Battery Waste Management Life Cycle Assessment

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ABSTRACT

A life cycle assessment (LCA) of options for the collection and recycling of waste portable batteries has been undertaken. Its objective was to inform on the costs and benefits of various options for implementing the collection and recycling requirements of the proposed Batteries Directive. To compare options, the study considered the environmental impacts associated with the management of forecast consumer portable battery waste arisings in the UK between 2006 and 2030. The scope of the assessment included the collection, sorting, recycling and residual waste management of the waste batteries. Inputs and outputs from each process were quantified and traced back to the extraction of raw materials. Avoided flows resulting from the recovery of metals in recycling processes were also quantified. The study subsequently found that increasing recycling of batteries conveyed environmental benefit. For example, The CO_2 savings that can be achieved through implementation of the Directive amount to between 198kg and 248kg CO_2-equivalents avoided per tonne of battery waste arisings. However, analyses of the economics of implementation show that this benefit is achieved at significant financial cost when compared with disposal. A full report documenting the study methods and results can be found at http://www.defra.gov.uk/environment/waste/topics/batteries/pdf/erm-lcareport0610.pdf.

Background

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

The study was 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, has been critically reviewed by a third party. Findings of the review were that the methods employed for the study are consistent with the international standards, are scientifically valid and reflect the state of the art for LCA. Considering the goals of the study, the data used were considered to be adequate, appropriate and consistent. The consistency of interpretations with regard to the goals and the limitations of the study were regarded to be fully fulfilled.

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 (an estimated 621,259 tonnes).

The scope of the assessment 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 Civic Amenity (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). The composition and quantity of battery waste arisings was the same for all scenarios. Collection levels were assumed to increase linearly from 2006 to 2012 and from 2012 to 2016, with no increases assumed post 2016.

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 flows were quantified and traced back to the extraction of raw materials that were required to supply them. Any avoided flows resulting from the recovery of metals in recycling processes, and displacement of virgin metals production, were also quantified. Figure 1 shows the system that was studied for each implementation scenario.

Key players in the battery waste management industry provided primary data on the materials and energy requirements of collection, sorting and recycling operations (including materials recovery). Published life cycle inventory data were, in turn, used to describe the production of these material and energy inputs.

Combined flows were compiled for each stage of the life cycle and used to assess the environmental impacts of each system. Life cycle impact assessment (LCIA) was carried out for a number of categories of environmental impact: abiotic resource depletion; global warming; ozone layer depletion; human, aquatic and terrestrial toxicity; acidification; and eutrophication. The CML baseline 2000 LCIA method, as housed in the SimaPro LCA software, was used.

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 and benefits associated with each scenario.

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 displays the net environmental benefit associated with implementation scenarios (1-9), over and above the baseline scenario (10). Table 2 displays the waste management and average environmental and social costs that have been estimated for each implementation scenario.

