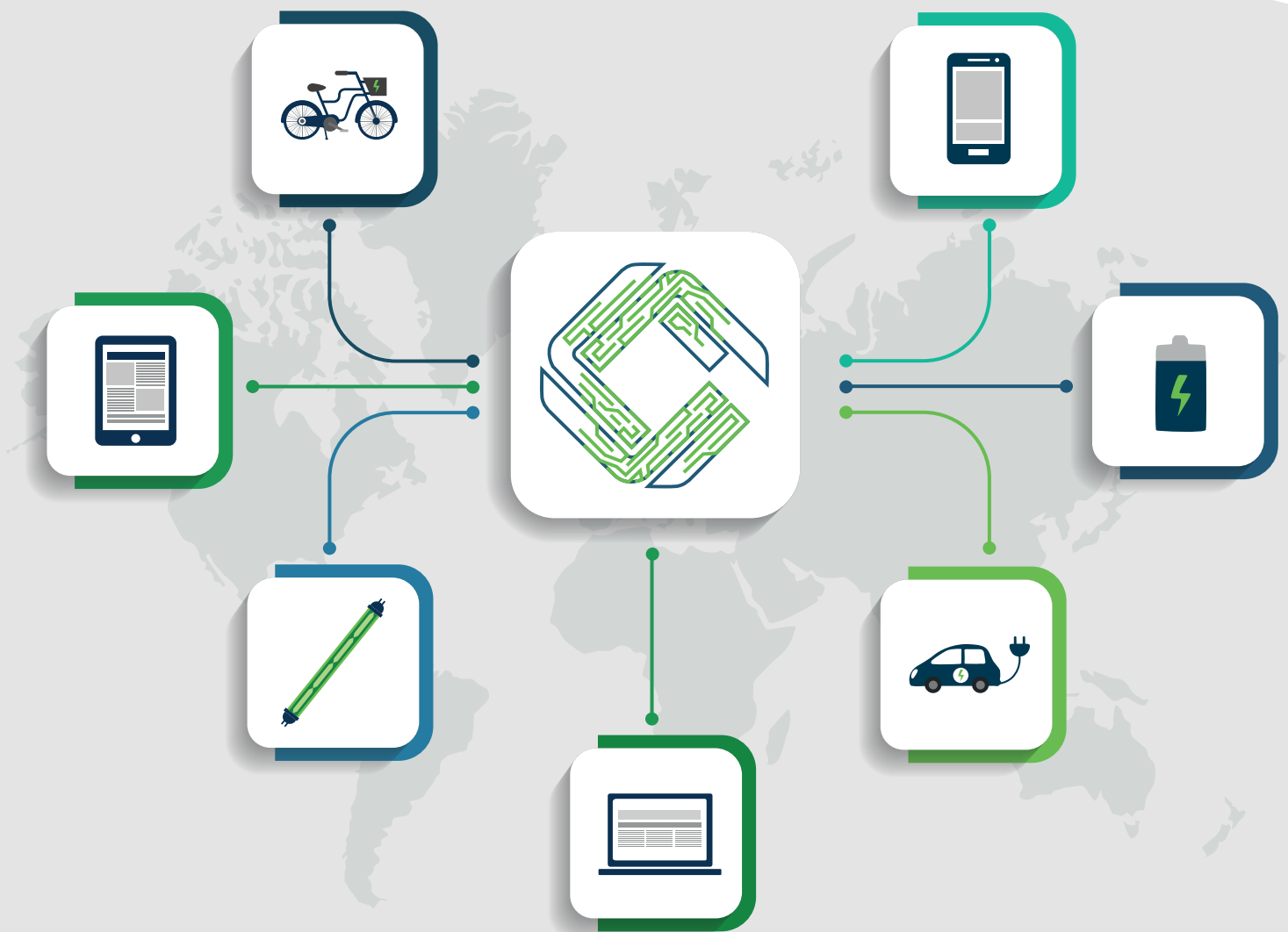


A contribution to future Critical Raw Materials Recycling

CEWASTE PROJECT FINAL REPORT



This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 820859.



