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PART 2

COMMISSION STAFF WORKING DOCUMENT

IMPACT ASSESSMENT

Accompanying the document

Proposal for a

DIRECTIVE OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL

amending Directive 2006/66/EC on batteries and accumulators and waste batteries and accumulators as regards the placing on the market of portable batteries and accumulators containing cadmium intended for use in cordless power tools

{COM(2012) 136 final}
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Disclaimer

This report commits only the Commission's services involved in its preparation and does not prejudge the final form of any decision to be taken by the Commission.

ANNEX

1. SUMMARY OF STAKEHOLDER CONSULTATION (MARCH-MAY 2010)

SUMMARY OF THE STAKEHOLDER CONSULTATION ON THE REVIEW OF
ARTICLE 4(3)(C) OF DIRECTIVE 2006/66/EC ON
(WASTE) BATTERIES AND ACCUMULATORS
MARCH – MAY 2010
Available to public at: http://circa.europa.eu/Public/irc/env/exempt_cadmium_ban/library

The European Commission held an on-line public stakeholder consultation from 10 March 2010 until 10 May 2010 on the exemption from the cadmium ban for portable batteries and accumulators intended for use in cordless power tools (CPTs) in accordance with Article 4(3)(c) of the Batteries Directive 2006/66/EC[1]. The Directive prohibits the placing on the market of batteries containing more than 0.002 % of cadmium by weight. The Commission received 14 contributions in response to the consultation (including from national authorities, industry and battery associations).

The consultation was based on a synthesis study published earlier[2]. The available data indicated that extending the ban to cover cadmium-containing batteries and accumulators (NiCd[3] technologies) in CPTs was possible and would not entail substantial technical problems and inacceptable economic or social impacts, as alternatives already exist (such as Li-ion[4] and NiMH[5] technologies).

Stakeholders were consulted on the following topics:[6]

– Impacts of a future cadmium ban for portable batteries and accumulators intended for use in CPTs:

– environmental

– social

– economic

– Time needed to introduce such a cadmium ban in EU legislation

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1 OJ L 266, 26.9.2006, p. 1. Directive as last amended by Directive 2008/103/EC (OJ L 327, 5.12.2008, p. 7-8).

2 See ESWI Final report at: http://ec.europa.eu/environment/consultations/pdf/batteries_study.pdf.

3 NiCd = nickel-cadmium.

4 Li-ion = lithium-ion.

5 NiMH = nickel-metal hydride.

6 A more detailed description of the subject of the consultation can be found in the original stakeholder consultation document: http://circa.europa.eu/Public/irc/env/exempt_cadmium_ban/library.

– Consequences of such a cadmium ban, based on available technical and scientific evidence:

– environmental

– social

– economic

While some stakeholders commented on each specific option of the consultation document, several restricted themselves to the issues directly affecting their respective areas of activities.

Respondents' profile

The stakeholders responding to the consultation can be grouped into four categories: producers, producer responsibility organisations and industrial associations (8 respondents);

recyclers (2 respondents); raw material suppliers (2 respondents); and Member States (2 respondents).

Highlights from the contributions of the largest stakeholder groups are given below.

Contributions of producers, producer responsibility organisations and industrial associations

– Among the industrial actors there was general agreement on the technical feasibility of replacing NiCd batteries with existing cadmium-free technologies (e.g. Li-ion or NiMH batteries). These actors confirmed that the use of NiCd batteries was decreasing while sales of Li-ion batteries were on the increase, with NiMH technology a less popular option for CPTs.

– Some respondents highlighted that it could be disadvantageous in the short term to introduce a cadmium ban for CPTs, given the price, safety issues and life-time of the substitutes as well the number of waste batteries that would result.

– Other industrial actors mentioned the higher cost of Li-ion technology compared to NiCd technology as an important element.

– Many industrial actors opposed withdrawal of the exemption and underlined that the data available on economic, environmental and social impacts do not justify withdrawal. This stakeholder group highlighted the importance of compliance with waste battery collection and recycling requirements within the EU.

– One industry actor favoured withdrawal of the exemption for NiCd batteries in CPTs since mature and viable battery alternatives already exist (e.g. Nickel-Zinc batteries). This stakeholder argued that cadmium-containing batteries could be replaced without significantly affecting the performance and economics of power tools and other portable devices.

– The majority of respondents confirmed the need for a **comparative life-cycle assessment** of the main battery alternatives in order to provide sound scientific and technical information on the costs and benefits of the use of cadmium and its alternatives in portable batteries and accumulators intended for use in CPTs.

– There was some support among the industry representatives for the introduction of a cadmium ban for portable batteries used in CPTs after 2020 so as to allow any performance, economic or environmental issues to be resolved.

Contributions by Member States

– Some Member States clearly supported the withdrawal of the exemption for the use of NiCd batteries in CPTs since they viewed the economic costs as minimal and the environmental and health benefits as substantial in the long term.

– Some Member States argued that withdrawal of the exemption is technically possible today, since some NiCd batteries have already been replaced by existing Li-ion and NiMH battery technologies, with reservations for applications where temperatures are below 0 °C.

– Member States generally seemed to favour a cadmium ban for CPTs since the economic and social impacts are not expected to be disproportionate. Furthermore, Europe currently has no producers of NiCd batteries intended for use in CPTs.

– Member States supported the shift from cadmium to Li-ion batteries.

Suppliers of raw materials for battery manufacturers

– Most raw material suppliers confirmed that cadmium is a by-product of zinc production and is contained in all zinc raw materials. However, they generally took the view that cadmium emissions from ore processing would not change substantially if cadmium production were to be stopped.

– Some raw material suppliers expressed concerns that a ban on NiCd batteries for CPTs could mean that cadmium extraction, as a by-product of zinc-mining, would no longer be economic. Some argued that the disappearance of the cadmium market would cause a revenue loss (e.g. > € 1 m) for a medium-sized zinc producer.

– Several stakeholders expressed preference for a ban after 2020-2025, as the changeover from NiCd batteries to alternatives would occur naturally and the market would have sufficient time to prepare.

Contributions by the waste management sector

– Several battery recyclers were generally concerned by the still high level of toxicity of the materials used in cadmium-free technologies (Li-ion, NiMH) for CPTs compared to cadmium-containing batteries (NiCd). Some stakeholders underlined that a cadmium ban would lead to even more toxic materials entering the market than is currently the case with NiCd batteries.

– Some battery recyclers stressed the importance of the average life-time of different battery technologies. As a consequence, the switch from NiCd to Li-ion power tools would double the waste stream generated by discarded power tool batteries.

– One stakeholder proposed introducing a payment for battery collectors and/or consumers for returning their scrap power tool battery.

– Some recyclers were generally concerned that, while NiCd batteries could be recycled at maximum efficiency (> 80 %) and the cadmium could be used directly in new applications, Li-ion batteries could not be recycled fully (recycling efficiency < 50 %) and at a reasonable cost.

– Some highlighted that a cadmium ban would affect small-scale recyclers unable to invest in innovative recycling processes for Li-ion batteries.

2. MINUTES OF STAKEHOLDER WORKSHOP (18 JULY 2011)

Comparative Life-Cycle Assessment of nickel-Cadmium (NiCd) batteries used in Cordless Power Tools (CPTs) vs. their alternatives nickel-metal hydride (NiMH) and lithium-ion (Li-ion) batteries

Minutes of Stakeholder Workshop

Brussels, 18 July 2011

Project:	Comparative Life-Cycle Assessment of nickel-Cadmium (NiCd) batteries used in Cordless Power Tools (CPTs) vs. their alternatives nickel-metal hydride (NiMH) and lithium-ion (Li-ion) batteries (Contract N° 07.0307/2010/573669/ETU/C2)
Client:	European Commission, DG ENV Contact: Ruska Kelevska
Contact BIO:	Shailendra Mudgal / Benoît Tinetti / Augustin Chanoine / Sandeep Pahal Tel.: +33 (0)1 53 90 11 80 Email: shailendra.mudgal@biois.com; benoit.tinetti@biois.com; augustin.chanoine@biois.com; sandeep.pahal@biois.com

Venue:

Avenue de Beaulieu 5, B-1160 Brussels, Meeting Room BU-5, 00/C

Agenda:

10:00 - 10:15	*Arrival, registration and coffee*	*ALL*
10:15 - 10:30	Welcome and introduction	DG ENV
10:30 - 11:45	Comparative Life-Cycle Assessment of NiCd batteries used in CPTs vs. their alternatives NiMH and Li-ion batteries	BIO
11:45 - 12:15	Discussion	ALL
12.15 - 13.30	*Lunch Break*	*ALL*
13:30 - 14:00	Presentation on findings of 2009 ESWI study	DG ENV

14:00 - 14:30	Policy Analysis	BIO
14:30 - 15:00	*Coffee break*	*ALL*
15.00 - 15.30	Impacts of portable batteries in CPTs	EPTA
15.30 - 16.00	End-of-life management of portable NiCd batteries	RECHARGE
16.00 - 16.30	Life-Cycle Assessments involving Umicore's battery recycling process	UMICORE
16:30 - 17:15	Discussion	ALL
17:15 - 17:30	Conclusion and wrap up	DG ENV

Participants:

COUNTRY	**NAME**	**FIRST NAME**	**COMPANY**	**EMAIL**
CH	BARBISCH	Benno	Robert Bosch Power Tools	Benno.Barbisch@ch.bosch.com
BE	CRAEN	Hans	EPBA	epba@kelleneurope.com
FR	DAVID	Jacques	SCRELEC	jacques.david@screlec.fr
FR	de METZ	Patrick	SAFT Batteries	patrick.de_metz@saftbatteries.com
DE	DAVIS	Tony	Vale Europe	Tony.Davis@Vale.com
DK	HOFFENBERG	Jacques	Waste Denmark Belgium	jh@wastedenmark.dk
DE	JUNG	Matthias	German Federal Environment Agency	matthias.jung@uba.de
BE	LEEMANS	Marc	OVAM	marc.leemans@ovam.be
FR	NOTTEZ	Eric	SNAM	eric.nottez@snam.com
FR	OLIVARD	Sylvie	SNAM	sylvie.olivard@snam.com
DE	WEYHE	Reyner	Accurec	accurec@t-online.de
DE	SCHILLING	Stephanie	Oekopol GmbH	Schilling@oekopol.de
BE	SMITS	Laurent	Floridienne Chimie	laurent.smits@floridiennechimie.com
UK	SPENCER	Liz	EPTA	lizspencer@publicaffairs.ac
UK	THIRLAWAY	Colin	StanleyBlack&Decker	Colin.Thirlaway@blackdecker.com

UK	TOLLIT	Charles	European Power tools Association	charles.tollit@epta.eu
BE	VAN REENEN	Gertjan	GP Batteries	gvanreenen@gpbatteries-europe.com
BE	WIAUX	Jean-Pol	RECHARGE aisbl	jpwiaux@rechargebatteries.org
BE	YAZICIOGLU	Begum	Umicore Battery Recycling	begum.yazicioglu@eu.umicore.com
	PAHAL	Sandeep	bio Intelligence Service	sandeep.pahal@biois.com
	MUDGAL	Shailendra	bio Intelligence Service	sm@biois.com
	CHANOINE	Augustin	bio Intelligence Service	augustin.chanoine@biois.com
	KELEVSKA	Ruska	DG ENV	Ruska.kelevska@ec.europa.eu
	VAN DER VLIES	Rosalinde	DG ENV	Rosalinde.van-der-vlies@ec.europa.eu

Total number of participants: 23

Presentations made by BIO, DG ENV, EPTA, RECHARGE and Umicore are available on the DG ENV website: http://ec.europa.eu/environment/waste/batteries/index.htm

- Introduction by DG ENV

The workshop was chaired by **Rosalinde van der Vlies (RVDV)** from DG ENV (Waste Management Unit), who welcomed the participants and introduced the subject of the workshop, i.e. the review of the current exemption to NiCd batteries for use in Cordless Power Tools (CPTs).

The main objective of the workshop was to present and discuss with stakeholders the initial findings of the study conducted by BIO Intelligence Service on the Comparative Life-Cycle Assessment of Nickel-Cadmium (NiCd) batteries used in Cordless Power Tools (CPTs) vs. their alternatives Nickel-metal hydride (NiMH) and Lithium-ion (Li-ion) batteries. The workshop also included presentations by DG ENV, European Power Tool Association (EPTA), RECHARGE[7] and Umicore.

DG ENV made it clear to stakeholders that their input is of great importance and value for this study.

