Appendix 25

European Commission, Brussels

Study on the calculation of recycling efficiencies and implementation of export article (Art. 15) of the Batteries Directive 2006/66/EC

Final Report

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Consortium **ESWI**

Expert Team to **S**upport **W**aste **I**mplementation

umweltbundesamt

ENVIROPLAN
Consultants & Engineers

BiPRO
Beratungsgesellschaft für integrierte Problemlösungen

Executive Summary

This final report is not only a compilation of technical data and information but also at providing the basis for a European Commission policy proposal on

1. a method for the calculation of the recycling efficiencies laid down in Part B of Annex III of the Batteries Directive (2006/66/EC);
2. an appropriate recording/reporting format to be used by recycling facilities;
3. a description of minimum treatment requirements concerning Part A of Annex III of the Batteries Directive (2006/66/EC);
4. criteria to assess equivalent conditions that the recycling operations need to meet when waste batteries and accumulators are exported out of the Community;
5. a set of practical sound evidence that should be provided in order to prove compliance with these criteria.

Detailed technical information compiled in the report as a practical and factual information source concerns particularly

6. Information on BAT
7. Description of the core elements of BAT

The project results were elaborated by the project team and on the basis of an interactive stakeholder consultation.

In the executive summary available information is interpreted and recommendations and proposals are summarised for policy decisions including the major decision aspects and relevant environmental, economic and social advantages and disadvantages of different options. The executive summary is arranged in the order of the points 1. to 7. above.

1. Method for the calculation of the minimum recycling efficiencies

1.1 Definition of system boundaries (input and output) of the recycling process in the sense of the Batteries Directive (2006/66/EC)

According to the definition in chapter 3.3, the term “recycling process” of the Batteries Directive (2006/66/EC) has to be understood as the whole process of recycling starting from waste batteries as received after collection and eventual sorting until obtaining final fractions to be used for their original purpose or for other purposes, which do not undergo further treatment.

The system boundaries are defined by the collected waste batteries entering the whole recycling process on the one hand and by the output fractions leaving the whole recycling process on the other hand. It is not relevant whether the whole battery recycling process is carried out at a single recycling plant or at several sites, in a single country or in several countries.

According to Article 3(10) of Directive 2006/66/EC, the term "treatment" means any activity carried out on waste batteries and accumulators after they have been handed over to a facility for sorting, preparation for recycling or preparation for disposal. As a consequence, the recycling process does not start with the activities carried out at the recycling facility. The recycling process starts after sorting and preparation for recycling.

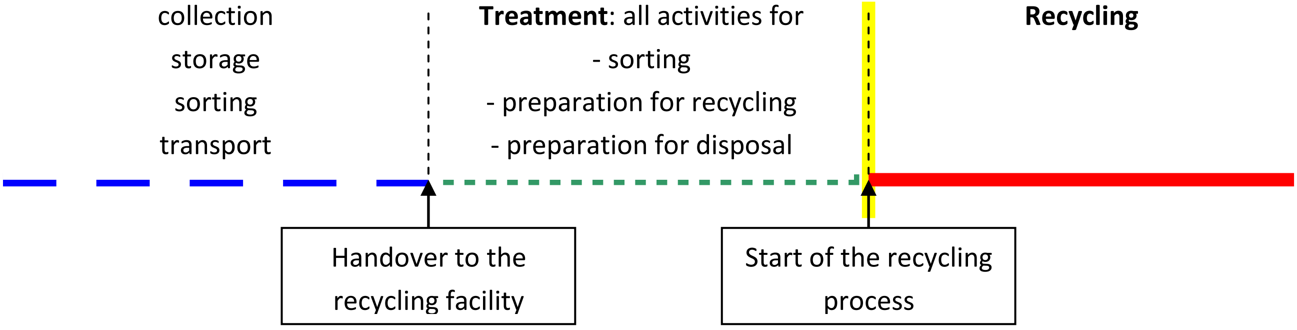

Figure 0-1: Illustration of the boundaries of treatment activities and the start of the recycling process (i.e. the input system boundary of the recycling process) in the sense of Directive 2006/66/EC.

For the definition of the system boundary on the output side of the recycling process an endpoint of battery recycling needs to be determined. According to Article 3(17) of Directive 2008/98/EC a recycling process ends when the output fractions are definitely approved products or by-products, when they are a waste for disposal, material used for energy recovery or when they are released to air, water or land (see Figure 4-3). Conversely, a recycling process is not terminated as long as output fractions are generated that are destined for recycling.

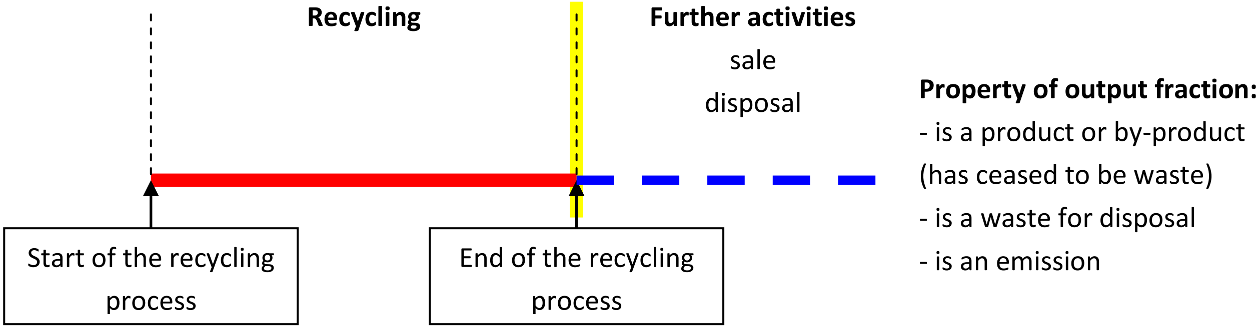

Figure 0-2: Illustration of the termination (i.e. the output system boundary) of a recycling process

Specific criteria can be applied to the output fraction in order to define the end of the recycling process. The recycling process can be considered as being terminated for the individual output fractions if:

- the output fraction ends its waste status according to Article 6 of Directive 2008/98/EC
- and the output fraction is a product
- or the output fraction is a by-product according to Article 5 of Directive 2008/98/EC
- or the output fraction is a waste for disposal in the sense of Directive 2008/98/EC
- or the output fraction is an emission, i.e. a direct or indirect release of substances from individual or diffuse sources into air, water or land.

To conclude, it is considered that the battery recycling process in the sense of Directive 2006/66/EC comprises the following steps:

- Separation of fractions belonging to the battery (including the removal of fluids and acids);
- Production of metals, metal compounds and other recycled output fractions such as plastics, recovery products of electrolytes etc.

The termination of the recycling processes can be defined for each output fraction by means of the specific criteria.

1.2 Approach recommended to be used for the calculation of recycling efficiencies (“black-box” or individual process step)

A question which is directly related to the definition of the system boundaries is whether the calculation of the recycling efficiency should be considered for the complete battery recycling or for individual process steps.

Option (A) regarding the inputs and outputs of the complete recycling process altogether (in a “black-box” approach; see Figure 4-4) or

Option (B) regarding the inputs and outputs of all process steps individually (see Figure 4-5).

Both approaches are based on a mass balance of input and output weights.

The “black-box” approach is a model that illustrates which input and output fractions should be accounted for the calculation of the recycling efficiency. Irrespective of this the reporting on the recycling efficiency should cover all individual steps of recycling and all corresponding output fractions. Accordingly the “black-box” approach will maintain full transparency at all stages of the process and will allow to use information in order to evaluate the effective environmental impact of the materials used as input to the process at all stages where an original battery material is entering a recycling step. Carbon used as reducing agent for the recycling of ZnC batteries is one relevant example for an intermediate fraction which is used as a reducing agent and combustible and is finally emitted to the air. Other examples for other battery chemistries are carbohydrates (plastics), Fe, Al or organic fluids.

The general question is whether intermediate fractions that are internally used and consumed within the recycling process (i.e. they are released as emission or as waste for disposal) should be accounted for the calculation of the recycling efficiency. Relevant intermediate fractions are not only reducing agents but also other substances used for example as oxidising agent or any other agent that is consumed within the recycling process.

The proposal of the project team which is justified in the draft final report is not to account such intermediate fractions for the calculation of the recycling efficiency. Many comments where made on this issue, particularly related to the accountability of carbon and plastics as reducing agents but also on other reducing agents. This issue was intensively discussed. The arguments for and against accounting of intermediate fractions that are consumed within the recycling process are summarised in detail in chapter 4.1.1.

Considering the pros and cons, the proposal of the project team is to apply the “black-box” approach in a strict sense and not to account the use of intermediate fractions that are consumed during the process for the recycling efficiency (option A).

The following table summarises the environmental, economic and social advantages and disadvantages of the proposed option to apply the "black-box" approach in a strict sense versus the option to apply an individual step approach.

Scope	Advantages	Disadvantages
Environment	Increases the motivation and/or necessity to recycle the accountable output fractions or to improve the actual use of output fractions (e.g. to use slag as a construction material instead of disposal)	1) If certain processes would be substituted by others these are not necessarily environmentally preferable (explanation: see Table 4.2) 2) Output fractions that are released as an emission would be accounted for the recycling efficiency (explanation: see Table 4.2) 3) Output fractions that are used for energy recovery would be accounted for the recycling efficiency (explanation: see Table 4.2)
Economy	Economic gains for certain process types possible if other process types lose competitiveness (explanation: see Table 4.2)	1) Concerns have been expressed that the required recycling efficiencies may not be achievable by specific processes (some of these are BAT) if reducing agents that are leaving the process as an emission are not accounted for the recycling efficiency → economic losses for certain process types possible 2) Concerns have been expressed that discrimination of processes is possible where an intermediate fraction is used internally versus processes where the intermediate fraction is withdrawn from the process and sold
Social	Job gains in certain process types possible	Job losses in certain process types possible

Table 0.1 : Environmental, economic and social advantages and disadvantages of the proposed option to apply the "black-box" approach in a strict sense (no accountability of intermediate fractions such as reducing agents versus the contrary option to apply the individual step approach and to account intermediate fractions such as reducing agents)

According to the estimation of the project team, the recycling efficiencies as required according to Annex III, part B of the Batteries Directive (2006/66/EC) will be achievable without taking reducing agents into account in actually performed recycling processes. This estimation is related to those selected cases where corresponding concerns have been expressed and is based on the information provided by individual stakeholders including e.g. information on the actual use of the by-product slag. Changing conditions e.g. for the use of slag may lead to altered results of this estimation. Future reporting will show the results of the recycling efficiency calculation in practice and according to technical progress. The practical results from reporting will enable to evaluate the appropriateness of the required recycling efficiencies. Based on the experience gained in Member States it may be necessary to adjust the recycling efficiencies as required according to Annex III, part B of the Batteries Directive (2006/66/EC). In the view of the project team such an adjustment should generally consider all possible options, A to increase, B to maintain or C to decrease the required recycling efficiencies. A possible adjustment should be based on a thorough assessment of the reported recycling efficiencies at European level. It should also take into account the overall environmental performance of the concerned battery recycling processes and possible socio-economic consequences.

However the project team acknowledges the relevance of the arguments for an individual step approach and would like to note that also another option could be considered, i.e. to account that share of reducing agents that is actually used for reducing for the recycling efficiency.

If the decision will be taken for the option to account that share of reducing agents that is actually used for reducing, the following aspects should be considered:

- Results from individual attempts to quantify the share that is actually used as reducing agents can not be simply transferred on other battery recycling processes.
- A stoichiometric approach[1] seems to be appropriate to exactly quantify the share of the reducing agent that is actually used as reducing agent. Based on the share of oxidised substances that have to be reduced within a process a stoichiometric calculation enables to exactly determine the amount of reducing agent that is indeed required as reducing agent. This share could be accounted for the recycling efficiency.
- The quantification should be made on the basis of an independent scientific stoichiometric expertise for each specific battery recycling process (if required or desired).). Such expertise could be provided by independent institutions with appropriate chemical and technical know how such as universities or consulting engineers. The correctness of the expertise could be verified by the competent licensing authority. The costs for such individual scientific expertise seem to be economically reasonable. Estimated costs depend on the complexness of the concerned process and are estimated to range from several hundred to several thousand euros per expertise.

Environmental, economic and social advantages and disadvantages of the option to apply the “black-box” in a strict sense (no accountability of intermediate fractions such as reducing agents) versus the

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[1] Explanation: see footnote 15.

option to apply the “black-box” approach but to account intermediate fractions (such as reducing agents) to a certain share are summarised in **Table 4.3**.

1.3 Should fluids and acids be accounted for the input mass or not?

The recycling efficiency is related to the battery as the functional unit. A battery converts chemical energy directly to electrical energy. At least in wet batteries, this is only possible if the battery contains electrolyte. Therefore the electrolyte is component of the battery. As a consequence, the removal of fluids and acids should be regarded as part of the recycling process because components of the battery are removed.

Scope	Advantages	Disadvantages
Environment	Increased motivation to recycle fluids and acids because this will increase the recycling efficiency → saving of resources	In specific cases a negative environmental impact is possible e.g. due to energy need for recycling and transport of output products
Economy	Not relevant	Negative cost balance possible
Social	Not relevant	Not relevant

Table 0.2 : Environmental, economic and social advantages and disadvantages of the proposed option to include fluids and acids in the input mass versus the contrary option to exclude fluids and acids

1.4 Should the input mass be on a dry or on a wet basis?

Portable batteries contain between zero and approximately 13 % of water. According to industry information industrial batteries may contain up to 25 % of water.

Two relevant options concerning the consideration of the water content in the input mass for the calculation of the recycling efficiency are:

Option A: Input is defined as the mass of waste batteries including all liquids and including its water content (wet basis)

Option B: Input is defined as the mass of waste batteries including all liquids but excluding its water content (dry basis)

Water is usually evaporated during the recycling process or undergoes a physico-chemical treatment prior to its release as an emission. Finally it usually enters the natural water cycle. An exception is for example the recovery of sulphuric acid from lead-acid batteries. In specific cases the acid is recycled and sold including its water content. The water is then component of the product.

Concerns have been expressed, that it will be difficult for several battery recycling processes to achieve the recycling efficiency if the input mass is on a wet basis and the output of water after physico-chemical treatment prior to its release as an emission is not accounted as a product or by-product. The project team considers the release of water to the environment as an emission.

The calculation of the recycling efficiency on a dry basis will usually increase the recycling efficiency as the relative shares of the other battery components increase and contribute more to the recycling efficiency. A water content of e.g. 13% and a recycling efficiency of 50% of material on a wet basis (option A) correspond to a recycling efficiency of approximately 57% (50/0.87) on a dry basis (option B)[2].

The project team proposes option B in order to exclude water from the calculation of the recycling efficiency. However it has to be noted that liquids[3] and acids[4] are accounted on a dry basis for the recycling efficiency.

The following table summarises the environmental, economic and social advantages and disadvantages of the proposed option.

Scope	Advantages	Disadvantages
Environment	Not relevant as water is emitted only after physico-chemical treatment and according to approved quality criteria.	Negative effects possible if the recycling efficiency will be achievable too easy
Economy	Concerns have been expressed that if water will be included in the calculation it will be difficult to achieve the required recycling efficiency. Due to the proposed option the recycling efficiency will usually increase → less efforts required to achieve the recycling efficiency	Not relevant
Social	Not relevant	Not relevant

Table 0.3 : Environmental, economic and social advantages and disadvantages of the proposed option to define the relevant input as the mass of waste batteries including all liquids but excluding its water content (option B: dry basis) versus the contrary option to define the mass of waste batteries including all liquids and its water content (option A: wet basis)

1.5 Should the battery pack and ancillary parts be accounted for the input mass or not?

The recycling efficiency is related to batteries. Relevant for the recycling efficiency are strictly the batteries consisting of one or more battery cells. The outer casings of batteries are part of the

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[2] Example calculation see footnote 20

[3] e.g. aqueous solutions of potassium hydroxide or ammonium chloride

[4] e.g. sulphuric acid

batteries. Liquids and acids are part of the batteries as well. Components of the battery packs (e.g. outer casings of battery packs) are not part of the batteries. Ancillary equipment (such as electrical components or racking systems) is not part of the batteries. This definition applies to batteries from the lead-acid sector as well as for NiCd and other batteries.

To conclude the project team proposes the following:

Relevant input is the battery consisting of one or several cells. The outer casing of a battery is to be regarded as part of the battery and should be taken into account for the recycling efficiency.

Parts such as the following (if these are not integral parts of the outer casing) should not be regarded being part of the battery and should not be accounted for the recycling efficiency (non-exhaustive list):

- Components of the battery pack
- Electrical components (switches, LEDs[5], fuses, wires…) which are supplied to provide monitoring and communication functionalities to a complete power back-up system
- Racking systems in which the batteries are incorporated to ensure structural integrity
- Components for impact protection or easy maintenance

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[5] LED = Light Emitting Diode

The following table summarises the environmental, economic and social advantages and disadvantages of the proposed option.

Scope	Advantages	Disadvantages
Environment	Increased motivation to recycle metals and metal compounds from the batteries. The aim of Directive 2006/66/EC remains in the focus.	Decreased motivation to recycle components of the pack and ancillary parts in order to achieve the required recycling efficiency.
Economy	Positive effects possible if components need not to be recycled if economically not reasonable.	Concerns have been expressed that the required recycling efficiency cannot be achieved pack components (e.g. steel casings) are not accounted for the recycling efficiency[6] → economic losses theoretically possible
Social	Not relevant	Job losses theoretically possible

Table 0.4 : Environmental, economic and social advantages and disadvantages of the proposed option to regard the outer casing of a battery as a part of the battery but to exclude the components of the battery pack and ancillary parts versus the contrary option to include the pack and ancillary parts that are collected together with the batteries

A problem with the definition of battery and battery packs may occur in the context of future developments in new types of batteries such as those used e.g. for electric or hybrid cars. According to information from industry the share of plastics in this type of batteries may increase to high degrees. If these components would be taken into consideration for the calculation of the recycling efficiency, the required efficiencies might already be achieved by recycling the plastic share.

1.6 Should intermediate fractions consumed within the recycling process be accounted for the recycling efficiency?

Carbon or plastics and/or other agents are commonly used in pyrometallurgical battery recycling processes. Usually these agents have a dual function as (a) combustible and (b) reducing agent. Carbon and/or plastic but also other agents that have a function within the recycling process are introduced as components of the waste batteries into the process and are consumed within the process and emitted (e.g. as CO_2 into the atmosphere). Consequently they are not available in a recycled product or by-product at the end of the process.

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[6] Which is not expected by the project team

The proposal of the project team is:

If carbon is a component of an approved product (= a final output fraction) of a recycling process (e.g. graphite powder) it can be taken into account for the calculation of the recycling efficiency.[7]

If carbon is consumed within the recycling process (e.g. incinerated and used as reducing carbon and finally released as CO_2 to the atmosphere) it cannot be taken into account for the calculation of the recycling efficiency.

This proposal corresponds to applying the “black-box” approach in a strict sense and not to account intermediate fractions such as reducing agents for the recycling efficiency. The corresponding advantages and disadvantages from an environmental, economic and social perspective of the proposal are summarised above (see point 1.2).

1.7 Should the output fraction “water” be accounted for the recycling efficiency?

Fluids and acids are considered components of a battery and the input to the battery recycling process can be either on a wet basis or on a dry basis. The project team proposes the dry basis option. If this option is chosen water will not be taken into account for the calculation. The mass of the water content will be subtracted from the waste batteries input mass.

If the wet basis option will be chosen, further reflection is required on the question how to consider water in the calculation of the recycling efficiency:

As water is finally released into the natural water cycle, it could be taken into account in the calculation of the recycling efficiency in numerator and denominator. Consequently the water content would be counted as if being a recycled. This is line with a comprehensible joint industry position that considers the output of treated water as a by-product as defined in Article 5 of the Waste Framework Directive 2008/98/EC.

According to the definition of emissions according to the IPPC Directive the output of treated water into the environment is an emission and cannot be accounted for recycling.

This background is related to the following options:

Water originating from the batteries that is released to air or water after appropriate physico-chemical treatment

Option (A) has ended its waste status and can be accounted for the recycling efficiency as a by-product or

Option (B) is considered an emission and cannot be accounted for the recycling efficiency.

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[7] see footnote 21

In the opinion of the project team releases of water to air, water or land are emissions in the sense of the IPPC Directive and should not be accounted for recycling efficiency (option B).

The project team proposes to exclude water from the calculation. The corresponding advantages and disadvantages from an environmental, economic and social perspective of the proposal are summarised above (see point 1.4).

1.8 Should the output fraction "oxygen" be accounted for the recycling efficiency?

The question how oxygen contributes to the recycling efficiency depends on the mass flows of oxygen into and out of the recycling process. Consequently, oxygen contributes (like all other input elements) to the recycling efficiency if it originates from the input batteries and becomes part of a relevant output fraction of the battery recycling process.

The proposed option has only low effects on the recycling efficiency and is usually only related to irrelevant environmental, economic and social advantages and disadvantages. In specific cases, however, the accountability of oxygen may be decisive to achieve the required recycling efficiency. In these cases relevant economic disadvantages may be avoided if oxygen is accounted for the recycling efficiency.[8]

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[8] For further explanation see footnote 22

1.9 Should the output fraction "slag" be accounted for the recycling efficiency?

Slags are an output fraction of many thermal processes. They can partly be recovered in construction work (e.g. road construction, landfill construction and backfilling) or are used as feedstock-material for further production processes. Hence it has to be decided whether the content of battery materials (metals and metal oxides) transferred to slag can be accounted for the recycling efficiency.

Even if slags are classifiable as by-products in the sense of Directive 2008/98/EC, slag use is permitted according to the corresponding legislation of the respective Member State. This may lead to discrimination of battery recyclers in Member States where the slag is not authorized to be used, e.g. for road construction, but has to be disposed.

Several options concerning the accountability of slag being a final fraction of the battery recycling process for the recycling efficiency have been identified: Battery materials in slag are

Option A: not accounted for the recycling efficiency;

Option B: accounted for the recycling efficiency if the slag is an approved product or a by-product according to Directive 2008/98/EC AND if it is actually used for purposes other than disposal;

Option C: accounted for the recycling efficiency if the slag is an approved product or a by-product according to Directive 2008/98/EC AND if it is actually used for purposes other than disposal or landfill construction.

Concerns have been expressed that in several cases the accountability of slag is decisive for the achievability of the required recycling efficiency.

The project team decided to propose option C, since insertion of slag on a landfill definitely terminates any recycling of the material. This would also help to avoid possible market distortions.

The following table summarises the environmental, economic and social advantages and disadvantages of accounting battery materials in slag according to the actual use of the slag versus not accounting them for the recycling efficiency (options B and C versus option A).

Scope	Advantages	Disadvantages
Environment	Not relevant since slags can only be used that are in accordance with specific quality criteria → no impact on the environment	1) Not relevant since slags can only be used that are in accordance with specific quality criteria → no impact on the environment 2) If quality criteria are not appropriate → negative impact on the environment possible
Economy	The accountability of slag for the recycling efficiency is decisive in several cases for the achievability of the required recycling efficiency → economic losses can be avoided	Not relevant
Social	Job losses can be avoided	Not relevant

Table 0.5 : Environmental, economic and social advantages and disadvantages of options B and C (to account battery materials in slag according to the actual use of the slag) versus option A (not to account battery materials in slag for the recycling efficiency)

The following table summarises the environmental, economic and social advantages and disadvantages of the proposed option C (accounting for battery materials in slag if they are not used for disposal or landfill construction) versus option B (accounting for battery materials in slag if they are not used for disposal).

Scope	Advantages	Disadvantages
Environment	Increases the motivation to use slag for purposes other than landfill construction. → saving of resources possible	1) Not relevant since slags can only be used for purposes other than landfill construction or disposal if they are in accordance with specific quality criteria → no impact on the environment 2) If quality criteria are not appropriate → negative impact on the environment possible
Economy	The accountability of slag for the recycling efficiency is decisive in several cases for the achievability of the required recycling efficiency → economic losses can be avoided	The accountability of slag used for landfill construction for the recycling efficiency may be decisive in specific cases for the achievability of the required recycling efficiency → economic losses possible
Social	Not relevant	Job losses possible

Table 0.6 : Environmental, economic and social advantages and disadvantages of the proposed option C (accounting for battery materials in slag if they are not used for disposal or landfill construction) versus option B (accounting for battery materials in slag if they are not used for disposal).

A further topic to decide upon is the question, whether all materials (elements and compounds) contained in a slag accepted for recycling could actually be counted or not. In this context there are two alternative options:

Option A: All battery materials account for “recycling”

Option B: Battery materials constituting undesirable contamination for the particular application of the slag are not accepted for “recycling”

Option A is supported by the argument that the slag has ceased to be waste and thus falls into the category of product, by-product with no reason to treat it differently than any other product containing e.g. heavy metals as trace elements.

Option B is supported by the argumentation that the battery compounds contained in the slag (e.g. heavy metals) are not the reason for the recycling possibility and market demand, but an undesirable contamination. Although there is not yet a European regulation existing, several Member States have already established guidelines and regulations for recycling different wastes/materials with regard to environmental protection. According to a review of these guidelines/regulations containing requirements for recycled materials used as construction material usually the following heavy metals are limited: Pb, Ni, Cd, As, Ba, Cr, CrVI, Cu, Hg, Mo, Zn and Va. [JRC, 2008].

The project team proposes option B: elements and compounds contained in slag (if the slag as such is accounting for recycling) should not account for recycling if they represent undesired contamination regarding the particular application of the slag (i.e. heavy metals for which limit values are applicable for road construction material).

The following table summarises the environmental, economic and social advantages and disadvantages of the proposed option B (not accounting for battery materials in slag if they represent an undesired contamination) versus option A (accounting for all battery materials in slag).

Scope	Advantages	Disadvantages
Environment	Increases the motivation to improve the recycling of hazardous substances (low increase of the motivation as low effect on the recycling efficiency)	Not relevant
Economy	Not relevant	Higher efforts to improve the recycling of hazardous substances may be related to relevant costs (low pressure as low effect on the recycling efficiency)
Social	Not relevant	Not relevant

Table 0.7 : Environmental, economic and social advantages and disadvantages of the proposed option B (not accounting for battery materials in slag if they represent an undesired contamination) versus option A (accounting for all battery materials in slag).

1.10 Proposal for a method for the calculation of the recycling efficiencies laid down in Part B of Annex III of the Batteries Directive (2006/66/EC)

According to Annex III, Part B of Directive 2006/66/EC recycling processes shall achieve minimum recycling efficiencies. Furthermore, recycling processes shall achieve the recycling of the Pb content of lead-acid batteries and accumulators and of the Cd content of nickel-cadmium batteries and accumulators to the highest degree that is technically feasible while avoiding excessive costs. The following calculation methods are proposed:

a) A calculation method for the overall Recycling Efficiency (RE) of a recycling process

$$RE\ [\text{mass\%}] = \frac{\Sigma\ (\textit{mass of final fractions accounting for recycling})}{\textit{input mass into the battery recycling process}} * 100$$

Explanations:

1) whereby the RE has to be calculated **separately** at least for:

- **lead-acid** batteries and accumulators,
- **nickel-cadmium** batteries and accumulators and
- **other** waste batteries and accumulators.

2) whereby the **system boundaries** of the battery recycling process are illustrated in Figure 4-12 .

3) whereby the “**input mass into the battery recycling process”** is defined as the dry mass of the waste batteries excluding the mass of components belonging to battery packs entering the battery recycling process per calendar year.

4) whereby the RE is calculated on an **elemental/compound** level.

5) The “**input**” on an **elemental/compound** level is defined as the composition of the **spent** batteries and accumulators as they are received by the recycler (chemical analysis), with the following exemptions:
For batteries and accumulators, for which there is little change in the chemical composition between new and spent batteries and for which there is little change in the composition over time due to technical development (e.g. AlMn and ZnC) the “**input”** on an **elemental/compound level** is defined as the composition of the **new** batteries and accumulators. The share of several battery chemistries in the “input” has to be determined by sorting analysis (e.g. 40 mass % of battery chemistry 1 (e.g. ZnC-batteries) and 60 mass % of battery chemistry 2 (e.g. AlMn-batteries)). The analyses can e.g. be carried out by the recycler or the collector. To guarantee harmonization between recycling processes the sampling and sorting procedure should be standardized. However, it seems not necessary to implement authorised or certified sorting analysis mechanisms.

6) whereby **“final fractions”** are defined as **approved products**, **by-products**, **emissions** or **waste for disposal or materials for energy recovery** (=definition of the end the battery recycling process)

7) whereby “**final fractions accounting for recycling”** have to be (1) **products** or (2) **by-products**, whereby for the latter (e.g. **slags**) the actual utilization for recovery has to be proved.

8) whereby the “**mass of final fractions accounting for recycling”** is the share of the elements or compounds contained in these fractions which originates from the processed batteries and accumulators.

9) whereby elements and compounds contained in slag (although if the slag as such is accounting for recycling) do not account for recycling if they represent undesired **contamination** regarding the particular application of the slag (i.e. heavy metals for which there exist limit values for road construction material).

10) according to 7) the use of **carbon** as a reducing agent is accounting for recycling if it is component of a final fraction (by-product or product) of the battery recycling process.

b) A calculation method for the Degree of Recycled Lead (RPb) of a recycling process

$$\textit{RPb}\ [\text{mass\%}] = \frac{\Sigma\ (\textit{mass of Pb in final fractions accounting for recycling})}{\textit{Pb input mass into the battery recycling process}} * 100$$

Explanations (in addition to those regarding RE (see a)):

1) whereby the "**Pb input mass into the battery recycling process"** is defined as the yearly average Pb content of spent lead-acid batteries and accumulators multiplied with the input mass of lead-acid batteries and accumulators.

2) whereby the "**mass of Pb in final fractions accounting for recycling"** is the share of Pb contained in these fractions, which originates from the processed lead-acid batteries and accumulators.

3) whereby Pb contained in slag (although if the slag as such is accounting for recycling) does not account for recycling since it represents an undesired **contamination** regarding the utilization of slag (i.e. as road construction material).

c) A calculation method for the Degree of Recycled Cadmium (RCd) of a recycling process

$$\textit{RCd}\ [\text{mass\%}] = \frac{\Sigma\ (\textit{mass of Cd in final fractions accounting for recycling})}{\textit{Cd input mass into the battery recycling process}} * 100$$

Explanations (in addition to those regarding RE (see a):

1) whereby the "**Cd input mass into the battery recycling process"** is defined as the yearly average Cd content of spent nickel-cadmium batteries and accumulators multiplied with the input mass of nickel-cadmium batteries and accumulators.

2) whereby the "**mass of Cd in final fractions accounting for recycling"** is the share of Cd contained in these fractions, which originates from the processed nickel-cadmium batteries and accumulators.

3) whereby Cd contained in slag (although if the slag as such is accounting for recycling) does not account for recycling since it represents an undesired **contamination** regarding the utilization of slag (i.e. as road construction material).

2. Proposal for an appropriate recording/reporting format to be used by recycling facilities

According to Article 12(5) of the Batteries Directive (2006/66/EC), Member States shall report on the levels of recycling achieved in each calendar year concerned and whether the efficiencies referred to in Annex III, Part B have been met. Thus data on the efficiencies of the applied recycling processes has to be reported to the Member States. The aim of this project was – with respect to harmonisation between Member States - to provide a reporting format to be filled in by the recycling facilities, which provides all necessary information to calculate the recycling efficiency in a uniform way.

Since the format for lead-acid and nickel-cadmium batteries and accumulators shall contain data on the degree of recycled lead and cadmium, respectively, we propose 3 different reporting formats to be used for reporting on the recycling efficiency (RE) of

-**lead-acid** batteries and accumulators,

-**nickel-cadmium** batteries and accumulators and

-**other** waste batteries and accumulators.

The proposed reporting format consists of **2 parts:**

Form A) Description of the battery **input** into the recycling process, (calculated) Recycling Efficiency

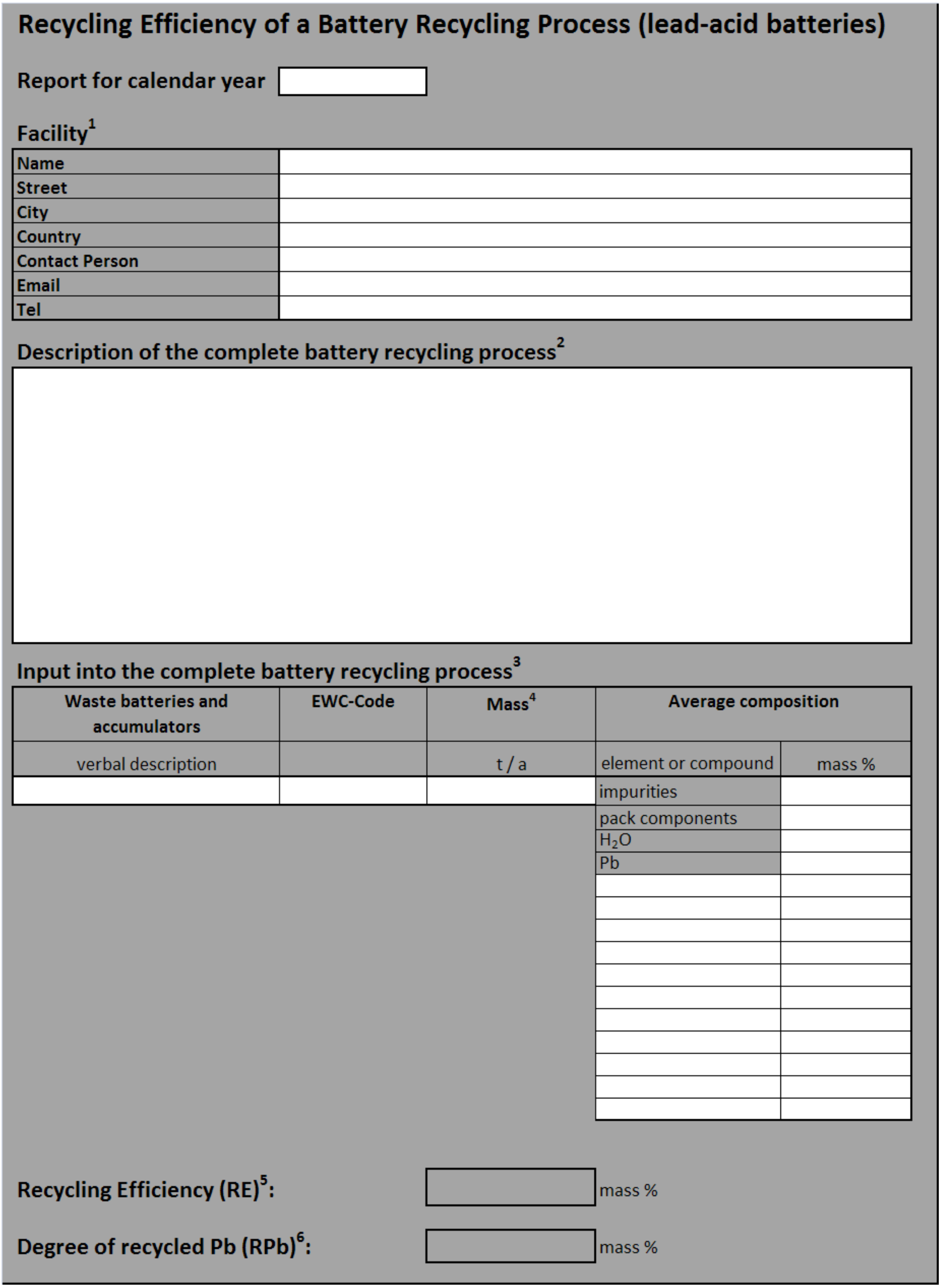
(In our assumption Form A is filled by the facility receiving the waste batteries and accumulators)

Form B) Data on the **individual steps** of the battery recycling process (Material flows originating from batteries input)

(In our assumption Form B is filled by every facility carrying out an individual process step.)

In the following the proposed format for lead-acid batteries is shown exemplarily:

Form A



Recycling Efficiency of a Battery Recycling Process (lead-acid batteries)

Report for calendar year

Facility[1]

Name	
Street	
City	
Country	
Contact Person	
Email	
Tel	

Description of the complete battery recycling process[2]

Input into the complete battery recycling process[3]

Waste batteries and accumulators	**EWC-Code**	**Mass**[4]	**Average composition**	
verbal description		t / a	element or compound	mass %
			impurities	
			pack components	
			H_2O	
			Pb	

Recycling Efficiency (RE)[5]**:** mass %

Degree of recycled Pb (RPb)[6]**:** mass %

Explanations:

1) Facility receiving the waste batteries and accumulators after collection and eventual sorting

2) Description of the complete battery recycling process, no matter if carried out by one or several facilities (including a description of the individual recycling steps and their output fractions)

3) waste batteries and accumulators as received after collection and eventual sorting

4) wet mass of waste batteries and accumulators as received after collection and eventual sorting (the mass of separated impurities and pack components as well as the water content as specified in the field “average composition” are subtracted for the calculation of the RE)

5) calculated automatically according to the formula for RE based on data filled in Forms B

6) calculated automatically according to the formula for RPb based on data filled in Forms B

Form B

Process step **1**

Report for calendar year ☐

Facility[1]

Name	
Street	
City	
Country	
Contact Person	
Email	
Tel	

Description of the indiviudal process step

Input (waste batteries or waste batteries fractions)[2]

Description of input	**EWC-Code**	**Mass**
verbal description		t /a

Output

1) Intermediate fractions [3]

Fraction	**EWC-Code**	**Mass**[4]	**Further treatment**	**Recipient**[5]	**Further process step**
verbal description		t / a	verbal description	Name	
					1_1
					1_2
					1_3
					1_4
					1_5
					1_6
					1_7
					1_8
					1_9
					1_10

2) Final fractions accounting for recycling [6]

Element or compound[7]	**Fraction (product or by-product) containing the element or compound**	**Concentration of the element or compound in the fraction**	**Mass of the element or compound, which originates from batteries input**	**Fate of the fraction**
		mass %	t / a	verbal description

Explanations:

1) Facility carrying out an individual process step

2) For step 1 = the same as input into the complete battery recycling process

For subsequent steps = intermediate fractions from the previous process

3) Intermediate fractions = waste for recycling

4) Originating from the batteries input (wet mass)

5) Facility to which the intermediate fraction is handed over or - if the further process step is carried out internally - the same as 1)

6) Final fractions accounting for recycling = approved products, by-products

7) All elements and compounds if they were component of the batteries input (spent battery). Elements and compounds contained in slag do not account for recycling if they represent undesired contamination regarding the particular application of the slag (i.e. heavy metals for which there exist limit values for road construction material). Lead must be entered as “Pb”.

3. Proposal for a description of minimum treatment requirements concerning Part A of Annex III of the Batteries Directive (2006/66/EC)

According to Article 12(2) of the Batteries Directive (2006/66/EC) treatment shall meet minimum treatment requirements regarding

- treatment shall include removal of all fluids and acids (Annex III Part A.1)
- treatment and storage at treatment facilities shall take place in sites with
  - impermeable surfaces and
  - suitable weatherproof covering or in
  - suitable containers (Annex III Part A.2)

Details on these requirements are not laid down in the Directive. One project objective is to describe these treatment requirements in detail.

Due to the different characteristics of batteries containing liquids and other batteries a differentiation between these categories is proposed. A mixture of waste batteries containing liquids should be regarded as batteries containing liquids.

<u>Proposal for the specification of the minimum treatment requirement: "Removal of all fluids and acids, their collection and treatment":</u>

Proposed Specification	Validity for batteries	
	containing liquids	other
Batteries should be drained and prepared for recycling by adequately trained and personally protected workers	yes	no
In operational areas a ground cover has to be utilised that may retain any leakage and direct it to a collecting container from where it can be removed.	yes	no
The capacity to retain leakage must at least be equal to the amount of liquid stored	yes	no
Surfaces of operational areas, drainage systems and other subsurface structures should be maintained, including applying measures to prevent or quickly clear away leaks and spillages.	yes	no
Electrolyte should be directed to appropriate treatment (recycling/recovery or appropriate waste treatment)	yes	no
Recycling/recovery of electrolyte should be done if appropriate; direct discharge of neutralised and/or untreated electrolyte should be avoided.	yes	no
When applying a neutralisation process customary measurement methods have to be used	yes	no
Neutralised waste water of a neutralisation process has to be stored separately	yes	no
A final inspection of the neutralised waste water of a neutralisation process has to be performed	yes	no

Table 0.8: Proposal for the specification of the minimum treatment requirement: "Removal of all fluids and acids, their collection and treatment"

Proposal for the specification of the minimum treatment requirement: "Impermeable surfaces and suitable weatherproof covering"

Proposed Specification	Validity for batteries	
	containing liquids	other
Surfaces in operational areas should be resistant to chemicals and fire	yes	yes
Storage of waste batteries at treatment and recycling facilities must take place in a proper building or covered place with the following minimum requirements:	yes	yes
– Impermeable and acid and/or lye resistant floor depending on the electrolyte used	yes	no
– Efficient water collection system which directs spilled liquids towards the effluent or electrolyte treatment plant	yes	no
Storage in a proper building or under cover must also be applied to any container that is pending sampling and emptying.	yes	yes
Storage may be carried out without cover if the stored waste batteries and containers are not affected by ambient conditions (e.g. sunlight, temperature, water)	yes	yes
Covered areas need to have adequate provision for ventilation.	yes	yes
The availability and access to storage areas for containers holding substances that are known to be sensitive to heat, light and water, under cover and protected from heat and direct sunlight has to be maintained.	yes	yes
For storing quantities of more than 2500 litres or kilograms dangerous substances a storage building and/or an outdoor storage area covered with a roof has to be applied according to the BREF on Emissions from Storage [EIPPCB 2006a].	yes	yes
For storing quantities of less than 2500 litres or kilograms dangerous substances, at least a storage cell has to be applied according to the BREF on Emissions from Storage [EIPPCB 2006a].	yes	yes

Table 0.9: Proposal for the specification of the minimum treatment requirement: "Impermeable surfaces and suitable weatherproof covering"

<u>Proposal for the specification of the minimum treatment requirement: "suitable containers"</u>

Proposed Specification	Validity for batteries	
	containing liquids	other
Storage must take place in leak proof containers that are acid and/or lye resistant depending on the electrolyte used.	yes	no
Containers must be clearly labelled as regards the nature of the waste and the relevant danger symbols	yes	yes
If appropriate, the use of re-usable packaging (drums, containers, IBCs[9], palettes, etc.) should be maximised.	yes	yes

Table 0.10: Proposal for the specification of the minimum treatment requirement: "suitable containers"

4. Proposal for criteria to assess equivalent conditions that the recycling operations need to meet when waste batteries and accumulators are exported out of the Community

According to Article 15 of Directive 2006/66/EC treatment and recycling may take place outside the Member State concerned or even outside the Community, provided EU legislation on the shipment of waste is respected and if there is sound evidence that treatment and recycling outside the EU adheres to treatment requirements that are equivalent to those within the EU. Particular criteria for the assessment of equivalent conditions shall be laid down through Commitology procedure.

An important project objective is therefore to establish criteria to assess the conditions equivalent to the requirements of the Batteries Directive (2006/66/EC) that recycling processes outside the EU have to meet.

Criteria that are suitable to provide sound evidence are the following:

- Evidence that applied technology is BAT or is equivalent to BAT (taking also account of protection of health and environment and of local conditions in third countries)
- Evidence that requirements of existing and approved guidelines are fulfilled (i.e. Technical Guidelines for the environmentally sound Management of waste batteries)
- Evidence that there is no danger to human health and the environment (information e.g. taken from plant permits)
- Evidence that minimum treatment requirements are met
- Evidence that recycling efficiencies are fulfilled (reporting on input of waste batteries per type and corresponding output of products, materials and substances)
- Evidence that health & safety and waste management conditions for recycling, treatment, transport and storage are fulfilled (currently put in practice at Member State level during the licensing and control process of recycling facilities; each operation permit includes specific

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[9] Intermediate bulk container (IBC) is a container used for transport and storage of fluids and bulk materials

requirements on health & safety and waste management conditions implementing the relevant EU legislation such as the IPPC Directive, EU working protection legislation or the Waste Framework Directive)

5. Proposal for a set of practical sound evidence that should be provided in order to prove compliance with the above criteria

A sound evidence system for equivalent conditions should be differentiated for export of waste batteries to OECD countries and non-OECD countries.

Information should be equivalent to the requirements within the EU and should therefore contain equivalent conditions to the requirements of the Batteries Directive (2006/66/EC) and the IPPC Directive. Unnecessary administrative burden should be avoided.

Specific evidence required from operators within OECD countries can be provided by the operator on the basis of appropriate documentation. Specific evidence from operators outside OECD countries should be provided by certification by an independent institution.

Specific requirements for transport conditions are not required as these are sufficiently regulated in international transport regulation. For the export of waste batteries the requirements of the waste shipment regulation are to be considered.

Specific evidence required from operators in OECD countries should provide the following evidence:

The operator receiving the waste batteries for recycling must

- proof to hold a valid operation permit for the recycling of the relevant waste batteries
- provide summary information from the permit in order to provide evidence that the recycling facility is operated in a way that (in equivalence to the requirements of the IPPC Directive)
    - (a) all the appropriate preventive measures are taken against pollution, in particular through application of the best available techniques
    - (b) no significant pollution is caused
    - (c) measures are implemented in accordance with Directive 2008/98/EC to protect the environment and human health by preventing or reducing the adverse impacts of the generation and management of waste and by reducing overall impacts of resource use and improving the efficiency of such use
    - (d) energy is used efficiently
    - (e) the necessary measures are taken to prevent accidents and limit their consequences

  - (f) the necessary measures are taken upon definitive cessation of activities to avoid any pollution risk and return the site of operation to a satisfactory state
- provide summary information on the permit requirements related to the
  - (g) nature, quantity and sources of emissions and measures for preventing/reducing and monitoring of emissions
  - (h) protection of human health and the environment
  - (i) minimum treatment requirements
  - (j) storage and treatment
  - (k) prevention and recovery of waste
  - (l) the conditions of the site of the installation and how local conditions are considered
- report on input of waste batteries and corresponding output fractions to provide evidence that the required recycling efficiencies are fulfilled

Specific evidence required from operators in non-OECD countries should be similar information on the identical issues. The information should be provided by an independent institution by certificate.

For both, operators inside and outside OECD countries the evidence needs to be up-dated annually particularly concerning any changes, such as

- Reporting on recycling efficiencies
- Information on all issues were changes take place or where operation requirements are not fulfilled such as
  - changes in the relevant permit requirements
  - changes in the applied techniques
  - monitoring/exceeding of emission limit values
  - accidents

6. Information on BAT

Relevant BREFs in the context of Battery recycling are:

- Reference Document on Best Available Techniques in the Non Ferrous Metals Industries, December 2001 [EIPPCB 2001]. A new draft of this BREF from November 2008 is available [EIPPCB 2008].

- Reference Document on Best Available Techniques on Emissions from Storage, July 2006 [EIPPCB 2006a].

- Reference Document on Best Available Techniques for the Waste Treatment Industries, August 2006 [EIPPCB 2006b].

Existing technical guidelines related to battery recycling have been analysed with respect to information on BAT for battery recycling. The following technical guidelines containing specific provision on batteries were identified and analysed:

- Technical Guideline on the Environmentally Sound management of Waste Lead Acid Batteries [SBC 2003]

- Austrian ordinance Management on Waste Treatment Obligations [MinEnv AT 2004]

A dedicated BREF on battery recycling does not exist. BAT in the field of battery recycling is not defined except for those processes that are explicitly described in one of the above mentioned BREF documents such as the recycling of lead-acid batteries (see [EIPPCB 2008]).

An additional information source which is relevant for BAT is information that is available on actually performed processes within the Community. There is only a limited number of dedicated processes in the battery recycling industry in the EU. The facilities carrying out these processes are each holding a valid permit and it can be assumed that they are operating in compliance with EU legislation on waste, environment and health & safety. Accordingly the actually carried out processes are representing the state of the art in battery recycling within the Community. Flow charts and short textual description of the treatment and recycling process steps the output fractions and their fate are provided in chapter 3.2 and in the Annex (section 10.6) as a valuable and specific expert information source on actually applied technologies in dedicated processes for battery recycling in addition to generally defined BAT.

This information has been established in close co-ordination with representatives from the battery recycling industry and could be used as a starting point for a further description of (best) available techniques and also for the consideration of the general impact of battery recycling processes on the environment as a whole.

However, it has to be clearly stated, that the information that has been compiled in the frame of the present project is not appropriate to evaluate the overall impact of battery recycling processes on the environment as a whole. Appropriate information would be necessary to enable an assessment of processes applied in battery recycling in a corresponding way and not with a single focus on the recycling efficiency.

Together with the core elements from BREFs and Technical Guidelines this information provides a practical and factual information source for experts for technical experts and economic actors.

7. Description of the core elements of BAT

The relevant core elements of BAT are described in the Annex as a factual source of information for technical experts in Member States and economic actors:

- BAT core elements identified from relevant BREFs are documented in the Annex, section 10.7.1
- BAT core elements identified from relevant guidelines and technical documents are documented in the Annex, section 10.7.2).

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Abbreviations

AlMn	Alkaline Manganese
ZnC	Zinc Carbon
HgO	Mercury oxide
ZnO	Zinc air
Li	Lithium
MnO	Alkaline Manganese
AgO	Silver oxide
LiMn	Lithium Manganese
NiCd	Nickel Cadmium
NiMH	Nickel Metal Hydride
Li-ion	Lithium Ion
PbA	Lead-acid
%	per cent (indication in per cent of mass if not stated otherwise)

1 Background and objectives

It is one long term goal of the European Union to become a recycling society that seeks to avoid waste and uses waste as a resource. With the revised Waste Framework Directive 2008/98/EC [10] life cycle thinking including the five step treatment hierarchy (waste prevention, preparation for reuse, recycling, recovery and disposal) has been further strengthened in order to ensure that negative environmental impact of waste generation and management is minimised throughout the entire life of resources.

As regards batteries the overall aim of optimised recycling has been further targeted by means of a revision of the related legislation. The new Batteries Directive 2006/66/EC, repealing Directive 91/157/EEC, came into force in September 2006. The transposition deadline for the Member States was set on 26 September 2008. Among other, the Directive applies to all types of batteries and accumulators, promotes a high rate of collection and recycling of waste batteries and accumulators, and aims at improvement in the environmental performance of all activities involved in the life-cycle of batteries and accumulators, including their recycling and disposal.

1. Member States have to ensure that, from 26 September 2009 at the latest, batteries and accumulators that have been collected are treated and recycled using the best available techniques. Recycling must exclude energy recovery.

2. Minimum treatment requirements and recycling efficiencies are laid down in Annex III to the Directive. Detailed rules regarding the calculation of recycling efficiencies shall be added to Annex III no later than 26 March 2010.

3. Treatment and recycling may take place outside the Member State concerned or even outside the Community, provided EU legislation on the shipment of waste is respected and treatment and recycling outside the EU adheres to treatment requirements that are equivalent to those within the EU.

In order to give guidance for a harmonised interpretation of the requirements of the Batteries Directive (2006/66/EC) the European Commission intends to lay down detailed implementation rules. Against this background, the Directorate General for Environment of the European Commission has launched a project with the objectives

- to collect and assess information and develop a possible method for the calculation of minimum recycling efficiencies,

- to provide information on Best Available Technology (BAT) and a description of treatment requirements,

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[10] Directive 2008/98/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 19 November 2008 on waste and repealing certain Directives, OJ L 312/3 from 22.11.2008

- to establish criteria to assess the conditions equivalent to the requirements of the Batteries Directive (2006/66/EC) that recycling processes outside the EU have to meet.

In order to achieve a broadly accepted project outcome, the results shall also be based on an intensive stakeholder consultation which includes collection of expertise, information exchange and discussion of project results in order to reach the above mentioned objectives.

Batteries and accumulators are the focus of the Batteries Directive (2006/66/EC) and this project. If not stated otherwise, throughout the present document, the term “battery” comprises both, batteries and accumulators.

2 Methodology and data collection

2.1 Methodology

The project approach was outlined along the project objectives and related tasks in order to provide sound information on the state of batteries recycling in the EU and to prepare a decision basis for European Commission proposals related to calculation of recycling efficiency, minimum treatment requirements, reporting and evidence for equivalency.

The first task, to develop a method for the calculation of recycling efficiency processes, is based on a survey of already existing calculation methods, stakeholder positions and technical background information. Taking account of this information the project team develops a calculation method based on a mass balance between waste batteries input and output of recyclates. For the proposed calculation method the definition of the term "recycling" is pursuant to the Batteries Directive 2006/66/EC. The calculation method for recycling efficiency is specifically related to the recycling processes available for the different types of batteries. On the basis of the calculation method a format for reporting recycling efficiencies is proposed.

The second task, dedicated to the identification of key parameters of best available techniques (BAT) and a more detailed description of minimum treatment requirements according to the Batteries Directive (2006/66/EC), was performed by means of an evaluation of existing documents and stakeholder consultation. The relevant parameters for BAT were identified from BREFs, relevant technical guidelines and information from stakeholders (see chapter 6). The suitability for the purposes of the Batteries Directive (2006/66/EC) has been assessed and the relevant core elements of BAT are described as a factual source of information for technical experts. On the basis of the technical background a detailed description of technically feasible and environmental sound parameters for the minimum treatment requirements according to the Batteries Directive (2006/66/EC) is proposed.

The third task focuses on the establishment of criteria that are suitable to assess the conditions equivalent to the requirements of the Batteries Directive (2006/66/EC) that recycling processes outside the EU have to meet (see chapter 7). To this end a selection of information needs (or criteria) has been established that are adequate to provide sound evidence that for waste battery exports a recycling operation takes place under conditions equivalent to the requirements of the Directive. On the basis of the established criteria a set of practical sound evidence is proposed that should be provided in order to prove that recycling operations taking place outside the EU meet the equivalent conditions as set out by the Batteries Directive (2006/66/EC).

The project work included an intense stakeholder consultation covering the process of information collection as well as the presentation and discussion of the project results. To this end a dedicated project website has been established and will be maintained at least until September 2009 (www.bipro.de/batteries-directive), a questionnaire survey including telephone contacts has been performed, several meetings with concerned stakeholders where organised and a stakeholder workshop was held on 20 January 2009 in Brussels. In this way up-to-date, practical and very useful information of the most relevant experts in the field of battery recycling has been made available for the purposes of the present study.

On 10 February 2009 the minutes of the stakeholder workshop and the draft final report were made available on the project website together with the proposed reporting forms for testing. The participants of the workshop and the TAC Members were informed on the publication and were invited to provide their comments by 20 February 2009. Comments received were taken into consideration for the formulation of this final report.

2.2 Data collection – Stakeholder consultation

2.2.1 Questionnaire survey

For initiating the stakeholder involvement a questionnaire has been prepared and distributed to relevant experts and stakeholders. The questionnaire was distributed to 112 stakeholders including battery recyclers, collection and recycling initiatives, relevant industry associations (EBPA, EUROBAT, EBRA, Recharge, ILA), NGOs and Member States (TAC members according to Batteries Directive 2006/66/EC).

The project team has received 32 completed questionnaires with up-to-date, practical and very useful information of the most relevant experts in the field of battery recycling. The information was used for the purposes of the present study.

A synopsis of the textual feedback is documented in the Annex of the draft final report (see section 9.3 of the draft final report).

2.2.2 Expert workshop

A stakeholder workshop was organised on 20 January 2009 in Brussels where the project results achieved so far were presented and discussed. A list of participants can be found is contained in the minutes of the workshop (see Annex 10.3).

The group of participants was composed of 3 European Commission representatives, 5 TAC members (including representatives/experts of Member States), 22 industry representatives and 3 consultants from the ESWI team. The stakeholder was open to all interested stakeholders. All those stakeholders who contributed to the questionnaire survey were specifically informed about the time and the place of the event. All other stakeholders were informed in the context of the questionnaire survey. A draft agenda and presentations were uploaded to the project website prior to the workshop.

A draft agenda and presentations were uploaded to the project website prior to the workshop. Presentations of the workshop are available at www.bipro.de/batteries-directive.

3 Current state and legal provisions for batteries recycling

3.1 Battery types and chemistry

The Batteries Directive (2006/66/EC) distinguishes between three battery types (see the Directive and [EC 2008]):

- Portable batteries

  Portable batteries are batteries that are sealed, can be hand-carried and are neither industrial nor automotive batteries.

- Industrial batteries

  Industrial batteries are batteries that are designed for exclusively industrial or professional uses or used in any type of electric vehicles.

- Automotive batteries

  Batteries used for vehicle starting, lightning and ignition.