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Year of publication

2021

ISBN

978-2-9602819-0-3

Design and layout

Weblink Software Sp. z o. o., Sosnowiec, Poland
weblinksoftware.com

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ACRONYMS

Ag	Silver
Au	Gold
BEV	Battery Electric Vehicle
Bi	Bismuth
CDD	Compact disc drive
Ce	Cerium
CEN	European Committee for standardization
CENELEC	European Committee for Electrotechnical Standardization
Co	Cobalt
CRM	Critical Raw Material
CRT	Cathode Ray Tube
Dy	Dysprosium
EEE	Electrical and Electronic Equipment
ELV	End-of-life Vehicle
Eu	Europium
EU	European Union
HDD	Hard Disc Drive
HEV	Hybrid Electric Vehicle
IEC	International Electrotechnical Commission
Ir	Iridium
KCC	Key CRM Component
KCE	Key CRM-Equipment
LHA	Large household appliances
La	Lanthanum
Li	Lithium
Li-ion	Lithium-ion
MSX	Membrane Solvent Extraction
MtM	Magnet to Magnet
Nd	Neodymium

NdFeB-magnets	Neodymium iron boron (NdFeB) magnets
NiMH	Nickel Metal Hydride
ODD	Optical Disc Drive
PCB	Printed Circuit Board
Pd	Palladium
PGM	Platinum Group Metal (Pd, Pt, Rh, Ru, Os, Ir), sub-group of precious metals
PHEV	Plug-in Hybrid Electric Vehicle
PM	Precious Metal (Ag, Au, PGMs)
Pr	Praseodymium
PRO	Producer Responsibility Organisation
Pt	Platinum
REE	Rare Earth Elements
Rh	Rhodium
Ru	Ruthenium
Sb	Antimony
Tb	Terbium
TRL	Technology Readiness Level
TS	Technical Specification
TV	Television
WEEE	Waste Electrical and Electronic Equipment
Y	Yttrium

GLOSSARY

Accreditation

Third-party attestation related to a conformity assessment body conveying formal demonstration of its competence to carry out specific conformity assessment tasks.

CENELEC (European Committee for Electrotechnical Standardization)

CENELEC is one of 3 European Standardization Organisations and is responsible for publishing standards in the electrotechnical engineering field. CENELEC maintains close relationships with the International Electrotechnical Commission (IEC) and the European Committee for standardization (CEN). Through its Technical Committee TC 111X "Environment", CENELEC addresses the generic environmental standardization needs of the electrotechnical sector, especially in support of European legislation.

The members of CENELEC are the 33 national standardization bodies and national committees of EU member states, 3 EFTA countries, and Turkey and Macedonia. In addition, there are 29 affiliates. CENELEC acts as a platform of experts from national committees and affiliates who develop European standards (EN) and technical specifications (TS). Over 20,000 standards have been published so far.

The process of making standards is transparent and consensus based. The ENs are reviewed every 6 years and the TSs every 3 years, thereby reflecting the state-of-the-art of technologies and market needs, and they can be used to support legislation. Standards have a harmonizing effect and can remove trade barriers and enhance economic growth.

The aims of the CENELEC EN 50625 series, which both improves the way Waste Electrical and Electronic Equipment (WEEE) is collected and treated and to which the CEWASTE project is applicable, are to:

- Assist operators in fulfilling the requirements of the Directive 2012/19/EU (WEEE Directive) by using SMART (**S**pecific, **M**easurable, **A**chievable, **R**ealistic, and **T**imely) goals.
- Give additional guidance to operators.
- Cover the treatment of all products within the extended scope of the Directive.
- Cover the collection and logistics of WEEE to allow for proper treatment.

At present, close to 200 treatment processes of operators are certified according to the CENELEC standards.

Certification

Third-party attestation related to products, processes, systems or persons.

Conformity assessment

Demonstration that specified requirements relating to a product, process, system, person or body are fulfilled.

European Standards

A standard is a document that provides rules, guidelines or characteristics for activities or their results, for common and repeated use. Standards are created by bringing together all interested parties, including manufacturers, users, consumers and regulators, of a particular material, product, process or service, to reach consensus on what can be considered best practice and `state of the art`. A European Standard is a standard that has been adopted by one of the three recognized European Standardization

Organizations: CEN, CENELEC or ETSI and is identified by a unique reference code which contains the letters 'EN'.

First-party conformity assessment activity

Conformity assessment activity that is performed by the person or organization that provides the object (source: ISO IEC DIS 17029).

Requirement

A normative (prescriptive) element, quality or qualification, applicable to the whole or part of a business process that should be followed in order to comply with regulations or a voluntary certification scheme.

Removal

Manual, mechanical, chemical or metallurgic handling with the result that hazardous substances, mixtures and components are contained in an identifiable stream or are an identifiable part of a stream within the treatment process. A substance, mixture or component is identifiable if it can be monitored to verify environmentally safe treatment (source: Directive 2012/19/EU (WEEE Directive)).

Recovery

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; (source: Directive 2008/98/EC (Waste Framework Directive)).

Recycling

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; (source: Directive 2008/98/EC (Waste Framework Directive)).

Technical Reports

A Technical Report (TR) is an informative document that provides information on the technical content of standardization work. A Technical Report is established by a CEN Technical Body and approved through a simple majority vote by the CEN national members. It involves no obligation at national level and has no specified time limit.

