.12
Soil	Azinphos-ethyl (ind.)	kg	3700
Water	Zn (sea)	kg	1.8E-21
Air	methyl-mercury	kg	7300
Soil	Diazinon (ind.)	kg	4600
Water	anthracene (sea)	kg	17
Water	acrolein	kg	250000

Impact category	x Fresh water aquatic ecotox.	kg 1,4-DB eq	
Water	anthracene	kg	57000
Air	Phoxim	kg	0.44
Air	1,4-dichlorobenzene	kg	0.0024
Soil	Chlorfenvinphos (ind.)	kg	59
Soil	Trifluarin (agr.)	kg	40
Soil	hydrogen fluoride (agr.)	kg	9.4
Water	Ba (sea)	kg	2.4E-19
Soil	Permethrin (ind.)	kg	3700
Soil	Fentin hydroxide (ind.)	kg	1500
Air	zineb	kg	940
Soil	2,3,4,6-tetrachlorophenol (agr.)	kg	32
Water	Demeton (sea)	kg	0.017
Water	MCPA	kg	27
Water	2,3,4,6-tetrachlorophenol	kg	5200
Soil	3,4-dichloroaniline (agr.)	kg	1800
Water	DDT	kg	29000
Soil	selenium (agr.)	kg	1500
Water	Malathion (sea)	kg	0.018
Soil	2,4-D (ind.)	kg	82
Soil	PAH (carcinogenic) (ind.)	kg	230
Water	Heptachlor	kg	18000
Soil	Cyromazine (ind.)	kg	6500
Water	indeno[1,2,3-cd]pyrene	kg	77000
Water	chlorobenzene	kg	0.36
Soil	Carbofuran (ind.)	kg	1800
Soil	benzo(a)pyrene (agr.)	kg	130
Water	Heptachlor (sea)	kg	0.039
Water	Oxydemethon-methyl	kg	70000
Water	Atrazine (sea)	kg	0.0083
Soil	naphtalene (agr.)	kg	3.8
Soil	pentachlorobenzene (agr.)	kg	0.59
Water	Sn (sea)	kg	9.5E-23
Water	Propachlor	kg	1200
Water	1,3-butadiene (sea)	kg	0.000000056
Water	2,4,5-trichlorophenol (sea)	kg	0.054
Air	dinoterb	kg	2900
Water	pentachlorobenzene (sea)	kg	0.24
Water	DNOC (sea)	kg	0.000000021
Water	Propachlor (sea)	kg	0.0005
Soil	Carbofuran (agr.)	kg	580
Water	Fentin chloride	kg	170000
Water	diisooctylphthalate (sea)	kg	0.0039
Water	Fenitrothion	kg	240000
Soil	Disulfoton (ind.)	kg	290
Soil	Fenitrothion (agr.)	kg	760
Soil	benzo[ghi]perylene (ind.)	kg	240
Soil	Captafol (ind.)	kg	83000
Air	2,4-dichlorophenol	kg	1.4
Water	phenanthrene (sea)	kg	0.058
Soil	Carbaryl (ind.)	kg	120
Air	diisodecylphthalate	kg	0.56
Soil	anthracene (agr.)	kg	82
Soil	1,2-dichlorobenzene (ind.)	kg	0.019
Water	2,4,6-trichlorophenol (sea)	kg	0.00024
Soil	Permethrin (agr.)	kg	920
Soil	ethylene oxide (agr.)	kg	0.79
Water	MCPA (sea)	kg	5.3E-13
Water	pentachloronitrobenzene	kg	4000
Air	Isoproturon	kg	190
Water	Disulfothon	kg	64000
Air	benzo(ghi)perylene	kg	44
Soil	dichloromethane (agr.)	kg	0.00016
Soil	diisodecylphthalate (ind.)	kg	0.018
Water	ethyl benzene (sea)	kg	0.0000094
Water	Propoxur (sea)	kg	0.00012
Water	Diuron (sea)	kg	0.0019
Soil	Parathion-methyl (agr.)	kg	1100
Water	benzo(ghi)perylene (sea)	kg	0.049
Water	Dichlorprop	kg	5.3
Water	dioctylphthalate	kg	2.8
Soil	Isoproturon (agr.)	kg	170
Soil	formaldehyde (agr.)	kg	15
Soil	Methomyl (agr.)	kg	14000
Water	Zineb	kg	28000
Water	Heptenophos	kg	22000
Soil	hydrogen fluoride (ind.)	kg	9.4
Soil	dihexylphthalate (agr.)	kg	0.018
Soil	2,4,5-T (agr.)	kg	0.44
Soil	indeno[1,2,3-cd]pyrene (ind.)	kg	360
Water	pentachlorobenzene	kg	51
Soil	chlorobenzene (ind.)	kg	0.0032
Soil	ortho-xylene (ind.)	kg	0.0025
Soil	Heptachlor (ind.)	kg	8.9
Soil	Glyphosate (agr.)	kg	0.92
Water	Dimethoate	kg	170
Water	As (sea)	kg	3.8E-20
Water	3-chloroaniline	kg	2500
Soil	1,2,4,5-tetrachlorobenzene (ind.)	kg	0.09
Water	p-xylene (sea)	kg	0.00001
Water	acrolein (sea)	kg	5
Water	benzo(a)anthracene (sea)	kg	1.1
Water	Benomyl	kg	6800
Soil	tin (ind.)	kg	6.9
Soil	para-xylene (ind.)	kg	0.0014
Soil	Oxydemethon-methyl (agr.)	kg	970
Soil	1,4-dichlorobenzene (agr.)	kg	0.014
Soil	dimethylphthalate (agr.)	kg	0.0074
Water	tetrachloroethene (sea)	kg	0.0002
Water	Carbaryl (sea)	kg	0.0000019
Air	dimethylphthalate	kg	0.052
Water	Desmetryn (sea)	kg	0.0000041
Air	Demeton	kg	23
Soil	carbon disulfide (agr.)	kg	0.34

Impact category	x Fresh water aquatic ecotox.	kg 1,4-DB eq	
Soil	Ethoprophos (ind.)	kg	30000
Water	Azinphos-ethyl	kg	270000
Water	chlorobenzene (sea)	kg	0.00026
Soil	1,1,1-trichloroethane (ind.)	kg	0.00037
Soil	Chlorpropham (agr.)	kg	1.8
Water	dichloromethane (sea)	kg	0.000005
Air	Carbofuran	kg	900
Air	dimethoate	kg	13
Air	Endosulfan	kg	45
Soil	1-chloro-4-nitrobenzene (ind.)	kg	150
Soil	4-chloroaniline (agr.)	kg	170
Water	Isoproturon (sea)	kg	0.000029
Water	Dinoterb	kg	230000
Soil	phenanthrene (agr.)	kg	0.29
Soil	2,4,5-trichlorophenol (agr.)	kg	28
Soil	1,3-butadiene (agr.)	kg	0.000057
Soil	Metobromuron (agr.)	kg	95
Water	1,1,1-trichloroethane	kg	0.11
Soil	pentachloronitrobenzene (ind.)	kg	58
Water	Lindane (sea)	kg	0.11
Water	Chlorpropham	kg	83
Water	tributyltinoxide	kg	450000
Soil	Mo (ind.)	kg	260
Water	Diazinon	kg	110000
Water	Captan	kg	2100
Soil	Hg (agr.)	kg	850
Water	cyanazine (sea)	kg	0.0000025
Soil	vinyl chloride (agr.)	kg	0.000064
Soil	Cypermethrin (ind.)	kg	690000
Water	Fentin acetate (sea)	kg	0.087
Water	dihexylphthalate (sea)	kg	0.011
Water	methylbromide (sea)	kg	0.0023
Water	1,2-dichlorobenzene	kg	1
Water	1,2,4,5-tetrachlorobenzene (sea)	kg	0.029
Air	Heptachlor	kg	1.4
Soil	Phoxim (ind.)	kg	7.9
Water	Dieldrin (sea)	kg	16
Soil	Metobromuron (ind.)	kg	95
Water	Pyrazophos (sea)	kg	0.0023
Soil	Deltamethrin (agr.)	kg	24
Soil	Mo (agr.)	kg	260
Water	Endrin	kg	700000
Air	Trichlorfon	kg	13000
Soil	2,4,6-trichlorophenol (agr.)	kg	1.2
Water	Carbofuran	kg	13000
Air	Fenthion	kg	2500
Water	4-chloroaniline	kg	3100
Soil	acrolein (agr.)	kg	45000
Soil	MCPA (ind.)	kg	1.7
Water	carbon disulfide (sea)	kg	0.0065
Water	Dinoterb (sea)	kg	0.042
Water	Oxydemethon-methyl (sea)	kg	0.0003
Water	2,4-dichlorophenol	kg	170
Soil	Disulfoton (agr.)	kg	72
Water	butylbenzylphthalate	kg	76

B1.6 TERRESTRIAL ECOTOXICITY

Impact category	x Terrestrial ecotoxicity	kg 1,4-DB eq	
Air	1,1,1-trichloroethane	kg	0.00018
Air	1,2,3-trichlorobenzene	kg	0.075
Air	1,2,4-trichlorobenzene	kg	0.0088
Air	1,2-dichloroethane	kg	0.000026
Air	1,3,5-trichlorobenzene	kg	0.0019
Air	1,3-butadiene	kg	0.000000023
Air	2,4,6-trichlorophenol	kg	0.32
Air	2,4-D	kg	0.6
Air	acrolein	kg	16
Air	acrylonitrile	kg	0.008
Air	Aldrin	kg	0.014
Air	As	kg	1600
Air	Atrazine	kg	2
Air	Azinphos-methyl	kg	0.19
Air	Ba	kg	4.9
Air	Be	kg	1800
Air	Bentazon	kg	0.25
Air	benzene	kg	0.000016
Air	benzo(a)anthracene	kg	0.23
Air	benzo(a)pyrene	kg	0.24
Air	benzylchloride	kg	0.0017
Air	Carbendazim	kg	20
Air	Cd	kg	81
Air	cobalt	kg	110
Air	Cr (III)	kg	3000
Air	Cr (VI)	kg	3000
Air	CS2	kg	0.0051
Air	Cu	kg	7
Air	di(2-ethylhexyl)phthalate	kg	0.00022
Air	dibutylphthalate	kg	0.0039
Air	dichloromethane	kg	0.0000043
Air	Dichlorvos	kg	9.8
Air	Dieldrin	kg	1.1
Air	dioxin (TEQ)	kg	12000
Air	Diuron	kg	8.7
Air	DNOC	kg	0.24
Air	ethene	kg	1.3E-12
Air	ethylbenzene	kg	0.0000014
Air	ethylene oxide	kg	0.0025
Air	Fentin-acetate	kg	5.3
Air	fluoranthene	kg	0.018

Impact category	x Terrestrial ecotoxicity	kg 1,4-DB eq	
Air	formaldehyde	kg	0.94
Air	heavy metals	kg	48.93
Air	hexachlorobenzene	kg	0.26
Air	HF	kg	0.0029
Air	Hg	kg	28000
Air	m-xylene	kg	0.00000065
Air	Malathion	kg	0.02
Air	Mecoprop	kg	1.8
Air	Metabenzthiazuron	kg	0.45
Air	metals	kg	48.93
Air	Metamitron	kg	0.019
Air	methyl bromide	kg	0.013
Air	Mevinfos	kg	43
Air	Mo	kg	18
Air	naphthalene	kg	0.00082
Air	Ni	kg	120
Air	o-xylene	kg	0.0000013
Air	p-xylene	kg	0.00000053
Air	PAH's	kg	1
Air	Pb	kg	16
Air	pentachlorophenol	kg	2.3
Air	phenol	kg	0.0033
Air	phthalic acid anhydride	kg	0.00051
Air	propyleneoxide	kg	0.0015
Air	Sb	kg	0.61
Air	Se	kg	53
Air	Simazine	kg	8.8
Air	Sn	kg	14
Air	styrene	kg	0.00000014
Air	tetrachloroethene	kg	0.0081
Air	tetrachloromethane	kg	0.00047
Air	Thiram	kg	32
Air	Tl	kg	340
Air	toluene	kg	0.000016
Air	trichloroethene	kg	0.0000047
Air	trichloromethane	kg	0.00004
Air	Trifluralin	kg	0.017
Air	V	kg	670
Air	vinyl chloride	kg	0.00000026
Air	Zn	kg	12
Water	1,2,3-trichlorobenzene	kg	0.073
Water	1,2,4-trichlorobenzene	kg	0.0085
Water	1,2-dichloroethane	kg	0.000026
Water	1,3,5-trichlorobenzene	kg	0.0018
Water	1,3-butadiene	kg	0.000000021
Water	2,4,6-trichlorophenol	kg	0.00067
Water	2,4-D	kg	9.3E-10
Water	acrylonitrile	kg	0.0039
Water	Aldrin	kg	0.014
Water	As	kg	1E-17
Water	Atrazine	kg	0.00076
Water	Azinphos-methyl	kg	0.0000033
Water	Ba	kg	5.1E-19
Water	Be	kg	3.3E-16
Water	Bentazon	kg	0.00000018
Water	benzene	kg	0.000014
Water	benzo(a)anthracene	kg	0.014
Water	benzo(a)pyrene	kg	0.0025
Water	benzylchloride	kg	0.00083
Water	Carbendazim	kg	0.000000063
Water	Cd	kg	1.4E-20
Water	Co	kg	2.7E-18
Water	Cr (III)	kg	2.3E-19
Water	Cr (VI)	kg	2.3E-19
Water	Cu	kg	4.1E-21
Water	di(2-ethylhexyl)phthalate	kg	0.0000066
Water	dibutylphthalate	kg	0.000013
Water	dichloromethane	kg	0.0000039
Water	Dichlorvos	kg	0.014
Water	Dieldrin	kg	0.26
Water	dioxins (TEQ)	kg	590
Water	Diuron	kg	0.0017
Water	DNOC	kg	0.00000085
Water	ethyl benzene	kg	0.0000012
Water	ethylene oxide	kg	0.0018
Water	fluoranthene	kg	0.0049
Water	formaldehyde	kg	0.0016
Water	hexachlorobenzene	kg	0.26
Water	Hg	kg	930
Water	Malathion	kg	0.000011
Water	Mecoprop	kg	0.000000011
Water	metallic ions	kg	5.754E-21
Water	Metamitron	kg	8.5E-10
Water	Mevinfos	kg	0.000023
Water	Mo	kg	2.3E-18
Water	Ni	kg	1E-18
Water	PAH's	kg	0.0021
Water	Pb	kg	4.8E-22
Water	pentachlorophenol	kg	0.00032
Water	phenol	kg	0.0000025
Water	propylene oxide	kg	0.00065
Water	Sb	kg	1.7E-20
Water	Se	kg	1.6E-17
Water	Simazine	kg	0.001
Water	Sn	kg	7.9E-22
Water	styrene	kg	0.00000013
Water	tetrachloroethene	kg	0.0079
Water	tetrachloromethane	kg	0.00047
Water	Thiram	kg	0.093
Water	toluene	kg	0.000014
Water	trichloroethene	kg	0.0000046
Water	trichloromethane	kg	0.000039
Water	Trifluralin	kg	0.013
Water	V	kg	1E-17
Water	vinyl chloride	kg	0.00000026
Water	Zn	kg	2.5E-21
Soil	1,2,3-trichlorobenzene (ind.)	kg	8

Impact category	x Terrestrial ecotoxicity	kg 1,4-DB eq	
Soil	1,2,4-trichlorobenzene (ind.)	kg	0.99
Soil	1,2-dichloroethane (ind.)	kg	0.0017
Soil	1,3,5-trichlorobenzene (ind.)	kg	0.22
Soil	1,3-butadiene (ind.)	kg	0.00031
Soil	2,4,6-trichlorophenol (ind.)	kg	0.68
Soil	2,4-D (agr.)	kg	1.6
Soil	acrylonitrile (ind.)	kg	2.1
Soil	Aldrin (agr.)	kg	20
Soil	As (ind.)	kg	3300
Soil	Atrazine (agr.)	kg	6.6
Soil	Azinphos-methyl (agr.)	kg	0.97
Soil	Bentazon (agr.)	kg	0.59
Soil	benzene (ind.)	kg	0.0034
Soil	benzo(a)pyrene (ind.)	kg	23
Soil	benzylchloride (ind.)	kg	0.71
Soil	Carbendazim (agr.)	kg	49
Soil	Cd (agr.)	kg	170
Soil	Cd (ind.)	kg	170
Soil	Cr (III) (ind.)	kg	6300
Soil	Cr (VI) (ind.)	kg	6300
Soil	Cu (ind.)	kg	14
Soil	di(2-ethylhexyl)phthalate(ind)	kg	0.0014
Soil	dibutylphthalate (ind.)	kg	0.023
Soil	dichloromethane (ind.)	kg	0.00025
Soil	Dichlorvos (agr.)	kg	200
Soil	Dieldrin (agr.)	kg	110
Soil	dioxin (TEQ) (ind.)	kg	27000
Soil	Diuron (agr.)	kg	23
Soil	DNOC (agr.)	kg	0.52
Soil	ethylene oxide (ind.)	kg	0.19
Soil	fluoranthene (ind.)	kg	2.3
Soil	formaldehyde (ind.)	kg	4.4
Soil	gamma-HCH (Lindane) (agr.)	kg	23
Soil	hexachlorobenzene (ind.)	kg	3
Soil	Hg (ind.)	kg	56000
Soil	Malathion (agr.)	kg	0.076
Soil	Mecoprop (agr.)	kg	4.7
Soil	Metamitron (agr.)	kg	0.042
Soil	Mevinfos (agr.)	kg	87
Soil	Ni (ind.)	kg	240
Soil	Pb (ind.)	kg	33
Soil	pentachlorophenol (ind.)	kg	4.8
Soil	propylene oxide (ind.)	kg	0.12
Soil	Simazine (agr.)	kg	29
Soil	styrene (ind.)	kg	0.0012
Soil	tetrachloroethene (ind.)	kg	0.3
Soil	tetrachloromethane (ind.)	kg	0.0021
Soil	Thiram (agr.)	kg	51
Soil	toluene (ind.)	kg	0.019
Soil	trichloroethene (ind.)	kg	0.0021
Soil	trichloromethane (ind.)	kg	0.0016
Soil	vinyl chloride (ind.)	kg	0.00031
Soil	Zn (ind.)	kg	25
Soil	phenol (agr.)	kg	0.045
Soil	Bentazon (ind.)	kg	0.5
Water	Fentin chloride (sea)	kg	0.0025
Water	dihexylphthalate	kg	0.00026
Soil	Zineb (ind.)	kg	15
Soil	Iprodione (ind.)	kg	0.3
Water	Fentin acetate	kg	0.0061
Soil	Metolachlor (ind.)	kg	0.41
Soil	diethylphthalate (agr.)	kg	2.1
Water	Aldicarb	kg	0.19
Soil	Fenitrothion (ind.)	kg	81
Air	DDT	kg	19
Water	carbon disulfide	kg	0.0048
Water	Dichlorvos (sea)	kg	0.00022
Soil	1,3,5-trichlorobenzene (agr.)	kg	0.25
Soil	2-chlorophenol (agr.)	kg	0.38
Air	Propachlor	kg	0.54
Soil	Captan (agr.)	kg	0.041
Water	toluene (sea)	kg	0.0000019
Soil	2,4-dichlorophenol (ind.)	kg	0.54
Air	Parathion-ethyl	kg	1.1
Soil	styrene (agr.)	kg	0.0014
Soil	barium (agr.)	kg	10
Water	m-xylene	kg	0.0000006
Water	Parathion-methyl	kg	0.034
Water	Trichlorfon	kg	0.00007
Soil	Demeton (agr.)	kg	60
Water	Cypermethrin	kg	16
Soil	ethylene (ind.)	kg	2.3E-09
Water	1,4-dichlorobenzene	kg	0.012
Water	Acephate (sea)	kg	5.3E-10
Soil	1,3-dichlorobenzene (agr.)	kg	0.062
Soil	benzylchloride (agr.)	kg	0.8
Soil	Oxamyl (agr.)	kg	5.9
Air	tributyltinoxide	kg	17
Water	Pirimicarb (sea)	kg	0.000017
Water	Methomyl	kg	0.0022
Water	dimethylphthalate	kg	0.00037
Air	hexachloro-1,3-butadiene	kg	4.2
Soil	As (agr.)	kg	3300
Soil	2,3,4,6-tetrachlorophenol (ind.)	kg	0.97
Water	Dinoseb (sea)	kg	0.001
Water	Folpet (sea)	kg	0.074
Soil	Metazachlor (agr.)	kg	0.17
Water	o-xylene (sea)	kg	0.00000021
Soil	anilazine (agr.)	kg	0.23
Soil	diisodecylphthalate (agr.)	kg	0.004
Soil	Dichlorvos (ind.)	kg	200
Water	Anilazine	kg	0.00000005
Water	Metobromuron	kg	0.00046
Soil	Azinphos-ethyl (agr.)	kg	220

Impact category	x Terrestrial ecotoxicity	kg 1,4-DB eq	
Water	Aldicarb (sea)	kg	0.0048
Soil	carbon disulfide (ind.)	kg	1.6
Water	Oxamyl	kg	0.0000071
Water	Chlorpyriphos (sea)	kg	0.000057
Soil	Metazachlor (ind.)	kg	0.15
Air	2-chlorophenol	kg	0.053
Water	Fenthion (sea)	kg	0.0017
Air	Tolclophos-methyl	kg	0.00034
Soil	pentachlorobenzene (ind.)	kg	1.7
Air	dihexylphthalate	kg	0.00078
Soil	MCPA (agr.)	kg	0.094
Soil	Chlorpyriphos (ind.)	kg	17
Soil	Parathion-ethyl (agr.)	kg	17
Soil	Cyanazine (ind.)	kg	63
Soil	Glyphosate (ind.)	kg	0.096
Air	Carbaryl	kg	0.063
Soil	Pyrazophos (agr.)	kg	30
Water	hexachloro-1,3-butadiene	kg	4
Air	phenanthrene	kg	0.00014
Soil	benzene (agr.)	kg	0.0034
Soil	chrysene (ind.)	kg	4.5
Water	Chlordane (sea)	kg	0.28
Water	Dimethoate (sea)	kg	0.00000018
Water	Iprodione (sea)	kg	1.5E-10
Soil	dioxin (TEQ) (agr.)	kg	27000
Soil	phenanthrene (ind.)	kg	0.037
Water	Carbaryl	kg	0.00000026
Soil	Desmetryn (agr.)	kg	2.9
Water	fluoranthene (sea)	kg	0.00096
Water	Bifenthrin (sea)	kg	0.00059
Water	1,2,3,4-tetrachlorobenzene	kg	0.0093
Water	Heptenophos (sea)	kg	0.000024
Soil	Dinoseb (ind.)	kg	420
Air	cypermethrin	kg	8900
Soil	Heptenophos (ind.)	kg	16
Air	1-chloro-4-nitrobenzene	kg	0.54
Soil	Malathion (ind.)	kg	0.075
Soil	para-xylene (agr.)	kg	0.0015
Water	1,4-dichlorobenzene (sea)	kg	0.0057
Air	chrysene	kg	0.22
Soil	acrolein (ind.)	kg	7000
Air	Glyphosate	kg	0.047
Water	Glyphosate	kg	2.2E-11
Water	2,3,4,6-tetrachlorophenol (sea)	kg	0.0000052
Water	1,2,3-trichlorobenzene (sea)	kg	0.035
Soil	Chlorothalonil (ind.)	kg	0.61
Soil	Acephate (ind.)	kg	1.3
Soil	Methabenzthiazuron (ind.)	kg	0.88
Water	1,2-dichlorobenzene (sea)	kg	0.00024
Soil	naphtalene (ind.)	kg	2.6
Water	2,4-D (sea)	kg	1.8E-12
Soil	Dinoseb (agr.)	kg	590
Soil	diisooctylphthalate (ind.)	kg	0.00055
Soil	methylbromide (ind.)	kg	0.37
Water	Demeton	kg	0.012
Soil	Aldicarb (agr.)	kg	4200
Soil	Endrin (agr.)	kg	4200
Air	Heptenophos	kg	2.2
Soil	Folpet (ind.)	kg	78
Air	Chlorpropham	kg	0.037
Water	2,4-dichlorophenol (sea)	kg	0.0000062
Soil	Diuron (ind.)	kg	19
Soil	Acephate (agr.)	kg	1.7
Soil	1,1,1-trichloroethane (agr.)	kg	0.0015
Soil	chlorobenzene (agr.)	kg	0.12
Water	Triazophos	kg	0.039
Soil	dihexylphthalate (ind.)	kg	0.0073
Water	Mo (sea)	kg	2.9E-18
Soil	fluoranthene (agr.)	kg	2.3
Water	Sb (sea)	kg	3E-20
Soil	Fenthion (agr.)	kg	290
Water	Oxamyl (sea)	kg	0.000000023
Water	Fenthion	kg	0.088
Water	ethene (sea)	kg	9.9E-14
Water	Bentazon (sea)	kg	3.3E-10
Water	Fentin hydroxide (sea)	kg	0.000038
Air	1,2,4,5-tetrachlorobenzene	kg	0.24
Water	Cu (sea)	kg	2.5E-20
Soil	Mevinfos (ind.)	kg	90
Soil	chrysene (agr.)	kg	4.6
Water	1,2,3,5-tetrachlorobenzene	kg	0.17
Water	Iprodione	kg	0.000000044
Water	Ethoprophos	kg	0.24
Water	diisodecylphthalate (sea)	kg	0.000064
Water	methyl-mercury	kg	930
Air	dinoseb	kg	97
Soil	2,4,5-T (ind.)	kg	0.64
Soil	Methomyl (ind.)	kg	220
Soil	Triazophos (agr.)	kg	250
Water	diisodecylphthalate	kg	0.00038
Soil	Cyromazine (agr.)	kg	630
Soil	Thiram (ind.)	kg	81
Water	Co (sea)	kg	4.9E-18
Soil	ethylbenzene (ind.)	kg	0.0019
Water	propylene oxide (sea)	kg	0.000018
Soil	vanadium (agr.)	kg	1400
Water	Dichlorprop (sea)	kg	1.1E-14
Water	chrysene	kg	0.0084
Water	thallium	kg	3.1E-17
Water	Chlorothalonil (sea)	kg	0.00038
Water	Triazophos (sea)	kg	0.00084
Air	3-chloroaniline	kg	0.47
Water	phenanthrene	kg	0.00006
Soil	bifenthrin (ind.)	kg	83
Water	tetrachloromethane (sea)	kg	0.00036
Water	4-chloroaniline (sea)	kg	0.000086