- Structure of BIO's presentation

The presentation of BIO's study started with an overview of the study's objectives and methodology, followed by the main data sources and assumptions behind the Life Cycle Assessment (LCA) of the the three battery types. A comparative analysis of the LCA results was then presented. The preliminary results of the policy analysis were presented separately in detail for each key policy action area (baseline scenario (no withdrawal of the exemption);

7 The international association for the promotion and management of portable rechargeable batteries through their life cycle. www.rechargebatteries.org.

immediate withdrawal of the exemption (2012/2013); and delayed withdrawal of the exemption (2016)). BIO's presentation on LCA and policy analysis was followed by a discussion session with stakeholders.

- LCA Presentation

Augustin Chanoine (AC), BIO, presented the methodology used for the LCA. **Patrick de Metz (PdM)**, SAFT Batteries, questioned the choice of LiFePO4 chemistry out of the other Li-ion battery chemistries for the LCA. **AC** replied that this was due to the higher market share of $LiFePO_4$ chemistry in the CPT market as compared to other Li-ion battery chemistries. **Jacques Hoffenberg (JH)**, Waste Denmark Belgium, questioned the choice of Power Drill as the CPT for the LCA. **AC** commented that a similar Power Drill is available for all the three chemistry types and also was the CPT used in the PE study. **Charles Tollit (CT)**, EPTA, confirmed that this product represents the largest share of CPTs in EU.

AC then presented the various primary data sources and the key assumptions made for conducting the LCA. AC further presented the preliminary LCA results for each of the three battery types (NiCd, NiMH and Li-ion) followed by a comparative analysis of these preliminary results. **JH** asked if alternative function units than 1 kWh were considered. **AC** informed that "Ah" was considered as a potential functional unit however, kWh is more appropriate candidate for functional unit since the primary function of the battery is to deliver electrical energy. **AC** further commented that different lifespan for each of the three batteries is assessed in the sensitivity analysis.

Eric Nottez (EN), SNAM, asked if the benefit of recycling materials as compared to virgin raw materials was taken into account in LCA. **AC** confirmed that it was taken into account.

JH enquired about the source of primary data for LCA. **AC** responded that primary LCA data was gathered from RECHARGE and EPTA. **JH** asked if the lifespan of batteries for Do It Yourself (DIY) users was taken into account and if the charger used for both NiCd and NiMH batteries based CPTs was same. **AC** answered that only the lifespan of batteries in case of Professional (PRO) users was used for the LCA. **JH** further enquired if same charger was used for both NiCd and NiMH batteries based CPTs. **AC** confirmed that this was the case.

Stephanie Schilling (SS), Oekopol GmbH, asked if the hoarding effect is observed in case of PRO users. **AC** answered that it is mostly true for DIY users. **EN** further added that no reliable statistics on the hoarding effect exist at the EU level. **RVDV** asked if there the hoarding effect is influenced by the chemistry of the batteries. **EN** answered that it is the same for all three battery chemistries considered here.

PdM questioned the choice of collection rate value of 25%. He suggested that it is better to take into account the actual situation of waste battery collection which varies from 5% to 50% across Member States. **AC** answered that the chosen value for the collection rate is as per collection rate targets already specified in the Battery Directive (2006/66/EC). **RVDV** further clarified that the objective of this study is to assess the withdrawal of current exemption to to NiCd batteries use in CPTs and review of collection targets is beyond its scope.

PdM enquired about the lifespan of the Li-ion batteries. **Colin Thirlaway (CTh),** Stanley Black & Decker, clarified that it is assumed for the Li-ion batteries that they last as long as the tool.

EN remarked that nowadays the recycling efficiency of Cadmium in the waste NiCd batteries is more than 99% instead of 90% (as reported in the presentation). **AC** requested for the updated numbers on recycling efficiency from the stakeholders and proposed to revise these numbers in the report.

PdM pointed out the value of 24-35% recycling efficiency for waste Li-ion batteries reported in the presentation does not correspond to the recycling target for these batteries set in the Battery Directive. **AC** agreed to revise these numbers.

JH commented that Cadmium is produced as a by-product of Zinc refining and therefore questioned its consideration as being scarce. **PdM** agreed with **JH** and added that Cadmium is available in surplus in the world and hence cannot result in high abiotic resource depletion. **AC** agreed to consider this aspect in the LCA model.

PdM asked for a description of the term Long Term Ecotoxicity indicator. **AC** replied it concerns the amount of metals released in environment over long term.

PdM commented that in case the exemption is withdrawn then the unused Cadmium recovered as a by-product of Zinc smelting will have to be landfilled resulting in similar impacts as the landfilling of waste NiCd Batteries.

Jean-Pol Wiaux (JPW), RECHARGE, asked if different collection rates for the three battery types were accounted in the LCA. **PdM** supported JPW question adding that due to large environmental issues, waste NiCd batteries go to recycling plants more often than the other two battery types and hence different collection rates for the three battery types should be used. **AC** replied that this was not the case as same collection rates were considered for the three battery types.

JH asked why different inputs were used for NiCd and NiMH chargers. He also asked if the impacts of only batteries (without chargers) could be considered. **AC** answered that the difference in inputs is due to the influence of scaling to 100%. **AC** further clarified that only batteries can be considered only if all three battery types can use a same charger, which is not the case and hence the impacts of charger have to be incorporated as well. **JPW** added that Li-ion battery chargers require an additional electronic circuit for battery management as compared to the chargers for other two battery types.

PdM suggested revisiting the calculation for the higher energy capacity of the Li-ion battery.

JPW enquired about the types of resources included in the abiotic resource depletion indicator. **AC** replied that it includes non-renewable resources (coal, etc.) consumed over the whole life cycle of the battery-charger system. **EC** remarked that the emission data from recycling plants is monitored 24 hrs a day and 7 days a week.

JH asked if the battery manufacturers are covered by Industrial Emissions Directive (IED). **CTh** commented that the waste battery recyclers are covered by the IED, however as the battery manufacturers are based outside EU (in Asia), they most likely may not be covered by it. **Tony Davis (TD)**, Vale, confirmed that the raw materials manufactured in EU used for the battery production in Asia are covered by IED.

- Presentation on findings of 2009 ESWI study

Ruska Kelevska (RK), DG ENV, presented the main outcomes of the ESWI study. **TD** highlighted that the analysis of impacts on EU raw materials suppliers industry (due to the withdrawal of current exemption to NiCd batteries use in CPTs) is not correct as it underestimates the resulting economic and social impacts on them. **TD**'s view was supported by **Laurent Smits (LS)**, Floridienne Chimie.

JPW remarked that the analysis performed in the ESWI study has already been subject to criticism by industry and hence these results do not have any significance. **RK** agreed with **JPW** and further clarified that the objective of presenting the ESWI study was to support the context of current study.

- Policy analysis presentation

Sandeep Pahal (SP), BIO, presented the preliminary outcomes of the policy analysis carried out in current study. **JH** enquired about the market share of overall CPT market in EU represented by DIY and PRO users. **CT** responded that in terms of market value, PRO users represented 65% and DIY 35% of the market in 2008. **JPW** suggested using the term "recycling treatment fees" instead of "cost/benefits of recycling" for assessing the economic impacts on waste CPT battery recyclers. **SP** agreed to it. **EN** commented that the recycling gate fees reported for the waste NiMH and Li-ion batteries was not correct. **SP** requested for correct values of recycling gate fees for these batteries and assured to incorporate them in the report.

- EPTA presentation

CT, presented statistics on past trends and future forecast of the EU portable power tool market. **CT** also shared EPTA's opinion on economic impacts on consumer resulting from the withdrawal of current exemption to NiCd batteries use in CPTs. **CT** concluded with EPTA's position on the issue of NiCd battery use in CPTs and recommended that the best environmental solution remains increased focus on collection and recycling across all Member States in EU.

- RECHARGE presentation

JPW presented the end-of-life waste management practices for portable NiCd batteries in EU. He provided the statistics on past trends in NiCd waste battery collection in EU and across Member States. **JPW** talked about the high Cadmium recycling efficiency of various recycling processes used by waste NiCd battery recyclers in EU. **JPW** also commented on the overall cadmium emissions associated NiCd batteries in EU and stresses that NiCd batteries represent a minor fraction of all sources of exposure of humans to cadmium via the environment. **Shailendra Mudgal (SM)**, BIO, asked what share of the overall waste batteries recycled by SNAM and Accurec is represented by waste NiCd batteries arising from CPTs. **EN** answered that approximately 85% of the waste batteries recycled by SNAM are of NiCd chemistry and almost half of them waste NiCd CPT batteries whereas the other half are waste industrial NiCd batteries. **EN** further commented that SNAM's exposure to the withdrawal of current exemption to NiCd batteries use in CPTs is around 65% of their annual turnover.

Reyner Weyhe (RW), Accurec, added that for Accurec almost 80% of the waste batteries recycled by them arise from NiCd batteries used in CPTs.

- Umicore presentation

Begum Yazicioglu (BY), Umicore battery recycling, presented the results of Life Cycle Assessment of Umicore's recycling processes and stressed on recycling being the most environmental friendly way of production of new battery materials and batteries.

- Concluding remarks and next steps

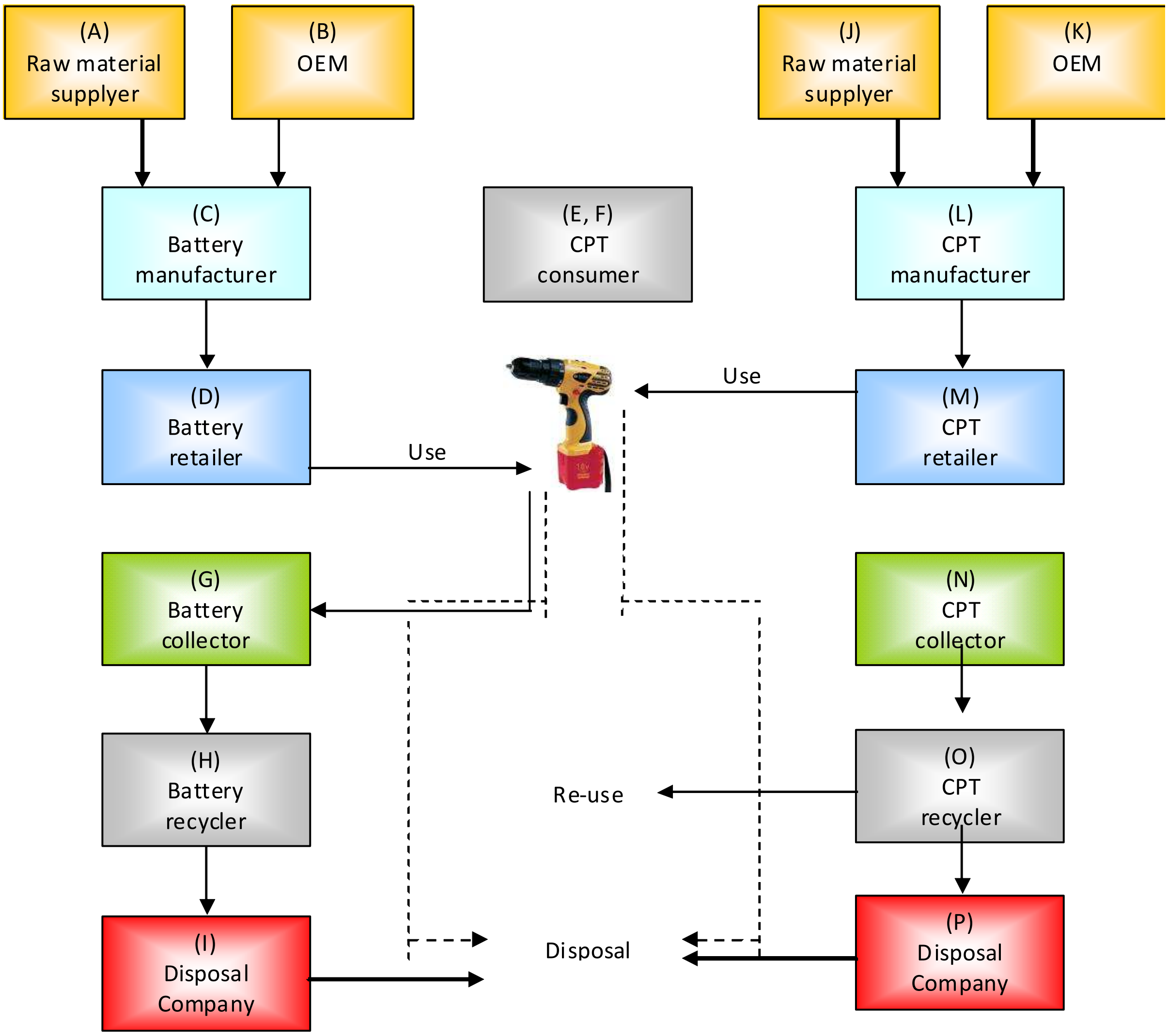
Stakeholders showed a genuine interest in the study and results. Their comments will be very useful for the finalisation of the study. In addition to verbal comments made during the workshop, stakeholders were invited to submit written comments to BIO by 5th August 2011.