Technical Specification

A Technical Specification (TS) is a normative document developed in anticipation of future harmonization when there is not yet sufficient agreement on a European Standard (EN), or for providing specifications in experimental circumstances and/or evolving technologies.

Treatment

Recovery or disposal operations, including preparation prior to recovery or disposal; (source: Directive 2008/98/EC (Waste Framework Directive)).



EXECUTIVE SUMMARY

Secure access to critical raw materials (CRMs) is crucial to sustain our high-tech lifestyle and secure the competitiveness of European firms. CRMs also play a big role in the defence and renewables industry. Europe remains too reliant on foreign supply and, therefore, its access to some raw materials remains uncertain. Even though recycling is one of the important means to mitigate the criticality of CRMs, recycling rates of most of them are close to zero. Recycling is not economically attractive for most CRMs, due to, on the one hand, huge capital required in the development of technologies and, on the other, low and volatile prices of CRMs.

In its 2020 Communication “Critical Raw Materials Resilience: Charting a Path towards greater Security and Sustainability” (available [here](#)), the European Commission proposes actions to make Europe less dependent on third countries, inter alia by diversifying supply from both primary and secondary sources of CRMs, while improving resource efficiency and circularity. The CEWASTE project ties into action area 3.2 Circular use of resources, sustainable products and innovation and has developed a voluntary certification scheme for the collection, transport and treatment facilities of key types of waste containing significant amounts of valuable materials and CRMs, such as WEEE and batteries.

The project singles out the types of equipment and components that contain high concentrations of CRMs and ascertains if recovery of CRMs from those products is achievable with current technologies. It focusses on:

1. Printed circuit boards from IT equipment, hard disc drives and optical disc drives.
2. Waste batteries from WEEE and end-of-life vehicles.
3. Neodymium iron boron magnets (NdFeB-magnets) from hard disc drives and electrical engines of end-of-life vehicles (ELVs).
4. Fluorescent powders from cathode ray tubes (CRTs; in TVs and monitors) and fluorescent lamps.

The recovery technologies and processes for some CRMs are well established, for example the recovery of palladium from printed circuit boards and of cobalt from lithium-ion batteries. But for others this is not the case. For certain products and components, the ongoing development of recycling technologies will soon allow industrial scale operations to be provided. However, this will not happen unless the necessary financing and sufficient volume of feedstock is made available.

More than sixty standards and regulatory references were analysed in the project, but very few of them appeared to directly address products containing CRMs in WEEE, batteries and ELVs. Of all the standards, only six contain specific requirements relating to CRMs. The consortium designed a set of technical requirements enabling the sound collection and treatment of equipment containing key CRMs and suggested integrating them into the current collection and treatment procedures, so that collectors and treatment operators maintain their established routines.

Furthermore, the project developed a set of management requirements for operators and facilities involved in the collection, pre-treatment and final treatment including related handling, sorting and storage of WEEE and waste batteries, as well as requirements associated with risk management, documentation, communication, staff management and sustainability.

The CEWASTE assurance and verification system seeks to attest the conformity of facilities that manage WEEE and batteries with the CEWASTE standard. Assurance refers to the rules and procedures that

actors must follow in the implementation of the scheme, whilst verification supports the auditing of facilities against the CEWASTE requirements, and training of auditors and operators for these audits. The rules describe the certification process in detail, referring to the application for certification, performance of the audit and the decision as regards conformity and certification.

The scheme was piloted at companies in Belgium, Italy, Portugal, Spain and Switzerland as well as in Colombia, Rwanda and Turkey. In addition, face to face and online consultation was conducted with stakeholders to gather feedback on the scheme. Input from the pilot audits and the consultation was included in revised versions of the scheme.

The CEWASTE consortium believes that the responsibility of undertaking actions to increase recycling of CRMs lies with various actors in the value chain; it is a societal challenge. Considering this, the relevant authorities must make the recovery of CRMs economically viable.

CEWASTE recommends that:

- Legislation should require recovery of specific CRMs.
- Supplementary market incentives should stimulate, as much as possible, the use of secondary CRMs in new products.
- Financial or fiscal incentives should be used to spur the economic viability of recovering CRMs and using secondary CRMs.
- Platforms where demand for recycled components, materials and CRMs meets supply should be promoted.
- Actors involved in the collection of e-waste should raise awareness of the importance of recycling of CRMs.
- Producer Responsibility Organizations (PROs) should consider consolidating fractions of CRM-rich products in adequate quantities ("clustering") to make recycling attractive.
- Actors in the value chain should be in the position to access information on the CRM rich components, thereby making monitoring of actual recycling of CRMs easier.
- The relevant authorities should do a better job at enforcing rules around transboundary shipment of CRM-rich fractions outside the EU and the respect of technical standards along the value chain.
- The CEWASTE normative requirements must be integrated into the EN 50625 series and the whole set must be made legally binding.
- The sector needs more targeted investments in research and development of new technologies.