Impact category	x Terrestrial ecotoxicity	kg 1,4-DB eq	
Water	Parathion-ethyl	kg	0.0031
Soil	benzo[a]anthracene (agr.)	kg	31
Air	Chlorpyriphos	kg	0.13
Soil	ethylene (agr.)	kg	2.3E-09
Soil	pentachloronitrobenzene (agr.)	kg	2.7
Soil	Folpet (agr.)	kg	110
Soil	anthracene (ind.)	kg	8.8
Air	Parathion-methyl	kg	5.7
Air	Lindane	kg	1.8
Water	trichloroethene (sea)	kg	0.0000019
Water	Phoxim (sea)	kg	0.0013
Soil	Heptachlor (agr.)	kg	5.5
Soil	Dimethoate (agr.)	kg	0.8
Water	Glyphosate (sea)	kg	4.4E-14
Water	3,4-dichloroaniline (sea)	kg	0.0000067
Soil	benzo[ghi]perylene (agr.)	kg	8.3
Soil	Metolachlor (agr.)	kg	0.54
Soil	Dichlorprop (ind.)	kg	0.0014
Soil	1,4-dichlorobenzene (ind.)	kg	1
Soil	Chlordane (agr.)	kg	74
Water	Linuron (sea)	kg	0.00031
Air	Metobromuron	kg	0.99
Soil	toluene (agr.)	kg	0.019
Water	styrene (sea)	kg	0.000000027
Air	Oxamyl	kg	2.9
Water	Chloridazon (sea)	kg	0.000064
Soil	Dichlorprop (agr.)	kg	0.0014
Water	Ethoprophos (sea)	kg	0.0072
Soil	phenol (ind.)	kg	0.041
Soil	Parathion-methyl (ind.)	kg	79
Air	Chlordane	kg	2.2
Soil	Fentin acetate (agr.)	kg	12
Water	Metamitron (sea)	kg	1.4E-11
Water	Methabenzthiazuron	kg	0.00002
Air	Permethrin	kg	26
Soil	Pyrazophos (ind.)	kg	29
Soil	4-chloroaniline (ind.)	kg	11
Air	4-chloroaniline	kg	0.016
Soil	thallium (agr.)	kg	700
Air	Acephate	kg	0.69
Water	naphtalene	kg	0.00049
Air	Metolachlor	kg	0.11
Water	benzylchloride (sea)	kg	0.000025
Soil	Ethoprophos (agr.)	kg	270
Air	Deltamethrin	kg	0.76
Soil	anilazine (ind.)	kg	0.23
Soil	Dinoterb (ind.)	kg	9.9
Soil	Coumaphos (agr.)	kg	16000
Water	Permethrin (sea)	kg	0.017
Air	anilazine	kg	0.092
Water	1,2-dichloroethane (sea)	kg	0.00002
Soil	tetrachloromethane (agr.)	kg	0.0021
Soil	tributyltinoxide (ind.)	kg	37
Water	Pb (sea)	kg	4.6E-21
Water	dioxins (TEQ) (sea)	kg	830
Water	naphtalene (sea)	kg	0.000019
Soil	Propoxur (ind.)	kg	1300
Soil	dibutylphthalate (agr.)	kg	0.023
Air	Ethoprophos	kg	17
Soil	diethylphthalate (ind.)	kg	2.1
Soil	Pirimicarb (ind.)	kg	94
Water	Metazachlor (sea)	kg	0.00000003
Air	Dichlorprop	kg	0.00068
Water	3-chloroaniline (sea)	kg	0.000000017
Water	p-xylene	kg	0.00000049
Water	butylbenzylphthalate (sea)	kg	0.0000001
Water	V (sea)	kg	2.2E-17
Water	Chlordane	kg	0.097
Water	Cd (sea)	kg	1.1E-19
Soil	acrylonitrile (agr.)	kg	2.5
Soil	Co (agr.)	kg	220
Soil	butylbenzylphthalate (ind.)	kg	0.01
Water	Thiram (sea)	kg	0.00031
Soil	Endrin (ind.)	kg	3600
Water	benzo(ghi)perylene	kg	0.00043
Water	methyl-mercury (sea)	kg	7600
Soil	Carbendazim (ind.)	kg	38
Air	2,4,5-trichlorophenol	kg	0.24
Water	ethylene oxide (sea)	kg	0.000097
Soil	Propoxur (agr.)	kg	1800
Water	DDT (sea)	kg	0.96
Water	Deltamethrin (sea)	kg	0.0014
Water	benzene (sea)	kg	0.0000017
Soil	antimony (agr.)	kg	1.3
Soil	diisooctylphthalate (agr.)	kg	0.00055
Soil	Dieldrin (ind.)	kg	100
Water	dioctylphthalate (sea)	kg	0.000000088
Water	Chlorpropham (sea)	kg	0.00000045
Air	Pyrazophos	kg	2.3
Air	Triazophos	kg	34
Air	Oxydemethon-methyl	kg	41
Soil	dioctylphthalate (agr.)	kg	0.000048
Soil	Oxamyl (ind.)	kg	6
Soil	pentachlorophenol (agr.)	kg	4.8
Soil	Linuron (ind.)	kg	18
Soil	Chloridazon (ind.)	kg	0.68
Water	Endosulfan (sea)	kg	0.000016
Soil	propylene oxide (agr.)	kg	0.14
Soil	Atrazine (ind.)	kg	4.4
Soil	Pb (agr.)	kg	33
Soil	2,4-dichlorophenol (agr.)	kg	0.59
Water	benzo(k)fluoranthrene	kg	0.21
Water	Chlorfenvinphos (sea)	kg	0.00000086
Soil	Metamitron (ind.)	kg	0.038
Water	hexachlorobenzene (sea)	kg	0.24
Water	o-xylene	kg	0.0000012

Impact category	x Terrestrial ecotoxicity	kg 1,4-DB eq	
Water	Fenitrothion (sea)	kg	0.000084
Water	Coumaphos (sea)	kg	0.5
Water	Ni (sea)	kg	2.6E-18
Soil	indeno[1,2,3-cd]pyrene (agr.)	kg	13
Soil	PAH (carcinogenic) (agr.)	kg	6.3
Soil	Cyanazine (agr.)	kg	69
Soil	Zineb (agr.)	kg	16
Soil	ethylbenzene (agr.)	kg	0.0019
Soil	hexachloro-1,3-butadiene (agr.)	kg	53
Soil	Azinphos-methyl (ind.)	kg	1
Air	butylbenzylphthalate	kg	0.0013
Water	Tri-allate (sea)	kg	0.00013
Water	pentachlorophenol (sea)	kg	0.0000026
Water	Mecoprop (sea)	kg	1.8E-11
Soil	dimethylphthalate (ind.)	kg	1.4
Water	1,2,3,4-tetrachlorobenzene (sea)	kg	0.0037
Water	Methabenzthiazuron (sea)	kg	0.0000006
Soil	Tolclophos-methyl (agr.)	kg	1.8
Soil	Aldicarb (ind.)	kg	4200
Air	pentachloronitrobenzene	kg	0.12
Soil	hexachloro-1,3-butadiene (ind.)	kg	47
Soil	hexachlorobenzene (agr.)	kg	3.5
Soil	vanadium (ind.)	kg	1400
Soil	bifenthrin (agr.)	kg	83
Soil	trichloroethene (agr.)	kg	0.0021
Soil	DDT (agr.)	kg	60
Water	Captafol (sea)	kg	0.000000016
Water	Methomyl (sea)	kg	0.000075
Soil	Deltamethrin (ind.)	kg	8.5
Water	phthalic anhydride	kg	1.2E-10
Soil	1,2-dichloroethane (agr.)	kg	0.0017
Water	diethylphthalate	kg	0.0056
Soil	Cu (agr.)	kg	14
Water	dimethylphthalate (sea)	kg	0.0000047
Soil	Benomyl (ind.)	kg	3.5
Water	Permethrin	kg	0.39
Soil	1,2,3,4-tetrachlorobenzene (agr.)	kg	0.83
Air	diazinon	kg	0.29
Air	indeno[1,2,3-cd]pyrene	kg	0.8
Water	Folpet	kg	0.6
Soil	Cr (III) (agr.)	kg	6300
Air	2,3,4,6-tetrachlorophenol	kg	0.31
Soil	Chloridazon (agr.)	kg	0.9
Soil	benzo[k]fluoranthrene (ind.)	kg	390
Soil	Fentin hydroxide (agr.)	kg	12
Water	Parathion-methyl (sea)	kg	0.00071
Air	methomyl	kg	120
Water	Propoxur	kg	0.00031
Soil	meta-xylene (ind.)	kg	0.003
Water	Deltamethrin	kg	0.032
Soil	Dimethoate (ind.)	kg	0.62
Water	1-chloro-4-nitrobenzene (sea)	kg	0.096
Water	methylbromide	kg	0.011
Water	PAH (sea)	kg	0.00081
Soil	Oxydemethon-methyl (ind.)	kg	85
Soil	Chlorothalonil (agr.)	kg	0.68
Water	1,2,4-trichlorobenzene (sea)	kg	0.004
Water	1,3-dichlorobenzene	kg	0.00042
Soil	benzo[k]fluoranthrene (agr.)	kg	390
Soil	3,4-dichloroaniline (ind.)	kg	18
Water	thallium (sea)	kg	4.2E-17
Water	Dinoseb	kg	0.34
Air	anthracene	kg	0.032
Water	Mevinfos (sea)	kg	0.00000032
Soil	Triazophos (ind.)	kg	200
Water	Isoproturon	kg	0.000016
Water	tributyltinoxide (sea)	kg	0.0069
Water	1,3-dichlorobenzene (sea)	kg	0.0002
Water	HF (sea)	kg	0.000045
Water	Azinphos-methyl (sea)	kg	0.000000049
Air	Bifenthrin	kg	8.8
Air	diethylphthalate	kg	0.53
Soil	Aldrin (ind.)	kg	20
Water	diethylphthalate (sea)	kg	0.0001
Water	2,4,5-T	kg	0.000000036
Water	Hg (sea)	kg	7600
Water	Cypermethrin (sea)	kg	0.25
Soil	trichloromethane (agr.)	kg	0.0016
Water	Trichlorfon (sea)	kg	0.00000048
Soil	Mecoprop (ind.)	kg	3.3
Air	Iprodione	kg	0.11
Water	Chlorpyriphos	kg	0.021
Soil	Benomyl (agr.)	kg	3.5
Soil	Chlordane (ind.)	kg	73
Soil	3-chloroaniline (agr.)	kg	1.4
Soil	Ni (agr.)	kg	240
Soil	Fenthion (ind.)	kg	280
Water	Lindane	kg	0.16
Soil	1,2,3-trichlorobenzene (agr.)	kg	9.3
Soil	tin (agr.)	kg	30
Water	Captafol	kg	0.00000019
Water	Cr (VI) (sea)	kg	2E-18
Soil	benzo[a]anthracene (ind.)	kg	31
Water	Chlorfenvinphos	kg	0.000046
Water	indeno[1,2,3-cd]pyrene (sea)	kg	0.0000041
Air	tri-allate	kg	0.0069
Soil	Trichlorfon (ind.)	kg	2600
Air	pentachlorobenzene	kg	0.039
Air	2,4,5-T	kg	0.32
Soil	selenium (ind.)	kg	110

Impact category	x Terrestrial ecotoxicity	kg 1,4-DB eq	
Air	1,2,3,5-tetrachlorobenzene	kg	0.18
Water	dibutylphthalate (sea)	kg	0.00000021
Water	Cr (III) (sea)	kg	2E-18
Water	benzo(a)pyrene (sea)	kg	0.0008
Air	chlorobenzene	kg	0.00073
Soil	Fentin chloride (agr.)	kg	12
Soil	Simazine (ind.)	kg	21
Water	chrysene (sea)	kg	0.0016
Soil	1,2,3,5-tetrachlorobenzene (ind.)	kg	12
Soil	methylbromide (agr.)	kg	0.36
Water	Parathion-ethyl (sea)	kg	0.000082
Soil	Pirimicarb (agr.)	kg	120
Water	Pyrazophos	kg	0.0017
Soil	1,2,4-trichlorobenzene (agr.)	kg	1.2
Water	trichloromethane (sea)	kg	0.000019
Air	Captafol	kg	5.9
Soil	Propachlor (ind.)	kg	2.3
Air	Endrin	kg	49
Soil	Fentin chloride (ind.)	kg	11
Soil	thallium (ind.)	kg	700
Air	Fentin hydroxide	kg	5.5
Soil	1,2,3,5-tetrachlorobenzene (agr.)	kg	15
Air	Desmetryn	kg	1.2
Soil	Iprodione (agr.)	kg	0.14
Air	Pirimicarb	kg	46
Air	MCPA	kg	0.043
Soil	Tri-allate (agr.)	kg	1.3
Soil	dioctylphthalate (ind.)	kg	0.000048
Water	1-chloro-4-nitrobenzene	kg	0.44
Water	vinyl chloride (sea)	kg	0.00000013
Water	Fentin hydroxide	kg	0.0021
Soil	gamma-HCH (Lindane) (ind.)	kg	22
Soil	butylbenzylphthalate (agr.)	kg	0.01
Air	coumaphos	kg	1000
Soil	Isoproturon (ind.)	kg	4.6
Soil	Captafol (agr.)	kg	28
Water	phenol (sea)	kg	0.000000038
Water	Diazinon (sea)	kg	0.000082
Water	diisooctylphthalate	kg	0.0000064
Soil	antimony (ind.)	kg	1.3
Water	Captan (sea)	kg	9.4E-10
Water	Cyromazine (sea)	kg	0.000000073
Air	3,4-dichloroaniline	kg	8.7
Water	Metobromuron (sea)	kg	0.000038
Soil	Trichlorfon (agr.)	kg	1900
Soil	Chlorpyriphos (agr.)	kg	17
Soil	Desmetryn (ind.)	kg	2.6
Water	pentachloronitrobenzene (sea)	kg	0.029
Soil	2,4,5-trichlorophenol (ind.)	kg	3.9
Water	Anilazine (sea)	kg	7E-10
Water	1,2,3,5-tetrachlorobenzene (sea)	kg	0.074
Air	dioctylphthalate	kg	0.0000098
Air	1,2,3,4-tetrachlorobenzene	kg	0.0099
Water	Trifluralin (sea)	kg	0.003
Soil	1,2-dichlorobenzene (agr.)	kg	0.054
Soil	Diazinon (agr.)	kg	12
Soil	methyl-mercury (agr.)	kg	56000
Air	1,2-dichlorobenzene	kg	0.00053
Water	Be (sea)	kg	3.9E-16
Soil	di(2-ethylhexyl)phthalate (agr.)	kg	0.0014
Air	Metazachlor	kg	0.074
Soil	2-chlorophenol (ind.)	kg	0.37
Water	HF	kg	0.000045
Water	Tolclophos-methyl (sea)	kg	0.000067
Soil	Chlorpropham (ind.)	kg	0.12
Soil	Co (ind.)	kg	220
Water	Metazachlor	kg	0.0000014
Soil	Fentin acetate (ind.)	kg	11
Water	Cyromazine	kg	0.0000019
Water	1,3,5-trichlorobenzene (sea)	kg	0.00083
Soil	Dinoterb (agr.)	kg	9.9
Air	Disulfothon	kg	0.043
Water	phthalic anhydride (sea)	kg	2.8E-12
Soil	methyl-mercury (ind.)	kg	56000
Soil	Tolclophos-methyl (ind.)	kg	1.5
Water	Desmetryn	kg	0.000036
Water	Chlorothalonil	kg	0.0055
Water	Pirimicarb	kg	0.00093
Water	formaldehyde (sea)	kg	0.000024
Soil	Linuron (agr.)	kg	21
Soil	1-chloro-4-nitrobenzene (agr.)	kg	17
Water	2,4,5-trichlorophenol	kg	0.061
Soil	tributyltinoxide (agr.)	kg	37
Water	Azinphos-ethyl (sea)	kg	0.00034
Water	Chloridazon	kg	0.00038
Water	Phoxim	kg	0.015
Air	Captan	kg	0.024
Soil	Phoxim (agr.)	kg	4.7
Water	Tri-allate	kg	0.0027
Air	benzo(k)fluoranthrene	kg	30
Water	2,4,5-T (sea)	kg	6.4E-11
Soil	beryllium (ind.)	kg	3600
Soil	Carbaryl (agr.)	kg	0.11
Soil	Captan (ind.)	kg	0.12
Soil	beryllium (agr.)	kg	3600
Soil	meta-xylene (agr.)	kg	0.003
Water	Endrin (sea)	kg	0.38
Water	Metolachlor	kg	0.00021
Water	Aldrin (sea)	kg	0.0067
Soil	tetrachloroethene (agr.)	kg	0.3

Impact category	x Terrestrial ecotoxicity	kg 1,4-DB eq	
Water	Se (sea)	kg	1.8E-17
Air	Chlorothalonil	kg	0.0071
Soil	Propachlor (agr.)	kg	2.5
Air	cyromazine	kg	310
Soil	Parathion-ethyl (ind.)	kg	17
Water	ethene	kg	1.1E-12
Water	1,1,1-trichloroethane (sea)	kg	0.0001
Soil	ortho-xylene (agr.)	kg	0.0034
Air	Propoxur	kg	700
Air	Fenitrothion	kg	21
Water	di(2-ethylhexyl)phthalate (sea)	kg	0.00000096
Water	Carbendazim (sea)	kg	1.6E-10
Soil	Heptenophos (agr.)	kg	16
Air	Linuron	kg	0.2
Soil	Endosulfan (ind.)	kg	2.8
Soil	Coumaphos (ind.)	kg	12000
Soil	Phtalic anhydride (ind.)	kg	0.00042
Air	Fentin chloride	kg	0.26
Water	acrylonitrile (sea)	kg	0.00012
Water	Coumaphos	kg	6
Soil	Cr (VI) (agr.)	kg	6300
Water	hexachloro-1,3-butadiene (sea)	kg	2.1
Soil	Trifluarin (ind.)	kg	34
Soil	DDT (ind.)	kg	59
Water	Zineb (sea)	kg	0.000028
Water	Bifenthrin	kg	0.021
Water	Simazine (sea)	kg	0.000019
Air	Aldicarb	kg	2000
Soil	Cypermethrin (agr.)	kg	90000
Water	3,4-dichloroaniline	kg	0.00076
Water	Disulfothon (sea)	kg	0.000021
Soil	barium (ind.)	kg	10
Air	cyanazine	kg	31
Soil	Tri-allate (ind.)	kg	1.3
Soil	1,2,3,4-tetrachlorobenzene (ind.)	kg	0.77
Water	Metolachlor (sea)	kg	0.0000054
Soil	Phtalic anhydride (agr.)	kg	0.0026
Water	Linuron	kg	0.011
Air	Chlorfenvinphos	kg	0.49
Water	Acephate	kg	0.000000022
Water	Tolclophos-methyl	kg	0.00032
Soil	1,2,4,5-tetrachlorobenzene (agr.)	kg	19
Water	m-xylene (sea)	kg	0.00000011
Soil	1,3-dichlorobenzene (ind.)	kg	0.062
Water	Endosulfan	kg	0.0018
Soil	Demeton (ind.)	kg	49
Air	Benomyl	kg	0.47
Water	benzo(k)fluoranthrene (sea)	kg	0.088
Soil	DNOC (ind.)	kg	0.49
Air	Chloridazon	kg	0.00046
Water	Carbofuran (sea)	kg	0.00000061
Soil	3-chloroaniline (ind.)	kg	1.2
Soil	Zn (agr.)	kg	25
Air	Folpet	kg	1.7
Soil	Chlorfenvinphos (agr.)	kg	1.3
Water	1,2,4,5-tetrachlorobenzene	kg	0.23
Water	2-chlorophenol (sea)	kg	0.000027
Water	Benomyl (sea)	kg	1.4E-09
Air	Azinphos-ethyl	kg	2.4
Soil	Methabenzthiazuron (agr.)	kg	1.1
Air	1,3-dichlorobenzene	kg	0.00044
Water	cyanazine	kg	0.0000022
Water	2-chlorophenol	kg	0.0013
Soil	Endosulfan (agr.)	kg	2.7
Air	diisooctylphthalate	kg	0.00011
Soil	Azinphos-ethyl (ind.)	kg	72
Water	Zn (sea)	kg	1.9E-20
Air	methyl-mercury	kg	28000
Soil	Diazinon (ind.)	kg	10
Water	anthracene (sea)	kg	0.004
Water	acrolein	kg	5.8
Water	anthracene	kg	0.02
Air	Phoxim	kg	0.017
Air	1,4-dichlorobenzene	kg	0.012
Soil	Chlorfenvinphos (ind.)	kg	1.2
Soil	Trifluarin (agr.)	kg	35
Soil	hydrogen fluoride (agr.)	kg	0.006
Water	Ba (sea)	kg	6.6E-19
Soil	Permethrin (ind.)	kg	250
Soil	Fentin hydroxide (ind.)	kg	11
Air	zineb	kg	7.2
Soil	2,3,4,6-tetrachlorophenol (agr.)	kg	1
Water	Demeton (sea)	kg	0.00023
Water	MCPA	kg	1.4E-11
Water	2,3,4,6-tetrachlorophenol	kg	0.0017
Soil	3,4-dichloroaniline (agr.)	kg	26
Water	DDT	kg	0.31
Soil	selenium (agr.)	kg	110
Water	Malathion (sea)	kg	0.0000002
Soil	2,4-D (ind.)	kg	1.1
Soil	PAH (carcinogenic) (ind.)	kg	6.3
Water	Heptachlor	kg	0.00053
Soil	Cyromazine (ind.)	kg	630
Water	indeno[1,2,3-cd]pyrene	kg	0.0000062
Water	chlorobenzene	kg	0.00072
Soil	Carbofuran (ind.)	kg	5.9
Soil	benzo(a)pyrene (agr.)	kg	23
Water	Heptachlor (sea)	kg	0.000024
Water	Oxydemethon-methyl	kg	0.00046
Water	Atrazine (sea)	kg	0.00005
Soil	naphtalene (agr.)	kg	3.1
Soil	pentachlorobenzene (agr.)	kg	2.1

Impact category	x Terrestrial ecotoxicity	kg 1,4-DB eq	
Water	Sn (sea)	kg	7.2E-21
Water	Propachlor	kg	0.00081
Water	1,3-butadiene (sea)	kg	0.000000004
Water	2,4,5-trichlorophenol (sea)	kg	0.00091
Air	dinoterb	kg	3.4
Water	pentachlorobenzene (sea)	kg	0.026
Water	DNOC (sea)	kg	1.5E-09
Water	Propachlor (sea)	kg	0.000013
Soil	Carbofuran (agr.)	kg	7.5
Water	Fentin chloride	kg	0.092
Water	diisooctylphthalate (sea)	kg	0.0000035
Water	Fenitrothion	kg	0.0047
Soil	Disulfoton (ind.)	kg	11
Soil	Fenitrothion (agr.)	kg	83
Soil	benzo[ghi]perylene (ind.)	kg	8.3
Soil	Captafol (ind.)	kg	22
Air	2,4-dichlorophenol	kg	0.03
Water	phenanthrene (sea)	kg	0.0000063
Soil	Carbaryl (ind.)	kg	0.14
Air	diisodecylphthalate	kg	0.00092
Soil	anthracene (agr.)	kg	8.9
Soil	1,2-dichlorobenzene (ind.)	kg	0.054
Water	2,4,6-trichlorophenol (sea)	kg	0.000013
Soil	Permethrin (agr.)	kg	250
Soil	ethylene oxide (agr.)	kg	0.22
Water	MCPA (sea)	kg	2.2E-14
Water	pentachloronitrobenzene	kg	0.05
Air	Isoproturon	kg	2.5
Water	Disulfothon	kg	0.0012
Air	benzo(ghi)perylene	kg	0.2
Soil	dichloromethane (agr.)	kg	0.00025
Soil	diisodecylphthalate (ind.)	kg	0.004
Water	ethyl benzene (sea)	kg	0.0000001
Water	Propoxur (sea)	kg	0.0000032
Water	Diuron (sea)	kg	0.000032
Soil	Parathion-methyl (agr.)	kg	81
Water	benzo(ghi)perylene (sea)	kg	0.00025
Water	Dichlorprop	kg	6.1E-12
Water	dioctylphthalate	kg	0.00000013
Soil	Isoproturon (agr.)	kg	6.4
Soil	formaldehyde (agr.)	kg	5.8
Soil	Methomyl (agr.)	kg	300
Water	Zineb	kg	0.0013
Water	Heptenophos	kg	0.0016
Soil	hydrogen fluoride (ind.)	kg	0.006
Soil	dihexylphthalate (agr.)	kg	0.0073
Soil	2,4,5-T (agr.)	kg	0.74
Soil	indeno[1,2,3-cd]pyrene (ind.)	kg	13
Water	pentachlorobenzene	kg	0.038
Soil	chlorobenzene (ind.)	kg	0.12
Soil	ortho-xylene (ind.)	kg	0.0034
Soil	Heptachlor (ind.)	kg	5.3
Soil	Glyphosate (agr.)	kg	0.096
Water	Dimethoate	kg	0.000012
Water	As (sea)	kg	3E-17
Water	3-chloroaniline	kg	0.0000094
Soil	1,2,4,5-tetrachlorobenzene (ind.)	kg	17
Water	p-xylene (sea)	kg	0.000000089
Water	acrolein (sea)	kg	0.16
Water	benzo(a)anthracene (sea)	kg	0.0062
Water	Benomyl	kg	0.000000082
Soil	tin (ind.)	kg	30
Soil	para-xylene (ind.)	kg	0.0015
Soil	Oxydemethon-methyl (agr.)	kg	92
Soil	1,4-dichlorobenzene (agr.)	kg	1
Soil	dimethylphthalate (agr.)	kg	1.4
Water	tetrachloroethene (sea)	kg	0.004
Water	Carbaryl (sea)	kg	1.1E-09
Air	dimethylphthalate	kg	0.64
Water	Desmetryn (sea)	kg	0.00000075
Air	Demeton	kg	0.3
Soil	carbon disulfide (agr.)	kg	1.6
Soil	Ethoprophos (ind.)	kg	190
Water	Azinphos-ethyl	kg	0.021
Water	chlorobenzene (sea)	kg	0.00041
Soil	1,1,1-trichloroethane (ind.)	kg	0.0015
Soil	Chlorpropham (agr.)	kg	0.13
Water	dichloromethane (sea)	kg	0.00000065
Air	Carbofuran	kg	3
Air	dimethoate	kg	0.3
Air	Endosulfan	kg	0.036
Soil	1-chloro-4-nitrobenzene (ind.)	kg	17
Soil	4-chloroaniline (agr.)	kg	16
Water	Isoproturon (sea)	kg	0.00000038
Water	Dinoterb	kg	0.013
Soil	phenanthrene (agr.)	kg	0.037
Soil	2,4,5-trichlorophenol (agr.)	kg	4.4
Soil	1,3-butadiene (agr.)	kg	0.00031
Soil	Metobromuron (agr.)	kg	2.2
Water	1,1,1-trichloroethane	kg	0.00018
Soil	pentachloronitrobenzene (ind.)	kg	2.6
Water	Lindane (sea)	kg	0.0039
Water	Chlorpropham	kg	0.000025
Water	tributyltinoxide	kg	0.11
Soil	Mo (ind.)	kg	36
Water	Diazinon	kg	0.0041
Water	Captan	kg	0.000000062
Soil	Hg (agr.)	kg	56000
Water	cyanazine (sea)	kg	0.00000004
Soil	vinyl chloride (agr.)	kg	0.00031
Soil	Cypermethrin (ind.)	kg	78000
Water	Fentin acetate (sea)	kg	0.00011
Water	dihexylphthalate (sea)	kg	0.000017

Impact category	x Terrestrial ecotoxicity	kg 1,4-DB eq	
Water	methylbromide (sea)	kg	0.00091
Water	1,2-dichlorobenzene	kg	0.00052
Water	1,2,4,5-tetrachlorobenzene (sea)	kg	0.095
Air	Heptachlor	kg	0.00088
Soil	Phoxim (ind.)	kg	3.8
Water	Dieldrin (sea)	kg	0.1
Soil	Metobromuron (ind.)	kg	2.2
Water	Pyrazophos (sea)	kg	0.000029
Soil	Deltamethrin (agr.)	kg	8.5
Soil	Mo (agr.)	kg	36
Water	Endrin	kg	0.35
Air	Trichlorfon	kg	1200
Soil	2,4,6-trichlorophenol (agr.)	kg	0.7
Water	Carbofuran	kg	0.000035
Air	Fenthion	kg	16
Water	4-chloroaniline	kg	0.0036
Soil	acrolein (agr.)	kg	7000
Soil	MCPA (ind.)	kg	0.086
Water	carbon disulfide (sea)	kg	0.001
Water	Dinoterb (sea)	kg	0.000051
Water	Oxydemethon-methyl (sea)	kg	0.0000052
Water	2,4-dichlorophenol	kg	0.00096
Soil	Disulfoton (agr.)	kg	11
Water	butylbenzylphthalate	kg	0.0000066

B1.7 *PHOTOCHEMICAL OXIDATION*

Impact category	Photochemical oxidation	kg C2H2	
Air	1,1,1-trichloroethane	kg	0.009
Air	1,2,3-trimethylbenzene	kg	1.27
Air	1,2,4-trimethylbenzene	kg	1.28
Air	1,3,5-trimethylbenzene	kg	1.38
Air	1,3-butadiene	kg	0.85
Air	1-butene	kg	1.08
Air	1-butoxy propanol	kg	0.463
Air	1-hexene	kg	0.874
Air	1-methoxy-2-propanol	kg	0.355
Air	1-pentene	kg	0.977
Air	2,2-dimethylbutane	kg	0.241
Air	2,3-dimethylbutane	kg	0.541
Air	2-butoxyethanol	kg	0.483
Air	2-ethoxyethanol	kg	0.386
Air	2-methoxyethanol	kg	0.307
Air	2-methyl-1-butanol	kg	0.489
Air	2-methyl-1-butene	kg	0.771
Air	2-methyl-2-butanol	kg	0.228
Air	2-methyl-2-butene	kg	0.842
Air	2-methyl hexane	kg	0.411
Air	2-methyl pentane	kg	0.42
Air	3,5-diethyltoluene	kg	1.3
Air	3,5-dimethylethylbenzene	kg	1.32
Air	3-methyl-1-butanol	kg	0.433
Air	3-methyl-1-butene	kg	0.671
Air	3-methyl-2-butanol	kg	0.406
Air	3-methyl hexane	kg	0.364
Air	3-methyl pentane	kg	0.479
Air	3-pentanol	kg	0.595
Air	acetaldehyde	kg	0.641
Air	acetic acid	kg	0.097
Air	acetone	kg	0.094
Air	benzaldehyde	kg	-0.092
Air	benzene	kg	0.22
Air	butane	kg	0.352
Air	CO	kg	0.027
Air	cyclohexane	kg	0.29
Air	cyclohexanol	kg	0.518
Air	cyclohexanone	kg	0.299
Air	decane	kg	0.384
Air	diacetone alcohol	kg	0.307
Air	dichloromethane	kg	0.068
Air	diethyl ether	kg	0.445
Air	dimethyl ether	kg	0.189
Air	dodecane	kg	0.357
Air	ethane	kg	0.123
Air	ethanol	kg	0.399
Air	ethene	kg	1
Air	ethyl t-butyl ether	kg	0.244
Air	ethylacetate	kg	0.209
Air	ethylbenzene	kg	0.73
Air	ethylene glycol	kg	0.373
Air	ethyne	kg	0.085
Air	formaldehyde	kg	0.52
Air	formic acid	kg	0.032
Air	heptane	kg	0.494
Air	hexane	kg	0.482
Air	i-butane	kg	0.307
Air	i-butanol	kg	0.36
Air	i-butyraldehyde	kg	0.514
Air	i-propyl acetate	kg	0.211
Air	i-propyl benzene	kg	0.5
Air	isoprene	kg	1.09
Air	isopropanol	kg	0.188
Air	m-ethyl toluene	kg	1.02
Air	m-xylene	kg	1.1
Air	methane	kg	0.006
Air	methanol	kg	0.14
Air	methyl acetate	kg	0.059
Air	methyl chloride	kg	0.005
Air	methyl formate	kg	0.027
Air	methyl i-propyl ketone	kg	0.49
Air	methyl t-butyl ether	kg	0.175