For reasons of consistency and practicability the classification of batteries for the present report is done in line with the battery types as covered by the Directive.

According to a stakeholder comment it would be reasonable to consider batteries used in hybrid cars as automotive batteries and not as industrial batteries. In this context it is referred an answer of the non legally binding document of the Commission on questions and answers on the Batteries Directive (2006/66/EC): “There is a battery in hybrid vehicles that is used as an automotive starter for lighting and for ignition power. This is generally a 12 Volt battery (usually lead-acid battery). This battery is an automotive battery. There is another type of battery in hybrid cars used mainly for propulsion purposes and as a warm starter (Lithium ion or a Nickel Metal Hydride battery). As this battery does not have the function of automotive batteries, it does not fall under the definition of automotive batteries. It is used in a car that is partly powered by electricity, so it is used in some type of electric vehicle. It therefore qualifies as an industrial battery.“ [EC 2008]

The three types of batteries comprise various products and models with varying chemistry. This is of relevance for the availability of recycling options and the calculation of the recycling efficiency.

Table 3.1 gives an overview on relevant battery types, technologies and battery chemistry.

Battery type	Technology	
	Non rechargeable (primary)	Rechargeable (secondary)
Portable	▪ zinc-carbon (ZnC) ▪ alkaline manganese (AlMn) ▪ lithium-oxide (Li) ▪ button cells (zinc air, silver oxide, manganese oxide, lithium).	▪ nickel-cadmium (NiCd) ▪ nickel metal hydride (NiMH) ▪ lithium-ion (Li-ion) ▪ lead-acid batteries
	Represent around 75%* of portable battery segment	Represent about 25% of the portable battery segment.
Industrial	▪ alkaline manganese (AlMn) ▪ zinc-oxide (ZnO) ▪ lithium-oxide (Li)	▪ lead-acid batteries (standby, traction; 96% of industrial batteries) ▪ NiCd batteries (standby, motive power; 2% of industrial batteries) ▪ lithium-ion (Li-ion) ▪ lithium polymer ▪ other batteries (e.g. NiMH; 2% of industrial batteries)
Automotive		▪ lead-acid batteries

Table 3.1 Classification of battery types and technologies (* indication in per cent per mass)

Most relevant battery chemistry containing liquids and acids are lead-acid and vented NiCd batteries.

Detailed information on battery types and related market information is available from up-to date studies performed on behalf of the European Commission, DG Environment (see e.g. [BIO 2008]) and other literature sources (see e.g. [ERM 2006]).

Portable batteries are the classical consumer batteries. They are generally collected by means of public collection systems via collection boxes and containers set up in shops, schools and other public sites (e.g. civic amenity sites). Hence collected batteries are normally a mix of different types and models and need to be sorted before recycling can start. The wide variety of types and chemical composition requests a variety of recycling technologies and entails potential difficulties in meeting the required recycling efficiencies.

Industrial batteries can be huge. They are collected separately and can be directly directed towards the appropriate recycling process. Industrial batteries are mostly lead-acid batteries.

The same applies for automotive batteries for which a separate collection system is put in place. Currently automotive batteries are lead-acid batteries. Changes will arise when hybrid cars are increasingly put in place.

More than 90% of battery recycling concerns the recycling of industrial and automotive lead-acid batteries.

3.2 Dedicated processes for battery recycling

Dedicated processes for battery recycling are understood as recycling processes that aim specifically at the recycling of spent batteries.

Only a limited number of dedicated battery recycling processes are currently carried out by European battery recyclers. In close coordination with the relevant representatives from the battery recycling industry these processes are shortly described by means of flow charts showing the relevant input and output fractions and a short textual description of the treatment and recycling process steps, the output fractions and their fate.

The description is related to some frame conditions. Relevant for the recycling efficiency are the batteries consisting of one or more battery cells. Casings of batteries are part of the batteries. Battery packs and casings of battery packs are not part of the batteries. Liquids and acids are part of the batteries. Correspondingly, the system boundary that determines the start of the recycling process is illustrated in the flow charts according to the following presumptions:

- Removal of components belonging to the battery pack or ancillary parts is not considered being part of the recycling process.
- Removal of components belonging to the battery itself is considered as being part of the recycling process. This includes fluids and acids.

On the basis of the process descriptions and the flow charts the output fractions can be allocated case by case to the following categories:

- Products including by-products (accounted as recycled)
- Intermediate fractions (Some companies have indicated output fractions destined for further recycling. These fractions for recycling are intermediate fractions. The recycling process is not terminated for such fractions)
- Use for energy recovery (not recycled)
- Waste for disposal (not recycled)
- Emissions (not recycled)

This allocation enables an unambiguous allocation of output fractions from battery recycling processes in order to achieve a uniform and harmonised calculation of the recycling efficiency. Table 3.2 gives an overview on the most relevant battery recycling processes as reported by main recycling companies that are actually recycling waste batteries collected within the EU, on selected companies carrying out these or similar processes and the location of the corresponding companies. The recycling activities may be carried out at other locations.

Designation of the process	Selected companies carrying out the process or similar processes	Location of the company
1. Mechanical separation and subsequent Waelz process for ZnC and AlMn batteries (primary)	Redux GmbH DELA GmbH	DE DE
2. Thermal treatment separation and subsequent Waelz process for ZnC and AlMn batteries (primary)	Fernwärme Wien GmbH	AT
3. Pyrolysis and pyrometallurgical treatment for ZnC, AlMn and ZnAir batteries (primary)	Batrec Industrie AG	CH
4. Thermal treatment for button cells and hydrometallurgical treatment for ZnC and Alkaline batteries (primary)	Pilagest S.L. Revatech (mechanical/hydrometallurgic)	ES BE
5. Pyrometallurgical treatment for ZnC and AlMn batteries and NiMH accumulators (primary and secondary)	AFE Valdi	FR
6. Oxyreducer: Thermal process under reductive atmosphere for ZnC, AlMn and lithium batteries (primary)	Citron AG	CH
7. Cd-distillation for NiCd batteries (secondary)	Accurec GmbH SAFT Group S.N.A.M.	DE FR FR
8. Mechanical separation for NiMH accumulators (secondary)	Redux GmbH	DE
9. Pyro- and hydrometallurgical treatment for sorted Li-ion and NiMH batteries (secondary)	Xstrata Nickel	BE
10. Pyrometallurgical treatment for Li-ion and NiMH batteries (secondary)	Umicore	BE
11. Room temperature recycling process for AlMn, ZnC, ZnAir and Li-ion batteries (primary and secondary)	Recupyl	FR
12. Pyrometallurgical treatment for lead-acid batteries (secondary)	Approximately 30 secondary lead smelters throughout the EU	

Table 3.2: Overview on most relevant battery recycling processes, on selected companies carrying out these or similar processes and the location of the corresponding companies

These processes include some non-dedicated processes. Apart of these processes a limited number of other technologies may exist and further processes can be developed in future. In general the recovery of the metal content in a metallurgical process however, is the driving factor behind most processes in place. Further potentials for plastic compounds and liquids can partly be realised.

Specific information on dedicated processes (textual description, flow charts) and on selected individual battery recycling companies is available in the Annex (section 10.6).

3.3 Relevant definitions and wording from legislation

In order to have a common understanding of the project issues several terms have to be defined unambiguously and several general considerations are useful.

3.3.1 Batteries, battery packs

Batteries and accumulators are the focus of the Batteries Directive (2006/66/EC) and this project. If not stated otherwise, throughout the present document, the term “battery” comprises both, batteries and accumulators. The relevant definition is according to Article 3(1) of Directive 2006/66/EC:

> *“battery”* or *“accumulator”* means any source of electrical energy generated by direct conversion of chemical energy and consisting of one or more primary battery cells (non-rechargeable) or consisting of one or more secondary battery cells (rechargeable);”

According to Annex III, Part B of Directive 2006/66/EC the definition of the recycling efficiencies refers to the average weight of [...] batteries and accumulators. According to the definition in Article 3 of Directive 2006/66/EC “batteries” and “accumulators” consist of one or more primary or secondary battery cells. The recycling efficiency is therefore to be related to batteries consisting of one or several cells as a whole.

Furthermore the distinction between batteries and battery packs is an important aspect to take into account. The term “battery pack” is defined in Article 3(2) of Directive 2006/66/EC:

> *“battery pack”* means any set of batteries or accumulators that are connected together and/or encapsulated within an outer casing so as to form a complete unit that the end-user is not intended to split up or open;

According to Article 11 of Directive 2006/66/EC Member States shall ensure that manufacturers design appliances in such a way that “waste batteries and accumulators” can be readily removed.

Since “battery packs” are not intended to split up or open, Article 11 can be interpreted in such a way that the term “waste batteries and accumulators” comprise batteries as well as battery packs.

Thus there is no clear evidence from Directive 2006/66/EC if the recycling efficiency refers to “batteries” is including “battery packs” or not.

The position of the project team is given in section 4.1.2.1.

3.3.2 Recycling, recovery

The definition of recycling laid down in Article 3(8) of the Batteries Directive (2006/66/EC) is the following:

> *“recycling”* means the reprocessing in a production process of waste materials for their original purpose or for other purposes, but excluding energy recovery;

Material recovery is not specifically defined in the Batteries Directive (2006/66/EC), but included in this definition.

This definition differs from that applied in the revised Waste Framework Directive (2008/98/EC). The terms *“recycling”, “recovery”* and *“waste”* pursuant to Articles 3(17), 3(15) and 3(1) of the revised Waste Framework Directive 2008/98/EC are as follows:

> "*recycling*" means any recovery operation by which waste materials are reprocessed into products, materials or substances whether for the original or other purposes. It includes the reprocessing of organic material but does not include energy recovery and the reprocessing into materials that are to be used as fuels or for backfilling operations;
>
> "*recovery*" means any operation the principal result of which is waste serving a useful purpose by replacing other materials which would otherwise have been used to fulfil a particular function, or waste being prepared to fulfil that function, in the plant or in the wider economy. Annex II sets out a non-exhaustive list of recovery operations;
>
> "*waste*" means any substance or object which the holder discards or intends or is required to discard.

It is clearly stated in preamble 23 of Directive 2008/98/EC that the definition of the Batteries Directive (2006/66/EC) has to be applied for the determination of the recycling efficiency for batteries. The mentioned preamble lays down:

> "In order to verify or calculate if the recycling and recovery targets set in … … Directive 2006/66/EC …… on batteries and accumulators and waste batteries and accumulators [are met]… …, the amounts of waste which have ceased to be waste should be accounted for as recycled and recovered waste when the recycling or recovery requirements of that legislation are satisfied."

Considering the recycling of batteries, all recycling process output fractions originating from batteries after a final recycling stage and that are not used for energy recovery and that are not waste for disposal or an emission are recycled. Possible output fractions are "products", "materials" or "substances".

This shall be shown in the following illustration:

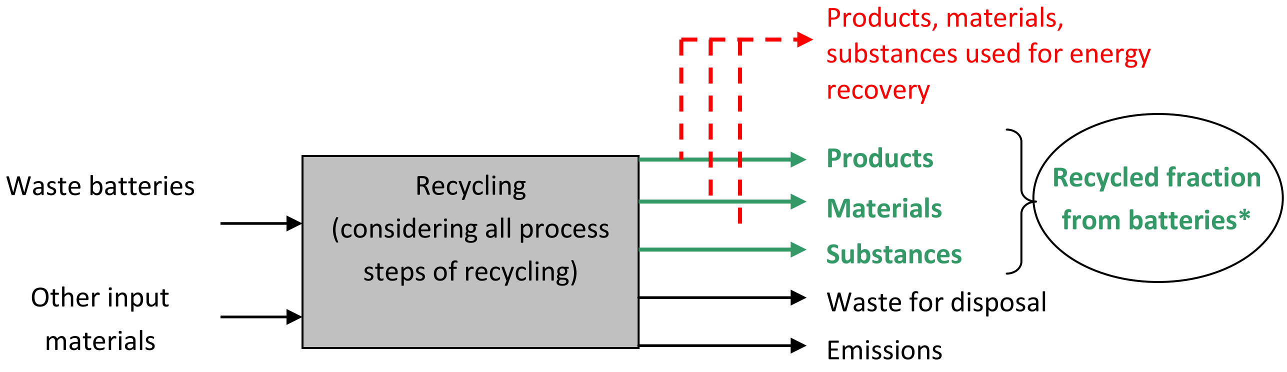

Figure 3-1 : Illustration of the term "recycling" in the sense of the Batteries Directive (2006/66/EC)
*** Regarding the recycling of batteries, only the share originating from batteries contributes to the recycling efficiency in the sense of the Batteries Directive (2006/66/EC)**

3.3.3 Products, by-products, substance, waste for disposal and emission

According to preamble 23 of Directive 2008/98/EC: "…, the amounts of waste **which have ceased to be waste should be accounted for as recycled and recovered waste** …… when the recycling or recovery requirements of …… are satisfied.""

Hence in Figure 3-1 the term

- "products" includes by-products in the sense of Article 5 of Directive 2008/98/EC;

- “materials” includes waste materials that have ceased to be waste in the sense of Article 6 of Directive 2008/98/EC.
- “substance”[11] is understood as any chemical element and its compounds in the sense of Article 2.1 of Directive 2008/01/EC (IPPC directive);
- “waste for disposal” is understood according to the definitions of Directive 2008/98/EC (see Article 3(1) and 3(19)). Annex I to the Directive sets out a non-exhaustive list of disposal operations;
- “emission” is understood as the direct or indirect release of substances from individual or diffuse sources into the air, water or land.

3.3.4 Treatment

According to Directive 2006/66/EC, Article 3(10), “treatment” means any activity carried out on waste batteries and accumulators after they have been handed over to a facility for sorting, preparation for recycling or preparation for disposal. In addition according to Annex III part A of Directive 2006/66/EC “treatment shall, as a minimum, include removal of all fluids and acids”.

3.3.5 Recycling efficiencies

The relevant wording related to the “recycling efficiencies” is laid down in Annex III part B of Directive 2006/66/EC:

> “3. Recycling processes shall achieve the following minimum recycling efficiencies:
>
> (a) recycling of 65 % by average weight of lead-acid batteries and accumulators, including recycling of the lead content to the highest degree that is technically feasible while avoiding excessive costs;
>
> (b) recycling of 75 % by average weight of nickel-cadmium batteries and accumulators, including recycling of the cadmium content to the highest degree that is technically feasible while avoiding excessive costs; and
>
> (c) recycling of 50 % by average weight of other waste batteries and accumulators.”

According to this definition the efficiency has to be achieved on “process” level (see also chapter 3.2) and by weight of the battery/accumulator (see definition above).

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[11] The term substance is defined here because (1) substances are possible outputs of recycling processes, (2) it is used in the definition of the term “emission” and (3) it is used for the criteria to determine the end of waste status of objects and substances.

3.3.6 Minimum treatment requirements

The relevant wording related to minimum "treatment requirement" is laid down in Annex III part A of Directive 2006/66/EC:

> "1. Treatment shall, as a minimum, include removal of all fluids and acids.
>
> 2. Treatment and any storage, including temporary storage, at treatment facilities shall take place in sites with impermeable surfaces and suitable weatherproof covering or in suitable containers."

3.3.7 Equivalent conditions

The relevant wording related to sound evidence for equivalent conditions is laid down in Article 15(2) of Directive 2006/66/EC:

> "Waste batteries and accumulators exported out of the Community … … shall count towards the fulfilment of the obligations and efficiencies laid down in Annex III to this Directive only if there is sound evidence that the recycling operation took place under conditions equivalent to the requirements of this Directive."

4 Method for the calculation of the recycling efficiency

4.1 Discussion of relevant issues related to the calculation of the recycling efficiency

According to Annex III, Part B of Directive 2006/66/EC recycling processes shall achieve defined minimum recycling efficiencies. For a common understanding of the calculation of the recycling efficiency several key parameter need to be discussed and harmonised rules for a common use of these terms need to be established. The relevant parameters are particularly related to the following questions:

- Where does the recycling process start and where does it end (system boundaries and “black-box” approach see section 4.1.1)?
- What is the relevant input to the recycling process (components of waste batteries to be considered see section 4.1.2; Water content see section 4.1.2.2; input reference value see section 4.1.2.3)?
- At which level shall the minimum recycling efficiencies be achieved (see section 4.1.3)?
- What are the relevant output fractions to be accounted/not to be accounted for the recycling efficiency (see section 4.1.2.4)?

These issues are discussed in more detail in the following chapters.

4.1.1 System boundaries

A battery recycling process is a production process for the reprocessing of waste batteries for their original purpose or for other purposes, but excluding energy recovery. The recycling efficiency of a recycling process is the percentage of the mass of output fractions accounting for recycling divided by the average weight of the battery input mass. According to the definition in chapter 3.3, the term “recycling process” of the Batteries Directive (2006/66/EC) has to be understood as the whole process of recycling starting from waste batteries as received after collection and eventual sorting until obtaining final fractions to be used for their original purpose or for other purposes, which do not undergo further treatment. This shall be illustrated in Figure 4-1. The system boundaries are defined by the waste batteries entering the whole recycling process on the one hand and by the output fractions leaving the whole recycling process. It is not relevant whether the whole battery recycling process is carried out at a single recycling plant or at several sites, in a single country or in several countries.

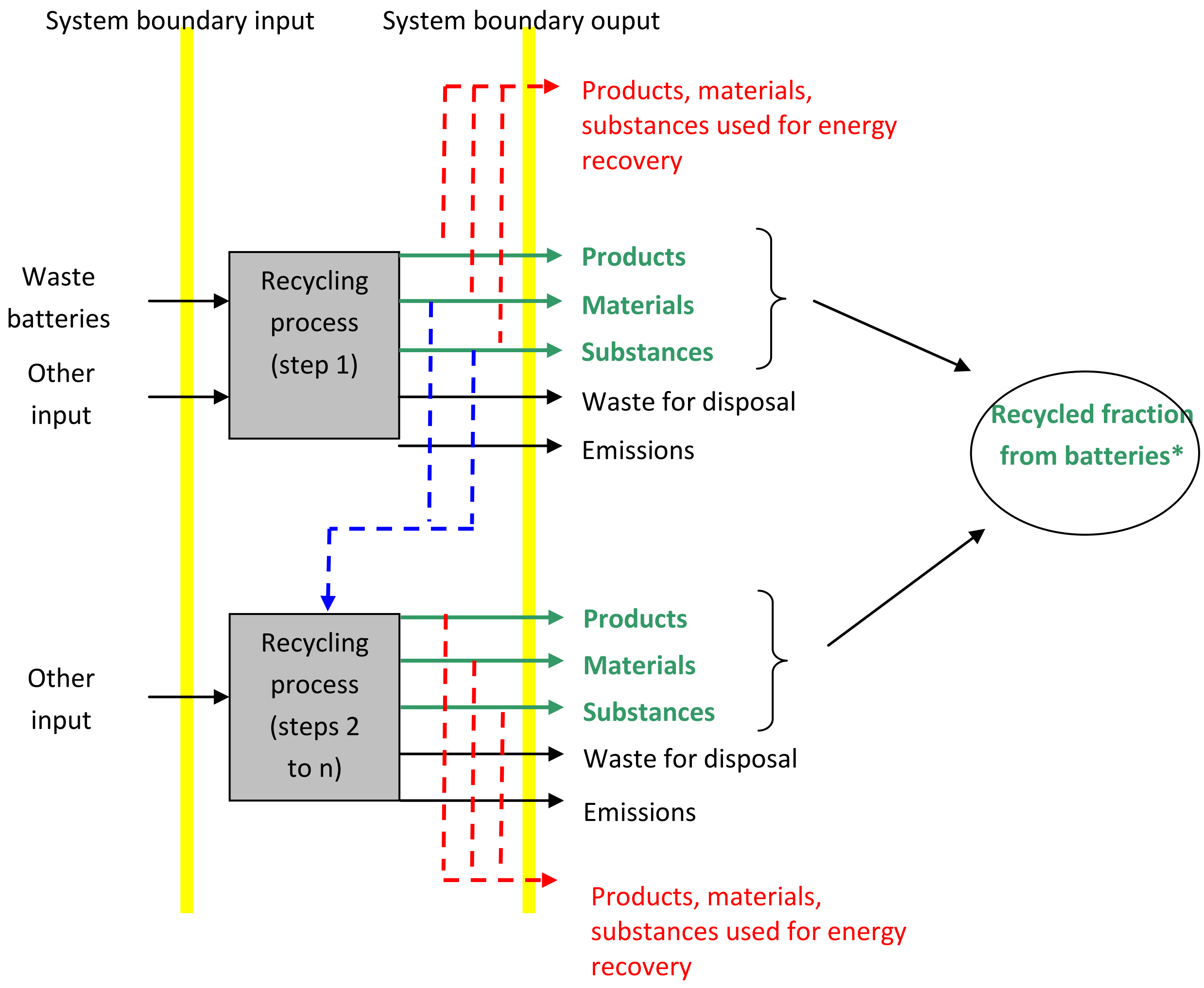

Figure 4-1 : Understanding of the term "recycling process" and related system boundaries in the sense of the Batteries Directive (2006/66/EC)
*** Regarding the recycling of batteries, only the share originating from batteries contributes to the recycling efficiency**

4.1.1.1 The input system boundary

Corresponding to the requirements for recycling efficiencies (different rates for different types), waste batteries have to be sorted at least into the fractions lead-acid batteries, NiCd batteries and other batteries.

Two basic topics however are to be discussed:

1. Where does the recycling process start?

2. Are acids and fluids to be accounted or not?

According to Article 3(10) of Directive 2006/66/EC, the term “treatment” means any activity carried out on waste batteries and accumulators after they have been handed over to a facility for sorting, preparation for recycling or preparation for disposal. As a consequence, the recycling process does not necessarily start with the activities carried out at the recycling facility.

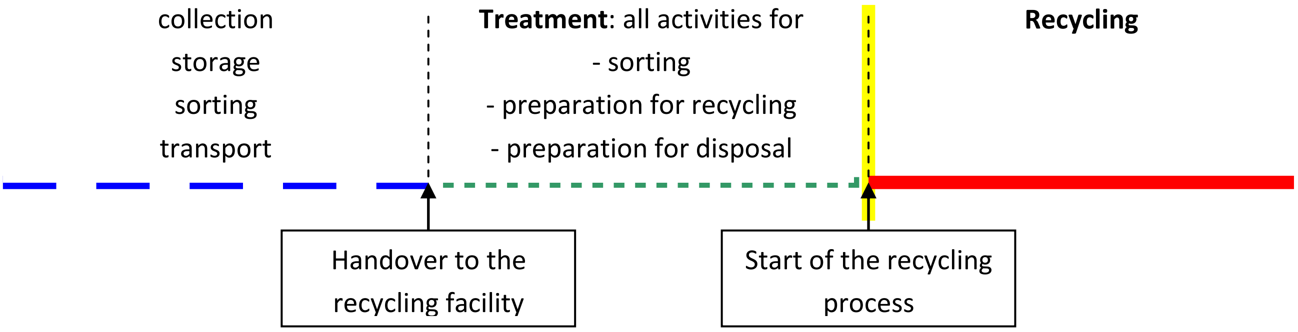

Figure 4-2: Illustration of the boundaries of treatment activities and the start of the recycling process (i.e. the input system boundary of the recycling process) in the sense of Directive 2006/66/EC.

In practice treatment at recycling facilities includes for example storage, handling, sorting or dismantling of battery packs, breaking of battery packs and separation of all those fractions that are not part of the battery itself.

It is debatable whether the removal of fluids and acids is to be allocated to the treatment activities or to the recycling process:

1. On the one hand, according to the wording of the Batteries Directive (2006/66/EC), treatment includes the removal of all fluids and acids (see Annex III, Part A: Treatment). Consequently removal of fluids and acids could be considered as being treatment and not recycling.

2. On the other hand, the recycling efficiency is related to the battery as the functional unit. A battery converts chemical energy directly to electrical energy. At least in wet batteries, this is only possible if the battery contains electrolyte. Therefore the electrolyte is component of the battery. As a consequence, the removal of fluids and acids can be regarded as being part of the recycling process because components of the battery are removed.

According to a joint industry position[12] the drainage and treatment of acids and liquids is rather a treatment than a recycling step. According to this position recycling starts with the production of the metal fractions after treatment steps.

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[12] joint industry statement of EBRA, Recharge and EPBA, December 2008

At the dedicated project workshop this question was discussed and it was agreed that the fluids and acids are components of the battery and should be considered in the calculation of the recycling efficiencies.

The project team proposes to consider the electrolyte as component of the battery. As a consequence, the removal of fluids and acids is regarded as being part of the recycling process. Fluids and acids should be accounted for the recycling efficiency (on a dry basis; see section 4.1.2.2).

The following table summarises the environmental, economic and social advantages and disadvantages of the proposed option.

Scope	Advantages	Disadvantages
Environment	Increased motivation to recycle fluids and acids because this will increase the recycling efficiency → saving of resources	In specific cases a negative environmental impact is possible e.g. due to energy need for recycling and transport of output products
Economy	Not relevant	Negative cost balance possible
Social	Not relevant	Not relevant

Table 4.1 : Environmental, economic and social advantages and disadvantages of the proposed option to include fluids and acids in the input mass versus the contrary option to exclude fluids and acids

4.1.1.2 The output system boundary

For the definition of the system boundary on the output side of the recycling process an endpoint of battery recycling needs to be determined. According to Article 3(17) of Directive 2008/98/EC the recycling process ends when the output fractions are definitely approved products or by-products, when they are a waste for disposal, material used for energy recovery or when they are released to air, water or land (see Figure 4-3). Conversely, a recycling process is not terminated as long as output fractions are generated that are destined for recycling.

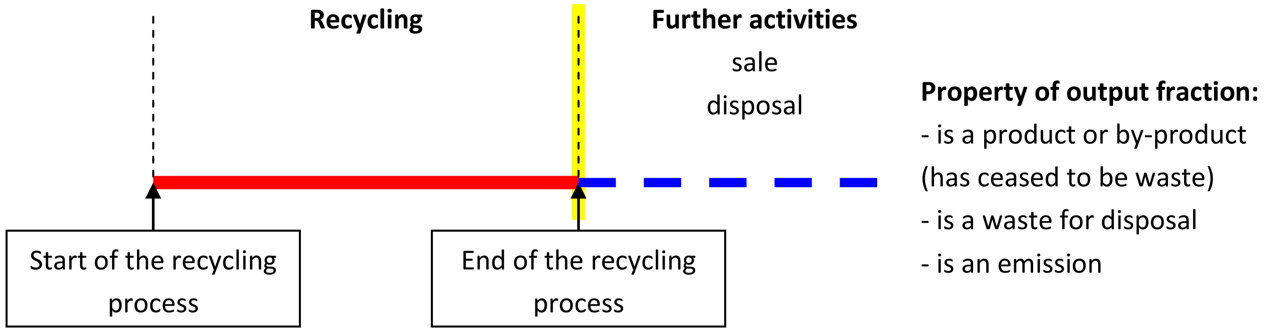

Figure 4-3: Illustration of the termination (i.e. the output system boundary) of a recycling process

Specific criteria can be applied to the output fraction in order to define the end of the recycling process. The recycling process can be considered as being terminated for the individual output fractions if:

- the output fraction ends its waste status according to Article 6 of Directive 2008/98/EC, i.e.

  (a) the substance or object is commonly used for specific purposes;

  (b) a market or demand exists for such a substance or object;

  (c) the substance or object fulfils the technical requirements for the specific purposes and meets the existing legislation and standards applicable to products; and

  (d) the use of the substance or object will not lead to overall adverse environmental or human health impacts.

- and the output fraction is a product

- or the output fraction is a by-product according to Article 5 of Directive 2008/98/EC, i.e.

  (a) further use of the substance or object is certain;

  (b) the substance or object can be used directly without any further processing other than normal industrial practice;

  (c) the substance or object is produced as an integral part of a production process; and

  (d) further use is lawful, i.e. the substance or object fulfils all relevant product, environmental and health protection requirements for the specific use and will not lead to overall adverse environmental or human health impacts.

- the output fraction is a waste for disposal in the sense of Directive 2008/98/EC

- the output fraction is an emission, i.e. a direct or indirect release of substances from individual or diffuse sources in into the air, water or land.

4.1.1.3 Conclusion on system boundaries

Following collection, transport, storage and sorting of waste batteries, the usual steps related to battery recycling could be considered the following:

(Step 1) Dismantling or breaking of battery packs, separation and treatment of fractions belonging to the battery pack

(Step 2) Separation of fractions belonging to the battery.

(Step 3) Production of metals, metal compounds and other recycled output fractions such as plastics, recovery products of electrolytes etc.

Based on the explanations and discussions above, within the present study, it is considered that the battery recycling process in the sense of Directive 2006/66/EC comprises steps 2 and 3. The removal of fluids and acids (as being fractions of the battery itself) is allocated to step 2. The termination of the recycling processes can be defined for each output fraction by means of the above mentioned specific criteria. Thus it can be enabled that the recycling process is followed uniformly from the start to its end.

On the basis of this information the output fractions can be allocated on a case by case analyses for each recycling process to the categories (a) product/material/substance originating from batteries input not used for energy recovery, (b) product/material/substance originating from batteries input used for energy recovery, (c) waste for disposal and (d) emission.

A question which is directly related to the definition of the system boundaries is whether the calculation of the recycling efficiency should be considered for the complete battery recycling or for individual steps.

Option (A) regarding the inputs and outputs of the complete recycling process altogether (in a "black-box" approach; see Figure 4-4) or

Option (B) regarding the inputs and outputs of all process steps individually (see Figure 4-5).

Both approaches are based on a mass balance of input and output weights.

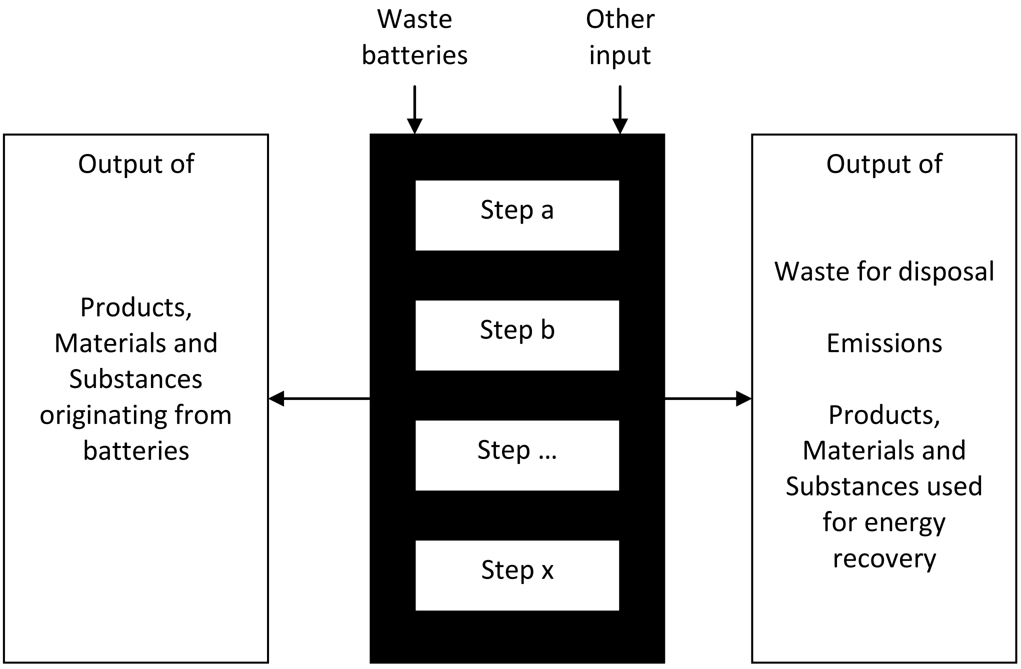

Figure 4-4: “Black-box” approach for the calculation of recycling efficiencies

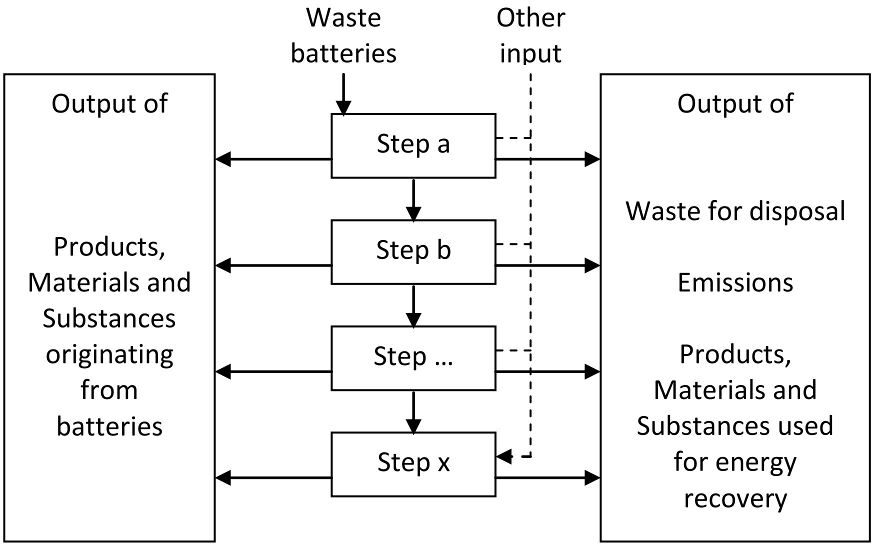

Figure 4-5: **Individual process step approach for the calculation of recycling efficiencies**

Considering the input and output fractions of each individual process step may have an impact on the calculation result of the recycling efficiency.

Intermediate fractions contribute to the total amount of output even if they are consumed in subsequent steps resulting in releases (example: the case of reducing agents, such as carbon in ZnC battery recycling which is an intermediate output fraction of a recycling step) and can be used as an input of a subsequent recycling step (function: combustible and reducing agent for metal reduction; the carbon is released as CO_2 from this process step). This issue shall be illustrated by the following figure:

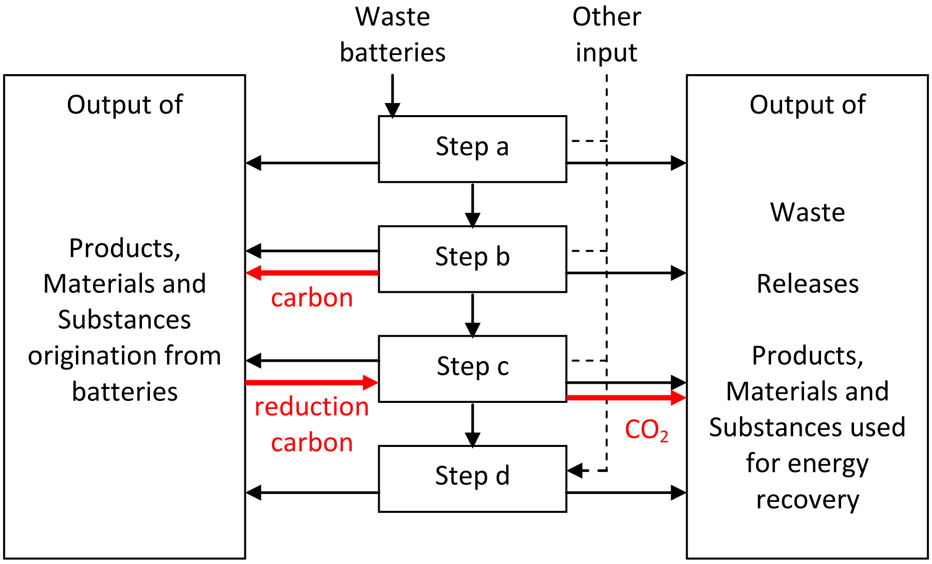

Figure 4-6:Illustration of the individual process step approach for the calculation of recycling efficiencies for the example of carbon in recycling of ZnC batteries

The "black-box" approach is a model that shall illustrate which input and output fractions shall be accounted for the calculation of the recycling efficiency. Irrespective of this the reporting on the recycling efficiency should cover all individual steps of recycling and all corresponding output fractions (see also the corresponding proposal for reporting formats in chapter 5.2). Accordingly the "black-box" approach will maintain full transparency at all stages of the process[13] and will allow to use information in order to enable appropriate reliability and transparency of reporting on recycling efficiencies and will allow to evaluate the effective environmental impact of the materials used as input to the process at all stages where an original battery material is entering a recycling step.

The case of carbon used as reducing agent for the recycling of ZnC batteries is only one example. It is also relevant for other battery chemistries and other reducing agents e.g. carbohydrates (e.g. plastics), Fe, Al or organic fluids.

A general question is whether intermediate fractions that are internally used and consumed within the recycling process (i.e. they are released as emission or as waste for disposal) can be accounted for the calculation of the recycling efficiency. Relevant intermediate fractions are not only reducing agents but also other substances used for example as oxidising agent or any other agent that is consumed within the recycling process.

The proposal of the project team which is justified in the draft final report is not to account such intermediate fractions for the calculation of the recycling efficiency. Many comments where made on this issue, particularly related to the accountability of carbon and plastics as reducing agents but also on other reducing agents. Comments related to the issue were provided by the following stakeholders:

1. EBRA, EPBA, Recharge (industry association)
2. Dela GmbH (battery recycler)
3. TAC Member Sweden
4. TAC Member Belgium
5. German EPA
6. GRS (collection system)
7. Revatech (battery recycler)
8. ILA (industry association)
9. Boliden (battery recycler)
10. Campine (battery recycler)
11. Xstrata (battery recycler)
12. Redux (battery recycler)
13. Recupyl (battery recycler)

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[13] Comment of TAC Member Belgium from 17.02.2009 on the draft report: "It must be clear that there must be reported about all the different treatment steps and intermediate fractions."

In order to appropriately consider this issue of intensive discussion, the main arguments of the comments provided are compiled in the Annex (see section 10.4), each followed by a short note of the project team related to the corresponding comment.

To summarise, as regards the accountability of such waste materials, which are consumed during a recycling process, such as reducing agents, several main arguments have been brought forward in favour of accounting intermediate fractions (pros):

P.1. Positive environmental aspects should be reflected in the recycling efficiency formula (for example the low energy need to extract metal from batteries compared to extraction from metal ores; substitution of raw materials and thus saving of resources).

P.2. Recycling options using reducing agents internally must not be discriminated versus options where the reducing agent is withdrawn from the process and sold. Internally used reducing agents should be accounted for.

P.3. The reducing agents that are present in a battery and that are used for the reduction of battery material but also of other materials (not originating from batteries, e.g. steel works dusts) should be accounted for the recycling efficiency.

P.4. Usually only a share of a reducing agent is indeed fulfilling its function as reducing agent. It is difficult to assess what proportion of the reducing agent is used as reducing agent. However, at least a share of the reducing agent should be accounted for recycling. According to conclusions from specific studies approximately 60% of plastic fractions are used as reducing agents in specific shaft furnace processes (see particularly [PLE 2006]).

P.5. Concerns have been expressed that the required recycling efficiencies according to Annex III, part B of the Batteries Directive (2006/66/EC) may not be achievable by specific BAT processes if reducing agents that are leaving the process as an emission are not accounted for the recycling efficiency.

P.6. The Batteries Directive (2006/66/EC) defines recycling as: "… reprocessing in a production process of waste materials for the original purpose or for other purposes, but excluding energy recovery…". The recycling efficiency calculation method must respect the definition of the Batteries Directive (2006/66/EC). The use of reducing agents originating from batteries within recycling processes has to be considered as reprocessing in a production process for other purposes.

Arguments against accounting waste materials, which are consumed during a process, such as reducing agents (cons):

C.1. The recycling efficiency is clearly a balance of output of recycled fractions and corresponding inputs. Output fractions that are released as an emission or as a waste for disposal or as a material for energy recovery from the recycling process as a whole cannot be accounted for the recycling efficiency.

C.2. The calculation of the recycling efficiency is not an instrument that aims at the assessment of the (environmental) performance or of the energy efficiency of a recycling process. It can be used to reflect upon one specific aspect of the environmental performance (i.e. on the recycling efficiency). Therefore the recycling efficiency formula should not reflect any other aspects (e.g. the saving of resources or energy) than a mass balance of accountable input and output fractions.

C.3. Recycling options using reducing agents internally do not discriminate options where the reducing agent is withdrawn from the process and sold. Reducing agents that are sold (as an intermediate output fraction for further recycling) must be traced and their recycling efficiency has to be reported under the same conditions as internally used reducing agents. If they are used for the same purpose as internally (e.g. as reducing agents) and are finally emitted, they should not be accounted for the recycling efficiency.

C.4. Reducing agents have only a partial function as reducing agent. They also contribute as combustible to the process. This is incineration or use for energy recovery which is per definition excluded from recycling.

C.5. In order to avoid possible contradictions with the definition of recycling in the Batteries Directive (2006/66/EC) (including reprocessing for other purposes) it could be considered to account that share that is actually used as reducing agent. Using carbon for reduction purposes in metallurgical processes represents a partly chemical/energetic recovery. Rombach & Friedrich [IME 2007a] point out that even if one would accept the share of carbon that is used for reduction (chemical recovery) as “recycling” there are severe difficulties determining the actual degree of carbon being used for reduction in a certain process (rotary hearth furnace, waelz kiln, mini shaft furnace...). The results from individual attempts to quantify the share that is actually used as reducing agents can not be simply transferred on battery recycling processes. A stoichiometric approach seems to be appropriate to quantify the share of the reducing agent that is actually used as reducing agent.

C.6. In specific cases concerns have been expressed that currently used techniques for battery recycling (among these defined BAT) cannot achieve the required recycling efficiencies if reducing agents will not be accounted for the recycling efficiency. According to the assessment of several example calculations the recycling efficiencies will be achievable. This assessment is based on the information provided by individual stakeholders including e.g. information on the use of the by-product slag for purposes other than disposal or landfill construction.

C.7. The proposal is not contradictory to the definition of recycling in the Batteries Directive (2006/66/EC). The proposal aims to stay consistent with the logical approach and thus not to account emissions (e.g. to the air) for the calculation of the recycling efficiency. This does not prevent to use waste materials for their original purpose or for other purposes (e.g. carbon as reducing agent) and to consider this as recycling. However it has to be stated that - according to the proposal - the use of reducing agents that are finally emitted would not increase the recycling efficiency.

C.8. If waste material used as reducing agents and consumed within the recycling process will be accounted for the recycling efficiency this will not motivate for material recycling e.g. plastics. This can be considered being contradictory to the waste hierarchy according to Directive 2008/98/EC.

The general opinion at the stakeholder workshop was that the "black-box" approach seems generally being preferable if a solution can be found for internally used fractions in order to avoid counterproductive activities such as the sale and re-buy of intermediate fractions. Sale and recycling efficiency-buy is not really a viable option as sold intermediate fractions have to be followed within the recycling process as internally used fractions (see argument C.3).

Considering the pros and cons, the proposal of the project team is to apply the "black-box" approach in a strict sense and not to account the use of intermediate fractions that are consumed during the process for the recycling efficiency (option A).

The following table summarises the environmental, economic and social advantages and disadvantages of the proposed option versus the option to apply an individual step approach.

Scope	Advantages	Disadvantages
Environment	Increases the motivation and/or necessity to recycle the accountable output fractions or to improve the actual use of output fractions (e.g. to use slag as a construction material instead of disposal)	1) If certain processes would be substituted by others these are not necessarily environmentally preferable. Explanation: The method for the calculation of the recycling efficiency is not an instrument that aims at the assessment of the (environmental) performance of a recycling process. It can be used to reflect upon one specific aspect of the environmental performance (i.e. on the recycling efficiency). As a consequence the overall environmental performance of a process with a lower recycling efficiency may be higher compared to another process with a higher recycling efficiency but other environmental drawbacks (for example high energy consumption or high demand of primary resources). 2) Output fractions that are released as an emission would be accounted for the recycling efficiency. Explanation: Large proportions of carbon or plastics that are used as input material to the battery recycling process are released as CO_2 emission to the atmosphere. In the individual step approach these emissions would be accounted for the recycling efficiency. 3) Output fractions that are used for energy recovery would be accounted for the recycling efficiency.

Scope	Advantages	Disadvantages
		Explanation: The most relevant reducing agents such as carbon or plastics have only a partial function as reducing agent. They also contribute as combustible to the process. This is incineration or use for energy recovery which is per definition excluded from recycling and should therefore not be accounted for the recycling efficiency.
Economy	Economic gains for certain process types possible if other process types loose competitiveness. Explanation: If certain companies that are carrying out processes that have difficulties to achieve the required recycling efficiencies and will have to reduce or shut down their recycling activities due to the proposed option other companies will be able to increase their capacities and their economic gains. Such difficulties could for example arise under specific conditions in the case of the recycling of ZnC and AlMn Batteries or lead acid batteries if carbon and/or the plastic fraction is used as reducing agent and other relevant fractions are not recycled.	1) Concerns have been expressed that the required recycling efficiencies may not be achievable by specific processes (some of these are BAT) if reducing agents that are leaving the process as an emission are not accounted for the recycling efficiency[14] → economic losses for certain process types possible 2) Concerns have been expressed that discrimination is possible of processes where an intermediate fraction is used internally versus processes where the intermediate fraction is withdrawn from the process and sold
Social	Job gains in certain process types possible	Job losses in certain process types possible

Table 4.2 : **Environmental, economic and social advantages and disadvantages of the proposed option to apply the "black-box" approach in a strict sense (no accountability of intermediate fractions such as reducing agents versus the contrary option to apply the individual step approach and to account intermediate fractions such as reducing agents)**

According to the estimation of the project team, the recycling efficiencies as required according to Annex III, part B of the Batteries Directive (2006/66/EC) will be achieved without taking reducing agents into account in actually performed recycling processes. This estimation is related to those selected cases where corresponding concerns have been expressed and is based on the information provided by individual stakeholders including e.g. information on the actual use of the by-product slag. Changing conditions e.g. for the use of slag may lead to altered results of this estimation. Future reporting will show the results of the recycling efficiency calculation in practice and according to technical progress. The practical results from reporting will enable to evaluate the appropriateness of the required recycling efficiencies. Based on the experience gained in Member States it may be necessary to adjust the recycling efficiencies as required according to Annex III, part B of the Batteries Directive (2006/66/EC).. In the view

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[14] The project team does not expect that the required recycling efficiencies will not be achievable if this option is chosen.

of the project team such an adjustment should generally consider all possible options, A to increase, B to maintain or C to decrease the requirements concerning the recycling efficiencies. A possible adjustment should be based on a thorough assessment of the reported recycling efficiencies at European level. It should also take into account the overall environmental performance of the concerned battery recycling processes and possible socio-economic consequences.

However the project team acknowledges the relevance of the above mentioned pro arguments and would like to note that also another option could be considered, i.e. to account that share of reducing agents that is actually used for reducing for the recycling efficiency.

If the decision will be taken for this option the following aspects should be considered:

- Results from individual attempts to quantify the share that is actually used as reducing agents can not be simply transferred on other battery recycling processes.
- A stoichiometric approach[15] seems to be appropriate to exactly quantify the share of the reducing agent that is actually used as reducing agent. Based on the share of oxidised substances that have to be reduced within a process a stoichiometric calculation enables to exactly determine the amount of reducing agent that is indeed required as reducing agent. This share could be accounted for the recycling efficiency
- The quantification should be made on the basis of an independent scientific stoichiometric expertise for each specific battery recycling process (if required or desired). Such expertise could be provided by independent institutions with appropriate chemical and technical know how such as universities or consulting engineers. The correctness of the expertise could be verified by the competent licensing authority. The costs for such individual scientific expertise seem to be economically reasonable. Estimated costs depend on the complexness of the concerned process and are estimated to range from several hundred to several thousand euros per expertise.

The following table summarises the environmental, economic and social advantages and disadvantages of the option to apply the “black-box” in a strict sense (no accountability of intermediate fractions such as reducing agents) versus the option to apply the “black-box” approach but to account intermediate fractions (such as reducing agents) to a certain share (upon scientific and independent certification). Some of the advantages and disadvantages are similar to those outlined in Table 4.2 but have lower relevance.

Scope	Advantages	Disadvantages

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[15] Stoichiometry is based on the calculation of quantitative relationships of reactants and reaction products in a balanced chemical reaction. Since chemical reactions can neither create nor destroy matter, nor transmute one element into another, the amount of each element must be the same throughout the overall reaction. For example, the amount of element X on the reactant side must equal the amount of element X on the product side. In the case of reducing agents in battery recycling a stoichiometric approach enables to exactly quantify how much reducing agent (e.g. carbon) is required in order to reduce a metal oxide to metal. In battery recycling the reduction of metal oxides to metal is necessary for the desired separation of the metal.

Scope	Advantages	Disadvantages
Environment	Increases the motivation and/or necessity to recycle the accountable output fractions or to improve the actual use of output fractions (e.g. to use slag as a construction material instead of disposal)	1) If certain processes would be substituted by others these are not necessarily environmentally preferable 2) Output fractions that are released as an emission would be accounted for the recycling efficiency
Economy	Economic gains for certain process types possible if other process types loose competitiveness	1) Concerns have been expressed that the required recycling efficiencies may not be achievable by specific processes (some of these are BAT) if reducing agents that are leaving the process as an emission are not accounted for the recycling efficiency[16] → economic losses for certain process types possible 2) Discrimination of processes where an intermediate fraction is used internally versus processes where the intermediate fraction is withdrawn from the process and sold (and thus possibly – depending on its actual use – accountable for the recycling efficiency) 3) Costs for scientific and independent certification
Social	Job gains in certain process types possible	Job losses in certain process types possible

Table 4.3 : Environmental, economic and social advantages and disadvantages of the option to apply the "black-box" in a strict sense (no accountability of intermediate fractions such as reducing agents) versus the option to apply the "black-box" approach but to account intermediate fractions (such as reducing agents) to a certain share (upon scientific and independent certification)

4.1.2 Components of waste batteries to be considered in the calculation

4.1.2.1 Outer casings/external jackets of batteries and of battery packs

The definition of the terms "battery" and "battery pack" according to the Batteries Directive (2006/66/EC) is given in section 3.3.1.

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[16] The project team does not expect that the required recycling efficiencies will not be achievable if this option is chosen.

In a battery (consisting of one or several cells) the external jacket or outer casing of the battery is aiming at ensuring the mechanical integrity of the battery and its proper functioning. There are even cases where the external jacket is one of the electrical poles of the battery. After removing its external jacket/part the battery cannot function anymore.

Three examples of batteries (consisting of one or more cells and enclosed in an external jacket) are illustrated below in Figure 4-7, Figure 4-8 and Figure 4-9.

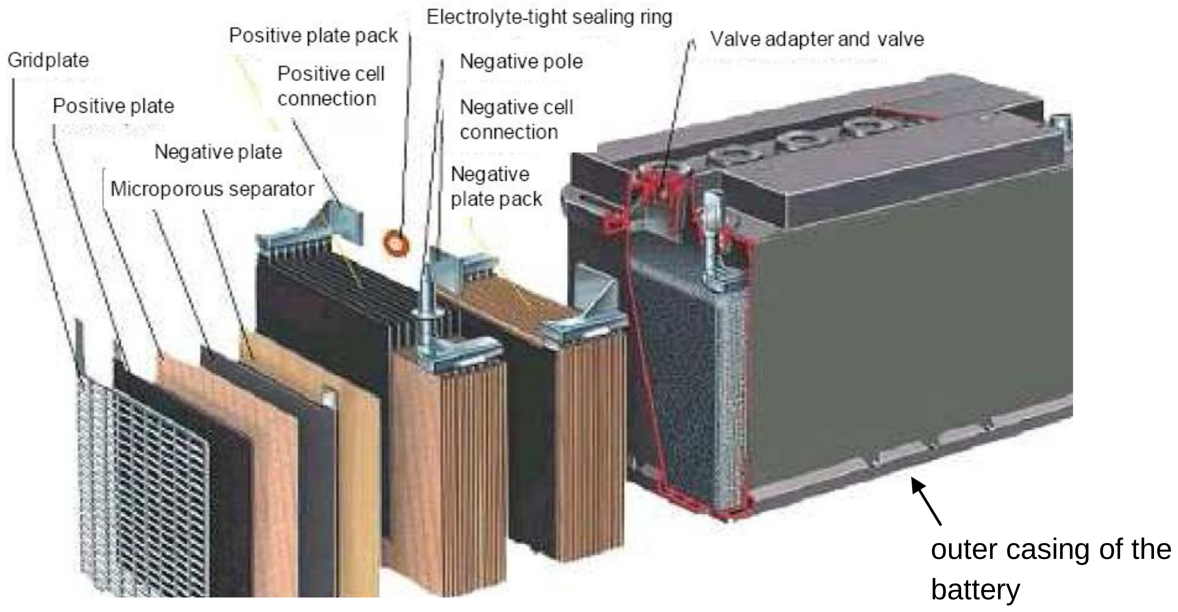

Figure 4-7: Components of a typical lead-acid battery source [BIO 2008]

A typical lead-acid battery consists of several cells within an outer casing of the battery. The whole battery is the relevant input reference for the recycling process. A battery pack would consist of several such batteries that are connected to each other and/or are encapsulated in an additional outer casing that the end-user is not intended to split up.

Figure 4-8 illustrates the components of a typical sealed NiCd battery. The outer casing of the battery is part of the battery.

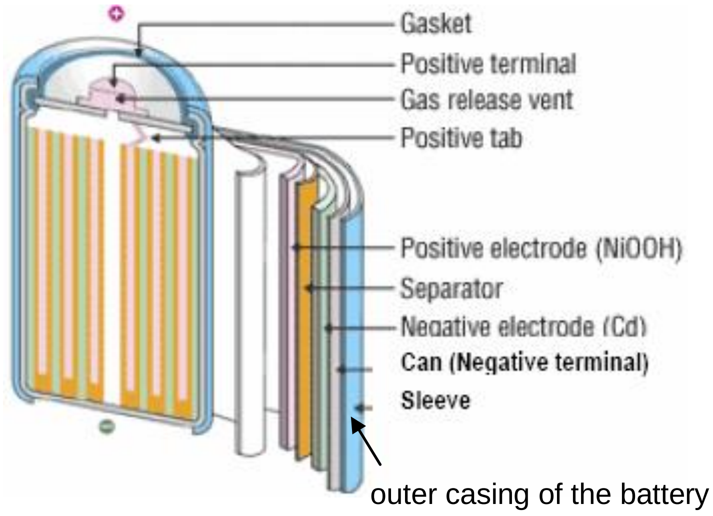

Figure 4-8: **Components of a typical sealed NiCd Battery (source: Mr. J.-P. Wiaux, Recharge, Jan 2009)**

Figure 4-9 illustrates the components of a typical vented NiCd battery. The outer casing of the battery is part of the battery.

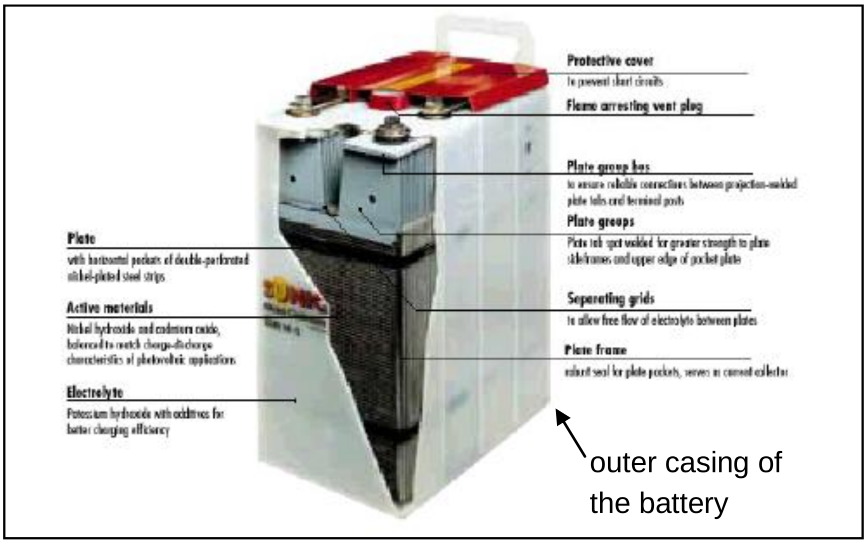

Figure 4-9: **Components of a typical vented NiCd Battery (source: Mr. J.-P. Wiaux, Recharge, Jan 2009)**

Two examples of packs of portable batteries are illustrated in Figure 4-10.

Figure 4-10: Examples illustrating packs of portable batteries

The role of the outer casing of the battery pack is to hold mechanically the assembly of batteries in order to give the appropriate geometry for fitting into the appliance while insuring an electrical contact.

Outer casings of a battery pack are customer specific add-ons which are built to ensure the battery operates properly under demanding operating conditions (protection against heat, impact, dust, humidity, water, electrical insulation…). Outer Casings also often ensures the battery is securely fastened to the equipment to which it supplies power. Finally, such Outer Casings often allow the battery to work within a rack structure so as to ensure easier access and maintenance.