The report will be finalised by beginning of October 2011, taking into account the comments received from stakeholders. This report will be used as a basis by the Commission for its review of current exemption to NiCd batteries use in CPTs which is planned to be completed by the end of 2011.

3. Causal relations in the supply, recycling and disposal chain of batteries used in CPT and of CPT

Figure 5 illustrates the causal relations in the supply, recycling and disposal chain of all batteries used in CPT and of CPT themselves. The dotted lines shall illustrate that relevant shares of waste batteries and waste CPTs are directly disposed instead of being collected and recycled.[8]

Figure 4: Causal relations in the supply, recycling and disposal chain of batteries used in CPT and of CPT



Along the chain of raw material supply, manufacturing, collection, recycling and disposal all relevant actors and all relevant impacts can be systematically identified. Battery manufacturers are manufacturers of NiCd, NiMH, Li-ion batteries and manufacturers of all possible technical substitutes.

8 Source: ESWI study (2010)

In addition to the actors illustrated in Figure 4 the environment and the society as a whole and public authorities have to be considered. The state of the environment may change due to altered releases of pollutants to air, water and soil. Also, altered loss of scarce resources and the society may be concerned due to impacts on life quality and external costs. Public authorities may be concerned due to different administrative burden.

4. CONCLUSIONS FROM A TECHNICAL ASSESSMENT OF COMMERCIALLY AVAILABLE TECHNICAL SUBSTITUTES FOR CADMIUM BATTERIES IN CORDLESS POWERTOOLS

Criterion	Technology	Advantages	Disadvantages	Ranking (1 to 5)	Conclusion and justification
(1) Power density and energy density	NiCd	High lifetime energy density	-	4	3 technologies are more or less equal
	NiMH	High per cycle energy density	Low lifetime energy density	4	
	Li-ion	High per cycle energy density	Low volumetric lifetime energy density	4	
(2) Temperature range	NiCd	Can be operated below 0 °C	Reduced performance below 0 °C	4	Limits below °C for all, more so for NiMH and Li-ion
	NiMH	-	Much reduced performance below 0 °C	3	
	Li-ion	-	Much reduced performance below 0 °C	3	
(3) Charging cycles and lifetime	NiCd	Life time 7 years	-	5	NiCd seem to have the longest lifetime, NiMH the shortest, the lifetime of Li-ion needs to be confirmed, but seems to be between NiMH and NiCd
	NiMH	-	Life time approx. 4 years	3	
	Li-ion	Life time maybe 7 years	Life time maybe 4 years	4	
(4) Overcharge and over-discharge	NiCd	Equipment for avoiding overcharge/overdischarge included	May be destroyed by overcharge or overdischarge	4	No differentiation because charging equipment ensures safe operation
	NiMH	Equipment for avoiding overcharge/overdischarge included	May be destroyed by overcharge or overdischarge	4	
	Li-ion	Equipment for avoiding overcharge/overdischarge included	May be destroyed by overcharge or overdischarge	4	
(5) Energy efficiency of discharge/charge	NiCd	-	67 to 91 % effieciency	3	Li-ion is most efficient with respect to energy
	NiMH	-	91 to 95 %	4	

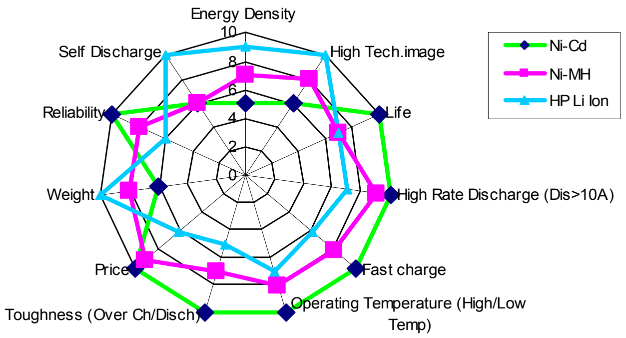
Criterion	Technology	Advantages	Disadvantages	Ranking (1 to 5)	Conclusion and justification
			effieciency		utilisation
	Li-ion	Almost 100 % efficiency	-	5	
(6) Fast charge	NiCd	Fast charge possible	Better performance when charged at lower rate	4	All 3 more or less equal
	NiMH	Fast charge possible	Better performance when charged at lower rate	4	
	Li-ion	Fast charge possible	Better performance when charged at lower rate	4	
(7) Low self discharge	NiCd	-	15 to 20% self discharge/month	3	Li-ion can keep the stored energy over the longest time and needs to be recharged less frequently during "shelf live"
	NiMH	-	15 to 20% self discharge/month	3	
	Li-ion	<5% self discharge/month	Loses energy storage capacity when stored fully charged	4	
(8) Reliability	NiCd	Very reliable	-	5	Only small differentiation because charging equipment ensures safe operation
	NiMH	Reliable	-	4	
	Li-ion	Reliable	-	4	
(9) Maturity and development potential	NiCd	Highest degree of maturity	(Nearly) no further development potential	5	Longer experience for NiCd is outweighed by future potential of Li technologies
	NiMH	-	-	4	
	Li-ion	Highest development potential	Maturity may be further improved	5	
Average of ranking points	**NiCd**			**4.1**	
	NiMH			**3.7**	

(Source: EWSI study, 2010)

SUBSTITUTION
NiCd, NiMH and Li-Ion

•Power Tool companies and their battery suppliers invest heavily in researching new technologies to serve the needs of their customers and the wider community
•The “spidergram” shows some attributes (of importance for Power Tools) of NiCd when compared to NiMH and Li-Ion
•Each technology has its own distinct advantages and disadvantages, none is either best or worst in all attributes.
•Technology developments are moving at some pace, and therefore any comparison of attributes is only relevant for a given time

CHEMISTRY COMPARISON



June 09

Result of an EPTA technical assessment of NiCd, NiMH and Li-ion batteries intended for the use in cordless power tools [source: ESWI study, EPTA 2009a]

5. **EVOLUTION OF THE OVERALL CPT BATTERY MARKET (PRO AND DIY) IN EU OVER THE PERIOD 2010-2025 (OPTION 1)**

The evolution of the overall CPT battery market (PRO and DIY) in the BaU scenario over the period 2010-2025 is presented in Figure 6 to Figure 8 below. Figure 6 shows that the overall CPT market grows from around 35.4 million batteries sold in 2010 to 103 million batteries (battery packs units) sold in 2025. Figure 7 shows that the PRO CPT market would grow from around 13.2 million batteries sold in 2010 to 38.7 million batteries in 2025. Figure 8 shows that the DIY CPT market would grow from around 22 million batteries sold in 2010 to 64 million in 2025.

Figure 6: Evolution of overall CPT battery market (number of battery pack units) in EU until 2025 in BaU scenario based on annual sales (Option 1)

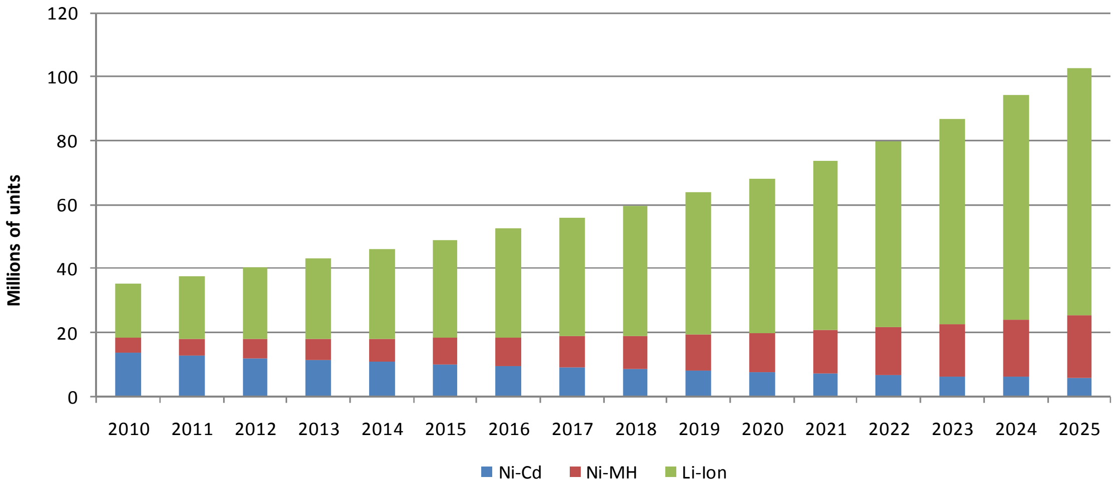


Figure 7: Evolution of PRO CPT battery market (number of battery pack units) in EU until 2025 in BaU scenario (Option 1)

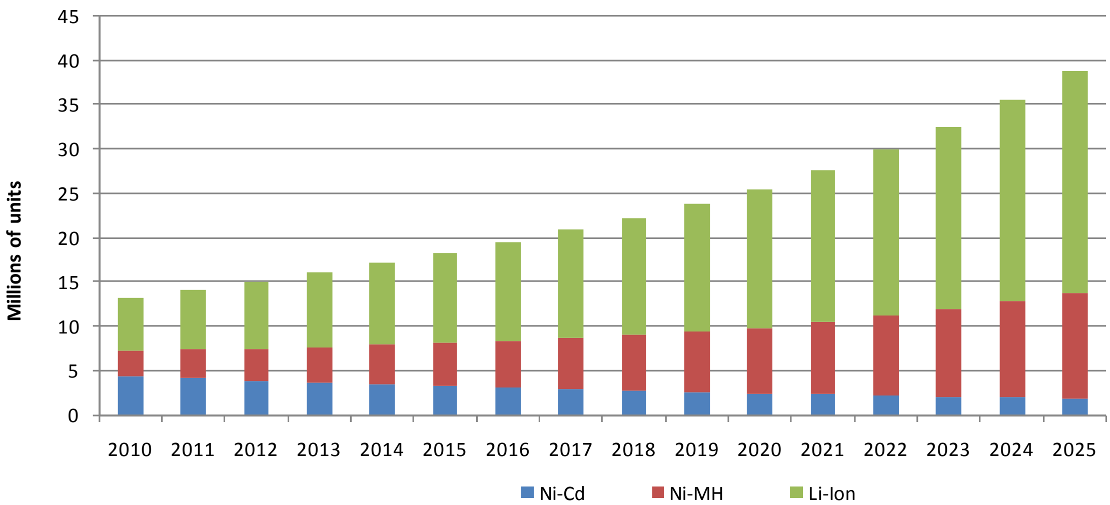
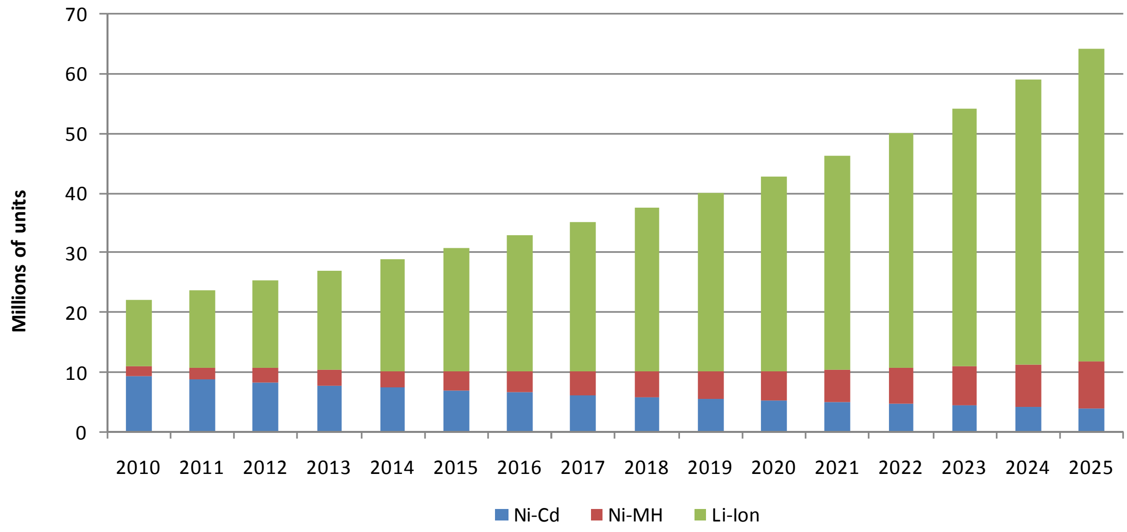


Figure 8: Evolution of DIY CPT battery market (number of battery pack units) in EU until 2025 in BaU scenario (Option 1)