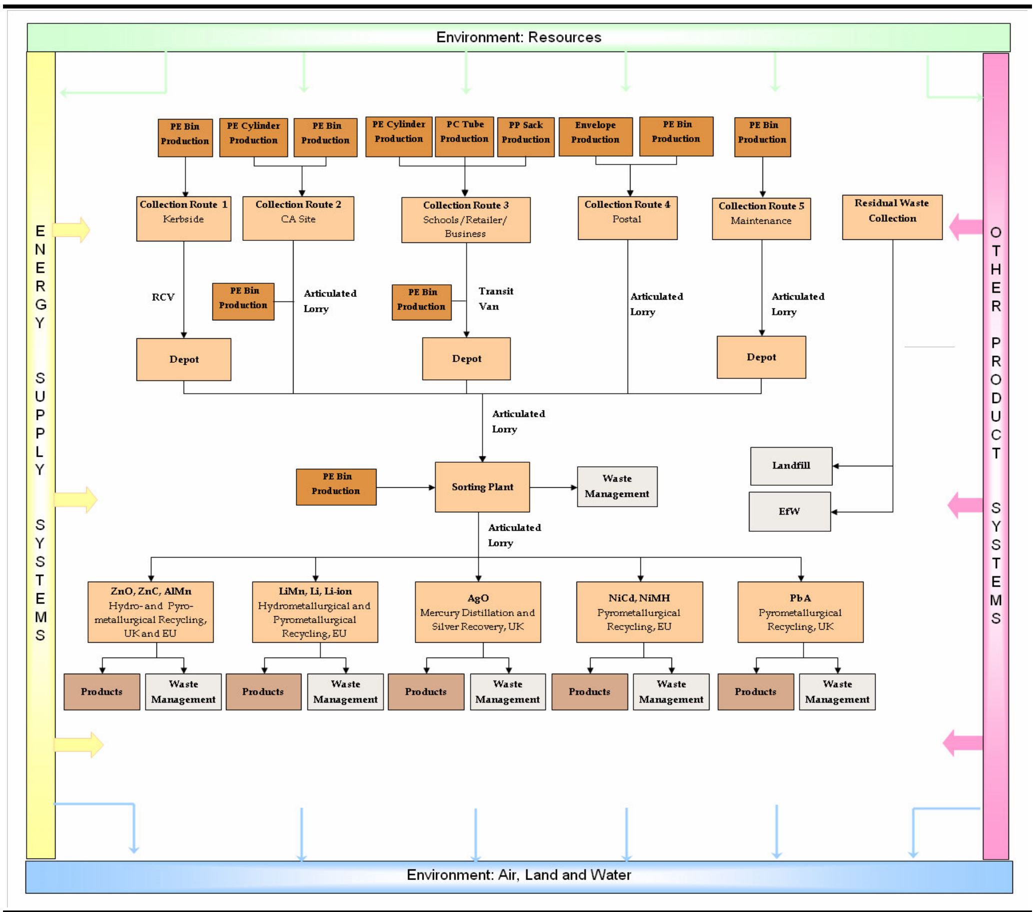

Figure 1: System Boundary of Scenarios

Table 1: Environmental Benefit of Implementation Scenarios (net Benefit in Comparison with Baseline)

Implementation Scenario	Abiotic depletion	Global warming (GWP100)	Ozone layer depletion	Human toxicity	Fresh water aquatic ecotoxicity	Terrestrial ecotoxicity	Acidification	Eutrophication
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 (C1R1)	1751	133,764	26	1,908,108	2,224,908	26,750	1659	310
Scenario 2 (C1R2)	1894	153,764	24	1,914,538	2,224,775	26,762	1718	310
Scenario 3 (C1R3)	1525	135,064	16	2,051,248	2,240,745	261,128	2152	309
Scenario 4 (C2R1)	1744	133,164	26	1,908,028	2,224,885	26,697	1654	310
Scenario 5 (C2R2)	1887	153,164	23	1,914,458	2,224,752	26,760	1713	310
Scenario 6 (C2R3)	1518	134,464	16	2,051,168	2,240,722	261,125	2147	308
Scenario 7 (C3R1)	1672	123,044	25	1,902,468	2,223,758	26,656	1620	306
Scenario 8 (C3R2)	1815	143,044	22	1,908,898	2,223,625	26,719	1679	306
Scenario 9 (C3R3)	1446	124,344	15	2,045,608	2,239,595	261,085	2113	305

C = collection scenario (1,2,3), R = recycling scenario (1,2,3)

Table 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 (C1R1)	235.2		-34.6	Effect of NOx, SO_2, NMVOC and	200.6
Scenario 2 (C1R2)	235.2		-35.4	particulate emissions on human	199.8
Scenario 3 (C1R3)	235.2	Collection,	-30.5	health (human toxicity). Climate	204.7
Scenario 4 (C2R1)	235.2	sorting and	-34.5	change costs of carbon (CO_2 and CH_4	200.7
Scenario 5 (C2R2)	235.2	recycling service	-35.4	emissions only). Abiotic depletion,	199.8
Scenario 6 (C2R3)	235.2	charges. Landfill	-30.5	ozone depletion, aquatic ecotoxicity,	204.7
Scenario 7 (C3R1)	233.5	and incineration	-33.9	acidification (with the exception of	199.6
Scenario 8 (C3R2)	233.5	gate fees	-34.7	damage to buildings) and	198.8
Scenario 9 (C3R3)	233.5		-30.1	eutrophication impacts have not been	203.4
Scenario 1 (C1R1)	28.1		1.8	quantified.	29.9

C = collection scenario (1,2,3), R = recycling scenario (1,2,3)

It was 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. Life cycle inventory and sensitivity analyses showed 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.

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. This is predominantly due to additional fuel consumption and CO_2 emissions through the collection transportation network.

Summary

The assessment shows that there is a net environmental benefit associated with the implementation of the proposed Batteries Directive when compared with disposal (scenario 10). Little difference is shown between scenarios 1-9, in terms of net environmental benefit. 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.

Estimates also 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. However, it should be noted that a number of external benefits associated implementation scenarios have not been quantified in terms of financial cost.

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.