Such Outer Casings are made from a wide variety of different materials (woods, metals, plastics) depending on the exact customer requirements. The removal of an outer casing of a battery pack does not destroy the electrochemical properties of the individual batteries inside the pack.

A treatment operation can be carried out on battery packs after they have been handed to a facility for sorting and/or preparation for recycling. In this case, the removal of the outer casing would liberate the batteries that can be further treated in the recycling process.

Two examples of packs of industrial batteries are illustrated in Figure 4-11.

Figure 4-11: Examples illustrating packs of industrial lead-acid batteries

The role of the outer casing of the battery pack is to hold multiple batteries in a single pack. The removal of an outer casing of a battery pack does not destroy the electrochemical properties of the individual batteries inside the pack.

According to some representatives of the lead-acid sector the relevant input for the recycling efficiency should be the battery pack. Particularly in the case of industrial lead-acid batteries one or several batteries are often encapsulated in outer steel casings that are recycled. The steel casings contribute approximately 1.5% to the battery input weight. It has been suggested that a differentiation should be made between lead-acid batteries and all other batteries. According to this suggestion components of battery packs should be taken into account for the recycling efficiency of lead-acid batteries but not for other batteries.

According to some industry representatives the relevant input for the recycling efficiency of portable batteries should be the cell. The wording “cell” which is frequently used by industry representatives means often the term “battery” in the sense of the Batteries Directive (2006/66/EC) which consists of one or several cells and includes the outer casing of the battery[17]. The project team assumes that the position to relate to the “cell” means the battery consisting of one or several cells.

According to the opinion of the project team and in order to enable a uniform basis for the calculation of the recycling efficiency a differentiation for different battery types is not necessary. As stated in chapter 3.3.1 the recycling efficiency is related to batteries. Relevant for the recycling efficiency are strictly the batteries consisting of one or more battery cells. The external jackets are part of the batteries. Liquids and acids are part of the batteries. Components of the battery packs are not part of the batteries. This definition applies to batteries from the lead-acid sector as well as for NiCd and other batteries.

To conclude the project team proposes the following:

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[17] (see e.g. comments on the draft final report by EBRA et. al 18.02., point 2.1: “In an electrochemical cell, (a battery) …”)

Relevant input is the battery consisting of one or several cells. The outer casing or external jacket of a battery is to be regarded as part of the battery and should be taken into account for the recycling efficiency.

Parts such as the following (if these are not integral parts of the outer casing) can be regarded not being part of the battery and should not be accounted for the recycling efficiency (non-exhaustive list):

- Components of the battery pack
- Electrical components (switches, LEDs[18], fuses, wires…) which are supplied to provide monitoring and communication functionalities to a complete power back-up system
- Racking systems in which the batteries are embedded to ensure structural integrity
- Components for impact protection or easy maintenance

The following table summarises the environmental, economic and social advantages and disadvantages of the proposed option.

Scope	Advantages	Disadvantages
Environment	Increased motivation to recycle metals and metal compounds from the batteries. The aim of Directive 2006/66/EC remains in the focus.	Decreased motivation to recycle components of the pack and ancillary parts in order to achieve the required recycling efficiency.
Economy	Positive effects possible if components need not to be recycled if economically not reasonable.	Concerns have been expressed that the required recycling efficiency cannot be achieved pack components (e.g. steel casings) are not accounted for the recycling efficiency[19] → economic losses theoretically possible
Social	Not relevant	Job losses theoretically possible

Table 4.4 : Environmental, economic and social advantages and disadvantages of the proposed option to regard the outer casing of a battery as a part of the battery but to exclude the components of the battery pack and ancillary parts versus the contrary option to include the pack and ancillary parts that are collected together with the batteries

Although throughout this report it is suggested that parts belonging to battery packs are not regarded for the calculation of the recycling efficiency, there is one reason for which the project team proposes to also consider the option to account the amount of waste batteries as they are collected - and thus including the mass of components of battery packs - as input reference. This would enable the comparison of the amounts of batteries collected and the actually recycled fraction thereof.

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[18] LED = Light Emitting Diode

[19] Which is not expected by the project team

This would be furthermore in line with the interpretation that the recycling efficiency which refers to the average weight of “batteries and accumulators” (Annex III, Part B) comprises waste batteries and accumulators as they are collected (including also the components of battery packs). This is in line with an industry position. It is mentioned that more than 90% by weight of rechargeable batteries are placed on the market as removable packs or exchangeable individual cells. Applications like laptop computers, mobile phones and cordless tools are equipped with a removable pack. According to the industry position it has never been the intention of the legislator to address the disassembly of battery packs in the context of removal and removability (Recital 18 and Article 11). As a logical consequence if the battery packs are included in the term “batteries and accumulators” in Recital 18 and Article 11, they could be included in the term “batteries and accumulators” of Annex III, Part B (definition of recycling efficiency).

A problem with the definition of battery and battery packs may occur in the context of future developments in new types of batteries such as those used e.g. for electric or hybrid cars. According to information from industry the share of plastics in this type of batteries may increase to high degrees. If these components would be taken into consideration for the calculation of the recycling efficiency, the required efficiencies might already be achieved by recycling the plastic share.

4.1.2.2 Water content

Portable batteries contain between zero and approximately 13 % of water (see [ERM 2006]). According to industry information industrial batteries may contain up to 25 % of water. Water is usually evaporated during the recycling process or passes a physico-chemical treatment prior to its release. Finally it usually enters the natural water cycle. The operating permits of recycling plants allow the release of water to the environment, either as a liquid effluent (after a physico-chemical waste water treatment) or as vapour (after an off-gas treatment).

Two relevant options concerning the consideration of the water content in the input for the calculation of the recycling efficiency are:

Option A: Input is defined as the mass of waste batteries including all liquids and including its water content (wet basis)

Option B: Input is defined as the mass of waste batteries including all liquids but excluding its water content (dry basis)

These options were discussed at the dedicated project workshop and the agreement within the audience was on option A. According to other industry statements an appropriate option would also be Option B. Option C is not relevant any more

The intention of the requirements for recycling of the Batteries Directive (2006/66/EC) is not the recycling of water to products. Water is usually released as an emission (treated off gas or as treated waste water to air or to receiving water) from the recycling process (see also discussion in section 4.1.2.4).

One exception is for example the recovery of sulphuric acid from lead-acid batteries. In specific cases the acid is recycled and sold including its water content. The water is then component of the product.

According to the position of some industry stakeholders, water that originates from batteries and that leaves the recycling process in an approved product from the process (e.g. sulphuric acid) should be accounted for the recycling efficiency. In these cases the input could be defined as the mass of waste batteries including all liquids but excluding its water content (dry basis) except the water content that ends up in the approved product.

The project team proposes option B in order to exclude water from the calculation of the recycling efficiency. However it has to be noted that liquids and acids are accounted on a dry basis for the recycling efficiency.

The following table summarises the environmental, economic and social advantages and disadvantages of the proposed option.

Scope	Advantages	Disadvantages
Environment	Not relevant as water is emitted only after physico chemical treatment and according to approved quality criteria.	Negative effects possible if the recycling efficiency will be achievable too easy
Economy	Concerns have been made that if water will be included in the calculation it will be difficult to achieve the required recycling efficiency. Due to the proposed option the recycling efficiency will usually increase → less efforts required to achieve the recycling efficiency	Not relevant
Social	Not relevant	Not relevant

Table 4.5 : Environmental, economic and social advantages and disadvantages of the proposed option to define the relevant input as the mass of waste batteries including all liquids but excluding its water content (option B: dry basis) versus the contrary option to define the mass of waste batteries including all liquids and its water content (option A: wet basis)

The proposal to calculate on a dry basis will usually increase the recycling efficiency as the relative shares of the other battery components increase and contribute more to the recycling efficiency. Assuming e.g. a water content of 13% and a recycling efficiency of 50% of material on a wet basis (option A) corresponds to a recycling efficiency of approximately 57% (50/0.87) on a dry basis (option B).[20]

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[20] Example calculation: 100 kg battery input mass is recycled to 50 kg of output fractions accounting for recycling. The input mass includes 13 kg water.
Calculation a, wet basis: 50 kg output / 100 kg input = 0.5 → 50% recycling efficiency.
Calculation b, dry basis: 50 kg output / (100 kg - 13 kg) input = 0.57 → 57% recycling efficiency.

The proposal of the project team is related to some practical issues such as:

- The mass of batteries being collected and entering the recycling process is not identical with the input mass for the calculation of the recycling efficiency. The water content must be quantified and subtracted from the input mass (the same is the case for the mass of packs, ancillary battery equipment and impurities that are collected together with the batteries).
- Quantification of the water content may be difficult but is feasible on the basis of representative sampling and analyses or a database on average water content based on industry information or literature (see Annex 10.5).
- What happens if batteries are already drained when they are receipt? Electrolytes are components of batteries and the efficiency of their recycling has to be reported. If batteries are drained prior to the reception at a recycling facility, it has to be traced back what has happened to the electrolyte.

4.1.2.3 Elemental composition

The general proposal by the project team to perform the calculation of recycling efficiencies on compounds (for plastics and paper etc.) and elemental level (for metals, for C, O and H from hydroxides, binder, graphite, electrolyte, etc.) has been agreed by the audience of the stakeholder workshop on 20 January 2009.

For the calculation of the recycling efficiency as a mass balance at an elemental level it has to be defined whether input materials considered should be those elements and compounds contained in new batteries (A) or those in collected (spent) waste batteries (B).

Waste batteries may contain materials which were generated by different chemical reactions during the use of the batteries. However, for particular battery chemistries the elemental composition remains identical and it seems not practical to analyse the composition of the battery scrap.

The joint industry position [EBRA, EPBA, RECHARGE, 2008] states that for portable and other dry batteries, the most reliable information to describe battery composition at an elemental level is the average composition of an unused battery.

On the other hand in the case of lead-acid batteries the relation of the elemental composition may change due to changes in the water content of lead-acid batteries. Furthermore it was stated that in the case of other batteries the substance composition may change but the elemental composition remains identical.

Another point raised was that in some cases the technical development of specific batteries is rather fast and the composition of newly developed batteries may differ from that of collected batteries due to the technical development and related changes in the elemental composition.

A pragmatic way for the determination of the element composition of batteries would be to generate a database on the material composition (including the H_2O content) of batteries and or waste batteries on the basis of data provided by battery manufacturers and literature.

Industry associations (Recharge, EPBA) offer to provide a database (including regular up-date) on the chemical composition of different battery types (chemistry) as placed on the market on an elemental level. Based on this and knowing the battery mix that is used in a certain recycling process it will be possible to determine the composition of the relevant input to recycling processes on an elemental basis for most types of batteries.

There are clear differences in the batteries market mix. Eastern European countries still use more NiCd and ZnC batteries that Western European countries for example. So, in order to enable the quantification of the input flows of elements and compounds into a specific recycling process, it is necessary that each recycler evaluates and documents the battery mix entering his specific recycling process. This can be realised by continuous or representative sampling of the actual waste battery input.

EPBA offers to supply information on the average market mix for primary batteries according to national market conditions. EPBA and RECHARGE furthermore offer to supply a market share of portable rechargeable batteries. This information will be regularly updated. It could be used to check plausibility of the battery mixes reported by the recyclers.

The Annex contains a compilation of information on the chemical composition of batteries (see section 10.5). Information on the assumed composition of collected batteries is also given in a study on battery waste management life cycle assessment ([ERM 2006], see Tables 2.12 to 2.23 of the study).

Although, there is a statement of a Member States representative proposing that the batteries input should be defined by the analysis results of regular on-site sampling for all kinds of batteries, for practical reasons, the project team proposes a differentiated approach:

1) The input into a battery recycling process should be determined and documented by the recycler, whereby

a) For batteries, for which there is little change in the chemical composition between new and spent batteries and for which there is little change in the composition over time due to technical development (e.g. AlMn and ZnC) the input on an elemental/compound level is defined as the composition of the new batteries. The share of individual battery chemistries in the input has to be determined by sorting analysis (continuous or representative sampling).

b) For batteries, for which there is considerable change in the chemical composition between new and spent batteries and for which there is considerable change in the composition over time due to technical development (i.e. lead-acid batteries) the input on an elemental/compound level is defined as the composition of the spent batteries (the actual input). This can be determined either by chemical analysis of the actual input or by data from literature.

2) The information on the composition of new and waste batteries as provided e.g. by the industry should be administrated and up-dated by an independent third party, which should also elaborate lists of batteries belonging to a) and b) respectively.

4.1.2.4 Final output fractions to be accounted for the recycling efficiency

The recycling process ends when all output fractions are either products or by-products, waste for disposal or released as an emission to air, water or land. Whilst allocation to one of these fractions is clear for most substances or materials, further discussion on specific fractions is needed in order to ensure a uniform calculation of the recycling efficiency. This will be done in the following for water, carbon, oxygen and slag.

(a) Consideration of water in the calculation of the recycling efficiency

As outlined in chapter 4.1.1.1 fluids and acids are considered components of a battery and the input to the battery recycling process can be either on a wet basis or on a dry basis (see chapter 4.1.2.2).

The project team proposes the dry basis option. If this option is chosen water will not be taken into account for the calculation. The mass of the water content will be subtracted from the waste batteries input mass.

If the wet basis option will be chosen, further reflection is required on the question how to consider water in the calculation of the recycling efficiency:

As water is finally released into the natural water cycle, it could be taken into account in the calculation of the recycling efficiency in numerator and denominator. Consequently the water content would be counted as if being a recycled. This is generally in line with a joint industry position [EBRA, EPBA, RECHARGE 2008]. The industry position that treated water that is released as a liquid effluent or as vapour from a recycling process should be considered a by-product from the recycling process. Treated water has ended its waste status and fulfils the criteria of a by-product as defined in Article 5 of the Waste Framework Directive 2008/98/EC. The conclusion of the industry representatives is that the water content of a spent battery should be considered as a by-product of the recycling process when this water receives an appropriate treatment that makes it re-usable in the environment and when this re-use will not lead to overall adverse environmental or human health impact and for which further use is lawful.

The question "How to consider the output of treated water (such as waste water after physico-chemical treatment or exhaust air after treatment)?" was also discussed at the dedicated project workshop. According to several statements from the audience outputs should be considered as materials that have ended the waste status and are therefore to be accounted for recycling as a product. According to other statements and according to the definition of emissions according to the IPPC directive the output of treated water into the environment is an emission and cannot be accounted for recycling. There was no agreement within the workshop audience achieved.

The two options to consider are as follows:

Water originating from the batteries that is released to air or water after appropriate physico-chemical treatment

Option (A) has ended its waste status and can be accounted for the recycling efficiency as a product or

Option (B) is considered an emission and cannot be accounted for the recycling efficiency.

If the wet basis option would be chosen, the project team would propose to stay in line with the proposed systematic approach: “All … output fractions … that end up … as a product, a material or a substance and that are not waste for disposal or an **emission** and if they are not used for energy recovery are accounted for the recycling efficiency”.

In the opinion of the project team releases of water to air, water or land are clearly emissions in the sense of the IPPC Directive (see chapter 4.1.1.1) and thus can not be accounted for recycling efficiency (option B).

The project team proposes to exclude water from the calculation. The corresponding advantages and disadvantages from an environmental, economic and social perspective of the proposal are summarised in Table 4.5.

(b) Consideration of carbon in the calculation of the recycling efficiency

Carbon or plastics and/or other agents are commonly used in pyrometallurgical battery recycling processes. Usually these agents have a dual function as (a) combustible and (b) reducing agent. Carbon and/or plastic but also other agents that have a function within the recycling process are introduced as components of the waste batteries into the process and are consumed within the process and emitted (e.g. as CO2 into the atmosphere). Consequently they are not available in a recycled product or by-product at the end of the process.

The arguments speaking for and against the accountability of carbon (and other intermediate fractions) are discussed in section 4.1.1.

The proposal of the project team is:

If carbon is a component of an approved product (= a final output fraction) of a recycling process (e.g. graphite powder) it can be taken into account for the calculation of the recycling efficiency.[21]

If carbon is consumed within the recycling process (e.g. incinerated and used as reducing carbon and finally released as CO_2 to the atmosphere) it cannot be taken into account for the calculation of the recycling efficiency.

This proposal corresponds to apply the “black-box” approach in a strict sense and not to account intermediate fractions such as reducing agents for the recycling efficiency. The corresponding advantages and disadvantages from an environmental, economic and social perspective of the proposal are summarised in Table 4.2.

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[21] Reducing agents that are withdrawn from the process as (component) of an approved product should be accounted for the recycling efficiency if they are not used for energy recovery. In practice the use of the corresponding output has to be reported in the reporting form as final fraction accounting for recycling and will thus be considered in the calculation of the recycling efficiency.

(c) Consideration of oxygen in the calculation of the recycling efficiency

The question how oxygen contributes to the recycling efficiency depends on the mass flows of oxygen into and out of the recycling process. Consequently, oxygen contributes (like all other input elements) to the recycling efficiency if it originates from the input batteries and becomes part of a relevant output fraction of the battery recycling process (i.e. a product, a by-product or a material or substance which has ceased to be waste and is neither an emission nor a waste for disposal and is not used for energy recovery).

This is consistent with a joint industry position [EBRA, EPBA, RECHARGE, 2008] which states that oxygen can only be taken into account and included in the numerator when it is present in the components of the spent batteries and if it is part of a compound that is an end product of a recycling process and in accordance with the mass balance.

The proposed option has only low effects on the recycling efficiency and is usually only related to irrelevant environmental, economic and social advantages and disadvantages. However in specific cases the accountability of oxygen may be decisive to achieve the required recycling efficiency. In these cases relevant economic disadvantages can be avoided if oxygen is accounted. [22]

(d) Consideration of slag in the calculation of the recycling efficiency

Slags are an outcome of many thermal processes that can partly be recovered in construction work (e.g. road construction, landfill construction and backfilling) or are used as feedstock-material for further production processes. Hence it has to be discussed whether the content of battery materials (metals and metal oxides) transferred to slag can be accounted for the recycling efficiency.

If slag is waste for recycling (used as feedstock material in a subsequent production process) we consider it an **intermediate fraction** of the battery recycling process, which means that the RE of the subsequent recycling step has to be determined for calculation of the overall RE. But: this slag being waste for recycling is not the object of the following considerations. They just refer to slag being a **final fraction** of the battery recycling process.

The pre-existing calculation methods (see section 10.9 of the draft final report) propose to distinguish between slag that is an approved product according to the EU Waste Directive (used for example as foundation material for road construction) and slag that is declared as waste and destined to landfill. Depending on their actual use slags not being waste can be classified as products or by-products according to the criteria listed in the revised Waste Framework Directive 2008/98/EC (see section 4.1.1.2). In this context it is also noteworthy that, depending on the registration

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[22] At European level at least nine battery recyclers of ZnC and AlMn batteries are applying the waelz process which produces zinc oxide as output fraction. The question whether the oxygen share of the zinc oxide originates from the battery input mass or not and whether it will be accounted for the recycling efficiency may be relevant in specific cases. It is difficult to quantify possible economic impacts as these depend on several other factors and strategies of individual companies.

procedure under REACH for specific slags, it can be expected that these will be considered as registered “substance” under REACH with demonstrated safe eco-toxicological effects.

Even if classifiable as by-products in the sense of Directive 2008/98/EC, slag use is permitted according to the corresponding legislation of the respective Member State. This may lead to discrimination of battery recyclers in Member states where the slag is not authorized to be used e.g. for road construction but has to be disposed off.

At the dedicated project workshop it has been discussed whether slag should be accounted at all for recycling, whether slag can be accounted if it is an approved product or by-product or whether it can only be accounted depending on its actual use. Whereas industry largely voted for a general accountability if product criteria and potential limit values are met, some TAC members stated that the accountability should depend on the use of the slag and that slag for landfill construction should not be accounted for recycling. The issue was raised that due to different authorisation practice in Member States (and within Member States) market distortions actually occur.

Against this background several options concerning the accountability of slag being a final fraction of the battery recycling process for the recycling efficiency have been identified: Battery materials in slag are

Option A: not accounted for the recycling efficiency;

Option B: accounted for the recycling efficiency if the slag is an approved product or a by-product according to Directive 2008/98/EC AND if it is actually used for purposes other than disposal;

Option C: accounted for the recycling efficiency if the slag is an approved product or a by-product according to Directive 2008/98/EC AND if it is actually used for purposes other than disposal or landfill construction.

Even if there have been many arguments brought forward that no difference should be made between road construction and landfill construction, the project team finally decided to propose option C, since insertion of slag on a landfill definitely terminates any recycling of the material. This would also help to avoid possible market distortions.

The following table summarises the environmental, economic and social advantages and disadvantages of accounting battery materials in slag according to the actual use of the slag versus not accounting them for the recycling efficiency (options B and C versus option A).

Scope	Advantages	Disadvantages
Environment	Not relevant since slags can only be used that are in accordance with specific quality criteria → no impact on the environment	1) Not relevant since slags can only be used that are in accordance with specific quality criteria → no impact on the environment 2) If quality criteria are not appropriate → negative impact on the environment possible
Economy	The accountability of slag for the recycling efficiency is decisive in several cases for the achievability of the required recycling efficiency → economic losses can be avoided	Not relevant
Social	Job losses can be avoided	Not relevant

Table 4.6 : Environmental, economic and social advantages and disadvantages of options B and C (to account battery materials in slag according to the actual use of the slag) versus option A (not to account battery materials in slag for the recycling efficiency)

The following table summarises the environmental, economic and social advantages and disadvantages of the proposed option C (accounting for battery materials in slag if they are not used for disposal or landfill construction) versus option B (accounting for battery materials in slag if they are not used for disposal).

Scope	Advantages	Disadvantages
Environment	Increases the motivation to use slag for purposes other than landfill construction. → saving of resources possible	1) Not relevant since slags can only be used for purposes other than landfill construction or disposal if they are in accordance with specific quality criteria → no impact on the environment 2) If quality criteria are not appropriate → negative impact on the environment possible
Economy	The accountability of slag for the recycling efficiency is decisive in several cases for the achievability of the required recycling efficiency → economic losses can be avoided	The accountability of slag used for landfill construction for the recycling efficiency may be decisive in specific cases for the achievability of the required recycling efficiency → economic losses possible
Social	Not relevant	Job losses possible

Table 4.7 : Environmental, economic and social advantages and disadvantages of the proposed option C (accounting for battery materials in slag if they are not used for disposal or landfill construction) versus option B (accounting for battery materials in slag if they are not used for disposal).

The proposal of the project team corresponds also to the position of industry representatives, whereas there are positions of recyclers, a battery association and a collection scheme, which claim for the accountability of slag utilized for landfill construction or recultivation if this application is classified as a recovery operation by local authorities. However, we received also positions of Member States representatives being strictly against the accountability of slag even when utilized for road construction.

A further topic to decide upon is the question, whether all materials (elements and compounds) contained in a slag accepted for recycling could actually be counted or not. In this context there are two alternative options:

Option A: All battery materials account for “recycling”

Option B: Battery materials constituting undesirable contamination for the particular application of the slag are not accepted for “recycling”

Option A is supported by the argument that the slag has ceased to be waste and thus falls into the category of product, by-product with no reason to treat it differently than any other product containing e.g. heavy metals as trace elements.

Option B is supported by the argumentation that the battery compounds contained in the slag (e.g. heavy metals) are not the reason for the recycling possibility and market demand, but an “acceptable” hazard. Under the premises of the precautionary principle and given the understanding of recycling as a measure to “salvage“ valuable substances an accountability can not be accepted in this case.

There are positions of Member States representatives supporting option B, although pointing out that it will probably not affect the calculated recycling efficiency significantly.

However, after thorough balancing of the arguments for both options, the project team decided that elements and compounds contained in slag (although if the slag as such is accounting for recycling) should not account for recycling if they represent undesired contamination regarding the particular application of the slag (i.e. heavy metals for which limit values are applicable for road construction material). Although there is not yet a European regulation existing, several Member States have already established guidelines and regulations for recycling different wastes/materials with regard to environmental protection. According to a review of these guidelines/regulations containing requirements for recycled materials used as construction material usually the following heavy metals are limited: Pb, Ni, Cd, As, Ba, Cr, CrVI, Cu, Hg, Mo, Zn and Va. [JRC, 2008].

Thus the proposal of the project team is option B.

The following table summarises the environmental, economic and social advantages and disadvantages of the proposed option B (not accounting for battery materials in slag if they represent an undesired contamination) versus option A (accounting for all battery materials in slag).

Scope	Advantages	Disadvantages
Environment	Increases the motivation to improve the recycling of hazardous substances (low increase of the motivation as low effect on the recycling efficiency)	Not relevant
Economy	Not relevant	Higher efforts to improve the recycling of hazardous substances may be related to relevant costs (low pressure as low effect on the recycling efficiency)
Social	Not relevant	Not relevant

Table 4.8 : Environmental, economic and social advantages and disadvantages of the proposed option B (not accounting for battery materials in slag if they represent an undesired contamination) versus option A (accounting for all battery materials in slag).

4.1.3 At which level shall the minimum recycling efficiencies be achieved?

The relevance of this issue has to be considered in the context of the question for what specific scope the targets set recycling efficiencies of "Recycling processes" according to Annex III, Part B of Directive 2006/66/EC have to be achieved.

There are different options:

The achievement might be required (A) at the level of individual facility, (B) at the level of individual treatment processes, (C) in average for all batteries of one of the categories listed in Annex III collected within a country or (D) in average for all batteries of one of the categories listed in Annex III recycled within a country?

Options (A) and (B) might lead to a discrimination of recyclers treating particular battery chemistries (e.g. Li batteries), which can not achieve the required recycling efficiencies due to the low recycling potential of these battery types (although applying BAT). This might occur for particular battery types (i.e. ZnO and Li). ZnO batteries constitute only a minor part of waste batteries and are usually treated together with batteries of other chemistry (ZnC and AlMn). For Li batteries, indeed, the problem may occur. This concern could be resolved by making exemptions or creating a separate class for such batteries.

If it would be decided to calculate the recycling efficiency on process level it is important to state, that every company runs its own process(es). Each company does an effort to differentiate (to perform better than others). If all more or less similar processes would be considered together, this would favour the cheapest process with possibly the lowest recycling efficiency. "Better" processes would be punished.

Options (C) and (D) would oblige to achieve the recycling efficiency at a higher level of aggregation. This would enable to achieve the recycling efficiency for the sum of "other batteries" and would probably not pose a problem of feasibility. However these options have one important drawback: there will be no motivation at process level to increase the recycling efficiency and recyclers that take efforts to increase the recycling efficiency would be penalised.

According to an industry position, option B would not be in line with Annex III of Directive 2006/66/EC which states “Recycling processes shall achieve the following minimum recycling efficiencies: recycling of 50% by average weight of other batteries and accumulators”. According to this industry position, option B would not stimulate technological improvement of recycling options for certain types of batteries and accumulators but would be a benefit for those recycling facilities treating a mixture of all other batteries. The preferred option according to this industry position is option C.

These options were also discussed at the dedicated project workshop, whereby the possible exemption of specified battery chemistries (e.g. ZnO, Li) was stated as a possible solution.

The proposal of the project team is option B, in order to stimulate technological improvement in combination with exemptions of those battery chemistries treated in a dedicated process and for which the required recycling efficiency are not achievable with the use of BAT.

The proposal

- maintains competition and the motivation to improve the recycling efficiency at process level
- does not discriminate processes for the recycling of “difficult” [23] battery chemistries because it foresees possible exemptions for those battery chemistries treated in a dedicated process and for which the required recycling efficiency are not achievable with the use of BAT
- can be implemented without difficulties (reporting on the process on facility level and exemptions for specific processes/battery chemistries after an appropriate assessment)

In practice the facility or facilities carrying out a specific battery recycling would be obliged to report for each process the recycling efficiency achieved in a calendar year to a specific Member State (either to the Member State of the facility carrying out the first process step(s) or to the Member State of the facility carrying out the main process step(s)) in order to enable Member States to fulfil their reporting obligations according to Article 12(5) of the Batteries Directive (2006/66/EC).

Member States will report the corresponding information on the levels of recycling achieved in all battery recycling processes and whether the recycling efficiencies have been met.

In those processes where required recycling efficiencies are not achieved, an assessment can be carried out in order to decide whether an exemption for recycling processes for “difficult” battery chemistries is justified. An information exchange between Member States should be encouraged and could be coordinated by the European Commission (as the Commission will be aware of the reporting results from all relevant Member States).

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[23] difficult means that difficulties exist for some specific battery chemistries (e.g. ZnO, Li) to achieve the required recycling efficiency

The following table summarises the environmental, economic and social advantages and disadvantages of option A (achievement required at the level of individual facility) versus the status quo.

Scope	Advantages	Disadvantages
Environment	Increases the motivation to improve the recycling efficiency at facility level	Other environmental aspects possibly disregarded
Economy	Competition between facilities	Discrimination of facilities that recycle “difficult” battery chemistries
Social	Job gains and losses possible	Job gains and losses possible

Table 4.9 : Environmental, economic and social advantages and disadvantages of option A versus the status quo.

The following table summarises the environmental, economic and social advantages and disadvantages of option B (achievement required at process level) versus the status quo.

Scope	Advantages	Disadvantages
Environment	Increases the motivation to improve the recycling efficiency at process level	Other environmental aspects possibly disregarded
Economy	Competition between processes	Discrimination of processes that recycle “difficult” battery chemistries
Social	Job gains and losses possible	Job gains and losses possible

Table 4.10 : Environmental, economic and social advantages and disadvantages of option B versus the status quo.

The following table summarises the environmental, economic and social advantages and disadvantages of option C (achievement required or all batteries of one of the categories listed in Annex III collected within a country) versus the status quo.

Scope	Advantages	Disadvantages
Environment	Increases the motivation to improve the recycling efficiency only to a degree that enables to achieve the recycling efficiency at country collection level (good traceability and allocation of responsibility possible compared to option D)	1) Other environmental aspects possibly disregarded 2) Processes achieving low recycling efficiency are “rewarded“ if other processes achieve high recycling efficiency. This is counterproductive and may lead to an overall low recycling efficiency.
Economy	Lower efforts to achieve the recycling efficiency	Discrimination of processes with high recycling efficiency
Social	Not relevant	Not relevant

Table 4.11 : Environmental, economic and social advantages and disadvantages of option C versus the status quo.

The following table summarises the environmental, economic and social advantages and disadvantages of option D (achievement required or all batteries of one of the categories listed in Annex III recycled within a country) versus the status quo.

Scope	Advantages	Disadvantages
Environment	Increases the motivation to improve the recycling efficiency only to a degree that enables to achieve the recycling efficiency at country level (difficult traceability and allocation of responsibility possible compared to option D)	1) Other environmental aspects possibly disregarded 2) Processes achieving low recycling efficiency are “rewarded“ if other processes achieve high recycling efficiency. This is counterproductive and may lead to an overall low recycling efficiency.
Economy	Lower efforts to achieve the recycling efficiency	Discrimination of processes with high recycling efficiency
Social	Not relevant	Not relevant

Table 4.12 : Environmental, economic and social advantages and disadvantages of option D versus the status quo.

4.2 Pre-existing information on calculation methods for recycling efficiencies

According to Annex III, Part B of Directive 2006/66/EC recycling processes shall achieve defined minimum recycling efficiencies. In order to propose detailed rules for the calculation of recycling efficiencies, as announced in Article 12(6)of the Directive pre-existing studies were reviewed.

4.2.1 Pre-existing calculation models for recycling efficiencies for waste batteries

The proposals for the calculation of the recycling efficiency for waste batteries cited below were available to the project team:

- 1) **EBRA, EPBA, RECHARGE** (2008): The Recycling Efficiency of spent portable batteries, A guidance note prepared by EBRA, EPBA and RECHARGE.
- 2) **IME:** Bernd Friedrich et al. (RWTH Aachen University, IME Process Metallurgy and Metal Recycling) (2007): Development of a Calculation Method for Recycling Efficiencies.
- 3) **Berger:** Manfred Berger (Redux Recycling GmbH and Accurec Recycling GmbH): Suggested Method for Calculating Recycling Efficiency.

In the annex (see section 10.9.1) the interpretations of relevant issues of the existing calculation models are summarized.

4.2.2 *Pre-existing calculation models for the degree of recycled lead from waste lead-acid batteries*

Specific information was provided on lead recycling by the Lead Development Association International (see section 10.9.2).

4.2.3 *Pre-existing calculation methods for comparable treatment targets*

Information is available from a calculation model regarding the treatment of waste electric and electronic equipment (WEEE). For corresponding information see Annex (section 10.9.3)

4.3 Proposal for a method for the calculation of recycling efficiencies for batteries

4.3.1 *Calculation method for the overall Recycling Efficiency (RE) of a recycling process*

According to Annex III, Part B of Directive 2006/66/EC recycling processes shall achieve minimum recycling efficiencies.

Against the background of the relevant definitions, discussions and proposals in chapters 3 and 4 the project team proposes the following calculation method:

$$\boldsymbol{RE}\ [\text{mass\%}] = \frac{\Sigma\ (\textit{mass of final fractions accounting for recycling})}{\textit{input mass into the battery recycling process}} * \mathbf{100}$$

<u>**Explanations:**</u>

1) whereby the RE has to be calculated **separately** at least for:

-**lead-acid** batteries and accumulators,

-**nickel-cadmium** batteries and accumulators and

-**other** waste batteries and accumulators.

2) whereby the **system boundaries** of the battery recycling process are illustrated in Figure 4-12 .

3) whereby the “**input mass into the battery recycling process”** is defined as the dry mass of the waste batteries excluding the mass of components belonging to battery packs (s. 3.3.1) entering the battery recycling process per calendar year..

4) whereby the RE is calculated on an **elemental/compound** level.

5) The "**input**" on an **elemental/compound** level is defined as the composition of the **spent** batteries and accumulators as they are received by the recycler (chemical analysis), with the following exemptions:

For batteries and accumulators, for which there is little change in the chemical composition between new and spent batteries and for which there is little change in the composition over time due to technical development (e.g. AlMn and ZnC) the "**input"** on an **elemental/compound level** is defined as the composition of the **new** batteries and accumulators. The share of several battery chemistries in the "input" has to be determined by sorting analysis (e.g. 40 mass % of battery chemistry 1 (e.g. ZnC-batteries) and 60 mass % of battery chemistry 2 (e.g. AlMn-batteries)). The analyses can e.g. be carried out by the recycler or the collector. To guarantee harmonization between recycling processes the sampling and sorting procedure should be standardized. However, it seems not necessary to implement authorised or certified sorting analysis mechanisms.

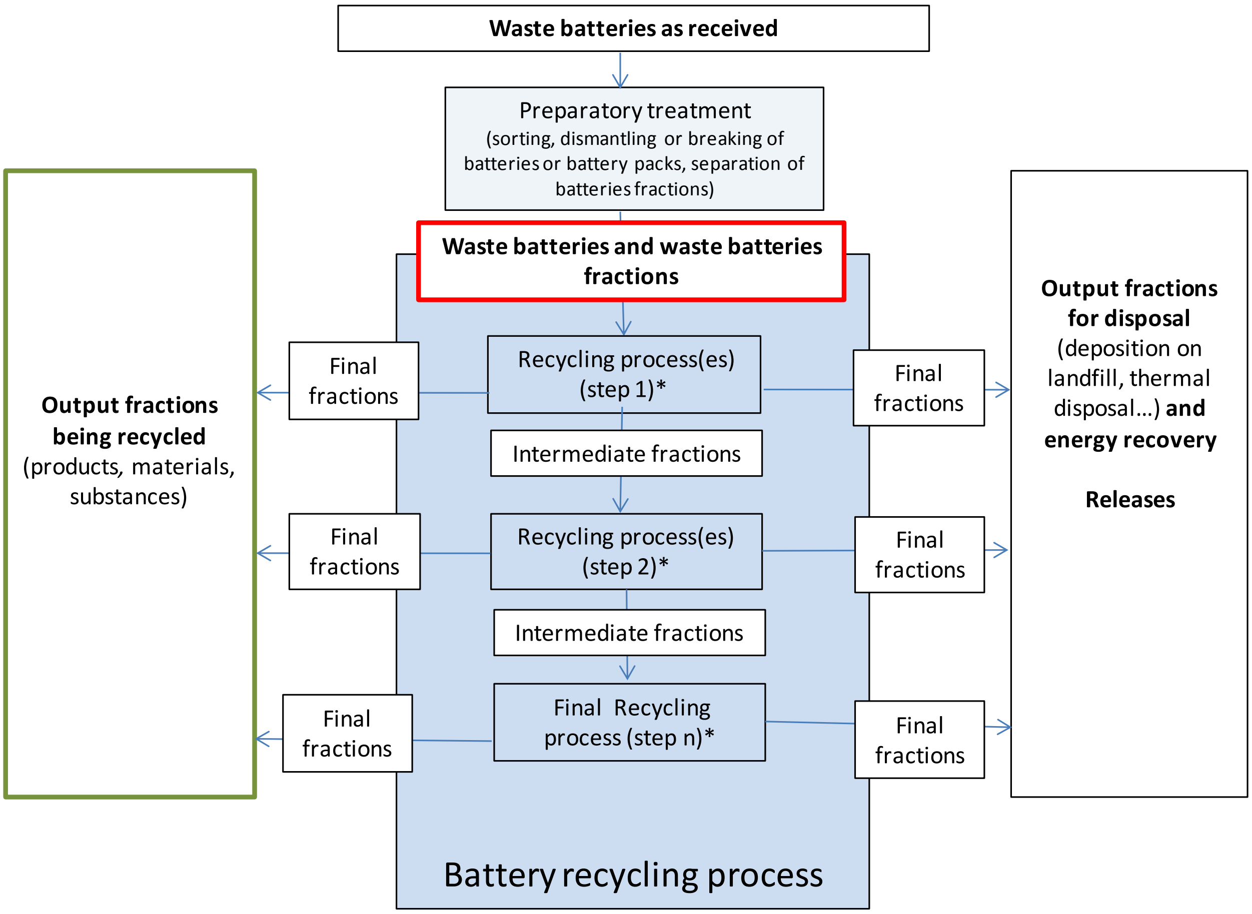
6) whereby **"final fractions"** are defined as **approved products**, **by-products**, **emissions** or **waste for disposal or materials for energy recovery** (=definition of the end the battery recycling process)

7) whereby "**final fractions accounting for recycling"** have to be (1) **products** or (2) **by-products**, whereby for the latter (e.g. **slags**) the actual utilization for recovery has to be proved.

8) whereby the "**mass of final fractions accounting for recycling"** is the share of the elements or compounds contained in these fractions which originates from the processed batteries and accumulators.

9) whereby elements and compounds contained in slag (although if the slag as such is accounting for recycling) do not account for recycling if they represent undesired **contamination** regarding the particular application of the slag (i.e. heavy metals for which there exist limit values for road construction material).

10) according to 7) the use of **carbon** as a reducing agent is accounting for recycling if it is component of a final fraction (by-product or product) of the battery recycling process.



* Subsequent Treatment/Recycling processes might be carried out by one treatment facility or several facilities either in the same country or in further countries (waste batteries and accumulators exported out of the EC […] shall count towards the fulfilment of the efficiencies only if there is sound evidence that the recycling operation took place under conditions equivalent to the requirements of Directive 2006/66/EC)

Figure 4-12 : Illustration of the system boundaries of a "battery recycling process"

4.3.2 Calculation method for the Degree of Recycled Lead (RPb) of a recycling process

According to Annex III, Part B of Directive 2006/66/EC recycling processes shall achieve the recycling of the Pb content of lead-acid batteries and accumulators and of the Cd content of nickel-cadmium batteries and accumulators to the highest degree that is technically feasible while avoiding excessive costs.

$$\textbf{RPb}\ [\text{mass\%}] = \frac{\Sigma\ (\text{mass of Pb in final fractions accounting for recycling})}{\text{Pb input mass into the battery recycling process}} * 100$$

Explanations (in addition to those regarding RE (see section 4.3.1)):

1) whereby the "**Pb input mass into the battery recycling process"** is defined as the yearly average Pb content of spent lead-acid batteries and accumulators multiplied with the input mass of lead-acid batteries and accumulators.

2) whereby the "**mass of Pb in final fractions accounting for recycling"** is the share of Pb contained in these fractions, which originates from the processed lead-acid batteries and accumulators.

3) whereby Pb contained in slag (although if the slag as such is accounting for recycling) does not account for recycling since it represents an undesired **contamination** regarding the utilization of slag (i.e. as road construction material).

4.3.3 Calculation method for the Degree of Recycled Cadmium (RCd) of a recycling process

According to Annex III, Part B of Directive 2006/66/EC recycling processes shall achieve the recycling of the Cd content of nickel-cadmium batteries and accumulators to the highest degree that is technically feasible while avoiding excessive costs.

$$\textit{RCd}\ [\text{mass\%}] = \frac{\Sigma\ (\textit{mass of Cd in final fractions accounting for recycling})}{\textit{Cd input mass into the battery recycling process}} * 100$$

Explanations (in addition to those regarding RE (see section 4.3.1)):

1) whereby the "**Cd input mass into the battery recycling process"** is defined as the yearly average Cd content of spent nickel-cadmium batteries and accumulators multiplied with the input mass of nickel-cadmium batteries and accumulators.

2) whereby the "**mass of Cd in final fractions accounting for recycling"** is the share of Cd contained in these fractions, which originates from the processed nickel-cadmium batteries and accumulators.

3) whereby Cd contained in slag (although if the slag as such is accounting for recycling) does not account for recycling since it represents an undesired **contamination** regarding the utilization of slag (i.e. as road construction material).

5 Reporting on recycling efficiencies

According to Article 12.5 of the Batteries Directive (2006/66/EC), Member States shall report on the levels of recycling achieved in each calendar year concerned and whether the efficiencies referred to in Annex III, Part B have been met. They shall submit the information to the Commission within six months of the end of the calendar year concerned. Thus data on the efficiencies of the applied recycling processes has to be reported to the Member States.

It is not the scope of this project to decide which institution will be responsible for collecting and reporting this data to the Member States.

The aim of this project is – with respect to harmonisation between Member States - to provide a reporting format to be filled in by the recycling facilities, which provides all necessary information to calculate the recycling efficiency in a uniform way.

5.1 Pre-existing reporting formats for comparable reporting obligations

Information on reporting formats regarding the treatment of waste electric and electronic equipment (WEEE) and the treatment of end-of-life vehicles are documented in the Annex (see section 10.10)

5.2 Proposal for a reporting format

Since the format for lead-acid batteries and accumulators and nickel-cadmium batteries and accumulators shall contain data on the degree of recycled lead and cadmium, respectively, we propose 3 different reporting formats to be used for reporting on the recycling efficiency (RE) of

-**lead-acid** batteries and accumulators,

-**nickel-cadmium** batteries and accumulators and

-**other** waste batteries and accumulators.

The proposed reporting format consists of **2 parts:**

Form A) Description of the battery **input** into the recycling process, (calculated) Recycling Efficiency

(In our assumption Form A is filled by the facility receiving the waste batteries and accumulators)

Form B) Data on the **individual steps** of the battery recycling process (Material flows originating from batteries input)

(In our assumption Form B is filled by every facility carrying out an individual process step.)

If, for example, there is 1 process step leading directly to the final fractions, Form A is filled once and Form B is filled once (for process step 1).

If, for example, process step 1 produces 3 intermediate fractions, which are treated in further steps (1_1, 1_2 and 1_3) of the recycling process, Form A is filled once and Form B is filled 4 times (for step 1, for step 1_1, step 1_2 and step 1_3).

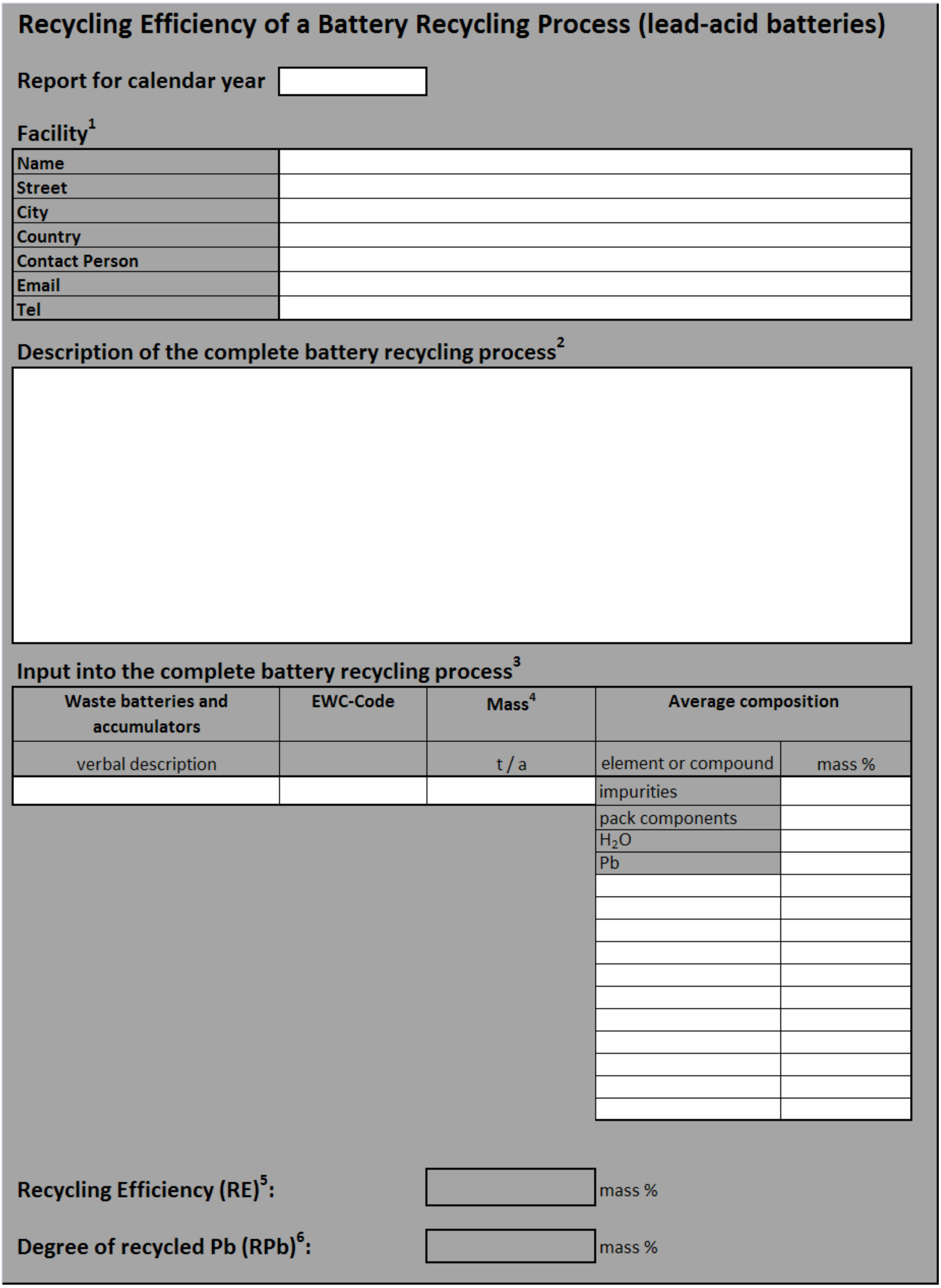
All mass entries are in t/a (tonnes per calendar year).

The following table summarises the environmental, economic and social advantages and disadvantages of the proposed reporting format. Since there are a lot of possibilities regarding the level of detail, one proposal was made, which aims to be simple and short in relation to mandatory information needs and which is compared to the option of no reporting.

Scope	Advantages	Disadvantages
Environment	Supports environmental control activities: - Enables to establish data on applied battery recycling processes as a basis for further adjustments and improvements. - Enables monitoring of the recovery rates of Cd and Pb. - Enables comparison of data on waste batteries collected with waste batteries treated applying certain processes.	The financial resources spent on the reporting activities might be missing for technological improvements with environmental benefits.
Economy	Economic gains for auditing activities by experts	Costs for reporting (increasing with the complexity of the recycling process)
Social	Not relevant	Not relevant

Table 5.1: Environmental, economic and social advantages and disadvantages of the proposed reporting format versus no reporting by recyclers.

5.2.1 Reporting Format for lead-acid batteries and accumulators, Form A



Recycling Efficiency of a Battery Recycling Process (lead-acid batteries)

Report for calendar year ☐

Facility[1]

Name	
Street	
City	
Country	
Contact Person	
Email	
Tel	

Description of the complete battery recycling process[2]

Input into the complete battery recycling process[3]

Waste batteries and accumulators	**EWC-Code**	**Mass**[4]	**Average composition**	
verbal description		t / a	element or compound	mass %
			impurities	
			pack components	
			H_2O	
			Pb	

Recycling Efficiency (RE)[5]**:** ☐ mass %

Degree of recycled Pb (RPb)[6]**:** ☐ mass %

Explanations:

1) Facility receiving the waste batteries and accumulators after collection and eventual sorting

2) Description of the complete battery recycling process, no matter if carried out by one or several facilities (including a description of the individual recycling steps and their output fractions)

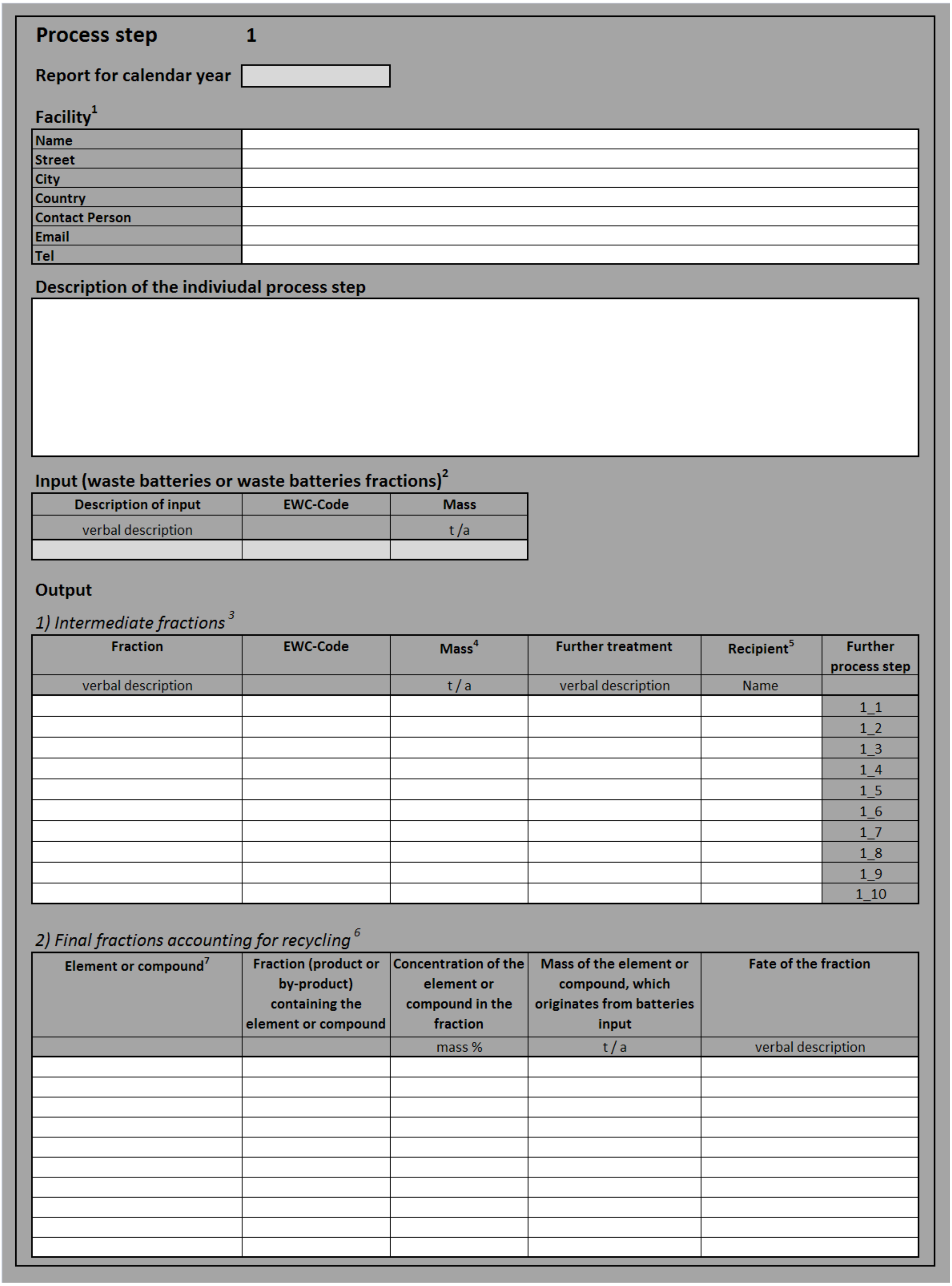
3) waste batteries and accumulators as received after collection and eventual sorting

4) wet mass of waste batteries and accumulators as received after collection and eventual sorting (the mass of separated impurities and pack components as well as the water content as specified in the field “average composition” are subtracted for the calculation of the RE)

5) calculated automatically according to the formula for RE based on data filled in Forms B

6) calculated automatically according to the formula for RPb based on data filled in Forms B

5.2.2 Reporting Format for lead-acid batteries and accumulators, Form B



Process step **1**

Report for calendar year ☐

Facility[1]

Name	
Street	
City	
Country	
Contact Person	
Email	
Tel	

Description of the indiviudal process step

Input (waste batteries or waste batteries fractions)[2]

Description of input	EWC-Code	Mass
verbal description		t /a

Output

1) Intermediate fractions [3]

Fraction	EWC-Code	Mass[4]	Further treatment	Recipient[5]	Further process step
verbal description		t / a	verbal description	Name	
					1_1
					1_2
					1_3
					1_4
					1_5
					1_6
					1_7
					1_8
					1_9
					1_10

2) Final fractions accounting for recycling [6]

Element or compound[7]	Fraction (product or by-product) containing the element or compound	Concentration of the element or compound in the fraction	Mass of the element or compound, which originates from batteries input	Fate of the fraction
		mass %	t / a	verbal description

Explanations:

1) Facility carrying out an individual process step

2) For step 1 = the same as input into the complete battery recycling process

For subsequent steps = intermediate fractions from the previous process

3) Intermediate fractions = waste for recycling

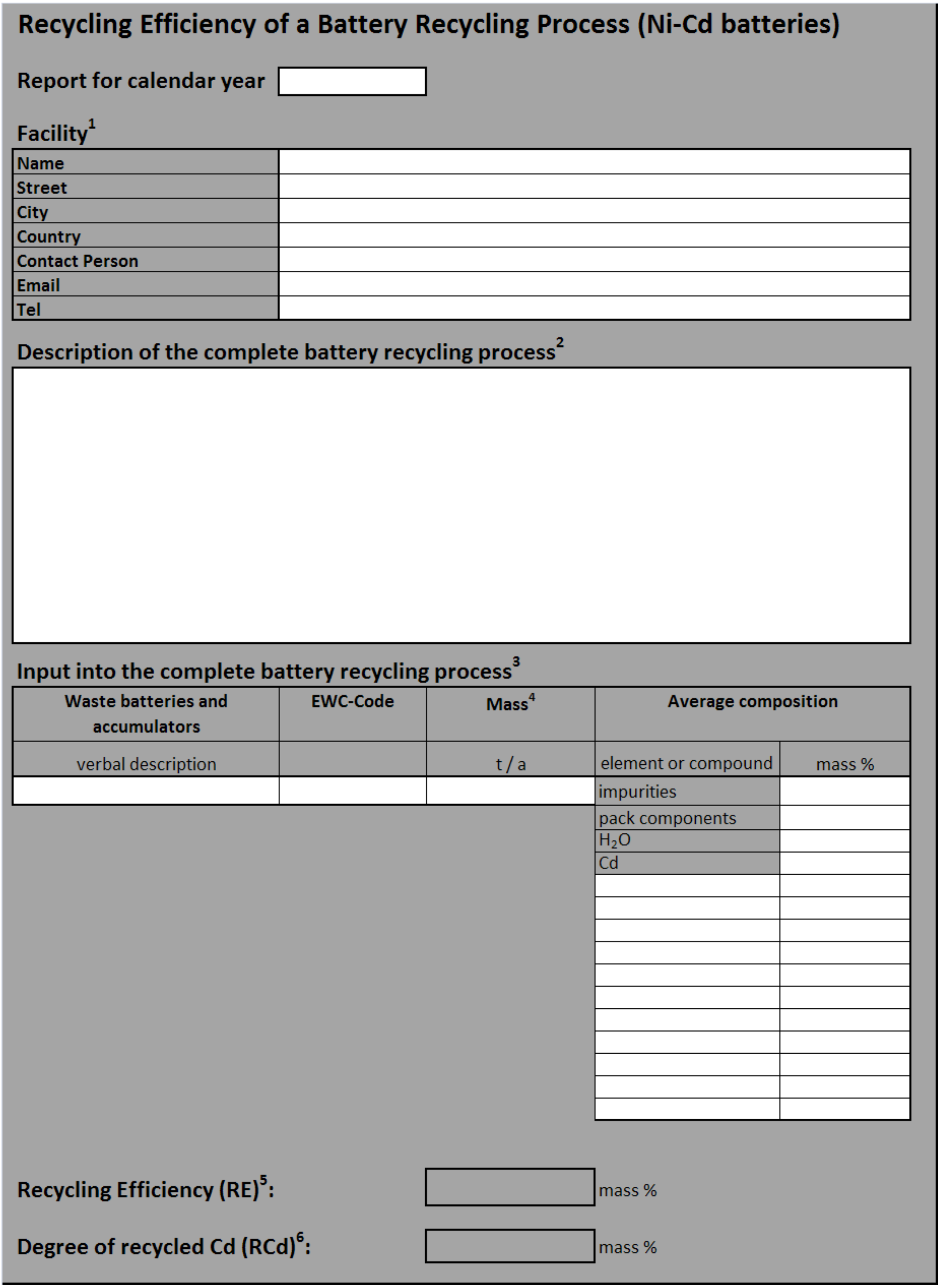
4) Originating from the batteries input (wet mass)

5) Facility to which the intermediate fraction is handed over or - if the further process step is carried out internally - the same as 1)

6) Final fractions accounting for recycling = approved products, by-products

7) All elements and compounds if they were component of the batteries input (spent battery). Elements and compounds contained in slag do not account for recycling if they represent undesired contamination regarding the particular application of the slag (i.e. heavy metals for which there exist limit values for road construction material). Lead must be entered as "Pb".