1 Introduction

Raw materials are crucial to Europe's economy, as they have a key role in the European industrial base, producing a broad range of goods and applications widely used in modern technologies. However, Europe has restricted access to certain raw materials and is reliant on foreign supply. This is a growing concern within the EU and across the globe. Aiming to address this challenge, the European Commission created a [list of critical raw materials](#) (CRMs) for the EU, combining raw materials of high importance to the EU economy and of high risk associated with their supply.

To ensure a more secure and sustainable supply of CRMs, the European Commission has developed an action plan. The aim is to propose actions to reduce Europe's dependency on other countries and regions, diversifying supply from both primary and secondary sources of CRMs, while improving resource efficiency and circularity. Some initiatives are already in place, providing tools to support resilient and sustainable value chains, such as the Raw Materials Initiative and the [European Raw Materials Alliance](#). The CEWASTE (Voluntary Certification Scheme for Waste Treatment) project feeds into action area 3.2: Circular use of resources, sustainable products and innovation.

CEWASTE contributes to an improved recycling of valuable and CRMs from key types of waste through the auditing and certification of traceable and sustainable treatment processes in the entire supply chain of secondary raw materials. CEWASTE addresses the specific challenge to secure the sustainable access to CRMs for the EU economy as well as objectives set by the [EU Action Plan for the Circular Economy](#), the issue of illegal trade of wastes within the EU and to non-EU countries, and the need to support the development of environmentally and socially sound recycling systems globally.

Figure 1 below outlines the key challenges and solutions of the CEWASTE projects.

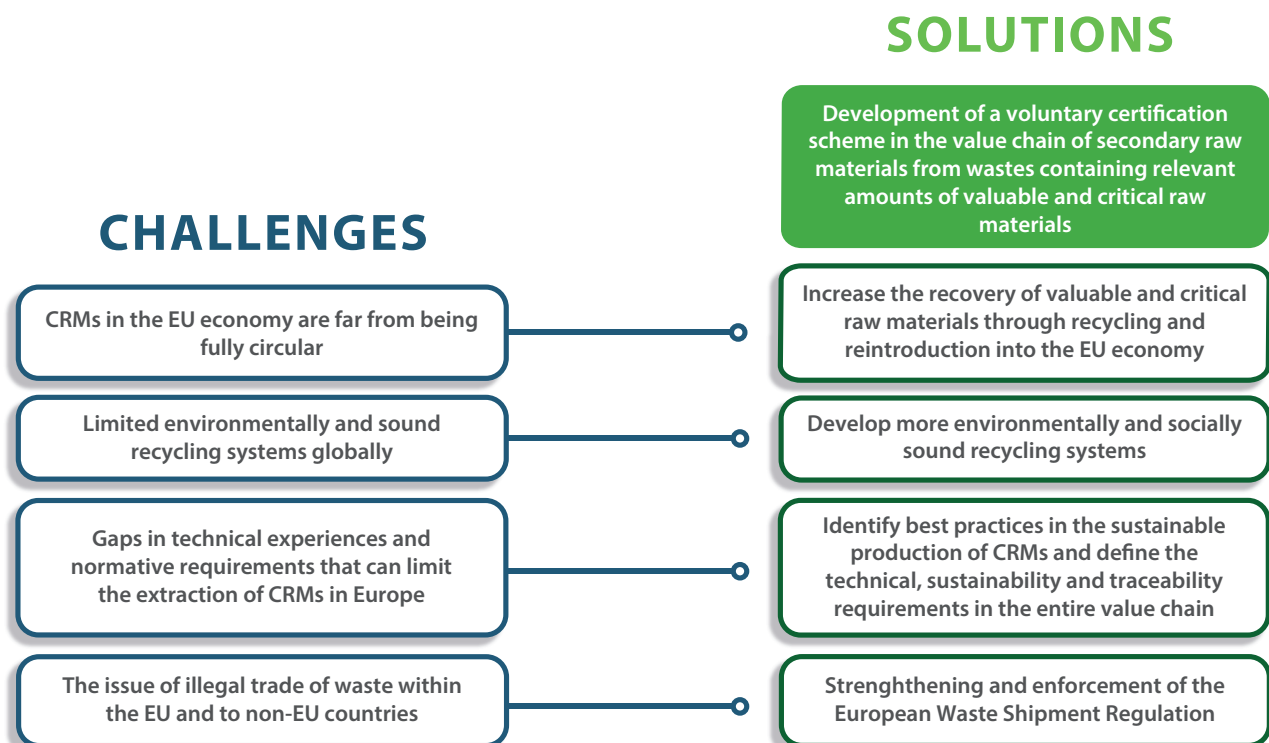


Figure 1 'Challenge and Solution Tree' defined for the CEWASTE project

The project has developed, validated and launched a voluntary certification scheme for collection, transport and treatment facilities of key types of waste containing significant amounts of valuable

materials and CRMs. The project addresses the value chain as outlined in Figure 2.