<u>Policy Option 1:</u>

EU market by number of units (batteries for CPTs)

Battery type	2008		2009		2010		2013		2016	
	Million units	%	Million units	%	Million units	%	Million units	%	Million units	%
NiCd	15.27	49%	14.41	43%	13.60	38%	11.44	27%	9.62	18%
NiMH	3.35	11%	4.11	12%	4.70	13%	6.63	15%	8.83	17%
Li-ion	12.48	40%	14.67	44%	17.13	48%	25.03	58%	33.98	65%
Total	31.09	100%	33.19	100%	35.43	100%	43.10	100%	52.43	100%

EU market by value of the sold CPT

Battery type	2008		2009		2010		2013		2016	
	Million euros	%	Million euros	%	Million euros	%	Million euros	%	Million euros	%
NiCd	464.07	44%	438.02	39%	413.44	34%	347.66	23%	292.35	17%
NiMH	111.96	11%	137.27	12%	157.18	13%	221.71	15%	283.27	16%
Li-ion	474.00	45%	557.53	49%	650.77	53%	951.08	63%	1174.84	67%
Total	1050.03	100%	1132.83	100%	1221.38	100%	1520.44	100%	1750.45	100%

6. EVOLUTION OF WASTE CPT BATTERY COLLECTION (IN TONNES) IN EU, 2010-2025 IN BAU SCENARIO (OPTION 1)

CPTs are classified under the Category 6 of WEEE (Electrical & electronic tools)[9]. CPTs represented 38% of the overall power tool market in EU in 2007. As the batteries are discarded together with the CPT when it reaches its end of life, it necessitates taking into consideration the WEEE statistics (only official source of information on actual waste collection in EU) while analysing the collection rate of the waste CPT batteries. The WEEE statistics for Category 6 in 2008 reported a collection rate of around 10%. It is therefore deemed necessary to also consider a lower collection rate (than expected under the Batteries Directive) to assess the potential impacts of various policy options by taking into account the WEEE statistics reported for 2008. Potentially, it would be a worst case scenario as the collection rate is lower than what is required by the Batteries Directive.

The average mass[10] of batteries used in CPTs placed on the EU market, are as per following:

– The average mass of a NiCd cell used in CPTs is 51.4 g and the weight of a 18V power pack used in CPTs is 774 g
– The average mass of a NiMH cell used in CPTs is 58 g and the weight of a 18V power pack used in CPTs is 870 g
– The average mass of a Li-ion cell used in CPTs is 38.3 g and the weight of a 19.8V power pack used in CPTs is 459.6 g

Following two scenarios for CPT waste battery collection are developed:

- Waste CPT battery collection rate scenario 1

Collection rate as specified in the Batteries Directive: 25% in September 2012 and 45% in September 2016[11]. Following collection rate values are used to develop the scenarios:

– 2010 till 2012: 25%
– 2013 till 2016: linear increase from 25% to 45%
– 2016 onwards: 45%

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9 The Category 6 of WEEE, named “Electrical & electronic tools”, includes, but is not limited to “drills”, “saws”, “sewing machines”, “equipment for turning, milling, sanding, grinding, sawing, cutting, shearing, drilling, making holes, punching, folding, bending or similar processing of wood, metal and other materials”, “tools for riveting, nailing or screwing or removing rivets, nails, screws or similar uses”, “tools for welding, soldering or similar use”, “equipment for spraying, spreading, dispersing or other treatment of liquid or gaseous substances by other means”, “tools for mowing or other gardening activities”. Note that large-scale stationary industrial tools are specifically exempt under this category. This category therefore includes a wider range of tools as CPTs.

10 Source : the mass of individual cells is based upon the primary LCA data reported by stakeholder

11 Though increased collection rates have been reported by the industry, the policy options considered in this analysis don’t use change in collection rates as a mechanism and assumes that all battery types have same collection rates. This of course will be an important aspect in the review of the Batteries Directive which will be carried out after the second round of implementation reports from the Member States in 2016.

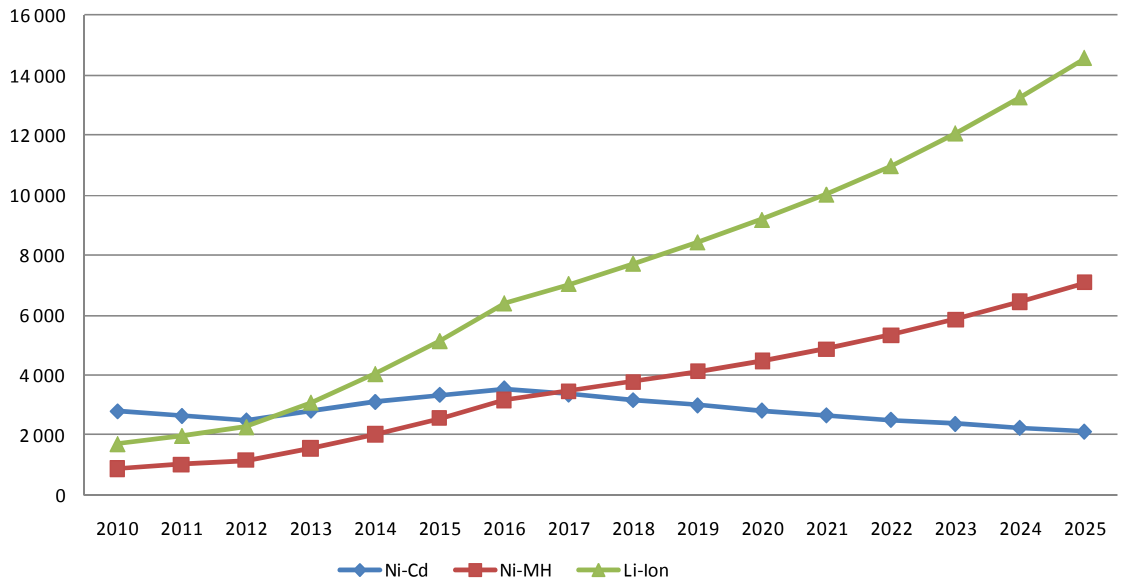
- Waste CPT battery collection rate scenario 2

10% collection rate, as reported by the WEEE statistic for Category 6 in 2008. In this scenario a constant collection rate of 10% over the period 2010 till 2015 is assumed.

The calculation of the collected quantities of waste CPT batteries is performed as per the guidance provided in the Battery Directive[12] for both the scenarios described above.

Figure 9 shows that the overall collected quantities of waste CPT batteries increase from 5,370 tonnes in 2010 to 23,800 tonnes in 2025. The overall quantity of waste CPT batteries collected during the period 2010-2025 would be 220,535 tonnes.

Figure 9: Evolution of waste CPT battery collection (in tonnes) in EU, 2010-2025 in BaU scenario (Option 1)



[12] The Batteries Directive defines collection rate for a given Member State in a given calendar year, as the percentage obtained by dividing the weight of waste portable batteries and accumulators collected in accordance with Article 8(1) of this Directive or with Directive 2002/96/EC in that calendar year by the average weight of portable batteries and accumulators that producers either sell directly to end-users or deliver to third parties in order to sell them to end-users in that Member State during that calendar year and the preceding two calendar years.

7. EVOLUTION OF THE OVERALL CPT BATTERY MARKET (PRO AND DIY) IN EU OVER THE PERIOD 2010-2025 (OPTION 2)

The assumptions concerning overall CPT market forecast, replacement rate of NiCd batteries in CPTs by Li-ion and NiMH batteries and number of batteries sold per CPT which are used for the projections made here are same as the BaU scenario (Option 1).

The evolution of the overall, PRO and DIY CPT market in current scenario over the period 2010-2025 is presented in figures below.

Figure 10: Evolution of overall CPT battery market (number of battery pack units) in EU until 2025 (Option 2)

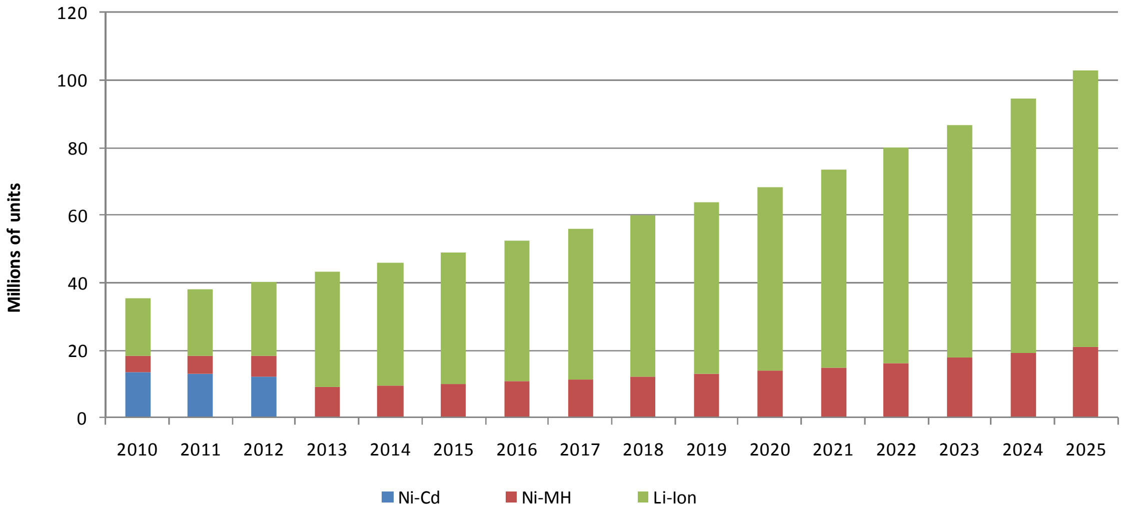


Figure 11: Evolution of PRO CPT battery market (number of battery pack units) in EU until 2025 (Option 2)

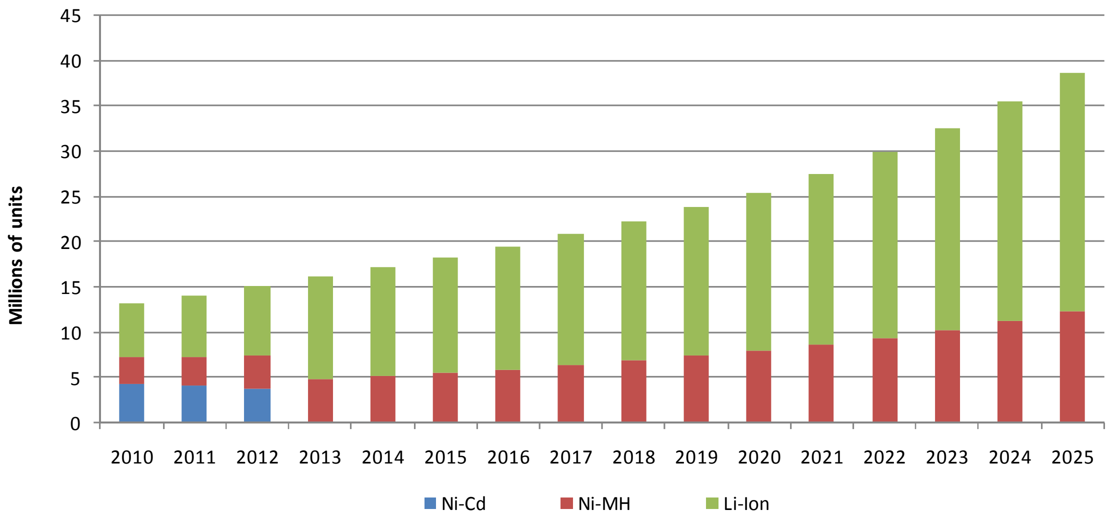
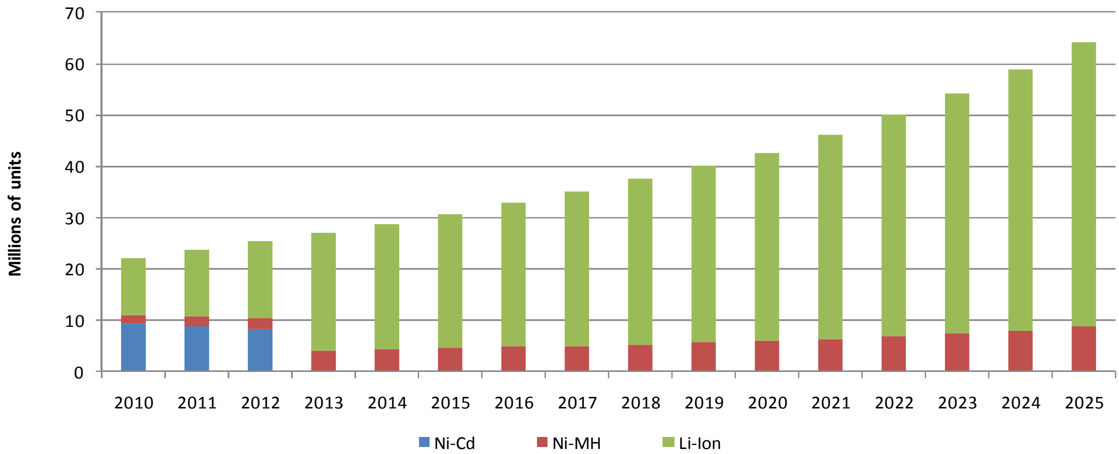