5.2.3 *Reporting Format for nickel-cadmium batteries and accumulators, Form A*



Recycling Efficiency of a Battery Recycling Process (Ni-Cd batteries)

Report for calendar year ____

Facility[1]

Name	
Street	
City	
Country	
Contact Person	
Email	
Tel	

Description of the complete battery recycling process[2]

Input into the complete battery recycling process[3]

Waste batteries and accumulators	**EWC-Code**	**Mass**[4]	**Average composition**	
verbal description		t / a	element or compound	mass %
			impurities	
			pack components	
			H_2O	
			Cd	

Recycling Efficiency (RE)[5]**:** ____ mass %

Degree of recycled Cd (RCd)[6]**:** ____ mass %

Explanations:

1) Facility receiving the waste batteries and accumulators after collection and eventual sorting

2) Description of the complete battery recycling process, no matter if carried out by one or several facilities (including a description of the individual recycling steps and their output fractions)

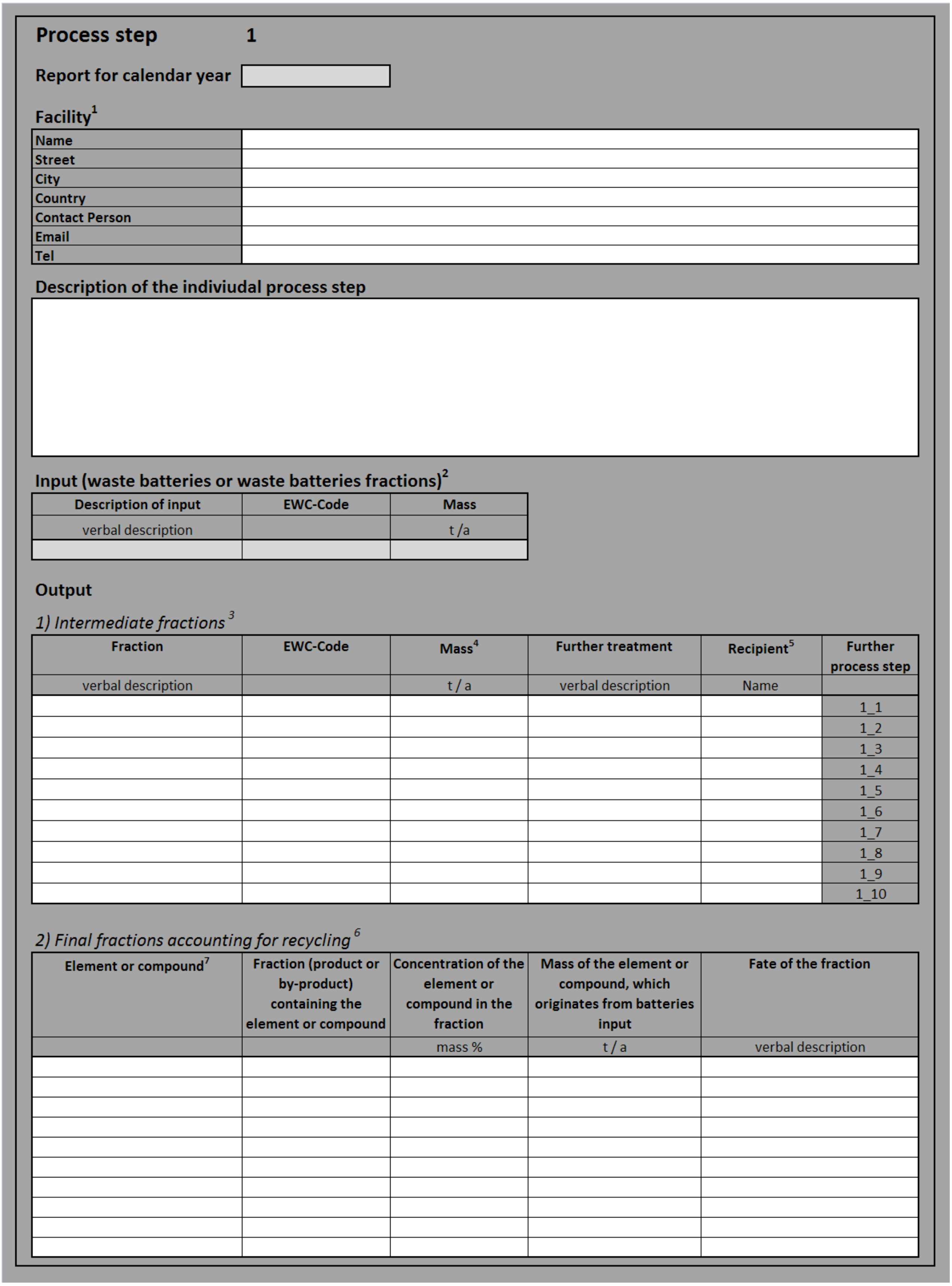
3) waste batteries and accumulators as received after collection and eventual sorting

4) wet mass of waste batteries and accumulators as received after collection and eventual sorting (the mass of separated impurities and pack components as well as the water content as specified in the field "average composition" are subtracted for the calculation of the RE)

5) calculated automatically according to the formula for RE based on data filled in Forms B

6) calculated automatically according to the formula for RCd based on data filled in Forms B

5.2.4 *Reporting Format for nickel-cadmium batteries and accumulators, Form B*



Process step **1**

Report for calendar year ☐

Facility[1]

Name	
Street	
City	
Country	
Contact Person	
Email	
Tel	

Description of the indiviudal process step

Input (waste batteries or waste batteries fractions)[2]

Description of input	**EWC-Code**	**Mass**
verbal description		t /a

Output

1) Intermediate fractions[3]

Fraction	**EWC-Code**	**Mass**[4]	**Further treatment**	**Recipient**[5]	**Further process step**
verbal description		t / a	verbal description	Name	
					1_1
					1_2
					1_3
					1_4
					1_5
					1_6
					1_7
					1_8
					1_9
					1_10

2) Final fractions accounting for recycling[6]

Element or compound[7]	**Fraction (product or by-product) containing the element or compound**	**Concentration of the element or compound in the fraction**	**Mass of the element or compound, which originates from batteries input**	**Fate of the fraction**
		mass %	t / a	verbal description

Explanations:

1) Facility carrying out an individual process step

2) For step 1 = the same as input into the complete battery recycling process

For subsequent steps = intermediate fractions from the previous process

3) Intermediate fractions = waste for recycling

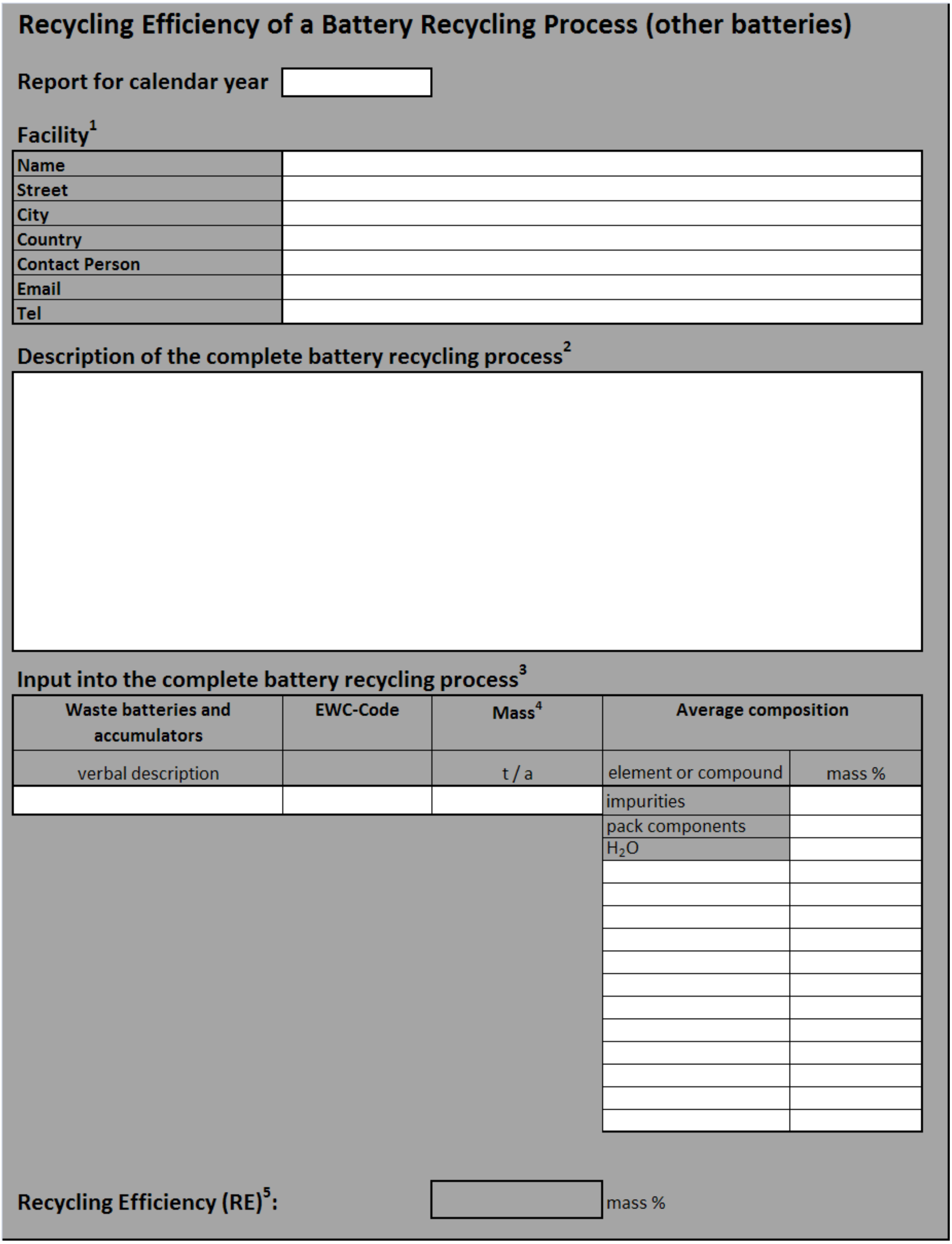
4) Originating from the batteries input (wet mass)

5) Facility to which the intermediate fraction is handed over or - if the further process step is carried out internally - the same as 1)

6) Final fractions accounting for recycling = approved products, by-products

7) All elements and compounds if they were component of the batteries input (spent battery). Elements and compounds contained in slag do not account for recycling if they represent undesired contamination regarding the particular application of the slag (i.e. heavy metals for which there exist limit values for road construction material). Cadmium must be entered as “Cd”.

5.2.5 *Reporting Format for other batteries and accumulators, Form A*



Recycling Efficiency of a Battery Recycling Process (other batteries)

Report for calendar year

Facility[1]

Name	
Street	
City	
Country	
Contact Person	
Email	
Tel	

Description of the complete battery recycling process[2]

Input into the complete battery recycling process[3]

Waste batteries and accumulators	**EWC-Code**	**Mass**[4]	**Average composition**	
verbal description		t / a	element or compound	mass %
			impurities	
			pack components	
			H_2O	

Recycling Efficiency (RE)[5]**:** mass %

Explanations:

1) Facility receiving the waste batteries and accumulators after collection and eventual sorting

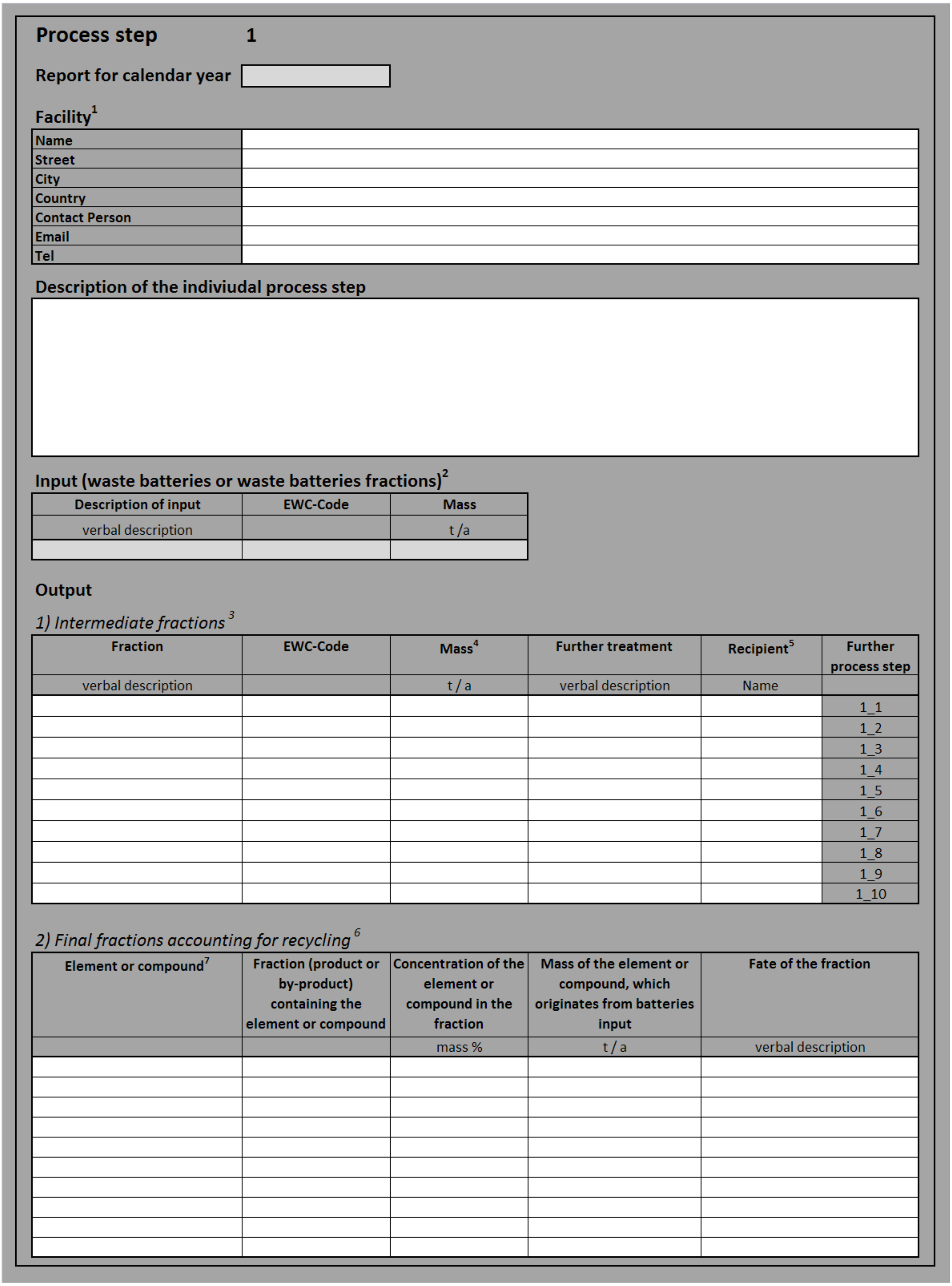
2) Description of the complete battery recycling process, no matter if carried out by one or several facilities (including a description of the individual recycling steps and their output fractions)

3) waste batteries and accumulators as received after collection and eventual sorting

4) wet mass of waste batteries and accumulators as received after collection and eventual sorting (the mass of separated impurities and pack components as well as the water content as specified in the field "average composition" are subtracted for the calculation of the RE)

5) calculated automatically according to the formula for RE based on data filled in Forms B

5.2.6 Reporting Format for other batteries and accumulators, Form B



Process step **1**

Report for calendar year ☐

Facility[1]

Name	
Street	
City	
Country	
Contact Person	
Email	
Tel	

Description of the indiviudal process step

Input (waste batteries or waste batteries fractions)[2]

Description of input	**EWC-Code**	**Mass**
verbal description		t /a

Output

1) Intermediate fractions [3]

Fraction	**EWC-Code**	**Mass**[4]	**Further treatment**	**Recipient**[5]	**Further process step**
verbal description		t / a	verbal description	Name	
					1_1
					1_2
					1_3
					1_4
					1_5
					1_6
					1_7
					1_8
					1_9
					1_10

2) Final fractions accounting for recycling [6]

Element or compound[7]	**Fraction (product or by-product) containing the element or compound**	**Concentration of the element or compound in the fraction**	**Mass of the element or compound, which originates from batteries input**	**Fate of the fraction**
		mass %	t / a	verbal description

Explanations:

1) Facility carrying out an individual process step

2) For step 1 = the same as input into the complete battery recycling process

For subsequent steps = intermediate fractions from the previous process

3) Intermediate fractions = waste for recycling

4) Originating from the batteries input (wet mass)

5) Facility to which the intermediate fraction is handed over or - if the further process step is carried out internally - the same as 1)

6) Final fractions accounting for recycling = approved products, by-products

7) All elements and compounds if they were component of the batteries input (spent battery). Elements and compounds contained in slag do not account for recycling if they represent undesired contamination regarding the particular application of the slag (i.e. heavy metals for which e.g. limit values for road construction material exist).

6 Best available techniques and treatment requirements

6.1 BAT for collection, treatment and recycling of different battery types

6.1.1 Definition of BAT

This chapter focuses on the description of core elements of BAT and treatment requirements in the EU. The term BAT is defined in the IPPC Directive 2008/1/EC as follows:

> 'best available techniques' means the most effective and advanced stage in the development of activities and their methods of operation which indicate the practical suitability of particular techniques for providing in principle the basis for emission limit values designed to prevent and, where that is not practicable, generally to reduce emissions and the impact on the environment as a whole:
>
> (a) 'techniques' shall include both the technology used and the way in which the installation is designed, built, maintained, operated and decommissioned;
>
> (b) 'available techniques' means those developed on a scale which allows implementation in the relevant industrial sector, under economically and technically viable conditions, taking into consideration the costs and advantages, whether or not the techniques are used or produced inside the Member State in question, as long as they are reasonably accessible to the operator;
>
> (c) 'best' means most effective in achieving a high general level of protection of the environment as a whole.

6.1.2 Information sources

At European level information on BAT is conferred in the Best Available Techniques Reference Documents (BREFs). These must be taken into account when the competent authorities of Member States determine conditions for IPPC permits. Starting point for giving an overview on BAT are therefore existing relevant BREFs. Relevant in the context of Battery recycling are the following BREFs:

- Reference Document on Best Available Techniques in the Non Ferrous Metals Industries, December 2001 [EIPPCB 2001]. A new draft of this BREF from November 2008 is available [EIPPCB 2008].
- Reference Document on Best Available Techniques on Emissions from Storage, July 2006 [EIPPCB 2006a].
- Reference Document on Best Available Techniques for the Waste Treatment Industries, August 2006 [EIPPCB 2006b].

In addition to the analyses of BREFs, existing technical guidelines related to battery recycling have been analysed with respect to information on BAT for battery recycling. The following technical guidelines containing specific provision on batteries were identified and analysed:

- Technical Guideline on the Environmentally Sound management of Waste Lead Acid Batteries [SBC 2003]
- Austrian ordinance Management on Waste Treatment Obligations [MinEnv AT 2004]

A dedicated BREF on battery recycling does not exist. BAT in the field of battery recycling is not defined except for those processes that are explicitly described in one of the above mentioned BREF documents such as the recycling of lead-acid batteries (see [EIPPCB 2008]).

An additional information source which is relevant for BAT is information that is available on actually performed processes within the Community. There is only a limited number of dedicated processes in the battery recycling industry in the EU. The facilities carrying out these processes are each holding a valid permit and it can be assumed that they are operating in compliance with EU legislation on waste, environment and health & safety. Accordingly the actually carried out processes are representing the state of the art in battery recycling within the Community. Flow charts and short textual description of the treatment and recycling process steps the output fractions and their fate are provided in chapter 3.2 and in the Annex (section 10.6) as a valuable and specific expert information source on actually applied technologies in dedicated processes for battery recycling in addition to generally defined BAT.

This information has been established in close co-ordination with representatives from the battery recycling industry and could be used as a starting point for a further description of (best) available techniques and also for the consideration of the general impact of battery recycling processes on the environment as a whole.

However, it has to be clearly stated, that the information that has been compiled in the frame of the present project is by far not sufficient to evaluate the overall impact of battery recycling processes on the environment as a whole. The consideration of the overall impacts would be necessary to enable an assessment of processes applied in battery recycling in a corresponding way and not with a single focus on the recycling efficiency.

Together with the core elements from BREFs and Technical Guidelines this information provides a practical and factual information source for experts for technical experts and economic actors.

The relevant core elements of BAT are described in the Annex (see sections 10.7) as a factual source of information for technical experts.

On the basis of the technical background a detailed description of technically feasible and environmental sound parameters is proposed in chapter 6.3 in order to concretisise the minimum treatment requirements according to the Batteries Directive (2006/66/EC) “removal of all fluids and acids and their collection and treatment”, “impermeable surfaces”, “suitable weatherproof covering” and “suitable containers”.

6.1.3 *Assessment of the suitability of BAT for the purpose of the Batteries Directive (2006/66/EC)*

In order to systematically assess the suitability of different BAT for the purpose of the Batteries Directive (2006/66/EC) comprising all steps of collection, treatment and recycling an assessment roaster has been established (see Table 6.1). It differentiates between BAT according to the different battery types and their chemistry and takes account of the following issues:

- Economic costs and opportunities including an estimate of investment necessary;
- Level of environmental protection and efficiency;
- Geographical conditions of different regions in the EU (climate, infrastructure...);
- Social criteria including potential generation of new employment.

The assessment of the economic costs and opportunities considers required investments and operation costs. If BAT is related to low or reasonable investment costs in combination with low or reasonable operation costs this enables business opportunities (increased economic income) and also the generation of new employment. In the assessment investment and operation costs are assessed and allocated to the categories/scores: no additional costs/2, reasonable additional costs/1 and high additional costs/0. The economic opportunities are allocated to the categories/scores existing/2, potentially existing/1 and not existing/0. For the assessment it has to be kept in mind that the costs related to BAT are per definition "economically viable". So, even BAT that is assessed to be related to high investment or operation costs is generally affordable in the relevant industry sector.

The level and efficiency of BAT concerning environmental protection is assessed according to the degree of environmental protection e.g. a 50% emission reduction ("level") and the effort which is necessary to achieve the environmental protection ("efficiency"). The level and efficiency is allocated to the categories/scores: no positive effects/0, considerable positive effects/1 and high positive effects/2.

The suitability of a BAT with respect to local conditions of different regions depends on the question whether a BAT is dependent from local conditions or not. For example the use of acid resistant containers is reasonable under all geographic conditions throughout the whole EU. In contrast, if a BAT concerns e.g. noise emissions or waste water releases from recycling process steps, the use of BAT will depend on the local conditions. In the case of the examples "noise" and "wastewater" it depends e.g. from the situation relative to residential areas or the availability of receiving water courses or waste water treatment plants. The dependency of BAT from geographical conditions is allocated to the categories/scores: independent from local conditions/1 and local conditions should be considered/0.

The assessment of social criteria is particularly related to the generation of new employment. The generation of new employment is generally expected if a BAT enables opportunities to increase the economic income which enables as a consequence the generation of new employment. In the assessment the potential to generate new employment is allocated to the categories/scores: social effects not existing/0, potential positive social effects/1, positive social effects existing/2.

The assessment of the suitability of BAT is based on the presumption that BAT that are related to

- low or reasonable cost
- considerable or high positive environmental effects
- independency from local conditions
- no or positive social effects

are most suitable for the purposes of the Batteries Directive (2006/66/EC).

BAT that are assessed to be suitable are adequate to be used for complementing rules or information aiming to support the implementation of the Batteries Directive (2006/66/EC).

The following table shows an assessment scheme for BATs. The first three lines (in grey) of the scheme are used to define the battery type and chemistry of the BAT in consideration. The following lines are related to the assessment criteria “investment costs”, “operation costs”, “economic opportunities”, “Environmental impact”, “Local conditions” and “Social criteria”, For the overall assessment it is possible to aggregate the scores to a sum value. Generally, the higher the sum value, the better is the suitability of the BAT in consideration. However, the assessment needs to be justified by expert judgement.

Battery type			Battery chemistry		
Portable	Industrial	Automotive	Lead-Acid	Nickel-Cadmium	Other

Criterion	Score/Assessment	Assessment (justification)
Investment costs	0: high additional costs 1: reasonable additional costs 2: no additional costs	e.g. information on investment costs
Operation costs	0: high additional costs 1: reasonable additional costs 2: no additional costs	e.g. information on operation costs
Economic opportunities	0: not existing 1: potentially existing 2: existing	e.g. information on opportunities
Environmental impact	0: no positive effects 1: considerable positive effects 2: high positive effects	e.g. information on the level of protection (x% abatement) and on the efficiency (e.g. comparison with other possible measures)
Local conditions	1: independent from local conditions 0: local conditions should be considered	e.g. information on the need to consider local conditions
Social criteria	0: social effects not existing 1: potential positive social effects 2: positive social effects existing	e.g. information on effects on employment
Overall assessment	Sum of scores	Expert judgement

Table 6.1 : Scheme explaining the methodology for the assessment of the suitability of BAT for the purpose of the Batteries Directive (2006/66/EC)

For the assessment the scheme has been applied to the identified core elements of BAT considering all steps of collection, treatment and recycling with the result that, as far as BAT is defined in existing BREF Documents, it is suitable for the purposes of the Batteries Directive (2006/66/EC).

6.2 Core elements of BAT

6.2.1 Core elements from BREFs

BAT core elements identified from relevant BREFs are documented in the Annex (see section 10.7.1)

6.2.2 Core elements from relevant guidelines

BAT core elements identified from relevant guidelines and technical documents are documented in the Annex (see section 10.7.2).

6.3 Proposal for detailed requirements of Annex III of Directive 2006/66

According to Article 12(2) of the Batteries Directive (2006/66/EC) treatment shall meet minimum treatment requirements regarding

- treatment shall include removal of all fluids and acids (Annex III Part A.1)
- treatment and storage at treatment facilities shall take place in sites with
  - impermeable surfaces and
  - suitable weatherproof covering or in
  - suitable containers (Annex III Part A.2)

Details on these requirements are not laid down in the Directive. One project objective is to describe these treatment requirements in detail. To this end relevant BREFs and available technical guidelines have been analysed for appropriate technologies that can be used to describe the minimum treatment requirements in detail.

From relevant BREF Documents [EIPPCB] and guidelines [SBC 2003 and MinEnv AT 2004] a set of requirements has been identified that are related to the minimum treatment requirements. These are documented in the Annex (see section 10.8)

On the basis of the identified requirements a first draft proposal for specific, technically feasible, and environmental sound parameters for the minimum treatment requirements has been established and has been presented and discussed at the dedicated project workshop on 20 January 2009 in Brussels. Battery recyclers were asked to check operation permits and to inform the ESWI team whether there is information contained that could be used for further specification of the minimum treatment requirements.

The specification of minimum treatment requirements should strictly relate to treatment. Transport and collection are not in the focus of the minimum treatment requirements according to Annex III, Part A of the Directive. Due to the different characteristics of batteries containing liquids and other batteries a differentiation between these categories is required. A mixture of waste batteries containing a significant share of batteries containing liquids should be regarded as batteries containing liquids.

Against this background and the discussion at the project workshop the proposal for the minimum treatment requirements has been adjusted accordingly.

Proposal for the specification of the minimum treatment requirement: "Removal of all fluids and acids, their collection and treatment":

Proposed Specification	Validity for batteries	
	containing liquids	other
Batteries should be drained and prepared for recycling by adequately trained and personally protected workers	yes	no
In operational areas a ground cover has to be utilised that may retain any leakage and direct it to a collecting container from where it can be removed.	yes	no
The capacity to retain leakage must at least be equal to the amount of liquid stored	yes	no
Surfaces of operational areas, drainage systems and other subsurface structures should be maintained, including applying measures to prevent or quickly clear away leaks and spillages.	yes	no
Electrolyte should be directed to appropriate treatment (recycling/recovery or appropriate waste treatment)	yes	no
Recycling/recovery of electrolyte should be done if appropriate; direct discharge of neutralised and/or untreated electrolyte should be avoided.	yes	no
When applying a neutralisation process customary measurement methods have to be used	yes	no
Neutralised waste water of a neutralisation process has to be stored separately	yes	no
A final inspection of the neutralised waste water of a neutralisation process has to be performed	yes	no

Table 6.2: Proposal for the specification of the minimum treatment requirement: "Removal of all fluids and acids, their collection and treatment"

Proposal for the specification of the minimum treatment requirement: "Impermeable surfaces and suitable weatherproof covering"

Proposed Specification	Validity for batteries	
	containing liquids	other
Surfaces in operational areas should be resistant to chemicals and fire	yes	yes
Storage of waste batteries at treatment and recycling facilities must take place in a proper building or covered place with the following minimum	yes	yes

Proposed Specification	Validity for batteries	
	containing liquids	other
requirements:		
– Impermeable and acid and/or lye resistant floor depending on the electrolyte used	yes	no
– Efficient water collection system which directs spilled liquids towards the effluent or electrolyte treatment plant	yes	no
Storage in a proper building or under cover must also be applied to any container that is pending sampling and emptying.	yes	yes
Storage may be carried out without cover if the stored waste batteries and containers are not affected by ambient conditions (e.g. sunlight, temperature, water)	yes	yes
Covered areas need to have adequate provision for ventilation.	yes	yes
The availability and access to storage areas for containers holding substances that are known to be sensitive to heat, light and water, under cover and protected from heat and direct sunlight has to be maintained.	yes	yes
For storing quantities of more than 2500 litres or kilograms dangerous substances a storage building and/or an outdoor storage area covered with a roof has to be applied according to the BREF on Emissions from Storage [EIPPCB 2006a].	yes	yes
For storing quantities of less than 2500 litres or kilograms dangerous substances, at least a storage cell has to be applied according to the BREF on Emissions from Storage [EIPPCB 2006a].	yes	yes

Table 6.3: **Proposal for the specification of the minimum treatment requirement: "Impermeable surfaces and suitable weatherproof covering"**

Proposal for the specification of the minimum treatment requirement: "suitable containers"

Proposed Specification	Validity for batteries	
	containing liquids	other
Storage must take place in leak proof containers that are acid and/or lye resistant depending on the electrolyte used.	yes	no
Containers must be clearly labelled as regards the nature of the waste and the relevant danger symbols	yes	yes
If appropriate, the use of re-usable packaging (drums, containers, IBCs, palettes, etc.) should be maximised.	yes	yes

Table 6.4: **Proposal for the specification of the minimum treatment requirement: "suitable containers"**

According to industry statements it would be reasonable to establish a general requirement that treatment and recycling of waste batteries should only be carried out in installations with a corresponding permit according to the IPPC directive.

7 Criteria for equivalency of recycling operations outside the European Union

7.1 Identification of applicable criteria

According to Article 15 of Directive 2006/66/EC treatment and recycling may take place outside the Member State concerned or even outside the Community, provided EU legislation on the shipment of waste is respected and if there is sound evidence that treatment and recycling outside the EU adheres to treatment requirements that are equivalent to those within the EU. Particular criteria for the assessment of equivalent conditions shall be laid down through Commitology procedure.

An important project objective is therefore to establish criteria to assess the conditions equivalent to the requirements of the Batteries Directive (2006/66/EC) that recycling processes outside the EU have to meet.

Consequently it is necessary to establish a selection of information needs (or criteria) that are adequate to provide sound evidence that for waste battery exports a recycling operation takes place under conditions equivalent to the requirements of Directive 2006/66/EC. These criteria must particularly enable to provide sound evidence that a recycling operation

- is carried out using BAT (this includes protection of health and the environment) according to local conditions and
- meets the minimum treatment requirements set out in Annex III, Part A and
- meets the recycling efficiencies set out in Annex III, Part B
- meets conditions for recycling, treatment, transport and storage of waste prescribed by other Community legislation in particular with regard to health and safety and waste management
- is adequate considering local conditions in third countries

Criteria that are suitable to provide sound evidence could e.g. be the following:

- Evidence that applied technology is BAT or is equivalent to BAT (taking also account of protection of health and environment and of local conditions in third countries)
- Evidence that requirements of existing and approved guidelines are fulfilled (i.e. Technical Guidelines for the environmentally sound Management of waste batteries)
- Evidence that there is no danger to human health and the environment (information e.g. taken from plant permits)
- Evidence that minimum treatment requirements are met

- Evidence that recycling efficiencies are fulfilled (reporting on input of waste batteries per type and corresponding output of products, materials and substances)
- Evidence that health & safety and waste management conditions for recycling, treatment, transport and storage are fulfilled (currently put in practice at Member State level during the licensing and control process of recycling facilities; each operation permit includes specific requirements on health & safety and waste management conditions implementing the relevant EU legislation such as the IPPC Directive, EU working protection legislation or the Waste Framework Directive)

Specific evidence can be provided in three different categories of information.

1. as a statement of the recycler that the individual requirements are kept
2. as a certificate of an independent institution confirming that the individual requirements are kept
3. as a proof by documentation and reporting of the recycler or an independent institution that the individual requirements are kept e.g. by documentation of
   - operating conditions and requirements (e.g. from plant permits)
   - input and output data of waste batteries
   - final treatment and fate of output fractions and residues
   - procedures for transport, storage, treatment
   - measurement data on occupational exposure
   - measurement data of emissions to air, water and land

Such evidence can also be specifically applied, if a BAT is not available for an applied technology in a third country. Evidence for equivalency to BAT can be provided by a comparison of the applied technology with European BAT processes for these specific points. Local conditions should be considered.

According to these three categories of information evidence could be provided by exporters of waste batteries or by recyclers outside the EU as statements, certificates or proofs related to the relevant criteria. This leads to a list of possible information that could be provided:

- Statement of the recycler that applied technology is BAT or equivalent to BAT (taking also account of local conditions)
- Certificate that the applied technology is BAT or equivalent to BAT
- Proof that the applied technology is BAT or equivalent to BAT (information e.g. taken from plant permits)
- Statement that requirements of existing and approved guidelines are fulfilled (only relevant where such guidelines exist)
- Certificate that requirements of existing and approved guidelines are fulfilled.

- Proof that requirements of existing and approved guidelines are fulfilled.
- Statement that there is no danger to human health and the environment
- Certificate that there is no danger to human health and the environment
- Proof that there is no danger to human health and the environment (information e.g. on the basis of plant permits, measurement data on occupational exposure, procedures for transport, pre-treatment, storage, air emissions, emissions to soil and water, final treatment of process residues)
- Statement that minimum treatment requirements are fulfilled
- Certificate that minimum treatment requirements are fulfilled
- Proof that minimum treatment requirements are fulfilled (e.g. on the basis of information taken from plant permits)
- Statement that recycling efficiencies are fulfilled
- Certificate that recycling efficiencies are fulfilled
- Proof that recycling efficiencies are fulfilled (e.g. on the basis of input data of waste batteries (mass and battery types) and corresponding output data (mass) of products, materials and substances)
- Statement that health & safety and waste management conditions for recycling, treatment, transport and storage are fulfilled
- Certificate that health & safety and waste management conditions for recycling, treatment, transport and storage are fulfilled
- Proof that health & safety and waste management conditions for recycling, treatment, transport and storage are fulfilled

7.2 Assessment of the identified criteria

In this chapter the information will be assessed in order to select a set of practical sound evidence that should be provided in order to prove compliance with the criteria for equivalent conditions showing that recycling operations outside the EU meet equivalent conditions as set out by Directive 2006/66/EC. Unnecessary administrative burden should be avoided.

Assessment criteria:

- Availability of the required information/data
- Effort required to provide the evidence
- Credibility of the evidence

For the three categories of information (statement, certificate, proof) it can be concluded for all required criteria of evidence that with respect to the assessment criteria “availability”, “effort” and “credibility” the following can be stated:

- Statements are easily available, can be provided with low effort but are related to a low credibility because there is no entity which could control the trueness of the information provided.
- Proofs and certificates are in several cases difficult to provide to due to limited availability (e.g. if measurements were not performed and data are therefore not available) and comparatively high effort (costly generation of data e.g. for measurements). The credibility of certificates and proofs by appropriate documentation and measurement data can be considered high.

To conclude, statements can not be regarded sufficient to provide sound evidence. Proofs and certificates seem to be appropriate. This is in agreement with the opinions of stakeholders in response to the questionnaire survey where the majority of repliers voted for proofs and certificates for the provision of sound evidence for equivalent conditions.

It seems to be common sense that evidence with respect to transport will not contribute any added value for the sound evidence of equivalent conditions as transport of waste batteries is exhaustively regulated in the following documents related to international transport regulations:

- For transport via road the UNECE “ADR” Regulations (European Agreement concerning the International Carriage of Dangerous Goods by Road, concluded at Geneva on 30 September 1957, as amended);
- For transport via railway the “RID” Regulations (Regulations concerning the International Carriage of Dangerous Goods by Rail, appearing as Appendix C to the Convention concerning International Carriage by Rail (COTIF) concluded at Vilnius on 3 June 1999, as amended);
- For transport via seaways the IMO IMDG Code and the UNECE “ADN” Agreement (European Agreement concerning the International Carriage of Dangerous Goods by Inland Waterways, concluded at Geneva on 26 May 2000, as amended) respectively.

Specific evidence related to transport is therefore not necessary.

For the export of waste for recovery, the Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and Their Disposal, the OECD Decision 2001(107) final and Regulation (EC) 2006/1013 on shipments of waste apply. According to article 36 of the EC Regulation on shipments of waste, exports from the Community of hazardous waste batteries destined for recovery in non-OECD countries are prohibited. Only the export of green listed waste batteries is allowed.

Accordingly the export of the following waste batteries to non-OECD countries is prohibited:

A1160	Waste lead-acid batteries, whole or crushed
A1170	Unsorted waste batteries excluding mixtures of only list B batteries. Waste batteries not specified on list B containing Annex I constituents to an extent to render them hazardous
A1180	Waste electrical and electronic assemblies or scrap containing components such as accumulators and other batteries included on list A, mercury-switches, glass from cathode-ray tubes and other activated glass and PCB-capacitors, or contaminated with Annex I constituents (e.g. cadmium,

mercury, lead, polychlorinated biphenyl) to an extent that they possess any of the characteristics contained in Annex III (note the related entry on list B, B1110) (3)

(3) PCBs are at a concentration level of 50 mg/kg or more

The export of the following waste battery categories to non-OECD countries is allowed:

B1090 Waste batteries conforming to a specification, excluding those made with lead, cadmium or mercury

B1110 Electrical and electronic assemblies:

- Electronic assemblies consisting only of metals or alloys
- Waste electrical and electronic assemblies or scrap (2)(including printed circuit boards) not containing components such as accumulators and other batteries included on list A, mercury-switches, glass from cathode-ray tubes and other activated glass and PCB capacitors, or not contaminated with Annex I constituents (e.g. cadmium, mercury, lead, polychlorinated biphenyl) or from which these have been removed, to an extent that they do not possess any of the characteristics contained in Annex III (note the related entry on list A, A1180)
- Electrical and electronic assemblies (including printed circuit boards, electronic components and wires) destined for direct reuse (3) and not for recycling or final disposal (4):

  (3) Re-use can include repair, refurbishment or upgrading, but not major reassembly.

  (4) In some countries these materials destined for direct re-use are not considered wastes.

B4030 Used single use cameras, with batteries not included on list A

According to the opinion of several stakeholders all types of batteries should be regarded as hazardous due to the characteristics of their constituents. If so, the export prohibition would apply to all types of batteries.

At the dedicated project workshop it was suggested to make a differentiation between OECD and non-OECD countries in order to reflect similarity of standards within the OECD. It is not considered useful to request from a recycler within the OECD evidence that goes further than the information that is required from a company situated within the Community.

Requirements for equivalency should take into account all aspects of BAT and thus requirements according to the IPPC permits. Particularly relevant are the general principles governing the basic obligations of the operator according to Article 3 and applications for permits according to Article 6 IPPC Directive 2008/1EC. Treatment facilities outside the EU should be requested a similar level of information as within the Community.

7.3 Proposal of a sound evidence system for equivalent conditions

Against this background a sound evidence system for equivalent conditions should be differentiated for export of waste batteries to OECD countries and non-OECD countries.

Information should be equivalent to the requirements within the EU and should therefore contain equivalent conditions to the requirements of the Batteries Directive (2006/66/EC) and the IPPC Directive. Unnecessary administrative burden should be avoided.

Specific evidence required from operators within OECD countries can be provided by the operator on the basis of appropriate documentation. Specific evidence from operators outside OECD countries should be provided by certification by an independent institution.

Specific requirements for transport conditions are not required as these are sufficiently regulated in international transport regulation. For the export of waste batteries the requirements of the waste shipment regulation are to be considered.

Specific evidence required from operators in OECD countries should provide the following evidence:

The operator receiving the waste batteries for recycling must

- proof to hold a valid operation permit for the recycling of the relevant waste batteries
- provide summary information from the permit in order to provide evidence that the recycling facility is operated in a way that (in equivalence to the requirements of the IPPC Directive)
    - (a) all the appropriate preventive measures are taken against pollution, in particular through application of the best available techniques
    - (b) no significant pollution is caused
    - (c) measures are implemented in accordance with Directive 2008/98/EC to protect the environment and human health by preventing or reducing the adverse impacts of the generation and management of waste and by reducing overall impacts of resource use and improving the efficiency of such use
    - (d) energy is used efficiently
    - (e) the necessary measures are taken to prevent accidents and limit their consequences
    - (f) the necessary measures are taken upon definitive cessation of activities to avoid any pollution risk and return the site of operation to a satisfactory state

- provide summary information on the permit requirements related to the
    - (g) nature, quantity and sources of emissions and measures for preventing/reducing and monitoring of emissions
    - (h) protection of human health and the environment
    - (i) minimum treatment requirements
    - (j) storage and treatment
    - (k) prevention and recovery of waste
    - (l) the conditions of the site of the installation and how local conditions are considered
- report on input of waste batteries and corresponding output fractions to provide evidence that the required recycling efficiencies are fulfilled

Specific evidence required from operators in non-OECD countries should be similar information on the identical issues. The information should be provided by an independent institution by certificate.

For both, operators inside and outside OECD countries the evidence needs to be up-dated annually particularly concerning any changes, such as

- Reporting on recycling efficiencies
- Information on all issues were changes take place or where operation requirements are not fulfilled such as
    - changes in the relevant permit requirements
    - changes in the applied techniques
    - monitoring/exceeding of emission limit values
    - accidents

8 Conclusion and outlook

The conclusions of the project team concerning the specific project tasks are compiled in the executive summary. In the course of the project several issues beyond were identified that should be kept in mind for the further process of the implementation of the recycling efficiencies and the export article of Directive 2006/66:

Achievement of the required recycling efficiency in practice

- The general approach to establish requirement for recycling efficiencies prior to determine a calculation method is sub optimal because of policymakers and stakeholders that assuming different frame conditions for the calculation of the recycling efficiency. A proposal for the conditions for the calculation has been established with the present project with several difficulties, since concerns of stakeholders had to be considered in order to avoid inappropriate economic impacts for established technologies.

- According to the estimation of the project team, the recycling efficiencies as required according to Annex III, part B of the Batteries Directive (2006/66/EC) will be achieved without taking reducing agents into account in actually performed recycling processes for the most relevant battery chemistries. This estimation is related to those selected cases where corresponding concerns have been expressed and is based on the information provided by individual stakeholders including e.g. information on the actual use of the by-product slag. Changing conditions e.g. for the use of slag may lead to altered results of this estimation. Future reporting will show the results of the recycling efficiency calculation in practice and according to technical progress. The practical results from reporting will enable to evaluate the appropriateness of the required recycling efficiencies. Based on the experience gained in Member States it may be necessary to adjust the requirements. In the view of the project team such an adjustment should generally consider all possible options, A to increase, B to maintain or C to decrease the requirements concerning the recycling efficiencies.

Level to achieve the recycling efficiency

- The proposal of the project team is option B (efficiency to be achieved at the level of individual treatment processes), in order to stimulate technological improvement in combination with exemptions of those battery chemistries treated in a dedicated process and for which the required recycling efficiency are not achievable with the use of BAT.

- As difficulties to achieve the required recycling efficiency are probable to occur for recycling processes where certain battery types with particular chemistries are treated, the proposal of the project team is to allow exemptions for specific processes. As a consequence it would be necessary to thoroughly define these exemptions. The exemptions should be regularly revised according to the state of the art. In the view of the project team to allow exemptions is the best option in order to maintain competition between recycling processes and the motivation to improve the corresponding processes. It is difficult to make a reliable prognosis for which processes exemptions could be required because this depends from many factors and individual strategies of companies. Relevant factors are for example the input mixture of different battery chemistries into a specific process, the fate of the output fractions, the material flows in individual processes, etc. However it can be assumed that difficulties to achieve the required recycling efficiencies could for example occur for selected processes for the recycling of ZnC and AlMn batteries, for ZnO or for LiO batteries. ZnO batteries constitute only a minor part of waste batteries and are usually treated together with batteries of other chemistry (ZnC and AlMn). In the future the results of reporting on the recycling efficiencies will make clear in which cases possible exemptions may be appropriate.

Clarification on the properties of treated water

- A comprehensible joint industry position considers the output of treated water as a by-product as defined in Article 5 of the Waste Framework Directive 2008/98/EC. In the view of the project team the release of treated water into the environment is an emission. This issue may also raise difficulties in other context and a clarification by the Commission services could be reasonable.

Accountability of slag

- Slags are classifiable as by-products in the sense of Directive 2008/98/EC. Slag use is permitted according to the corresponding legislation of the respective Member State. This may lead to discrimination of battery recyclers in Member states where the slag is not authorized to be used e.g. for road construction but has to be disposed off. In order to avoid market distortions a harmonised approach should be envisaged.

Determination of batteries input

- In order to determine the batteries input into a recycling process on an elemental/compound level, we propose either to conduct chemical analysis of the waste batteries or to determine the share of defined battery chemistries by conducting sorting analysis and subsequent calculation based on data on average composition of the batteries. Both options need representative samples of the batteries input. To guarantee harmonization between recycling processes the sampling procedure as well as the chemical analysis should be standardized.

- A comprehensive and regularly updated list of the composition of all battery chemistries on the EU-market is necessary, whereby administration by an independent third party (based on data of producer associations) is proposed.

Battery recycling processes / BAT / environmental performance

- The project team proposes to update the inventory of applied recycling processes, the resulting output fractions, their possible fates and the resulting classification regarding “recycling” on a regular basis.
- This information has been established in close co-ordination with representatives from the battery recycling industry and could be used as a starting point for a further description of (best) available techniques and also for the consideration of the general impact of battery recycling processes on the environment as a whole.
- The stakeholder consultation process showed that further criteria - in addition to the overall recycling efficiency – are to be considered for the evaluation of the impacts of battery recycling processes on the environment as a whole. These are for example emission monitoring - in particular of heavy metals, such as Cd and Hg, the energy efficiency of the processes and quality parameters for by-products to be used for recovery. Therefore it seems appropriate to establish an up-to-date comprehensive review of the state of the art of battery recycling.

Evaluation of the calculation method and the reporting format

- Due to the complexity of battery recycling (numerous battery chemistries and continuing developments, various recycling processes) an evaluation of the proposed calculation method as well as of the reporting format after the first reporting period should be foreseen. We consider this essential for assessing the applicability of the tools and for improving them if needed.

9 References

[BIO 2008]
Bio Intelligence Service, Establishing harmonised methods to determine the capacity of all portable and automotive batteries and rules for the use of the label indicating the capacity of these batteries, Final Report, September 2008
http://ec.europa.eu/environment/waste/batteries/pdf/battery_report.pdf

[EC 2008]
European Commission, Questions and Answers on the Batteries Directive (2006/66/EC), Commission Services document – not legally binding, update April 2008
http://ec.europa.eu/environment/waste/batteries/pdf/questions_answers_directive.pdf

[ECHA 2008]
Guidance for the implementation of REACH - Guidance on Registration, European Chemicals Agency, May 2008
http://guidance.echa.europa.eu/guidance_en.htm

[EIPPCB 2001]
European Integrated Pollution Prevention and Control Bureau, Reference Document on Best Available Techniques in the Non Ferrous Metals Industries, December 2001
http://eippcb.jrc.es/reference/nfm.html

[EIPPCB 2006a]
European Integrated Pollution Prevention and Control Bureau, Reference Document on Best Available Techniques on Emissions from Storage, July 2006
http://eippcb.jrc.es/reference/esb.html

[EIPPCB 2006b]
European Integrated Pollution Prevention and Control Bureau, Reference Document on Best Available Techniques for the Waste Treatment Industries, August 2006
http://eippcb.jrc.es/reference/wt.html

[EIPPCB 2008]
European Integrated Pollution Prevention and Control Bureau, Draft Reference Document on Best Available Techniques for the Non-Ferrous Metals Industries, Draft November 2008

[ERM 2006]
Environmental Resources Management (ERM), Battery Waste Management Life Cycle Assessment, study on behalf of DEFRA, Final report, October 2006
http://www.defra.gov.uk/environment/waste/topics/batteries/pdf/erm-lcareport0610.pdf

[MinEnv AT 2004]
Ordinance of the Austrian Federal Minister of Agriculture and Forestry, Environment and Water on Waste

Treatment Obligations (Abfallbehandlungspflichtenverordnung), BGBl. (Federal Law Gazette) II No. 459/2004

[SBC 2003]
Secretariat of the Basel Convention, Technical Guideline on the Environmentally Sound management of Waste Lead Acid Batteries, ISBN: 92-1-158627-5, 2003
http://www.basel.int/meetings/sbc/workdoc/techdocs.html

[Citron AG]
http://www.citron.ch/myUploadData/files/Batterie_Broschuere.pdf

[EBRA 2003]
Recycling of used portable batteries in Europe. The 2002 facts and figures and how to improve them, Presentation, ICBR, Lugano, June 2003

[EBRA, EPBA, Recharge 2003]
The RECYCLING EFFICIENCY OF SPENT PORTABLE BATTERIES, A GUIDANCE NOTE prepared by EBRA, EPBA and RECHARGE, 10.12.2008

[JRC 2008]
Joint Research Centre, JRC Scientific and Technical Reports, End of Waste Criteria, Final Report, 2008.

[ÖP 2004]
Ökopol, Definition of waste recovery and disposal operations, Report compiled for the European Commission, DG Environment, March 2004
http://ec.europa.eu/environment/waste/studies/pdf/r_d_part_b.pdf

[OVAM 2006]
Integrale evaluatie van verwerkingstechnieken voor Belgische afvalbatterijen (zinkkool en alkaline fractie), Public Waste Agency of Flanders, 2006
http://www.ovam.be/jahia/Jahia/cache/bypass/pid/176?appid=39739_29&appparams=http%3A%2F%2Fwww.ovam.be%2FovamPublicationsWeb_myjahiasite%2FPublicaties&resetAppSession=true#field_39739

[PLE 2006]
Plastics Europe, Johan Brusselars, Frank E. Mark, Lein Tange, USING METAL-RICH WEEE PLASTICS AS FEEDSTOCK / FUEL SUBSTITUTE FOR AN INTEGRATED METALS SMELTER, November 2006
http://www.flameretardants.eu/Objects/2/Files/Using%20Metal-Rich%20WEEE%20Plastics%20as%20Feedstock.pdf

10 Annexe

10.1 Questionnaire

For information collection and as a discussion basis a questionnaire has been sent out to relevant stakeholders on 25 November 2008. It was accompanied by a recommendation letter of the European Commission and some background information. The deadline to submit the questionnaire to the ESWI team was 14 December 2008. The following questionnaire was distributed:

QUESTIONNAIRE

related to the "Study on the calculation of recycling efficiencies and implementation of export article of the Batteries Directive 2006/66/EC"

1) Aim of the questionnaire

In order to achieve a broadly accepted project outcome, the results of the above mentioned project shall be based on an intensive stakeholder consultation which includes collection of expertise, information exchange and discussion of project results. To this end a short questionnaire has been prepared by ESWI[24] in close coordination with the Commission Services.

2) Background information

The Batteries Directive 2006/66/EC came into force in September 2006 repealing Directive 91/157/EEC. The transposition deadline for the Member States was set on 26 September 2008. Among other, the Directive promotes a high rate of collection and recycling of waste batteries and accumulators and improvement in the environmental performance of all involved in the life-cycle of batteries and accumulators, including their recycling and disposal.

Directive 2006/66/EC on batteries and accumulators requires that, as of 26 September 2009 at the latest, batteries and accumulators which have been collected are treated and recycled using the best available techniques.

This Directive lays down minimum treatment requirements and recycling efficiencies for batteries and accumulators (Annex III). By 26 March 2010, these requirements need to be complemented by rules regarding the calculation of the recycling efficiencies.

Treatment and recycling may take place outside the Member State concerned or even outside the Community, provided EU legislation on the shipment of waste is respected and treatment and recycling outside the EU adheres to treatment requirements that are equivalent to those within the EU.

The objectives of the study are:

- to collect and assess information and develop a possible method for the calculation of minimum recycling efficiencies,
- to establish criteria to assess the conditions equivalent to the requirements of the Batteries Directive recycling processes outside the EU,
- to provide information on Best Available Techniques (BAT) and a description of treatment requirements.

You may also have a look at the dedicated project web-site:
www.bipro.de/batteries-directive

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[24] ESWI = Expert team to Support Waste Implementation; a consortium consisting of BiPRO GmbH (Germany), Austrian Environmental Protection Agency (Austria) and Enviroplan (Greece).
E-mail: eswi@bipro.de

3) Instructions on using the questionnaire

We have developed this questionnaire in a way that allows answering in a time saving and efficient way. The questionnaire is provided as an MS-Word-file. The most convenient way for completing the questionnaire is using this electronic version.

Questions are numbered and highlighted in blue. All fields where input is desired are grey. Some of these are text fields where written input is wanted, others are check boxes which can be activated or disabled with a mouse-click.

If a question is unclear or if you desire to discuss a certain aspect, please do not hesitate to contact one of the following contact person of the ESWI team:

Contact person	Organisation	E-mail address	Telephone	Geographical responsibility
Mr Alexander Potrykus	BiPRO GmbH, Munich, Germany	alexander.potrykus@bipro.de	+49 89 18979050	DE, BE, DK, EE, FI, FR, IE, LV, LT, LU, NL, PT, ES, SE, UK
Ms Maria Tesar	UBA Austria, Vienna, Austria	maria.tesar@umweltbundesamt.at	+43 1 313045539	AT, HU, SI, SK, CZ, IT, PL
Mr Costas Raptis	Enviroplan, Maroussia Athens, Greece	costas.raptis@enviroplan.gr	+30 2106105127	GR, BG, RO, CY, MT

We intend to contact you in order to discuss open questions or specific topics after having received your completed questionnaire. You may also indicate in the questionnaire if you would like to discuss a certain point with us.