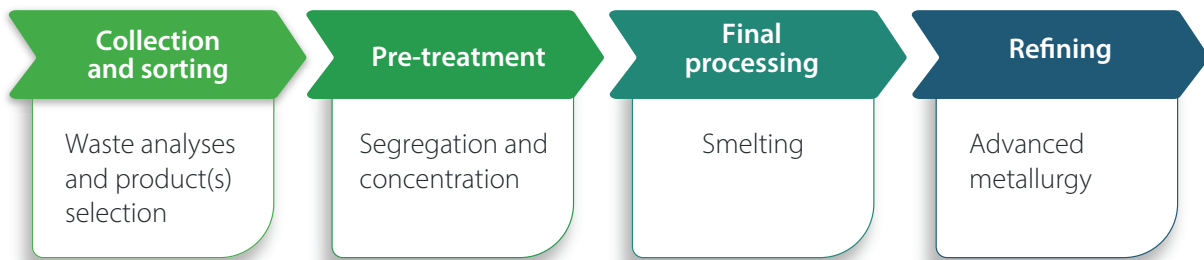


Figure 2 Schematic overview of the end-of-life value chain for key CRM containing equipment in the CEWASTE project

To ensure a comprehensive approach and a robust result, the project was developed along the following six specific objectives:

- **Objective 1:** Understand existing recovery practices, standards and verification schemes related to valuable materials and CRMs and how these can be leveraged for CEWASTE.
- **Objective 2:** Leverage existing normative requirements to develop technical, sustainability and traceability requirements for the voluntary certification scheme.
- **Objective 3:** Develop an assurance system and related verification procedures that effectively ensure that facilities and raw material streams are compliant with sustainability and traceability requirements.
- **Objective 4:** Validate the new voluntary scheme through pilot audits with selected and committed stakeholders of the value chain.
- **Objective 5:** Ensure long term sustainability of the scheme, reflecting on the needs from existing governance mechanisms, and resulting in a roadmap addressing the amendments of new requirements or mechanisms needed.
- **Objective 6:** Ensure a transparent stakeholder process that allows for broad acceptance and dissemination of the essentials of the scheme.

CEWASTE has delivered tangible results in the form of analysis of reports, a set of rules (normative requirements), related administrative and procedural mechanisms to ensure compliance with the rules and practical guidelines. In addition, the project has produced a series of recommendations as part of these results.

CEWASTE did not develop the new voluntary scheme from scratch nor formally amend existing standards. The project focussed on developing the scheme based on the current developments in recovery technologies and on the existing normative landscape in the field of waste treatment and responsible sourcing of raw materials. It has also presented a clear roadmap for the large-scale roll-out of the scheme noting the wider policy, legislative and fiscal alterations that also need to be made to support the increased recovery of CRMs.

This is the final report of the project and presents the key research and key findings of the project. It does not present in-depth analysis, this is available through the numerous reports that have been produced during the project that present the research and results in more detail. These reports are referenced at the relevant points in this document and are also accessible through the [Library section](#) of the project website.

2 Key CRM Equipment, Recycling Technologies & Normative Requirements

2.1 Identification of Key CRM Equipment

CRMs are widely used in various types of products, often in tiny amounts per product. In many cases the CRMs are not recycled because the CRM contents are too low, or because recycling technologies to extract these materials are not commercially available or viable.




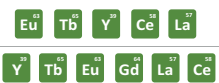
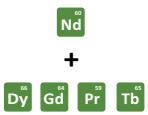
CEWASTE assessed electrical and electronic equipment (EEE), vehicle batteries, and engines of electric vehicles to identify products for which the CRM contents might be high enough to allow recycling. Criteria were developed to assess the Key CRM Equipment (KCE), i.e. those devices from which the recycling of CRMs could be feasible. In order to qualify as KCE, the products have to match all of the below criteria.

1. The product, or at least one component contained within it, (key CRM component, KCC) contains relevant concentrations and amounts of CRMs which can be isolated in pre-treatment.
2. The final treatment, i.e. the recycling of the CRMs from the above products, must be technically feasible. This is the case if a processing technology has achieved a technology readiness level (TRL)¹ of at least 7 so that an adequate industrial scale final treatment is possible already or verifiable in the near future.
3. Collectors and pre-treatment operators must be able to provide the input which the end treatment processes require for the recycling of the CRMs.
4. Collection and treatment targeting the recycling of the CRMs from the KCE is either commercially feasible already or could be achieved by additional financing within a reasonable cost-benefit ratio. An example for such financing is extended producer responsibility enacted with the WEEE Directive, which enabled the sound treatment and disposal of many types of e-waste whose recycling was economically not feasible before.