Figure 12: Evolution of DIY CPT battery market (number of battery pack units) in EU until 2025 (Option 2)



<u>Policy Option 2:</u>

EU market by number of units (batteries for CPTs)

Battery type	2008		2009		2010		2013		2016	
	Million units	%	Million units	%	Million units	%	Million units	%	Million units	%
NiCd	15.27	49%	14.41	43%	13.60	38%	0.00	0%	0.00	0%
NiMH	3.35	11%	4.11	12%	4.70	13%	8.92	21%	10.76	21%
Li-ion	12.48	40%	14.67	44%	17.13	48%	34.18	79%	41.67	79%
Total	31.09	100%	33.19	100%	35.43	100%	43.10	100%	52.43	100%

EU market by value of the sold CPT

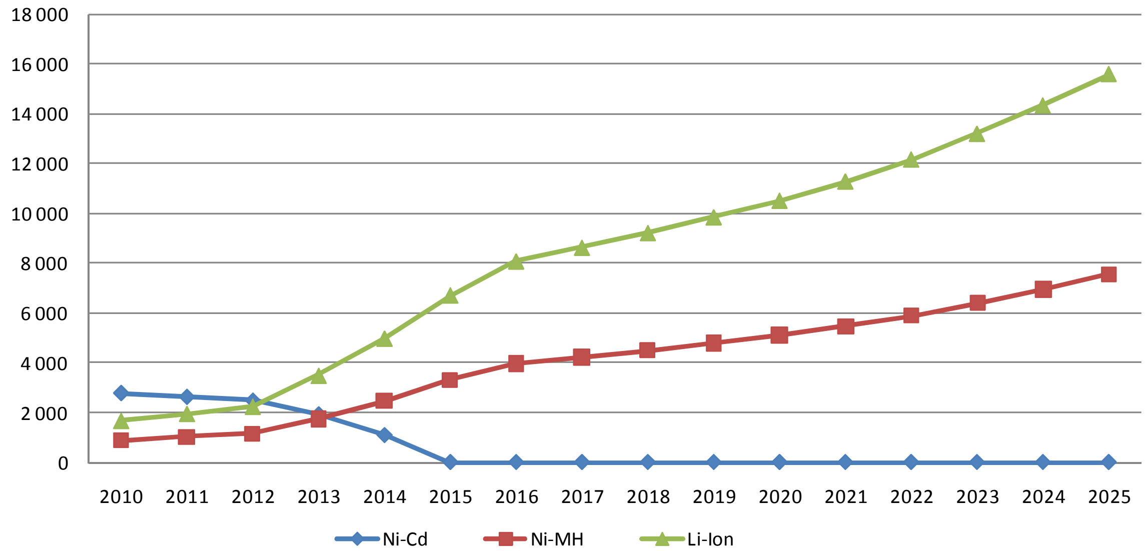
Battery type	2008		2009		2010		2013		2016	
	Million euros	%	Million euros	%	Million euros	%	Million euros	%	Million euros	%
NiCd	464.07	44%	438.02	39%	413.44	34%	0.00	0%	0.00	0%
NiMH	111.96	11%	137.27	12%	157.18	13%	298.19	19%	344.96	19%
Li-ion	474.00	45%	557.53	49%	650.77	53%	1298.74	81%	1440.87	81%
Total	1050.03	100%	1132.83	100%	1221.38	100%	1596.93	100%	1785.83	100%

8. EVOLUTION OF WASTE CPT BATTERY COLLECTION (IN TONNES) IN EU, 2010-2025 IN BAU SCENARIO (OPTION 2)

The calculation methodology and the assumptions behind the projections of waste CPT battery waste collected in EU in this scenario over the period 2010-2025 are the same as the BaU scenario (Option 1).

Figure 13 shows that the overall collected quantities of waste CPT batteries will increase from 5,370 tonnes in 2010 to 23,140 tonnes in 2025. The overall quantity of waste CPT batteries collected during the period 2010-2025 would be 210,325 tonnes.

Figure 13: Evolution of waste CPT battery collection (in tonnes) in EU, 2010-2025 (Option 2)



9. EVOLUTION OF THE OVERALL CPT BATTERY MARKET (PRO AND DIY) IN EU OVER THE PERIOD 2010-2025 (OPTION 3)

The assumptions concerning overall CPT market forecast, replacement rate of NiCd batteries in CPTs by Li-ion and NiMH batteries and number of batteries sold per CPT which are used for the projections made here are same as the BaU scenario (Option 1).

The evolution of the overall, PRO and DIY CPT market in current scenario over the period 2010-2025 is presented in figures below.

Figure 14: Evolution of overall CPT battery market (number of battery pack units) in EU until 2025 (Option 3)

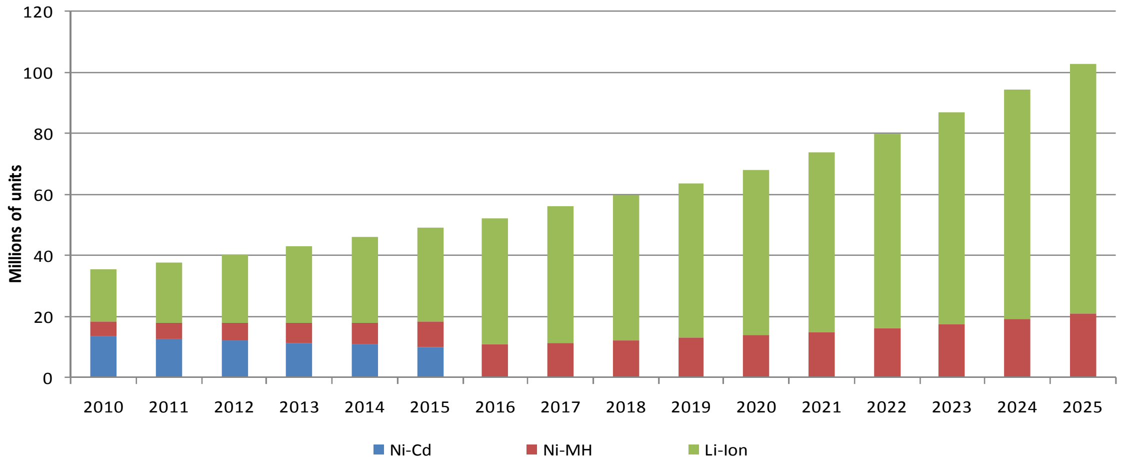


Figure 15: Evolution of PRO CPT battery market (number of battery pack units) in EU until 2025 (Option 3)

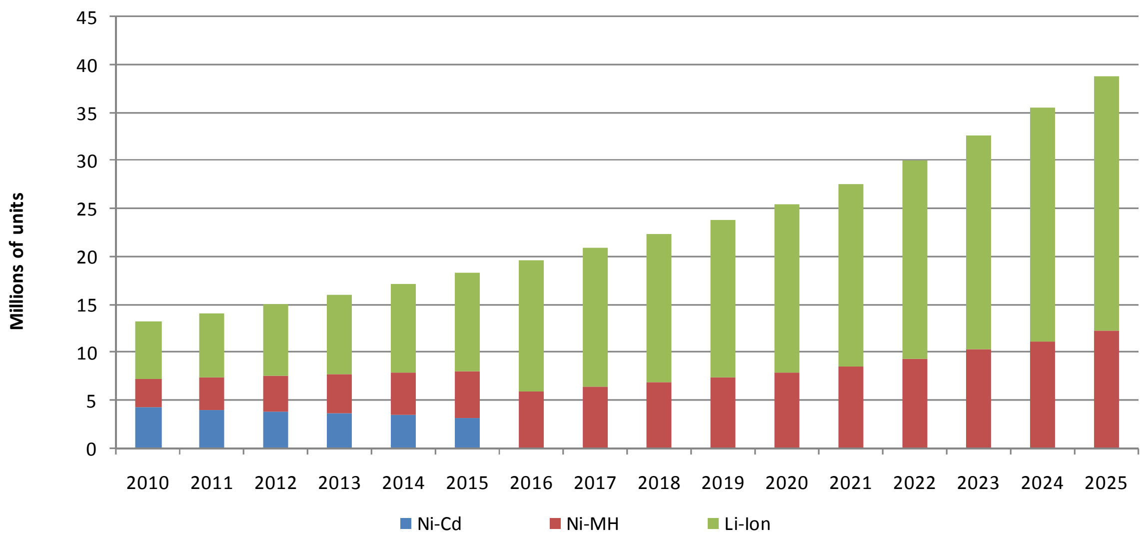
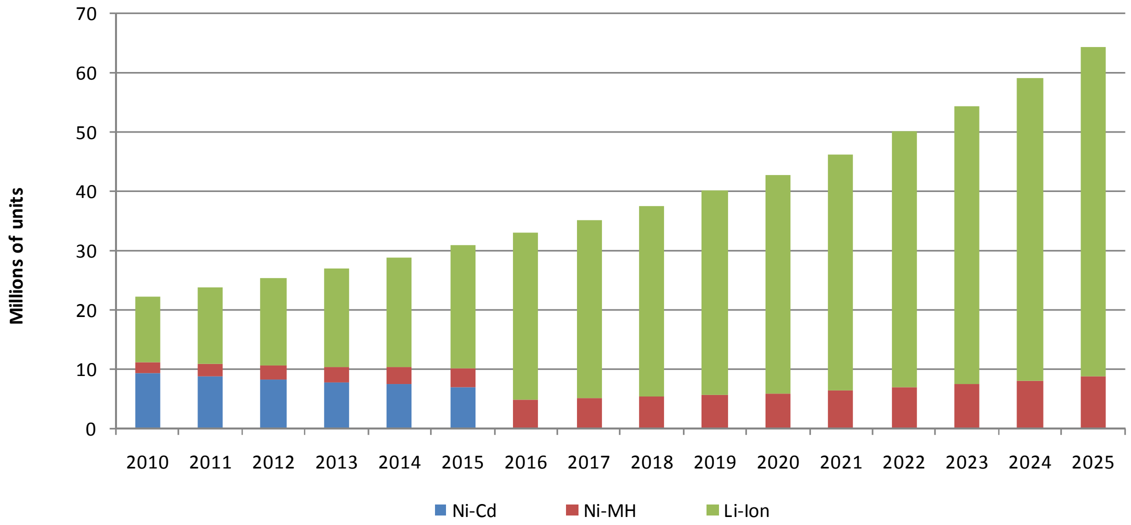


Figure 16: Evolution of DIY CPT battery market (number of battery pack units) in EU until 2025 (Option 3)



<u>Policy Option 3:</u>

EU market by number of units (batteries for CPTs)

Battery type	2008		2009		2010		2013		2016	
	Million units	%	Million units	%	Million units	%	Million units	%	Million units	%
NiCd	15.27	49%	14.41	43%	13.60	38%	11.44	27%	0.00	0%
NiMH	3.35	11%	4.11	12%	4.70	13%	6.63	15%	10.76	21%
Li-ion	12.48	40%	14.67	44%	17.13	48%	25.03	58%	41.67	79%
Total	31.09	100%	33.19	100%	35.43	100%	43.10	100%	52.43	100%

EU market by value of the sold CPT

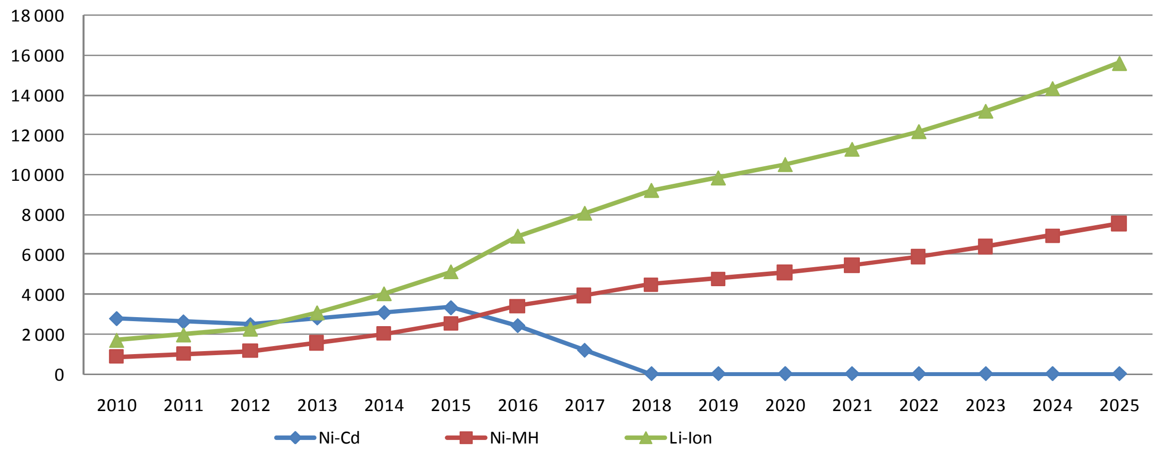
Battery type	2008		2009		2010		2013		2016	
	Million euros	%	Million euros	%	Million euros	%	Million euros	%	Million euros	%
NiCd	464.07	44%	438.02	39%	413.44	34%	347.66	23%	0.00	0%
NiMH	111.96	11%	137.27	12%	157.18	13%	221.71	15%	344.96	19%
Li-ion	474.00	45%	557.53	49%	650.77	53%	951.08	63%	1440.87	81%
Total	1050.03	100%	1132.83	100%	1221.38	100%	1520.44	100%	1785.83	100%

10. EVOLUTION OF WASTE CPT BATTERY COLLECTION (IN TONNES) IN EU, 2010-2025 IN BAU SCENARIO (OPTION 3)

The calculation methodology and the assumptions behind the projections of CPT battery waste collected in EU in this scenario over the period 2010-2025 are the same as the BaU scenario (Option 1).