Impact category	Photochemical oxidation	kg C2H2	
Air	methyl t-butyl ketone	kg	0.323
Air	neopentane	kg	0.173
Air	NO	kg	-0.427
Air	NO2	kg	0.028
Air	nonane	kg	0.414
Air	o-ethyl toluene	kg	0.898
Air	o-xylene	kg	1.1
Air	octane	kg	0.453
Air	p-ethyl toluene	kg	0.906
Air	p-xylene	kg	1
Air	pentanal	kg	0.765
Air	pentane	kg	0.395
Air	propane	kg	0.176
Air	propene	kg	1.12
Air	s-butanol	kg	0.4
Air	s-butyl acetate	kg	0.275
Air	SO2	kg	0.048
Air	styrene	kg	0.14
Air	t-butanol	kg	0.106
Air	t-butyl acetate	kg	0.053
Air	tetrachloroethene	kg	0.029
Air	toluene	kg	0.64
Air	trichloroethene	kg	0.33
Air	trichloromethane	kg	0.023
Air	hexan-3-one	kg	0.599
Air	1-butyl acetate	kg	0.269
Air	cis-2-pentene	kg	1.12
Air	1-butanol	kg	0.62
Air	cis-dichloroethene	kg	0.447
Air	dimethyl carbonate	kg	0.025
Air	butyraldehyde	kg	0.795
Air	2-butanone	kg	0.373
Air	propylene glycol	kg	0.457
Air	hexan-2-one	kg	0.572
Air	diisopropylether	kg	0.398
Air	trans-2-pentene	kg	1.12
Air	isopentane	kg	0.405
Air	propanoic acid	kg	0.15
Air	cis-2-hexene	kg	1.07
Air	trans-2-butene	kg	1.13
Air	diethylketone	kg	0.414
Air	1-propyl acetate	kg	0.282
Air	dimethoxy methane	kg	0.16
Air	1-undecane	kg	0.384
Air	trans-2-hexene	kg	1.07
Air	methyl propyl ketone	kg	0.548
Air	trans-dichloroethene	kg	0.392
Air	1-propanol	kg	0.561
Air	i-butene	kg	0.627
Air	1-propyl benzene	kg	0.636
Air	propionaldehyde	kg	0.798
Air	cis-2-butene	kg	1.15

B1.8 *ACIDIFICATION*

Impact category	Acidification	kg SO2 eq	
Air	ammonia	kg	1.6
Air	NO2	kg	0.5
Air	NOx	kg	0.5
Air	NOx (as NO2)	kg	0.5
Air	SO2	kg	1.2
Air	SOx	kg	1.2
Air	SOx (as SO2)	kg	1.2

B1.9 *EUTROPHICATION*

Impact category	Eutrophication	kg PO4--- eq	
Air	ammonia	kg	0.35
Air	nitrates	kg	0.1
Air	NO	kg	0.2
Air	NO2	kg	0.13
Air	NOx (as NO2)	kg	0.13
Air	P	kg	3.06
Air	phosphate	kg	1
Water	COD	kg	0.022
Water	NH3	kg	0.35
Water	NH4+	kg	0.33
Water	nitrate	kg	0.1
Water	P2O5	kg	1.34
Water	phosphate	kg	1
Water	NH3 (sea)	kg	0.35
Soil	phosphor (ind.)	kg	3.06
Soil	nitrogen (ind.)	kg	0.42
Soil	phosphoric acid (ind.)	kg	0.97
Soil	ammonia (agr.)	kg	0.35
Soil	phosphate (ind.)	kg	1
Soil	ammonium (ind.)	kg	0.33
Water	phosphate (sea)	kg	1
Soil	ammonium (agr.)	kg	0.33
Soil	nitric acid (agr.)	kg	0.1
Soil	nitric acid (ind.)	kg	0.1
Water	COD (sea)	kg	0.022
Water	HNO3 (sea)	kg	0.1
Water	P	kg	3.06
Soil	ammonia (ind.)	kg	0.35
Soil	phosphoric acid (agr.)	kg	0.97
Water	phosphoric acid	kg	0.97
Water	nitrogen (sea)	kg	0.42
Water	nitrate (sea)	kg	0.1

Impact category	Eutrophication	kg PO4--- eq	
Soil	nitrate (ind.)	kg	0.1
Soil	nitrate (agr.)	kg	0.1
Water	NH4+ (sea)	kg	0.33
Water	phosphoric acid (sea)	kg	0.97
Soil	phosphor (agr.)	kg	3.06
Air	phosphoric acid	kg	0.97
Soil	phosphate (agr.)	kg	1
Water	nitrogen	kg	0.42
Soil	nitrogen (agr.)	kg	0.42
Water	P (sea)	kg	3.06
Air	ammonium	kg	0.33
Water	HNO3	kg	0.1
Air	HNO3	kg	0.1
Water	nitrite	kg	0.1
Air	N2	kg	0.42
Water	P2O5 (sea)	kg	1.34
Air	P2O5	kg	1.34
Soil	P2O5 (ind.)	kg	1.34
Soil	P2O5 (agr.)	kg	1.34
Water	nitrite (sea)	kg	0.1

Annex C

Assessment of Alternative Growth Scenarios

C1 INTRODUCTION

A full analysis of the environmental and cost implications of two alternative predictions for growth in battery waste arisings was carried out to inform Regulatory Impact Assessment evaluations. The two alternative growth scenarios were:

1. growth in battery waste arisings at a constant rate of 2.5% from 2003 onwards (reflecting a constant GDP growth rate of 2.5%); and
2. growth in battery waste arisings in line with historic trends for individual chemistries.

Resulting tonnages of batteries handled over the 25 year period are shown in *Table 1.1*. Assuming that the Battery Directive is implemented in 2008 and collection targets are achieved along the same projection as for the core analyses, resulting tonnages of batteries collected over the 25 year period are shown in *Table 1.2*.

Inventory analyses, impact and cost assessment results are subsequently presented. All calculations, assumptions and background data used to carry out this analysis are as reported in *Sections 1* and *2* of the main report.

C1.1 BATTERY ARISINGS AND COLLECTION

Table 1.1 Battery Arisings under Alternative Growth Scenarios (2006-2030)

Battery Type	GDP Growth Scenario	Historic Growth Scenario
Silver Oxide (AgO)	163	88
Zinc Air (ZnO)	70	507
Lithium Manganese (LiMn)	572	614
Lithium (Li)	2682	4496
Zinc Carbon (ZnC)	127,774	66,788
Alkaline Manganese (AlMn)	529,394	577,341
Lithium Ion (Li-ion)	49,505	89,507
Nickel Cadmium (NiCd)	81,540	75,474
Nickel Metal Hydride (NiMH)	45,056	89,220
Lead Acid (PbA)	26,224	37,718
Total	**862,950**	**941,753**

Table 1.2 *Battery Collection under Alternative Growth Scenarios (2006-2030)*

Battery Type	GDP Growth Scenario	Historic Growth Scenario
Silver Oxide (AgO)	59	30
Zinc Air (ZnO)	25	195
Lithium Manganese (LiMn)	207	223
Lithium (Li)	970	1675
Zinc Carbon (ZnC)	46,182	22,544
Alkaline Manganese (AlMn)	191,386	210,024
Lithium Ion (Li-ion)	17,897	33,446
Nickel Cadmium (NiCd)	29,478	27,120
Nickel Metal Hydride (NiMH)	16,289	33,456
Lead Acid (PbA)	9480	13,948
Total	**311,972**	**342,661**

C1.2 *RESULTS OF ANALYSES*

Life cycle inventory and impact assessment results for the alternative growth scenarios are presented in *Table 1.3* to *Table 1.10*, together with an estimation of collection, recycling and disposal costs and the external cost savings associated with reductions in pollutant emissions.

All calculations, assumptions and background data used to carry out analyses are consistent with those reported in *Sections 1* and *2* of the main report.

Table 1.3 GDP Growth Scenario - Inventory Analysis of Selected Flows

Emission	Unit	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7	Scenario 8	Scenario 9	Scenario 10
Coal	kg	-9.8E+07	-1.1E+08	-8.4E+07	-9.8E+07	-1.1E+08	-8.4E+07	-9.6E+07	-1.1E+08	-8.2E+07	642000
Gas	kg	507000	-3970000	-8510000	648000	-3830000	-8370000	1140000	-3350000	-7880000	723000
Oil	kg	-7750	6700000	26900000	277000	6990000	27200000	3910000	10600000	30800000	2420000
Cadmium, in ore	kg	-4190000	-4190000	-4190000	-4190000	-4190000	-4190000	-4190000	-4190000	-4190000	x
Lead, in ore	kg	-1.6E+07	-1.6E+07	-1.5E+07	-1.6E+07	-1.6E+07	-1.5E+07	-1.6E+07	-1.6E+07	-1.5E+07	2550
Zinc, in ore	kg	-7.7E+07	-7.7E+07	-7.5E+07	-7.7E+07	-7.7E+07	-7.5E+07	-7.7E+07	-7.7E+07	-7.5E+07	254
CO_2	kg	-1.2E+08	-1.4E+08	-1.3E+08	-1.2E+08	-1.4E+08	-1.3E+08	-1E+08	-1.3E+08	-1.2E+08	60200000
CH_4	kg	1240000	1090000	611000	1240000	1090000	611000	1240000	1090000	611000	938000
NOx	kg	-1270000	-1270000	-974000	-1270000	-1270000	-972000	-1240000	-1250000	-948000	231000
SOx	kg	-1240000	-1310000	-1940000	-1230000	-1310000	-1940000	-1200000	-1280000	-1910000	62700
NH_3	kg	-111000	-110000	-105000	-111000	-110000	-105000	-110000	-110000	-104000	1070
Cd (air)	kg	3930	3930	3930	3930	3930	3930	3930	3930	3930	6550
Ni (air)	kg	12500	12400	12400	12500	12400	12400	12500	12500	12400	19700
Pb (air)	kg	-29900	-29900	-28900	-29900	-29900	-28900	-29900	-29800	-28900	6800
Co (air)	kg	2960	2960	2960	2960	2960	2960	2960	2960	2960	4660
Hg (air)	kg	-1130	-1130	-12600	-1130	-1130	-12600	-1130	-1130	-12600	4.09
Cd (water/soil)	kg	343000	343000	343000	343000	343000	343000	343000	343000	343000	562000
Ni (water/soil)	kg	1080000	1080000	1080000	1080000	1080000	1080000	1080000	1080000	1080000	1700000
Pb (water/soil)	kg	269000	269000	267000	269000	269000	267000	269000	269000	267000	586000
Co (water/soil)	kg	255000	255000	255000	255000	255000	255000	255000	255000	255000	399000
Hg (water/soil)	kg	-93.6	-91	-58.4	-93.5	-90.9	-58.3	-92.8	-90.2	-57.5	364
PAH (water/soil)	kg	-4270	-4260	-4480	-4270	-4260	-4480	-4260	-4260	-4480	1.65
Phosphate (water)	kg	103000	102000	102000	103000	102000	102000	104000	102000	102000	170000

Table 1.4 Historic Growth Scenario - Inventory Analysis of Selected Flows

Emission	Unit	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7	Scenario 8	Scenario 9	Scenario 10
Coal	kg	-1.2E+08	-1.3E+08	-1.1E+08	-1.2E+08	-1.3E+08	-1.1E+08	-1.2E+08	-1.3E+08	-1E+08	701000
Gas	kg	-1070000	-5460000	-9910000	-922000	-5310000	-9760000	-400000	-4790000	-9240000	789000
Oil	kg	-2850000	3720000	23500000	-2550000	4020000	23800000	1400000	7970000	27700000	2640000
Cadmium, in ore	kg	-3860000	-3860000	-3860000	-3860000	-3860000	-3860000	-3860000	-3860000	-3860000	x
Lead, in ore	kg	-2.3E+07	-2.3E+07	-2.3E+07	-2.3E+07	-2.3E+07	-2.3E+07	-2.3E+07	-2.3E+07	-2.3E+07	2780
Zinc, in ore	kg	-7.5E+07	-7.5E+07	-7.4E+07	-7.5E+07	-7.5E+07	-7.4E+07	-7.5E+07	-7.5E+07	-7.4E+07	277
CO_2	kg	-1.6E+08	-1.9E+08	-1.8E+08	-1.6E+08	-1.9E+08	-1.8E+08	-1.5E+08	-1.7E+08	-1.6E+08	65700000
CH_4	kg	1280000	1120000	655000	1280000	1120000	655000	1280000	1120000	655000	1020000
NOx	kg	-1500000	-1510000	-1210000	-1500000	-1500000	-1210000	-1470000	-1480000	-1190000	252000
SOx	kg	-1460000	-1530000	-2150000	-1450000	-1530000	-2150000	-1420000	-1500000	-2110000	68500
NH_3	kg	-137000	-137000	-131000	-137000	-137000	-131000	-137000	-136000	-131000	1170
Cd (air)	kg	4270	4270	4270	4270	4270	4270	4270	4270	4270	7150
Ni (air)	kg	13500	13500	13500	13500	13500	13500	13600	13500	13500	21500
Pb (air)	kg	-30600	-30600	-29700	-30600	-30600	-29700	-30600	-30600	-29700	7420
Co (air)	kg	3220	3220	3220	3220	3220	3220	3220	3220	3220	5080
Hg (air)	kg	-1080	-1080	-12300	-1080	-1080	-12300	-1080	-1080	-12300	4.46
Cd (water/soil)	kg	367000	367000	367000	367000	367000	367000	367000	367000	367000	613000
Ni (water/soil)	kg	1180000	1180000	1180000	1180000	1180000	1180000	1180000	1180000	1180000	1850000
Pb (water/soil)	kg	250000	251000	248000	250000	251000	248000	250000	251000	248000	640000
Co (water/soil)	kg	278000	278000	277000	278000	278000	277000	278000	278000	277000	436000
Hg (water/soil)	kg	-208	-206	-174	-208	-206	-174	-207	-205	-173	397
PAH (water/soil)	kg	-4190	-4180	-4390	-4190	-4180	-4390	-4180	-4180	-4390	1.8
Phosphate (water)	kg	106000	105000	105000	106000	105000	105000	107000	106000	106000	186000

Table 1.5 GDP Growth Scenario - Life Cycle Impact Assessment

Impact Category	Unit	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7	Scenario 8	Scenario 9	Scenario 10
abiotic depletion	kg Sb eq	-2610000	-2800000	-2300000	-2590000	-2790000	-2280000	-2490000	-2690000	-2180000	73900
global warming (GWP100)	kg CO_2 eq	-1.4E+08	-1.7E+08	-1.4E+08	-1.4E+08	-1.7E+08	-1.4E+08	-1.3E+08	-1.5E+08	-1.3E+08	65200000
ozone layer depletion (ODP)	kg CFC-11 eq	-1.44	1.91	12.2	-1.32	2.04	12.3	0.175	3.53	13.8	43
human toxicity	kg 1,4-DB eq	-1.5E+08	-1.6E+08	-3.5E+08	-1.5E+08	-1.6E+08	-3.5E+08	-1.5E+08	-1.5E+08	-3.4E+08	2.58E+09
fresh water aquatic ecotoxicity	kg 1,4-DB eq	5.08E+09	5.08E+09	5.05E+09	5.08E+09	5.08E+09	5.05E+09	5.08E+09	5.08E+09	5.06E+09	8.26E+09
terrestrial ecotoxicity	kg 1,4-DB eq	-3.2E+07	-3.2E+07	-3.6E+08	-3.2E+07	-3.2E+07	-3.6E+08	-3.2E+07	-3.2E+07	-3.6E+08	5130000
Acidification	kg SO_2 eq	-2300000	-2390000	-2990000	-2290000	-2380000	-2980000	-2240000	-2330000	-2930000	192000
eutrophication	kg PO_4^{---} eq	136000	136000	138000	136000	137000	139000	141000	142000	144000	617000

Table 1.6 Historic Growth Scenario - Life Cycle Impact Assessment

Impact Category	Unit	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7	Scenario 8	Scenario 9	Scenario 10
abiotic depletion	kg Sb eq	-2940000	-3130000	-2630000	-2920000	-3120000	-2620000	-2810000	-3010000	-2510000	80600
global warming (GWP100)	kg CO_2 eq	-2E+08	-2.2E+08	-2E+08	-1.9E+08	-2.2E+08	-2E+08	-1.8E+08	-2.1E+08	-1.8E+08	71100000
ozone layer depletion (ODP)	kg CFC-11 eq	-23.6	-20.3	-10.2	-23.4	-20.1	-10.1	-21.8	-18.5	-8.47	47
human toxicity	kg 1,4-DB eq	-2.3E+08	-2.3E+08	-4.2E+08	-2.3E+08	-2.3E+08	-4.2E+08	-2.2E+08	-2.2E+08	-4.1E+08	2.82E+09
fresh water aquatic ecotox.	kg 1,4-DB eq	5.49E+09	5.49E+09	5.47E+09	5.49E+09	5.49E+09	5.47E+09	5.49E+09	5.49E+09	5.47E+09	9.02E+09
terrestrial ecotoxicity	kg 1,4-DB eq	-3.1E+07	-3.1E+07	-3.5E+08	-3.1E+07	-3.1E+07	-3.5E+08	-3E+07	-3.1E+07	-3.5E+08	5600000
Acidification	kg SO_2 eq	-2720000	-2810000	-3400000	-2710000	-2800000	-3390000	-2660000	-2750000	-3340000	210000
eutrophication	kg PO_4^{---} eq	82500	83000	85200	83000	83500	85700	88700	89200	91400	673000

Table 1.7 GDP Growth Scenario - Collection, Sorting, Recycling and Disposal Costs

Year	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7	Scenario 8	Scenario 9	Scenario 10
2006	2.1	2.1	2.1	2.1	2.1	2.1	2.2	2.2	2.2	0.9
2007	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	1.0
2008	4.4	4.4	4.4	4.4	4.4	4.4	4.5	4.5	4.5	1.1
2009	5.7	5.7	5.7	5.7	5.7	5.7	5.9	5.9	5.9	1.2
2010	7.1	7.1	7.1	7.1	7.1	7.1	7.2	7.2	7.2	1.3
2011	8.4	8.4	8.4	8.4	8.4	8.4	8.7	8.7	8.7	1.4
2012	9.3	9.3	9.3	9.3	9.3	9.3	9.4	9.4	9.4	1.4
2013	11.1	11.1	11.1	11.1	11.1	11.1	11.2	11.2	11.2	1.5
2014	11.5	11.5	11.5	11.5	11.5	11.5	11.4	11.4	11.4	1.5
2015	13.1	13.1	13.1	13.1	13.1	13.1	13.1	13.1	13.1	1.5
2016	14.8	14.8	14.8	14.8	14.8	14.8	14.5	14.5	14.5	1.6
2017	15.0	15.0	15.0	15.0	15.0	15.0	14.8	14.8	14.8	1.6
2018	15.3	15.3	15.3	15.3	15.3	15.3	15.1	15.1	15.1	1.6
2019	15.6	15.6	15.6	15.6	15.6	15.6	15.4	15.4	15.4	1.6
2020	15.9	15.9	15.9	15.9	15.9	15.9	15.7	15.7	15.7	1.7
2021	16.2	16.2	16.2	16.2	16.2	16.2	16.0	16.0	16.0	1.7
2022	16.5	16.5	16.5	16.5	16.5	16.5	16.3	16.3	16.3	1.7
2023	16.8	16.8	16.8	16.8	16.8	16.8	16.5	16.5	16.5	1.8
2024	17.1	17.1	17.1	17.1	17.1	17.1	16.8	16.8	16.8	1.8
2025	17.4	17.4	17.4	17.4	17.4	17.4	17.1	17.1	17.1	1.8
2026	17.6	17.6	17.6	17.6	17.6	17.6	17.4	17.4	17.4	1.9
2027	17.9	17.9	17.9	17.9	17.9	17.9	17.7	17.7	17.7	1.9
2028	18.2	18.2	18.2	18.2	18.2	18.2	18.0	18.0	18.0	1.9
2029	18.5	18.5	18.5	18.5	18.5	18.5	18.2	18.2	18.2	1.9
2030	18.8	18.8	18.8	18.8	18.8	18.8	18.5	18.5	18.5	2.0
Total (Mill £)	**327.57**	**327.57**	**327.57**	**327.57**	**327.57**	**327.57**	**324.78**	**324.78**	**324.78**	**39.27**

Table 1.8 *Historic Growth Scenario - Collection, Sorting, Recycling and Disposal Costs*

Year	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7	Scenario 8	Scenario 9	Scenario 10
2006	2.1	2.1	2.1	2.1	2.1	2.1	2.2	2.2	2.2	0.9
2007	3.2	3.2	3.2	3.2	3.2	3.2	3.3	3.3	3.3	1.0
2008	4.5	4.5	4.5	4.5	4.5	4.5	4.6	4.6	4.6	1.1
2009	5.8	5.8	5.8	5.8	5.8	5.8	5.9	5.9	5.9	1.2
2010	7.2	7.2	7.2	7.2	7.2	7.2	7.4	7.4	7.4	1.4
2011	8.6	8.6	8.6	8.6	8.6	8.6	8.9	8.9	8.9	1.5
2012	9.6	9.6	9.6	9.6	9.6	9.6	9.7	9.7	9.7	1.5
2013	11.5	11.5	11.5	11.5	11.5	11.5	11.6	11.6	11.6	1.6
2014	11.8	11.8	11.8	11.8	11.8	11.8	11.8	11.8	11.8	1.6
2015	13.6	13.6	13.6	13.6	13.6	13.6	13.5	13.5	13.5	1.6
2016	15.3	15.3	15.3	15.3	15.3	15.3	15.1	15.1	15.1	1.7
2017	15.7	15.7	15.7	15.7	15.7	15.7	15.5	15.5	15.5	1.7
2018	16.0	16.0	16.0	16.0	16.0	16.0	15.8	15.8	15.8	1.8
2019	16.4	16.4	16.4	16.4	16.4	16.4	16.2	16.2	16.2	1.8
2020	16.7	16.7	16.7	16.7	16.7	16.7	16.5	16.5	16.5	1.8
2021	17.1	17.1	17.1	17.1	17.1	17.1	16.9	16.9	16.9	1.9
2022	17.5	17.5	17.5	17.5	17.5	17.5	17.2	17.2	17.2	1.9
2023	17.8	17.8	17.8	17.8	17.8	17.8	17.6	17.6	17.6	2.0
2024	18.2	18.2	18.2	18.2	18.2	18.2	17.9	17.9	17.9	2.0
2025	18.5	18.5	18.5	18.5	18.5	18.5	18.3	18.3	18.3	2.0
2026	18.9	18.9	18.9	18.9	18.9	18.9	18.6	18.6	18.6	2.1
2027	19.2	19.2	19.2	19.2	19.2	19.2	19.0	19.0	19.0	2.1
2028	19.6	19.6	19.6	19.6	19.6	19.6	19.3	19.3	19.3	2.2
2029	20.0	20.0	20.0	20.0	20.0	20.0	19.7	19.7	19.7	2.2
2030	20.3	20.3	20.3	20.3	20.3	20.3	20.0	20.0	20.0	2.3
Total (Mill £)	**345.28**	**345.28**	**345.28**	**345.28**	**345.28**	**345.28**	**342.16**	**342.16**	**342.16**	**42.93**

Table 1.9 GDP Growth Scenario - Cost of Pollutant Emissions (Average Estimate)

Pollutant	Unit	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7	Scenario 8	Scenario 9	Scenario 10
NOx	Million £	-0.74	-0.75	-0.57	-0.74	-0.75	-0.57	-0.73	-0.73	-0.55	0.17
SO_2	Million £	-2.79	-2.74	-3.63	-2.78	-2.73	-3.63	-2.73	-2.68	-3.57	0.01
NMVOC	Million £	-0.10	-0.09	-0.06	-0.10	-0.08	-0.06	-0.09	-0.08	-0.05	0.02
Particulates	Million £	-43.50	-43.90	-37.10	-43.50	-43.90	-37.00	-43.10	-43.60	-36.70	0.66
CO_2	Million £	-3.66	-4.33	-3.73	-3.64	-4.32	-3.71	-3.27	-3.95	-3.34	1.14
CH_4	Million £	0.54	0.45	0.35	0.54	0.45	0.35	0.54	0.45	0.35	0.53
Total	**Million £**	**-50.26**	**-51.36**	**-44.74**	**-50.22**	**-51.33**	**-44.62**	**-49.38**	**-50.59**	**-43.87**	**2.53**

Table 1.10 Historic Growth Scenario - Cost of Pollutant Emissions (Average Estimate)

Pollutant	Unit	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7	Scenario 8	Scenario 9	Scenario 10
NOx	Million £	-0.88	-0.89	-0.71	-0.88	-0.88	-0.71	-0.87	-0.87	-0.69	0.18
SO_2	Million £	-3.18	-3.13	-4.01	-3.18	-3.13	-4.01	-3.12	-3.07	-3.95	0.02
NMVOC	Million £	-0.12	-0.10	-0.08	-0.11	-0.10	-0.08	-0.11	-0.09	-0.07	0.02
Particulates	Million £	-49.30	-49.80	-43.00	-49.30	-49.80	-43.00	-48.90	-49.40	-42.60	0.72
CO_2	Million £	-4.89	-5.56	-4.96	-4.87	-5.54	-4.94	-4.47	-5.14	-4.54	1.25
CH_4	Million £	0.56	0.47	0.37	0.56	0.47	0.37	0.56	0.47	0.37	0.58
Total	**Million £**	**-57.81**	**-59.01**	**-52.39**	**-57.79**	**-58.99**	**-52.36**	**-56.91**	**-58.10**	**-51.48**	**2.77**