We would kindly ask you to

- provide direct information in form of replies
- submit additional background information in form of documents, reports, data sets or as links to websites. (If it is not possible to enter this information in the questionnaire we would kindly ask you to send it as separate document files (preferably electronically, but also by postal mail where appropriate);
- return even incomplete forms if specific questions cannot be answered. If information is available but can not be provided immediately, please indicate this.

4) Returning the completed questionnaire

Please return the completed questionnaire and relevant document files to eswi@bipro.de before 14 December 2008.

Questionnaire regarding the recycling of batteries and accumulators (BAT and treatment requirements; calculation of recycling efficiencies; requirements for treatment outside the EU) Related to the "Study on the calculation of recycling efficiencies and implementation of export article of the Batteries Directive 2006/66/EC"	
Please provide your name and contact data	
Name of Institution	
Country	
City/ CIP Code	
Street	
Competent contact person	
e-mail	
Phone	
Remark	
Questions related to the calculation of recycling efficiencies	

1 **Do you have information on methods to calculate the recycling efficiency in recycling processes of lead acid batteries, Ni-Cd batteries and/or other batteries?**

☐ Yes ☐ No

If yes, please specify and/or refer to information source/reference:

2 **What is in your opinion the information that is required to calculate the recycling efficiency in the sense of Directive 2006/66/EC? Please select the information that you regard as appropriate to calculate the recycling efficiency in battery recycling processes:**

☐ weight of batteries input of

☐ lead acid batteries ☐ Ni-Cd batteries ☐ other batteries

Information on all output fractions from the recycling process for each battery type (lead acid, Ni-Cd, other):

☐ type ☐ weight

☐ type of subsequent treatment process or subsequent use

☐ share (weight) of output fraction that is recycled, ☐ type of final recycling process

☐ share (weight) of output fraction that is used for other recovery (e.g. energy recovery and reprocessing into materials that are to be used as fuels or for backfilling operations, ☐ type of recovery

☐ share (weight) of output fraction that is disposed, ☐ type of disposal

☐ other, please specify here:

Questions related to the reporting on recycling efficiencies in processes	
3	**Do you have information on reporting formats to report on the efficiency of batteries recycling for lead acid batteries, Ni-Cd batteries and/or other batteries?**

☐ Yes ☐ No

If yes, please specify here and/or refer to information source/reference:

4	**What is in your opinion the information that should be reported on the recycling efficiency in processes?** **Please select the information that you regard as necessary and sufficient for reporting on recycling efficiency in battery recycling processes:**

☐ identity of the recycler (name, address, contact)

Input:

☐ types of batteries recycled

☐ lead acid batteries ☐ Ni-Cd batteries ☐ other batteries ☐ specification of other batteries

☐ type of preparatory treatment (to be specified; e.g. removal of fluids and acids, dismantling, crushing)

☐ type of recycling process (to be specified; e.g. hydrometallurgic, pyrometallurgic, thermal treatment)

☐ weight of batteries input of

☐ lead acid batteries, ☐ Ni-Cd batteries, ☐ other batteries

Output:

Information on all output fractions from the recycling process for each battery type (lead-acid, Ni-Cd, other)

☐ type

☐ weight

☐ type of subsequent treatment process or subsequent use ☐ recipient

☐ share (weight) of output fraction that is recycled, ☐ type of final recycling process, ☐ recipient

☐ share (weight) of output fraction that is used for other recovery (e.g. energy recovery and reprocessing into materials that are to be used as fuels or for backfilling operations, ☐ type of recovery, ☐ recipient

☐ share (weight) of output fraction that is disposed, ☐ type of disposal, ☐ recipient

☐ other; please specify here: ☐

Questions related to best available techniques (BAT) and treatment requirements

5 What is BAT for the different battery types concerning

- **collection** (the gathering of waste, including the preliminary sorting and preliminary storage of waste for the purposes of transport to a waste treatment facility)
- **treatment** (any activity carried out on waste batteries and accumulators after they have been handed over to a facility for sorting, preparation for recycling or preparation for disposal) **and**
- **recycling** (reprocessing in a production process of waste materials for their original purpose or for other purposes, but excluding energy recovery) **including recycling of the lead/cadmium content to the highest degree that is technically feasible while avoiding excessive costs?**

Please specify here and/or refer to information source/reference (e.g. national legislation, technical guidelines): ☐

6 What do you consider an adequate specification for minimum treatment requirements concerning

a) **removal of all fluids and acids (including their collection and treatment)?**

Please specify here: ☐

b) **impermeable surfaces?**

Please specify here: ☐

c) **suitable weatherproof covering?**

Please specify here: ☐

d) **suitable containers?**

Please specify here: ☐

Questions related to criteria for sound evidence for equivalent conditions

7 What is in your opinion the information that should be required in order to provide sound evidence that for waste battery exports a recycling operation takes place under conditions equivalent to the requirements of the Batteries Directive?

Please select or propose information that you regard as necessary and sufficient to provide sound evidence:

☐ Statement of the recycler that applied technology is BAT (taking also account of local conditions)

☐ Certificate that requirements of existing and approved guidelines are fulfilled

☐ Statement that requirements of existing and approved guidelines are fulfilled (only relevant where such guidelines exist)

☐ Statement that there is no relevant danger to human health and the environment

☐ Statement that recycling efficiencies are fulfilled

☐ Certificate that recycling efficiencies are fulfilled

☐ Proof that the applied technology is BAT (information e.g. taken from plant permits)

☐ Proof that there is no relevant danger to human health and the environment (information e.g. on the basis of plant permits, measurement data on occupational exposure, procedures for transport, pre-treatment, storage, air emissions, releases to soil and water, final treatment of process residues)

☐ Input data of waste batteries (weight and battery types) and corresponding output data (weights) of products, materials and substances)

☐ Other proposal(s); please specify here:

10.2 List of contacted stakeholders and experts

The following list is the list of stakeholders that have been contacted for the purposes of the study.

Country	Institution	E-mail contact	Contact Person
Battery Recycler			
DE	Accurec GMBH	info@accurec.de reiner.weyhe@accurec.de	R. Weyhe
DE	Berzelius	s.buch@berzelius.de	S. Buch
CH	Batrec Industrie AG	mailto:andreas.krebs@batrec.ch	A. Krebs
CH	Citron	b.schutz@citron.ag mailto:	B. Schutz
FR	Duclos Environnement	mailto:frank.margnat@duclos.sa.com	F. Margnat
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BE	Campine	paul.rooze@campine.be	P. Rooze
FR	Euro Dieuze Industrie	Internet-Formular	
UK	G&P Batteries	Michel.green@g-pbatt.co.uk mailto:	M. Green
IE	KMK Metals Recycling Ltd	info@metalsrecycling.ie	
FR	MBM (Mercure.Boy. Manufacture.)	mercure.boys.manufacture@wanadoo.fr	
SE	Nife Recycling	Internet-Formular	
SE	Boliden	Per.swartling@boliden.com	P. Swartling
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Technical Adaption Committee (2006/66/EC)			
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Collection and Recycling Initiatives			
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The draft final report and the minutes of the workshop was communicated to the participants of the stakeholder workshop and to all TAC members. To this end, an updated list of TAC members has been considered:

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10.3 Minutes of the workshop

The workshop was organised on Tuesday, 20 January 2009 in Brussels, at the premises of the European Commission, Directorate General Environment, 5, Avenue de Beaulieu, Room 0/C (ground floor). Project results achieved so far were presented and discussed.

A list of participants can be found at the end of the present document. The group of participants was composed of 3 European Commission representatives, 5 TAC[25] members (including representatives/experts of Member States), 22 Industry representatives and 3 consultants from the ESWI team.

The sequence of the topics as announced in the draft agenda was changed. The topics were presented and discussed in the following order:

1 Welcome (EC – DG ENV)

2 Background and objectives

3 Reporting on recycling efficiencies

4 Best available techniques and minimum treatment requirements

5 Project approach, data collection, specifications and definitions

6 Method for calculation of recycling efficiencies

7 Criteria for equivalency of recycling operations outside the European Union

8 Conclusions and final discussion

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[25] Technical Adaptation Committee (TAC) = Committee for the adaptation to scientific and technical progress of EC-Legislation on Waste

The minutes of the meeting and the presentations made by the consultant are available at www.bipro.de/batteries-directive/sub/workshop.htm.

1 Welcome (EC - DG ENV)

Ms Karolina Fras welcomed the workshop participants and gave background information to the study project.

2 Background and objectives

A presentation on the project background and objectives was given by Ms Maria Tesar (see TOP 2 presentation).

3 Reporting on recycling efficiencies

A presentation on the reporting of recycling efficiencies was given by Ms Maria Tesar (see TOP 5 presentation).

Discussion:

The question was raised who is responsible for reporting? The first recycling facility within a recycling chain or each facility individually. There was a statement of the representatives of the lead-acid sector that for lead-acid batteries not to many should be concerned with reporting (lead recyclers, battery breakers: yes; collectors: no). A question was raised and need to be clarified how the exported batteries can be calculated. It has to be kept in mind that exporting of lead-acid batteries requires the removal of the fluids. There was a discussion about options A ("first step" treatment/recycling facility) and B ("individual step" treatment/recycling facility) (see chart 1 of TOP 5 presentation) and opinions differed. A preference was given to option A even if there was no final agreement. A clarification was made that the definition of "recycling" pursuant to the Batteries Directive 2006/66/EC should be used as a basis for the inclusion or exclusion of the output fractions. The opinion was raised that a differentiation between reporting of collected batteries and those undergoing recycling should be made. It was discussed which institution will be responsible for collection of the information to be reported. In this context it was clarified that this issue is not in the scope of this project and is in the responsibility of the individual Member State. The focus of the project is to provide an appropriate reporting format to be filled in by the recyclers and that provides all necessary information to uniformly calculate the recycling efficiency.

Agreements within the audience:

1. The reporting format should contain the result of the recycling efficiency calculation (overall result and result for lead and cadmium).

2. A reporting format will be provided soon to battery recyclers for testing and commenting. The ESWI team will soon provide a corresponding form.

No final conclusions were taken as concerns the responsibility to fill in the data in the form.

4 Best available techniques and minimum treatment requirements

A presentation on BAT and minimum treatment requirements according to Annex III, Part A of the Batteries Directive (2006/66/EC) was given by Ms Maria Tesar and Mr Alexander Potrykus (see TOP 6 presentation).

Discussion:

It has been stated that BAT for dedicated battery recycling processes is not yet defined. It has been agreed that the identified documents (BREFs and technical guidelines) are appropriate to withdraw core elements of BAT.

It was discussed whether it is appropriate to establish the specifications of the minimum treatment requirements (regarding Annex III, Part A of the Batteries Directive) for all battery types. It was stated that several of the specifications that may be appropriate for lead-acid batteries and other liquid containing batteries are not appropriate for batteries not containing liquids. A general statement was that over-regulation should be avoided and already existing legislation should be considered where relevant.

The statement was given that the specification of minimum treatment requirements should strictly relate to treatment. Transport and collection are not in the focus of the minimum treatment requirements according to Annex III, Part A of the Directive. Proposals related to transport and collection should be deleted.

Specific comments to proposed minimum treatment requirements where:

Chart 8, last bullet: Delete “after a sufficient storage time has elapsed”.

Chart 10, first bullet: Is this not over-regulated?

Chart 11, fourth bullet: Is not always useful as depending on individual conditions; should be deleted.

Chart 12, second bullet: The proposals should be compliant with ADR provisions. (note: the bullet relates to transport and is therefore obsolete).

Chart 12, third bullet: Only relevant for liquid containing batteries.

Chart 12, last bullet: Not relevant as collection and transport is according to national law.

Battery recyclers were asked to check operation permits and to inform the ESWI team whether there is information contained that could be used for the specification of the minimum treatment requirements (regarding Annex III, Part A of the Directive).

Agreements within the audience:

1. With respect to a specification of minimum treatment requirements (regarding requirements of Annex III, Part A of the Directive) a differentiation is required between batteries containing liquids and others.
2. The specification of minimum treatment requirements (regarding Annex III, Part A of the Directive) should strictly relate to treatment. Transport and collection should not be part of the specification.

5 Project approach, data collection, specifications and definitions

A presentation on the project approach, data collection and relevant specifications and definitions was given by Mr Alexander Potrykus (see TOP 3 presentation).

Discussion:

What is the relevant input into the recycling process? The question was raised what is the meaning of the "average weight" of batteries and accumulators and the recycling that is "technically feasible". Further specification on these issues is needed. According to "Recharge" the relevant input for the recycling efficiency on the input side is the battery cell. Components belonging to the battery pack should not be taken into consideration for the recycling efficiency.

According to representatives of the lead-acid sector the relevant input for the recycling efficiency should be the battery pack (battery would not be applicable for lead-acid batteries). It has been proposed that a differentiation should be made between lead-acid batteries and other batteries (battery pack for lead-acid batteries, battery cell for other batteries). It has been stated that clear definitions of the "battery pack" and the "battery cell" would be required.

With respect to the start of the recycling process the question was discussed whether recycling of fluids and acids contained in batteries should be considered in the calculation of the recycling efficiency or not. The opinion was that fluids and acids should be considered as being part of the recycling process.

The question was discussed how the output system boundary can be defined. It was stated that the recycling process can be considered being terminated if the output fractions are products or by-products or have ended their waste status (these three categories are accountable for the recycling efficiency if they are not emissions) or if the output fractions are a waste for disposal or an emission (the latter two categories are not accountable for the recycling efficiency).

The question was discussed whether the recycling efficiency should be calculated on the basis of a “black-box” or on the basis of an “individual step” approach. The "black-box" approach was generally accepted. However, there were statements from Industry representatives that within the "black-box" approach there should be a solution found to also take into account internally used fractions for the calculation of the recycling efficiency (e.g. for carbon or plastics used as a reducing agent but also for oxidising agents). Other Industry representatives were opposed to this opinion and stated that the recycling efficiency is clearly a balance of output of recycled fractions and corresponding inputs. Furthermore the issue was raised that reducing agents have only a partial function as reducing agent. They also contribute thermally to the process which is to energy recovery and can not be accounted for recycling. There was no agreement on this point within the audience. Further reflection on this issue is required.

Agreements within the audience

1. A differentiation should be made for the relevant input into the recycling process ("battery pack" for lead-acid batteries, "battery cell" for other batteries). No final conclusion.
2. Fluids and acids contained in batteries should be considered in the calculation of the recycling efficiency.
3. The recycling process can be considered being terminated if the output fractions are products or by-products or have ended their waste status or if the output fractions are a waste for disposal or an emission.
4. The "Black-box" approach has generally been accepted. Agreement that a solution should be found for internally used fractions. Further reflection required.

No final conclusion was made concerning the input at the start of the recycling process and for the issue of internally used fractions.

6 Method for calculation of recycling efficiencies

A presentation on the reporting of recycling efficiencies was given by Ms Maria Tesar (see TOP 4 presentation).

Discussion:

Question: At which level shall the recycling processes achieve the recycling efficiencies? The issue was raised that the duty to achieve the efficiencies can not be required at process level for specific battery types as some types would never achieve a recycling efficiency of 50% as required for “other batteries”. A possible solution might be exemptions for defined battery chemistries. Another issue is that recyclers achieving a high recycling efficiency should not be penalised and that the duty should therefore be required at for processes at facility level. This is an important issue that needs a solution. There was no final agreement. A solution has to be found after internal discussion. The Commission will check the question on the level of the duty to achieve the recycling efficiency with its legal service.

Question: How to characterize the waste batteries input weight? It was stated that for lead-acid batteries the changes of the element composition (new/spent battery) are relevant, whereas for most portable batteries this is not relevant. It was further stated that there are differences between different battery chemistries regarding possible changes of the composition in short time frames due to technical development. It was proposed that for lead-acid batteries and some other batteries analysis of the element composition of the spent batteries (actual input) could be applicable and that for the remaining batteries the input can be quantified on the basis of information on the average element composition of new batteries (will be provided by Industry) in combination with sorting analysis (continuous or representative sampling) of the batteries input.

Question: Does the input include the water content? Agreement: Yes, input reference is the wet weight.

Question: How to consider the output of treated water (such as waste water after physico-chemical treatment or exhaust air after treatment)? According to several statements from the audience outputs should be considered as materials that have ended the waste status and are therefore to be accounted for recycling. According to other statements the output of treated water into the environment is an emission and can not be accounted for recycling. No agreement. Further reflection required.

Question: How to account slag? It has been discussed whether slag should be accounted at all for recycling, whether slag can be accounted if it is an approved product or by-product or whether it can only be accounted depend on its actual use. A TAC member position was that the accountability should depend on the use of the slag and that slag used for landfill construction should not be considered as recycling. The issue was raised that due to different authorisation practice in Member States (and within Member States) market distortions actually occur. There was no agreement in the audience.

Agreements within the audience:

1. For the characterisation of the input composition at elemental level a differentiated approach should be taken for lead-acid batteries and some other batteries (analysis of the actual input) and the remaining batteries (information on the average element composition of new batteries in combination with sorting analysis).

2. The input weight includes the water content.

No final conclusion was made on the level of reporting, on the consideration of the output of treated water and of slag.

7 Criteria for equivalency of recycling operations outside the European Union

A short presentation on criteria for equivalency of recycling operations outside the EU was given by Mrs Anke Joas (see TOP 7 presentation).

In this context it was stated that equivalency should take into account all aspects of BAT and BEP (Best Environmental Practice) and thus IPPC permitting and that treatment facilities outside the EU should be requested a similar level of information as within the EU. As concerns information that should practically be provided to assure credibility of the information it was suggested to do a differentiation between OECD and non-OECD countries in order to reflect similarity of standards within the OECD.

Whereas the provision of the local permit and corresponding monitoring data similar to IPPC requirements shall be acceptable for OECD countries an additional audit and certificate on equivalency and compliances with environmental and operational health standards should be requested for non-OECD countries.

Discussion:

It was mentioned as important to add the reference and link to IPPC in addition to the request of BAT/BEP. As concerns the responsibility to provide such information it was stated that national collection schemes and recyclers might be prepared to collect such information.

Agreements within the audience:

1. The proposal was generally agreed with.
2. For amber listed batteries the information and procedures required in the EU waste shipment regulation will be applied and referred to.
3. The responsibility to provide such information will be at national authorities if they want to use such practice to achieve the recycling efficiency limits set.

8 Conclusions and final discussion

The relevant issues of the discussion and agreements achieved within the audience were summarised (see above).

In addition it was made clear that for some issues final conclusions could not be drawn due to opposing positions and interpretations and that additional work is necessary in order to come to clear and practical options for decision. Relevant in this context are particularly:

- The relevant input to the recycling process (“battery cell”, “battery pack” or “battery”)
- The use of reducing or oxidising agents within the recycling process itself
- The level of reporting
- The consideration of the output of water after treatment in the recycling efficiency

- The consideration of slag in the recycling efficiency

Further steps:

- The minutes will be distributed to the workshop participants.
- The output of the workshop will be taken into consideration for the elaboration of the draft final report (deadline: 01.02.2009). After approval by the Commission services the draft final report will be placed on the project website in order to enable comments by stakeholders.
- Additional input will particularly be sought for at Member State level.
- The final report has to be delivered to the Commission by 01.03.2009.

Participation list Workshop on Batteries Recycling, 20 January 2009, EC, DG ENV, Room 0/C

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10.4 Selected comments on the draft final report

The minutes of the workshop and the draft final report were placed on the project website on 10 February 2009 and interested stakeholders were invited to provide their comments to eswi@bipro.de by 20 February 2009. Comments received were considered for the elaboration of the final report.

An intensively discussed issue is whether intermediate fractions that are internally used and consumed within the recycling process (i.e. they are released as emission or as waste for disposal) can be accounted for the calculation of the recycling efficiency. Relevant intermediate fractions are not only reducing agents but also other substances used for example as oxidising agent or any other agent that is consumed within the recycling process.

The proposal of the project team which is justified in the draft final report is not to account such intermediate fractions for the calculation of the recycling efficiency. Many comments where made on this issue, particularly related to the accountability of carbon and plastics as reducing agents but also on other reducing agents. Comments related to this issue were provided by the following stakeholders:

14. EBRA, EPBA, Recharge (industry association)
15. Dela GmbH (battery recycler)
16. TAC Member Sweden
17. TAC Member Belgium
18. German EPA
19. GRS (collection system)
20. Revatech (battery recycler)
21. ILA (industry association)
22. Boliden (battery recycler)

23. Campine (battery recycler)
24. Xstrata (battery recycler)
25. Redux (battery recycler)
26. Recupyl (battery recycler)

In order to appropriately consider this issue of intensive discussion, the main arguments of the comments provided are compiled in the Annex (see section 10.4), each followed by a short note of the project team related to the corresponding comment.

1) Comment EBRA et al.:

> *Spent Batteries are "articles" containing various types of chemicals, some are in a reduced state and others are in an oxidative state.*
>
> *The objective of the Batteries Directive is the Recycling of the materials content of spent batteries: the Legislator didn't consider that the materials contained in spent Batteries are in various chemical/physical status.*
>
> *When spent batteries are compared to metallic ores they should be considered as an alternative source of metals and their recycling process be evaluated in comparison with the production of primary metals from ores.*
>
> *The production of metals from metallic ores involves inevitably the reduction step.*
>
> *Only when a metal can be found in a highly concentrated native metallic form in nature, there is no need for reduction steps of the oxidized form into a metallic state.*
>
> *Recycling Processes used today for the production of metals from spent materials such as batteries requires much less energy than the production for the same metal from primary ores. This is illustrated in Figure 4 & 5* (note: of the original comment) *and referenced in a publication of the EU Commission (note: see original comment)*
>
> *There are several ways to reduce an oxidized chemical:*
>
> 1. *By chemical reduction*
> 2. *By thermal reduction*
> 3. *By electrochemical reduction*
>
> *The 3 processes have emissions:*
>
> *The chemical reduction will emit an oxidized form of the reducing agent. The reagent used has also an environmental footprint that needs to be considered. The thermal reduction will emit CO2 when C is used as a*

reducing agent. The production of electricity used in an electrolytic process will emit, either CO2 or Nuclear Waste. NB. In all processes, the use of energy will release CO2.

In the black box approach, one should not consider that the use of a chemical as reducing agent is neutral. Indeed the production of this chemical has an environmental footprint that should be accounted in the recycling efficiency equation.

Experience of Industry anticipates that Recycling Companies will find ways to exchange materials in the case where buying reducing agents for their use in a recycling process would not penalise the calculation of the RE while using internal batteries materials would penalise it.

It seems appropriate to consider the reduction process of an oxidized metallic substance as a basic process for metals extraction from natural ores or secondary ores such as spent batteries.

The Recycling Efficiency formula should reflect the positive aspects of this approach.

Most metals found in the Earth's crust exist as oxide and sulfide compounds. The reduction of these compounds can be carried out through either electrolytic or chemical processes. Chemical reduction includes reductive smelting and autoclave hydrogen reduction. Electrolytic reduction consists of simply passing a current through a dissolved or molten metal oxide to produce the neutral metal. A conventional thermal reduction process is illustrated in Figure 6 (note: of the original comment).

Spent batteries are also containing oxidized forms of metals such as oxides, hydroxides, salts, etc… If the objective of the Recycling Process is the recovery of the metallic form of the metal, the use of reducing agents is fundamental to the process.

These reducing agents can be found inside the battery, and if not in sufficient quantity, they have to be added to the Process. The Recycling Efficiency cannot be penalized by the use of reducing agents which are necessary to the achievement of the recycling process.

EPBA, EBRA and RECHARGE's recommendations on the use of reducing agents has been formulated previously and is reproduced below.

If carbon is a captured end product of a recycling process then it can be taken into account in the numerator e.g graphite powder,

If the carbon is used as a reagent (reducing agent) during the recycling process then its weight in the unused battery can be included in the numerator for the calculation of the RE.

If the carbon is incinerated during the recycling process it cannot be included within the numerator of the RE.

This statement is also valid for any other reducing agent present in the spent batteries.

Note project team: This is all reasonable and comprehensible but it is not related to the calculation method which is a balance of input and output mass. The calculation method for the recycling efficiency does not hamper the recycling of materials from spent batteries. The calculation of the recycling efficiency is not an instrument that aims at the overall assessment of the (environmental) performance or of the energy efficiency of a recycling process. It can be used to reflect upon one specific aspect of the environmental performance (i.e. on the recycling efficiency). Therefore the project team does not agree that the recycling efficiency formula should reflect other aspects than a mass balance of accountable input and output fractions. Substances that leave the process as an emission are not an accountable output fraction. If at all it could be reasonable to account the share of a reducing agent that is indeed used as reducing agent and not the whole share of potential reducing agent that is present in the battery but is used in the process for combustion and leaves the process after combustion as an emission. The quantification of the share of the reducing agent that is actually used as reducing agent could be made on the basis of an independent scientific stoichiometric expertise for a specific battery recycling process.

2) Comment DELA GmbH:

> *Die Feinfraktion aus unserem Aufbereitungsverfahren wird im Wälzrohrprozess aufbereitet. Das SDHL-Wälzverfahren nutzt dabei die in der Feinfraktion vorhandenen Kohlenstoffanteile, um nur unterstöchiometrisch Kohlenstoff zugeben zu müssen, um die entsprechenden chemischen Bedingungen für die Reduktion von zinkoxidhaltigen Abfällen einzustellen. Hierbei ist zusätzlich zu beachten, dass der größte Inputstrom in den Wälzprozess Stahlwerksstäube sind, die infolge ihrer thermischen Entstehung keinen Kohlenstoff enthalten. Insofern ist die Nutzung von Kohlenstoff und kohlenstoffhaltigen Verbindungen aus der Batteriefeinfraktion ein wesentlicher Bestandteil des Wälzprozesses und damit auch der Verwertungsquote im Batterierecycling.*

Note project team: If the carbon is used in a process to reduce e.g. steel works dusts the same applies as mentioned above: Substances that leave the process as an emission are not an accountable output fraction. If at all it could be reasonable to account the share of a reducing agent that is indeed used as reducing agent (for the reduction of metal oxides of the spent battery and for the reduction of metal oxides of the steel works dusts) for and not the whole share of potential reducing agent that is present in the battery but is used in the process for combustion and leaves the process after combustion as an emission. The quantification of the share of the reducing agent that is actually used as reducing agent could be made on the basis of an independent scientific stoichiometric expertise for a specific battery recycling process.

3) Comment of TAC Member Sweden (Par Angerheim)

> *There are two main types of processes in Europe for the recovery of lead from PbA batteries. The most common ones such as rotary furnaces use separated batteries as raw material and represents about 80 % of the battery recycling. The other technology were whole drained batteries are used as raw material is called the Varta process and represents about 20 % of the PbA battery recycling. This process is available in four different European countries. Both types of processes have been defined as BAT (Best Available Technology) and both types recycle the same amount of lead from batteries, about 97 %.*
>
> *In the Varta process (shaft furnace process) were charging of coarse material such as whole batteries rather than dense fractions of separated batteries is a prerequisite, the plastic in the batteries is used as reduction agent, and as fuel. For recyclers using this process it is impossible to deliver an "approved product" from the plastic in the battery for above mentioned reasons.*

> *However, if these recyclers would be prohibited from accounting use of the plastic as a reducer and fuel in the process they would risk not meeting the recycling efficiency in the directive. This would not result in any environmental benefits, but rather that recyclers who use BAT will not live up to the battery directive.*
>
> *The battery directive defines recycling as: "… reprocessing in a production process of waste materials for the original purpose or for other purposes, but excluding energy recovery…" (Article 3, p8).*
>
> *This means that the battery directive states that organics which is used as reduction agency in a recycle process should be accounted for as recycled. Another interpretation from directive 2008/98/EG is not applicable.*

Note project team: The project team is aware of the processes carried out in Europe and has carried out example calculations in order to find out whether the recycling efficiency will be achieved for relevant processes in lead-acid battery recycling. The results ranged from approximately 68 to 83% without taking plastics as a reducing agent into account. Therefore the project team does not expect that any BAT processes for the recycling of lead-acid batteries will be put into question because the required recycling efficiency of 65% would not be achieved. Substances that leave the process as an emission are not an accountable output fraction. If at all it could be reasonable to account the share of plastic that is indeed used as reducing agent and not the whole share of plastic potentially acting as reducing agent that is present in the battery but is used in the process for combustion and leaves the process after combustion as an emission. The quantification of the share of the reducing agent that is actually used as reducing agent could be made on the basis of an independent scientific stoichiometric expertise for a specific battery recycling process.

4) Comment of TAC Member Belgium (Lore Mariën)

> *The use of carbon etc. as reducing agent saves the use of primary ressources. The proposal of BiPRO is contradictory with the definition of recycling in the battery directive who says that recycling means the reprocessing in a production process of waste materials for their original purpose or for other purposes.*
>
> *The calculation method must respect the definition of the battery directive (specific legislation) and can not make it more strictly. The recycling definition of directive 2008/98/EC is not applicable for the calculation of the recycling efficiencies for batteries.*
>
> *We do not agree with the assumption made in the conclusion-box on p. 26 (last paragraph in the box): we are already informed about an intermediate fraction that is sold and used as reductans in another battery recycling process.*
>
> *It must be clear that there must be reported about all the different treatment steps and intermediate fractions.*

Note project team: The proposal is not contradictory to the definition of recycling in the Batteries Directive (2006/66/EC). We only propose not to take emissions into the air into account for the calculation of the recycling efficiency. This does not prevent to use waste materials for their original purpose or for other purposes (e.g. carbon as reducing agent). We agree that reporting has to be carried out on all steps of recycling. The “black-box” approach is a model that shall illustrate which input and output fractions shall be accounted for the calculation of the recycling efficiency.

5) Comment German EPA (Sandra Leuthold)

> *In order to prevent unequal treatment of recyclers using intermediate fractions in their own process and those selling them to other plants intermediate fractions should be taken into account if they can be sold as a product but are instead used internally. Therefore, it is necessary to use a modified black box approach.*

Note project team: Intermediate fractions have not terminated the recycling process. The recycling efficiency for intermediate fractions has to be followed irrespective whether they are used internally or externally. What concerns materials that are consumed within the recycling process, the proposal of the project team is not to take them into account for the recycling efficiency. This is equal for all recyclers.

6) Comment GRS

> *The black box approach was generally accepted at the workshop (20. January 2009). But this must not discriminate such recycling options using the Carbon content internally as a reducing agent against recycling methods where the Carbon is separated, sold and also used as reducing agent afterwards in another process. So we demand to use the black box approach but to take measures that internally used material either Carbon or Oxygen can be taken into account for the recycling efficiency.*

Note project team: Substances that leave the process as an emission are not an accountable output fraction. If at all it could be reasonable to account the share of a reducing agent or oxygen that is indeed used as reducing agent and not the whole share of potential reducing agent that is present in the battery but is used in the process for combustion and leaves the process after combustion as an emission. The quantification of the share of the reducing agent that is actually used as reducing agent could be made on the basis of an independent scientific stoichiometric expertise for specific battery recycling process.

7) Comment Revatech

> *It looks like as this item is becoming a sensitive due to the fact that the C is transformed into CO2 after using it as reducer. From our point of view, there is no doubt: the C has to be taken in account in the calculation method according following arguments. The definition of the recycling is clear: “recycling means the reprocessing in a production process of waste materials for their original purpose or other purposes but excluding energy recovery”. The definition of the recycling doesn’t reject any other use than energy recovery. We have to avoid any emotional statement (CO2 emission’ s problem). There is no reason to be more severe than the definition of the recycling. Furthermore, the C replaces natural resources, spare them and doesn’t contribute to higher CO2 emissions.*

Note project team: Substances that leave the process as an emission are not an accountable output fraction. If at all it could be reasonable to account the share of a reducing agent that is indeed used as reducing agent and not the whole share of potential reducing agent that is present in the battery but is used in the process for combustion and leaves the process after combustion as an emission. The quantification of the share of the reducing agent that is actually used as reducing agent could be made on the basis of an independent scientific stoichiometric expertise for a specific battery recycling process.

8) Comment ILA

> *I do appreciate the complications of assessing what proportion of the plastic fraction constitutes a reductant as against an energy source, but I believe a very strong case has been made that some at least of the plastic is a reductant and that allowance for this could be included in the calculations. This would provide a margin of safety to the small number of companies using the shaft furnace technology which is, as you know, recognised as a BAT process under the EU IPPC Directive.*

Note project team: Substances that leave the process as an emission are not an accountable output fraction. If at all it could be reasonable to account the share of a reducing agent that is indeed used as reducing agent and not the whole share of potential reducing agent that is present in the battery but is used in the process for combustion and leaves the process after combustion as an emission. The quantification of the share of the reducing agent that is actually used as reducing agent could be made on the basis of an independent scientific stoichiometric expertise for a specific battery recycling process.

9) Comment Boliden

> *The shaft furnace process is described in the IPPC Bref note as one of the processes that is BAT for recycling of lead acid batteries. Furthermore it represents a significant part of the total recycling of secondary lead in Europe.*
>
> *The fundamental principles of shaft furnace processes for metal extraction involves the reduction of metal oxides to metals and in the lead application also of sulfates to iron sulfide (matte) in order to prohibit sulphur to enter the atmosphere in the form of sulphur dioxide.*
>
> *The reducing atmosphere is achieved by adding coke to the charge and by pyrolysis of the organics that is part of the battery. Charging of whole batteries is a prerequisite for operating the furnace in the sense that the material entering has to be coarse enough to allow for a high porosity in the reaction shaft in order to get a good contact between the reducing gases and the charge. If this criteria is not met mass and heat transfer will not take place.*
>
> *An integrated part of the process is the after burning of energy rich gases from the furnace. Surplus of CO and hydrocarbons from the reduction are burned at high temperature maintained by use of external energy (natural gas) when the energy content is not sufficient. This has to be done in order to meet strict limits for emmisions of dioxins, CO and organics to the atmosphere. If surplus of organics were not present more external energy would have been consumed. Organics (plastics) act as a reductant and the portion of the plastics that could be related to this is according to various investigations approx 60%. The remainder could to a large extent be accounted for as energy substitution in the afterburner. We recommend that at least 60% of plastics should be accounted for when calculating the RE.*

Note project team: The project team has carried out example calculations in order to find out whether the recycling efficiency will be achieved for the relevant process. The result was approximately 68% without taking plastics as a reducing agent into account. Therefore the project team does not expect that the shaft furnace processes for the recycling of lead-acid batteries will be put into question because the required recycling efficiency of 65% would not be achieved. Substances that leave the process as an emission are not an accountable output fraction. If at all it could be reasonable to account the share of a reducing agent that is indeed used as reducing agent and not the whole share of potential reducing agent that is present in the battery but is used in the process for combustion and leaves the process after combustion as an emission. The quantification of the share of the reducing agent that is actually used as reducing agent could be made on the basis of an independent scientific stoichiometric expertise for a specific battery recycling process.

10) Comment Campine

> *Due to the composition of materials making the burden of the furnace, reduction is a necessity. Reduction can occur with cokes, or this metallic Iron (part of it only, the rest being used to "capture" S in the furnace).*
>
> *Having plastic available enables this plastic to play EXACTLY the same role as cokes in the hart of the furnace: pyrolised plastics is simply "C" chains, nothing else than cokes. The blast air coming inside the furnace cannot see the difference between the "C" coming from the cokes and the "C" coming from the plastic.*
>
> *So the fact that part of the plastic is used as a reducing agent cannot be discussed. Several studies has been conducted to try to quantity the part of plastic fraction which is exactly used as reducing agent (vs energy recovery). ("Definition of waste recovery and disposal operations", Ökopol GmbH, Report compiled for the commission of European Community, March 2004) and "using metal-rich WEEE fraction as fuel substitute for an integrated metal smelter, Nov 2006, Plastics Europe).*
>
> *Both studies concluded that plastics were clearly partly used for reducing the metallic compounds present in the furnace, to a level estimated to be of 60%. WE RECOMMEND TO INTEGRATE THE PLASTICS AS REDUCING AGENT FOR 60% of their weight.*

Note project team: The project team has carried out example calculations in order to find out whether the recycling efficiency will be achieved for the relevant process. The result was approximately 68% without taking plastics as a reducing agent into account. Therefore the project team does not expect that the shaft furnace processes for the recycling of lead-acid batteries will be put into question because the required recycling efficiency of 65% would not be achieved. Substances that leave the process as an emission are not an accountable output fraction. If at all it could be reasonable to account the share of a reducing agent that is indeed used as reducing agent and not the whole share of potential reducing agent that is present in the battery but is used in the process for combustion and leaves the process after combustion as an emission. The project team has considered the studies that attempt to quantify the part of plastic fraction which is used as reducing agent versus energy recovery. The attempt of quantification has been made upon a mass and energy balance of inputs and outputs for a specific integrated metal smelter process (not battery recycling) and specific conditions concerning the choice of input materials (see [PLE 2006]). In the view of the project team the results can 1) not be simply transferred on battery recycling processes and considers 2) a stoichiometric approach for the determination of the quantity of reducing agents that are actually used as reducing agents more appropriate. The quantification of the share of the reducing agent that is actually used as reducing agent could be made on the basis of an independent scientific stoichiometric expertise for a specific battery recycling process.

11) Comment Xstrata

> *C present in the Li-ion batteries as graphite is used as reducing agent directly into our pyro process, without this C we would need to buy another reducing agent such as FeSi which is energy intensive at its production step, this is also valid for other elements such as Fe and Al for example. Please note that industrial pyrometallurgical processes such as the Xstrata Nickel process need reducing agents to produce a NiCuCo matte which is amenable to further metal refining; the intrinsic presence of C, Al and Fe in the Li-ion batteries destined for recycling is an environmental benefit, why should they be excluded of the Recycling Efficiency? As such I consider that the Recycling Efficiency should account for reducing agents in a positive way*

Note project team: Substances that leave the process as an emission are not an accountable output fraction. If at all it could be reasonable to account the share of a reducing agent that is indeed used as reducing agent and not the whole share of potential reducing agent that is present in the battery but is used in the process for combustion and leaves the process after combustion as an emission. According to the assessment of the project team the required recycling efficiency of 50% will be achievable for Li-ion batteries without accounting the carbon, Fe and Al content as reducing agents. This depends largely on the actual use of the slag which contains the main shares of the Fe, Al and Li originating from the batteries and which is (according to the information from the recycler) fully inert and suitable for construction applications. The project team expects that a full utilisation of slag as an accountable by-product will enable to achieve a recycling efficiency for Li-ion batteries up to approximately 70% (without C, Fe and Al accounted as reducing agents).

12) Comment Redux

> *According to Bipro's report [4.1.2.4 (b)], the incineration of carbon as well as the use of it as a reducing agent is stated to be irrelevant to the calculation. However, Befesa's waelz-process doesn't incinerate the carbon. Instead the carbon is used entirely as a reducing agent! Therefore we do not agree with Bipro and would like to see the carbon content be included in the calculation.*
>
> *Contrary to the opinion of IME (Prof. Bernd Friedrich and Dr. Elinor Rombach), the whole carbon content treated during the waelz-process has to be included in the calculation of the recycling efficiency.*
>
> *Here a brief description of Befesa's waelz-process:*
>
> *At Befesa's plants, the patented SDHL-waelz-process is used to recycle Zinc-containing waste. The principle is based on selective volatility of Zinc compounds through carbothermic reduction. Contrary to classic metallurgy, the SDHL process uses only 75% of the necessary additional carbon mass to fully reduce the Zinc content. It follows that the incineration of the carbon is inhibited.*

Note project team: Substances that leave the process as an emission are not an accountable output fraction. If at all it could be reasonable to account the share of a reducing agent that is indeed used as reducing agent (for the reduction of metal oxides of the spent battery and for the reduction of metal oxides of the zinc containing waste) and not the whole share of potential reducing agent that is present in the battery but is used in the process for combustion and leaves the process after combustion as an emission. The quantification of the share of the reducing agent that is actually used as reducing agent could be made on the basis of an independent scientific stoichiometric expertise for a specific battery recycling process.

Comment 13: Recupyl

Generally speaking the concept of recycling efficiency is related to a mass conservation and comparison between input and output

Worldwide recycling efficiency concept
Is based on real comparison between input/output

This is not equilibrated mass balance and recycling bas is lost

The second concept is that the output product need to be reused on the market of secondary product.

Starting from this observations, a product converted to a gas which is not reused cannot be introduced in calculation.

This situation is complicated by the that this gas is CO2. This means that as we realize CO2 the source of CO2 is positively accounted while EU accepted Kyoto Protocol and is spending several billions in CO2 capture and CO2 avoiding mainly in cement and steel industry (acronyms of project on EU data base).

This means that is this point is accepted, the Directive and his annex is pushing, facilitating and accepting processes with high CO2 potential.

The use of internal carbon instead of raw material carbon is relevant to Life Cycle Assessment and not Recycling Efficiency.

It is then relevant to the marketing aspect of each process but not to a Neutral Guideline.

> *In my opinion the annex including this will not resists to any reaction on behalf of the Parliament or from the International Consumers and Environment Association.*

Note project team: The project team agrees that the calculation method is a balance of input and output mass. Substances that leave a process as an emission are not an accountable output fraction. However, the calculation of the recycling efficiency is not an instrument that aims at the assessment of the greenhouse gas emissions of recycling processes. Considerations concerning CO_2 emissions are not relevant for the development of a calculation method for the recycling efficiency.

10.5 Information on the material composition of new and/or waste batteries

Data on the composition of new and waste batteries are provided in a separate excel file to the report.

10.6 Description of dedicated processes and categorisation of output fractions

There is only a limited number of dedicated processes that are currently carried out by European battery recyclers (see chapter 3.2). Specific information on dedicated processes (textual description, flow charts) and on selected individual battery recycling companies is provided in the following.

10.6.1 Recycling process: Mechanical separation and subsequent Waelz process for ZnC and AlMn batteries (primary)

General description of the process

Process description	Mechanical separation and Waelz process
Battery types	ZnC and AlMn batteries
Recycling	In the first step of the recycling process batteries are ground and separated in three fractions: the marketable fraction CuNiFe scrap and reduction carbon and the intermediate product black mass. In the second step (waelz process) waelz oxid and slag are produced from the black mass.
Products	NiCuFe scrap → stainless steel industry Carbon → reduction processes (note: intermedialte fraction that is consumed within the process; accountability for the recycling efficiency not yet decided) Waelz oxide with around 65% zinc Mercury Slag used for recultivation
Intermediate fractions	Not relevant
Use for energy recovery	Not relevant
Waste for disposal	Slag for disposal
Emissions	Treated off gas including water vapour

Table 10.1: Process description (Mechanical separation and subsequent Waelz process for ZnC and AlMn batteries)

Process flow chart according to the industry

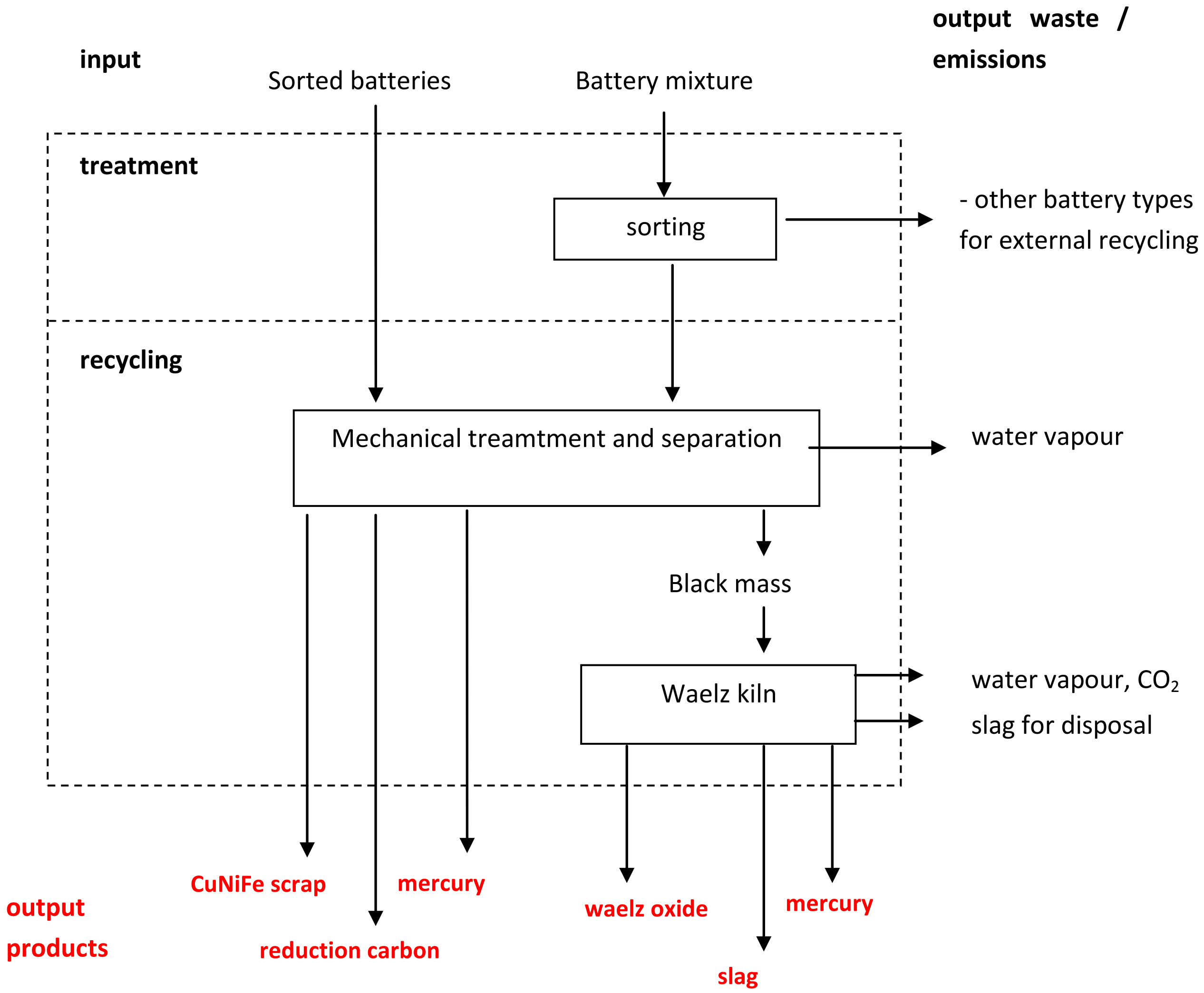


Figure 10-1: Process flow chart (Mechanical separation and subsequent Waelz process for ZnC and AlMn batteries)

10.6.2 Recycling process: Thermal treatment separation and subsequent Waelz process for ZnC and AlMn batteries (primary)

General description of the process

Process description:	Thermal treatment, separation, waelz process
Battery type:	Zinc-carbon and alkaline manganese batteries
Treatment	Received batteries are undergoing a visual inspection in order to identify eventual impurities or unwanted types of batteries.
Recycling	Waste batteries are first stored and fed into feeding bin. Transported by a conveyor and feeding system they are brought into the rotary kiln where they are treated at temperatures of approx. 650°C for about one hour. During this the spent batteries disintegrate, carbon, zinc and manganese are oxidised and heavy metals leave the kiln with the dust fraction of the flue gas. After post combustion (550°C) the solids (i.e. the recyclable fraction) are shredded, sieved and divided by a magnetic separator into a zinc/manganese-oxide fraction and a scrap metal (steel) fraction. The remaining volatiles are first dedusted in a hot gas cyclone and then cleaned in a three stage flue gas treatment system. The flue gas is connected to the post combustion system of the main hazardous waste kiln and is treated at above 1,250°C again. Afterwards it passes the same multi-stage gas cleaning system including scrubbers, activated carbon filter and nitrogen oxide removal as the flue gas out of the main hazardous waste treatment plant. Similarly the waste water from the battery recycling process is treated in the main waste water treatment facility. Large amounts of hazardous contents (such as mercury) are washed out of the flue gas. The zinc/manganese-oxide fractions are further processed in a waelz process.
Intermediate fractions	Non magnetic coarse fraction (zinc/manganese-oxide) → waelz-process Fines (zinc/manganese-oxide) → waelz-process
Products	Magnetic coarse fraction (steel scrap) → steel industry Waelz oxide → NE industry Waelz slag being recycled → recultivation etc.
Use for energy recovery	not relevant
Waste for disposal	Residues from flue gas and waste water treatment → disposal Waelz slag for disposal
Emissions	CO/CO2 H2O

Table 10.2: Process description (Thermal treatment, separation and subsequent Waelz process for ZnC and AlMn batteries)

Process flow chart

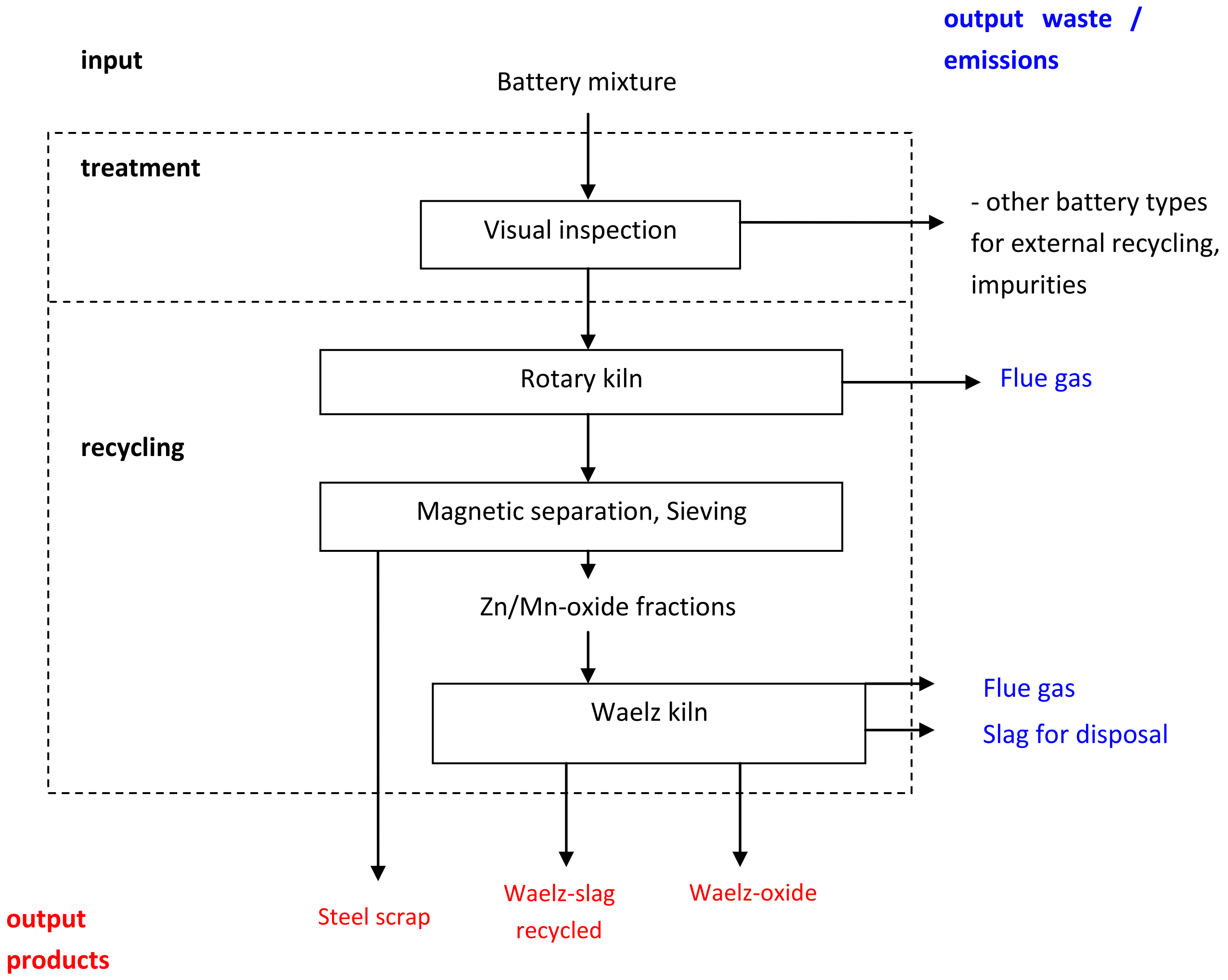


Figure 10-2: **Process flow chart (Thermal treatment, separation and subsequent Waelz process for ZnC and AlMn batteries)**

10.6.3 Recycling process: Pyrolysis and pyrometallurgical treatment of AlMn, ZnC and ZnAir batteries (primary).

General description of the process

Treatment	Batteries are sorted to extract impurities from the input material as from the products produced. All non batteries are sorted out as well as Lead, Nickel, Cadmium and Lithium batteries. All alkaline manganese, zinc carbon and zinc air batteries, with or without mercury remain in the mix and are processed in the recycling process.
Recycling	Batteries are fed to the pyrolysis furnace where water and mercury is vaporized at 650°C. Organics are reduced to carbon. The pyrolysis gas is treated in the waste gas treatment, where mercury is condensed and recovered through the mercury distillation. The pyrolysed batteries are fed to the melting furnace where the metals are reduced and molten at 1500°C. Iron is molten and manganese oxides are reduced to Ferromanganese. Zinc oxide is reduced and vaporized and then recovered as zinc in the zinc condenser.
Products (including by-products)	Ferromanganese → used as additive in foundries Zinc → sold on the metal market Mercury → sold on the metal market
Intermediate fractions	Not relevant
Use for energy recovery	Carbon is used the reduction of the oxides in the melting furnace. The so produced carbon monoxide gas is afterwards used as hot gas to heat the pyrolysis furnace.
Waste for disposal	Slag → disposed in a landfill
Emissions	Waste gas and waste water are treated in house. Treated air and water are emitted. Emission levels are below the limit values for municipal waste incineration plants.