CEWASTE assumes that for the KCE identified, politicians in the EU will adapt the economic conditions accordingly to increase the EU resource supply security by recycling of CRMs as politically intended.

CRM recycling should not conflict with the recycling of valuable metals, in particular the precious metals (PMs). Sacrificing PMs for the sake of CRM recycling would be an economically and ecologically questionable decision. As a result of assessing products against these criteria the consortium identified the 14 types/categories of KCE from WEEE and ELVs. These are shown in Figure 3 below.

1 HORIZON 2020 –WORK PROGRAMME 2014-2015, General Annexes, [Technology readiness levels](#)

	WASTE TYPE	Valuable and Critical Raw Materials	Required/Viable Input for End-processing	Current Business Practice
PCBs Desktop computers, professional IT Laptops Mobile phones Tablets External CDDs/ODDs, devices with internal CDDs/ODDs	WEEE		PCBs (shredded and unshredded), CuPM granulates, mobile phones w/o. batteries	✓
Li-ion BATTERIES Laptops Mobile phones Tablets Li-ion batteries in other WEEE (battery packs from e-bikes, tools, ...) BEV, (P)HEV	WEEE ELV		Batteries	✓*
LEAD-ACID BATTERIES Uninterruptable Power Supplies Other WEEE (e-scooters without seats, ride-on toys,...) Cars containing LABs, other vehicles (e-scooters with seats, ...)	WEEE ELV	 **	Batteries	✓
FLUORESCENT POWDERS Fluorescent lamps CRT monitors and TVs	WEEE		Fluorescent Powder	✗
Nd-MAGNETS Laptops (HDD) Desktop computers, professional IT (HDD) E-bikes BEV, (P)HEV (electro engine)	WEEE ELV		Magnets	✗

*Current business practice does not (yet) include recycling of Li

**Current feasibility refers to recycling with lead (Pb)

Figure 3 Key CRM Equipment for the development of the CEWASTE requirements

The valuable materials and CRMs in the above KCE are contained in four types of KCCs.

1. Printed circuit boards from IT equipment, hard disc drives (HDDs) and optical disc drives (ODDs).
2. Waste batteries from WEEE and ELVs.
3. NdFeB-magnets from household appliances, hard disc drives and electrical engines of ELVs.
4. Fluorescent powders from cathode ray tubes (CRTs; TVs and monitors) and fluorescent lamps.

The next section gives basic insights into the technical feasibility of CRM recycling from the identified KCE and their key CRM components.

2.2 Potential Contributions of CRM Recycling from KCE to CRM Supply in the EU

In order to estimate the recycling potential of CRMs from KCE, the project calculated the quantity of CRM contained in KCE on the market and in the annual amounts of waste KCE arising as far as sufficiently reliable data were available.² No reliable data were available for CRTs. All figures are rounded.

Overall, the CRMs in KCE have a good potential to contribute to the CRM supply in the EU if they are actually recycled.

- The number of waste fluorescent lamps arising has been declining since 2013. In 2025, it is estimated there will be 92 tonnes of CRMs in waste fluorescent lamps (Ce: 10 tonnes, Eu: 4 tonnes, La: 13 tonnes, Tb: 4 tonnes and Y: 61 tonnes).
- The volumes of printed circuit boards in WEEE has stabilized since around 2020. It is estimated that in 2025, waste printed circuit boards will contain Ag (41 tonnes), Au (10 tonnes), Bi (1 tonne), Pd (2 tonnes), and Sb (65 tonnes).
- The quantity of lead-acid batteries was stable until 2020, when the sales of vehicles declined, and it is assumed the quantity will increase again in the coming years. In 2025, waste lead acid batteries from ELVs with internal combustion engines are assumed to contain 1,775 tonnes of Sb. Another 1,060 tonnes of Sb will be contained in lead-acid batteries of newly registered vehicles.
- Volumes of Li-ion batteries in electrical (hybrid) vehicles have increased in the past years. Extending this trend to 2025 would mean that around 7,900 tonnes of Co will be generated from Li-ion batteries in electric ELVs, while 13,900 tonnes of Co will be contained in Li-ion batteries for newly registered electric vehicles.
- The volumes of NdFeB-magnets in WEEE have remained on the same level since around 2016, while their amounts in vehicles increased steadily in the past years, which seems to be an ongoing trend. In 2025, it is estimated that a total of 190 tonnes of CRMs (Dy: 15 tonnes, Nd: 146 tonnes, Pr: 28 tonnes, and Tb: 1 tonne) will arise in NdFeB magnets of waste KCE.