Annex D

Inventories

D1 INVENTORIES

Table 1.1 Inventories: Implementation Scenarios 1 to 9

Substance	Compartment	Unit	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7	Scenario 8	Scenario 9
Additives	Raw	tn.lg	1.56	1.56	1.56	1.56	1.56	1.56	1.56	1.56	1.56
Aluminium, 24% in bauxite, 11% in crude ore, in ground	Raw	tn.lg	-5520	-5500	-5630	-5520	-5500	-5630	-5510	-5490	-5610
Anhydrite, in ground	Raw	oz	628	638	60.2	648	658	80.2	777	786	209
Barite, 15% in crude ore, in ground	Raw	kg	-17600	-121	56500	-17600	-72.2	56600	-4970	12500	69200
Barium, in ground	Raw	kg	-952	-952	-952	-952	-952	-952	-952	-952	-952
Baryte, in ground	Raw	kg	-2930	-2930	-2930	-2930	-2930	-2930	-2900	-2900	-2900
Basalt, in ground	Raw	tn.lg	-83.3	-81.7	-124	-83.2	-81.7	-124	-82.3	-80.8	-123
Bauxite, in ground	Raw	kg	-2060	-2060	-2060	-2060	-2060	-2060	-2030	-2030	-2030
Borax, in ground	Raw	oz	-12.9	24.9	-138	-12.8	25.1	-138	-8.95	28.9	-134
Cadmium, in ground	Raw	kton	-2.86	-2.86	-2.86	-2.86	-2.86	-2.86	-2.86	-2.86	-2.86
Calcite, in ground	Raw	kton	-35.4	-34.9	-31.3	-35.4	-34.9	-31.3	-35.2	-34.7	-31.1
Calcium sulfate, in ground	Raw	kg	667	667	667	667	667	667	667	667	667
Carbon dioxide, in air	Raw	tn.lg	-4560	-4520	-4200	-4530	-4490	-4170	-4450	-4410	-4090
Chromium ore, in ground	Raw	g	38.7	38.7	38.7	38.7	38.7	38.7	38.7	38.7	38.7
Chromium, 25.5 in chromite, 11.6% in crude ore, in ground	Raw	tn.sh	-1.96	-1.07	-21	-1.9	-1.02	-20.9	3.2	4.08	-15.8
Chromium, in ground	Raw	lb	-158	-158	-158	-190	-190	-190	-176	-176	-176
Chrysotile, in ground	Raw	oz	842	849	747	842	850	747	847	854	751
Cinnabar, in ground	Raw	kg	-243	-243	-66800	-243	-243	-66800	-243	-243	-66800
Clay, bentonite, in ground	Raw	tn.lg	-852	-845	-345	-852	-845	-345	-846	-839	-339
Clay, unspecified, in ground	Raw	kton	25.8	26	25.5	25.8	26	25.5	25.9	26.1	25.5
Coal, 18 MJ per kg, in ground	Raw	tn.lg	27900	15900	2560	27900	15900	2570	27900	16000	2580
Coal, 29.3 MJ per kg, in ground	Raw	tn.lg	-498	-498	-498	-498	-498	-498	-498	-498	-498
Coal, brown, 10 MJ per kg, in ground	Raw	tn.lg	1.29	1.29	1.29	1.29	1.29	1.29	1.29	1.29	1.29
Coal, brown, 8 MJ per kg, in ground	Raw	tn.lg	340	251	137	340	251	137	355	266	152
Coal, brown, in ground	Raw	tn.lg	-39100	-38800	-23200	-39100	-38800	-23200	-38600	-38300	-22700
Coal, hard, unspecified, in ground	Raw	tn.lg	-53700	-53400	-34200	-53700	-53300	-34100	-53200	-52900	-33600
Cobalt ore, in ground	Raw	mg	-393	-393	-393	-393	-393	-393	-393	-393	-393
Cobalt, in ground	Raw	kg	-1680000	-1680000	-1680000	-1680000	-1680000	-1680000	-1680000	-1680000	-1680000
Colemanite, in ground	Raw	lb	-901	-897	-739	-901	-897	-739	-895	-890	-732
Copper, 0.99% in sulfide, Cu 0.36% and Mo 8.2E-3% in crude ore, in ground	Raw	kg	-608	-457	-667	-607	-455	-666	-192	-40.6	-251
Copper, 1.18% in sulfide, Cu 0.39% and Mo 8.2E-3% in crude ore, in ground	Raw	kg	-3350	-2510	-3670	-3340	-2500	-3660	-1040	-200	-1360
Copper, 1.42% in sulfide, Cu 0.81% and Mo 8.2E-3% in crude ore, in ground	Raw	kg	-888	-665	-972	-886	-663	-971	-276	-53	-361
Copper, 2.19% in sulfide, Cu 1.83% and Mo 8.2E-3% in crude ore, in ground	Raw	kg	-4410	-3300	-4830	-4400	-3290	-4820	-1370	-263	-1790
Copper, in ground	Raw	kg	-282	-282	-282	-282	-282	-282	-270	-270	-270
Cu, Cu 5.2E-2%, Pt 4.8E-4%, Pd 2.0E-4%, Rh 2.4E-5%, Ni 3.7E-2% in ore, in ground	Raw	tn.lg	-16.2	-16.2	-16.2	-16.2	-16.2	-16.2	-16.2	-16.2	-16.2
Diatomite, in ground	Raw	g	9.79	18.6	26	9.79	18.6	26	9.94	18.7	26.1
Dolomite, in ground	Raw	kg	-708000	-707000	-742000	-708000	-707000	-742000	-707000	-706000	-741000
Energy, from hydro power	Raw	TJ	-5.61	-5.61	-5.61	-5.61	-5.61	-5.61	-5.55	-5.55	-5.55
Energy, from uranium	Raw	TJ	-3.28	-3.28	-3.28	-3.28	-3.28	-3.28	-3.28	-3.28	-3.28
Energy, gross calorific value, in biomass	Raw	MWh	-14200	-14100	-13100	-14100	-14000	-13000	-13900	-13700	-12800
Energy, kinetic, flow, in wind	Raw	MWh	-7500	-7440	-4220	-7490	-7430	-4210	-7390	-7330	-4100
Energy, potential, stock, in barrage water	Raw	TJ	-897	-862	-126	-897	-862	-125	-892	-857	-120

Substance	Compartment	Unit	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7	Scenario 8	Scenario 9
Energy, solar	Raw	GJ	-356	-351	-195	-356	-350	-194	-348	-342	-186
Energy, unspecified	Raw	MWh	-223	-223	-223	-223	-223	-223	-223	-223	-223
Feldspar, in ground	Raw	g	-34	-33.5	-31.2	-35	-34.5	-32.1	-34.5	-34	-31.7
Fluorine, 4.5% in apatite, 1% in crude ore, in ground	Raw	kg	-1310	-1290	-1290	-1310	-1290	-1290	-1290	-1280	-1280
Fluorine, 4.5% in apatite, 3% in crude ore, in ground	Raw	kg	-572	-566	-564	-572	-566	-564	-566	-560	-558
Fluorspar, 92%, in ground	Raw	kg	-39700	-39300	-38900	-39600	-39200	-38700	-39300	-38900	-38400
Gas, mine, off-gas, process, coal mining/kg	Raw	kg	-7650	-7650	-7650	-7650	-7650	-7650	-7650	-7650	-7650
Gas, mine, off-gas, process, coal mining/m3	Raw	m3	-531000	-527000	-336000	-531000	-527000	-336000	-526000	-522000	-331000
Gas, natural, 30.3 MJ per kg, in ground	Raw	tn.lg	-65.6	-65.6	-65.6	-65.6	-65.6	-65.6	-63.8	-63.8	-63.8
Gas, natural, 35 MJ per m3, in ground	Raw	m3	11400000	6270000	312000	11400000	6270000	313000	11500000	6280000	317000
Gas, natural, in ground	Raw	m3	-10100000	-9520000	-8260000	-9920000	-9380000	-8110000	-9420000	-8870000	-7610000
Gas, off-gas, oil production, in ground	Raw	m3	-27100	-27100	-27100	-27100	-27100	-27100	-26900	-26900	-26900
Gas, petroleum, 35 MJ per m3, in ground	Raw	m3	4050	4050	4050	4050	4050	4050	4050	4050	4050
Granite, in ground	Raw	kg	277	303	325	390	417	439	337	364	386
Gravel, in ground	Raw	kton	-256	-232	-205	-256	-232	-205	-253	-229	-201
Gypsum, in ground	Raw	lb	486	515	401	490	518	404	498	527	413
Iron ore, in ground	Raw	kg	-15	-15	-15	-15	-15	-15	-15	-15	-15
Iron, 46% in ore, 25% in crude ore, in ground	Raw	tn.lg	-72600	-72000	-32300	-72600	-72000	-32300	-72100	-71600	-31900
Iron, in ground	Raw	tn.lg	-33.7	-33.7	-33.7	-33.7	-33.7	-33.7	-33.5	-33.5	-33.5
Kaolinite, 24% in crude ore, in ground	Raw	kg	27700	27800	28500	28500	28600	29200	28600	28800	29400
Kieserite, 25% in crude ore, in ground	Raw	kg	-1110	-1110	-1110	-1100	-1100	-1100	-1050	-1050	-1050
Land use II-III	Raw	m2a	-2030000	-2030000	-2030000	-2030000	-2030000	-2030000	-2030000	-2030000	-2030000
Land use II-III, sea floor	Raw	m2a	4230	4230	4230	4230	4230	4230	4230	4230	4230
Land use II-IV	Raw	m2a	-1350000	-1350000	-1350000	-1350000	-1350000	-1350000	-1350000	-1350000	-1350000
Land use II-IV, sea floor	Raw	m2a	437	437	437	437	437	437	437	437	437
Land use III-IV	Raw	m2a	-83800	-83800	-83800	-83800	-83800	-83800	-83700	-83700	-83700
Land use IV-IV	Raw	m2a	-19000	-19000	-19000	-19000	-19000	-19000	-19000	-19000	-19000
Lead, 5%, in sulfide, Pb 2.97% and Zn 5.34% in crude ore, in ground	Raw	tn.lg	-7650	-7560	-7480	-7650	-7560	-7480	-7640	-7550	-7480
Lead, in ground	Raw	kg	-3260	-3260	-3260	-3260	-3260	-3260	-3260	-3260	-3260
Limestone, in ground	Raw	tn.lg	21.3	21.3	21.3	21.3	21.3	21.3	21.3	21.3	21.3
Lithium, in ground	Raw	tn.lg	-949	-949	-949	-949	-949	-949	-949	-949	-949
Magnesite, 60% in crude ore, in ground	Raw	kg	-7780	-855	5660	-7760	-834	5680	-2130	4790	11300
Magnesium, 0.13% in water	Raw	g	-607	-600	-604	-605	-598	-601	-596	-588	-592
Manganese ore, in ground	Raw	g	22.6	22.6	22.6	22.6	22.6	22.6	22.6	22.6	22.6
Manganese, 35.7% in sedimentary deposit, 14.2% in crude ore, in ground	Raw	tn.lg	-90000	-90000	-70200	-90000	-90000	-70200	-90000	-90000	-70200
Manganese, in ground	Raw	lb	-114	-114	-114	-117	-117	-117	-116	-116	-116
Marl, in ground	Raw	kg	-67500	-67500	-67500	-67500	-67500	-67500	-66900	-66900	-66900
Methane	Raw	tn.lg	-18.9	-18.9	-18.9	-18.9	-18.9	-18.9	-18.8	-18.8	-18.8
Molybdenum, 0.010% in sulfide, Mo 8.2E-3% and Cu 1.83% in crude ore, in ground	Raw	kg	-81.9	-61.3	-89.7	-81.8	-61.2	-89.6	-25.5	-4.89	-33.3
Molybdenum, 0.014% in sulfide, Mo 8.2E-3% and Cu 0.81% in crude ore, in ground	Raw	oz	-411	-308	-450	-410	-307	-450	-128	-24.6	-167
Molybdenum, 0.022% in sulfide, Mo 8.2E-3% and Cu 0.36% in crude ore, in ground	Raw	kg	936	1080	863	941	1080	869	2860	3000	2790
Molybdenum, 0.025% in sulfide, Mo 8.2E-3% and Cu 0.39% in crude ore, in ground	Raw	kg	-42.8	-32	-46.9	-42.7	-31.9	-46.8	-13.3	-2.55	-17.4
Molybdenum, 0.11% in sulfide, Mo 4.1E-2% and Cu 0.36% in crude ore, in ground	Raw	kg	1890	2180	1740	1900	2190	1750	5770	6060	5620
Molybdenum, in ground	Raw	mg	-232	-232	-232	-232	-232	-232	-232	-232	-232

Substance	Compartment	Unit	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7	Scenario 8	Scenario 9
Nickel, 1.13% in sulfide, Ni 0.76% and Cu 0.76% in crude ore, in ground	Raw	kg	46.6	48.1	61.8	46.8	48.3	62	237	239	252
Nickel, 1.98% in silicates, 1.04% in crude ore, in ground	Raw	tn.lg	-24.3	-18.9	-34.5	-24.2	-18.8	-34.3	-3.48	1.88	-13.6
Nickel, in ground	Raw	lb	-65.2	-65.2	-65.2	-80.6	-80.6	-80.6	-73.3	-73.3	-73.3
Occupation, arable	Raw	m2a	-132000	-132000	-132000	-132000	-132000	-132000	-132000	-132000	-132000
Occupation, arable, non-irrigated	Raw	m2a	5150	7270	9780	5210	7330	9840	7360	9490	12000
Occupation, construction site	Raw	m2a	7810	8420	2040	7830	8440	2050	8280	8890	2500
Occupation, dump site	Raw	m2a	-7480000	-7460000	-6600000	-7470000	-7460000	-6600000	-7450000	-7440000	-6580000
Occupation, dump site, benthos	Raw	m2a	-3470	-2390	1230	-3460	-2380	1240	-2530	-1450	2170
Occupation, forest	Raw	m2a	-15.2	-15.2	-15.2	-15.2	-15.2	-15.2	-15.2	-15.2	-15.2
Occupation, forest, intensive	Raw	m2a	-2880000	-2880000	-2890000	-2870000	-2860000	-2880000	-2800000	-2790000	-2810000
Occupation, forest, intensive, normal	Raw	m2a	-6290000	-6230000	-6480000	-6260000	-6200000	-6460000	-6190000	-6130000	-6390000
Occupation, industrial area	Raw	m2a	-922000	-911000	-810000	-922000	-911000	-810000	-912000	-901000	-800000
Occupation, industrial area, benthos	Raw	m2a	-26.7	-16.8	14.3	-26.6	-16.7	14.4	-19.3	-9.41	21.7
Occupation, industrial area, built up	Raw	m2a	-146000	-143000	-204000	-146000	-143000	-204000	-143000	-141000	-201000
Occupation, industrial area, vegetation	Raw	m2a	-66800	-63500	-76700	-66700	-63500	-76700	-65400	-62200	-75300
Occupation, mineral extraction site	Raw	m2a	-952000	-942000	-844000	-951000	-942000	-844000	-948000	-938000	-840000
Occupation, permanent crop, fruit, intensive	Raw	m2a	9230	9460	9820	9340	9570	9930	9980	10200	10600
Occupation, shrub land, sclerophyllous	Raw	m2a	8200	8690	6720	8200	8700	6720	8370	8870	6890
Occupation, traffic area	Raw	m2a	-39700	-39700	-39700	-39700	-39700	-39700	-39700	-39700	-39700
Occupation, traffic area, rail embankment	Raw	m2a	-98200	-97300	-95100	-98200	-97300	-95100	-97800	-96900	-94700
Occupation, traffic area, rail network	Raw	m2a	-109000	-108000	-105000	-109000	-108000	-105000	-108000	-107000	-105000
Occupation, traffic area, road embankment	Raw	m2a	-42600	-22600	-8320	-42200	-22200	-7940	-2420	17600	31900
Occupation, traffic area, road network	Raw	m2a	349000	449000	551000	348000	449000	551000	532000	633000	735000
Occupation, urban, continuously built	Raw	m2a	-10800	-10800	-10800	-10800	-10800	-10800	-10800	-10800	-10800
Occupation, urban, discontinuously built	Raw	m2a	20.8	23.1	30.1	21	23.3	30.3	23.8	26	33.1
Occupation, water bodies, artificial	Raw	m2a	-429000	-412000	-296000	-429000	-411000	-296000	-423000	-405000	-290000
Occupation, water courses, artificial	Raw	m2a	-927000	-920000	-854000	-927000	-920000	-854000	-923000	-916000	-850000
Oil, crude, 41 MJ per kg, in ground	Raw	tn.lg	450	450	450	450	450	450	450	450	450
Oil, crude, 42.6 MJ per kg, in ground	Raw	tn.lg	632	550	149	632	550	149	635	554	152
Oil, crude, 42.7 MJ per kg, in ground	Raw	tn.lg	-655	-655	-655	-655	-655	-655	-655	-655	-655
Oil, crude, in ground	Raw	tn.lg	533	5390	20200	738	5600	20400	3260	8120	22900
Olivine, in ground	Raw	oz	191	195	17.8	201	204	27	236	239	62.2
Palladium, in ground	Raw	mg	-369	-369	-369	-369	-369	-369	-369	-369	-369
Pd, Pd 2.0E-4%, Pt 4.8E-4%, Rh 2.4E-5%, Ni 3.7E-2%, Cu 5.2E-2% in ore, in ground	Raw	g	59.1	63	78.8	59.1	63	78.8	91.3	95.2	111
Pd, Pd 7.3E-4%, Pt 2.5E-4%, Rh 2.0E-5%, Ni 2.3E+0%, Cu 3.2E+0% in ore, in ground	Raw	g	142	151	189	142	151	189	219	229	267
Peat, in ground	Raw	kg	-568	-529	-597	-504	-464	-533	-387	-347	-416
Phosphorus, 18% in apatite, 12% in crude ore, in ground	Raw	kg	-2320	-2290	-2270	-2320	-2290	-2270	-2280	-2260	-2240
Phosphorus, 18% in apatite, 4% in crude ore, in ground	Raw	kg	-5220	-5170	-5160	-5220	-5170	-5160	-5180	-5120	-5110
Phosphorus, in ground	Raw	kton	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9
Platinum, in ground	Raw	mg	-425	-425	-425	-425	-425	-425	-425	-425	-425
Pt, Pt 2.5E-4%, Pd 7.3E-4%, Rh 2.0E-5%, Ni 2.3E+0%, Cu 3.2E+0% in ore, in ground	Raw	g	1.2	1.31	1.76	1.2	1.32	1.76	1.99	2.1	2.54
Pt, Pt 4.8E-4%, Pd 2.0E-4%, Rh	Raw	g	4.31	4.71	6.31	4.31	4.71	6.31	7.12	7.52	9.11

Substance	Compartment	Unit	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7	Scenario 8	Scenario 9
2.4E-5%, Ni 3.7E-2%, Cu 5.2E-2% in ore, in ground											
Pyrite, in ground	Raw	kg	323	323	323	323	323	323	323	323	323
Rh, Rh 2.0E-5%, Pt 2.5E-4%, Pd 7.3E-4%, Ni 2.3E+0%, Cu 3.2E+0% in ore, in ground	Raw	g	1.35	1.44	1.8	1.35	1.44	1.8	2.09	2.18	2.54
Rh, Rh 2.4E-5%, Pt 4.8E-4%, Pd 2.0E-4%, Ni 3.7E-2%, Cu 5.2E-2% in ore, in ground	Raw	g	4.23	4.51	5.64	4.23	4.51	5.64	6.54	6.82	7.95
Rhenium, in crude ore, in ground	Raw	g	5.52	5.68	5.78	5.52	5.68	5.78	9.28	9.44	9.54
Rhenium, in ground	Raw	mg	-321	-321	-321	-321	-321	-321	-321	-321	-321
Rhodium, in ground	Raw	mg	-394	-394	-394	-394	-394	-394	-394	-394	-394
Rutile, in ground	Raw	g	-38.6	-38.2	-42.2	-38.3	-37.9	-41.9	-38.4	-37.9	-42
Sand, unspecified, in ground	Raw	kton	45.1	45.1	45.1	45.1	45.1	45.1	45.1	45.1	45.1
Shale, in ground	Raw	lb	111	112	10.3	114	116	13.9	137	139	36.7
Silicon, in ground	Raw	g	381	381	381	66.3	66.3	66.3	187	187	187
Silver, 0.01% in crude ore, in ground	Raw	g	-149	-146	-80.9	-148	-146	-80.7	-145	-142	-77.1
Silver, in ground	Raw	oz	-48.6	-48.6	-48.6	-48.6	-48.6	-48.6	-48.3	-48.3	-48.3
Sodium chloride, in ground	Raw	tn.lg	-18.7	29.1	-3.83	-11.3	36.5	3.61	148	196	163
Sodium sulphate, various forms, in ground	Raw	kg	-10600	-10500	-10700	-10600	-10500	-10700	-10600	-10400	-10600
Steel scrap	Raw	tn.lg	1.44	1.44	1.44	1.44	1.44	1.44	1.44	1.44	1.44
Stibnite, in ground	Raw	g	1.02	1.93	2.7	1.02	1.93	2.7	1.03	1.95	2.71
Sulfur dioxide, secondary	Raw	tn.lg	8.63	8.63	8.63	8.63	8.63	8.63	8.63	8.63	8.63
Sulfur, in ground	Raw	tn.lg	186	186	186	186	186	186	186	186	186
Sylvite, 25 % in sylvinite, in ground	Raw	kg	-1870	-1830	-2280	-1870	-1830	-2280	-1690	-1650	-2100
Talc, in ground	Raw	kg	-1570	-1570	-1520	-1480	-1480	-1440	-1550	-1550	-1500
Tin, 79% in cassiterite, 0.1% in crude ore, in ground	Raw	kg	-38.5	-30.5	-50.7	-38.5	-30.5	-50.7	-37.2	-29.3	-49.4
Tin, in ground	Raw	g	-767	-767	-767	-766	-766	-766	-761	-761	-761
TiO2, 45-60% in Ilmenite, in ground	Raw	kg	-20300	-19100	-17500	-20000	-18700	-17100	-19200	-17900	-16400
Transformation, from arable	Raw	m2	-1230	-1230	-1220	-1230	-1230	-1220	-1230	-1220	-1210
Transformation, from arable, non-irrigated	Raw	m2	9490	13400	18000	9600	13500	18200	13600	17500	22100
Transformation, from arable, non-irrigated, fallow	Raw	sq.yd	-433	-431	-441	-433	-431	-441	-432	-430	-440
Transformation, from dump site, inert material landfill	Raw	m2	-1610	-1520	-354	-1610	-1520	-353	-1590	-1500	-336
Transformation, from dump site, residual material landfill	Raw	m2	2470	2480	1480	2470	2480	1480	2490	2500	1490
Transformation, from dump site, sanitary landfill	Raw	sq.yd	883	883	261	883	883	261	883	883	261
Transformation, from dump site, slag compartment	Raw	sq.ft	351	354	9.93	351	354	10	355	358	13.7
Transformation, from forest	Raw	m2	-5120	-638	14000	-5110	-627	14000	-1930	2560	17200
Transformation, from forest, extensive	Raw	m2	-67400	-66900	-71000	-67100	-66600	-70700	-66100	-65600	-69700
Transformation, from industrial area	Raw	m2	-283	-278	-174	-283	-278	-174	-277	-272	-168
Transformation, from industrial area, benthos	Raw	sq.in	-518	-511	-471	-517	-509	-469	-509	-502	-462
Transformation, from industrial area, built up	Raw	dm2	-187	-185	-184	-187	-185	-184	-185	-183	-182
Transformation, from industrial area, vegetation	Raw	dm2	-318	-315	-314	-318	-315	-314	-315	-312	-311
Transformation, from mineral extraction site	Raw	m2	-26200	-25700	-24000	-26200	-25700	-24000	-26100	-25600	-23900
Transformation, from pasture and meadow	Raw	m2	-4330	-4160	-3640	-4330	-4150	-3640	-4250	-4080	-3560
Transformation, from pasture and meadow, intensive	Raw	sq.ft	82.4	116	157	83.3	117	157	118	152	192
Transformation, from sea and ocean	Raw	m2	-3470	-2390	1230	-3460	-2380	1240	-2530	-1450	2170
Transformation, from shrub land, sclerophyllous	Raw	m2	-4010	-3890	-4050	-4010	-3890	-4050	-3950	-3840	-4000
Transformation, from unknown	Raw	m2	-170000	-161000	-139000	-170000	-161000	-139000	-168000	-159000	-137000
Transformation, to arable	Raw	m2	-3580	-3550	-2760	-3580	-3550	-2760	-3540	-3510	-2720

Substance	Compartment	Unit	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7	Scenario 8	Scenario 9
Transformation, to arable, non-irrigated	Raw	m2	9500	13400	18100	9610	13500	18200	13600	17500	22200
Transformation, to arable, non-irrigated, fallow	Raw	m2	-417	-415	-426	-417	-415	-426	-416	-414	-425
Transformation, to dump site	Raw	m2	-58300	-58200	-51300	-58300	-58200	-51300	-58100	-58000	-51100
Transformation, to dump site, benthos	Raw	m2	-3470	-2390	1230	-3460	-2380	1240	-2530	-1450	2170
Transformation, to dump site, inert material landfill	Raw	m2	-1610	-1520	-354	-1610	-1520	-353	-1590	-1500	-336
Transformation, to dump site, residual material landfill	Raw	m2	2470	2480	1480	2470	2480	1480	2490	2500	1490
Transformation, to dump site, sanitary landfill	Raw	sq.yd	883	883	261	883	883	261	883	883	261
Transformation, to dump site, slag compartment	Raw	sq.ft	351	354	9.93	351	354	10	355	358	13.7
Transformation, to forest	Raw	m2	-20900	-20300	-19800	-20900	-20300	-19800	-20700	-20200	-19700
Transformation, to forest, intensive	Raw	m2	-19200	-19200	-19300	-19100	-19100	-19200	-18700	-18600	-18700
Transformation, to forest, intensive, normal	Raw	m2	-47300	-46800	-50800	-47100	-46600	-50600	-46600	-46100	-50000
Transformation, to heterogeneous, agricultural	Raw	m2	-241	-16.8	700	-241	-16.3	700	-91.5	133	850
Transformation, to industrial area	Raw	m2	-37000	-36900	-35400	-37000	-36900	-35400	-36900	-36900	-35300
Transformation, to industrial area, benthos	Raw	dm2	-270	-184	-142	-270	-184	-142	-232	-146	-104
Transformation, to industrial area, built up	Raw	m2	-3110	-3060	-4240	-3110	-3050	-4230	-3050	-3000	-4170
Transformation, to industrial area, vegetation	Raw	m2	-1400	-1340	-1580	-1400	-1330	-1580	-1370	-1300	-1550
Transformation, to mineral extraction site	Raw	m2	-85900	-75000	-49100	-85900	-75000	-49100	-81800	-70900	-45000
Transformation, to pasture and meadow	Raw	sq.ft	-799	-789	-721	-798	-788	-719	-787	-777	-708
Transformation, to permanent crop, fruit, intensive	Raw	sq.yd	184	189	196	186	191	198	199	204	211
Transformation, to sea and ocean	Raw	sq.in	-518	-511	-471	-517	-509	-469	-509	-502	-462
Transformation, to shrub land, sclerophyllous	Raw	m2	1640	1730	1340	1640	1740	1340	1670	1770	1380
Transformation, to traffic area, rail embankment	Raw	m2	-229	-226	-221	-229	-226	-221	-228	-225	-220
Transformation, to traffic area, rail network	Raw	m2	-251	-249	-243	-251	-249	-243	-250	-248	-242
Transformation, to traffic area, road embankment	Raw	m2	-618	-564	-564	-614	-561	-560	-507	-454	-453
Transformation, to traffic area, road network	Raw	m2	-161	103	1110	-161	103	1110	115	379	1390
Transformation, to unknown	Raw	m2	-710	-699	-488	-709	-699	-487	-701	-690	-479
Transformation, to urban, continuously built	Raw	ha	-23.8	-23.8	-23.8	-23.8	-23.8	-23.8	-23.8	-23.8	-23.8
Transformation, to urban, discontinuously built	Raw	dm2	41.5	46	60	41.9	46.3	60.4	47.4	51.8	65.9
Transformation, to water bodies, artificial	Raw	m2	-17400	-16000	-13600	-17400	-16000	-13600	-17200	-15700	-13400
Transformation, to water courses, artificial	Raw	m2	-11400	-11300	-10600	-11400	-11300	-10600	-11300	-11300	-10600
Ulexite, in ground	Raw	kg	461	462	467	461	462	467	896	896	901
Uranium ore, 1.11 GJ per kg, in ground	Raw	mg	156	156	156	180	180	180	294	294	294
Uranium, 451 GJ per kg, in ground	Raw	kg	1770	3230	4390	1770	3230	4390	1770	3230	4390
Uranium, 560 GJ per kg, in ground	Raw	g	79.3	79.3	79.3	79.3	79.3	79.3	79.3	79.3	79.3
Uranium, in ground	Raw	kg	-2040	-2010	-1180	-2030	-2010	-1180	-1990	-1970	-1140
Vermiculite, in ground	Raw	lb	26.7	27.2	82.1	26.7	27.2	82.1	27.2	27.6	82.5
Volume occupied, final repository for low-active radioactive waste	Raw	cuft	-149	-147	-86.2	-148	-147	-86.1	-146	-144	-83.2
Volume occupied, final repository for radioactive waste	Raw	gal*	-280	-277	-163	-280	-277	-163	-275	-271	-158
Volume occupied, reservoir	Raw	m3y	-2920000	-2860000	-1840000	-2920000	-2860000	-1840000	-2840000	-2780000	-1760000
Volume occupied, underground deposit	Raw	cu.yd	107	108	114	109	109	115	111	112	118