Figure 17 shows that the overall collected quantities of waste CPT batteries increase from 5,370 tonnes in 2010 to 23,140 tonnes in 2025. The overall quantity of waste CPT batteries collected during the period 2010-2025 is 213,300 tonnes.

Figure 17: Evolution of waste CPT battery collection (in tonnes) in EU, 2010-2025 (Option 3)

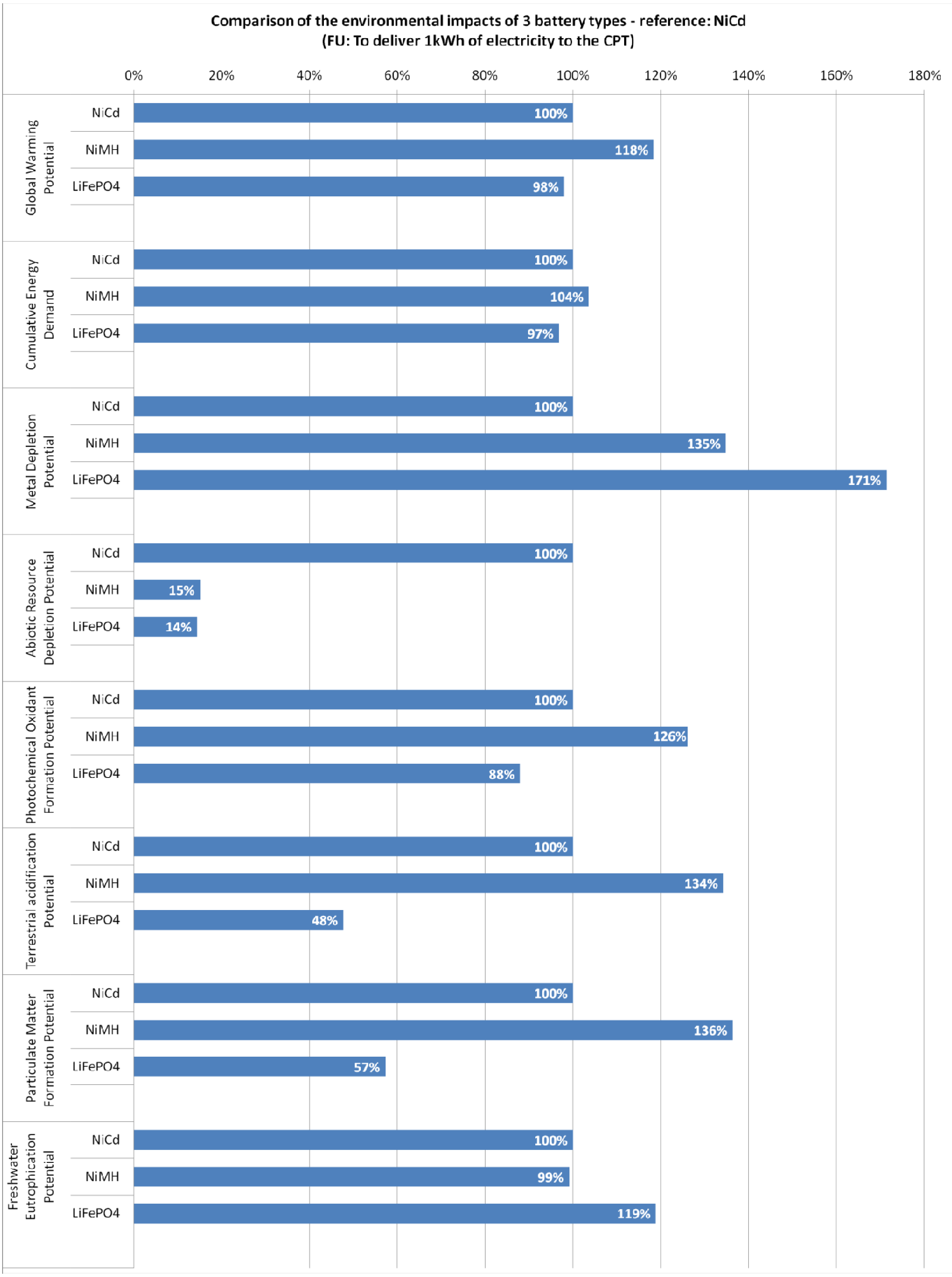


11. LIFE-CYCLE ASSESSMENT – COMPARATIVE ANALYSIS

Comparison for indicators other than toxicity

Figure 18 presents the comparison for all considered indicators except toxicity indicators, treated in a further section. In order to improve the readability of the results, it shows the relative ranking of the batteries for each indicator, the NiCd being the reference (100%). This normalisation allows presenting all indicators on the same graph. However, this does not make several indicators of the same graph comparable.

Figure 18: Comparative results for each indicator (except toxicity indicators) - Reference:NiCd



The following interpretations can be made:

- Global Warming Potential and Cumulative Energy Demand

Even though on can see a higher impact of NiMH compared to the two other batteries, this difference cannot be considered as significant, considering the inherent uncertainty of the LCA model. Thus, it should be considered that there is no significant difference between the three batteries for these indicators. These impacts are mainly generated by the use phase for the three battery types. Since the energy consumption is similar for the three technologies, total impacts on Global Warming Potential and Cumulative Energy Demand lay in the same range for the three battery types.

- Resource Depletion
  - Metal Depletion Potential

The $LiFePO_4$ battery shows a higher impact than the two other batteries due to the inclusion of more electronic components both in the pack and the charger, and consequently due to a higher use of tin. The NiMH battery shows a higher impact on metal depletion than the NiCd battery due to its higher nickel content.

  - Abiotic Resource Depletion Potential

The NiCd battery has a significantly higher potential impact on this indicator than the two other battery types. This is mainly because NiCd contains cadmium that contributes highly to abiotic resource depletion.

- Photochemical Oxidant Formation Potential

NiMH battery shows a higher photochemical oxidant formation potential than the two other battery types, due to a higher contribution of NiMH cells to this impact (emissions of nitrogen oxides to air related to the production of $LaNi_5$)

- Terrestrial Acidification Potential

The NiMH battery shows a higher impact on acidification due to a higher contribution of the cells to this impact. This impact is mainly due to the emissions of SO_2 to air related to the production of nickel and $LaNi_5$. NiMH cells have a higher nickel content, hence the impact difference with NiCd.

The $LiFePO_4$ battery shows a lower acidification potential than the other battery types. The main reason is that the production of the $LiFePO_4$ compound emits less acidifying substances than the production of nickel.

- Particulate Matter Formation Potential

NiMH battery shows a higher impact for this indicator due to a higher contribution of the cells to this impact. This is mainly due to emissions of SO_2 to air during the production of nickel and $LaNi_5$ (for cells). NiMH cells have a higher nickel content, hence the impact difference with NiCd.

- Freshwater Eutrophication Potential

The $LiFePO_4$ battery shows slightly higher impact than the two other batteries due to a higher contribution to cells and charger to this impact. The main reasons are the higher copper content and the higher electronics content which both generate emissions of phosphate (respectively during the production of copper and during the production of silver for the charger's inductor).

Comparison for toxicity indicators

Figure 19 and Figure 20 present the comparison on toxicity impacts. Results are presented in absolute figures. For a better readability, each environmental impact is split between the contributions of short-term emissions (in brown), 5% long-term emissions (in red) and the rest of long-term emissions (95%, in pink).