² The calculations are based on data of WEEE generated from Eurostat for 2000-2018. These data were compared with the results obtained adopting the EU common methodology (see link below). For 2019-2025, projections and extrapolations were carried out based on trends from previous years, and from analyses conducted in various publications and national studies (such as Global E-waste Monitor 2020, the Future E-waste Scenarios, the Urban Mine Platform, etc.).

Magalini, F., et al., (2016): [Study On Collection Rates Of Waste Electrical And Electronic Equipment \(WEEE\), possible measures to be initiated by the Commission as required by Article 7\(4\), 7\(5\), 7\(6\) and 7\(7\) of Directive 2012/19/EU On Waste Electrical And Electronic Equipment \(WEEE\)](#).

2.3 Recycling Practices & Technologies for KCE

2.3.1 Established recycling technologies and practices

Recycling of PMs including the CRM palladium from WEEE containing printed circuit boards is well established and commercial practice. Recycling of antimony from lead-acid batteries and of cobalt from lithium-ion (Li-ion) and nickel-metal-hydride (NiMH) batteries is economically viable under the current economic framework conditions and is already practised on industrial scale.

Recycling of rare earth elements (REE) from fluorescent powders in fluorescent lamps had been practiced until 2016. Technically, this recycling process is therefore practicable on industrial scale. The operations stopped due to decreasing prices of REEs after the 2011 peak³ so that it could not be clarified whether this process would be appropriate for CRT fluorescent powders as well. Another operator noted it could run a plant capable of processing 400 t of fluorescent powders per year⁴ from CRTs and from fluorescent lamps for REE recycling if the financing could be ensured.

2.3.2 New and pilot-scale recycling process: recycling of NdFeB magnets

NdFeB magnets need to be separated from hard disc drives and other equipment to enable their further processing. Several pre-treatment options have been developed by private companies and in projects.⁵

The final treatment of NdFeB-magnets includes two different processing routes:

1. The recycling of REEs from the NdFeB-magnets.
2. The production of new NdFeB-magnets from old NdFeB-magnets (magnet to magnet (MtM) recycling).

REE recycling from NdFeB-magnets is technically feasible, but the TRL of end-treatment is probably below 9. Hitachi Metals uses molten Mg as an extraction method to recycle Nd and Dy from NdFeB-magnets. In 2012, Santoku Corporation is said to have started a recycling route for neodymium and dysprosium from magnets of air conditioner motors and magnet production scrap.⁶ Another process is Momentum's hydrometallurgical MSX (membrane solvent extraction) technology process, which is said to be able to recycle more than 99 percent of the REE content from HDDs dissolved in acid while operating at room temperature and pressure.⁷ Finally, the Ames Laboratory's acid-free dissolution recycling technology is described as having the potential to recycle Nd from shredded HDD samples without obligatory pre-concentration of the magnet contents.⁸ Several EU-projects address recycling of REEs from magnets, including the [REE4EU pilot scale plant](#), [REEcover](#), and others.⁹

3 [Historical REE prices](#).

4 Information obtained from [RELIGHT](#) via e-mails

5 See for example the Hitachi process (in the CEWASTE report [Baseline and gap/obstacle analysis of standards and regulations](#) page 28) and the [REMANENCE project](#)

6 SCREEN (2016): [Production technologies of CRM from secondary resources \(page 126\)](#)

7 iNEMI: [Value Recovery Project 2 report](#).

8 iNEMI: [Value Recovery Project 2 report](#).

9 For an overview of EU and international developments, see [REE Recovery from End-of-Life NdFeB Permanent Magnet Scrap](#).

The US-based [Urban Mining Company](#) and EU-based [MagREESource](#) claim to produce NdFeB-magnets from waste NdFeB magnets (MtM processing¹⁰). In addition, the EU [ReproMag](#) and [SusMagPro](#) projects have been developing the patented 'Hydrogen Processing of Magnetic Scrap' (HPMS)¹¹ as an MtM process. Other alternatives include the reuse of NdFeB-magnets from HDDs in applications other than HDDs, or the reuse of NdFeB-magnets from HDDs in new DDs.¹² Although being replaced by SSDs in consumer products, HDDs are still being used in the increasing number of datacentres around the world.^{13 14}

The CEWASTE consortium believes that the ongoing development of recycling technologies and processes will soon allow industrial scale operations for recycling NdFeB-magnets if the necessary financing is provided.

2.4 Analyses of Normative Requirements with Relevance for the KCE

From the outset it was intended that the CEWASTE requirements enabling sustainable CRM recycling from the KCE would be built on established normative requirements embedded in legislation, standards, certification schemes and guidelines relevant to the KCE. New requirements were developed to fill any gaps identified. More than 60 normative requirements were analysed for stipulations that could be referenced within the following scopes:

- Environment, health and safety requirements and equitable working conditions;
- Traceability of flows of waste, components and fractions thereof;
- Ensurance of legal compliance;
- Technical requirements for collection, transport and treatment of waste with indirect or direct relevance for the KCE;
- Local community impacts and resilience.