Substance	Compartment	Unit	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7	Scenario 8	Scenario 9
Water, cooling, surface	Raw	Mtn	5.34	5.34	5.34	5.34	5.34	5.34	5.34	5.34	5.34
Water, cooling, unspecified natural origin/m3	Raw	m3	-2190000	-2130000	-2840000	-2180000	-2110000	-2820000	-2090000	-2030000	-2730000
Water, lake	Raw	m3	12600	12800	33000	12600	12800	33000	12800	13000	33200
Water, process, unspecified natural origin/kg	Raw	kton	10.1	10.1	10.1	10.1	10.1	10.1	10.1	10.1	10.1
Water, river	Raw	m3	-2600000	-2580000	-2090000	-2590000	-2580000	-2090000	-2570000	-2560000	-2070000
Water, salt, ocean	Raw	m3	-137000	-134000	-79100	-136000	-134000	-78900	-133000	-131000	-75900
Water, salt, sole	Raw	m3	-645000	-642000	-632000	-645000	-642000	-632000	-643000	-640000	-630000
Water, turbine use, unspecified natural origin	Raw	m3	-9.09E+09	-9.07E+09	-8.67E+09	-9.09E+09	-9.06E+09	-8.67E+09	-9.06E+09	-9.03E+09	-8.63E+09
Water, unspecified natural origin/kg	Raw	tn.lg	-294000	-294000	-294000	-294000	-294000	-294000	-291000	-291000	-291000
Water, unspecified natural origin/m3	Raw	m3	1600000	1650000	-420000	1600000	1660000	-419000	1620000	1680000	-398000
Water, well, in ground	Raw	m3	-2520000	-2500000	-2360000	-2520000	-2500000	-2360000	-2510000	-2500000	-2350000
Wood, dry matter	Raw	kg	19.1	19.1	19.1	19.1	19.1	19.1	19.1	19.1	19.1
Wood, hard, standing	Raw	m3	-1430	-1420	-1050	-1420	-1410	-1040	-1390	-1380	-1010
Wood, soft, standing	Raw	m3	-3620	-3580	-3720	-3600	-3560	-3700	-3530	-3500	-3640
Wood, unspecified, standing/kg	Raw	tn.sh	296	163	14.1	296	163	14.1	296	163	14.4
Wood, unspecified, standing/m3	Raw	l	-51.7	-50.1	-64.4	-50.7	-49.2	-63.4	-3.6	-2.09	-16.3
Zeolite, in ground	Raw	kg	-11.6	-11.6	-11.6	-11.6	-11.6	-11.6	-11.4	-11.4	-11.4
Zinc 9%, in sulfide, Zn 5.34% and Pb 2.97% in crude ore, in ground	Raw	kg	-55600000	-55600000	-54300000	-55600000	-55600000	-54300000	-55600000	-55600000	-54300000
Zinc, in ground	Raw	kg	314	314	314	364	364	364	597	597	597
Acenaphthene	Air	mg	-259	-257	-152	-259	-257	-152	-256	-254	-149
Acetaldehyde	Air	kg	263	264	268	263	264	268	264	264	268
Acetic acid	Air	kg	-294	-286	-313	-292	-284	-311	-288	-280	-307
Acetone	Air	lb	-129	-128	-106	-129	-128	-105	-127	-126	-104
Acrolein	Air	g	-34.8	-32.8	-22.8	-34.7	-32.7	-22.7	-33.7	-31.7	-21.7
Actinides, radioactive, unspecified	Air	Bq	-45.7	-45.2	-26.9	-45.6	-45.1	-26.9	-44.8	-44.4	-26.1
Aerosols, radioactive, unspecified	Air	kBq	-883	-874	-522	-882	-873	-521	-868	-859	-507
Alcohols, unspecified	Air	kg	496	496	496	496	496	496	496	496	496
Aldehydes, unspecified	Air	oz	212	215	217	214	217	219	460	463	464
Aluminum	Air	kg	-183000	-183000	-172000	-183000	-183000	-172000	-182000	-182000	-171000
Americium-241	Air	Bq	-29.9	-29.9	-29.9	-29.9	-29.9	-29.9	-29.9	-29.9	-29.9
Ammonia	Air	kg	-73000	-72600	-68600	-73000	-72600	-68600	-72700	-72300	-68200
Ammonium carbonate	Air	g	-58	-56.7	-36.4	-57.8	-56.6	-36.3	-54.3	-53.1	-32.8
Antimony	Air	kg	-6.36	-6.2	-5.94	-6.36	-6.2	-5.94	-6.13	-5.97	-5.71
Antimony-124	Air	Bq	-4.27	-3.88	-1.87	-4.27	-3.88	-1.86	-3.79	-3.4	-1.38
Antimony-125	Air	Bq	-40.2	-36.1	-15.1	-40.2	-36.1	-15	-35.2	-31.1	-10
Argon-41	Air	kBq	-519000	-514000	-292000	-518000	-513000	-291000	-510000	-505000	-283000
Arsenic	Air	kg	-467	-467	-456	-467	-467	-456	-466	-465	-454
Barium	Air	lb	-88.6	-88.3	-79.3	-88.6	-88.3	-79.3	-88	-87.7	-78.7
Barium-140	Air	Bq	-2620	-2350	-982	-2610	-2350	-979	-2290	-2020	-654
Benzaldehyde	Air	g	-8.29	-7.33	-6.29	-8.29	-7.33	-6.29	-7.91	-6.95	-5.92
Benzene	Air	kg	228	336	676	234	342	682	977	1080	1420
Benzene, ethyl-	Air	kg	-2.69	3.94	25.3	-2.69	3.95	25.4	12.6	19.2	40.6
Benzene, hexachloro-	Air	g	10.1	14.8	7.6	10.1	14.8	7.61	14	18.6	11.5
Benzene, pentachloro-	Air	g	28.9	28.9	0.38	28.9	29	0.385	28.9	29	0.441
Benzo(a)pyrene	Air	oz	-448	-446	-403	-448	-446	-403	-446	-444	-401
Beryllium	Air	g	-331	-330	-322	-331	-330	-322	-328	-326	-319
Boron	Air	kg	-1380	-1370	-880	-1370	-1370	-879	-1360	-1350	-862
Bromine	Air	lb	-204	-203	-137	-204	-203	-137	-201	-200	-135
Butadiene	Air	g	991	991	991	173	173	173	488	488	488
Butane	Air	kg	-262	32.3	1040	-260	33.5	1040	-105	189	1190
Butene	Air	kg	1.36	7.99	27.2	2.15	8.77	28	4.56	11.2	30.4
Cadmium	Air	tn.lg	2.84	2.84	2.84	2.84	2.84	2.84	2.84	2.84	2.84
Calcium	Air	kg	-336	-333	-350	-335	-333	-350	-331	-329	-345
Carbon-14	Air	kBq	-3620000	-3570000	-2090000	-3620000	-3570000	-2090000	-3540000	-3500000	-2020000

Substance	Compartment	Unit	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7	Scenario 8	Scenario 9
Carbon dioxide	Air	kton	83.3	49.9	11.1	83.3	49.9	11.1	83.4	50	11.2
Carbon dioxide, biogenic	Air	kton	14.3	14.3	4.73	14.3	14.3	4.74	14.4	14.4	4.79
Carbon dioxide, fossil	Air	kton	-169	-154	-99.1	-169	-154	-98.6	-159	-144	-89
Carbon disulfide	Air	kg	-61500	-61400	-60400	-61500	-61400	-60400	-61400	-61300	-60200
Carbon monoxide	Air	tn.lg	12.5	5.01	-3.82	12.5	5	-3.82	12.5	5.02	-3.81
Carbon monoxide, biogenic	Air	kg	-240000	-239000	-240000	-240000	-239000	-240000	-240000	-239000	-239000
Carbon monoxide, fossil	Air	tn.lg	-1680	-1620	-594	-1680	-1620	-594	-1620	-1570	-541
Cerium-141	Air	Bq	-633	-568	-236	-632	-568	-236	-553	-489	-157
Cerium-144	Air	Bq	-318	-318	-318	-318	-318	-318	-318	-318	-318
Cesium-134	Air	Bq	-1170	-1160	-1150	-1170	-1160	-1150	-1160	-1160	-1140
Cesium-137	Air	Bq	-2730	-2670	-2390	-2730	-2670	-2390	-2660	-2600	-2320
Chlorine	Air	kg	-131	-125	-43.4	-131	-125	-43.3	-129	-123	-41
Chloroform	Air	oz	-43.2	-43.2	-42.6	-43.2	-43.2	-42.6	-43.2	-43.1	-42.6
Chromium	Air	kg	-48.2	-45	-71.2	-48	-44.8	-71	-32.6	-29.4	-55.6
Chromium-51	Air	Bq	-46.1	-42	-20.7	-46.1	-41.9	-20.7	-41	-36.9	-15.6
Chromium VI	Air	oz	-63.5	-61.7	-83.8	-63.4	-61.5	-83.7	-50.4	-48.6	-70.7
Cobalt	Air	tn.lg	2.13	2.13	2.13	2.13	2.13	2.13	2.13	2.13	2.13
Cobalt-57	Air	mBq	-2.63	-2.63	-2.63	-2.63	-2.63	-2.63	-2.63	-2.63	-2.63
Cobalt-58	Air	Bq	-100	-94.3	-64.7	-100	-94.2	-64.6	-93	-87.2	-57.6
Cobalt-60	Air	Bq	-565	-514	-253	-565	-514	-252	-503	-452	-190
Copper	Air	kg	-53.9	-44.8	-40.5	-53.8	-44.7	-40.4	-44	-34.9	-30.6
Cumene	Air	lb	-29.9	-25.8	-67.4	-27.1	-23	-64.7	-28	-24	-65.6
Curium-242	Air	µBq	-151	-151	-151	-151	-151	-151	-151	-151	-151
Curium-244	Air	mBq	-1.37	-1.37	-1.37	-1.37	-1.37	-1.37	-1.37	-1.37	-1.37
Curium alpha	Air	Bq	-47.4	-47.4	-47.4	-47.4	-47.4	-47.4	-47.4	-47.4	-47.4
Cyanide	Air	lb	118	118	5.98	118	118	6	118	119	6.62
Dinitrogen monoxide	Air	tn.lg	-6.54	-6.33	-4.82	-6.53	-6.32	-4.81	-6.12	-5.91	-4.4
Dioxins, measured as 2,3,7,8-tetrachlorodibenzo-p-dioxin	Air	mg	-745	-740	-587	-745	-740	-587	-741	-736	-583
Ethane	Air	tn.lg	-2.26	-2.14	-1.44	-2.25	-2.14	-1.43	-2.16	-2.05	-1.34
Ethane, 1,1,1-trichloro-, HCFC-140	Air	kg	22.3	22.3	22.3	22.3	22.3	22.3	22.3	22.3	22.3
Ethane, 1,1,1,2-tetrafluoro-, HFC-134a	Air	lb	50.3	101	145	50.4	101	146	50.7	101	146
Ethane, 1,1,2-trichloro-1,2,2-trifluoro-, CFC-113	Air	kg	0	0	0	0	0	0	0	0	0
Ethane, 1,2-dichloro-	Air	lb	-83.1	-83	-101	-77.3	-77.2	-95.1	-84.2	-84	-102
Ethane, 1,2-dichloro-1,1,2,2-tetrafluoro-, CFC-114	Air	g	-884	-872	-528	-883	-871	-527	-865	-853	-510
Ethane, 2-chloro-1,1,1,2-tetrafluoro-, HCFC-124	Air	kg	0	0	0	0	0	0	0	0	0
Ethane, dichloro-	Air	kg	85.5	85.5	85.5	85.5	85.5	85.5	85.5	85.5	85.5
Ethane, hexafluoro-, HFC-116	Air	lb	-162	-161	-161	-162	-161	-161	-161	-161	-160
Ethanol	Air	lb	-196	-195	-176	-196	-194	-176	-193	-192	-173
Ethene	Air	kg	-177	-160	-1.77	-176	-160	-1.19	-166	-150	8.77
Ethene, chloro-	Air	oz	-437	-434	-630	-390	-387	-582	-436	-433	-628
Ethene, tetrachloro-	Air	kg	40.7	40.7	40.7	40.7	40.7	40.7	40.7	40.7	40.7
Ethylene diamine	Air	g	-45.4	-45.3	-45.3	-45.3	-45.2	-45.2	-44.8	-44.8	-44.7
Ethylene oxide	Air	g	-765	-745	-926	-755	-734	-916	-749	-728	-910
Ethyne	Air	kg	-110	-110	-105	-110	-110	-105	-110	-110	-104
Fluoranthene	Air	mg	25.6	25.6	25.6	4.46	4.46	4.46	12.6	12.6	12.6
Fluoride	Air	g	459	459	459	459	459	459	459	459	459
Fluorine	Air	oz	-35.5	-30.2	-29.1	-32	-26.8	-25.7	-7.84	-2.57	-1.47
Fluosilicic acid	Air	lb	-189	-188	-188	-189	-188	-188	-189	-188	-187
Formaldehyde	Air	kg	-386	-381	-378	-385	-381	-378	-381	-377	-374
Heat, waste	Air	TJ	-2750	-2520	-1740	-2740	-2510	-1730	-2580	-2360	-1580
Helium	Air	kg	3.99	33	122	3.95	33	122	11.3	40.3	129
Heptane	Air	lb	-0.823	145	614	-0.837	145	614	73.9	220	689
Hexane	Air	kg	-289	-145	428	-288	-144	428	-204	-60.2	512
Hydrocarbons, aliphatic, alkanes, cyclic	Air	g	-1.82	45	75.7	-1.44	45.4	76.1	-0.0577	46.8	77.4
Hydrocarbons, aliphatic, alkanes, unspecified	Air	kg	-8130	-8040	-3130	-8120	-8030	-3120	-7750	-7660	-2750
Hydrocarbons, aliphatic,	Air	kg	-10.9	-10.9	-10.9	-10.9	-10.9	-10.9	-10.8	-10.8	-10.8

Substance	Compartment	Unit	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7	Scenario 8	Scenario 9
alkenes, unspecified											
Hydrocarbons, aliphatic, unsaturated	Air	lb	-579	-575	-399	-579	-574	-398	-447	-443	-267
Hydrocarbons, aromatic	Air	kg	2910	2670	702	2940	2690	729	3020	2770	810
Hydrocarbons, chlorinated	Air	lb	115	115	98.7	121	121	105	192	192	176
Hydrocarbons, halogenated	Air	kg	178	178	178	178	178	178	178	178	178
Hydrocarbons, unspecified	Air	tn.lg	8.12	8.12	8.12	8.12	8.12	8.12	8.12	8.12	8.12
Hydrogen	Air	kg	-466	-444	-1010	-442	-420	-987	-321	-298	-865
Hydrogen-3, Tritium	Air	kBq	-21000000	-20800000	-12300000	-21000000	-20800000	-12300000	-20700000	-20400000	-11900000
Hydrogen chloride	Air	tn.sh	-1.21	-7.03	-9.46	-1.19	-7.01	-9.44	-1.02	-6.83	-9.27
Hydrogen fluoride	Air	kg	-2630	-3170	-2880	-2620	-3170	-2880	-2590	-3140	-2850
Hydrogen sulfide	Air	kg	-1060	-1050	-608	-1060	-1050	-607	-1050	-1040	-598
Iodine	Air	lb	-111	-110	-72.9	-111	-110	-72.8	-110	-109	-71.5
Iodine-129	Air	kBq	-3680	-3640	-2150	-3680	-3640	-2150	-3620	-3570	-2080
Iodine-131	Air	kBq	-204000	-202000	-114000	-204000	-202000	-114000	-201000	-199000	-111000
Iodine-133	Air	Bq	-3630	-3310	-1680	-3630	-3310	-1670	-3240	-2920	-1290
Iodine-135	Air	Bq	-761	-761	-761	-761	-761	-761	-761	-761	-761
Iron	Air	kg	-1890	-1890	-1670	-1890	-1890	-1670	-1880	-1880	-1660
Iron-59	Air	mBq	-59.7	-59.7	-59.7	-59.7	-59.7	-59.7	-59.7	-59.7	-59.7
Isocyanic acid	Air	oz	-574	-567	-344	-574	-566	-343	-563	-556	-333
Ketones, unspecified	Air	kg	59.5	59.5	59.5	59.5	59.5	59.5	59.5	59.5	59.5
Krypton-85	Air	kBq	-106000	-91200	604000	-104000	-89300	606000	-79200	-64200	631000
Krypton-85m	Air	kBq	-63700	-59700	-28800	-63700	-59600	-28800	-58600	-54500	-23700
Krypton-87	Air	kBq	-28100	-27100	-14200	-28100	-27000	-14200	-26700	-25700	-12900
Krypton-88	Air	kBq	-33100	-31800	-19400	-33100	-31800	-19400	-31500	-30200	-17800
Krypton-89	Air	kBq	-6070	-5580	-2560	-6060	-5570	-2560	-5460	-4970	-1950
Lanthanum	Air	g	-65.3	-65.3	-65.3	-65.3	-65.3	-65.3	-64.9	-64.9	-64.9
Lanthanum-140	Air	Bq	-227	-204	-87.3	-227	-204	-87.1	-199	-176	-59.3
Lead	Air	tn.lg	-20.5	-20.4	-19.8	-20.5	-20.4	-19.8	-20.5	-20.4	-19.8
Lead-210	Air	kBq	-26600	-26400	-19900	-26600	-26400	-19900	-26300	-26200	-19600
m-Xylene	Air	oz	-63.6	-63.1	-43.5	-63.5	-62.9	-43.3	-62.2	-61.6	-42.1
Magnesium	Air	kg	-822	-821	-828	-822	-821	-828	-819	-818	-825
Manganese	Air	tn.lg	35.5	35.5	35.5	35.5	35.5	35.5	35.5	35.5	35.5
Manganese-54	Air	Bq	-22.3	-20.2	-9.33	-22.3	-20.2	-9.31	-19.7	-17.6	-6.73
Mercaptans, unspecified	Air	kg	114	114	114	114	114	114	114	114	114
Mercury	Air	kg	-819	-820	-9100	-819	-820	-9100	-819	-819	-9100
Metals, unspecified	Air	tn.lg	8.37	6.95	5.35	8.37	6.95	5.35	8.37	6.95	5.35
Methane	Air	tn.lg	680	569	442	680	569	442	680	569	443
Methane, biogenic	Air	kg	216000	216000	-140	216000	216000	-133	216000	216000	-114
Methane, bromochlorodifluoro-, Halon 1211	Air	g	-523	-515	-479	-521	-513	-477	-513	-505	-469
Methane, bromotrifluoro-, Halon 1301	Air	oz	7.09	14	34.7	7.08	14	34.7	10.3	17.2	37.9
Methane, chlorodifluoro-, HCFC-22	Air	kg	13.9	14	14.6	13.9	14	14.6	14	14	14.7
Methane, chlorotrifluoro-, CFC-13	Air	mg	-164	-164	-164	-164	-164	-164	-164	-164	-164
Methane, dichloro-, HCC-30	Air	g	-82.7	-82.6	-82.2	-82.7	-82.6	-82.2	-82.6	-82.6	-82.1
Methane, dichlorodifluoro-, CFC-12	Air	kg	19.6	19.6	19.3	19.7	19.7	19.4	19.6	19.6	19.3
Methane, dichlorofluoro-, HCFC-21	Air	g	-827	-827	-827	-827	-827	-827	-827	-827	-827
Methane, fossil	Air	tn.lg	-310	-290	-143	-309	-288	-141	-298	-278	-131
Methane, monochloro-, R-40	Air	mg	-24.7	-24.6	-21.3	-24.7	-24.6	-21.3	-24.6	-24.6	-21.2
Methane, tetrachloro-, CFC-10	Air	oz	-383	-383	-380	-383	-383	-380	-383	-383	-380
Methane, tetrafluoro-, FC-14	Air	kg	-661	-659	-656	-661	-659	-656	-659	-657	-655
Methane, trichlorofluoro-, CFC-11	Air	g	-1.22	-1.22	-1.22	-1.22	-1.22	-1.22	-1.22	-1.22	-1.22
Methane, trifluoro-, HFC-23	Air	mg	-10.7	-10.3	12.7	-10.6	-10.2	12.7	-10.1	-9.68	13.3
Methanol	Air	kg	-132	-127	-167	-131	-126	-166	-118	-113	-153
Molybdenum	Air	oz	-111	-108	-127	-111	-108	-127	-107	-105	-124
Monoethanolamine	Air	oz	-207	-206	-229	-206	-204	-227	-196	-195	-218
Naphthalene	Air	kg	-1.08	-1.08	-1.08	-1.08	-1.08	-1.08	-1.08	-1.08	-1.08

Substance	Compartment	Unit	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7	Scenario 8	Scenario 9
Neptunium-237	Air	mBq	-1.56	-1.56	-1.56	-1.56	-1.56	-1.56	-1.56	-1.56	-1.56
Nickel	Air	tn.lg	8.97	8.96	8.92	8.97	8.96	8.92	8.98	8.97	8.92
Niobium-95	Air	Bq	-2.74	-2.49	-1.2	-2.74	-2.49	-1.2	-2.44	-2.18	-0.891
Nitrate	Air	oz	-287	-286	-269	-287	-286	-269	-286	-286	-268
Nitric oxide	Air	tn.lg	21.7	21.7	21.7	21.7	21.7	21.7	21.7	21.7	21.7
Nitrogen	Air	kg	-1.78E+11	-1.78E+11	-1.78E+11	-1.78E+11	-1.78E+11	-1.78E+11	-1.78E+11	-1.78E+11	-1.78E+11
Nitrogen dioxide	Air	tn.lg	17.4	17.4	17.4	17.4	17.4	17.4	17.4	17.4	17.4
Nitrogen oxides	Air	tn.lg	-849	-853	-639	-847	-851	-637	-830	-834	-620
NMVOC, non-methane volatile organic compounds, unspecified origin	Air	tn.lg	-138	-119	-90.3	-137	-118	-89.1	-129	-110	-81
Noble gases, radioactive, unspecified	Air	kBq	-3.53E+10	-3.49E+10	-2.06E+10	-3.53E+10	-3.49E+10	-2.05E+10	-3.47E+10	-3.43E+10	-1.99E+10
Organic substances, unspecified	Air	kg	1.33	1.33	1.33	1.33	1.33	1.33	1.33	1.33	1.33
Oxygen	Air	kton	6.71	6.71	x	6.71	6.71	x	6.71	6.71	x
Ozone	Air	kg	-1230	-1220	-764	-1230	-1220	-763	-1210	-1200	-743
PAH, polycyclic aromatic hydrocarbons	Air	lb	-753	-754	-725	-753	-754	-725	-750	-751	-723
Paraffins	Air	mg	-365	-358	-539	-365	-358	-538	-361	-354	-535
Particulates	Air	tn.lg	85.8	54.8	19.2	85.8	54.8	19.2	85.8	54.8	19.2
Particulates, < 10 um	Air	kg	-903	-903	-903	-903	-903	-903	-903	-903	-903
Particulates, < 10 um (mobile)	Air	oz	62.1	62.1	62.1	62.1	62.1	62.1	62.1	62.1	62.1
Particulates, < 10 um (stationary)	Air	kg	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5
Particulates, < 2.5 um	Air	tn.sh	-655	-649	-631	-655	-648	-631	-647	-641	-623
Particulates, > 10 um	Air	tn.lg	-538	-533	-366	-538	-533	-365	-534	-530	-362
Particulates, > 10 um (process)	Air	kg	57.2	57.2	57.2	57.2	57.2	57.2	57.2	57.2	57.2
Particulates, > 2.5 um, and < 10um	Air	tn.lg	-519	-516	-408	-518	-515	-408	-516	-512	-405
Particulates, SPM	Air	kg	-571	-571	-571	-571	-571	-571	-571	-571	-571
Particulates, unspecified	Air	tn.lg	11.9	11.9	12.1	11.9	11.9	12.1	11.9	11.9	12.1
Pentane	Air	kg	-823	-440	781	-821	-438	783	-623	-240	981
Phenol	Air	oz	-567	-550	-902	-541	-524	-876	-554	-537	-889
Phenol, pentachloro-	Air	oz	-43.2	-42.8	-24.3	-43.1	-42.8	-24.2	-42.5	-42.1	-23.6
Phosphorus	Air	oz	-640	-638	-622	-640	-638	-621	-635	-632	-616
Phosphorus pentoxide	Air	mg	-216	-216	-216	-216	-216	-216	-216	-216	-216
Phosphorus, total	Air	g	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7
Platinum	Air	mg	-624	-624	-623	-624	-624	-623	-450	-450	-449
Plutonium-238	Air	mBq	-505	-499	-296	-504	-499	-295	-495	-490	-286
Plutonium-241	Air	Bq	-2610	-2610	-2610	-2610	-2610	-2610	-2610	-2610	-2610
Plutonium-alpha	Air	Bq	-95.6	-95.6	-95.2	-95.6	-95.6	-95.1	-95.6	-95.6	-95.1
Polonium-210	Air	kBq	-47300	-47100	-35600	-47300	-47000	-35600	-46800	-46600	-35100
Polychlorinated biphenyls	Air	g	-364	-356	-140	-364	-356	-140	-358	-349	-133
Potassium	Air	kg	-621	-618	-522	-620	-617	-521	-612	-609	-513
Potassium-40	Air	kBq	-6340	-6310	-4970	-6340	-6310	-4970	-6290	-6260	-4920
Promethium-147	Air	Bq	-8.22E+16	-8.22E+16	-8.22E+16	-8.22E+16	-8.22E+16	-8.22E+16	-8.22E+16	-8.22E+16	-8.22E+16
Propanal	Air	g	-8.04	-7.08	-6.04	-8.04	-7.08	-6.04	-7.67	-6.71	-5.67
Propane	Air	kg	-879	-581	482	-877	-579	484	-715	-417	646
Propene	Air	kg	-138	-122	-76.2	-136	-121	-74.7	-131	-115	-68.7
Propionic acid	Air	oz	-283	-280	-259	-282	-279	-258	-279	-276	-255
Propylene oxide	Air	oz	62.6	129	188	62.6	129	188	64.4	131	190
Protactinium-234	Air	kBq	-500	-494	-291	-499	-493	-290	-490	-483	-281
Radioactive species, other beta emitters	Air	kBq	15700	29800	41600	15700	29800	41600	15900	30000	41900
Radioactive species, unspecified	Air	kBq	1.53E+11	2.8E+11	3.81E+11	1.53E+11	2.8E+11	3.81E+11	1.53E+11	2.8E+11	3.81E+11
Radium-226	Air	kBq	-23000	-22700	-14500	-23000	-22700	-14500	-22600	-22300	-14100
Radium-228	Air	kBq	-14500	-14500	-13800	-14500	-14500	-13800	-14500	-14400	-13700
Radon-220	Air	kBq	-459	-459	-455	-459	-459	-455	-459	-458	-454
Radon-222	Air	kBq	-6.65E+10	-6.56E+10	-3.87E+10	-6.64E+10	-6.55E+10	-3.86E+10	-6.51E+10	-6.42E+10	-3.73E+10
Ruthenium-103	Air	mBq	-559	-504	-220	-558	-503	-219	-491	-436	-152
Ruthenium-106	Air	Bq	-9450	-9450	-9450	-9450	-9450	-9450	-9450	-9450	-9450
Scandium	Air	g	-299	-299	-284	-299	-299	-284	-298	-298	-283