Table 10.3: Process description (Pyrolysis and pyrometallurgical treatment of AlMn, ZnC and ZnAir batteries)

Process flow chart

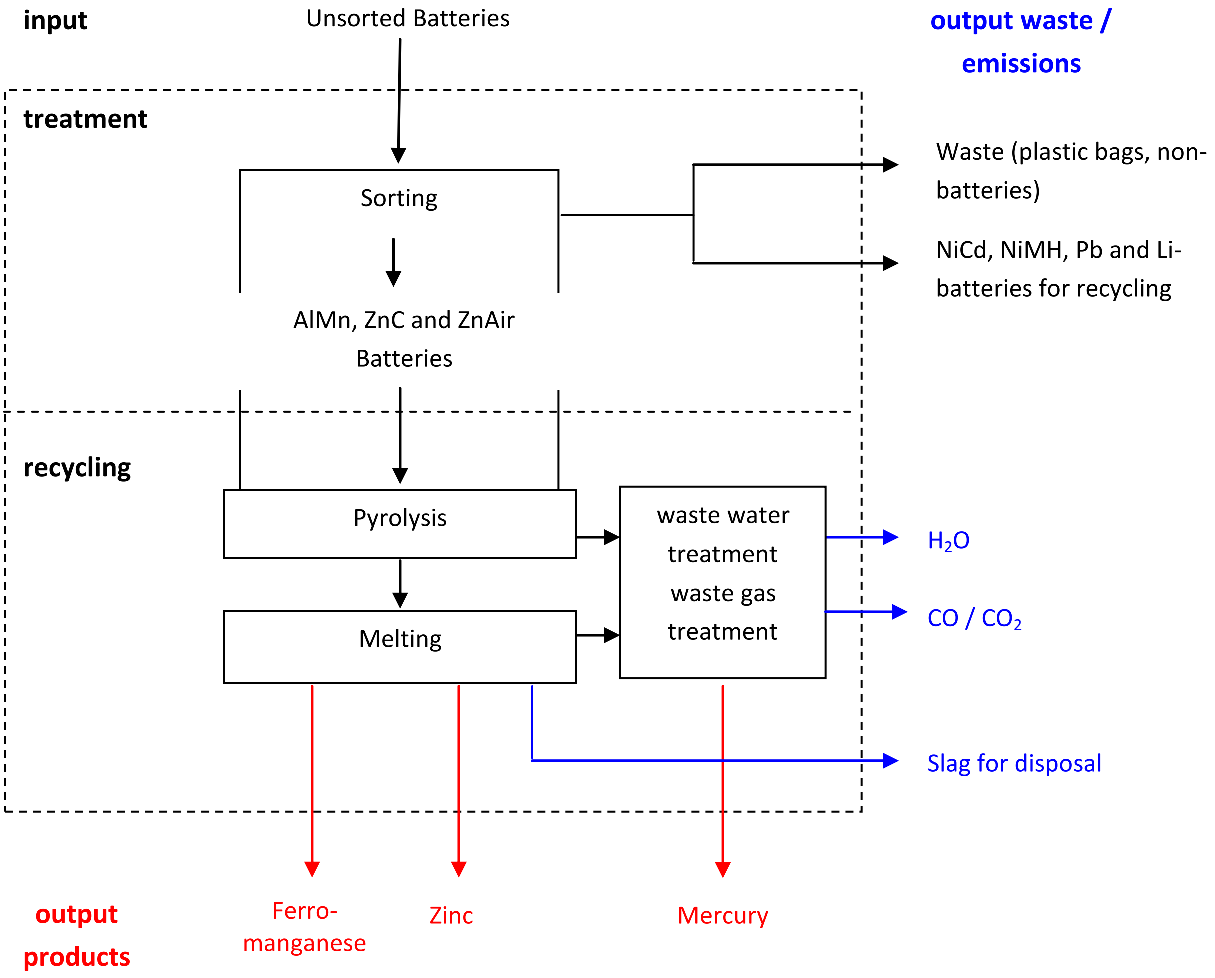


Figure 10-3: **Process flow chart (Pyrolysis and pyrometallurgical treatment of AlMn, ZnC and ZnAir batteries)**

10.6.4 Recycling process: Thermal treatment for button cells and hydrometallurgical treatment for ZnC and alkaline batteries (primary)

General description of the process

Process description:	Thermal and Hydrometallurgical treatment (2 different process)
Battery type:	Button cells (thermal) / Alkaline and zinc-carbon batteries (hydrometallurgical)
Treatment	Batteries are sorted after delivery in order to extract impurities and to separate button cells from the rest of shapes. Within this last group, some types like Ni-Cd, Ni-Mh, lithium and Lead batteries are removed and are sent to subsequent treatment, from zinc-carbon and alkaline batteries.
Recycling	Button cells are introduced in a vacuum system furnace. Batteries are heated up to appr. 550°C. Mercury and water are distilled and condensed. Other shapes of batteries, mainly alkaline and zinc-carbon batteries are introduced in a crushing and grinding step. Here they are decomposed in ferric and non ferric scraps, plastic and paper and black mass which is leached in an acidic medium. After several steps of purification zinc and manganese salts and graphite is obtained as well as a fraction with cemented metals that is sent to external treatment.
Products	Mercury → Lamps producers and others Ferric scraps → Stainless steel industry Non ferric scraps → Non ferrous industry Zinc salts → Fertilizers producers and others Manganese salts → Fertilizers producers
Intermediate fractions	Cemented metals → external recycling
Use for energy recovery	Graphite → energy recovery
Waste for disposal	Plastic and paper → landfill Impurities from the sorting step, meanly plastic bags → landfill
Emissions	CO / CO_2 (only thermal process)

Table 10.4: Process description (Thermal treatment for button cells and hydrometallurgical treatemnt for ZnC and alkaline batteries)

Process flow chart

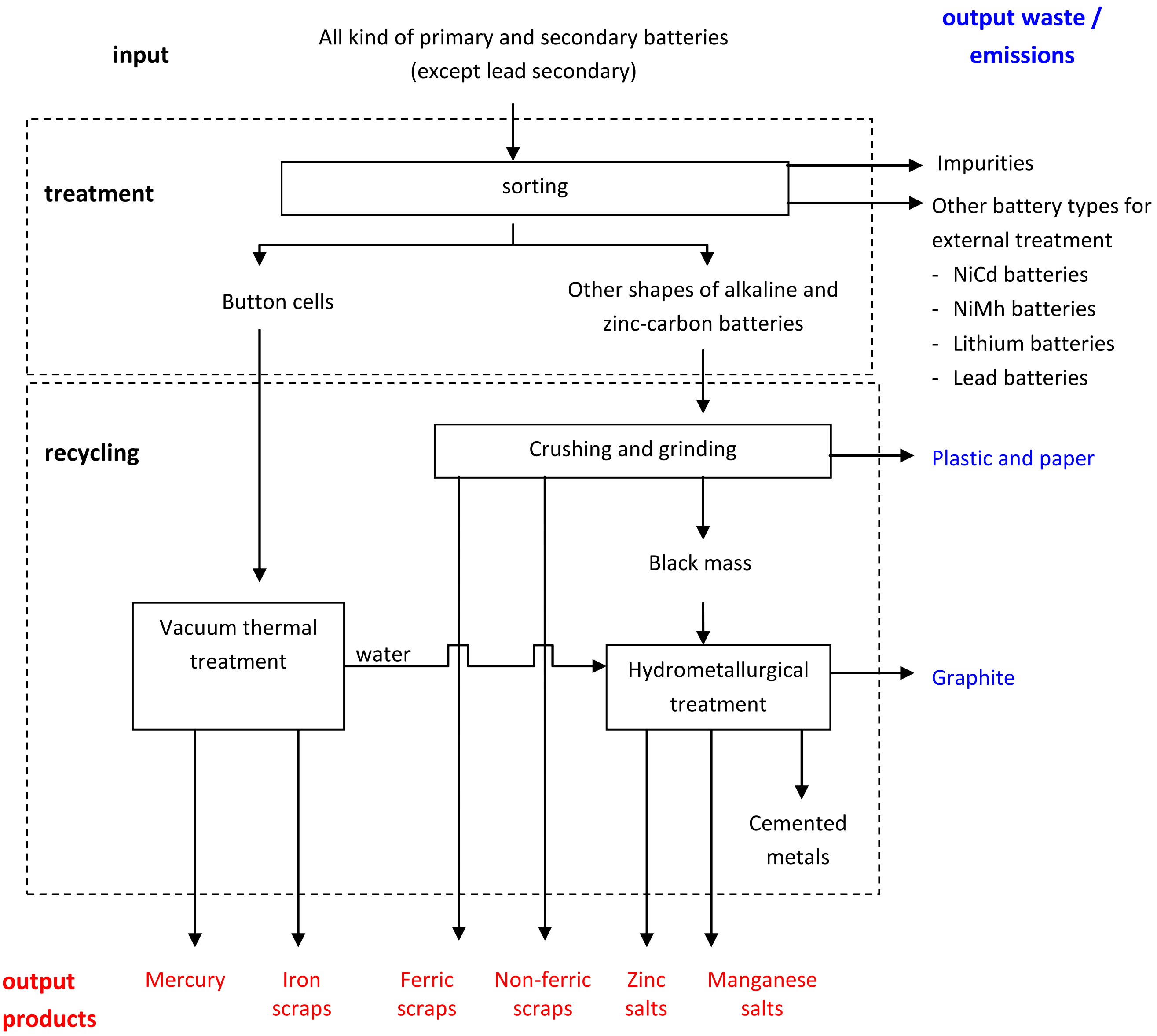


Figure 10-4: Process flow chart (Thermal treatment for button cells and hydrometallurgical treatemnt for ZnC and alkaline batteries)

10.6.5 Recycling process: Pyrometallurgical treatment for Alkaline and ZnC batteries and NiMH accumulators (primary and secondary)

General description of the process

Process description	Pyrometallurgical treatment
Battery type	Alkaline and Zinc carbon batteries, NiMH accumulators
Recycling	Through the melting process (1500°C), a thermal separation of volatile metals (zinc, mercury, cadmium, lead) from the ferrous ones is carried out. Fumes are treated and filtered, and the Zinc is recovered into a powder of zinc oxide used in the zinc metallurgy and chemical appliances. The steel, the manganese, the nickel and the copper are melted, yielded and recovered as a ferroalloy used in the stainless steel industry. The mineral part called the slag is tapped separately, vitrified, and slag is used as ore manganese substitute. The sold slag is used to produce silico manganese (which can be used as a deoxidizer and an alloying element in steel). The mercury (found in our sorted batteries) is vaporised and we can find it in the gases. After a primary filtration by the bag filter and recovery of zinc oxide dust, gases are cooled to reach a temperature around 50°C and directed towards a cartridge filter (secondary filtration). Then, gases go through two containers with sulphured activated carbon on fixed bed which collect the whole mercury and other pollutants before rejection of gases into the air (tertiary filtration). Used active carbon is treated by a specialised external supplier.
Products	Fe-Mn-Ni alloy → Stainless steel industry ZnO powder → Zinc metallurgy, chemistry Mn slag → Mn ore substitute used to produce silico manganese
Intermediate fractions	Not relevant
Use for energy recovery	Not relevant
Waste for disposal	Not relevant
Emissions	CO, CO2, H2O

Table 10.5: Process description (Pyrometallurgical treatment for Alkaline and ZnC batteries and NiMH accumulators)

Process flow chart

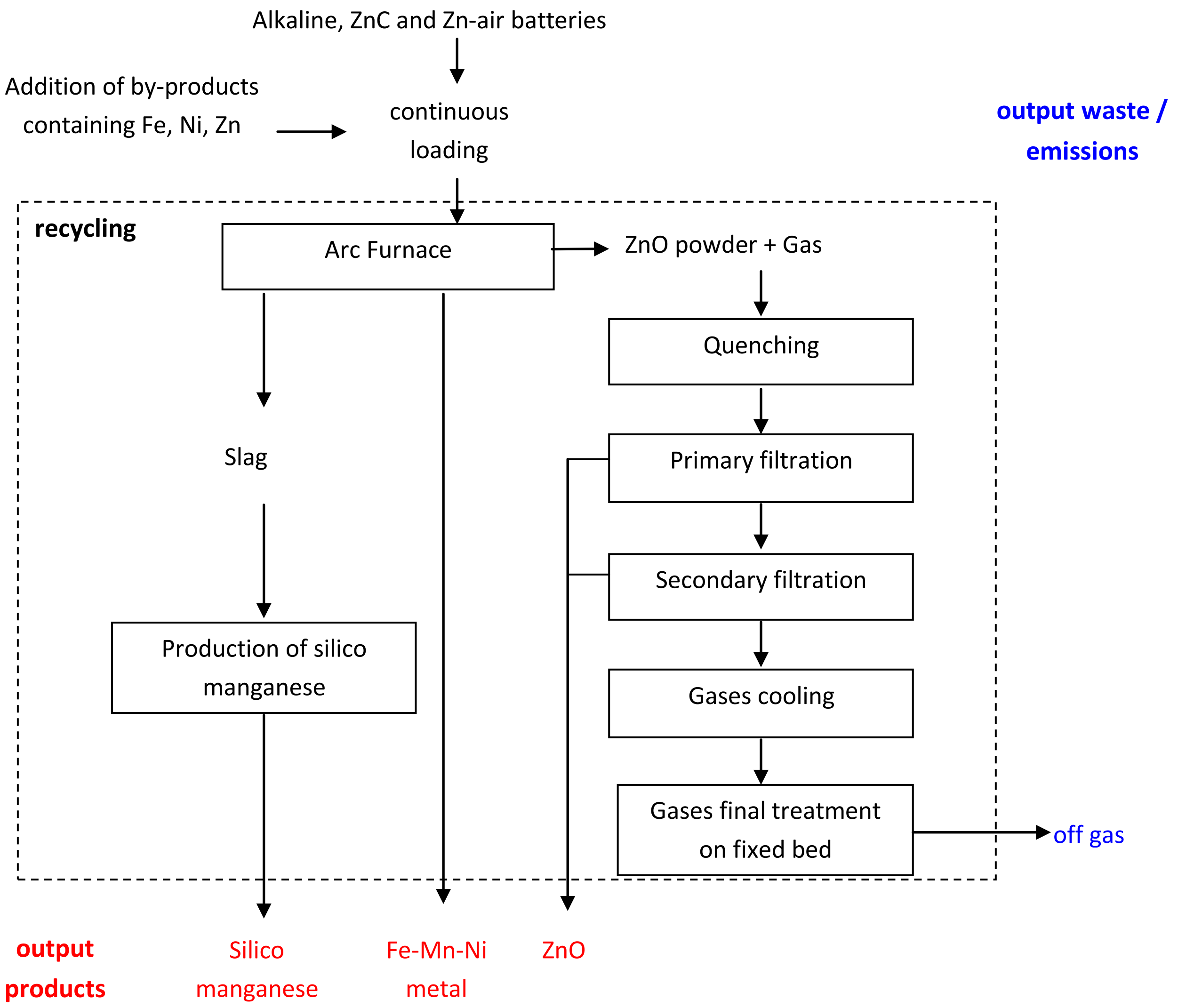


Figure 10-5: Process flow chart (Pyrometallurgical treatment for Alkaline and ZnC batteries and NiMH accumulators)

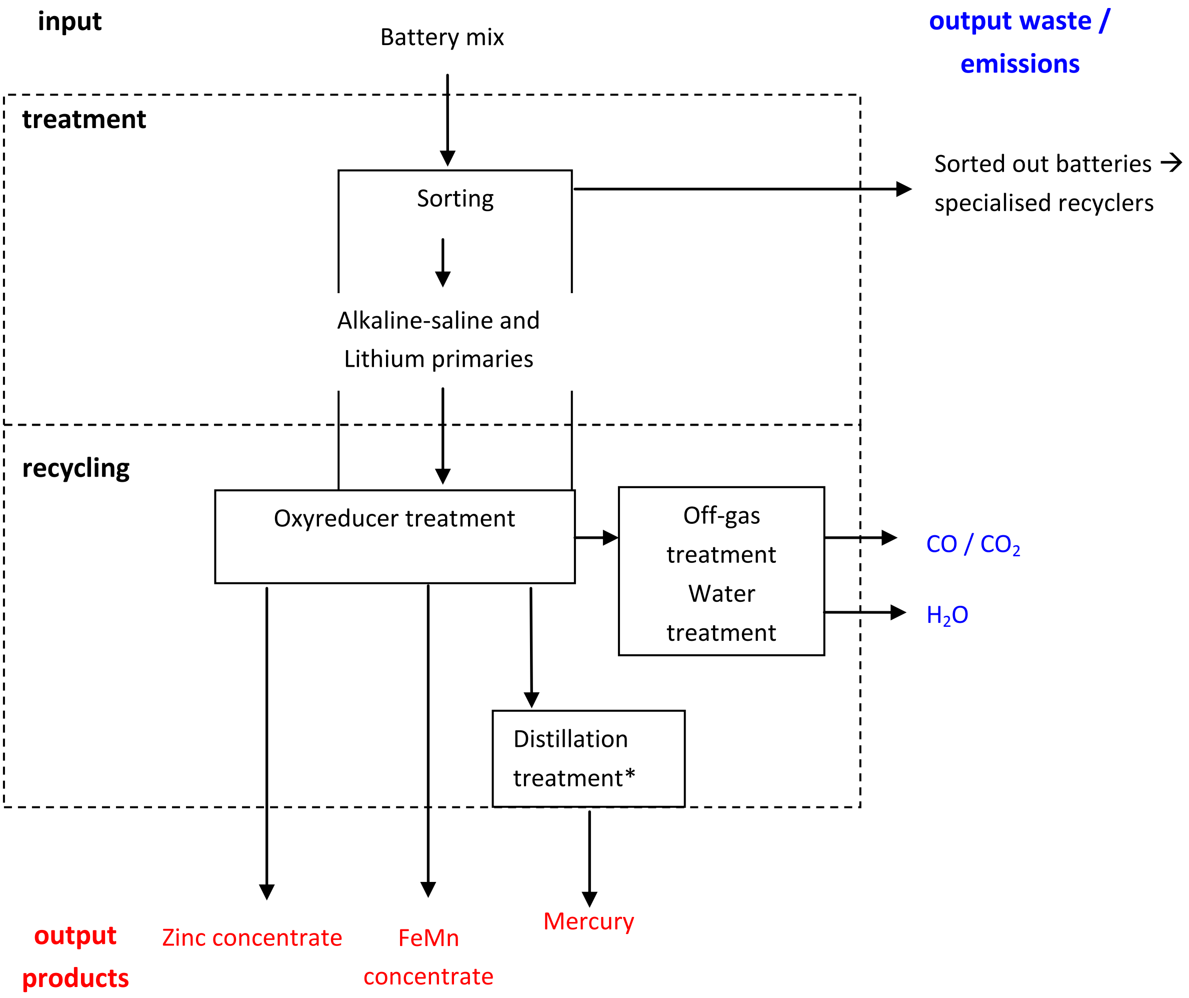
10.6.6 Recycling process: Oxyreducer: Thermal process under reductive atmosphere for ZnC, AlMn and lithium batteries (primary)

General description of the process

Process description:	Oxyreducer: Thermal process under reductive atmosphere
Battery type:	Alkaline-Saline batteries, Lithium primary batteries
Treatment	Batteries are sorted after delivery NiMH, Li-ion, Li-polymers, lead and NiCd accumulators and Oxide Ag button batteries are forwarded to a specialized recycler Alkaline-Saline and lithium primary batteries are homogeneously mixed with reducing agents before recycling
Recycling	Alkaline-Saline batteries, Lithium primary batteries are treated in the oxyreducer furnace in dedicated campaigns. Mixed batteries are charged to the oxyreducer furnace and heated up to 1200 °C under reduced atmosphere. Heavy metals such as Zn, Cd, Hg and Pb are evaporated and re-oxidized in the gaseous phase of the furnace. The heavy metals containing waste gas is brutally cooled with water. The process water now containing the heavy metals is physically and chemically treated and recovered as highly concentrated zinc hydroxide sludge. High energy efficiency because of the use of the organic part of the batteries and the reducing agent for energy recovery. Fe-Mn fraction remaining in the furnace can be taken out.
Products	Zinc concentrate → Secondary raw material for zinc production Fe-Mn concentrate → Additives for production of special steels Mercury metal → Mercury industry
Intermediate fractions	Not relevant
Use for energy recovery	Organic fraction of the batteries
Waste for disposal	Not relevant
Emissions	Treated off gas CO/CO_2; full mercury traceability and activated carbon fix bed filter (200 tons); 600 m^3/h water cleaning system to prevent dioxin formation. Treated water

Table 10.6: Process description (Oxyreducer: Thermal process under reductive atmosphere for ZnC, AlMn and lithium batteries)

Process flow chart



* internally or externally

Figure 10-6 : Process flow chart (Oxyreducer: Thermal process under reductive atmosphere for ZnC, AlMn and lithium batteries)

10.6.7 Recycling process: Cd-distillation for NiCd batteries (secondary)

General description of the process

Process description:	Cd-Distillation
Battery type:	Ni-Cd batteries (consumer and industrial type)
Treatment and recycling	The incoming gross waste is sorted. Outer casings of packs and industrial batteries are removed. The flushable electrolyte is removed from batteries → by-product Consumer batteries are directly sent to pyrolysis and distillation. Industrial cells are opened, plastic containers and Copper/Steel and NiFe-materials are removed. The Cd-containing Electrode is then treated to pyrolysis and distillation together with the sealed cells (event. with additional carbon as reducing agent). Ferro Nickel material and Cadmium are gained as output products. Air and water is released after treatment to the atmosphere and/or to a receiving water. Treated water
Products	Copper/Steel material → Non ferrous and steel mills Ferro Nickel material → stainless steel mills Cadmium → battery industry Mono-fraction plastic → plastic industry Electrolyte → chemical treatment industry (solvation /neutralisation)
Intermediate fractions	not relevant
Use for energy	mixed plastic containers → substitute fuel
Waste for disposal	eventually flushable electrolyte
Emissions	Treated off-gas

Table 10.7: Process description (Cd distillation for NiCd batteries)

Process flow chart

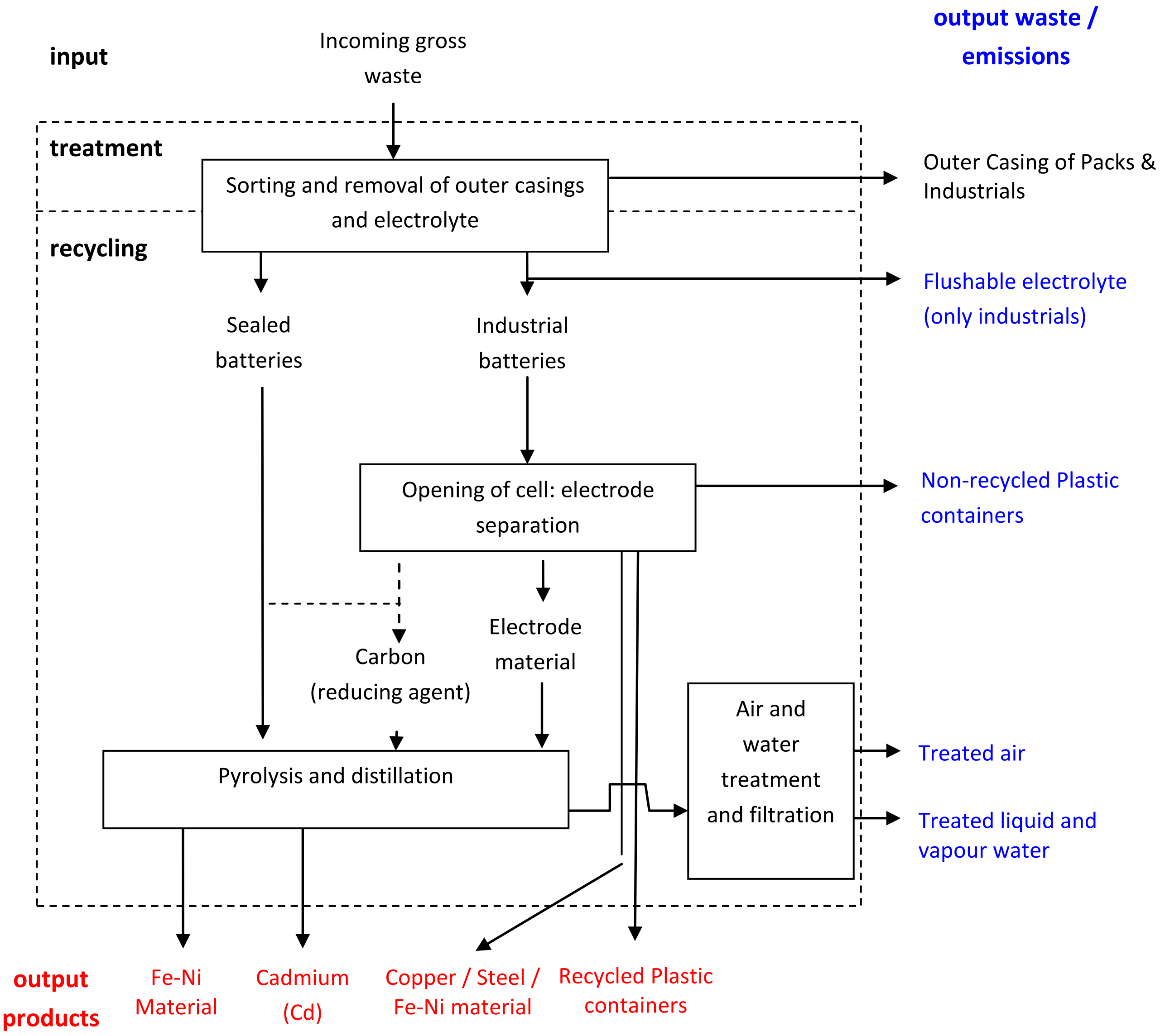


Figure 10-7: Process flow chart (Cd distillation for NiCd batteries)

10.6.8 Recycling process: Mechanical separation for NiMH accumulators (secondary)

General description of the process

Process description:	Mechanical separation of nickel iron
Battery type:	Ni MH accumulators
Treatment	Reception control / Re-sorting First step: Plastic and electronic components are separated from the battery packs. Remaining fraction: Batteries
Recycling	Second step: Removing of water and components which are contaminating the steel production process and trimming of marketable fraction.
Products	NiFe scrap → Stainless steel industry
Intermediate fractions	Electronic components → further recycling (conclusion: recycling process not terminated, process has to be followed until the output fractions are products, by-products, waste for disposal, emissions or they are used for energy recovery)
Use for energy recovery	Plastic components → energy recovery
Waste for disposal	Not relevant
Emissions	Water vapour

Table 10.8: Process description (Mechanical separation of Ni and Fe)

Process flow chart

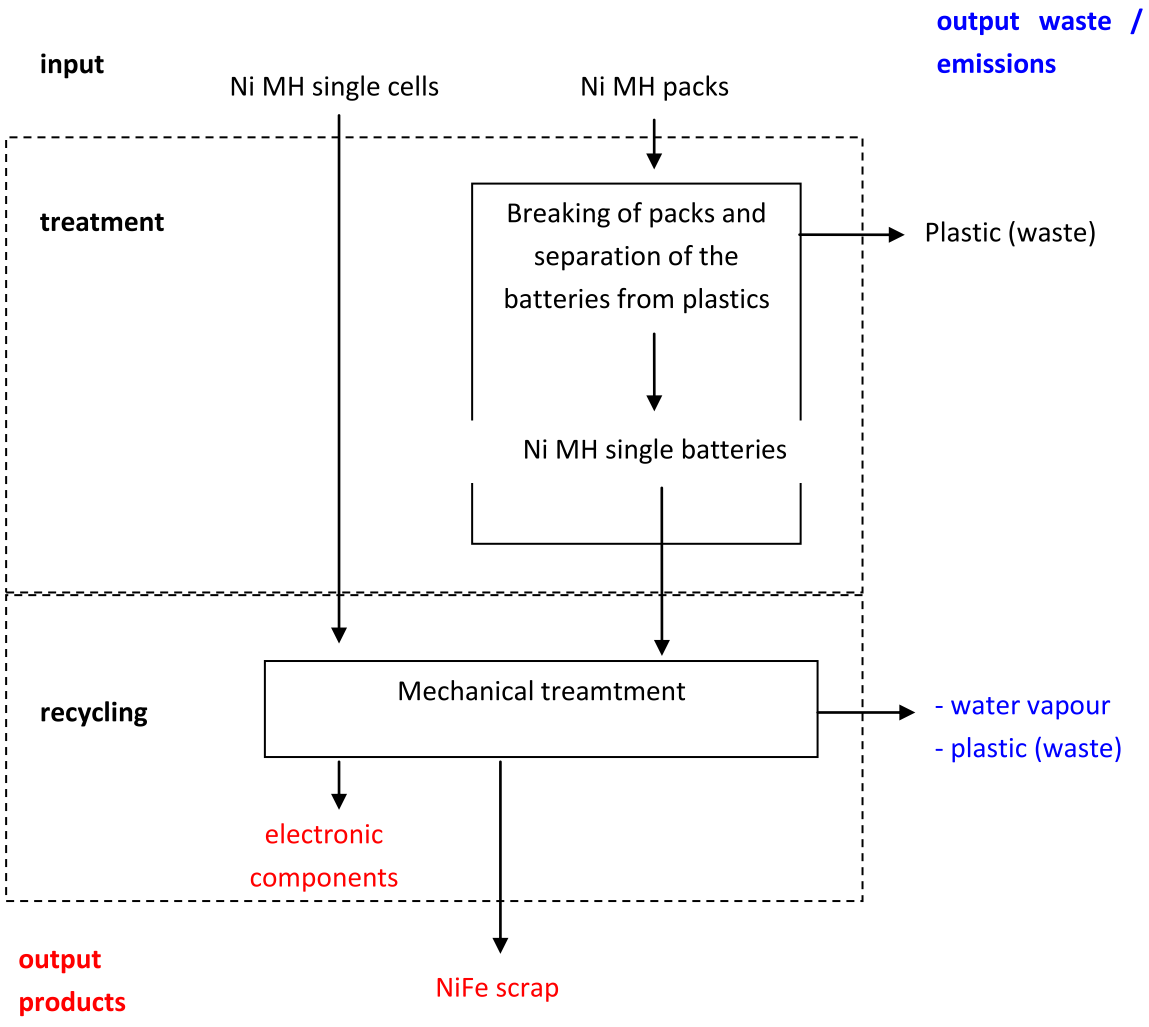


Figure 10-8: Process flow chart (Mechanical separation of Ni and Fe)

10.6.9 Recycling process: Pyrometallurgical and hydrometallurgical treatment for sorted Li-ion and NiMH batteries (secondary)

General description of the process

Process description:	Pyrometallurgy followed by hydrometallurgy
Battery type:	Sorted Li-ion and Ni-Mh batteries
Treatment / Recycling	Nickel, Cobalt, Copper production, and as such leads to high metal recoveries, good process economics and strict environmental compliance. After receiving at the smelter site, spent Li-ion batteries are weighted, sampled on site and directly fed into the calcining plant. The plant uses direct heat to process end-of-life (EOL) nickel metal hydride batteries from hybrid cars and EOL lithium-ion batteries from laptops and cell phones, along with other custom feeds, in order to extract nickel, copper and cobalt. The Nickel pyrometallurgical process in Canada produces a granulated Ni/Co/Cu and precious metals matte which is shipped to Norway where it is ground to a very fine powder and then incorporated into the Nickel Chlorine Leach hydrometallurgical process. There, the metals contained in the matte are separated and distributed to the various process areas (Ni, Cu, Co, precious metals) for further purification through extraction and electro winning for example. These process areas constitute different stages of purification, treating both solutions and solid substances. From there the finished metals are cut, packaged and shipped to world markets.
Products	Pure Ni, Cu, Co metals sold to markets Inert slag suitable for road construction for example
Intermediate fractions	not relevant
Use for energy recovery	not relevant
Waste for disposal	Not relevant
Emissions	Off gas

Table 10.9: Process description (Pyrometallurgical and hydrometallurgical treatment for sorted Li-ion and NiMH batteries)

Process flow chart

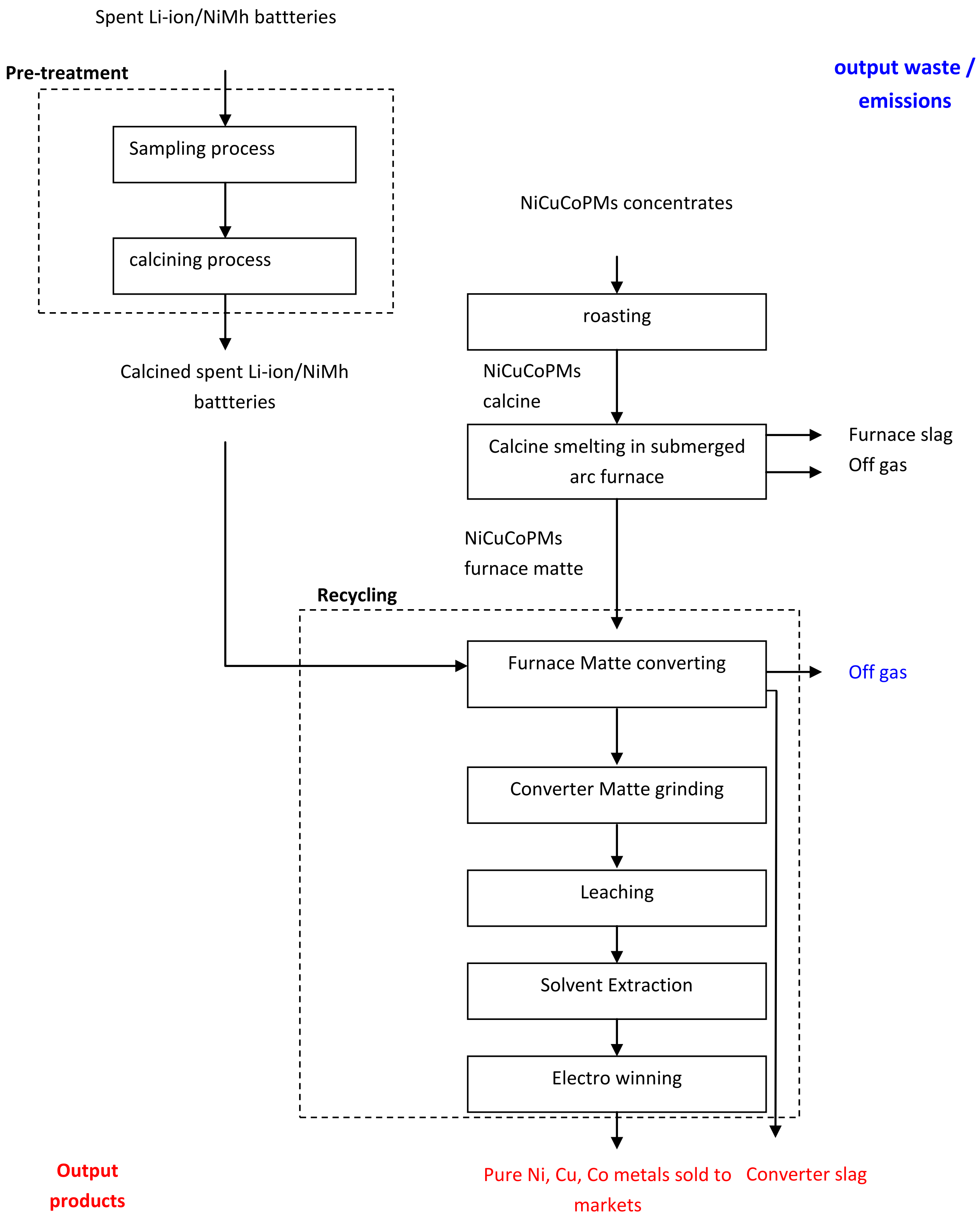


Figure 10-9: Process flow chart (Pyrometallurgical and hydrometallurgical treatment for sorted Li-ion and NiMH batteries)

10.6.10 Recycling process: Pyrometallurgical treatment for sorted Li-ion and NiMH batteries (secondary)

General description of the process

Process description:	Smelting furnace
Battery type:	NiMH and Li-ion batteries
Treatment / Recycling	Batteries (only NiMH and Li-ion batteries are accepted) are fed into a smelting furnace, together with slag forming agents (as sand, limestone). Graphite, plastics and aluminium from the batteries are used as reducing agents. The heat produced during the reduction process is sufficient to maintain the furnace at high temperature. The process produces three outputs: - gas, containing some dust - metal alloy - slags The gas is cleaned in a gas cleaning installation, equipped with a plasma gun, in order to destroy all volatile organic compounds. The gases are filtered to separate the dust, which contains mainly oxides from the slag forming agents. If the battery mix contains traces of NiCd or Zn alkaline batteries, Cd and Zn are captured in the dust. Therefore, the dust is treated as waste and processed by a Cd recycling company. The metal alloy is the main product. It is a commercial product that is refined and transformed to battery active cathode materials at several sites. The alloy could also be sold to the market The slags are suited for construction. The company is currently investigating new applications in order to valorize the Li
Products	Metal alloy Slags
Use for energy recovery	Not relevant
Intermediate fractions	Filter dust for recycling (Cd and Zn recovery)
Waste for disposal	Not relevant
Emissions	Treated off gas

Table 10.10: Process description (Pyrometallurgical treatment for sorted Li-ion and NiMH batteries)

Process flow chart

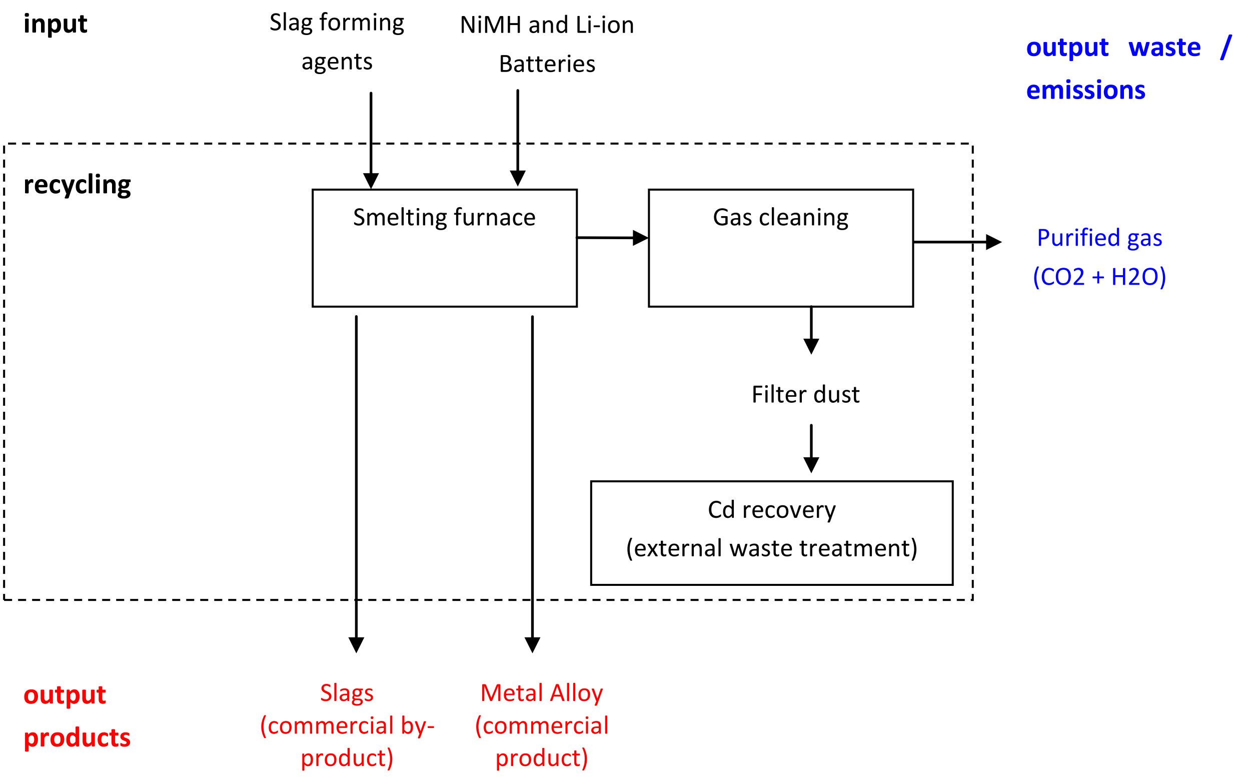


Figure 10-10: Process flow chart (Pyrometallurgical treatment for sorted Li-ion and NiMH batteries)

10.6.11 *Recycling process: Room temperature recycling process for AlMn, ZnC, ZnAir and Li-ion batteries*

General description of the process

Process description:	Room temperature recycling process
Battery type:	alkaline, zinc carbon, zinc air, lithium ion
Treatment	Batteries are sorted after delivery, due to extract impurities and to distinguish between primary cells and rechargeable batteries. Primary or lithium ion Batteries are treated separately in two different lines by a soft mechanical treatment to separate between ferrous, plastics and non ferrous metal fractions
Recycling	The Non ferrous metal fraction is treated in chemical line using room temperature and pressure conditions. Electrolyte is recovered into the used media of dissolving the active materials basics metals are separated as single products like zinc, manganese, cobalt and lithium salts.
Products	Steels → stainless steel industry Zn, Mn, Co→ non ferrous industry Li salt → Chemical industry
Intermediate fractions	Not relevant
Use for energy recovery	Solid waste with high carbon contents → energy recovery
Waste for disposal	Solid waste from chemical treatment
Emissions	Treated air → atmosphere Treated waste water → receiving water

Table 10.11: Process description (Room temperature recycling process for AlMn, ZnC, ZnAir and Li-ion batteries)

Process flow chart 1 – AlMn, ZnC, ZnAir batteries

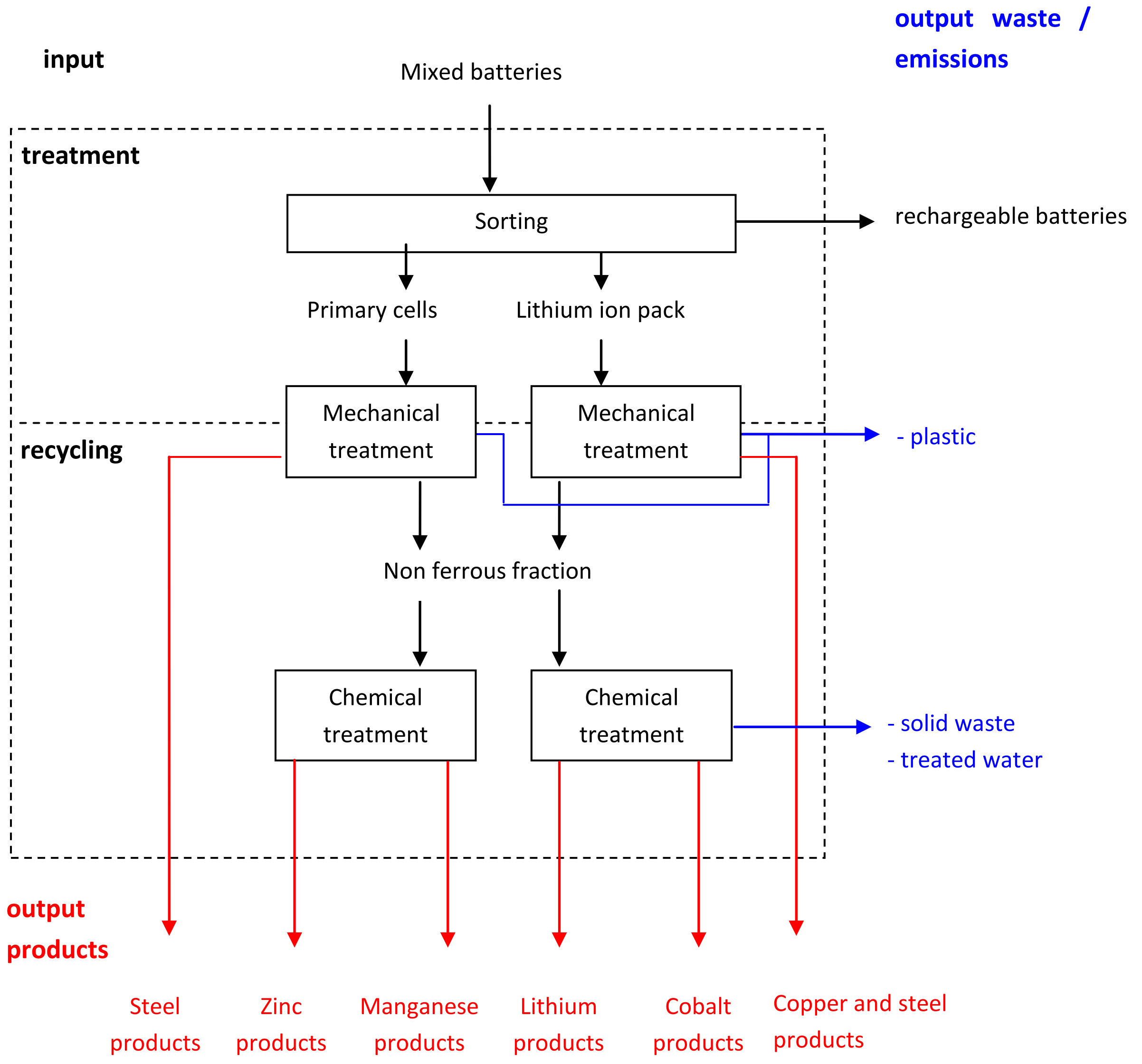


Figure 10-11: Process flow chart (Room temperature recycling process for AlMn, ZnC, ZnAir and Li-ion batteries)

10.6.12 Recycling processes: Lead-acid battery recycling

10.6.12.1 General description of several processes carried out for lead-acid battery recycling.

There are two main types of process for the recovery of lead from automotive batteries. These are described in the draft BREF note on non-ferrous metal industries (see [EIPPCB 2008] p. 426 ff).

1) The Varta process where whole batteries are drained of acid the batteries and fluxes are fed into a blast furnace via a seal and oxygen enriched air is used in the blast. Antimonial lead bullion is produced, along with a silica based slag and a lead-iron matte that can be recovered in a primary lead smelter. Organic components in the furnace off-gases are oxidised in an after- burner and the gases are then cooled and filtered in a fabric filter. The filter dust is de-chlorinated and returned to the furnace.

2) In the MA and CX processes batteries are drained of acid, broken and separated into various fractions using automated proprietary equipment (for details see [EIPPCB 2008]). In the CX and related processes, the lead sulphate paste may be desulphurised by reaction with sodium carbonate or sodium hydroxide prior to smelting.

In the following a short overview on general processes provided by industry representatives (Eurobat, Eurometaux and ILA) is given. These processes include dedicated and non dedicated battery recycling processes. In the following sections (10.6.12.2 ff) exemplary information on specific processes is given.

General description of several processes carried out for lead-acid battery recycling

Process description:	General lead-acid battery recycling (including rotary or blast furnaces)
Battery type:	Lead-acid batteries
Treatment / Recycling	The recycling results for spent Lead automotive and industrial batteries fluctuate depending on the process used at each recycling plant. In general, it can be said that: - The **lead** content (approx. 60 % of the battery weight) enters the recycling process and approx. 97% of the total material is recovered as secondary lead. - The **plastic** content (approx. 7 – 8 % of the weight) is usually separated before the lead is recycled, depending on the method used, and reprocessed and reused in the automobile industry, for example (in bumpers, wheel arches and other parts). With another recycling method, lead batteries are reprocessed completely, including their plastic casing. The pyrolysis gas produced in the shaft furnace by the pyrolysis of the plastics is then utilized as energy in the afterburning of thermal exhaust air as a substitute for natural gas. - The **slag** produced in the recycling process has as low a lead content as can be achieved and is, in some countries, usable as a construction material. However, in many instances it has to be

	disposed of to landfill because it is unsuitable for use due to its chemical/physical properties. - The **waste acid** (approx 30% of the weight) is treated in a variety of ways. Some companies separate and filter it to make it suitable for regenerating fresh acid for a variety of applications. Others convert the waste acid into calcium sulphate (gypsum) or sodium sulphate (soda) which can be used for various applications such as building products or detergents. Some companies simply neutralize the acid before disposal. - The **drosses** removed during the refining process contain small amounts of metals other than lead. Sometimes these are recovered by the company itself, in other cases they may be sold as waste to specialist recyclers of these metals. - The **matte of lead** is sold to companies which produce sulphuric acid from it through roasting. The residual lead is recycled during the further processing of the roasted material. - **Filter dusts** from air purification plant contain significant amounts of lead and other metals. These dusts are normally blended back into the smelter for recovery of the metals contained. Residues from wastewater treatment plant which contain lead and other metals can be dewatered and returned to the furnaces to remove lead and other metals. In one externally conducted hydrometallurgical pre-treatment, the lead contained in the filter dust is converted into lead carbonate which is reintroduced to the recycling process as a raw material.
Products	Lead Plastic → reprocessed in the automobile industry Slag → construction Fresh acid → several uses Calcium sulphate (gypsum), Sodium sulphate → Construction, detergents
Use for energy recovery	Plastic
Intermediate fractions	Drosses → metal recycling Matte of lead → production of sulphuric acid; recycling of residual lead Slags → slags for recycling
Waste for disposal	Slag → disposal, landfill construction Neutralised acid or waste from waste water treatment
Emissions	Cleaned off-gas (CO_2 and H_2O) Treated waste water

Table 10.12: Proposal for a general process description (Lead-acid batteries)

Process flow chart giving an overview on several processes in lead-acid battery recycling

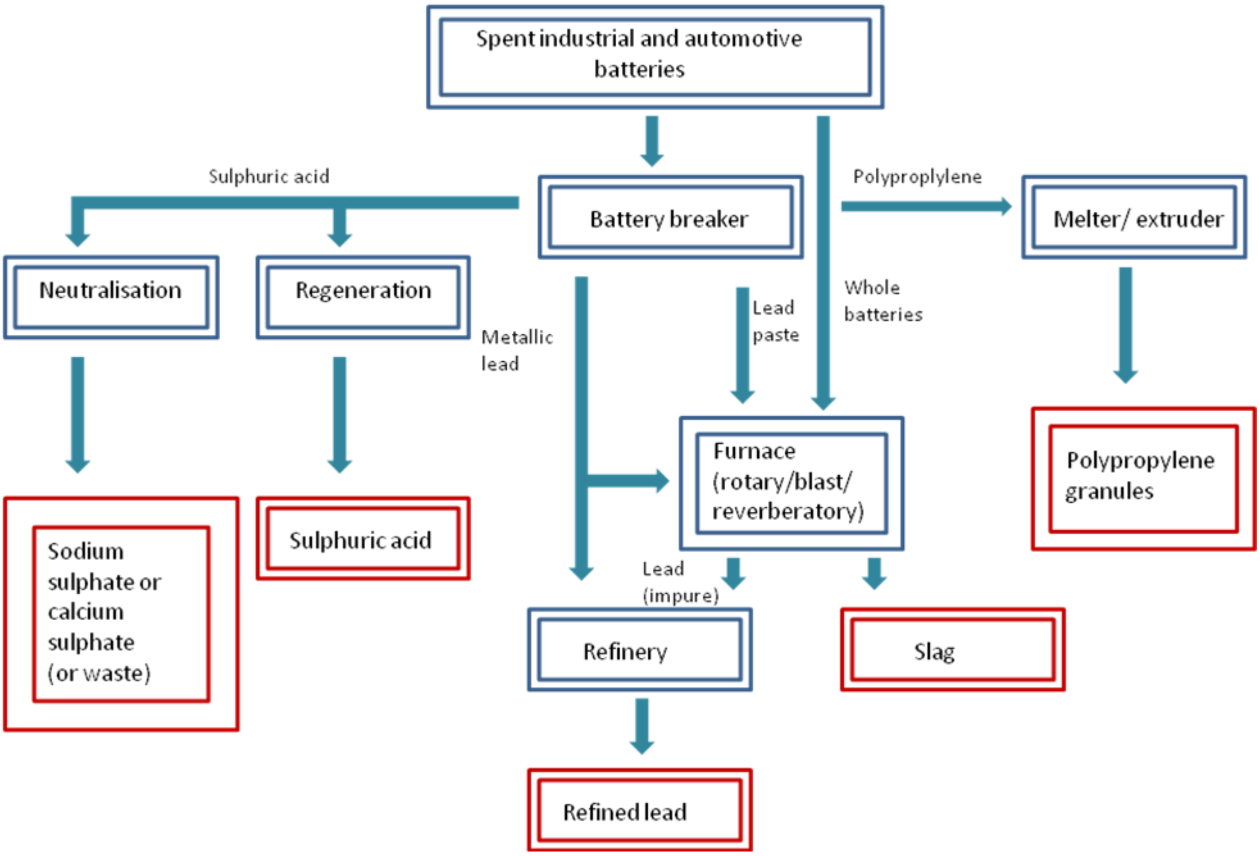


Figure 10-12: Simplified lead-acid battery recycling flowchart [EUROBAT/EUROMETAUX/ILA 2009]

10.6.12.2 Recycling process lead-acid batteries 1: Lead-acid battery breaking – acid recovery – PP-compounding – smelting in rotary furnace – refining

General description of the process

Treatment and recycling Recycling	The accumulators are delivered to the covered, acid-proof storehouse. The pre-treatment comprises separating them into fractions consisting of lead grids, lead paste, polypropylene housings, plastic separators as well as sulphuric acid. Before crushing, the sulphuric acid of the accumulators is drained off and collected in tanks. The acid is neutralized and in a further step recovered to sulphuric-acid or sodium- sulphate. A hammer crusher then breaks the accumulators into pieces. Lead paste is washed out and separated from the coarse battery pieces in a sieve drum before employing into the next process step using hydro classifiers to separate the remaining battery components into metallic and plastic fractions consisting of polypropylene and other plastics (separators). The upwards-directed stream of water separates the materials according to their densities, the plastics being carried out with the water. Lead grids, lead paste, lead scrap and residues containing lead and tin, e. g. ashes, dross or sludge are melted at approx. 1200 °C. Lead bullion or crude tin is produced in three encapsulated short rotary furnaces. The molten mixture of lead, tin and slag is poured separately during a number of consecutive tapping steps into moulds. The raw material is cast to large blocks (bullion). The lead bullion is refined in kettles, where metallic impurities are removed from the raw lead or tin and alloys produced according to customer specifications. The refined lead is cast to ingots. The polypropylene undergoes an intensive multiple stage cleaning process before being ground and mixed with additives and finally extruded to polypropylene compound granulate.
Products (including by-products)	Lead/lead-alloys Polypropylene SnPb-alloys Sodium- sulphate/ sulphuric acid
Intermediate fractions	Not relevant
Use for energy recovery	Plastic waste (separators)
Waste for disposal	Slag
Emissions	CO/CO2→ atmosphere after filter H2O → atmosphere Waste water → waste water treatment facility → receiving water

Table 10.13: Process description (Lead-acid battery breaking – acid recovery – PP-compounding – smelting in rotary furnace – refining)

Process flow chart

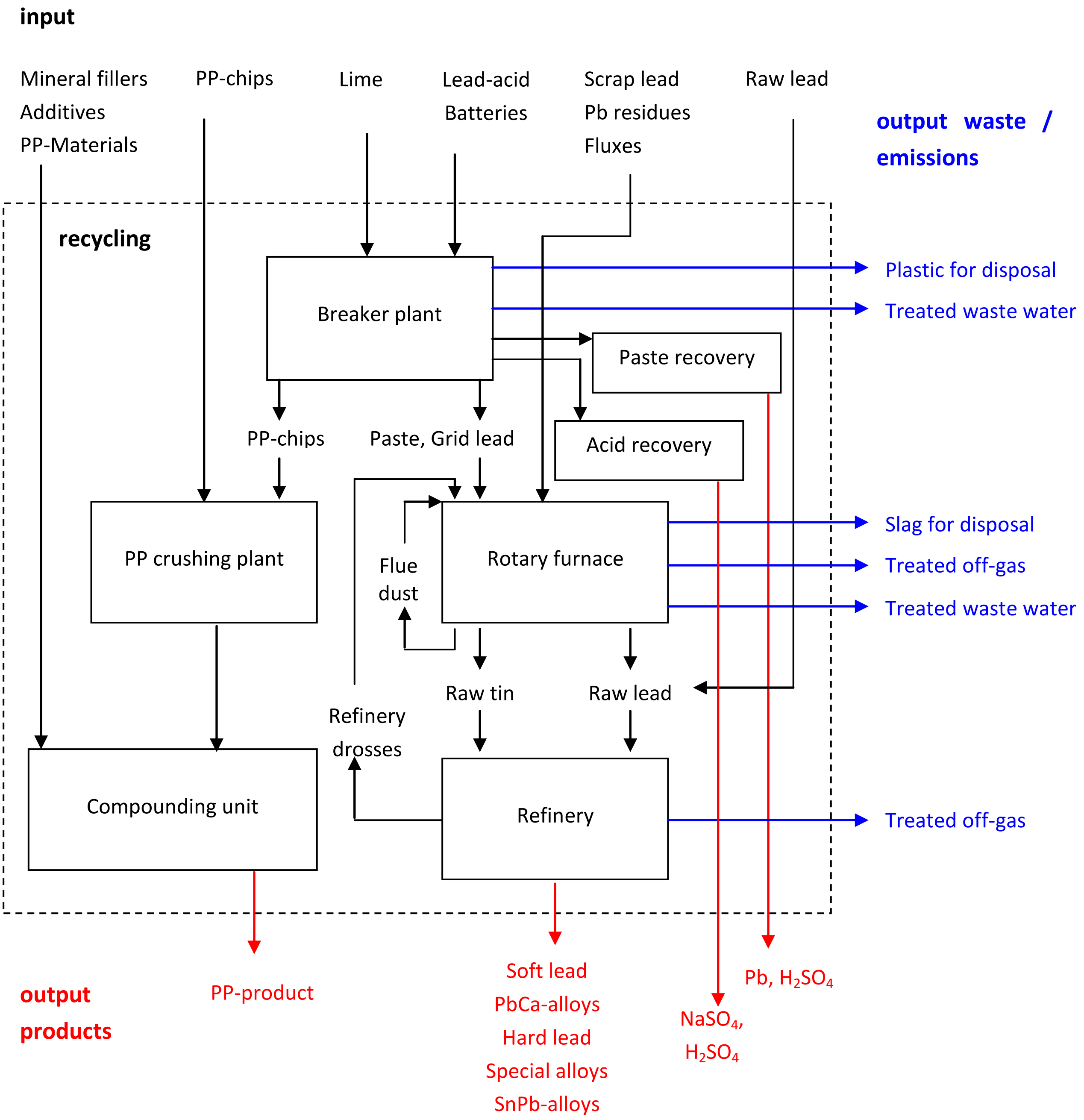


Figure 10-13: **Process flow chart (Lead-acid battery breaking – acid recovery – PP-compounding – smelting in rotary furnace – refining)**

10.6.12.3 Recycling process lead-acid batteries 2: Lead-acid battery breaking – acid recovery – PP-recovery – melting in rotary kiln and smelting in rotary furnace – refining