Figure 19: Comparative results for human toxicity

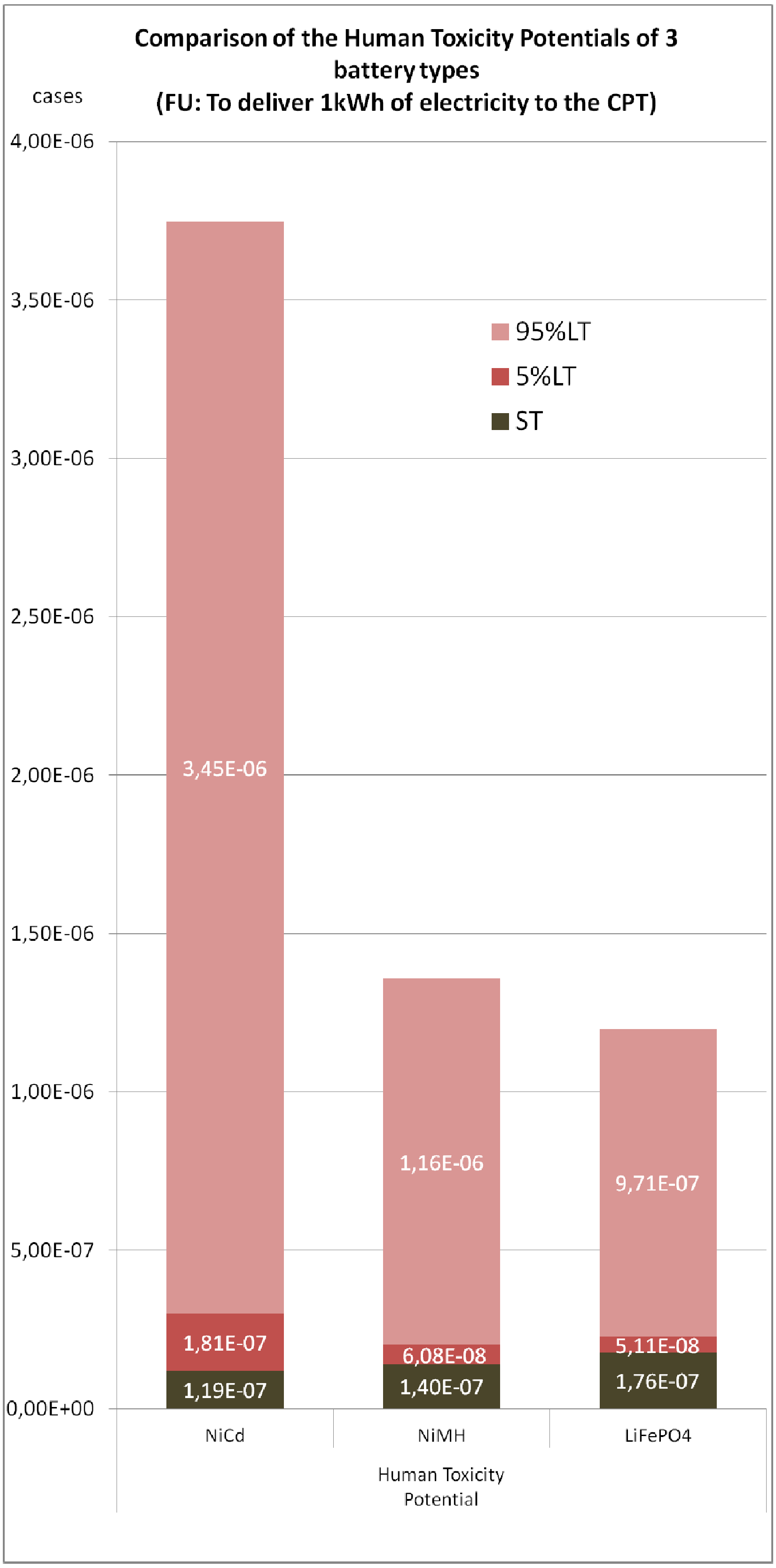
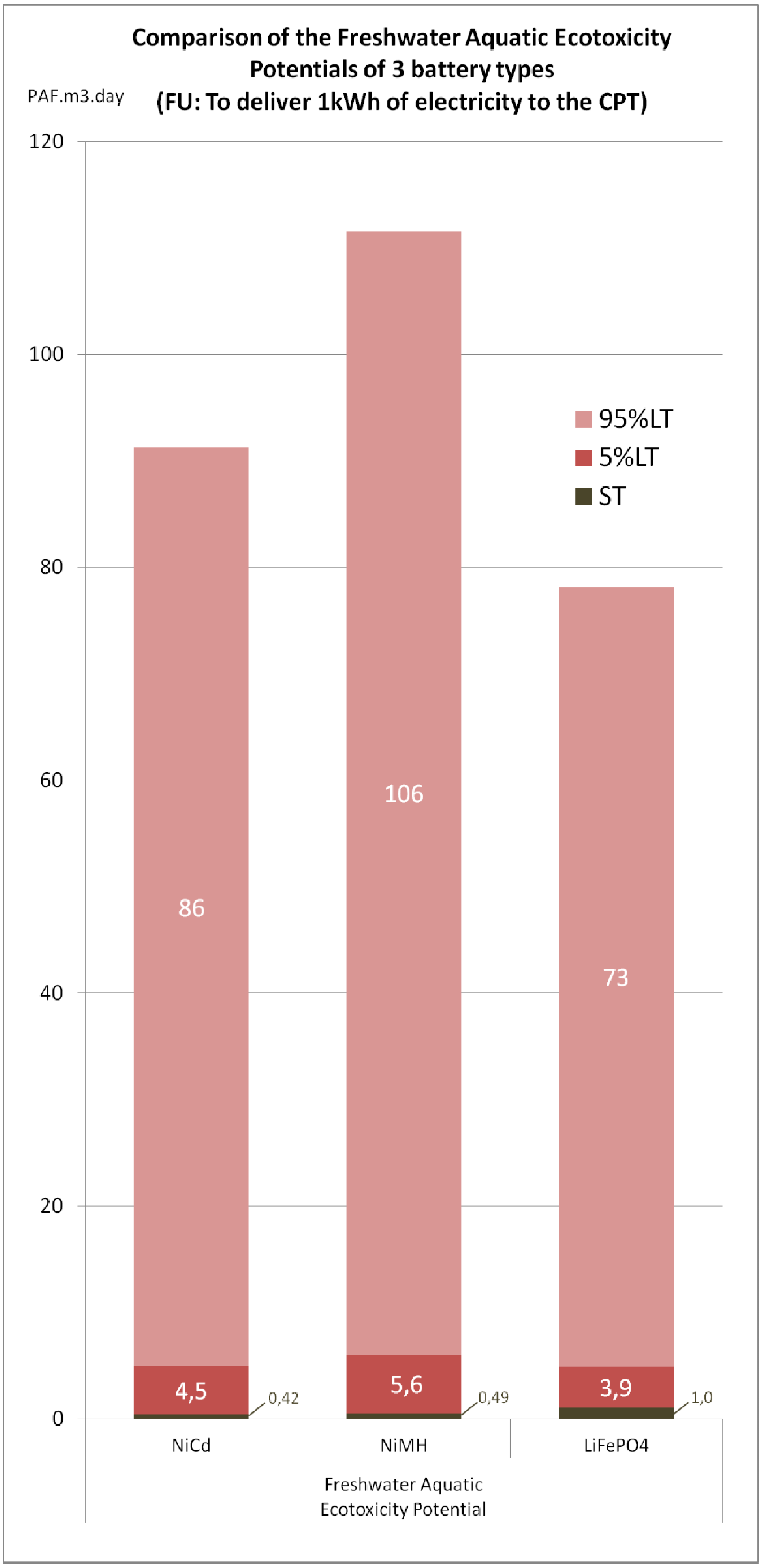


Figure 20: Comparative results for freshwater ecotoxicity



The following interpretations can be made:

- Long-term (LT) perspective

  – Human Toxicity Potential with long-term emissions

The NiCd battery has a higher potential impact than the two other battery types, mainly because of the presence of cadmium in the cells and consequently its potential emissions to water for the fraction of batteries that go into landfills.

  – Freshwater Aquatic Ecotoxicity Potential with LT emissions

The differences between batteries are low. The NiMH battery shows a slightly higher potential impact than the two other battery types, mainly because of the potential emissions of nickel to water in landfills.

- Intermediate situation

  – Human Toxicity Potential with 5% LT emissions

The NiCd battery has a higher potential impact than the two other battery types, mainly because of the presence of cadmium in the cells and consequently potential emissions to water of 5% of the metallic content of landfilled batteries.

  – Freshwater Aquatic Ecotoxicity Potential with 5% long-term emissions

Impacts of the three batteries do not significantly differ for this indicator (differences are lower than with 100% of LT emissions).

- Short-term (ST) perspective

  – Human Toxicity Potential - without LT emissions

For this indicator, $LiFePO_4$ has a higher potential impact than the two other battery types. The difference is due to a higher impact of:

– the cells (mainly due to the emissions of lead, arsenic, cadmium and zinc to air during the production of copper)

– the charger (mainly due to the emissions of lead, arsenic, cadmium and zinc to air during the production of electronic components). The charger of LiFePO4 batteries contains more electronic components than the charger of other battery technologies.

  – Freshwater Aquatic Ecotoxicity Potential - without LT emissions

For this indicator, $LiFePO_4$ has a higher potential impact than the two other battery types. The difference is due to the higher impact of:

– the pack (emission of zinc to water and copper to air related to the manufacturing of electronic components)

– the charger (mainly due to the emission of zinc to water related to the production of electronic components).

12. LIST OF ENVIRONMENTAL INDICATORS

Table 10: List of environmental impact indicators used for the policy analysis

Impact category	Indicator	Unit
Environmental	Global Warming Potential (GWP)	kg CO2 eq[13]
	Photochemical Oxidant Formation Potential (POFP)	kg NMVOC
	Terrestrial Acidification Potential (TAP)	kg SO2 eq.
	Abiotic Resource Depletion Potential (ARDP)	kg Sb eq.
	Human Toxicity Potential (HTP)	Cases[14]
	Freshwater Aquatic Ecotoxicity Potential (FAEP)	PAF[15]. m^3.day
	Particulate Matter Formation Potential (PMFP)	kg PM10 eq
	Freshwater Eutrophication Potential (FEP)	kg P eq

To allow for a coherent analysis based on the available data, these indicators were scaled to represent their contribution to the sum of the eight impacts indicators under consideration (see Table 10).[16] The results of this scaling are presented in Table 11.

Table 11: Scaled weighting factors[17]

Environmental impact indicator	%
GWP	33.2%
POFP	7.2%

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13 Please note: "eq" is used as an abbreviation for "equivalent"

14 Human toxicity potential assesses the impact of toxic substances released in the environment on the human health by providing an estimation of the increase in morbidity in the total human population (cases). Both cancer and non-cancer cases are taken into account.

15 Please note: Potentially Affected Fraction (PAF) of species integrated over time and volume, PAF m3.day, is the unit used to assesses the impact of toxic substances released in the environment on the ecosystem

16 Source: "Environmental effects in eco-efficiency: how to evaluate them?" Lauran van Oers; CML-IE, Leiden University, June 2010 (www.eco-efficiency-conf.org/content/Lauran%20van%20Oers%20-%20Environmental%20effects%20in%20eco-efficiency.pdf).

17 The factors were scaled by dividing by the sum of the weighting factors of the eight impact categories under consideration (69.3%).

TAP	5.8%
ARDP	10.1%
HTP	14.4%
FAEP	15.9%
PMFP	10.1%
FEP	3.4%

13. ENVIRONMENTAL IMPACTS OF BATTERY PACKS (INCLUDING CHARGERS) BASED ON LCA RESULTS

Table 12 to Table 14 present the environmental impacts for 2 battery packs (including the impact of their chargers) for each of the three battery types based on the outcomes of LCA for different waste battery collection rates (25%, 30%, 35%, 40%, 45% and 10%) in EU.

Table 12: Environmental impacts for two packs of NiCd batteries for different collection rate values

Environmental indicator	Units	Collection rate (in %)					
		25%	30%	35%	40%	45%	10%
Global Warming Potential	kg CO2 eq	70.60	70.49	70.38	70.27	70.16	70.90
Photochemical Oxidant Formation Potential	kg NMVOC	0.219	0.217	0.215	0.212	0.210	0.226
Terrestrial acidification Potential	kg SO2 eq	0.632	0.611	0.591	0.570	0.549	0.695
Metal depletion	kg Fe eq	18.82	18.47	18.13	17.78	17.43	19.86
Abiotic Resource Depletion Potential	kg Sb eq	3.29	3.13	2.97	2.81	2.64	3.78
Cumulative Energy Demand	MJ	1498	1498	1498	1498	1498	1498
Human Toxicity Potential without LT	Cases	6.79E-06	6.70E-06	6.61E-06	6.52E-06	6.43E-06	7.07E-06
Freshwater Aquatic Ecotoxicity Potential without LT	PAF.m3.day	23.60	23.14	22.68	22.21	21.75	25.00
Human Toxicity Potential, 5% LT	Cases	1.60E-05	1.53E-05	1.47E-05	1.41E-05	1.35E-05	1.79E-05
Freshwater Aquatic Ecotoxicity Potential, 5% LT	PAF.m3.day	256	243	230	217	204	295
Human Toxicity Potential with LT	Cases	1.90E-04	1.80E-04	1.69E-04	1.58E-04	1.47E-04	2.23E-04
Freshwater Aquatic Ecotoxicity Potential with LT	PAF.m3.day	4 666	4 414	4 162	3 909	3 657	5 423
Cadmium emissions to water, ST + LT	kg	0.309	0.289	0.268	0.248	0.227	0.37
Cadmium emissions to water, ST + 5%LT	kg	0.016	0.014	0.013	0.012	0.011	0.02
Particulate Matter Formation Potential	kg PM10 eq	0.172	0.168	0.163	0.158	0.153	0.19
Freshwater Eutrophication Potential	kg P eq	0.194	0.191	0.189	0.186	0.183	0.20

Table 13: Environmental impacts for two packs of NiMH batteries for different collection rate values

Environmental indicator	Units	Collection rate (in %)					
		25%	30%	35%	40%	45%	10%
Global Warming Potential	kg CO2 eq	82.92	82.59	82.25	81.92	81.58	83.90
Photochemical Oxidant Formation Potential	kg NMVOC	0.265	0.258	0.252	0.245	0.239	0.285
Terrestrial acidification Potential	kg SO2 eq	0.772	0.718	0.664	0.610	0.557	0.933
Metal depletion	kg Fe eq	24.63	23.92	23.21	22.50	21.79	26.77
Abiotic Resource Depletion Potential	kg Sb eq	0.56	0.56	0.56	0.56	0.56	0.57
Cumulative Energy Demand	MJ	1535	1529	1524	1518	1512	1552
Human Toxicity Potential without LT[18]	Cases	7.82E-06	7.67E-06	7.51E-06	7.35E-06	7.19E-06	8.30E-06
Freshwater Aquatic Ecotoxicity Potential without LT	PAF.m3.day	26.18	25.23	24.29	23.34	22.40	29.01
Human Toxicity Potential, 5% LT	Cases	1.08E-05	1.05E-05	1.01E-05	9.72E-06	9.35E-06	1.19E-05
Freshwater Aquatic Ecotoxicity Potential, 5% LT	PAF.m3.day	306	288	270	252	234	359
Human Toxicity Potential with LT	Cases	6.77E-05	6.33E-05	5.90E-05	5.47E-05	5.04E-05	8.06E-05
Freshwater Aquatic Ecotoxicity Potential with LT	PAF.m3.day	5 618	5 280	4 941	4 602	4 264	6 634
Cadmium emissions to water, ST + LT	kg	0	0	0	0	0	0
Cadmium emissions to water, ST + 5%LT	kg	0	0	0	0	0	0
Particulate Matter Formation Potential	kg PM10 eq	0.218	0.206	0.193	0.181	0.169	0.255
Freshwater Eutrophication Potential	kg P eq	0.184	0.179	0.174	0.168	0.163	0.200

18 Please note: Human toxicity and Freshwater Ecotoxicity are assessed both excluding and including long-term emissions: the so-called "short-term perspective" means that only short-term emissions are considered (long-term emissions are excluded), and the so-called "long-term perspective" means that both Short-Term (ST) and Long-Term (LT) emissions are included. This allows assessing impacts when all metals are leached (with LT) and when few metals are leached (without LT). An intermediate situation has also been considered, where 5% of the metals are eventually leached to the environment (i.e. in the long-term).