Substance	Compartment	Unit	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7	Scenario 8	Scenario 9
Selenium	Air	oz	-413	-406	-331	-413	-405	-331	-401	-393	-318
Silicates, unspecified	Air	kg	-214	-214	-214	-214	-214	-214	-212	-212	-212
Silicon	Air	kg	-3310	-3300	-3470	-3310	-3300	-3470	-3290	-3290	-3460
Silicon tetrafluoride	Air	g	-39.5	-39.1	-39	-39.5	-39.1	-39	-39.1	-38.8	-38.6
Silver	Air	kg	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5
Silver-110	Air	Bq	-6.91	-6.36	-3.55	-6.9	-6.36	-3.54	-6.24	-5.69	-2.87
Sodium	Air	kg	-101	-96.8	-258	-101	-96.6	-257	-96.2	-91.9	-253
Sodium chlorate	Air	g	-646	-641	-628	-644	-639	-626	-633	-628	-615
Sodium dichromate	Air	lb	67.5	67.5	-0.398	67.5	67.5	-0.397	67.6	67.6	-0.367
Sodium formate	Air	g	-103	-102	-107	-103	-102	-107	-103	-102	-107
Soot	Air	tn.lg	-3.46	-3.46	-3.46	-3.46	-3.46	-3.46	-3.46	-3.46	-3.46
Strontium	Air	kg	-55.6	-55.4	-49.4	-55.5	-55.4	-49.4	-55.3	-55.1	-49.1
Strontium-89	Air	Bq	-2.77	-2.77	-2.77	-2.77	-2.77	-2.77	-2.77	-2.77	-2.77
Strontium-90	Air	Bq	-1560	-1560	-1560	-1560	-1560	-1560	-1560	-1560	-1560
Styrene	Air	g	-21	-20.8	-14.1	-21	-20.8	-14.1	-20.7	-20.6	-13.9
Sulfate	Air	kg	208000	208000	2170	208000	208000	2170	208000	208000	2190
Sulfur dioxide	Air	tn.lg	-1030	-1010	-1360	-1020	-1000	-1360	-1000	-983	-1340
Sulfur hexafluoride	Air	oz	-725	-719	-450	-724	-718	-449	-714	-708	-439
Sulfur oxides	Air	tn.lg	226	153	59.9	226	153	59.9	226	153	59.9
Sulfuric acid	Air	kg	-135	-135	-150	-135	-135	-150	-135	-135	-150
t-Butyl methyl ether	Air	lb	67.4	67.4	67.4	67.4	67.4	67.4	129	129	129
Tar	Air	mg	259	259	259	259	259	259	259	259	259
Technetium-99	Air	mBq	-66.4	-66.4	-66.4	-66.4	-66.4	-66.4	-66.4	-66.4	-66.4
Tellurium-123m	Air	Bq	-6.85	-6.85	-6.85	-6.85	-6.85	-6.85	-6.85	-6.85	-6.85
Thallium	Air	kg	1.66	1.66	1.67	1.66	1.66	1.67	1.66	1.66	1.67
Thorium	Air	g	-533	-532	-515	-533	-532	-515	-531	-530	-513
Thorium-228	Air	kBq	-1830	-1830	-1550	-1830	-1830	-1550	-1820	-1820	-1530
Thorium-230	Air	kBq	-1930	-1910	-1160	-1930	-1900	-1150	-1890	-1870	-1120
Thorium-232	Air	kBq	-1840	-1830	-1410	-1840	-1830	-1410	-1820	-1810	-1390
Thorium-234	Air	kBq	-500	-494	-291	-500	-493	-290	-490	-483	-281
Tin	Air	kg	2.88	3.04	2.52	2.88	3.04	2.52	3.33	3.49	2.98
Titanium	Air	kg	-81.2	-80.8	-82.9	-81.2	-80.8	-82.9	-80.7	-80.3	-82.4
Toluene	Air	kg	537	646	857	537	647	858	1220	1330	1540
Uranium	Air	g	-586	-585	-570	-586	-585	-570	-584	-583	-568
Uranium-234	Air	kBq	-5910	-5830	-3470	-5900	-5820	-3460	-5790	-5710	-3340
Uranium-235	Air	kBq	-283	-280	-165	-283	-279	-165	-278	-274	-159
Uranium-238	Air	kBq	-10900	-10800	-7290	-10800	-10800	-7280	-10700	-10600	-7130
Uranium alpha	Air	kBq	-27300	-26900	-15900	-27200	-26900	-15800	-26700	-26400	-15300
Vanadium	Air	kg	-242	-237	-371	-242	-236	-370	-236	-230	-364
VOC, volatile organic compounds	Air	kg	31700	31700	31700	31700	31700	31700	31700	31700	31700
water	Air	Mtn	5.4	5.4	5.39	5.4	5.4	5.39	5.4	5.4	5.39
Xenon-131m	Air	kBq	-127000	-122000	-63200	-127000	-122000	-63100	-120000	-115000	-56400
Xenon-133	Air	kBq	-4050000	-3860000	-2010000	-4040000	-3860000	-2010000	-3810000	-3620000	-1770000
Xenon-133m	Air	kBq	-19000	-18700	-10400	-19000	-18700	-10400	-18500	-18200	-9910
Xenon-135	Air	kBq	-1640000	-1570000	-810000	-1640000	-1570000	-808000	-1550000	-1470000	-713000
Xenon-135m	Air	kBq	-948000	-902000	-456000	-947000	-901000	-455000	-889000	-843000	-396000
Xenon-137	Air	kBq	-16500	-15100	-6850	-16400	-15100	-6830	-14800	-13400	-5180
Xenon-138	Air	kBq	-152000	-142000	-67800	-152000	-142000	-67600	-139000	-129000	-54800
Xylene	Air	kg	-106	-7.27	401	-105	-6.32	402	519	618	1030
Zinc	Air	tn.lg	-16.6	-16.5	-15.4	-16.6	-16.5	-15.4	-16.6	-16.5	-15.4
Zinc-65	Air	Bq	-111	-100	-46	-111	-100	-45.9	-98	-87.4	-33
Zirconium	Air	g	-223	-222	-106	-223	-222	-106	-222	-220	-104
Zirconium-95	Air	Bq	-101	-91.1	-37.9	-101	-91	-37.8	-88.7	-78.4	-25.2
Acenaphthene	Water	g	-0.333	1.33	6.63	-0.333	1.33	6.63	0.656	2.32	7.62
Acenaphthylene	Water	oz	-54.3	-54.3	-54.3	-54.3	-54.3	-54.3	-54.3	-54.3	-54.3
Acetic acid	Water	oz	-151	-138	-194	-149	-136	-192	-145	-132	-188
Acidity, unspecified	Water	tn.lg	3.89	3.9	3.86	3.9	3.91	3.87	3.91	3.91	3.87
Acids, unspecified	Water	g	1.36	1.36	1.36	1.36	1.36	1.36	1.36	1.36	1.36
Actinides, radioactive, unspecified	Water	kBq	-5970	-5900	-3480	-5960	-5900	-3470	-5860	-5790	-3370
Aluminum	Water	tn.lg	386	369	228	386	369	228	388	371	231

Substance	Compartment	Unit	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7	Scenario 8	Scenario 9
Americium-241	Water	Bq	-3930	-3930	-3930	-3930	-3930	-3930	-3930	-3930	-3930
Ammonia	Water	tn.lg	411	411	411	411	411	411	411	411	411
Ammonia, as N	Water	g	368	368	368	368	368	368	368	368	368
Ammonium, ion	Water	kg	33500	33700	13800	33500	33700	13800	33500	33700	13800
Antimony	Water	tn.lg	14.6	14.6	14.3	14.6	14.6	14.3	14.6	14.6	14.3
Antimony-122	Water	Bq	-1590	-1430	-620	-1590	-1430	-618	-1400	-1240	-425
Antimony-124	Water	kBq	-957	-941	-557	-956	-940	-556	-933	-918	-533
Antimony-125	Water	kBq	-859	-844	-515	-858	-844	-514	-838	-823	-494
AOX, Adsorbable Organic Halogen as Cl	Water	lb	-96	-95.5	-94	-95.1	-94.6	-93	-90.6	-90.1	-88.5
Arsenic, ion	Water	kg	-3270	-3270	-3010	-3270	-3270	-3010	-3260	-3260	-3000
Barite	Water	kg	-2970	-2290	-39.8	-2960	-2290	-33.7	-2380	-1710	550
Barium	Water	kg	5760	4460	1110	5770	4460	1110	5930	4630	1280
Barium-140	Water	Bq	-6830	-6140	-2580	-6820	-6130	-2570	-5980	-5280	-1720
Benzene	Water	oz	-447	316	477	-276	487	648	-28.5	735	896
Benzene, chloro-	Water	mg	-2.92	-2.92	-2.92	-2.92	-2.92	-2.92	-2.92	-2.92	-2.92
Benzene, ethyl-	Water	lb	-1.6	12.5	57.7	-1.6	12.5	57.7	6.82	21	66.1
Beryllium	Water	oz	2.47	6.46	-302	3.09	7.08	-301	9.73	13.7	-295
BOD5, Biological Oxygen Demand	Water	tn.lg	803	863	1060	803	863	1060	842	902	1100
Boron	Water	kg	24.9	47.7	929	28.3	51.2	933	65.6	88.4	970
Bromate	Water	kg	126	127	112	126	127	112	127	128	113
Bromine	Water	tn.lg	13.4	13.5	13.5	13.4	13.5	13.5	13.5	13.7	13.6
Butene	Water	oz	332	332	159	398	398	224	316	316	142
Cadmium-109	Water	mBq	-237	-237	-237	-237	-237	-237	-237	-237	-237
Cadmium, ion	Water	tn.lg	250	251	251	250	251	251	250	251	251
Calcium compounds, unspecified	Water	kg	-3960	-3960	-3960	-3960	-3960	-3960	-3940	-3940	-3940
Calcium, ion	Water	kton	-1.33	-1.31	-1.16	-1.33	-1.31	-1.16	-1.31	-1.3	-1.14
Carbon-14	Water	kBq	-199	-199	-199	-199	-199	-199	-199	-199	-199
Carbonate	Water	kg	3220	3220	2930	3220	3230	2940	6120	6130	5840
Carboxylic acids, unspecified	Water	kg	-371	729	4250	-371	730	4250	315	1420	4940
Cerium-141	Water	Bq	-2720	-2440	-1020	-2720	-2440	-1020	-2380	-2100	-679
Cerium-144	Water	kBq	-91	-90.9	-90.4	-91	-90.9	-90.4	-90.9	-90.8	-90.3
Cesium	Water	oz	-2.31	7.11	37.2	-2.31	7.11	37.2	3.3	12.7	42.8
Cesium-134	Water	kBq	-1000	-994	-695	-1000	-993	-694	-989	-980	-681
Cesium-136	Water	Bq	-482	-433	-180	-481	-432	-180	-421	-372	-120
Cesium-137	Water	kBq	-689000	-681000	-402000	-688000	-680000	-401000	-676000	-668000	-389000
Chlorate	Water	kg	912	920	801	912	921	801	918	926	807
Chloride	Water	kton	1.21	1.3	9.25	1.21	1.3	9.25	1.38	1.47	9.41
Chlorinated solvents, unspecified	Water	kg	3.25	3.28	2.53	3.3	3.33	2.59	3.57	3.6	2.86
Chlorine	Water	oz	-316	-305	352	-314	-303	354	-301	-290	367
Chloroform	Water	oz	-500	-500	-500	-500	-500	-500	-500	-500	-500
Chromium	Water	kg	459	266	49.3	459	266	49.8	462	269	52.7
Chromium-51	Water	kBq	-924	-870	-462	-923	-869	-461	-856	-802	-394
Chromium VI	Water	tn.lg	6.86	6.95	7.04	6.86	6.95	7.04	6.94	7.03	7.12
Chromium, ion	Water	kg	393	396	142	393	396	142	395	397	143
Cobalt	Water	tn.lg	184	184	183	184	184	183	184	184	183
Cobalt-57	Water	kBq	-15.3	-13.8	-5.75	-15.3	-13.8	-5.74	-13.4	-11.9	-3.83
Cobalt-58	Water	kBq	-7260	-7010	-3980	-7260	-7000	-3970	-6920	-6670	-3640
Cobalt-60	Water	kBq	-6510	-6290	-3900	-6500	-6280	-3900	-6220	-6000	-3610
COD, Chemical Oxygen Demand	Water	tn.lg	1320	1390	524	1320	1390	525	1370	1440	568
Copper, ion	Water	tn.lg	-5.7	-5.59	-8.92	-5.69	-5.59	-8.92	-5.64	-5.53	-8.86
Crude oil	Water	kg	-20.8	-20.8	-20.8	-20.8	-20.8	-20.8	-20.8	-20.8	-20.8
Cumene	Water	lb	-71.8	-62	-162	-65.2	-55.3	-155	-67.4	-57.6	-158
Curium alpha	Water	Bq	-5220	-5220	-5220	-5220	-5220	-5220	-5220	-5220	-5220
Cyanide	Water	kg	-7120	-7080	-4240	-7120	-7080	-4240	-7080	-7040	-4200
Dichromate	Water	oz	-41.9	-41.1	-24.9	-41.8	-41.1	-24.8	-40.1	-39.3	-23.1
DOC, Dissolved Organic Carbon	Water	tn.lg	1670	1690	659	1670	1690	659	1680	1710	673
EDTA	Water	mg	378	378	378	378	378	378	378	378	378

Substance	Compartment	Unit	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7	Scenario 8	Scenario 9
Ethane, 1,1,1-trichloro-, HCFC-140	Water	g	-1.45	-1.45	-1.45	-1.45	-1.45	-1.45	-1.45	-1.45	-1.45
Ethane, 1,2-dichloro-	Water	oz	-843	-843	-841	-843	-842	-841	-842	-842	-841
Ethane, chloro-	Water	g	-17.3	-17.3	-17.3	-17.3	-17.3	-17.3	-17.3	-17.3	-17.3
Ethane, dichloro-	Water	g	-13.8	-13.8	-13.8	-13.8	-13.8	-13.8	-13.3	-13.3	-13.3
Ethane, hexachloro-	Water	mg	-515	-515	-515	-515	-515	-515	-515	-515	-515
Ethene	Water	oz	-156	-99.7	-635	-133	-77	-612	-139	-83.3	-619
Ethene, chloro-	Water	g	-293	-291	-337	-292	-290	-337	-285	-283	-329
Ethene, tetrachloro-	Water	g	-61.2	-61.2	-61.2	-61.2	-61.2	-61.2	-61.2	-61.2	-61.2
Ethene, trichloro-	Water	oz	-136	-136	-136	-136	-136	-136	-136	-136	-136
Ethylene diamine	Water	g	-110	-110	-110	-110	-110	-109	-109	-109	-108
Ethylene oxide	Water	g	-8.64	-8.58	-9.55	-8.56	-8.5	-9.47	-8.19	-8.13	-9.09
Fatty acids as C	Water	kton	1.08	1.08	1.08	1.08	1.08	1.08	1.08	1.08	1.08
Fluoride	Water	tn.lg	8.27	8.39	7.91	8.27	8.39	7.92	8.34	8.46	7.99
Fluorine	Water	g	140	140	140	140	140	140	140	140	140
Fluosilicic acid	Water	lb	-340	-339	-338	-340	-339	-338	-339	-338	-337
Formaldehyde	Water	oz	-51.7	-42	-117	-47.3	-37.6	-112	-9.31	0.331	-74.5
Glutaraldehyde	Water	g	-371	-288	-9.42	-370	-287	-8.66	-298	-215	63.3
Heat, waste	Water	MWh	110000	111000	37400	110000	111000	37400	111000	112000	38300
Hydrazine	Water	mg	174	174	174	174	174	174	174	174	174
Hydrocarbons, aliphatic, alkanes, unspecified	Water	kg	-4.2	30.5	141	-4.19	30.5	141	16.5	51.2	162
Hydrocarbons, aliphatic, alkenes, unspecified	Water	g	408	408	408	408	408	408	410	410	410
Hydrocarbons, aliphatic, unsaturated	Water	oz	-28	85.1	446	-27.9	85.1	446	39.4	152	514
Hydrocarbons, aromatic	Water	kg	41.3	172	589	41.3	172	589	126	257	674
Hydrocarbons, chlorinated	Water	g	221	145	44.4	221	145	44.4	221	146	44.8
Hydrocarbons, unspecified	Water	kg	-477	-457	-474	-461	-441	-458	-376	-355	-372
Hydrogen	Water	kg	-19.6	-19.6	-19.6	-19.6	-19.6	-19.6	-19.6	-19.6	-19.6
Hydrogen-3, Tritium	Water	kBq	-1.58E+09	-1.56E+09	-923000000	-1.58E+09	-1.56E+09	-921000000	-1.55E+09	-1.53E+09	-894000000
Hydrogen peroxide	Water	kg	7800	7800	2.31	7800	7800	2.32	7800	7800	2.37
Hydrogen sulfide	Water	kg	1340	1340	361	1340	1340	361	1340	1340	362
Hydroxide	Water	oz	-89.2	-88.1	-49.3	-89.1	-87.9	-49.2	-87.3	-86.2	-47.5
Hypochlorite	Water	lb	-247	-245	-148	-246	-245	-148	-243	-242	-145
Hypochlorous acid	Water	oz	-603	-603	-603	-603	-603	-603	-596	-596	-596
Iodide	Water	kg	-9.85	16.9	104	-9.84	16.9	104	6.14	32.9	120
Iodine-129	Water	kBq	-569	-569	-569	-569	-569	-569	-569	-569	-569
Iodine-131	Water	kBq	-173	-170	-100	-173	-170	-99.8	-168	-165	-95
Iodine-133	Water	Bq	-4450	-4010	-1780	-4440	-4010	-1780	-3910	-3480	-1240
Iron	Water	tn.lg	47	41.3	34.9	47	41.3	34.9	47	41.3	34.9
Iron-59	Water	Bq	-1170	-1050	-438	-1170	-1050	-437	-1030	-906	-291
Iron, ion	Water	tn.lg	-121	-119	-81.3	-120	-119	-81.1	-118	-116	-78.6
Kjeldahl-N	Water	oz	202	172	81.2	202	171	80.8	202	171	80.9
Krypton-85	Water	kBq	-14.1	-14.1	-14.1	-14.1	-14.1	-14.1	-14.1	-14.1	-14.1
Lanthanum-140	Water	Bq	-7240	-6500	-2710	-7230	-6490	-2700	-6330	-5590	-1800
Lead	Water	tn.lg	218	219	217	218	219	217	218	219	217
Lead-210	Water	kBq	-22600	-22400	-19700	-22600	-22400	-19700	-22400	-22200	-19400
Lithium carbonate	Water	mg	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5
Magnesium	Water	tn.lg	226	228	208	226	228	208	228	230	210
Manganese	Water	kton	3.11	3.11	3.1	3.11	3.11	3.1	3.11	3.11	3.1
Manganese-54	Water	kBq	-579	-563	-379	-578	-563	-379	-558	-543	-359
Mercury	Water	kg	-5.41	-3.51	20.1	-5.35	-3.45	20.1	-4.8	-2.9	20.7
Metallic ions, unspecified	Water	tn.lg	408	406	404	408	406	404	408	406	404
Methane, dichloro-, HCC-30	Water	oz	-102	-8.97	292	-101	-8.76	292	-35.9	56.7	358
Methane, tetrachloro-, CFC-10	Water	g	-93.6	-93.6	-93.6	-93.6	-93.6	-93.6	-93.6	-93.6	-93.6
Methanol	Water	oz	-335	-328	-301	-333	-326	-299	-317	-310	-283
Molybdenum	Water	kg	180	181	184	180	181	184	182	183	186
Molybdenum-99	Water	Bq	-2500	-2240	-934	-2490	-2240	-932	-2180	-1930	-621
Morpholine	Water	g	1.85	1.85	1.85	1.85	1.85	1.85	1.85	1.85	1.85
Neptunium-237	Water	Bq	-252	-252	-252	-252	-252	-252	-252	-252	-252
Nickel, ion	Water	tn.lg	778	778	779	778	778	779	778	778	779

Substance	Compartment	Unit	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7	Scenario 8	Scenario 9
Niobium-95	Water	Bq	-69800	-68600	-45600	-69800	-68500	-45500	-68100	-66800	-43800
Nitrate	Water	tn.lg	38.2	38	15.9	38.2	38	15.9	38.4	38.2	16.1
Nitrilotriacetic acid	Water	kg	225	225	225	225	225	225	225	225	225
Nitrite	Water	kg	2070	2070	1240	2070	2070	1240	2070	2070	1240
Nitrogen	Water	kg	-7550	-7530	-7090	-7550	-7530	-7080	-7520	-7500	-7050
Nitrogen, organic bound	Water	kg	20900	20900	-3650	20900	20900	-3650	20900	21000	-3590
Nitrogen, total	Water	oz	176	-34.7	-827	176	-34.3	-826	192	-18.4	-811
NMVOC, non-methane volatile organic compounds, unspecified origin	Water	kg	15	15	15	15	15	15	15	15	15
Oils, unspecified	Water	tn.lg	-122	-109	-44.6	-122	-109	-44.6	-112	-98.8	-33.9
PAH, polycyclic aromatic hydrocarbons	Water	kg	-3090	-3080	-3240	-3090	-3080	-3240	-3080	-3080	-3240
Paraffins	Water	g	-1.06	-1.04	-1.56	-1.06	-1.04	-1.56	-1.05	-1.03	-1.55
Phenol	Water	kg	4.42	29.2	103	5.82	30.7	105	26.1	50.9	125
Phenols, unspecified	Water	oz	283	234	97.3	283	234	97.3	283	234	97.3
Phosphate	Water	tn.lg	75.4	74.6	74.4	75.4	74.6	74.5	75.9	75.1	74.9
Phosphorus	Water	lb	-146	-141	-61.1	-145	-141	-60.5	-114	-110	-29.4
Phosphorus compounds, unspecified	Water	g	1.34	1.34	1.34	1.34	1.34	1.34	1.34	1.34	1.34
Phosphorus pentoxide	Water	g	-6.4	-6.4	-6.4	-6.4	-6.4	-6.4	-6.4	-6.4	-6.4
Phosphorus, total	Water	g	-11	-11	-11	-11	-11	-11	-10.9	-10.9	-10.9
Phthalate, butyl-benzyl-	Water	mg	-2.33	-2.33	-2.33	-2.33	-2.33	-2.33	-2.33	-2.33	-2.33
Phthalate, dibutyl-	Water	mg	-157	-157	-157	-157	-157	-157	-157	-157	-157
Phthalate, dimethyl-	Water	g	-1.02	-1.02	-1.02	-1.02	-1.02	-1.02	-1.02	-1.02	-1.02
Phthalate, dioctyl-	Water	g	-2.1	-2.1	-2.1	-2.1	-2.1	-2.1	-2.1	-2.1	-2.1
Phthalate, p-dibutyl-	Water	µg	51.4	51.4	51.4	51.4	51.4	51.4	51.4	51.4	51.4
Phthalate, p-dimethyl-	Water	µg	324	324	324	324	324	324	324	324	324
Plutonium-241	Water	kBq	-389	-389	-389	-389	-389	-389	-389	-389	-389
Plutonium-alpha	Water	Bq	-15600	-15600	-15600	-15600	-15600	-15600	-15600	-15600	-15600
Polonium-210	Water	kBq	-30400	-30100	-27400	-30400	-30100	-27400	-30100	-29800	-27100
Potassium	Water	tn.lg	739	739	9200	739	739	9200	739	739	9200
Potassium-40	Water	kBq	-11600	-11500	-8090	-11600	-11500	-8080	-11400	-11300	-7950
Potassium, ion	Water	tn.lg	689	690	688	689	690	688	690	691	689
Propene	Water	oz	128	310	-405	257	438	-276	136	317	-398
Propylene oxide	Water	oz	151	310	454	151	310	454	155	314	458
Protactinium-234	Water	kBq	-9260	-9140	-5390	-9250	-9130	-5380	-9070	-8950	-5200
Radioactive species, unspecified	Water	kBq	1.41E+09	2.57E+09	3.5E+09	1.41E+09	2.57E+09	3.5E+09	1.41E+09	2.57E+09	3.5E+09
Radioactive species, alpha emitters	Water	Bq	-44700	-44300	-44000	-44700	-44300	-44000	-44300	-43800	-43600
Radioactive species, from fission and activation	Water	Bq	232	232	232	232	232	232	232	232	232
Radioactive species, Nuclides, unspecified	Water	kBq	-3580000	-3540000	-2090000	-3580000	-3540000	-2080000	-3510000	-3470000	-2020000
Radium-224	Water	kBq	-3150	10200	52900	-3140	10200	52900	4810	18200	60800
Radium-226	Water	kBq	-5850000	-5750000	-3350000	-5840000	-5750000	-3340000	-5720000	-5620000	-3220000
Radium-228	Water	kBq	-6290	20400	106000	-6290	20400	106000	9610	36300	122000
Rubidium	Water	oz	-20.8	73.6	380	-20.7	73.6	380	35.6	130	436
Ruthenium	Water	g	30.3	30.3	30.3	30.3	30.3	30.3	30.3	30.3	30.3
Ruthenium-103	Water	Bq	-540	-486	-210	-539	-486	-210	-474	-420	-144
Ruthenium-106	Water	kBq	-945	-945	-945	-945	-945	-945	-945	-945	-945
Salts, unspecified	Water	kg	-169	-169	-169	-169	-169	-169	-116	-116	-116
Scandium	Water	lb	-77	-76.6	-57.6	-76.9	-76.5	-57.5	-76.2	-75.9	-56.9
Selenium	Water	kg	183	183	160	183	183	160	183	184	161
Silicon	Water	tn.lg	647	664	906	648	665	907	688	706	948
Silver	Water	kg	62.1	62.1	62.1	62.1	62.1	62.1	62.1	62.1	62.1
Silver-110	Water	kBq	-5260	-5040	-2750	-5250	-5030	-2740	-4970	-4750	-2460
Silver, ion	Water	tn.lg	1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.12
Sodium-24	Water	kBq	-20.1	-18.2	-8.31	-20.1	-18.2	-8.29	-17.8	-15.8	-5.94
Sodium formate	Water	g	-247	-246	-257	-247	-246	-257	-247	-246	-256
Sodium, ion	Water	kton	1.4	1.5	1.74	1.4	1.5	1.74	1.51	1.61	1.86
Solids, inorganic	Water	kg	-320000	-318000	-261000	-319000	-318000	-260000	-317000	-316000	-258000
Solved organics	Water	kg	-19.5	-19.5	-19.5	-19.4	-19.4	-19.4	-19.4	-19.4	-19.4

Substance	Compartment	Unit	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7	Scenario 8	Scenario 9
Solved solids	Water	tn.sh	-19600	-19600	-20700	-19600	-19600	-20700	-19600	-19600	-20600
Solved substances	Water	kg	-1850	-1850	-1850	-1850	-1850	-1850	-1830	-1830	-1830
Solved substances, inorganic	Water	kg	190000	126000	47100	190000	126000	47100	190000	126000	47100
Strontium	Water	kg	-144	1480	5750	-142	1480	5750	837	2460	6730
Strontium-89	Water	kBq	-90.6	-86	-49.3	-90.5	-85.9	-49.3	-84.8	-80.2	-43.6
Strontium-90	Water	kBq	-5630000	-5580000	-3160000	-5630000	-5580000	-3150000	-5540000	-5490000	-3070000
Styrene	Water	mg	-570	-570	-570	-570	-570	-570	-570	-570	-570
Sulfate	Water	kton	-1.64	-1.61	-1.36	-1.64	-1.61	-1.36	-1.62	-1.6	-1.35
Sulfide	Water	oz	-45.5	-74.8	-20	-14.3	-43.6	11.2	-13.8	-43.2	11.7
Sulfite	Water	lb	-644	-639	-387	-643	-638	-386	-635	-630	-379
Sulfur	Water	kg	-26.8	7.52	119	-26.7	7.58	119	1.6	35.9	147
Sulfur dioxide	Water	tn.lg	225	225	225	225	225	225	225	225	225
Sulfur trioxide	Water	oz	-62.8	-62.8	-62.8	-62.7	-62.7	-62.7	-62.4	-62.4	-62.4
Suspended solids, unspecified	Water	kg	26400	29400	-3590	26800	29800	-3180	29300	32300	-694
Suspended substances, unspecified	Water	tn.lg	25.8	24.7	21.2	25.8	24.7	21.2	25.8	24.7	21.2
t-Butyl methyl ether	Water	oz	56.2	70	65	56.2	70	65	83.3	97.1	92.2
Technetium-99	Water	kBq	-100	-100	-100	-100	-100	-100	-100	-100	-100
Technetium-99m	Water	kBq	-57.9	-52.1	-21.7	-57.9	-52	-21.7	-50.7	-44.9	-14.5
Tellurium-123m	Water	Bq	-104000	-103000	-62600	-104000	-102000	-62500	-102000	-101000	-60600
Tellurium-132	Water	Bq	-145	-130	-54.6	-145	-130	-54.5	-127	-112	-36.5
Thallium	Water	oz	662	663	30.9	663	663	31	664	664	32
Thorium-228	Water	kBq	-12800	40700	211000	-12800	40700	211000	19000	72500	243000
Thorium-230	Water	kBq	-1260000	-1250000	-735000	-1260000	-1250000	-734000	-1240000	-1220000	-709000
Thorium-232	Water	kBq	-1830	-1810	-1180	-1820	-1810	-1180	-1800	-1790	-1160
Thorium-234	Water	kBq	-9260	-9140	-5390	-9250	-9130	-5380	-9070	-8950	-5200
Tin, ion	Water	tn.lg	12.6	12.6	12.4	12.6	12.6	12.4	12.6	12.6	12.4
Titanium, ion	Water	kg	-34000	-33700	-41100	-34000	-33700	-41100	-33800	-33500	-40800
TOC, Total Organic Carbon	Water	tn.lg	1660	1670	632	1660	1670	633	1670	1690	646
Toluene	Water	kg	8.03	40.2	139	8.03	40.2	139	28.2	60.3	159
Tributyltin	Water	g	-94.2	-94.2	-94.2	-94.1	-94.1	-94.1	-93.4	-93.4	-93.4
Tributyltin compounds	Water	oz	-569	-560	-468	-569	-559	-468	-563	-553	-462
Triethylene glycol	Water	kg	-6.38	-6.29	-5.21	-6.36	-6.27	-5.19	-6.26	-6.16	-5.08
Tungsten	Water	lb	-63.5	-63.1	-41.4	-63.4	-63	-41.3	-62.7	-62.3	-40.6
Undissolved substances	Water	kg	163	163	163	163	163	163	163	163	163
Uranium-234	Water	kBq	-11100	-11000	-6470	-11100	-11000	-6450	-10900	-10700	-6240
Uranium-235	Water	kBq	-18300	-18100	-10700	-18300	-18100	-10600	-18000	-17700	-10300
Uranium-238	Water	kBq	-39400	-38900	-26200	-39400	-38900	-26200	-38700	-38200	-25500
Uranium alpha	Water	kBq	-534000	-527000	-310000	-533000	-526000	-310000	-523000	-516000	-300000
Vanadium, ion	Water	kg	269	296	-261	270	296	-260	294	320	-237
VOC, volatile organic compounds as C	Water	oz	37.4	37.4	37.4	37.4	37.4	37.4	37.4	37.4	37.4
VOC, volatile organic compounds, unspecified origin	Water	kg	-46.2	47.5	356	-46.2	47.6	356	9.91	104	412
Waste water/m3	Water	m3	2520000	2520000	2520000	2520000	2520000	2520000	2520000	2520000	2520000
Xylene	Water	kg	32.8	59.5	144	32.8	59.5	144	49.1	75.8	161
Yttrium-90	Water	Bq	-4.72	-4.72	-4.72	-4.72	-4.72	-4.72	-4.72	-4.72	-4.72
Zinc-65	Water	kBq	-258	-232	-97.6	-258	-231	-97.3	-226	-200	-65.5
Zinc, ion	Water	kton	2.41	2.41	2.41	2.41	2.41	2.41	2.41	2.41	2.41
Zirconium-95	Water	Bq	-11000	-10700	-9170	-11000	-10700	-9170	-10700	-10400	-8800
Dust, unspecified	Waste	g	24.7	24.7	24.7	14.6	14.6	14.6	26.7	26.7	26.7
Mineral waste	Waste	kg	-766	-766	-766	-766	-766	-766	-766	-766	-766
Oil waste	Waste	tn.lg	-7.44	-7.44	-7.44	-7.44	-7.44	-7.44	-7.44	-7.44	-7.44
Production waste, not inert	Waste	tn.lg	-51.1	-51.1	-51.1	-50	-50	-50	-43.5	-43.5	-43.5
Slags	Waste	kg	-270	-270	-270	-270	-270	-270	-270	-270	-270
Waste, final, inert	Waste	kton	-1.04	-1.04	-1.04	-1.04	-1.04	-1.04	-1.03	-1.03	-1.03
Waste, inorganic	Waste	g	148	148	148	25.8	25.8	25.8	72.8	72.8	72.8
Waste, nuclear, high active/m3	Waste	cu.in	-173	-173	-173	-173	-173	-173	-162	-162	-162
Waste, nuclear, low and medium active/m3	Waste	l	-669	-669	-669	-669	-669	-669	-657	-657	-657
Zinc waste	Waste	kg	183	183	183	212	212	212	345	345	345
Aclonifen	Soil	g	-2.14	6.06	12.6	-2.08	6.12	12.7	5.51	13.7	20.3