General description of the process

Treatment and recycling	Before crushing, the sulphuric acid of the accumulators is drained off and collected in tanks. The acid is stored in the acid storage and is externally recycled. The battery breaker breaks the batteries and separates a polypropylene (PP), a coarse metal, a fine metal and a battery paste fraction. The PP fraction is washed and cut to PP-chips. These are stored before delivery for external recycling. The non-PP plastic fraction (mainly PE) is burnt in the rotary kiln for energy recovery and recovery of the fine lead particles (paste) clinging to the separators and ending up in the drosses. These are introduced in the rotary furnace (see below). The coarse metal fraction is melted in a rotary kiln which produces hard lead for refining. The fine metal fraction and the battery paste is loaded together with refining drosses and flue dust for smelting and metal recovery to a rotary furnace which produces raw lead for refining and slag for disposal. The kiln, like the rotary furnaces, is equipped with a post-combustion chamber where the temperature is maintained around 900°C to avoid any dioxin build-up. The raw lead from the rotary furnace and the hard lead from the rotary kiln are refined and alloyed. The refined lead and lead alloys are cast to ingots.
Products (including by-products)	Lead/lead-alloys
Intermediate fractions	Sulfuric acid PP-chips
Use for energy recovery	Non-PP-plastic fraction
Waste for disposal	Slag
Emissions	Treated off-gas Treated waste water

Table 10.14: Process description (Lead-acid battery breaking – acid recovery – PP-recovery – melting in rotary kiln and smelting in rotary furnace – refining)

Process flow chart

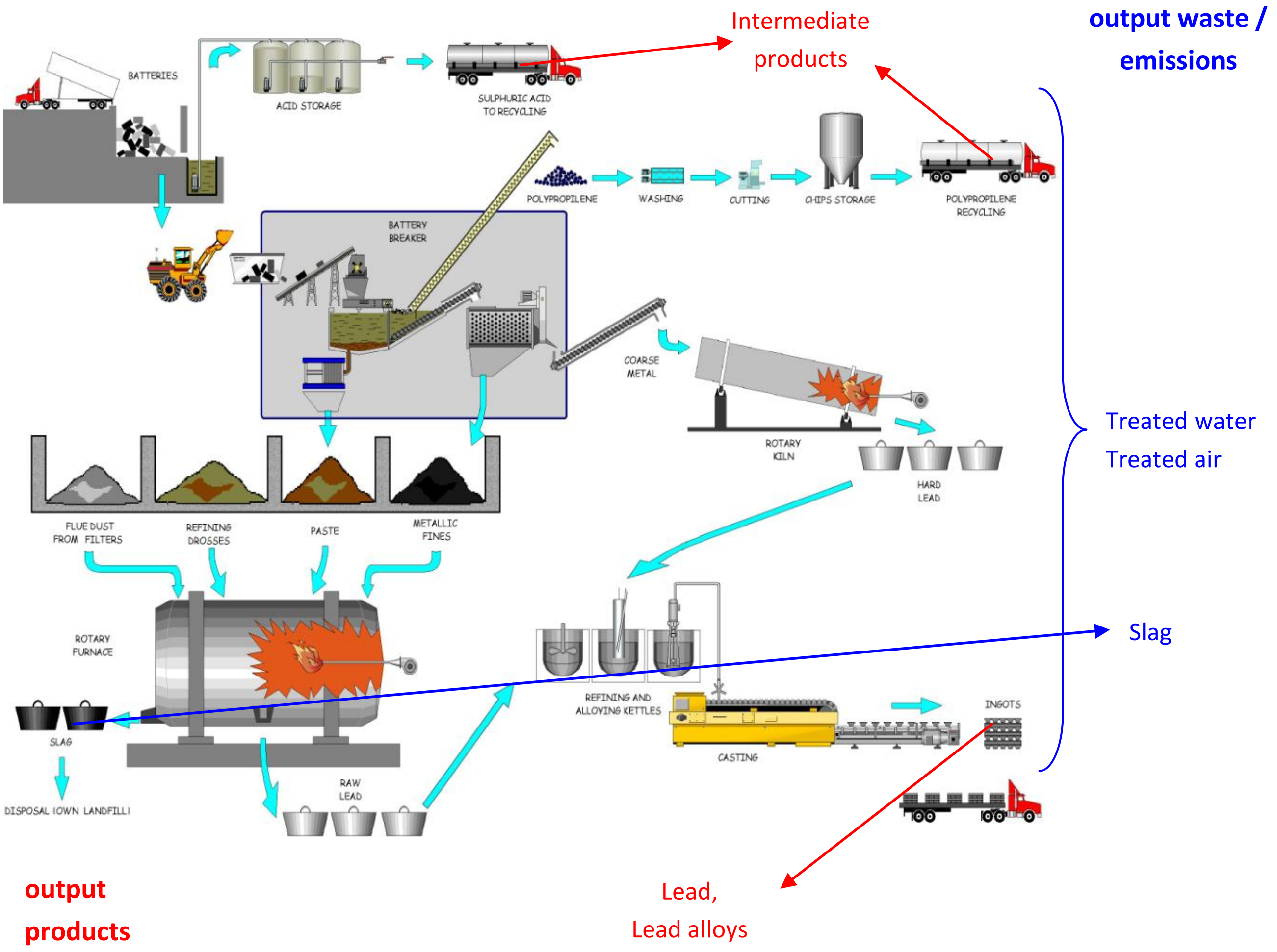


Figure 10-14: Process flow chart (Lead-acid battery breaking – acid recovery – PP-recovery – melting in rotary kiln and smelting in rotary furnace – refining)

10.6.12.4 Recycling process lead-acid batteries 3: Removal of acid – smelting in shaft furnace – refining

General description of the process

Process description	Removal of acid – smelting in shaft furnace – refining
Battery types	Lead-acid batteries
Recycling process	– Batteries are weighed at delivery and sorted. – Batteries containing steel casings are stripped from the casing. – The batteries are drained from acid by mechanical impact. – The acid (diluted sulphuric acid) is collected and neutralised or treated for external reuse. – The neutralised acid is treated in a waste water treatment plant and is sent to recipient. – Drained batteries are mixed with slag formers (silica, iron and lime), coke, reverts and other lead containing raw material. – The mixed material is fed to the top of a shaft furnace. – Smelting takes place in accordance with general shaft furnace principles. Lead and sulphur compounds are reduced to lead metal and iron sulphide with coke and organic compounds (plastics) coming from the batteries acting as reductants. – Process gas from the furnace containing CO and hydrocarbons is taken to an afterburner operating at approx 1100C. This ensures low emission of CO, hydrocarbons and dioxins. – Process gas leaving the process is cooled before entering textile filters. Energy recovered from afterburning can be used for district heating. – Crude lead from the smelting operation is taken to the refinery where impurities are removed and the final lead alloys are cast into ingots.
Products	– Lead and lead alloys. (Other metallic fractions such as steel casings from traction batteries)
Intermediate fractions	– Slag/matte for recycling – Drosses for internal and/or external recycling – Filter dust for internal and/or external recycling
Use for energy recovery	– Organic components (plastics) of the battery are used as reducing agent and for providing energy
Waste for disposal	– Slag/matte for disposal
Emissions	– CO_2 to atmosphere – Water to atmosphere and recipient

Table 10.15: Process description (Lead-acid batteries – removal of acid – smelting in shaft furnace – refining)

Process flow chart

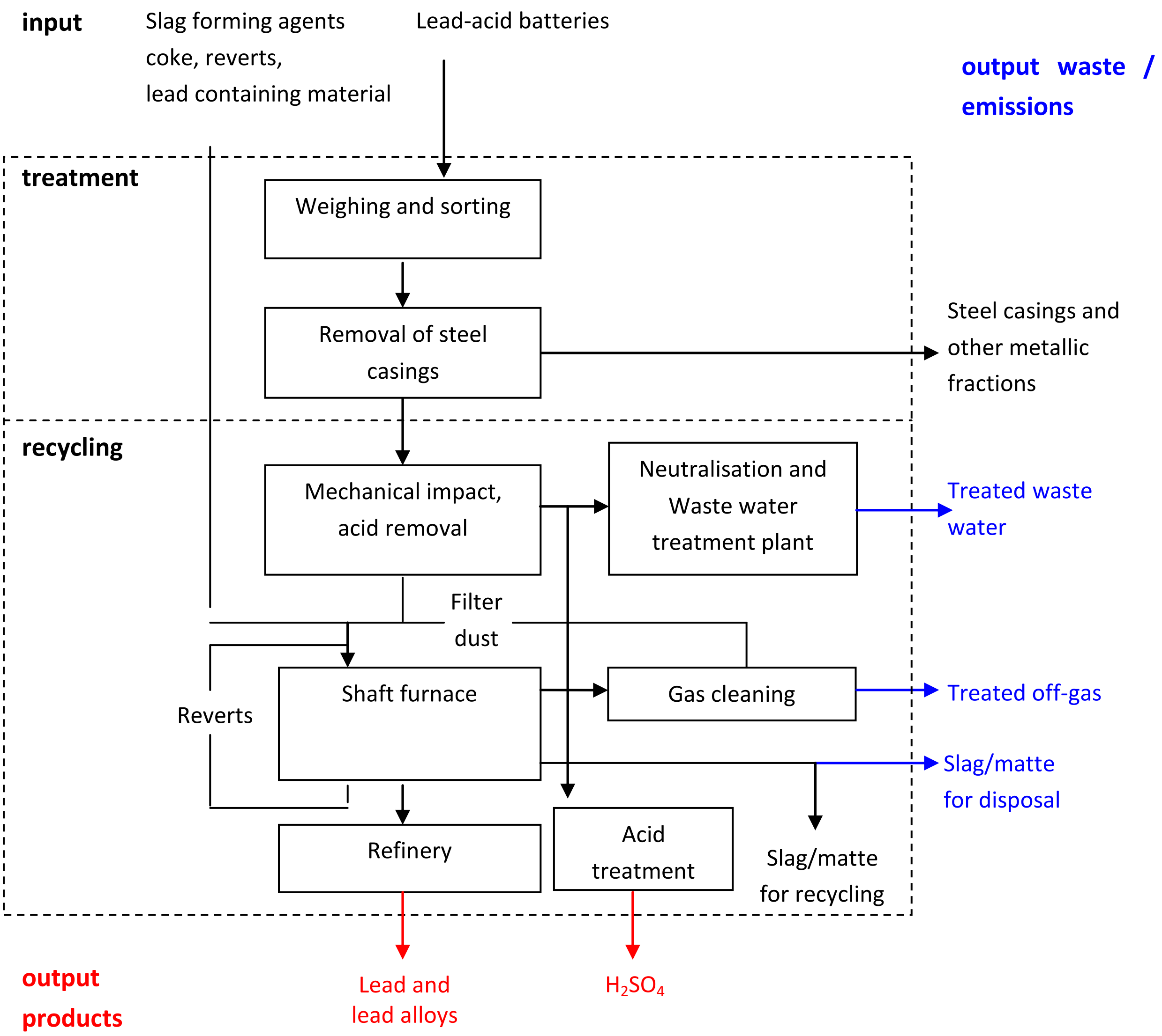


Figure 10-15: **Process flow chart (Lead-acid batteries – removal of acid – smelting in shaft furnace – refining)**

10.6.12.5 Recycling process lead-acid batteries 4: acid recovery – smelting in shaft furnace – refining – matte and slag recycling.

Process description and flow chart

This process is similar to the recycling process "lead-acid batteries 3" (see section 10.6.12.4). A process description and a flow chart is therefore not given here. The relevant specifics concerning the output fractions are the following:

Sulphuric acid

The drainable sulphuric acid is collected, purified, filtered and reused in industry for the same acidic properties as the original sulphuric acid.

This recycled sulphuric acid is a product accountable for the recycling efficiency.

Lead matte

Out of the blast furnace, a lead matte (composed of Fe and Pb Sulfide) is produced. In the process, this phase enables the capture of the "S" which enters into the furnace in the form of $PbSO_4$. The lead matte is sold to recycling industry based on the recycling of lead and sulphur (typical example is the integrated recycling smelter of Umicore Precious Metals in Hoboken, Belgium). In this company, lead is recycled at > 99,5% and sulphur is transformed into pure sulphuric acid and sold on the market. This lead matte is an intermediate fraction.

The facility recycling the matte has to inform the battery recycler on the recycling efficiency that is achieved for the lead and the sulphur. The recycled share originating from the battery input is accountable for the recycling efficiency.

Lead matte slag

Out of the blast furnace, a lead matte slag is produced. As for lead matte, the lead slag is sold to recycling smelters (Umicore Precious metals for instance). These smelters need a lead phase to collect their precious metals and have to buy some lead-containing materials on the market. Again, lead is recycled for > 99.5% and put back on the market as pure lead (> 99.98% purity).

The facility recycling the lead matte slag has to inform the battery recycler on the recycling efficiency that is achieved for the lead. The recycled share originating from the battery input is accountable for the recycling efficiency.

10.7 BAT core elements from BREFs and relevant Guidelines

10.7.1 BAT core elements from BREFs

10.7.1.1 BREF 'Waste Treatment Industries'

The BREF 'Waste Treatment Industries' contains the determined Best Available Techniques (BAT) for the waste treatment sector. Due to minimum treatment requirements of Annex III Part A of the Batteries Directive (2006/66/EC) exemplified the following techniques and BAT from the BREF 'Waste Treatment Industries' seem to be of major importance.

In the recommendations for future work it is stipulated that there are some waste treatments highlighted that may be good candidates for enlarging the scope of the BREF 'Waste Treatment Industries' e.g. composting and end-of-life materials including vehicles, fridges, electronic waste, cathode ray tubes, glass preparation, fluorescents containing mercury, switches as well as batteries.

1. **Techniques to Consider in the Determination of BAT (Section 4):**

- Physico-chemical treatments of specific wastes:
- Treatment of **waste containing mercury**, e.g. shredding/crushing of **batteries and button cells**, carrying out the following sequence of treatments:
  - separate and concentrate the mercury by evaporation and condensation;
  - treat the off gases with dust filters and activated carbon filters;
  - return the dust and the contaminated carbon from the gas treatment into the process;
  - treat the distillate (water and organic fractions) by:
    - Incineration in a waste incinerator;
    - Conducting the gases from the distillation through an after burner (at approximately 850 ºC) and a condenser. The off-gases are cleaned by flue-gas treatment (e.g. scrubber, dust filter and activated carbon filter). The separated dust and the contaminated carbon are returned to the distillation vessel. This alternative raises the recovery rate;
    - Purifying the water fraction (after separation) and returning the deposit to the distillation vessel. This alternative raises the recovery rate.

2. Best Available Techniques, Generic BAT (Section 5.1)

Other Common Techniques:

- BAT is to perform crushing, shredding and sieving operations in areas fitted with extractive vent systems linked to abatement equipment (BAT No. 32; see Section 4.1.6.1 of BREF Waste Treatment Industries) when handling materials that can generate emission to air (e.g. odours, dust, VOCs).

Air Emission Treatments

To prevent or control the emissions mainly of dust, odours and VOC and some inorganic compounds:

- BAT is to restrict the use of open topped tanks, vessels and pits by: a. not allowing direct venting or discharges to air by linking all the vents to suitable abatement systems when storing materials that can generate emissions to the air (e.g. odours, dust, VOCs) b. keeping the waste or raw materials under cover or in waterproof packaging (see Section 4.1.4.5 and this is also related to BAT number 31.a) c. connecting the head space above the settlement tanks (e.g. where oil treatment is a pre-treatment process within a chemical treatment plant) to the overall site exhaust and scrubber units. (BAT No. 35)

- BAT is to use an enclosed system with extraction, or under depression, to a suitable abatement plant. This technique is especially relevant to processes which involve the transfer of volatile liquids, including during tanker charging/discharging. (BAT No. 36)

- BAT is to apply a suitably sized extraction system which can cover the holding tanks, pretreatment areas, storage tanks, mixing/reaction tanks and the filter press areas, or to have in place a separate system to treat the vent gases from specific tanks (for example, activated carbon filters from tanks holding waste contaminated with solvents). (BAT No. 37)

- BAT is to correctly operate and maintain the abatement equipment, including the handling and treatment/disposal of spent scrubber media (BAT No. 38)

- BAT is to have a scrubber system in place for the major inorganic gaseous releases from those unit operations which have a point discharge for process emissions. Install a secondary scrubber unit to certain pretreatment systems if the discharge is incompatible, or too concentrated for the main scrubbers. (BAT No. 39)

- BAT is to have leak detection and repair procedures in place in installations a) handling a large number of piping components and storage and b) compounds that may leak easily and create an environmental problem (e.g. fugitive emissions, soil contamination). This may be seen as an element of the EMS. (BAT No. 40)

- BAT is to reduce air emission to the following levels:

Air parameter	Emission levels associated to the use of BAT (mg/Nm3)

VOC	7-20[1]
PM	5-20
1 For low VOC loads, the higher end of the range can be extended to 50	

- by using a suitable combination of preventive and/or abatement techniques (see Section 4.6). The techniques mentioned above in the BAT 'Air emission treatments' section (BAT numbers 35 – 41) also contribute to achieve these values. (BAT No. 41)

Soil contamination:

- BAT is to prevent soil contamination, BAT is to provide and then maintain the surfaces of operational areas, including applying measures to prevent or quickly clear away leaks and spillages, and ensuring that maintenance of drainage systems and other subsurface structures is carried out (BAT No. 62).
- Bat is to prevent soil contamination, BAT is to utilise an impermeable base and internal site drainage (BAT No. 63).
- To prevent soil contamination, BAT is to reduce the installation site and minimise the use of underground vessels and pipe work (BAT No. 64).

Storage and handling:

- BAT is to apply storing of containerised wastes under cover (BAT No. 31a). This can also be applied to any container that is held in storage pending sampling and emptying. Some exceptions on the applicability of this technique related to containers or waste not affected by ambient conditions (e.g. sunlight, temperature, water) have been identified. Covered areas need to have adequate provision for ventilation.
- BAT is to apply maintaining the availability and access to storage areas for containers holding substances that are known to be sensitive to heat, light and water, under cover and protected from heat and direct sunlight (BAT No. 31b).

Management of the process generated residues:

- BAT is to have a residue management plan as part of the EMS including: basic housekeeping techniques (related to BAT number 3), internal benchmarking techniques) (BAT No. 57).
- BAT is to maximise the use of re-usable packaging (drums, containers, IBCs, palettes, etc.) (BAT No. 58).
- BAT is to re-use drums when they are in a good working state. In other cases, they are to be sent for appropriate treatment (BAT No. 59).

3. Best Available Techniques, BAT for specific types of waste treatments (Section 5.2)

Physico-chemical treatment of waste waters:

- BAT is to apply the following techniques in physico-chemical reactors (BAT No. 72):
  - clearly defining the objectives and the expected reaction chemistry for each treatment process
  - assessing each new set of reactions and proposed mixes of wastes and reagents in a laboratory-scale test prior to waste treatment
  - specifically designing and operating the reactor vessel so that it is fit for its intended purpose
  - enclosing all treatment/reaction vessels and ensuring that they are vented to the air via an appropriate scrubbing and abatement system
  - monitoring the reaction to ensure that it is under control and proceeding towards the anticipated result
  - preventing the mixing of wastes or other streams that contain metals and complexing agents at the same time.
- BAT is to apply the following techniques for the neutralisation process (BAT No. 74)
  - ensuring that the customary measurement methods are used
  - separately storing the neutralised waste water
  - performing a final inspection of the neutralised waste water after a sufficient storage time has elapsed.

10.7.1.2 BREF ‘Non Ferrous Metals Industries’

The BREF ‘Non Ferrous Metals Industries’ contains the determined Best Available Techniques (BAT) for the non ferrous metals sector. Due to minimum treatment requirements according to Annex III Part A of the Batteries Directive exemplified following techniques and BAT from the BREF ‘Non Ferrous Metals Industries’ seem to be of major importance.

1. Common processes and equipment, Pre-processing and transfer of Raw Materials, Applied processes and techniques (Section 2.5.1):

Battery breaking (Section 2.5.1.4):

Is used to recover lead, nickel, cadmium and other materials from batteries. For lead-acid batteries, hammer mills are used to break the battery cases to liberate lead (as grids) and lead compounds (as paste) and allow the recovery of the plastic case material (mainly poly-propylene); the electrolyte is also removed and treated or used. Two-stage crushing can be used to control the particle size and prevent the lead oxide from being impacted into the plastic during a single stage mill. Plastic material is separated and washed to improve the quality and produce plastic that is suitable for recycling. The acid content of the batteries can contaminate land and water if it is not collected and handled properly, sealed acid resistant drainage systems can be used with dedicated collection and storage tanks. The milling stages can produce an acid mist; this can be collected in wet scrubbers or mist filters. Ni/Cd batteries are pyrolised to remove any plastic coating and to open the batteries. Pyrolysis is carried out at low temperatures and the gases are treated in an afterburner and then a bag filter. Cadmium and nickel are recovered from the electrodes and steel from the casing material.

Separation techniques (Section 2.5.1.12):

These processes are used to remove impurities from raw materials prior to their use. The separation techniques for ores and concentrates (such as flotation) are generally used at the mine when the material is concentrated or "beneficiated", but these techniques are also used at several production sites to treat slag to remove metal rich fractions. Magnetic separation is used to remove items of iron. Separation techniques are more frequently used for secondary raw materials and the most common is magnetic separation. Heavy media and density separation (swim/sink) is used by the scrap processing industry but may be encountered in the non-ferrous metals industry for example in the processing of battery scrap to remove plastic material. In this case the density and size difference of the various fractions is used to separate metal, metal oxides and plastic components using a water carrier. Air classification is also used to separate metals from less dense materials such as the plastic and fibres from electronic scrap. Flotation is also used to enrich leach residues. Magnetic separation is used to remove pieces of iron to reduce contamination of alloys. Generally, over-band magnets are used above conveyors. Sloping hearths in a reverberatory furnace are used to melt zinc, lead and aluminium to leave large, higher melting point impurities (e.g. iron) on the hearth for further processing. Moving electromagnetic fields (eddy current separation) are used to separate aluminium from other material. A variation on this technique uses this moving electromagnetic field to pump molten aluminium or other metals without direct contact between the metal and mechanical components. Other separation techniques involve the use of colour, UV, IR, X-ray, laser and other detection systems in combination with mechanical or pneumatic sorters. These are used for example to separate Ni/Cd batteries from other battery types and the techniques are being developed for other applications.

2. Common processes and equipment, Energy recovery (Section 2.11):

Applied techniques (Section 2.11.1):

During the smelting of electronic scrap or battery scrap in metallurgical vessels the heat content of the plastic content is used to melt the metal content and other additional scrap and slag forming components.

3. Processes to produce Lead, Zinc and Cadmium, Applied Processes, (Section 5.1.):

Secondary Lead, The recovery of lead from scrap batteries (Section 5.1.2.1):

Batteries are drained of acid and fed whole into a blast or shaft furnace or Batteries are drained of acid broken and separated into various fractions using hammer type mills to crush the whole batteries. The crushed material then passes through a series of screens, wet classifiers and filters to obtain separate fractions containing metallic components, lead oxide sulphate paste, polypropylene, non recyclable plastics and rubber and dilute sulphuric acid. Some processes use a second milling stage before the plastic fraction is finally treated. Polypropylene is recycled as far as possible. The sulphuric acid drained from the batteries is neutralised unless there is a local use for it and the sodium sulphate produced can be re-crystallised and sold. These are strongly market dependent options. Several alternatives are used to deal with the sulphur contained in the battery materials. 1. Prior to smelting, the lead sulphate paste may be desulphurised by reaction with sodium carbonate or sodium hydroxide (in the CX and related processes). Paste desulphurisation prior to smelting can reduce the quantity of slag produced and, depending on the smelting method used, the amount of sulphur dioxide released to the air. 2. Lead sulphate can be separated and sent to an installation capable of treating the sulphur content in the gases for example one of the direct smelting primary lead processes. 3. The sulphur may be fixed in the slag or as a Fe/Pb matte.

Cadmium, Production of cadmium from batteries (Section 5.1.10.2):

A main source of cadmium is from the recycling of Ni-Cd batteries. Several recycling initiatives exist and they supply batteries to the industry for automatic sorting and recovery. Ni-Cd batteries are first of all pre-treated thermally to remove plastic coatings and open the battery cases. The opened batteries are then heated in a closed retort to volatilise and then condense the cadmium, which is then cast into moulds. Nickel and iron residues are then recycled. Each of the process stages uses high quality extraction and abatement systems to remove dust, metals and VOCs such as dioxins. The process is dry and is isolated from the drainage system.

4. Processes to produce Lead, Zinc and Cadmium, Applied Processes, Present Emission and consumption level (Section 5.2.)

Emissions to air (Section 5.2.2):

The emissions can escape the process either as stack emissions or as fugitive emissions depending on the age of the plant and the technology used. Stack emissions are normally monitored continuously or periodically and reported. The main emissions to air from zinc and lead production are sulphur dioxide (SO2), other sulphur compounds and acid mists; oxides of nitrogen (NOx) and other nitrogen compounds; metals and their compounds; dust; VOCs and dioxins. Emissions are to a large extent bound to dust (except cadmium, arsenic and mercury that can be present in the vapour phase). One source of emissions from the process is pre-treatment (e.g. battery breaking) with a less significant emission potential to air of sulphur oxides and a more significant emission potential to air of dust and metals.

Emissions to water (Section 5.2.3):

Metals and their compounds and materials in suspension are the main pollutants emitted to water. The metals concerned are Zn, Cd, Pb, Hg, Se, Cu, Ni, As, Co and Cr. Other significant substances are fluorides, chlorides and sulphates. One possible wastewater stream is wastewater from battery breaking and classification stages. The battery breaking and washing stages produces an effluent which is acidic and contains lead and other metals in suspension and solution. This effluent is neutralised and the water is recycled in the process. If possible the acid is used elsewhere. A portion is usually bled from the system to control dissolved salts. These processes also produce contaminated surface water and consequently this water is also treated and reused. It is common practice to discharge a bleed of this sealed water circuit after further treatment and analysis. Road and surface contamination is minimised by frequent wet cleaning of roads, hard standing areas and lorries and by good practice in cleaning up spillages. The quality and quantity of wastewater depends on the process used, the composition of the raw materials that are used in the process and the practices used by the operators. The reuse of process and rainwater is common.

Process Residues and Waste (Section 5.2.4):

Pyrometallurgical slags and residues: Slags from the metal production processes usually contain very low concentrations of leachable metals. They are therefore generally suitable for use in construction. Slags from the battery processing plants may be suitable for construction uses depending on the leachability of the metals they contain. The leachability is influenced by the fluxes used and the operating conditions. The use of sodium based fluxes (Na2CO3) to fix sulphur in the slag causes an increase in the quantity of leachable metals. These slags and drosses from battery recovery processes can contain Sb. This is normally recovered but storage in damp conditions can cause the emission of stibine.

Other process residues and wastes: The battery processing plants also produce polypropylene from the crushed battery cases. There are a number of plastics fabricating plants designed specifically for this material and they produce granular polypropylene for the automobile industry. Effective washing of the polypropylene fraction and separation of other plastic components such as ebonite or PVC is essential to produce products within specification.

5. Processes to produce Lead, Zinc and Cadmium, Techniques to Consider in the Determination of BAT (Section 5.3.)

Materials storage, handling and pre-treatment processes (Section 5.3.1):

There are a variety of secondary raw materials used and they range from fine dusts to large single items. The metal content varies for each type of material and so does the content of other metals and contaminants. Batteries are a common source of lead and can contain acid, the storage and handling therefore needs to take account of the acid content and any acid mists that can be formed. Nickel cadmium batteries are usually dry but other batteries may be present and leakage of electrolyte is possible, this should be taken into account in the storage and separation method used. The techniques used for storage, handling and pre-treatment will therefore vary according to the material size and the extent of any contamination. These factors vary from site to site and the techniques discussed (see Table) are applied on a site and material specific basis.

Material	Storage	Handling	Pretreatment	Comment
Lead Acid Batteries	Covered Storage	Mechanical loader and conveyor	Crushing or whole feed	Acid collection. Reuse if possible
Ni/Cd Batteries	Sealed drums or containers	Mechanical loader and conveyor	Plastic removal and pyrolysis	Separation of Fe and Ni

Secondary lead smelters (5.3.3):

The range of secondary materials and the variation in metal content and degree of contamination has lead to the development of a range of smelters for secondary materials. Several of the techniques are applicable to fume extraction and abatement and the process control systems used by these furnaces. The process control system for some blast furnaces is considered to be suitable for development. Gases from secondary smelters contain some sulphur dioxide dependent on the source of the material. In particular the desulphurisation of battery paste may be needed unless paste is treated separately in a primary smelter or the sulphur can be fixed in a lead/iron matte or in the slag using sodium based flux or other fluxes that can perform the same function. If the sulphur is not fixed a scrubber system may be needed. The gases can contain significant quantities of the more volatile metals such as antimony and cadmium etc. The abatement stages for secondary smelting involve gas cooling (with heat/energy recovery), coarse particle separation if necessary and fabric filtration. Sulphur dioxide removal and after-burning may be needed depending on the composition of the furnace gases (e.g. VOCs and dioxins). The collected dusts are recycled to recover metals. In several instances there may be significant concentrations of organic material (including dioxins) depending on the raw material used. For example EAF dust will have high dioxin content and whole battery feed (or incomplete separation) will provide a significant load of organic carbon and chlorinated plastic material. After burning or carbon adsorption and high efficiency dust removal may be needed in these cases.

5. Processes to produce Lead, Zinc and Cadmium, Best Available Techniques (Section 5.4.)

Secondary lead smelting (Section 5.4.2.2):

For the production of lead from secondary raw materials the variation in feed stock also has to be taken into account at a local level and this will influence the combination of furnaces and the associated collection and abatement systems that are used. The processes that are considered to be BAT are: - The blast furnace (with good process control), ISA Smelt/Ausmelt, the electric furnace and the rotary furnace. The submerged arc electric furnace is used for mixed copper and lead materials. It is a sealed unit and is therefore inherently cleaner than the others, provided that the gas extraction system is adequately designed and sized. At the time of writing the electric furnace is used for secondary material containing sulphur and is connected to a sulphuric acid plant. The gas volume produced is reported to be lower than the other furnaces and the size of the abatement plant could therefore be smaller.

Applied Technique	Raw Materials	Comments
Sealed submerged arc electric	Cu/Pb materials	Sealed furnace, lower gas

furnace		volumes
ISA smelt	Secondary (most grades)	Slag treatment stage needs to be demonstrated
Rotary furnace	Most secondary materials	Batch process, can offer flexibility for various materials
Blast furnace	Whole batteries	High energy efficiency. Requires high performance control, afterburner abatement and monitoring of emissions
Melting crucibles and kettles	Clean lead and clean scrap only	Temperature control of kettle is needed

Table 10.16: Overview on secondary lead smelters considered as BAT [EIPPCB 2001]

Other process stages (Section 5.4.2.7):

BAT is:

Process stage	Techniques	Comments
Battery crushing	2 stage process to allow stage separation and minimise contamination of plastic fraction	Collection and re-use of battery acid, Collection of mists

Gas collection and abatement (Section 5.4.2.8):

The fume collection systems used can exploit furnace-sealing systems and be designed to maintain a suitable furnace depression that avoids leaks and fugitive emissions. Systems that maintain furnace sealing or hood deployment can be used. Examples are through hood additions of material, additions via tuyeres or lances and the use of robust rotary valves on feed systems. An intelligent fume collection system capable of targeting the fume extraction to the source and duration of any fume will consume less energy. Best Available Techniques for gas and fume treatment systems are those that use cooling and heat recovery if practical before a fabric filter except when carried out as part of the production of sulphuric acid and this is covered below. Fabric filters that use modern high performance materials in a well-constructed and maintained structure are applicable. They feature bag burst detection systems and on-line cleaning methods. The sulphur recovery systems and the associated dust and metal recovery stages are those described in Section 2.8 of BREF Non Ferrous Metals Industries, the production of sulphuric acid is most applicable technique unless a local market exists for sulphur dioxide. The gas cleaning stage that is used prior to the sulphuric acid plant will contain a combination of dry electrostatic precipitators, wet scrubbers, mercury removal and wet electrostatic precipitators. The factors that affect the processes in this section are described above under the section techniques to consider in the determination of BAT. Slag granulation systems need a venturi scrubber or wet electrostatic precipitator because of the high steam loading.

Process stage	Component in off-gas	Abatement option
Thermal refining	Dust and metals	Process operation; gas collection, cooling and fabric filter
	Sulphur dioxide may be present if sulphur containing raw materials (e.g. battery paste) or fuels is used and sulphur is not fixed in a slag or matte.	Scrubbing if necessary

Fume collection systems follow the best practice outlined in techniques described in Section 2.7 of BREF Non Ferrous Metals Industries. The abatement systems that are considered to be BAT for the components likely to found in the off gases are summarised in the following table. There may be variations in the raw materials that influence the range of components or the physical state of some components such as the size and physical properties of the dust produced, these should be assessed locally.

6. Processes to produce Mercury, Applied processes and techniques (Section 7.1):

Secondary production (Section 7.1.2):

In addition several companies operate mercury recovery systems using dental amalgam and silver oxide batteries as the raw material. These are usually delivered in drums to a reception cupboard that has fume extraction. Batteries and pastes are loaded into suitable receptacles to fit the furnace retort. The temperature of the retort is raised to 700 °C by indirect heating and a vacuum of ~100-mm mercury is applied driving off the mercury from the complex substrate. Heating cycles are up to 18 hours. Gases pass through a steel condenser, a sealed cooling system is used. Mercury is condensed into sealed pots and transferred periodically to storage. The vacuum can be produced by a variety of means for example a water ejector and a water ring pump can be used which allows wet feed material to be used. Vacuum pumps discharge to a scrubber system to remove mercury.

7. Processes to produce Mercury, Techniques to Consider in the Determination of BAT (Section 7.3):

Production from secondary raw materials (Section 7.1.2):

For the production of mercury from secondary raw materials e.g. batteries, the small scale of the process allows equipment to be contained and the gases to be condensed and scrubbed.

10.7.1.3 BREF ‘Emissions from Storage’

The BREF ‘Emissions from Storage’ contains the determined Best Available Techniques (BAT) for the storage, transfer and handling of liquids, liquefied gases and solids, regardless of the sector or industry. It addresses emissions to air, soil and water. There are no techniques and BAT mentioned in the BREF ‘Emissions from Storage’ that refers directly to the minimum treatment requirements for batteries according to Annex III Part A of the Batteries Directive.

1. Best Available Techniques, Storage of liquids and liquefied gases (5.1)

Storage of packaged dangerous substances (Section 5.1.2):

- BAT is to assess the risks of accidents and incidents on the site

- BAT is to appoint a person or persons who is or are responsible for the operation of the store.

- BAT is to provide the responsible person(s) with specific training and retraining in emergency procedures and to inform other staff on the site of the risks of storing packaged dangerous substances and the precautions necessary to safely store substances that have different hazards.

- BAT is to apply a storage building and/or an outdoor storage area covered with a roof, as described in the following:

  The floor of the building is made of non-combustible material, is liquid-tight and resistant to the stored substances. It has no apertures connecting directly onto any sewerage system or surface water other than a provision in connection with the collection or the controlled discharge of extinguishant or spilled materials. The floors, walls, and any thresholds of a storage building have liquid-tight reservoirs. The floor of the storage building (or area) where gases are stored with a specific gravity larger than air, has the same height as the surrounding buildings. Storage buildings normally have a roof constructed of lightweight materials. This allows the roof to act as explosion relief while leaving the remaining storage building structure intact. [36, HSE, 1998] Instead of a lightweight roof an intentionally weak spot can also be incorporated at another place, however is has to be located so as to prevent any hazard or damage to the surroundings in the event of an explosion. An alternative to explosion relief is to use mechanical exhaust ventilation that needs to be designed for every specific situation. To prevent dangerous concentrations of flammable vapours accumulating in a building or storage area as result of a leak, the space needs to be adequately ventilated. Containers stored in the open air allow for any vapours to be dispersed effectively by natural ventilation and leaks or releases can be quickly seen. In a storage building the number of air changes in the room depends on the nature of the stored materials and the layout of the room. For example, if the room contains materials in the form of powder, the minimum number of air changes is one per hour. In the case of (highly) flammable liquids and highly volatile toxic materials, the number of air changes is minimal four to five per hour. Ventilation openings are normally not installed in any partitions designed to be fire-resistant. Where this is unavoidable, such openings are required to self-close in a fire situation. Several norms give advice on ventilation principles and designing for (natural) ventilation in buildings, however, advice from a competent ventilation engineer is normally necessary. For protecting the outdoor storage from direct sunlight and rain, the storage can be equipped with a roof, however, in certain cases the erection of a roof may cause structural problems or it may hinder fire fighting. Compared to indoor storage, it is especially important for outdoor storage that the packaging of any dangerous material can withstand all possible climatic conditions. To ensure adequate ventilation in an outdoor storage area, a firewall is normally only provided on one side of a container stack.

- For storing quantities of less than 2500 litres or kilograms dangerous substances, applying a storage cell as described in the following is also BAT.

  Floors, walls and partition walls for compartmenting are made of non-flammable materials and are resistant to the substances stored. At a certain place in the storage cell, an intentionally weak spot is incorporated that will collapse in the event of an explosion while leaving the remaining structure of the storage cell intact. To prevent dangerous concentrations of flammable vapours accumulating in a storage cell, the cell will have adequate ventilation to the open air through diametrically opposed ventilation apertures in a wall near the floor (but above the liquid-tight reservoir) and near the top of a wall or in the top cover. Provisions are made to prevent ignition of the flammable liquids from outside through the ventilation apertures, e.g. self-closing.

- BAT is to separate the storage area or building of packaged dangerous substances from other storage, from ignition sources and from other buildings on- and off-site by applying a sufficient distance, sometimes in combination with fire-resistant walls. Member States apply different distances between the (outdoor) storage of packaged dangerous substances and other objects on- and offsite.

- BAT is to separate and/or segregate incompatible substances. For the compatible and incompatible combinations see Annex 8.3. Member States apply different distances and/or physical partitioning between the storage of incompatible substances.

- BAT is to install a liquid-tight reservoir, that can contain all or a part of the dangerous liquids stored above such a reservoir. These reservoirs can be internal bunded areas, in-rack bunds or drip trays under each pallet and connected to an appropriate drainage system. Only after controls are made, spills and accumulated precipitation water is pumped out and discharged or disposed of in an appropriate way. The arrangement of spillage reservoirs must consider material segregation to prevent spillages from running into areas where incompatible materials are stored. The choice whether all or only a part of the leakage needs to be contained depends on the substances stored and on the location of the storage (e.g. in a water catchment area) and can only be decided on a case-by-case basis. The floors of each compartment in a storage cell are fitted with a liquid-tight reservoir that can contain at least 100 % of the dangerous liquids stored in the storage cell.

- BAT is to install a liquid-tight extinguishant collecting provision in storage buildings and storage areas. The collecting capacity depends on the substances stored, the amount of substances stored, the type of package used and the applied fire-fighting system and can only be decided on a case-by-case basis.

2. Best Available Techniques, Storage of solids (Section 5.3):

Enclosed storage (Section 5.3.2):

- BAT is to apply enclosed storage by using, for example, silos, bunkers, hoppers and containers. Where silos are not applicable, storage in sheds can be an alternative. This is, e.g. the case if apart from storage, the mixing of batches is needed.

10.7.2 *BAT core elements from relevant guidelines and technical documents*

In addition to BAT as described in BREF documents at European level, further relevant documents containing specific requirements or techniques have been identified through literature and internet search and by analysing national execution measures communicated by the Member States concerning the Batteries Directive[26]. Two relevant documents have been identified so far:

- The Technical Guideline for the Environmentally Sound Management of Waste Lead-acid Batteries [SBC 2003]
- The Austrian Ordinance on Waste Treatment Obligations [MinEnv AT 2004]

The core elements from these documents are described in the following sections 10.7.2.1 and 10.7.2.2.

10.7.2.1 Technical Guideline for the Environmentally Sound Management of Waste Lead-acid Batteries

The Technical Guideline for the Environmentally Sound Management of Waste Lead-acid Batteries [SBC 2003] is a document containing specific technical requirements concerning collection, transport, storage, recycling and environmental control. It is restricted to the single lead-acid battery type. Concerning technical details the guideline refers to the BREF document on the Non ferrous Metal Industries.

Relevant technical details and requirements contained in the guideline are summarised in the following under the headings:

1. Collecting
2. Transporting
3. Storing
4. Recycling ((a) breaking, (b) lead reduction, (c) lead refining
5. Pollution sources treatment and pollution prevention

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[26] National provisions communicated by the Member States concerning Directive 2006/66/EC according to eurlex (http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:72006L0066:EN:NOT, accessed on 13.11.2008). The national provisions that are available in English, French, German and Spanish have been analysed for technical requirements.

1. Collecting

- Batteries should not be drained at collection points
    - Storage in acid resistant containers
    - Drainage by personally protected and trained workers
- Batteries must be stored in proper places at collection points
    - Ideal storage inside an acid-resistant container that may simply be sealed and used as the transport container as well minimizing the risk of an accidental spillage
    - Leaking batteries, i.e. those spilling electrolyte, must be stored inside acid-resistant containers
    - Storage place must
        - be sheltered from rain and other water sources;
        - be equipped with a water collection system;
        - be away from heat sources;
        - have a ground cover, preferably acid resistant concrete or any other acid-resistant material, that may retain any leakage and direct it to a collecting container from where it can be removed;
        - have an exhaust ventilation system, or simply a fast air recirculation system;
        - have restricted access and be identified as a hazardous material storing place;
    - Any other lead materials which may eventually arise, such as plumbing, should be conveniently packaged and stored in accordance with its characteristics
- Collection points must not store large amounts of used batteries

2. Transporting

- Used batteries must be transported inside shock resistant and acid resistant sealed containers
- In order to prevent move of containers during transport they must be well packed to the transport vehicle (i.e they must be bound, shrink wrapped or stacked properly)
- The transport vehicle should be identified with symbols (transport of corrosive and hazardous products)
- Minimum set of specific equipment to be provided to combat sillage or leakage during transport
- Drivers and auxiliaries should be trained
- Personal protection equipment to be provided
- Transport schedule and route to be selected in a way that reduces the risk of possible accidents

3. Storing

- Batteries should be drained and prepared for recycling and the electrolyte should be directed to the effluent treatment plant
- Batteries should be stored empty
- Batteries should be identified and segregated (identification, labelling, storage in different places)
- Storage in a proper building or covered place with the following minimum requirements
  - Impermeable and acid-resistant floor
  - Efficient water collection system which directs spilled solutions toward the effluent or acid electrolyte treatment plant
  - Only one entrance in and one exit, which should stay closed unless otherwise necessary (to avoid dust release)
  - Special gas collection system, which filters the air to remove lead dusts and at the same time renews the air inside the hangar in order to avoid the concentration of toxic gases
  - Provided with appropriate fire fighting equipment
  - Access only for authorized personnel

4. Recycling

The pre-recycling steps are finished when the batteries are received and properly stored at the storage place in the recycling plant. After this, the used batteries enter into the recycling process which could ideally be divided in three major processes:

(4.a) battery breaking;

(4.b) lead reduction;

(4.c) lead refining.

(4.a) Battery Breaking

Batteries must always be drained before they enter the recycling process, since the acidic electrolyte produces several complications in the lead fusion-reduction. After drainage, batteries may or may not be broken, depending on the specific recycling process adopted.

Classic methodologies of lead recycling processes, including Water-Jacket Blast furnaces, reverberatory furnaces, electric arc furnaces, and short and long rotary furnaces, do not require battery breakage before the smelting process. The drained batteries are entered directly into the recycling process since pyrometalurgic techniques accept organic materials and other substances, which are burned or incorporated into the slag.

However, processes in which the batteries are broken prior to the recycling process are preferable due to:

(a) increase in the percentage lead production and decrease in the slag formation;

(b) possibility of soft lead[27] production as well as antimonial lead;

(c) possibility of polypropylene recovery;

(d) simplification of furnace smoke treatment;

(e) pyrometalurgical techniques cannot accept the acid from battery electrolyte.

Improvements in the battery production industry lead ultimately to the production of sealed batteries and other systems which are no longer easily drained. Therefore, an increasing amount of batteries must be broken before entering the further recycling process.

Manual breaking of batteries should be avoided at all costs. If it is necessary all measures should be taken for proper protection of workers and environment.

Details on the modern lead-acid battery breaking process are described in section 4.1.2, point 43 to 50 of the technical guideline [SBC 2003]. Battery breaking methods differ from one another in process details and evolve as new technology becomes available. The suitability of each one for a given lead recovery plant depends on several specific factors such as local economy, quantity of raw materials as well as the demands of the smelting facility. Some examples of these systems are the Metaleurop, Bunker Hill, Engitec and MA Engineering, which can be understood in detail by consulting specialized references.

Every effort should be made to eliminate the use of manual battery breaking and the health and safety risks that are associated with this practice. According to the technical guideline, if mechanical battery breaking equipment is unavailable, for whatever reason, the safest approach to prepare the battery for smelting would be the following: puncture and drain the electrolyte for the battery and treat it accordingly; remove the top of the battery complete with plates and separators using a circular saw and observing the correct use of guards and protective equipment; send the plates and grids with the top of the battery to the smelter; return the battery case to the manufacturer for reuse.

The technical guideline contains a short list of common potential contamination sources during battery braking:

- Spilling batteries (source of acid electrolyte including soluble lead and lead particles resulting in lead dust)

  The electrolyte is a good carrier of soluble lead and lead particulates. Therefore, if this solution spills in an unprotected area, it may contaminate the soil or injure workers. Besides, after spilling on unprotected soil, the soil itself becomes a source of lead dust once the solution evaporates and the lead becomes incorporated into soil particles which may be blown by wind or raised by vehicle transit.

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[27] Low antimonial or antimony free lead

- Manual battery braking (source of acid electrolyte including soluble lead and lead particles resulting in lead dust)

  Manual breaking usually relies on primitive tools, poorly protected workers and no environmental protection whatsoever. The situation is even worst in the case of sealed batteries, which are not easily drained, increasing dramatically the risk of heavy spillage and damage to human health. Therefore, it should be avoided at all costs.

- Mechanical battery braking (source of lead particulate)

  Breaking batteries through crushing on hammer mills may spread lead particulate. However, the fact that the mill is sealed and uses copious quantities of water the formation of such particulates is prevented.

- Hydraulic separations (source of contaminated water if leakage occurs)

  Hydraulic separations, both metallic from organic and heavy organics from light organics, are usually preformed inside sealed machines and with a closed water system. However, if any water leakage occurs, it will be heavily contaminated by lead compounds;

- Plastic and ebonite chips (source of contaminated waste)

  Ebonite scraps removed from the breaking process may pose a problem, since they are usually contaminated by levels as high as 5% (w/w) of lead. Therefore, it is important that the final traces of lead are removed by a second wash, preferably in an alkaline solution, followed by another rinse prior to further treatment or disposal.

(4.b) Lead reduction

Details on lead reduction in the lead-acid battery recycling process are described in section 4.2 of the technical guideline [SBC 2003].

The battery scrap obtained from the breaking process is a mixture of several substances: metallic lead, lead oxide (PbO), lead sulfate (PbSO4) and other metals such as copper (Cu), antimony (Sb), arsenic (As), tin (Sn) and sometimes silver (Ag). In order to isolate the metallic lead from this mixture, two methods may be applied: pyrometallurgical processes (details see section 4.2.1 [SBC 2003]), also known as fusion-reduction methods, and hydrometallurgical processes (details see section 4.2.2 [SBC 2003], or electrolytic methods. It is also possible to combine the two and use a hybrid process.

Pyrometallurgical methods:

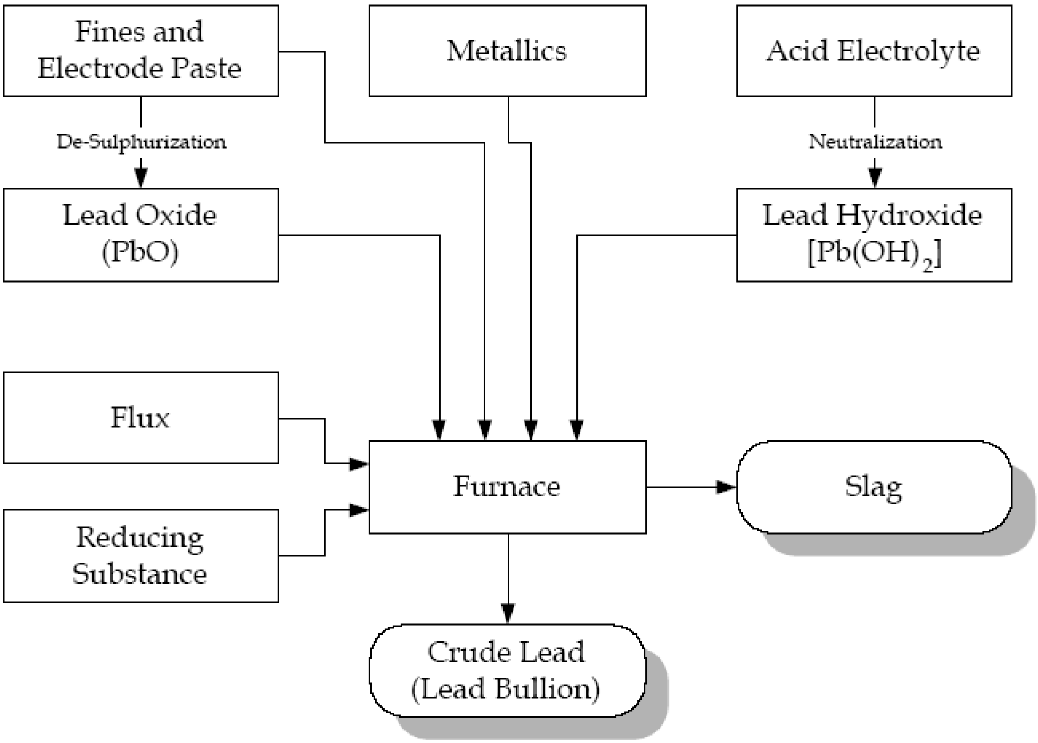


Figure 10-16 : Diagram of the lead smelting process in pyrometallurgical processes (source: Figure 3 [SBC 2003]

In pyrometallurgic processes de-sulphurisation prior to the smelting process reduces the amount of slag formation and also, depending on the smelting method, the amount of sulfur dioxide (SO_2) released into the air. However, other methods simply add controlled amounts of lead sulfate as well as de-sulphurizing agent directly into the furnace.

The acid electrolyte is neutralised with sodium hydroxide, which precipitates the present lead as lead hydroxide [$Pb(OH)_2$]. This compound is then removed by decantation or filtration and directed to the furnace. The remaining solution, sodium sulphate diluted in water (Na_2SO_4), may be further purified and the salt isolated in high purity grades.

The metallic fraction and the lead compounds derived from the de-sulphurization and neutralization processes are smelted with fluxing and reducing agents in different vessels (rotatory furnace, reverberatory furnace and blast or electric furnace, rotary kiln, etc.) The best method depends on several factors that include local economics, planned amount of recycling, etc.

The quantity of flux and reducing agent added must be carefully controlled and balanced as

- an insufficient amount of flux will not trap all sulfur and other materials present in the scrap and a great quantity of sulfur oxides may be released

- an insufficient amount of reducing agent will not reduce all lead oxides present in the scrap and the slag will be highly contaminated with lead.

The melted metallic lead accumulates in the bottom of the vessel. It is sometimes heavily contaminated with other metals of economic value. Therefore, this lead bullion must undergo a refining process before pure lead can be recovered from it.

Hydrometallurgical methods:

The objective of the hydrometallurgical methods, or electrolytic methods, is to electrically and selectively reduce all lead compounds to metallic lead (e.g. such as in the PLACID technology, see Figure 10-17).

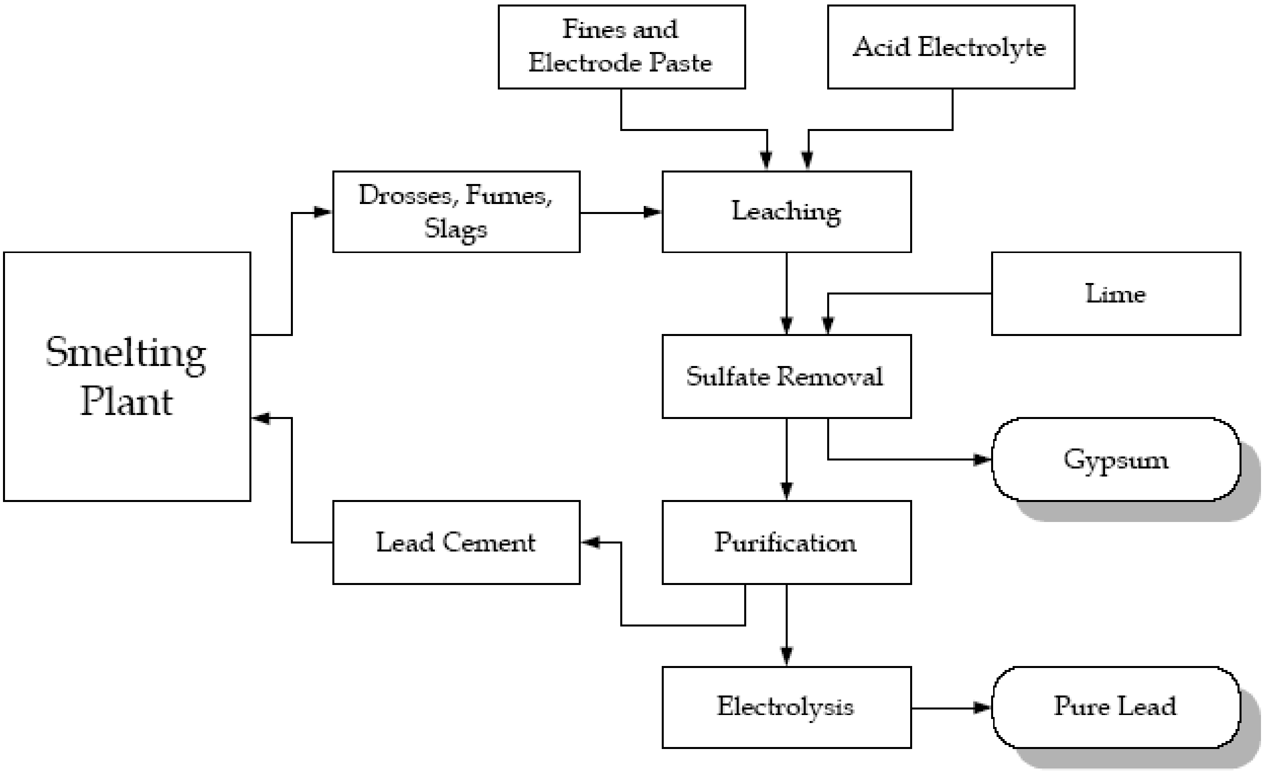


Figure 10-17 : Diagram of an electrolytic lead process (source: figure 4 [SBC 2003])

Although it may be sometimes costly when considered as an isolated plant, this process provides good results when linked to a low temperature smelting plant since, with the appropriate separation of raw materials, it is a technological solution to overcome the lead refining processes.

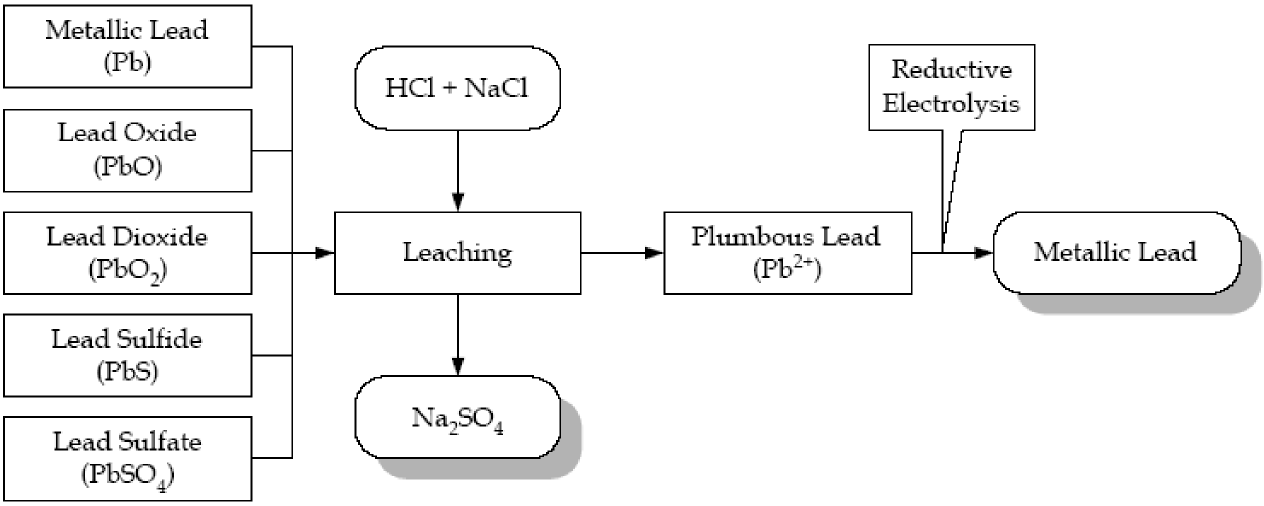


Figure 10-18 : **Electrochemical process in hydrometallurgical lead production (source: figure 5 [SBC 2003])**

The chemical concept behind the electrolytic process in hydrometallurgical processes is the conversion of all lead compounds into a single chemical species, lead in oxidation state +II (Pb^{2+} or plumbous lead) in this case, which is then electrolytically reduced to produce metallic lead (see Figure 10-18). The electrolysis deposits lead as dendrites or sponge, which are subsequently shaken off and collected on a conveyor belt and pressed to form platelets of pure lead (99.99%), which can then be conveyed to a melting kettle for casting into ingots.