Table 14: Environmental impacts for two packs of Li-ion (LiFePO4) batteries for different collection rate values

Environmental indicator	Units	Collection rate (in %)					
		25%	30%	35%	40%	45%	10%
Global Warming Potential	kg CO2 eq	76.52	76.57	76.62	76.67	76.73	76.43
Photochemical Oxidant Formation Potential	kg NMVOC	0.218	0.219	0.219	0.219	0.219	0.218
Terrestrial acidification Potential	kg SO2 eq	0.361	0.361	0.361	0.360	0.360	0.364
Metal depletion	kg Fe eq	37.10	37.04	36.97	36.91	36.84	37.43
Abiotic Resource Depletion Potential	kg Sb eq	0.60	0.60	0.60	0.60	0.60	0.60
Cumulative Energy Demand	MJ	1596	1597	1597	1597	1598	1595
Human Toxicity Potential without LT	Cases	1.13E-05	1.12E-05	1.11E-05	1.11E-05	1.10E-05	1.15E-05
Freshwater Aquatic Ecotoxicity Potential without LT	PAF.m3.day	66.97	66.92	66.86	66.80	66.74	67.25
Human Toxicity Potential, 5% LT	Cases	1.45E-05	1.45E-05	1.44E-05	1.43E-05	1.42E-05	1.48E-05
Freshwater Aquatic Ecotoxicity Potential, 5% LT	PAF.m3.day	295	287	280	272	264	319
Human Toxicity Potential with LT	Cases	7.68E-05	7.64E-05	7.60E-05	7.57E-05	7.53E-05	7.83E-05
Freshwater Aquatic Ecotoxicity Potential with LT	PAF.m3.day	4 633	4 477	4 320	4 163	4 006	5 108
Cadmium emissions to water, ST + LT	kg	0	0	0	0	0	0
Cadmium emissions to water, ST + 5%LT	kg	0	0	0	0	0	0
Particulate Matter Formation Potential	kg PM10 eq	0.117	0.117	0.117	0.117	0.117	0.118
Freshwater Eutrophication Potential	kg P eq	0.262	0.261	0.261	0.260	0.260	0.264

14. METHODOLOGY USED FOR ESTIMATION OF ECONOMIC, SOCIAL AND ENVIRONMENTAL IMPACTS

Selection of impact categories and indicators

Table 15 presents a selection of indicators that are used to guide the analysis of economic, social and environmental impacts of the proposed policy options. These indicators are mostly measured quantitatively and when data was not available (either through literature review or stakeholder consultation), a qualitative assessment was made.

Table15: List of impact categories and the corresponding methods of evaluation

Impact category	Indicator	Unit (if applicable)	Method for evaluation
Economic	Implementation cost (industry costs and MS administrative costs)	Euros	Expert consultation (Portable battery industry representatives and industry associations) and literature review
	Impact on consumers	Euros	Expert consultation and literature review
	Control and monitoring cost (MS)	Euros	Expert consultation (Portable battery industry representatives and industry associations) and literature review
	Waste management costs	Euros	Expert consultation and literature review
Social	Employment generation	Semi-quantitative	Expert consultation and literature review
Environmental	Cadmium introduction in the economy	Tonnes	Expert consultation and literature review
	Global Warming Potential (GWP)	kg CO2 eq[19]	Based on the results of LCA carried out in this study
	Cadmium emissions	Tonnes	Based on the results of LCA carried out in this study
	Cumulated Energy Demand (CED)	MJ	Based on the results of LCA carried out in this study
	Photochemical Oxidant Formation Potential (POFP)	kg NMVOC	Based on the results of LCA carried out in this study
	Terrestrial Acidification Potential (TAP)	kg SO2 eq.	Based on the results of LCA carried out in this study
	Metal Depletion (MD)	kg Fe eq.	Based on the results of LCA carried out in this study
	Abiotic Resource Depletion Potential (ARDP)	kg Sb eq.	Based on the results of LCA carried out in this study
	Human Toxicity Potential (HTP)	Cases[20]	Based on the results of LCA carried out in this study
	Freshwater Aquatic Ecotoxicity	PAF[21].	Based on the results of LCA carried out in this

[19] Please note: “eq” is used as an abbreviation for “equivalent”

[20] Human toxicity potential assesses the impact of toxic substances released in the environment on the human health by providing an estimation of the increase in morbidity in the total human population (cases). Both cancer and non-cancer cases are taken into account.

	Potential (FAEP)	m^3.day	study
	Particulate Matter Formation Potential (PMFP)	kg PM10 eq	Based on the results of LCA carried out in this study
	Freshwater Eutrophication Potential (FEP)	kg P eq	Based on the results of LCA carried out in this study

21 Please note: Potentially Affected Fraction (PAF) of species integrated over time and volume, PAF m3.day, is the unit used to assesses the impact of toxic substances released in the environment on the ecosystem

In addition to the impact categories and indicators listed in the Table 15, depending on availability of information and relevance, other criteria or impacts to examine include:

– Degree of uncertainty/risk

– Interaction with other Community interventions

– Efficiency & effectiveness (value for money)

- Methodology to assess the environmental impacts

The assessment of environmental impacts of the batteries used in CPTs under the three policy options considered here only include the impacts of the battery packs (for all the three battery types: NiCd, NiMH and Li-ion). The environmental impacts associated with the chargers of these battery packs are therefore **excluded** from the assessment carried out in this section[22]. This is mainly due to the reason that the charger is not covered by the Batteries Directive but by WEEE and RoHS Directives and the objective of current impact assessment is only to review an exemption under the Batteries Directive.

The most relevant environmental impact indicators selection (Table 15) was done based on the LCA performed in "BIO" study.

The environmental impacts reported as per functional unit[23] in the LCA were then characterised to impacts corresponding to 2 battery packs units (for each of the three battery types: NiCd, NiMH and Li-ion) for different waste battery collection rates (10%, 25%, 30%, 35%, 40% and 45%)[24] in EU.

The overall environmental impacts in EU for each of the three policy options was then calculated by summing up the environmental impacts corresponding to sales of all the three battery types in EU market over the period 2010-2025. This calculation was performed based on the following data and assumptions:

– The market forecast provided in Annexes 5, 7 and 9

– The environmental impacts corresponding to sales of all the three battery types (2 battery packs) presented in Annex 9 of "BIO" study

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22 For informational purpose, environmental impacts of the three battery types (including the environmental impacts of their chargers) are provided in Annex 13.

23 In practice, the functional unit is used to scale the inputs and outputs (materials, energy, etc.) of each system studied. Consequently, the environmental impacts computed from these flows are automatically scaled to the functional unit.

24 The 10% collection rate corresponds to the WEEE collection rate reported for Category 6 in 2008 whereas the 25%, and 45% collection rates correspond to the evolution of waste battery collection in EU as required by the Battery Directive whereas the 30%, 35% and 40% collection rates to correspond for years 2013, 2014 and 2015 respectively based on the assumption that under the Battery Directive requirement on collection rate, there will be natural linear evolution of collection rate from 25% in 2012 to 45% in 2016.

– Assuming all the environmental impacts associated with the sales of batteries happen during the year of sales (even those occurring during at the end-of-life of the battery)

– Using the collection rate values defined (10%, 25%, 30%, 35%, 40% and 45%)

To allow for a meaningful comparison between the different environmental impacts, each policy option's value for each impact indicator was normalised to its 'inhabitant equivalent'.

The values used for normalisation factors are presented in Table 16.

Table 16: Normalisation factors used to calculate 'inhabitant-equivalent'[25]

Environmental impact indicator	Normalisation factor (per inhabitant)
GWP	11 232 kg CO2 eq
POFP	57.0 kg NMVOC
TAP	53.7 kg SO2 eq
ARDP	36.4 kg Sb eq
HTP	0.000 85 Cancer and non-cancer cases
FAEP	23.9 PAF.m3.day
PMFP	17.5 kg PM10 eq
FEP	0.75 kg P eq

The normalised values for Metal Depletion (MD) and Cumulative Energy Demand (CED) were not available from these sources and hence these environmental impact indicators have not been considered in the normalisation step.

Having normalised values for impact indicators presented in Table 16, it is possible to apply an aggregation scheme to calculate a value for total environmental impact for each policy option. The normalisation process produces a value which is equal to the contribution of that many average Europeans' contribution to given impact indicator. Thus, saying "Policy Option X has a contribution of $Y_{\text{inhabitant-eq}}$ to impact indicator Z" would mean that Policy Option X's contribution to impact indicator Z is equivalent to that of Y average European citizens.

An example of such results is presented in Table 17.

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25 These values were developed taking into account EU 25 +3 (EU25+ Iceland +Norway+ Switzerland) level in 2000 based on the values presented in:
1: *"Normalisation in product LCA: an LCA of the global and european economic systems in the year 2000, Wegener Sleeswijk (2008)"* for GWP, POFP, TAP, PMFP and FEP;
2: *"Instititute of Environmental Sciences (CML) database (2008)"* for ARDP;
3: *"Laurent et al. Normalization references for Europe and North America for application with USEtox™ characterization factors (2011)"* for HTP and FAEP.

Table 17: Example of environmental impacts in 'inhabitant-equivalent' (Policy Option X)

Environmental impact indicator	Inhabitant-Eq
GWP	210 986
POFP	120 654
TAP	249 064
ARDP	788 517
HTP	355 255
FAEP	68 052 504
PMFP	236 698
FEP	9 638 276

The example shown inTable 17 could be thus explained as follows: Policy Option X's contribution to Freshwater Aquatic Ecotoxicity Potential (FAEP) is equivalent to that of approximately 68 million Europeans.

The weighting factors for various environmental impact categories used in study are summarised in Table 18.

Table18: Average weighting factors[26]

Environmental impact indicator	%
GWP	23.0%
POFP	5.0%
TAP	4.0%
ARDP	7.0%
HTP	10.0%
FAEP	11.0%
PMFP	7.0%
FEP	2.3%

[26] Source : "Environmental effects in eco-efficiency: how to evaluate them?" Lauran van Oers; CML-IE, Leiden University. June 2010 (www.eco-efficiency-conf.org/content/Lauran%20van%20Oers%20-%20Environmental%20effects%20in%20eco-efficiency.pdf)

As the chosen environmental impact indicators in this study do not include all impact indicators specified by Lauran van Oers[26], the values in Table 18 only represent 69.3% (=23 + 5 + 4 + 7 + 10 + 11 + 7 + 2.3) of the total environmental impact as calculated in this weighting scheme[27]. To allow for a coherent analysis based on the available data, these factors were scaled[28] to represent their contribution to the sum of the eight impacts indicators under consideration (see Table 18). The results of this scaling are presented in Table 19.

Table 19: Scaled weighting factors

Environmental impact indicator	%
GWP	33.2%
POFP	7.2%
TAP	5.8%
ARDP	10.1%
HTP	14.4%
FAEP	15.9%
PMFP	10.1%
FEP	3.4%

The aggregated environmental impact for each policy option was then calculated, using the following formula:

$$\begin{aligned} \textit{Aggregated Environmental Impact} = \; & (GWP_{inhabitant\text{-}Eq} \times 0.332) + \\ & (POFP_{inhabitant\text{-}Eq} \times 0.072) + \\ & (TAP_{inhabitant\text{-}Eq} \times 0.058) + \\ & (ARDP_{inhabitant\text{-}Eq} \times 0.101) + \\ & (HTP_{inhabitant\text{-}Eq} \times 0.144) + \\ & (FAEP_{inhabitant\text{-}Eq} \times 0.159) + \\ & (PMFP_{inhabitant\text{-}Eq} \times 0.101) + \\ & (FEP_{inhabitant\text{-}Eq} \times 0.034) \end{aligned}$$

An example of the weighted results, using the scaled weighting factors provided in Table 19, as well as the sum of the results (i.e. the aggregated impact) are presented in Table 20.

27 Examples of such impact indicators (and their weighting) include 'Ozone Depletion' (4%), 'Marine Eutrophication' (2.3%), etc.

28 The factors were scaled by dividing by the sum of the weighting factors of the eight impact categories under consideration (69.3%).

Table 20: Example of weighted impact values and aggregate impact, using scaled weighting factors (Policy Option X)

Environmental impact indicator	Inhabitant-Eq
GWP	58 986
POFP	6 439
TAP	11 993
ARDP	70 061
HTP	34 935
FAEP	29 023 244
PMFP	19 384
FEP	223 396
Aggregate	**29 448 438**