Substance	Compartment	Unit	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7	Scenario 8	Scenario 9
Aluminum	Soil	kg	-129	-24.3	484	-129	-24	484	-54.2	50.3	558
Antimony	Soil	mg	-161	-160	-162	-161	-160	-162	-160	-160	-162
Arsenic	Soil	g	-52.5	-10.8	149	-52.4	-10.7	149	-22.8	18.9	179
Atrazine	Soil	g	-17.1	-17	-16.7	-17.1	-17	-16.7	-16.9	-16.8	-16.5
Barium	Soil	kg	-48.5	3.41	172	-48.4	3.52	172	-11.7	40.2	209
Bentazone	Soil	g	-1.09	3.08	6.42	-1.06	3.12	6.45	2.8	6.98	10.3
Boron	Soil	oz	-323	-282	-48.1	-323	-281	-47.7	-285	-243	-9.92
Cadmium	Soil	g	157	289	411	157	289	411	215	348	470
Calcium	Soil	kg	-892	-471	1600	-891	-469	1600	-588	-167	1900
Carbetamide	Soil	g	1.33	2.82	4.26	1.36	2.85	4.28	2.79	4.28	5.72
Carbon	Soil	kg	-190	128	3010	-189	129	3010	37.7	355	3240
Chloride	Soil	kg	75600	97900	119000	75500	97800	119000	119000	141000	162000
Chlorothalonil	Soil	oz	63.6	64.2	73.2	64	64.7	73.7	66.7	67.3	76.3
Chromium	Soil	oz	72.1	139	223	72.2	140	223	104	172	255
Chromium VI	Soil	lb	-102	-100	-59.8	-102	-100	-59.7	-97.6	-95.9	-55.5
Cobalt	Soil	g	-24.7	-24.1	72.5	-24.6	-24.1	72.6	-23.9	-23.4	73.3
Copper	Soil	oz	-830	-727	-241	-828	-726	-239	-755	-652	-166
Cypermethrin	Soil	mg	79.1	112	150	80	113	151	113	146	184
Dinoseb	Soil	g	490	495	564	493	499	568	514	519	588
Fenpiclonil	Soil	g	70.9	71.9	82.1	71.4	72.4	82.6	74.5	75.5	85.8
Fluoride	Soil	lb	-79.7	-67.1	-2.58	-79.6	-67	-2.47	-68.7	-56.1	8.45
Glyphosate	Soil	oz	-170	-149	-127	-170	-149	-127	-133	-112	-90.2
Heat, waste	Soil	MWh	2400	2430	-397	2400	2430	-395	2500	2530	-296
Iron	Soil	kg	-12600	-12300	-9870	-12600	-12300	-9870	-12400	-12000	-9660
Lead	Soil	oz	39.9	64.8	105	39.9	64.8	105	50.3	75.2	116
Linuron	Soil	g	-16.6	46.9	97.6	-16.1	47.3	98.1	42.6	106	157
Magnesium	Soil	kg	-130	-46.6	304	-130	-46.3	304	-70.3	13.4	364
Mancozeb	Soil	oz	82.8	83.6	95.3	83.4	84.2	95.9	86.8	87.6	99.3
Manganese	Soil	lb	-89.5	-79.6	-15.1	-89.3	-79.4	-15	-81.7	-71.7	-7.31
Mercury	Soil	g	1.62	1.72	16.7	1.63	1.73	16.7	1.74	1.84	16.8
Metaldehyde	Soil	g	0.685	0.969	1.3	0.693	0.977	1.31	0.981	1.26	1.6
Metolachlor	Soil	oz	-4.76	11.4	24.4	-4.64	11.5	24.5	10.3	26.5	39.5
Metribuzin	Soil	g	82.5	83.3	95	83.1	83.9	95.6	86.5	87.3	99
Molybdenum	Soil	g	-1.67	-1.48	51.3	-1.65	-1.47	51.3	-1.42	-1.23	51.5
Napropamide	Soil	g	1.21	1.72	2.31	1.23	1.73	2.32	1.74	2.24	2.83
Nickel	Soil	oz	77.3	119	135	77.4	119	135	93.9	136	152
Nitrogen	Soil	g	-52.1	-52.1	-52.1	-52.1	-52.1	-52.1	-52.1	-52.1	-52.1
Oils, biogenic	Soil	kg	-142	-141	-154	-142	-140	-153	-141	-139	-152
Oils, unspecified	Soil	tn.sh	-11.2	3.1	49.6	-11.2	3.11	49.6	1.06	15.3	61.8
Orbencarb	Soil	g	445	450	513	448	453	516	467	471	534
Phosphorus	Soil	oz	-828	-640	178	-827	-638	180	-689	-500	318
Phosphorus, total	Soil	g	129	129	129	129	129	129	129	129	129
Pirimicarb	Soil	mg	-103	292	609	-100	295	612	266	662	978
Potassium	Soil	kg	-134	-96.4	56.8	-133	-96.2	57	-106	-69.1	84.2
Silicon	Soil	kg	-129	-117	285	-129	-116	285	-118	-106	296
Silver	Soil	g	30.2	34.9	11.3	30.2	34.9	11.3	30.3	35.1	11.5
Sodium	Soil	kg	17.7	258	962	18.3	259	963	278	518	1220
Strontium	Soil	oz	-34.4	2.64	123	-34.3	2.72	123	-8.2	28.8	149
Sulfur	Soil	kg	-64.2	-1.39	371	-64	-1.22	371	-19.4	43.5	416
Tebutam	Soil	g	2.87	4.07	5.46	2.91	4.1	5.5	4.11	5.31	6.7
Teflubenzuron	Soil	g	5.49	5.55	6.33	5.53	5.59	6.37	5.76	5.81	6.59
Tin	Soil	g	21.1	21.6	233	21.1	21.6	233	21.6	22.1	233
Titanium	Soil	oz	-89.1	-88.3	-56.8	-88.9	-88.1	-56.6	-87.6	-86.8	-55.3
Vanadium	Soil	g	-72.3	-71.6	-46.1	-72.2	-71.5	-45.9	-71.1	-70.5	-44.9
Zinc	Soil	kg	115	220	330	115	220	330	162	268	378
Zinc phosphide	Soil	g	38.7	38.7	38.7	38.7	38.7	38.7	38.7	38.7	38.7

Table 1.2 Inventory: Implementation Scenario 10

Substance	Compartment	Unit	Scenario 10
Additives	Raw Material	tn.lg	2.41
Aluminium, 24% in bauxite, 11% in crude ore, in ground	Raw Material	tn.lg	2.33
Anhydrite, in ground	Raw Material	g	56.2
Barite, 15% in crude ore, in ground	Raw Material	tn.lg	2.16
Barium, in ground	Raw Material	kg	362
Baryte, in ground	Raw Material	kg	12.2
Basalt, in ground	Raw Material	tn.lg	1.15
Bauxite, in ground	Raw Material	kg	95.6
Borax, in ground	Raw Material	g	37.5
Calcite, in ground	Raw Material	kton	9.75
Calcium sulfate, in ground	Raw Material	tn.lg	1.01
Carbon dioxide, in air	Raw Material	tn.lg	38.6
Chromium ore, in ground	Raw Material	g	59.7
Chromium, 25.5 in chromite, 11.6% in crude ore, in ground	Raw Material	tn.lg	1.08
Chromium, in ground	Raw Material	g	82.7
Chrysotile, in ground	Raw Material	g	468
Cinnabar, in ground	Raw Material	g	43
Clay, bentonite, in ground	Raw Material	tn.lg	9.94
Clay, unspecified, in ground	Raw Material	kton	54.8
Coal, 18 MJ per kg, in ground	Raw Material	tn.lg	47.8
Coal, 29.3 MJ per kg, in ground	Raw Material	tn.lg	-236
Coal, brown, 10 MJ per kg, in ground	Raw Material	tn.lg	1.98
Coal, brown, 8 MJ per kg, in ground	Raw Material	tn.lg	1.12
Coal, brown, in ground	Raw Material	tn.lg	89.9
Coal, hard, unspecified, in ground	Raw Material	tn.lg	550
Cobalt, in ground	Raw Material	g	6.48
Colemanite, in ground	Raw Material	g	480
Copper, 0.99% in sulfide, Cu 0.36% and Mo 8.2E-3% in crude ore, in ground	Raw Material	kg	16.8
Copper, 1.18% in sulfide, Cu 0.39% and Mo 8.2E-3% in crude ore, in ground	Raw Material	kg	92.9
Copper, 1.42% in sulfide, Cu 0.81% and Mo 8.2E-3% in crude ore, in ground	Raw Material	kg	24.6
Copper, 2.19% in sulfide, Cu 1.83% and Mo 8.2E-3% in crude ore, in ground	Raw Material	kg	122
Copper, in ground	Raw Material	kg	1.23
Diatomite, in ground	Raw Material	mg	224
Dolomite, in ground	Raw Material	kg	225
Energy, gross calorific value, in biomass	Raw Material	MWh	122
Energy, kinetic, flow, in wind	Raw Material	MWh	19.1
Energy, potential, stock, in barrage water	Raw Material	TJ	2.74
Energy, solar	Raw Material	GJ	2.93
Feldspar, in ground	Raw Material	mg	170
Fluorine, 4.5% in apatite, 1% in crude ore, in ground	Raw Material	kg	2.53
Fluorine, 4.5% in apatite, 3% in crude ore, in ground	Raw Material	kg	1.13
Fluorspar, 92%, in ground	Raw Material	kg	74.4
Gas, mine, off-gas, process, coal mining/kg	Raw Material	kg	3.43
Gas, mine, off-gas, process, coal mining/m3	Raw Material	m3	8120
Gas, natural, 30.3 MJ per kg, in ground	Raw Material	tn.lg	415
Gas, natural, 35 MJ per m3, in ground	Raw Material	m3	20000
Gas, natural, in ground	Raw Material	m3	121000
Gas, petroleum, 35 MJ per m3, in ground	Raw Material	m3	190
Granite, in ground	Raw Material	kg	7.05
Gravel, in ground	Raw Material	kton	10.1
Gypsum, in ground	Raw Material	g	464
Iron, 46% in ore, 25% in crude ore, in ground	Raw Material	tn.lg	91.8
Iron, in ground	Raw Material	tn.lg	14.3
Kaolinite, 24% in crude ore, in ground	Raw Material	kg	14.2
Kieserite, 25% in crude ore, in ground	Raw Material	g	94.8

Substance	Compartment	Unit	Scenario 10
Land use II-III	Raw Material	m2a	158
Land use II-III, sea floor	Raw Material	m2a	193
Land use II-IV	Raw Material	m2a	11.4
Land use II-IV, sea floor	Raw Material	m2a	20
Land use III-IV	Raw Material	m2a	16.6
Land use IV-IV	Raw Material	m2a	6.63
Lead, 5%, in sulfide, Pb 2.97% and Zn 5.34% in crude ore, in ground	Raw Material	tn.lg	1.8
Lead, in ground	Raw Material	g	261
Limestone, in ground	Raw Material	tn.lg	32.8
Magnesite, 60% in crude ore, in ground	Raw Material	tn.lg	4.22
Magnesium, 0.13% in water	Raw Material	g	6.76
Manganese ore, in ground	Raw Material	g	34.8
Manganese, 35.7% in sedimentary deposit, 14.2% in crude ore, in ground	Raw Material	tn.lg	1.18
Manganese, in ground	Raw Material	g	20.2
Marl, in ground	Raw Material	kg	30.1
Molybdenum, 0.010% in sulfide, Mo 8.2E-3% and Cu 1.83% in crude ore, in ground	Raw Material	kg	2.27
Molybdenum, 0.014% in sulfide, Mo 8.2E-3% and Cu 0.81% in crude ore, in ground	Raw Material	g	323
Molybdenum, 0.022% in sulfide, Mo 8.2E-3% and Cu 0.36% in crude ore, in ground	Raw Material	kg	421
Molybdenum, 0.025% in sulfide, Mo 8.2E-3% and Cu 0.39% in crude ore, in ground	Raw Material	kg	1.19
Molybdenum, 0.11% in sulfide, Mo 4.1E-2% and Cu 0.36% in crude ore, in ground	Raw Material	kg	850
Molybdenum, in ground	Raw Material	µg	369
Nickel, 1.13% in sulfide, Ni 0.76% and Cu 0.76% in crude ore, in ground	Raw Material	kg	2.92
Nickel, 1.98% in silicates, 1.04% in crude ore, in ground	Raw Material	tn.lg	4.76
Nickel, in ground	Raw Material	g	74.1
Occupation, arable, non-irrigated	Raw Material	m2a	120
Occupation, construction site	Raw Material	m2a	13900
Occupation, dump site	Raw Material	m2a	89100
Occupation, dump site, benthos	Raw Material	m2a	114
Occupation, forest, intensive	Raw Material	m2a	24000
Occupation, forest, intensive, normal	Raw Material	m2a	76100
Occupation, industrial area	Raw Material	m2a	2300
Occupation, industrial area, benthos	Raw Material	m2a	1.26
Occupation, industrial area, built up	Raw Material	m2a	1480
Occupation, industrial area, vegetation	Raw Material	m2a	2550
Occupation, mineral extraction site	Raw Material	m2a	29700
Occupation, permanent crop, fruit, intensive	Raw Material	m2a	29.7
Occupation, shrub land, sclerophyllous	Raw Material	m2a	13800
Occupation, traffic area, rail embankment	Raw Material	m2a	661
Occupation, traffic area, rail network	Raw Material	m2a	731
Occupation, traffic area, road embankment	Raw Material	m2a	1570
Occupation, traffic area, road network	Raw Material	m2a	128000
Occupation, urban, discontinuously built	Raw Material	m2a	0.235
Occupation, water bodies, artificial	Raw Material	m2a	7250
Occupation, water courses, artificial	Raw Material	m2a	2230
Oil, crude, 41 MJ per kg, in ground	Raw Material	tn.lg	960
Oil, crude, 42.6 MJ per kg, in ground	Raw Material	tn.lg	3.78
Oil, crude, in ground	Raw Material	tn.lg	748
Olivine, in ground	Raw Material	g	23.8
Palladium, in ground	Raw Material	µg	432
Pd, Pd 2.0E-4%, Pt 4.8E-4%, Rh 2.4E-5%, Ni 3.7E-2%, Cu 5.2E-2% in ore, in ground	Raw Material	mg	413
Pd, Pd 7.3E-4%, Pt 2.5E-4%, Rh 2.0E-5%, Ni 2.3E+0%, Cu 3.2E+0% in ore, in ground	Raw Material	mg	992
Peat, in ground	Raw Material	kg	23
Phosphorus, 18% in apatite, 12% in crude ore, in ground	Raw Material	kg	4.75

Substance	Compartment	Unit	Scenario 10
Phosphorus, 18% in apatite, 4% in crude ore, in ground	Raw Material	kg	10.1
Phosphorus, in ground	Raw Material	kton	2.93
Platinum, in ground	Raw Material	µg	492
Pt, Pt 2.5E-4%, Pd 7.3E-4%, Rh 2.0E-5%, Ni 2.3E+0%, Cu 3.2E+0% in ore, in ground	Raw Material	mg	13.6
Pt, Pt 4.8E-4%, Pd 2.0E-4%, Rh 2.4E-5%, Ni 3.7E-2%, Cu 5.2E-2% in ore, in ground	Raw Material	mg	48.6
Pyrite, in ground	Raw Material	kg	498
Rh, Rh 2.0E-5%, Pt 2.5E-4%, Pd 7.3E-4%, Ni 2.3E+0%, Cu 3.2E+0% in ore, in ground	Raw Material	mg	9.41
Rh, Rh 2.4E-5%, Pt 4.8E-4%, Pd 2.0E-4%, Ni 3.7E-2%, Cu 5.2E-2% in ore, in ground	Raw Material	mg	29.5
Rhenium, in crude ore, in ground	Raw Material	mg	19.8
Rhenium, in ground	Raw Material	µg	449
Rhodium, in ground	Raw Material	µg	460
Rutile, in ground	Raw Material	mg	26.7
Sand, unspecified, in ground	Raw Material	kton	68.6
Shale, in ground	Raw Material	g	159
Silver, 0.01% in crude ore, in ground	Raw Material	g	1.36
Silver, in ground	Raw Material	g	10.2
Sodium chloride, in ground	Raw Material	tn.lg	27.3
Sodium sulphate, various forms, in ground	Raw Material	kg	17.5
Steel scrap	Raw Material	tn.lg	2.23
Stibnite, in ground	Raw Material	mg	23.3
Sulfur, in ground	Raw Material	tn.lg	286
Sylvite, 25 % in sylvinite, in ground	Raw Material	kg	10.7
Talc, in ground	Raw Material	kg	11
Tin, 79% in cassiterite, 0.1% in crude ore, in ground	Raw Material	kg	2.34
Tin, in ground	Raw Material	g	4.82
TiO2, 45-60% in Ilmenite, in ground	Raw Material	kg	66.9
Transformation, from arable	Raw Material	dm2	91.4
Transformation, from arable, non-irrigated	Raw Material	m2	221
Transformation, from arable, non-irrigated, fallow	Raw Material	sq.in	226
Transformation, from dump site, inert material landfill	Raw Material	m2	4.91
Transformation, from dump site, residual material landfill	Raw Material	m2	2750
Transformation, from dump site, sanitary landfill	Raw Material	cm2	470
Transformation, from dump site, slag compartment	Raw Material	cm2	424
Transformation, from forest	Raw Material	m2	626
Transformation, from forest, extensive	Raw Material	m2	751
Transformation, from industrial area	Raw Material	m2	1.83
Transformation, from industrial area, benthos	Raw Material	cm2	15
Transformation, from industrial area, built up	Raw Material	cm2	36.1
Transformation, from industrial area, vegetation	Raw Material	cm2	61.6
Transformation, from mineral extraction site	Raw Material	m2	923
Transformation, from pasture and meadow	Raw Material	acre	1.09
Transformation, from pasture and meadow, intensive	Raw Material	sq.in	276
Transformation, from sea and ocean	Raw Material	m2	114
Transformation, from shrub land, sclerophyllous	Raw Material	m2	2770
Transformation, from unknown	Raw Material	m2	3680
Transformation, to arable	Raw Material	m2	47.9
Transformation, to arable, non-irrigated	Raw Material	m2	221
Transformation, to arable, non-irrigated, fallow	Raw Material	m2	12.5
Transformation, to dump site	Raw Material	m2	52.7
Transformation, to dump site, benthos	Raw Material	m2	114
Transformation, to dump site, inert material landfill	Raw Material	m2	4.91
Transformation, to dump site, residual material landfill	Raw Material	m2	2750
Transformation, to dump site, sanitary landfill	Raw Material	cm2	470
Transformation, to dump site, slag compartment	Raw Material	cm2	424
Transformation, to forest	Raw Material	m2	3620
Transformation, to forest, intensive	Raw Material	m2	160
Transformation, to forest, intensive, normal	Raw Material	m2	582
Transformation, to heterogeneous, agricultural	Raw Material	m2	32.9

Substance	Compartment	Unit	Scenario 10
Transformation, to industrial area	Raw Material	m2	36.3
Transformation, to industrial area, benthos	Raw Material	sq.in	278
Transformation, to industrial area, built up	Raw Material	m2	30.4
Transformation, to industrial area, vegetation	Raw Material	m2	51.7
Transformation, to mineral extraction site	Raw Material	m2	3440
Transformation, to pasture and meadow	Raw Material	sq.in	404
Transformation, to permanent crop, fruit, intensive	Raw Material	sq.in	777
Transformation, to sea and ocean	Raw Material	cm2	15
Transformation, to shrub land, sclerophyllous	Raw Material	m2	2760
Transformation, to traffic area, rail embankment	Raw Material	m2	1.54
Transformation, to traffic area, rail network	Raw Material	m2	1.69
Transformation, to traffic area, road embankment	Raw Material	m2	9.44
Transformation, to traffic area, road network	Raw Material	m2	1700
Transformation, to unknown	Raw Material	m2	59.1
Transformation, to urban, discontinuously built	Raw Material	cm2	46.8
Transformation, to water bodies, artificial	Raw Material	m2	611
Transformation, to water courses, artificial	Raw Material	m2	25.6
Ulexite, in ground	Raw Material	g	33.5
Uranium, 451 GJ per kg, in ground	Raw Material	kg	14.5
Uranium, 560 GJ per kg, in ground	Raw Material	g	41.3
Uranium, in ground	Raw Material	kg	12.7
Vermiculite, in ground	Raw Material	g	558
Volume occupied, final repository for low-active radioactive waste	Raw Material	l	26
Volume occupied, final repository for radioactive waste	Raw Material	cu.in	362
Volume occupied, reservoir	Raw Material	m3y	34700
Volume occupied, underground deposit	Raw Material	l	83.8
Water, cooling, surface	Raw Material	Mtn	8.24
Water, cooling, unspecified natural origin/m3	Raw Material	m3	14800
Water, lake	Raw Material	m3	585
Water, process, unspecified natural origin/kg	Raw Material	kton	15.6
Water, river	Raw Material	m3	62000
Water, salt, ocean	Raw Material	m3	654
Water, salt, sole	Raw Material	m3	419
Water, turbine use, unspecified natural origin	Raw Material	m3	17500000
Water, unspecified natural origin/kg	Raw Material	tn.lg	98.9
Water, unspecified natural origin/m3	Raw Material	m3	59600
Water, well, in ground	Raw Material	m3	185000
Wood, dry matter	Raw Material	kg	9.36
Wood, hard, standing	Raw Material	m3	7.31
Wood, soft, standing	Raw Material	m3	37.4
Wood, unspecified, standing/kg	Raw Material	kg	-989
Wood, unspecified, standing/m3	Raw Material	cm3	526
Zinc 9%, in sulfide, Zn 5.34% and Pb 2.97% in crude ore, in ground	Raw Material	kg	183
Zinc, in ground	Raw Material	g	6.17
Acenaphthene	Air	µg	530
Acetaldehyde	Air	kg	476
Acetic acid	Air	kg	2.5
Acetone	Air	g	246
Acrolein	Air	g	3.84
Actinides, radioactive, unspecified	Air	mBq	204
Aerosols, radioactive, unspecified	Air	kBq	3.59
Alcohols, unspecified	Air	kg	765
Aldehydes, unspecified	Air	g	423
Aluminum	Air	kg	131
Americium-241	Air	mBq	318
Ammonia	Air	kg	773
Ammonium carbonate	Air	mg	343
Antimony	Air	kg	3.08
Antimony-124	Air	mBq	285

Substance	Compartment	Unit	Scenario 10
Antimony-125	Air	Bq	2.92
Argon-41	Air	kBq	1780
Arsenic	Air	kg	5.31
Barium	Air	g	-605
Barium-140	Air	Bq	190
Benzaldehyde	Air	g	1.97
Benzene	Air	kg	73.4
Benzene, ethyl-	Air	kg	2.23
Benzene, hexachloro-	Air	mg	879
Benzene, pentachloro-	Air	mg	42.5
Benzo(a)pyrene	Air	g	5.92
Beryllium	Air	g	12
Boron	Air	kg	-2.62
Bromine	Air	g	-873
Butadiene	Air	µg	74.3
Butane	Air	kg	529
Butene	Air	kg	2.23
Cadmium	Air	tn.lg	4.64
Calcium	Air	kg	-5.3
Carbon-14	Air	kBq	23800
Carbon dioxide	Air	kton	19.6
Carbon dioxide, biogenic	Air	kton	12.9
Carbon dioxide, fossil	Air	kton	10.8
Carbon disulfide	Air	kg	23.9
Carbon monoxide	Air	tn.lg	19.7
Carbon monoxide, biogenic	Air	kg	49.4
Carbon monoxide, fossil	Air	tn.lg	20.8
Cerium-141	Air	Bq	46.1
Cerium-144	Air	Bq	3.38
Cesium-134	Air	Bq	14.3
Cesium-137	Air	Bq	62.5
Chlorine	Air	kg	12.5
Chloroform	Air	mg	392
Chromium	Air	kg	8.76
Chromium-51	Air	Bq	3.01
Chromium VI	Air	g	92.7
Cobalt	Air	tn.lg	3.3
Cobalt-57	Air	µBq	29.4
Cobalt-58	Air	Bq	4.6
Cobalt-60	Air	Bq	37.1
Copper	Air	kg	6.51
Cumene	Air	g	366
Curium-242	Air	µBq	1.68
Curium-244	Air	µBq	15.3
Curium alpha	Air	mBq	506
Cyanide	Air	g	69.1
Dinitrogen monoxide	Air	tn.lg	1.08
Dioxins, measured as 2,3,7,8-tetrachlorodibenzo-p-dioxin	Air	mg	38.9
Ethane	Air	tn.lg	1.21
Ethane, 1,1,1-trichloro-, HCFC-140	Air	kg	34.5
Ethane, 1,1,1,2-tetrafluoro-, HFC-134a	Air	g	571
Ethane, 1,1,2-trichloro-1,2,2-trifluoro-, CFC-113	Air	kg	0
Ethane, 1,2-dichloro-	Air	g	26.4
Ethane, 1,2-dichloro-1,1,2,2-tetrafluoro-, CFC-114	Air	g	6.51
Ethane, 2-chloro-1,1,1,2-tetrafluoro-, HCFC-124	Air	kg	0
Ethane, dichloro-	Air	kg	132
Ethane, hexafluoro-, HFC-116	Air	g	11.9
Ethanol	Air	g	376
Ethene	Air	tn.lg	1.15
Ethene, chloro-	Air	g	50.4
Ethene, tetrachloro-	Air	kg	62.8

Substance	Compartment	Unit	Scenario 10
Ethylene diamine	Air	mg	2.11
Ethylene oxide	Air	g	29.4
Ethyne	Air	kg	-2.72
Fluoride	Air	g	708
Fluorine	Air	g	137
Fluosilicic acid	Air	g	13.9
Formaldehyde	Air	kg	2.74
Heat, waste	Air	TJ	50.1
Helium	Air	kg	6.01
Heptane	Air	kg	22.3
Hexane	Air	kg	46.5
Hydrocarbons, aliphatic, alkanes, cyclic	Air	g	1.61
Hydrocarbons, aliphatic, alkanes, unspecified	Air	kg	563
Hydrocarbons, aliphatic, alkenes, unspecified	Air	kg	-2.82
Hydrocarbons, aliphatic, unsaturated	Air	g	921
Hydrocarbons, aromatic	Air	kg	802
Hydrocarbons, chlorinated	Air	g	30
Hydrocarbons, halogenated	Air	kg	275
Hydrocarbons, unspecified	Air	tn.lg	20.4
Hydrogen	Air	kg	227
Hydrogen-3, Tritium	Air	kBq	100000
Hydrogen chloride	Air	tn.lg	5.33
Hydrogen fluoride	Air	kg	13.1
Hydrogen sulfide	Air	kg	22.8
Iodine	Air	g	-171
Iodine-129	Air	kBq	18.8
Iodine-131	Air	kBq	654
Iodine-133	Air	Bq	233
Iodine-135	Air	Bq	8.47
Iron	Air	kg	-19.9
Iron-59	Air	µBq	665
Isocyanic acid	Air	g	98.7
Ketones, unspecified	Air	kg	91.8
Krypton-85	Air	kBq	1570000
Krypton-85m	Air	kBq	2820
Krypton-87	Air	kBq	670
Krypton-88	Air	kBq	926
Krypton-89	Air	kBq	347
Lanthanum	Air	g	-17.6
Lanthanum-140	Air	Bq	16.3
Lead	Air	tn.lg	4.82
Lead-210	Air	kBq	54.3
m-Xylene	Air	g	13.9
Magnesium	Air	kg	-18.3
Manganese	Air	tn.lg	54.8
Manganese-54	Air	Bq	1.53
Mercaptans, unspecified	Air	kg	176
Mercury	Air	kg	2.94
Metals, unspecified	Air	tn.lg	7.24
Methane	Air	tn.lg	664
Methane, biogenic	Air	kg	5.76
Methane, bromochlorodifluoro-, Halon 1211	Air	g	2.45
Methane, bromotrifluoro-, Halon 1301	Air	g	176
Methane, chlorodifluoro-, HCFC-22	Air	kg	26.2
Methane, chlorotrifluoro-, CFC-13	Air	mg	1.78
Methane, dichloro-, HCC-30	Air	mg	13.9
Methane, dichlorodifluoro-, CFC-12	Air	kg	29.5
Methane, dichlorofluoro-, HCFC-21	Air	mg	501
Methane, fossil	Air	tn.lg	8.21
Methane, monochloro-, R-40	Air	µg	11.2
Methane, tetrachloro-, CFC-10	Air	g	14.6