The technical guideline contains a short list of common potential contamination sources during lead reduction:

- Lead compounds derived from the breaking process (source of lead and lead compounds in dust and water)

  The separated and fine materials from the breaking process are usually wet, since the main processes of separation are based on water techniques. However, if they are not incorporated in a fully automated process, they will have to be transported from the breaking facility to the reduction facility and some muddy and/or watery material may spill and fall from the transport system. After drying, these materials become a powder and may contaminate the factory and its surroundings as fine lead dusts.

- Drosses (source of lead contaminated materials)

  Drosses are formed while the fusion process takes place. Its function is to remove materials that are not easily incorporated or wanted in the crude lead. However, these drosses still contain lead that can be recovered and are recycled in the fusion process. In order to accomplish this task, the drosses must be removed and transported to the furnace charging bay, but since they are usually a dusty material and occasionally powdery (copper dross), they may be a source of lead contamination while being transported.

- Filters (source of lead contaminated dusts)

Furnaces need filters in order to capture lead dusts formed in the fusion process. After being used, they are usually recycled in the same smelting process since they may contain as much as 65% of lead. However, the care and maintenance of these filters may be an important source of contaminating dust, which could pose a risk to the human health and the environment. Besides, over-used filters no longer capture lead dusts as originally intended and the dust emissions from the fusion oven becomes an important source of contamination. Finally, one must also realize that the furnace inlet is itself a source of lead dust to the environment, since it can be an open system. The high temperature fume that leaves the furnace inlet and tapping area, for example, have a high lead content, and will be readily absorbed by the human body.

- Sulfur dioxide (SO2) emissions

  The percentage of sulfur from a given amount of lead scrap load that leaves the reduction system as sulfur dioxide (SO2) is highly dependent not only on the furnace conditions, but also in the kind of skim material being formed. As a general trend, this number may fall between 0% to 10% and it is significantly reduced if the flux used is a mixture of iron and sodium based compounds producing sodium skims and pyrites. Ebonite also has 6-10% of sulfur that may contribute to the SO2 emission if it is added to the furnace charge;

- Organic material combustion (tar formation)

  A well structured and controlled refinery does not need to worry about tar formation, since its reduction process consumes all organic materials. On the other hand, the less controlled the reduction process is, the greater are the tar emissions, especially in artisan foundries. If the reduction furnace has filters, the emission of tars is an even greater problem since they are very pyrogenic and may produce fires in the filtration plant, thus increasing the risk of an accident and the possibility of a rogue emission. The introduction of afterburners to complete the combustion of gases from the furnace is the usual solution to this problem, but a complete restructuring of the process, removal of organics for example, may present better perspectives;

- Chlorine (Cl2) and chlorine compounds emission

  An initial separation of the materials allowed to enter the reduction process reduces the chlorine emission considerably. However, increasing amounts of PVC in the furnace increases the chances of chlorine emissions. The major part of it is absorbed by the basic skims of calcium or sodium, however some of the chlorine is chemically converted into lead chloride which is volatile under furnace conditions but captured by dust filters as the temperature decreases.

- Slag production

  This is the majority of the waste production during the reduction process. As an average picture, around 300-350kg of slag is produced for each ton of metallic lead, depending on specific factors of the process and the kind of residue being formed (calcium or sodium skims), and around 5% (w/w) of this slag is composed of lead compounds. Therefore, special consideration must be given to the leachate that may be produced if an unstable water soluble slag comes into contact with water or moist air. A purpose built under cover storage bay to store this material must be planned well in advance in order to avoid human health and environmental problems.

(4.c) Lead refining

Details on lead refining in the lead-acid battery recycling process are described in section 4.3 of the technical guideline [SBC 2003].

If a smelting plant stops at the stage of the fusion-reduction plant, it will produce what is known as hard or antimonial lead. If the plant is meant to produce soft lead, the crude lead bullion must undergo a refining process. The objective of the refining process is to remove almost all copper (Cu), antimony (Sb), arsenic (As) and tin (Sn), since the soft lead standard does not allow more than 10g per ton of these metals.

There are two methods of lead refining: hydrometallurgical methods, which were already described in the lead reduction section, and pyrometallurgical or thermal processes, which are described here:

Thermal refining is performed in liquid phase, which means that the crude lead must be melted to temperatures higher than 327ºC (lead melting point), but less than 650ºC (lead boiling point). As a general trend, the process is performed in batches of 20 to 200 tons, according to the refining plant capacity.

The chemical concept behind the refining process is the addition of specific reagents to the molten lead at appropriate temperatures. These reagents will then remove the unwanted metals in a specific order as they are added selectively (see Figure 10-19). Details on the individual metals are available in the technical guideline (see [SBC 2003] points 69 to 73)

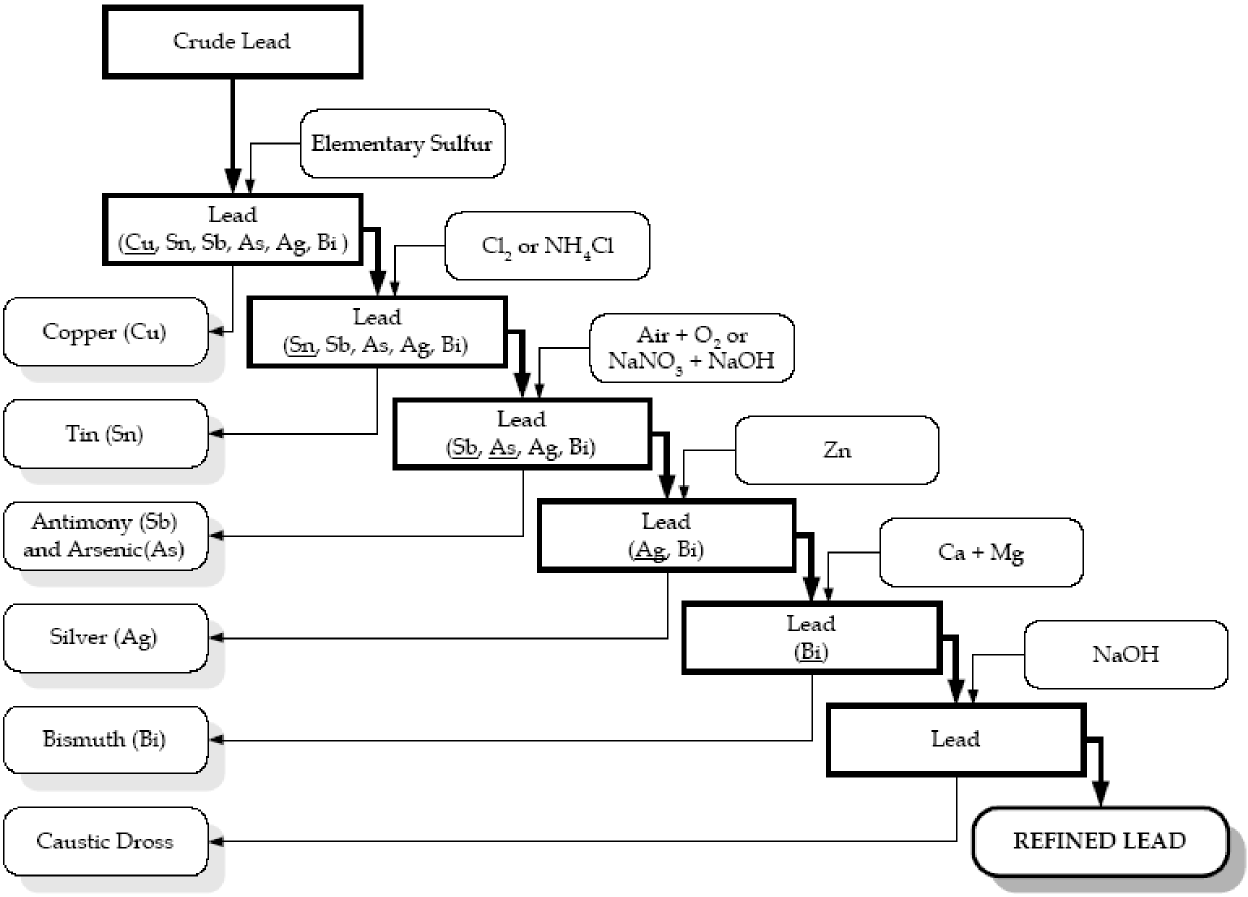


Figure 10-19 : Pyrometallurgic lead refining (source: figure 6 [SBC 2003])

The technical guideline contains a short list of common potential contamination sources during lead refining:

- Over heated lead (source of lead fumes)

  Sometimes the lead from the reduction process is introduced directly into the refining kettle, which may be as hot as 1,000ºC. Therefore, it is not uncommon that the lead refining process produces large amounts of lead vapour. Ideally lead should be tapped from the furnace directly into a lead bath or allowed to cool prior to pouring.

- Sulfur dioxide (SO2) emissions

  The copper removal by addition of elementary sulphur may produce large quantities of sulfur dioxide (SO2), since sulfur oxidizes readily in the presence of oxygen at the oven temperatures. The use of iron pyrites eliminates this problem.

- Skim production and removal (source of metal contaminations)

  The skim production and removal from the refining kettle while refining unwanted metals from the crude lead may pose threats to the human health and environment due to the physical characteristics of the skims. Sometimes they are in the form of a very fine and dry dust with a high percentage of lead and other metals, it is important to provide adequate covered or sealed transport, storage and a sound destination to this potentially hazardous by-product.

- Chlorine (Cl2) tin (Sn) removal and recovery (source of chlorine gas release)

  If the tin is removed by chlorine gas for later recovery, then this is a very delicate procedure. The intake of gas is planned in order avoid chlorine release, i.e. the gas reacts with the tin before reaching the surface of molten lead. However, an uncontrolled addition of chlorine may release the poisonous gas to the environment. Besides, the storage and handling of chlorine is itself a delicate operation due to its corrosiveness and toxicity.

- Oxygen (O_2) enriched air tin (Sn) removal (source of lead fume)

  While the air is being passed inside the molten metals, the nitrogen (N_2) present in the air does not react. The consequence of this is that the gas bubbles violently in the surface of the metals releasing dusts and metallic fume.

5. Pollution sources treatment and pollution prevention

The technical guideline contains a list of technical measures that can be taken in order to improve the technological and environmental performance. Details on possibilities for technological improvements are described in section 5.2 of the technical guideline [SBC 2003]. The possibilities for pollution prevention are directly related to the pollution sources:

Acid Electrolyte and Effluents

The direct discharge of these liquids into the environment without treatment would comprise a huge environmental impact. A suggested approach to this problem would be to try to stabilize them as much as possible in accordance with the available budget:

(a) there are some technologies used to remove, by liquid-liquid extraction, the sulfuric acid present in the electrolyte. These technologies provide means to produce lead-free acid, which can be used as battery electrolyte again or sold;

(b) the electrolyte may be treated by sodium carbonate (Na2CO3) or calcium carbonate (CaCO3), thus producing sodium sulfate (Na2SO4) or gypsum (CaSO4) which, after removing lead sludges by filtration, can be further purified and sold to the cement industry or the building trade;

(c) direct discharge of neutralized electrolyte should be avoided as much as possible;

(d) discharge of untreated electrolyte is not environmentally sound and must be avoided at all costs.

Every lead recycling plant should have an effluent treatment station in order to treat the water that leaves the recycling facility, including those coming from the electrolyte neutralization, rain water, spilled water from battery storage, etc., in order to control, protect and improve the water quality.

Dust Collection and Air Filtration

All stages in the battery recycling plant can release some sort of smoke or dust, which must be collected and either returned to the plant or treated before being released to the environment. Considering that an average recycling plant must filter around seventy tons of air for each ton of produced lead, it becomes clear that this is an important process to control.

The so-called "mechanical" dust, i.e. particulate material with large physical characteristics, is relatively easy to filter and remove from air. However, the finer the dust, the more difficult it is to remove it and special techniques must be employed in order to clean the air. There is a wide range of options that must be judged as a function of contamination level requirements and budget: fabric or bag filters, electrostatic precipitators, wet electrostatic precipitators, cyclones, ceramic filters and wet scrubbers. As a general trend, all collected dusts are redirected toward the smelting plant in order to recover the lead.

Fugitive Emissions

Fugitive emissions are atmospheric discharges from raw materials and/or industrial processes that are released to the atmosphere without passing through any filtering device or control mechanism designed to reduce or eliminate the hazardous content or amount of the materials being produced prior to release to the environment.

Several potential sources of fugitive emissions can be identified from topics already covered in the sections dealing with the control measures taken for storage facilities, battery breaking processes, lead refining, and so on, but also from the "red" hot molten lead as it is drained from a smelting furnace caused by the high vapor pressure of lead and its compounds at about 1000ºC. In the same context, fugitive emissions would be generated if lead furnace bullion is transferred in an open ladle or "pot" at about 1000ºC and poured into a refining kettle, and later during processing if the dusty dross is skimmed manually without extraction or ventilation.

Basically, there are two ways of controlling fugitive emissions:

(a) by controlled ventilated tapping of the furnace bullion into a casting mould to allow the bullion to solidify. Only when the lead block has solidified will it be moved to the refining kettle and then gently melted into a liquid bath of molten lead. Any dross produced would be removed in a procedure that ventilates the working area and extracts and contains any dusk produced in a baghouse filter system.

(b) by tapping the red-hot molten lead from the furnace into a bath of molten lead, where the lead bath is about twenty degrees above the freezing point of lead and well below the temperature that can produce fugitive emissions. The bath of molten lead must be covered and ventilated so that any emissions would be removed to the baghouse. As the refining kettle containing the bath of molten lead fills, the lead may be pumped to another kettle in order to start the refining process.

Sulfur Dioxide (SO2) Elimination

Some countries have very restrictive sulfur dioxide (SO_2) emission parameters and, in fact, this is an important pollutant to control since it produces severe impacts on the environment. Its elimination may be carried out in several ways, such as dry, semi-dry, semi-humid and humid processes, and a simple alternative is the use of wet scrubbers with calcium carbonate ($CaCO_3$) as reagent, which produces sulfurous gypsum. This compound can be, in turn, sold or used in the furnace as a slag formation reagent. Even after filtration and removal of dust, however, the gases will still have small quantities of vestigial dust and SO_2.

Use of Oxygen (O2)

Oxygen (O_2) is used to enrich the gases that are used in the heating processes and it has three main consequences:

(a) since air has a big percentage of nitrogen [N_2, ~72% (v/v)] which does not participate in any chemical reaction at normal temperatures, the use of pure oxygen (O_2) decreases dramatically the amount of combustion gas formation (around five times);

(b) decrease in heat loss, since less cold gas is flowing through the furnace;

(c) increase in the furnace production.

Therefore, the use of pure oxygen (O_2) to enrich the air supply to the furnace burners provides a much cleaner production process.

Flux Agent Choices and Slag Stabilization

Calcium slag, formed by the addition of calcium carbonate ($CaCO_3$) flux to the furnace, produces a non-leachable slag, which means a more environmentally sound waste. On the other hand, it increases the working temperature of the furnace and releases more sulfur dioxide (SO_2), which means more energy costs and alterations in the furnace performance, particularly the life of the refractories. Furthermore, limestone ($CaCO_3$) is a natural product that is much easier to deal with than sodium carbonate (Na_2CO_3), decreasing flux costs and other operation problems. Therefore, the choice of the fluxing agent must be well planned.

Stabilizing the slag, which ultimately means controlling the fusion-reduction-refining steps very well, would be a huge step toward cleaner production, since this is the major hazardous waste formation in the whole process. The sodium slag, arising from the utilization of sodium carbonate (Na_2CO_3), does not have any use due to its physical and chemical properties, and, therefore, it is being directed to hazardous waste landfills.

On the other hand, despite some cost increases in recycling, calcium slags have found some use as a raw material in cement production which has been employed in road building, bricks, etc., with promising results. Therefore, the utilization of calcium based flux may be considered as a viable option in the future since it provides a solution to the use of great amount of waste residues.

Heavy Organics Recycling

The heavy organic fraction is constituted by plate separators and ebonite, and 50% of its mass is carbon which means the heavy organics may be used as a reducing agent in the oven. Despite the fact that some extra care must be taken in order to prevent pollution, the usage of heavy organics as reducing agent decreases the amount of other reducing agents and also decreases the amount of wastes that otherwise would require a sound management. However, some process drawbacks, such as less fluid slag, tar formation and others, did not lead to a conclusive report and further studies are required, but this is a promising destination for these wastes.

Polypropylene Recycling

Polypropylene is such a valuable product that it alone could sustain the lead-acid battery breaking. Therefore, reprocessing of the plastic components should be seen as a profitable activity that, unfortunately, is not universal.

Sound Destination to unrecoverable wastes

Some wastes produced during the lead recycling process will not be recycled any further or reused and, therefore, will need a sound destination for disposal. It must be stressed that usually such wastes have lead contents as high as 2-5% and must be treated as hazardous wastes, even if the lead is not leachable, and thus requires a destination in a regulated hazardous waste landfill site.

10.7.2.2 Austrian Ordinance on Waste Treatment Obligations [MinEnv AT 2004]

The ordinance contains in its section 2 on batteries and accumulators several technical general treatment requirements for batteries and accumulators as well as for specific battery types according to the battery chemistry.

General treatment requirements:

- Batteries and accumulators collected shall be *stored in weatherproof conditions* in *leakproof containers that are acid or lye resistant depending on the electrolyte used*. (Article 14)
- The *mercury content of all fractions recovered*, with the exception of the pure mercury fraction, *shall not exceed 20 mg/kg dry mass*. (Article 15)

Treatment requirements for lead accumulators (Article 16):

- *Lead accumulators shall be treated separately* from all other batteries and accumulators.
- At any rate, the treatment of lead accumulators *shall demonstrably recover lead and plastics of adequate purity* so that they can be recycled and thus, shall ensure their re-introduction in the production cycle.
- The *lead content of the plastics recovered shall not exceed 500 mg/kg*.
- *The treatment shall include* measures to *prevent diffuse lead emissions*.
- *Free sulphuric acid shall be recovered*.

Treatment of nickel-cadmium accumulators and nickel metal hydride accumulators (Article 17):

- *Nickel-cadmium accumulators and nickel metal hydride accumulators shall be recovered separately* from all other batteries and accumulators.
- The *joint treatment of nickel-cadmium accumulators and nickel metal hydride accumulators* shall be permitted.
- *Nickel shall be demonstrably recovered from nickel-cadmium accumulators with adequate purity* so that it can be recycled.
- *Cadmium shall be recovered as a separate fraction*.

Treatment of button cells (Article 18):

- *Button cells shall be treated thermally*.
- *Mercury shall be collected as a separate fraction*.

Treatment of zinc-carbon batteries and alkaline-manganese batteries (Article 19):

- *From zinc-carbon and alkaline-manganese batteries, at least zinc and either iron scrap or ferromanganese shall be recovered and recycled*.

Treatment of lithium batteries (Article 20):

- *Lithium batteries and accumulators shall be treated separately* from all other batteries and accumulators.
- By way of *exemption*, it shall be permitted to *treat lithium batteries and accumulators together with button cells* and to *treat lithium batteries together with zinc-carbon and alkaline-manganese batteries*.
- *From lithium accumulators, iron scrap or ferromanganese shall be recovered and recycled*.
- *Mercury shall be collected as a separate fraction*.

10.8 Identified requirements from BAT core elements related to the minimum treatment requirements

From relevant BREF Documents [EIPPCB] and guidelines [SBC 2003 and MinEnv AT 2004] a set of requirements has been identified that are related to the minimum treatment requirements.

<u>Minimum treatment requirement: “Removal of all fluids and acids” including their collection and treatment</u>

- Collecting: Batteries should not be drained at collection points [SBC 2003]
- Collecting: Drainage by personally protected workers [SBC 2003]
- Storing: Batteries should be drained and prepared for recycling and the electrolyte should be directed to the effluent treatment plant [SBC 2003]
- Storing: Batteries should be stored empty [SBC 2003]
- Recycling: Batteries must always be drained before they enter the recycling process, since the acidic electrolyte produces several complications in the lead fusion-reduction [SBC 2003]
- Pollution sources treatment and pollution prevention [SBC 2003]:

  The direct discharge of acid electrolyte and effluent liquids into the environment without treatment would comprise a huge environmental impact. A suggested approach to this problem would be to try to stabilize them as much as possible in accordance with the available budget:

  (a) there are some technologies used to remove, by liquid-liquid extraction, the sulfuric acid present in the electrolyte. These technologies provide means to produce lead-free acid, which can be used as battery electrolyte again or sold;

  (b) the electrolyte may be treated by sodium carbonate (Na_2CO_3) or calcium carbonate ($CaCO_3$), thus producing sodium sulfate (Na_2SO_4) or gypsum ($CaSO_4$) which, after removing lead sludges by filtration, can be further purified and sold to the cement industry or the building trade;

  (c) direct discharge of neutralized electrolyte should be avoided as much as possible;

  (d) discharge of untreated electrolyte is not environmentally sound and must be avoided at all costs.
- Free sulphuric acid shall be recovered ([MinEnvAT 2004] for lead-acid batteries)
- To prevent soil contamination, BAT is to provide and then maintain the surfaces of operational areas, including applying measures to prevent or quickly clear away leaks and spillages, and ensuring that maintenance of drainage systems and other subsurface structures is carried out [EIPPC 2006b].

- To prevent soil contamination an impermeable base and internal site drainage has to be utilised [EIPPCB 2006b].
- When applying a neutralisation process the customary measurement methods have to be used [EIPPCB 2006b]
- neutralised waste water [of a neutralisation] process has to be stored separately [EIPPCB 2006b]
- a final inspection of the neutralised waste water [of a neutralisation process] after a sufficient storage time has elapsed has to be performed [EIPPCB, 2006b]

In the following further information (common techniques or techniques to consider in the determination of BAT)(not requirements) from BREFs regarding the "removal of all fluids and acids" including their collection and treatment is cited

- The acid content of the batteries has to be collected and handled properly, sealed acid resistant drainage systems can be used with dedicated collection and storage tanks. The milling stages can produce an acid mist; this can be collected in wet scrubbers or mist filters. [EIPPCB, 2001]
- The sulphuric acid drained from the batteries is neutralised unless there is a local use for it and the sodium sulphate produced can be re-crystallised and sold.

Minimum treatment requirement: "Impermeable surfaces and suitable weatherproof covering"

- Collecting: Storage place must [SBC 2003]
    - be sheltered from rain and other water sources;
    - be equipped with a water collection system;
    - have a ground cover, preferably acid resistant concrete or any other acid-resistant material, that may retain any leakage and direct it to a collecting container from where it can be removed;
- Storing: Storage in a proper building or covered place with the following minimum requirements [SBC 2003]:
    - Impermeable and acid-resistant floor
    - Efficient water collection system which directs spilled solutions towards the effluent or acid electrolyte treatment plant
- Storing in weatherproof conditions in leakproof containers that are acid or lye resistant depending on the electrolyte used [MinEnv AT 2004].
- Storing of containerised waste [EIPPCB 2006b]
- Containerised wastes have to be stored under cover. This can also be applied to any container that is held in storage pending sampling and emptying. Some exceptions on the

applicability of this technique related to containers or waste not affected by ambient conditions (e.g. sunlight, temperature, water) have been identified (e.g. Lithium batteries).

- Covered areas need to have adequate provision for ventilation.
- The availability and access to storage areas for containers holding substances that are known to be sensitive to heat, light and water, under cover and protected from heat and direct sunlight has to be maintained .
- Storage of packaged dangerous substances (liquids and liquefied gases) [EIPPCB 2006a]
- For storing quantities of more than 2500 litres or kilograms dangerous substances a storage building and/or an outdoor storage area covered with a roof has to be applied.

  Description of the storage building/outdoor storage area: The floor of the building is made of non-combustible material, is liquid-tight and resistant to the stored substances. It has no apertures connecting directly onto any sewerage system or surface water other than a provision in connection with the collection or the controlled discharge of extinguishant or spilled materials. The floors, walls, and any thresholds of a storage building have liquid-tight reservoirs. Storage buildings normally have a roof constructed of lightweight materials. This allows the roof to act as explosion relief while leaving the remaining storage building structure intact. Instead of a lightweight roof an intentionally weak spot can also be incorporated at another place, however is has to be located so as to prevent any hazard or damage to the surroundings in the event of an explosion. An alternative to explosion relief is to use mechanical exhaust ventilation that needs to be designed for every specific situation. Containers stored in the open air allow for any vapours to be dispersed effectively by natural ventilation and leaks or releases can be quickly seen. In a storage building the number of air changes in the room depends on the nature of the stored materials and the layout of the room. For protecting the outdoor storage from direct sunlight and rain, the storage can be equipped with a roof, however, in certain cases the erection of a roof may cause structural problems or it may hinder fire fighting. Compared to indoor storage, it is especially important for outdoor storage that the packaging of any dangerous material can withstand all possible climatic conditions. To ensure adequate ventilation in an outdoor storage area, a firewall is normally only provided on one side of a container stack.

- For storing quantities of less than 2500 litres or kilograms dangerous substances, at least a storage cell has to be applied.

  Description of the storage cell: Floors, walls and partition walls for compartmenting are made of non-flammable materials and are resistant to the substances stored. At a certain place in the storage cell, an intentionally weak spot is incorporated that will collapse in the event of an explosion while leaving the remaining structure of the storage cell intact. To prevent dangerous concentrations of flammable vapours accumulating in a storage cell, the cell will have adequate ventilation to the open air through diametrically opposed ventilation apertures in a wall near the floor (but above the liquid-tight reservoir) and near the top of a wall or in the top cover. Provisions are made to prevent ignition of the flammable liquids from outside through the ventilation apertures, e.g. self-closing.

Minimum treatment requirement: “Suitable containers”

- Collecting: Ideal storage inside an acid-resistant container that may simply be sealed and used as the transport container as well minimizing the risk of an accidental spillage [SBC 2003]
- Collecting: Leaking batteries, i.e. those spilling electrolyte, must be stored inside acid-resistant containers [SBC 2003]
- Transporting: Used batteries must be transported inside shock resistant and acid resistant sealed containers [SBC 2003]
- Storing in weatherproof conditions in leak proof containers that are acid or lye resistant depending on the electrolyte used [MinEnv AT 2004].
- Storing: The use of re-usable packaging (drums, containers, IBCs, palettes, etc.) is to be maximised [EIPPCB 2006]
- Storing: Drums in a good working state have to be re-used. In other cases, they are to be sent for appropriate treatment [EIPPCB 2006]

In the following further information (common techniques or techniques to consider in the determination of BAT)(not requirements) from BREFs regarding the “suitable containers” is summarized:

- Storing [EIPPCB 2001]: Nickel cadmium batteries are usually dry but other batteries may be present and leakage of electrolyte is possible, this should be taken into account in the storage and separation method used. The techniques used for storage, handling and pre-treatment will therefore vary according to the material size and the extent of any contamination. These factors vary from site to site and the techniques discussed (see Table) are applied on a site and material specific basis (Techniques to Consider in the Determination of BAT; see Section 5.3.1 and Section 2.4 of BREF Non Ferrous Metals Industries).

Material	Storage	Handling	Pre-treatment	Comment
Lead Acid Batteries	Covered Storage	Mechanical loader and conveyor	Crushing or whole feed	Acid collection. Reuse if possible
Ni-Cd Batteries	Sealed drums or containers	Mechanical loader and conveyor	Plastic removal and pyrolysis	Separation of Fe and Ni
Waste Acid	Acid resistant tank		Use in process or neutralisation.	

10.9 Pre-existing methods for the calculation of recycling efficiencies

10.9.1 Pre-existing calculation models for recycling efficiencies for waste batteries

The proposals for the calculation of the recycling efficiency for waste batteries cited below were available to the project team:

- 1) **EBRA, EPBA, RECHARGE** (2008): The Recycling Efficiency of spent portable batteries, A guidance note prepared by EBRA, EPBA and RECHARGE
- 2) **IME:** Bernd Friedrich et al. (RWTH Aachen University, IME Process Metallurgy and Metal Recycling) (2007): Development of a Calculation Method for Recycling Efficiencies.
- 3) **Berger:** Manfred Berger (Redux Recycling GmbH and Accurec Recycling GmbH): Suggested Method for Calculating Recycling Efficiency

In the following the interpretations of relevant issues of the existing calculation models are summarized.

1) Interpretation of the "recycling process":

<ins>EBRA, EPBA, RECHARGE:</ins>

> Battery recycling operations may consist of one or more process steps. For the purposes of the RE calculation each step is assessed separately and the values are consolidated by the recycler in charge of the processing of the spent batteries. (Q10)

<ins>IME:</ins>

> Battery recycling processes may consist of multiple (sub)steps; each step is assessed individually and recovery values have to be added.
>
> Not the single sub process is to be considered but the average recycling efficiency of the total ("black-box") recycling process. The sub processes can be carried out in different countries.

Berger:

no comment

2) Interpretation of the “recycling efficiency"

EBRA, EPBA, RECHARGE: All processes recycling batteries should calculate the efficiency according to a single method. (Q3)

The Recycling Efficiency of spent batteries in a given Recycling Process is calculated from the ratio between the total weight of the Qualified Recycled Materials Outflow over the total weight of spent battery materials entering the recycling process (Q4):

$$\underset{\text{(weight ratio in \%)}}{\textit{Recycling Efficiency}} = \frac{\sum \text{ Qualified Recycled Materials Outflow}}{\sum \text{ Spent Battery Materials Inflow}} \quad \text{X } 100$$

Mass balance between the input and output of recycling process(es) shall be carried out at an elemental level, except for water, based on an unused battery. This approach would apply equally to multistage recycling processes.

The recycling efficiency is calculated at elemental level for the initial components of the battery (Q5B).

Spent Battery Materials Inflow:

Annex III, part B refers exclusively to recycling of batteries and accumulators and does not reference battery packs.

The Directive defines “treatment” as any activity carried out on waste batteries and accumulators in preparation for recycling. It is concluded therefore that according to the Directive:

a. Plastic and electronic components used in the construction of batteries assembly should not be taken in account in the determination of batteries recycling efficiency,

b. Separating the battery cells from these materials constitutes treatment and NOT recycling;

c. Treatment of batteries assembly and packs should not intend to change the chemical composition of the individual cells when shredding and separating the cell components. (Q5A)

IME:

is defined as the weight ratio of the “**acceptable product fractions**” and the considered **battery scrap mass (without humidity)** as reference for calculating the recycling efficiencies the **mass of the waste batteries without humidity** (according to the EU Battery Directive) is used , not considering any plastic shells or electronics from battery packs

Berger:

RE = total salvaged products / battery weight - water

3) Output fractions to be considered for "recycling":

EBRA, EPBA, RECHARGE:

-Accepted definition of recycling should be according to Directive 2006/66/EC and its Art. 3.8: "recycling means the reprocessing in a production process of waste materials for their original purpose or for other purposes, but excluding energy recovery". (Q3)

-The definition of "battery material recycled" is independent of market value or final use and includes:

i. End products of a recycling process (including waste for recycling sent to a subsequent recycling process) which are captured and reused for their original purpose or for other purposes (e.g. in a one step process).

ii. That fraction of any subsequent recycling process which is not waste for disposal (when a multi-steps process is used),

iii. Components of waste batteries that are reused for their original purpose or for other purposes.(Q5B)

-if the definition for "battery material recycled" is met and up to the quantity present originally in the battery:

Water is considered as a neutral element of the Recycling Efficiency formula. According to the process, it can be accounted in the numerator and must then be accounted for in the denominator of the recycling efficiency formula.(Q6)

Oxygen can only be taken into account and included in the numerator when it is present in the components of the spent batteries and if it is part of a compound that is an end product of a recycling process and in accordance with the mass balance.(Q7)

If **carbon** is a captured end product of a recycling process then it can be taken into account in the numerator e.g graphite powder, If the carbon is used as a reagent (reducing agent) during the recycling process then its weight in the unused battery can be included in the numerator for the calculation of the RE, If the carbon is incinerated during the recycling process it cannot be included within the numerator of the RE. This statement is also valid for any other reducing agent present in the spent batteries.(Q7)

Battery materials reporting to **slag** from a recycling process which is subsequently used for road construction or as construction aggregate for example may be taken into account within the numerator of the RE calculation but only in proportion to that materials presence in new batteries and provided this use of slag is recognized by the government as a recovery operation. If the slag or any part of it is designated as waste then its equivalent content in the spent battery material cannot be included in the numerator.

Slag needs to be evaluated in accordance with new definitions of the Waste Framework Directive (2008/98/CE dated 19 November 2008): the slag can be accounted for in the Recycling Efficiency provided it fulfils the definition of by-product (Article 5).(Q9)

IME:

- end-products or feedstock in other processes

- materials not classified as a waste with regard to the EU Waste Directive

- All produced elements and downstream compounds are to be accepted by their full weight, if this element or compound was component of the new battery. (Waste batteries may contain a lot of materials which were generated by different chemical reactions during the use of the batteries. Those reaction products were not present in new batteries and it is not possible to analyse all of them in the battery scrap. Hence it is proposed to take only materials used for the manufacture of new batteries into account.)

- oxygen can only be taken into account for the calculation if it is part of a compound in an approved recycling product and this compound (formula) was already present as component in the virgin battery (e.g. MnO_2, NiOOH, $LiCoO_2$).

- only if carbon is part of the new battery and is unchanged present in an approved recycling product, it can be taken into account (e.g. graphite powder, FeMnC)

Berger:

- all **metals** contained in the battery

- **metallic compounds**, to the extent that there is a market for them, such as hydroxide, oxide, salts;

- **carbon**, when not intended for use as an energy carrier but as a process material.

- Since sampling and chemical analysis of waste batteries is laborious and expensive he suggests, to consider all those substances present in new batteries. He proposes to define the composition of special types of new batteries on the basis of data from manufacturers and literature to be updated regularly.

4) Output fractions explicitly not to be considered for "recycling":

EBRA, EPBA, RECHARGE::

The following materials are NOT considered as recycled (this is not applicable to water which is covered in Q 6 below):

- Battery materials that are disposed to landfill,
- Battery materials that are not captured and that are not used during the recycling process (conversely, if used but not captured or if captured in a recycled flow, then the material can be counted as recycled).
- Battery materials that are incinerated with or without energy recovery,
- Any battery materials at the end of all the recycling steps that are classified as waste for disposal/incineration within the EU Waste List (2000/532) - (pending to the results of the Waste Framework Directive and eventual adaptation(s) of the EU Waste List).

IME:

- any material produced during the entire recycling process that can**not** be **considered** as a **product** with regard to the EU Waste Directive
- materials **classified as a waste**

Berger:

no comment

5) Issues for which controversial viewpoints exist regarding the consideration for "recycling":

5.1) Slag

EBRA, EPBA, RECHARGE:

Battery materials reporting to slag from a recycling process which is subsequently used for **road construction or as construction aggregate** for example may be taken into account within the numerator of the RE calculation but only in proportion to that materials presence in new batteries and provided this use of slag is recognized by the government as a recovery operation. If the slag or any part of it is designated as waste then its equivalent content in the spent battery material cannot be included in the numerator.

Slag needs to be evaluated in accordance with new definitions of the Waste Framework Directive (2008/98/CE dated 19 November 2008): the slag can be accounted for in the Recycling Efficiency provided it fulfils the definition of by-product (Article 5).(Q9)

IME:

If slag is an approved product according to the EU Waste Directive (e.g. used for road or dump construction), the content of battery relevant metal or metal oxides can be used for the recycling efficiency calculation. But if the slag is declared as waste and described to landfill, it cannot be taken into account.

5.2) Carbon

EBRA, EPBA, RECHARGE:

If carbon is a captured end product of a recycling process then it can be taken into account in the numerator e.g graphite powder, If the carbon is used as a reagent (reducing agent) during the recycling process then its weight in the unused battery can be included in the numerator for the calculation of the RE, If the carbon is incinerated during the recycling process it cannot be included within the numerator of the RE.(Q8)

IME:

Only if carbon is part of the new battery and is unchanged present in an approved recycling product, it can be taken into account (e.g. graphite powder, FeMnC…). So if a recycler extracts the carbon from the battery scrap, it counts as product, but if the carbon is used in the process as a reducing agent, it is not considered.

5.3) Water

EBRA, EPBA, RECHARGE:

Water is considered as a neutral element of the Recycling Efficiency formula. According to the process, it can be accounted in the numerator and must then be accounted for in the denominator of the recycling efficiency formula.(Q6)

IME:

proposes battery dry weight as reference value for the calculation of the recycling efficiency

Berger:

proposes battery dry weight as reference value for the calculation of the recycling efficiency

5.4) Oxygen

EBRA, EPBA, RECHARGE:

Oxygen can only be taken into account and included in the numerator when it is present in the components of the spent batteries and if it is part of a compound that is an end product of a recycling process and in accordance with the mass balance.(Q7)

IME:

Oxygen can only be taken into account for the calculation if it is part of a compound in an approved recycling product and this compound (formula) was already present as component in the virgin battery (e.g. MnO2, NiOOH, LiCoO2…).

Berger:

no comment

10.9.2 Pre-existing calculation models for the degree of recycled lead from waste lead-acid batteries

Furthermore, information was provided on lead recycling:

- **Lead Development Association International :** David Wilson (Lead Development Association International) (2007): Developments and trends in global lead recycling

According to Wilson (2007) considerable effort has recently been devoted to recycling rates of several metals by a number of metals commodity organisations (For aluminium, copper, lead, nickel, zinc and iron/steel) and by the International Metals' Study Groups (for copper, nickel, lead and zinc). This work has resulted in the definition of a number of recycling rates, each of which is designed to serve a different purpose and to reflect different efficiencies. For waste batteries and accumulators in particular just a few countries (USA, Sweden, Italy) possess the hard data, which would enable accurate rates of battery recycling to be calculated.

However, these recycling rates are rather collection rates than recycling efficiencies.

10.9.3 Pre-existing calculation methods for comparable treatment targets

Calculation model regarding the treatment of waste electric and electronic equipment (WEEE)

According to Article 7.2 of Directive 2002/96/EC Member States have to ensure that producers of electric and electronic equipment meet targets for recovery and for component, material and substance reuse and recycling. However, detailed rules for monitoring the compliance of Member States with those targets including specifications for materials (as announced in Article 7.3 of the Directive) have not been established yet.

However, the WEEE Forum (European Association of electrical and electronic waste take back systems), for example, provides a calculation model implemented in the so called “RepTool”, a software product to be used by its members (WEEE take back systems and treatment operators) in order to determine transparent recycling rates. Parameters to be specified by treatment facilities are: information on the WEEE input treated (type and amount of WEEE), information on the output fractions (composition, recipient, technology applied by recipient, information on utilisation). Furthermore, the tool includes a model for assigning R/D operations depending on output fractions and their final use based on decisions of the European Court of Justice or alternatively based on national interpretations. The information is collected step-by-step by completion of the forms by individual treatment facilities. Finally, the rates are calculated by:

Rate of material recycling = $(\Sigma \text{ RU} + \Sigma \text{ MR}) / \text{INPUT}$

Rate of total recovery = $(\Sigma \text{ RU} + \Sigma \text{ MR} + \Sigma \text{ ER}) / \text{INPUT}$

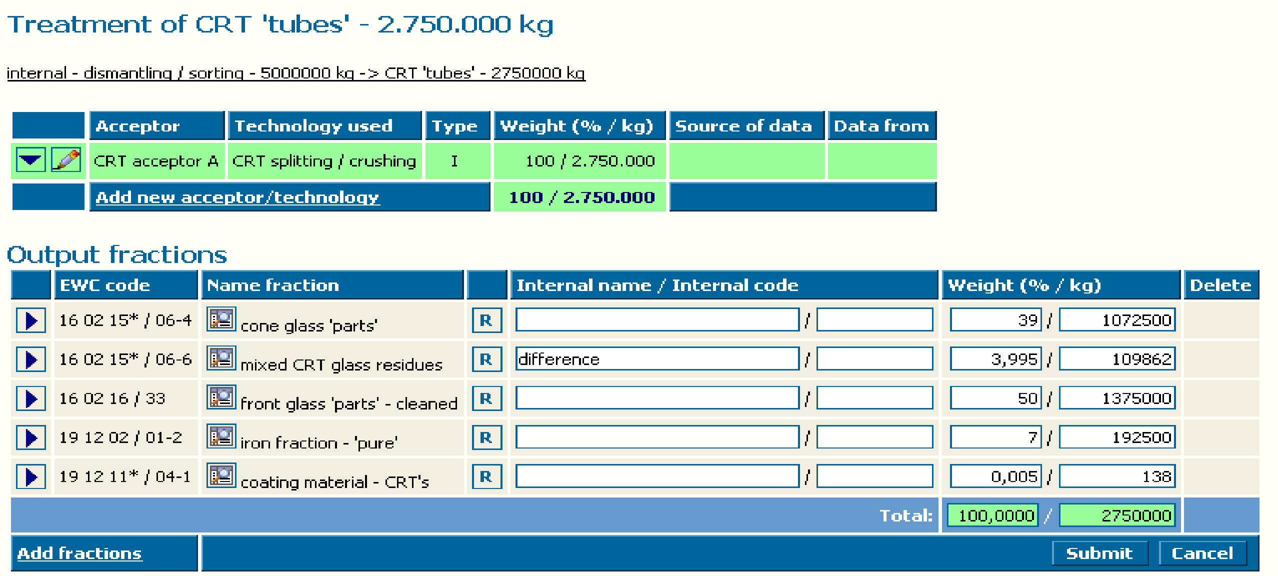
Rate of disposal = $(\Sigma \text{ TD} + \Sigma \text{ LD}) / \text{INPUT}$

whereby:
RU = reuse of components, ER = energy recovery, MR = material recycling,
TD = thermal disposal, LD = landfill disposal

10.10 Pre-existing reporting formats for comparable reporting obligations

Reporting formats regarding the treatment of waste electric and electronic equipment (WEEE)

The software product “RepTool” used by the members of the WEEE Forum provides various interfaces for entry of the required data. The following examples of entry masks have been taken from the User Manual for the use of ‘WF_RepTool’ at reporter level (WEEE Forum, 2007).



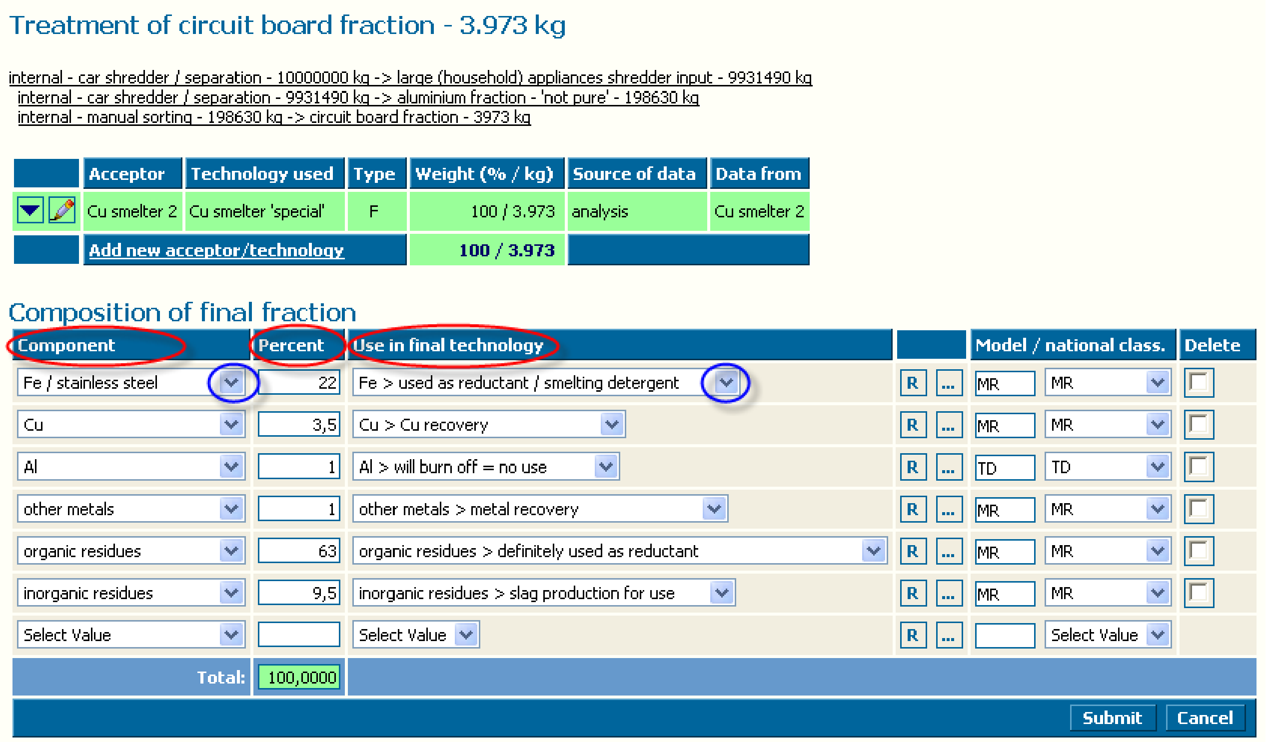
Treatment of CRT 'tubes' - 2.750.000 kg

internal - dismantling / sorting - 5000000 kg -> CRT 'tubes' - 2750000 kg

	Acceptor	Technology used	Type	Weight (% / kg)	Source of data	Data from
▼ ✎	CRT acceptor A	CRT splitting / crushing	I	100 / 2.750.000		
	Add new acceptor/technology			100 / 2.750.000		

Output fractions

	EWC code	Name fraction		Internal name / Internal code	Weight (% / kg)	Delete
▶	16 02 15* / 06-4	cone glass 'parts'	R	/	39 / 1072500	
▶	16 02 15* / 06-6	mixed CRT glass residues	R	difference /	3,995 / 109862	
▶	16 02 16 / 33	front glass 'parts' - cleaned	R	/	50 / 1375000	
▶	19 12 02 / 01-2	iron fraction - 'pure'	R	/	7 / 192500	
▶	19 12 11* / 04-1	coating material - CRT's	R	/	0,005 / 138	
				Total:	100,0000 / 2750000	
Add fractions					Submit	Cancel



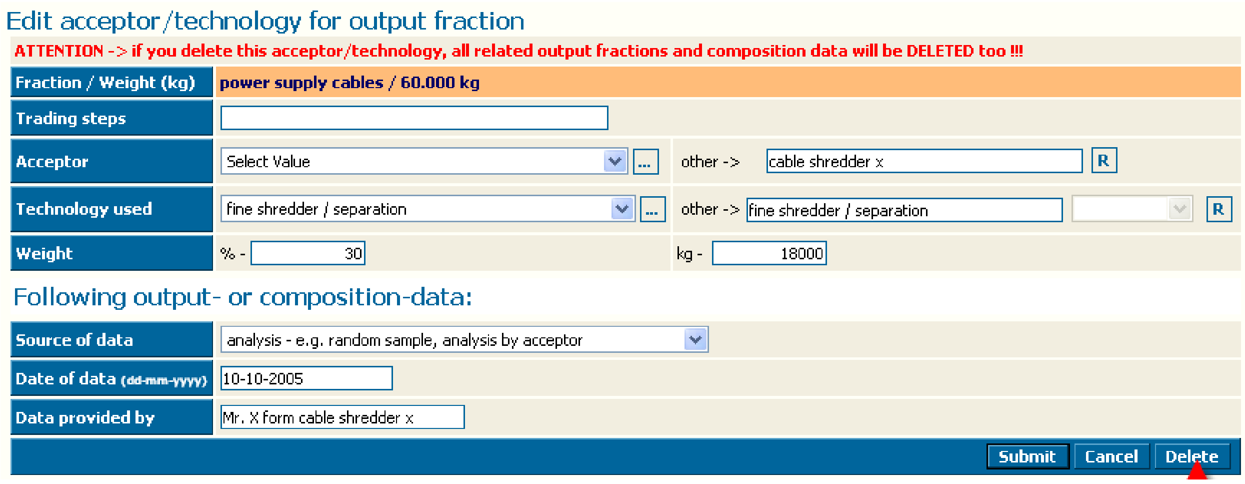
Treatment of circuit board fraction - 3.973 kg

internal - car shredder / separation - 10000000 kg -> large (household) appliances shredder input - 9931490 kg
internal - car shredder / separation - 9931490 kg -> aluminium fraction - 'not pure' - 198630 kg
internal - manual sorting - 198630 kg -> circuit board fraction - 3973 kg

	Acceptor	Technology used	Type	Weight (% / kg)	Source of data	Data from
▼ ✎	Cu smelter 2	Cu smelter 'special'	F	100 / 3.973	analysis	Cu smelter 2
	Add new acceptor/technology			100 / 3.973		

Composition of final fraction

Component	Percent	Use in final technology		Model / national class.	Delete
Fe / stainless steel	22	Fe > used as reductant / smelting detergent	R ...	MR MR	☐
Cu	3,5	Cu > Cu recovery	R ...	MR MR	☐
Al	1	Al > will burn off = no use	R ...	TD TD	☐
other metals	1	other metals > metal recovery	R ...	MR MR	☐
organic residues	63	organic residues > definitely used as reductant	R ...	MR MR	☐
inorganic residues	9,5	inorganic residues > slag production for use	R ...	MR MR	☐
Select Value		Select Value	R ...	Select Value	
Total:	100,0000				
				Submit	Cancel



Edit acceptor/technology for output fraction

ATTENTION -> if you delete this acceptor/technology, all related output fractions and composition data will be DELETED too !!!

Fraction / Weight (kg)	power supply cables / 60.000 kg		
Trading steps			
Acceptor	Select Value	other ->	cable shredder x
Technology used	fine shredder / separation	other ->	fine shredder / separation
Weight	% - 30	kg -	18000

Following output- or composition-data:

Source of data	analysis - e.g. random sample, analysis by acceptor
Date of data (dd-mm-yyyy)	10-10-2005
Data provided by	Mr. X form cable shredder x

Reporting formats regarding the treatment of end-of-life vehicles

According to Article 1.1 of the Commission Decision 2005/293/EC Member States shall calculate the reuse/recovery and reuse/recycling targets set out in the first subparagraph of Article 7.2 of Directive 2000/53/EC on the basis of the reused, recycled and recovered materials from de-pollution, dismantling and (post)-shredding operations. Member States shall ensure that for materials entering further treatment, the actually achieved recovery is taken into account. In the Annex to the Decision 4 tables are given to be used for reporting of the required data by Member States.

Table 1: Materials from de-pollution and dismantling (in tonnes per year) of end-of-life vehicles arising in the Member State and treated within the Member State

Materials from de-pollution and dismantling (*)	Reuse (A)	Recycling (B1)	Energy recovery (C1)	Total recovery (D1 = B1 + C1)	Disposal E1
Batteries					
Liquids (excluding fuel)					
Oil filters					
Other materials arising from de-pollution (excluding fuel)					
Catalysts					
Metal components					
Tyres					
Large plastic parts					
Glass					
Other materials arising from dismantling					
Total					

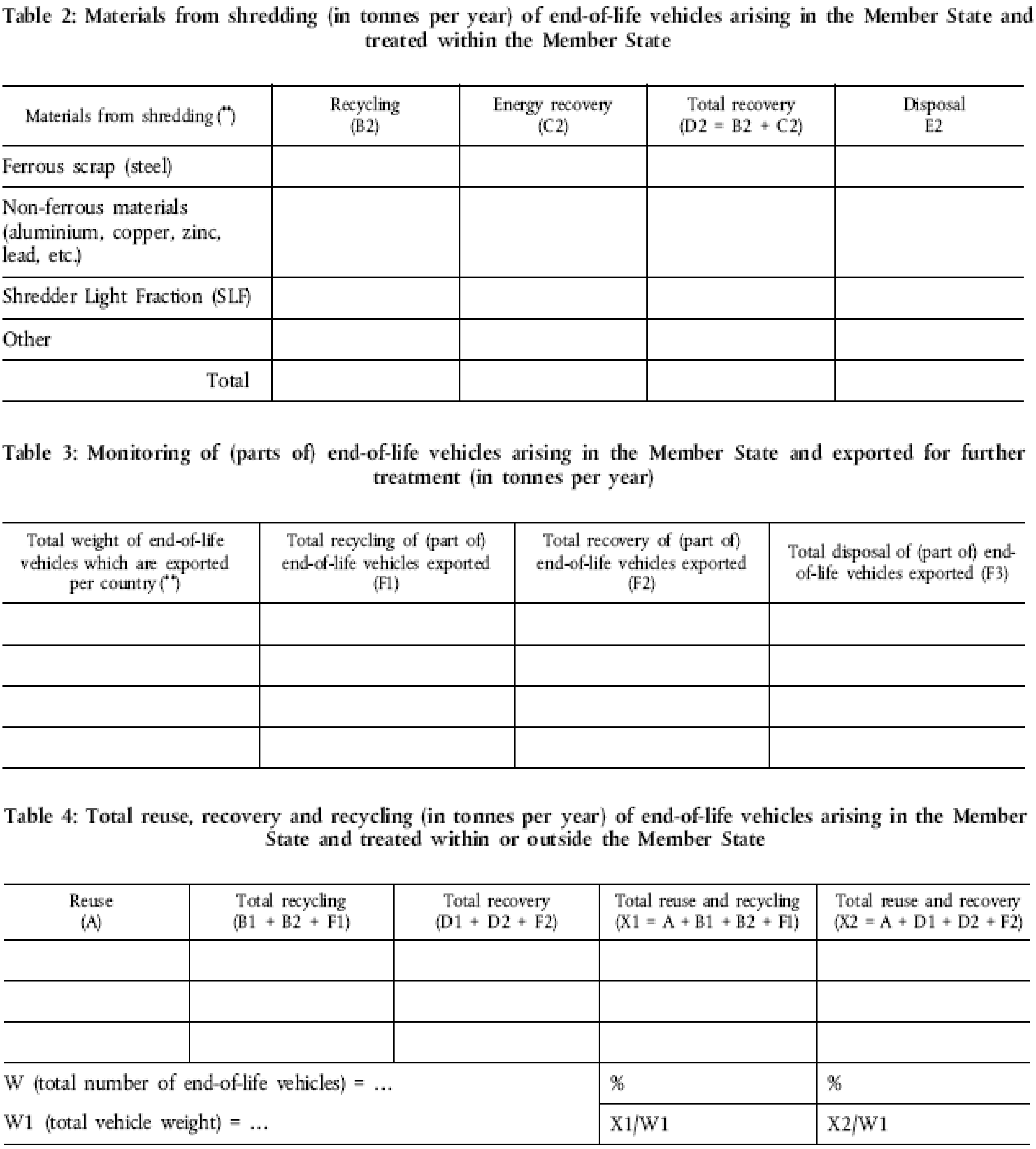


Table 2: Materials from shredding (in tonnes per year) of end-of-life vehicles arising in the Member State and treated within the Member State

Materials from shredding (**)	Recycling (B2)	Energy recovery (C2)	Total recovery (D2 = B2 + C2)	Disposal E2
Ferrous scrap (steel)				
Non-ferrous materials (aluminium, copper, zinc, lead, etc.)				
Shredder Light Fraction (SLF)				
Other				
Total				

Table 3: Monitoring of (parts of) end-of-life vehicles arising in the Member State and exported for further treatment (in tonnes per year)

Total weight of end-of-life vehicles which are exported per country (**)	Total recycling of (part of) end-of-life vehicles exported (F1)	Total recovery of (part of) end-of-life vehicles exported (F2)	Total disposal of (part of) end-of-life vehicles exported (F3)

Table 4: Total reuse, recovery and recycling (in tonnes per year) of end-of-life vehicles arising in the Member State and treated within or outside the Member State

Reuse (A)	Total recycling (B1 + B2 + F1)	Total recovery (D1 + D2 + F2)	Total reuse and recycling (X1 = A + B1 + B2 + F1)	Total reuse and recovery (X2 = A + D1 + D2 + F2)
W (total number of end-of-life vehicles) = …			%	%
W1 (total vehicle weight) = …			X1/W1	X2/W1