Substance	Compartment	Unit	Scenario 10
Methane, tetrafluoro-, FC-14	Air	g	107
Methane, trichlorofluoro-, CFC-11	Air	mg	13.1
Methane, trifluoro-, HFC-23	Air	µg	493
Methanol	Air	kg	1.29
Molybdenum	Air	g	13.4
Monoethanolamine	Air	g	22.9
Neptunium-237	Air	µBq	16.7
Nickel	Air	tn.lg	14
Niobium-95	Air	mBq	183
Nitrate	Air	g	8.3
Nitric oxide	Air	tn.lg	33.5
Nitrogen	Air	g	22.9
Nitrogen dioxide	Air	tn.lg	34.2
Nitrogen oxides	Air	tn.lg	129
NMVOC, non-methane volatile organic compounds, unspecified origin	Air	tn.lg	3.16
Noble gases, radioactive, unspecified	Air	kBq	1.8E+08
Organic substances, unspecified	Air	kg	2.05
Ozone	Air	kg	5.87
PAH, polycyclic aromatic hydrocarbons	Air	g	471
Paraffins	Air	mg	5.03
Particulates	Air	tn.lg	3.38
Particulates, < 10 um	Air	kg	11.9
Particulates, < 10 um (mobile)	Air	g	127
Particulates, < 10 um (stationary)	Air	kg	5.71
Particulates, < 2.5 um	Air	kg	937
Particulates, > 10 um	Air	tn.lg	2.43
Particulates, > 10 um (process)	Air	kg	1.13
Particulates, > 2.5 um, and < 10um	Air	tn.lg	1.05
Particulates, unspecified	Air	tn.lg	16.5
Pentane	Air	kg	131
Phenol	Air	g	354
Phenol, pentachloro-	Air	g	3.52
Phosphorus	Air	g	-436
Phosphorus pentoxide	Air	mg	-333
Phosphorus, total	Air	mg	532
Platinum	Air	µg	755
Plutonium-238	Air	mBq	2.59
Plutonium-241	Air	Bq	27.8
Plutonium-alpha	Air	Bq	1.02
Polonium-210	Air	kBq	91.7
Polychlorinated biphenyls	Air	g	1.55
Potassium	Air	kg	-3.4
Potassium-40	Air	kBq	9.39
Promethium-147	Air	Bq	8.59
Propanal	Air	g	1.97
Propane	Air	kg	452
Propene	Air	kg	1.77
Propionic acid	Air	g	26.6
Propylene oxide	Air	g	26.7
Protactinium-234	Air	kBq	3.09
Radioactive species, other beta emitters	Air	kBq	359
Radioactive species, unspecified	Air	kBq	1.27E+08
Radium-226	Air	kBq	113
Radium-228	Air	kBq	14
Radon-220	Air	kBq	2.4
Radon-222	Air	kBq	4.11E+08
Ruthenium-103	Air	mBq	39.6
Ruthenium-106	Air	Bq	101
Scandium	Air	g	-5.52
Selenium	Air	g	-36.1

Substance	Compartment	Unit	Scenario 10
Silicon	Air	kg	-78.5
Silicon tetrafluoride	Air	mg	76.5
Silver	Air	kg	19.3
Silver-110	Air	mBq	408
Sodium	Air	kg	-1.4
Sodium chlorate	Air	mg	987
Sodium dichromate	Air	g	1.79
Sodium formate	Air	g	5.62
Strontium	Air	kg	-1.02
Strontium-89	Air	mBq	30.4
Strontium-90	Air	Bq	16.7
Styrene	Air	mg	44.7
Sulfate	Air	kg	9.85
Sulfur dioxide	Air	tn.lg	5.55
Sulfur hexafluoride	Air	g	66.7
Sulfur oxides	Air	tn.lg	38.9
t-Butyl methyl ether	Air	g	4.13
Tar	Air	mg	399
Technetium-99	Air	µBq	707
Tellurium-123m	Air	mBq	76.4
Thallium	Air	kg	3.4
Thorium	Air	g	-10.6
Thorium-228	Air	kBq	2.34
Thorium-230	Air	kBq	11.7
Thorium-232	Air	kBq	2.75
Thorium-234	Air	kBq	3.09
Tin	Air	kg	6.11
Titanium	Air	kg	-1.84
Toluene	Air	kg	17.1
Uranium	Air	g	-10.3
Uranium-234	Air	kBq	36.2
Uranium-235	Air	kBq	1.75
Uranium-238	Air	kBq	43.2
Uranium alpha	Air	kBq	169
Vanadium	Air	kg	8.24
VOC, volatile organic compounds	Air	kg	216
water	Air	Mtn	8.32
Xenon-131m	Air	kBq	3450
Xenon-133	Air	kBq	126000
Xenon-133m	Air	kBq	165
Xenon-135	Air	kBq	50100
Xenon-135m	Air	kBq	31300
Xenon-137	Air	kBq	949
Xenon-138	Air	kBq	7160
Xylene	Air	kg	12.1
Zinc	Air	tn.lg	42.4
Zinc-65	Air	Bq	7.63
Zirconium	Air	g	-5.95
Zirconium-95	Air	Bq	7.38
Acenaphthene	Water	mg	234
Acenaphthylene	Water	mg	320
Acetic acid	Water	g	43
Acidity, unspecified	Water	tn.lg	5.93
Acids, unspecified	Water	mg	260
Actinides, radioactive, unspecified	Water	kBq	30.4
Aluminum	Water	tn.lg	610
Americium-241	Water	Bq	42
Ammonia	Water	tn.lg	635
Ammonia, as N	Water	g	124
Ammonium, ion	Water	kg	7.34
Antimony	Water	tn.lg	22

Substance	Compartment	Unit	Scenario 10
Antimony-122	Water	Bq	113
Antimony-124	Water	kBq	8.65
Antimony-125	Water	kBq	7.89
AOX, Adsorbable Organic Halogen as Cl	Water	g	174
Arsenic, ion	Water	kg	565
Barite	Water	kg	130
Barium	Water	kg	267
Barium-140	Water	Bq	495
Benzene	Water	kg	11.7
Benzene, chloro-	Water	ng	524
Benzene, ethyl-	Water	kg	2.5
Beryllium	Water	g	33.9
BOD5, Biological Oxygen Demand	Water	kton	3.8
Boron	Water	tn.lg	3.94
Bromate	Water	kg	2.46
Bromine	Water	tn.lg	19.2
Butene	Water	mg	79.2
Cadmium-109	Water	mBq	1.21
Cadmium, ion	Water	tn.lg	398
Calcium compounds, unspecified	Water	kg	115
Calcium, ion	Water	kton	1.05
Carbon-14	Water	kBq	2.12
Carbonate	Water	kg	2.09
Carboxylic acids, unspecified	Water	kg	150
Cerium-141	Water	Bq	198
Cerium-144	Water	kBq	1.02
Cesium	Water	g	49.7
Cesium-134	Water	kBq	5.79
Cesium-136	Water	Bq	35.1
Cesium-137	Water	kBq	3570
Chlorate	Water	kg	19
Chloride	Water	kton	3.47
Chlorinated solvents, unspecified	Water	kg	8.95
Chlorine	Water	g	379
Chloroform	Water	mg	80.1
Chromium	Water	kg	1.27
Chromium-51	Water	kBq	37.3
Chromium VI	Water	tn.lg	12.1
Chromium, ion	Water	kg	237
Cobalt	Water	tn.lg	283
Cobalt-57	Water	kBq	1.11
Cobalt-58	Water	kBq	168
Cobalt-60	Water	kBq	157
COD, Chemical Oxygen Demand	Water	kton	3.03
Copper, ion	Water	tn.lg	8.11
Cumene	Water	g	880
Curium alpha	Water	Bq	55.5
Cyanide	Water	kg	7.6
Dichromate	Water	g	6.62
DOC, Dissolved Organic Carbon	Water	kton	1.19
EDTA	Water	mg	583
Ethane, 1,1,1-trichloro-, HCFC-140	Water	µg	225
Ethane, 1,2-dichloro-	Water	g	2.09
Ethane, dichloro-	Water	mg	115
Ethane, hexachloro-	Water	µg	2.58
Ethene	Water	g	125
Ethene, chloro-	Water	g	1.11
Ethene, tetrachloro-	Water	µg	345
Ethene, trichloro-	Water	mg	21.9
Ethylene diamine	Water	mg	5.11
Ethylene oxide	Water	mg	33.7

Substance	Compartment	Unit	Scenario 10
Fatty acids as C	Water	kton	1.66
Fluoride	Water	tn.lg	29.5
Fluosilicic acid	Water	g	25.1
Formaldehyde	Water	g	46.3
Glutaraldehyde	Water	g	9.07
Heat, waste	Water	MWh	134
Hydrazine	Water	mg	269
Hydrocarbons, aliphatic, alkanes, unspecified	Water	kg	13.5
Hydrocarbons, aliphatic, alkenes, unspecified	Water	g	800
Hydrocarbons, aliphatic, unsaturated	Water	g	451
Hydrocarbons, aromatic	Water	kg	54.9
Hydrocarbons, chlorinated	Water	g	27.8
Hydrocarbons, unspecified	Water	kg	57.8
Hydrogen-3, Tritium	Water	kBq	8110000
Hydrogen peroxide	Water	g	3.26
Hydrogen sulfide	Water	g	532
Hydroxide	Water	g	15.2
Hypochlorite	Water	g	208
Hypochlorous acid	Water	g	9.6
Iodide	Water	kg	10.8
Iodine-129	Water	kBq	6.07
Iodine-131	Water	kBq	2.02
Iodine-133	Water	Bq	311
Iron	Water	tn.lg	50.7
Iron-59	Water	Bq	85.4
Iron, ion	Water	tn.lg	8.23
Kjeldahl-N	Water	g	8.06
Lanthanum-140	Water	Bq	527
Lead	Water	tn.lg	415
Lead-210	Water	kBq	47.6
Lithium carbonate	Water	mg	30.1
Magnesium	Water	tn.lg	375
Manganese	Water	kton	4.79
Manganese-54	Water	kBq	11.5
Mercury	Water	kg	262
Metallic ions, unspecified	Water	tn.lg	622
Methane, dichloro-, HCC-30	Water	g	328
Methane, tetrachloro-, CFC-10	Water	µg	465
Methanol	Water	g	42.6
Molybdenum	Water	kg	414
Molybdenum-99	Water	Bq	182
Morpholine	Water	g	2.85
Neptunium-237	Water	Bq	2.68
Nickel, ion	Water	kton	1.22
Niobium-95	Water	Bq	721
Nitrate	Water	tn.lg	3.89
Nitrilotriacetic acid	Water	kg	347
Nitrite	Water	kg	715
Nitrogen	Water	kg	5.12
Nitrogen, organic bound	Water	kg	11
Nitrogen, total	Water	kg	16.7
NMVOC, non-methane volatile organic compounds, unspecified origin	Water	kg	23.1
Oils, unspecified	Water	tn.lg	2.24
PAH, polycyclic aromatic hydrocarbons	Water	kg	1.19
Paraffins	Water	mg	14.6
Phenol	Water	kg	11.2
Phenols, unspecified	Water	g	29.8
Phosphate	Water	tn.lg	120
Phosphorus	Water	g	661
Phosphorus compounds, unspecified	Water	mg	69.4

Substance	Compartment	Unit	Scenario 10
Phosphorus pentoxide	Water	g	-9.88
Phthalate, dioctyl-	Water	µg	11.2
Phthalate, p-dibutyl-	Water	µg	30.9
Phthalate, p-dimethyl-	Water	µg	195
Plutonium-241	Water	kBq	4.15
Plutonium-alpha	Water	Bq	167
Polonium-210	Water	kBq	62.8
Potassium	Water	kton	1.16
Potassium-40	Water	kBq	26.8
Potassium, ion	Water	kton	1.09
Propene	Water	g	375
Propylene oxide	Water	g	64.2
Protactinium-234	Water	kBq	57.3
Radioactive species, unspecified	Water	kBq	1170000
Radioactive species, alpha emitters	Water	Bq	95.7
Radioactive species, from fission and activation	Water	Bq	126
Radioactive species, Nuclides, unspecified	Water	kBq	18200
Radium-224	Water	kBq	1890
Radium-226	Water	kBq	39300
Radium-228	Water	kBq	3770
Rubidium	Water	kg	1.04
Ruthenium	Water	g	1.38
Ruthenium-103	Water	Bq	38.4
Ruthenium-106	Water	kBq	10.1
Salts, unspecified	Water	kg	110
Scandium	Water	g	53.9
Selenium	Water	kg	341
Silicon	Water	kton	2.84
Silver	Water	kg	95.8
Silver-110	Water	kBq	145
Silver, ion	Water	tn.lg	1.72
Sodium-24	Water	kBq	1.38
Sodium formate	Water	g	13.5
Sodium, ion	Water	kton	2.82
Solids, inorganic	Water	kg	393
Solved organics	Water	kg	3.21
Solved solids	Water	kg	934
Solved substances	Water	g	343
Solved substances, inorganic	Water	kg	287
Strontium	Water	kg	630
Strontium-89	Water	kBq	3.12
Strontium-90	Water	kBq	18000
Sulfate	Water	kton	2.58
Sulfide	Water	kg	1.21
Sulfite	Water	g	534
Sulfur	Water	kg	3.58
Sulfur trioxide	Water	g	1.49
Suspended solids, unspecified	Water	kg	373
Suspended substances, unspecified	Water	tn.lg	14.4
t-Butyl methyl ether	Water	g	38.8
Technetium-99	Water	kBq	1.06
Technetium-99m	Water	kBq	4.18
Tellurium-123m	Water	Bq	557
Tellurium-132	Water	Bq	10.5
Thallium	Water	kg	1.55
Thorium-228	Water	kBq	7540
Thorium-230	Water	kBq	7820
Thorium-232	Water	kBq	4.35
Thorium-234	Water	kBq	57.3
Tin, ion	Water	tn.lg	18.9
Titanium, ion	Water	kg	20.4

Substance	Compartment	Unit	Scenario 10
TOC, Total Organic Carbon	Water	kton	1.2
Toluene	Water	kg	11.9
Tributyltin	Water	mg	134
Tributyltin compounds	Water	g	55.1
Triethylene glycol	Water	kg	3.19
Tungsten	Water	g	57.1
Undissolved substances	Water	kg	7.6
Uranium-234	Water	kBq	68.8
Uranium-235	Water	kBq	113
Uranium-238	Water	kBq	197
Uranium alpha	Water	kBq	3300
Vanadium, ion	Water	tn.lg	1.63
VOC, volatile organic compounds as C	Water	g	48.4
VOC, volatile organic compounds, unspecified origin	Water	kg	13.3
Waste water/m3	Water	m3	3890000
Xylene	Water	kg	66
Yttrium-90	Water	mBq	24.3
Zinc-65	Water	kBq	18.6
Zinc, ion	Water	kton	3.72
Zirconium-95	Water	Bq	302
Aclonifen	Soil	mg	312
Aluminum	Soil	kg	17.3
Antimony	Soil	µg	478
Arsenic	Soil	g	6.89
Atrazine	Soil	mg	11.9
Barium	Soil	kg	6.47
Bentazone	Soil	mg	159
Boron	Soil	g	174
Cadmium	Soil	g	2.7
Calcium	Soil	kg	70.8
Carbetamide	Soil	mg	68.4
Carbon	Soil	kg	53
Chloride	Soil	kg	533
Chlorothalonil	Soil	g	12.4
Chromium	Soil	g	115
Chromium VI	Soil	g	253
Cobalt	Soil	mg	203
Copper	Soil	g	211
Cypermethrin	Soil	mg	1.84
Dinoseb	Soil	g	3.36
Fenpiclonil	Soil	mg	497
Fluoride	Soil	g	818
Glyphosate	Soil	g	56.1
Heat, waste	Soil	MWh	8.36
Iron	Soil	kg	120
Lead	Soil	g	15.1
Linuron	Soil	g	2.41
Magnesium	Soil	kg	10.6
Mancozeb	Soil	g	16.1
Manganese	Soil	g	832
Mercury	Soil	mg	17.8
Metaldehyde	Soil	mg	16
Metolachlor	Soil	g	17.5
Metribuzin	Soil	mg	566
Molybdenum	Soil	mg	71.9
Napropamide	Soil	mg	28.3
Nickel	Soil	g	24.1
Nitrogen	Soil	mg	210
Oils, biogenic	Soil	kg	1.36
Oils, unspecified	Soil	tn.lg	1.27
Orbencarb	Soil	g	3.05

Substance	Compartment	Unit	Scenario 10
Phosphorus	Soil	g	727
Phosphorus, total	Soil	g	199
Pirimicarb	Soil	mg	15.1
Potassium	Soil	kg	4.93
Silicon	Soil	kg	2.14
Silver	Soil	mg	111
Sodium	Soil	kg	27.3
Strontium	Soil	g	131
Sulfur	Soil	kg	10.4
Tebutam	Soil	mg	67
Teflubenzuron	Soil	mg	37.7
Tin	Soil	mg	165
Titanium	Soil	g	10.1
Vanadium	Soil	mg	290
Zinc	Soil	kg	2.29
Zinc phosphide	Soil	g	59.7

Annex E

Critical Review

Critical review

of the report

"Battery Waste Management Life Cycle Assessment Study"

Final report, (12th July 2006) by ERM (UK).

Anders Schmidt, Ph.D.
FORCE Technology
Hjortekjaersvej 99
DK-2800 Lyngby

Executive summary

ERM authorized LCA Center Denmark to perform a critical review according to ISO 14040ff on the LCA study "Battery Waste Management Life Cycle Assessment" conducted by ERM. The critical review was performed by Anders Schmidt, Ph.D. and Senior Project Manager at FORCE Technology, one of the partners of LCA Center Denmark.

The review has first been conducted on the draft final report and – following amendments from ERM – also on the final report. Between the review of the two reports a telephone conference was held with participation of the authors and the reviewers, primarily discussing the issues raised in the first review. With this process the reviewer has not had the possibility of discussing main issues like Goal and Scope Definition, choice of methodologies, etc. prior to the review.

In summary the critical review of the study concludes the following:

- The methods employed for the study are consistent with the international standards ISO 14040ff.
- The methods considered for the study are scientifically valid and reflect the international state of the art for LCA.
- Considering the goals of the study, the used data are justified to be adequate, appropriate and consistent.
- The consistency of the interpretations with regard to the goals and the limitations of the study is regarded to be fully fulfilled.
- The report is certified to have a good transparency and consistency.
- Overall the critical review concludes that the study is in accordance with the requirements of the international standards ISO 14040ff.

Lyngby, July 20, 2006

Anders Schmidt
Senior Project Manager

Goal and scope of the critical review

The goal and scope of the critical review is defined in accordance with ISO 14040, paragraph 7.1. Following ISO 14040, the critical review process shall ensure that:

- the methods used to carry out the LCA are consistent with this International Standard
- the methods used to carry out the LCA are scientifically and technically valid
- the data used are appropriate and reasonable in relation to the goal of the study
- the interpretations reflect the limitations identified and the goal of the study
- the study report is transparent and consistent

Within the budgetary frame it has not been possible to verify all details in the study. Some spot checks were conducted, but the focus of the review was on the formal requirements in the ISO 14040 standard series. For this purpose, a checklist for critical reviews of LCA, published by the Danish Standards Association, was used in the first review. Due to the time constraints, not all points in the checklist were addressed at the same level of detail. In-depth considerations were thus only included in the cases where the reviewer identified issues which at the first glance did not seem to be fully explained.

The reviewer has not looked into the financial cost considerations outlined in the study.

Elements in the critical review

Goal and scope definition

Following the first review, the Goal and Scope of the study has been defined in an appropriate way, together with the target group and intended use of the report.

Functional unit and System boundaries

The functional unit for the study – "management of consumer portable battery arisings in the UK between 2006 and 2030" – is well explained and supplemented with calculations of the actual amounts being handled in the different scenarios. The production and use stage for the batteries is not included as this will not change as a consequence of altered disposal.

The systems examined have been described in great detail, allowing the target group to understand the processes and actors involved in each scenario. Nine scenarios combine the three different collection scenarios with three different recycling scenarios, offering results for a wide and realistic range of options. Also included is a baseline scenario in which batteries are being disposed as residual waste, i.e. current practice. The overall system description is thus fully consistent with the goal and scope of the study, although it may be difficult for the reader to distinguish between the scenarios throughout the report on the basis of their name alone. There is no ready solution for this; on the one hand the study has a large scope and on the other hand the scenarios have many common elements. As with most other technical reports the reader will have to find a way to remember the differences. An overview could possibly be established by combining the key features/differences between the collection and recycling scenarios, respectively.

Additionally, a number of sensitivity analyses are conducted in accordance with the ISO 14040 standard series. They seem to be well chosen, improving the understanding of the important elements in the nine scenarios and the overall results.

Allocation rules

Rules for allocation and system expansion are in accordance with ISO 14040. They yhave been set is a way that shows the changes in environmental impacts caused in each scenario. An important element in this is the assumption that materials from recycled batteries will replace virgin raw material. In the reviewers opinion this is the best choice, reflecting the most possible outcome of increased recycling.

Database and data quality

The database used in the study reflects the state-of-the-art of LCA inventories today. Large efforts have been devoted to collection of primary data on the recycling processes affected. The data are well-documented, including a discussion of mass balances where appropriate. Secondary data from publicly available databases are used to describe processes that are common to all scenarios, e.g. transportation, electricity production and waste disposal. The authors rightly acknowledge that these data in some cases are relatively old and not necessarily related to processes situated in the UK. Being common processes to all scenarios and often with a small impact on the overall results their use is in full accordance with the goal and scope of the study. The reviewer, however, also share the authors' wish for better/newer data for such processes.

The data quality is thus judged to be adequate to fulfil the goal of the study. An extensive tabular overview is provided with respect to the representativeness as well as geographical, time-related and technological coverage of each of the included processes/materials. However, a legend is missing for the attributes given ("X", resp. "√"), making it difficult to pinpoint potentially critical data from the table.

Impact assessment method

The impact assessment method chosen (The CML-method) is commonly accepted and widely used all over the World. It focuses on the impact categories for which scientific consensus exist, but it also includes an assessment of human toxicity and ecotoxicity. The latter two categories can only be assessed with a relatively high degree of uncertainty and this is acknowledged by the authors in both their introduction to the method and in their presentation of the results.

Results

The study approach generates a broad range of results. The inventory results are – as is usually the case – very comprehensive and they have therefore been annexed.

The results of the impact assessment are presented in tabular form, one for each scenario plus a comparison table, together with a short (2 page) summary of the findings identifying the key factors responsible for the differences between the scenarios. Unfortunately for the future decision-making process a high or best performing recycling scenario does not emerge, but the reviewer agrees to the conclusions drawn. A (subjective) weighting step could possibly be applied, but in accordance with the ISO-standards this possibility has not been utilized.

The subsequent sensitivity analysis examines the consequences of changing a number of important assumptions, i.e. battery waste arisings, collection targets, Directive implementation year, disposal assumptions, institutional collection points and electricity input to recycling.

This approach gives the Commissioner a good insight into the consequences of political decisions, e.g. regarding Directive implementation year. The approach, however, also pinpoints some of the uncertainties in the overall study approach. As the most prominent example, the choice of electricity input to recycling processes in Europe has a very large impact on abiotic resource depletion and global warming potential. The basic assumption is that the current mix of energy resources used to produce electricity in Europe (primarily France and Switzerland) will not change as a function of increased recycling of UK batteries. If, however, the extra need for electricity must be covered by power generated in combined cycle gas turbines, a significant extra draw on non-renewable resources is induced, together with a marked increase in emission of greenhouse gases. The inclusion of this sensitivity analysis is appreciated by the reviewer, but it is suggested that the implications are also addressed in the conclusions.

Study conclusions

The conclusions drawn from the study are not described in the same detail as the introductory parts. The most significant findings are emphasized, but no efforts have seemingly been devoted to use the results to point to how the best possible solution can be achieved by combining the best possible collection system with the best possible recycling system. It is acknowledged that this is outside the scope of the study, but it is suggested to include some remarks on how the study and results eventually can be used when the actual systems are specified in the near future.

Other comments

The first impression of the report is that an Executive Summary is missing. It is strongly recommended that this is included in the final report, giving the reader the possibility of understanding the background for the study, its technical implications and the results and their interpretation.

Review conclusions

The study has been conducted in accordance with all requirements of the ISO 14040 standard series on Life Cycle Assessment. The choices made are fully justified and well documented, and the results can therefore be assumed to reflect the consequences related to implantation of the nine different scenarios. As such they provide the information envisioned in the Goal and Scope of the study.

The choices made are transparent and consistent with the Goal and Scope. The data and their quality is state-of-the-art in European LCA, and especially the handling of recycling processes is exemplary. The data used are thus appropriate and reasonable in relation to the goal of the study as required by the ISO standard series.

The overall approach in the LCA study, including the allocation rules, is consistent with the ISO 14040 standard series. A special element, the impact assessment method, is internationally accepted as being scientifically and technically valid. The report describes its limitations in sufficient detail to avoid overinterpretation.

The study report is transparent and consistent, although it contains much technical information and data. The interpretation and conclusion sections are rather brief, but they address the main issues in a consistent manner as requested in the standard series.

Annex F

ERM Response to Critical Review

Dr Schmidt in his critical review (*Annex E*) concluded the following:

- The methods employed for the study are consistent with the international standards ISO 14040ff;
- The methods considered for the study are scientifically valid and reflect the international state of the art for LCA;
- Considering the goals of the study, the used data are justified to be adequate, appropriate and consistent;
- The consistency of the interpretations with regard to the goals and the limitations of the study is regarded to be fully fulfilled;
- The report is certified to have a good transparency and consistency; and
- Overall the critical review concludes that the study is in accordance with the requirements of the international standards ISO 14040ff.

The review identified no areas of non-conformance and as result no changes were required. However, a number of suggestions to improve the report were made by the reviewer.

These suggestions along with ERM's response to each are detailed below.

1. 'The data quality is thus judged to be adequate to fulfil the goal of the study. An extensive tabular overview is provided with respect to the representativeness as well as geographical, time-related and technological coverage of each of the included processes/materials. However, a legend is missing for the attributes given ("X", resp. "√"), making it difficult to pinpoint potentially critical data from the table.' ERM Response: Change made.

2. 'As with most other technical reports the reader will have to find a way to remember the differences. An overview could possibly be established by combining the key features/differences between the collection and recycling scenarios, respectively.' ERM Response: We suggest the reader bookmarks Sections 1.7 and 1.8 for easy referral, as Dr Schmidt points out the scenarios are described in great detail in these sections.

3. 'A (subjective) weighting step could possibly be applied, but in accordance with the ISO-standards this possibility has not been utilized.' ERM Response: No action taken.

4. 'If, however, the extra need for electricity must be covered by power generated in combined cycle gas turbines, a significant extra draw on non-renewable resources is induced, together with a marked increase in emission of greenhouse gases. The inclusion of this sensitivity analysis is appreciated by the reviewer, but it is suggested that the

implications are also addressed in the conclusions.' ERM Response: The conclusions have been amended to address this point.

5. 'The most significant findings are emphasized, but no efforts have seemingly been devoted to use the results to point to how the best possible solution can be achieved by combining the best possible collection system with the best possible recycling system. It is acknowledged that this is outside the scope of the study, but it is suggested to include some remarks on how the study and results eventually can be used when the actual systems are specified in the near future.' ERM Response: No action taken as this is outside the scope of the study.

6. 'The first impression of the report is that an Executive Summary is missing. It is strongly recommended that this is included in the final report.' ERM Response: An executive summary has been added to the report.