The normative requirements were assessed along the end-of-life chain illustrated in Figure 2 on page 12.

2.4.1 Normative requirements with relevance for the KCE

There was little that directly addressed products containing CRMs in the normative requirements that were analysed, although more than half of the texts (31) in the scope of the mapping were identified as containing requirements for secondary raw materials, with 40 texts containing requirements for traceability. 37 texts contained sustainability requirements which could be referenced.

10 For more detail see page 31 of iNEMI: [Value Recovery Project 2 report](#).

11 REProMag EU-H2020 project: [SDS, a new resource efficient production route for Rare Earth magnets](#)

12 See Demonstrators 1 and 2 in the iNEMI: [Value Recovery Project 2 report](#).

13 Anandtech: [Shipments of PC Hard Drives Predicted to Drop By Nearly 50% in 2019](#)

14 For details see Maximilian er al: [Recycling Decisions in 2020, 2030, and 2040—When Can Substantial NdFeB Extraction be Expected in the EU?](#)

Six key pieces of legislation were identified as being of particular relevance to the project:

- Directive 2012/19/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 4 July 2012 on WEEE,
- Directive 2006/66/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 6 September 2006 on batteries and accumulators and waste batteries and accumulators and repealing Directive 91/157/EEC,
- Directive 2000/53/EC of the European Parliament and of the Council of 18 September 2000 on end-of-life vehicles,
- Regulation (EC) No. 1013/2006 of the European Parliament and of the Council of 14 June 2006 on shipments of waste,
- Commission Decision (EU) 2019/63 of 19 December 2018 on the sectoral reference document on best environmental management practices, sector environmental performance indicators and benchmarks of excellence for the electrical and electronic equipment manufacturing sector.
- Commission Decision (EU) 2019/63 Related to Regulation (EC) No 1221/2009 (EMAS, environmental management).

[The CENELEC 50625 standard series for collection, transport and treatment of WEEE](#) was also central to the development of the CEWASTE scheme. Requirements which support the recycling of CRMs from the KCE listed in Figure 3 were identified in legal obligations in the WEEE Directive, such as those related to collection and specific treatment. For example, legislative requirements like the removal of batteries from WEEE and ELVs support subsequent treatment steps for CRM recycling, even though they do not address CRMs specifically.

2.4.2 Gaps and obstacles

As with the normative requirements, the gaps and obstacles for sound recycling of CRMs were assessed along the end-of-life chain illustrated in Figure 2 on page 12.

2.4.2.1 Collection and pre-treatment

While certain parts of the normative requirements analysed by the project could be adopted or referred to, they lack specific requirements for sorting of KCEs to support subsequent treatment steps toward the recycling of the CRMs, in particular the removal and separate treatment of the KCCs.

None of the normative requirements cover the specific pre-treatment of the KCE required to facilitate the recycling of CRMs. Nevertheless, some regulations and standards require the removal of certain components or parts/fractions thereof from waste equipment, which includes the KCE fluorescent lamps/powders, CRTs, printed circuit boards, and batteries from e-waste and vehicles.

There are no stipulations in any of the normative requirements analysed for the removal of NdFeB magnets from KCE or any other products, which is a gap that needed to be filled with new requirements.

2.4.2.2 End-treatment

The standard TS 50625-5 Specification for the final treatment of WEEE fractions - *Copper and Precious Metals* - encompasses normative requirements for the final processing and refining of copper, silver, gold and palladium from WEEE fractions. For CRMs in KCE other than palladium there are no final processing and refining standards.

2.4.2.3 Obstacles

In addition to gaps in current normative requirements, obstacles were identified in legal stipulations and framework conditions that needed to be overcome to enable the recycling of CRMs to happen. These were identified as follows:

- Lack of financing prevents the recycling of CRMs even in cases where this would be technically feasible with acceptable additional effort at a reasonable cost-benefit balance. Currently, recycling of CRMs is not economically attractive for CRMs other than palladium and, to a certain degree, cobalt and antimony under the present economic framework conditions.
- In the absence of clear requirements to recycle CRMs, the generic, weight-based collection and recycling targets for WEEE in the EU lead to producers and member states focusing on overall tonnages rather than the quality recycling of small amounts of CRMs.
- Difficult to access components that contain CRMs hamper CRM recycling. Ecodesign of products could improve this situation, e.g. by implementing measures based on the [Ecodesign Directive](#).
- Low collection rates of WEEE preventing the sound treatment including CRM recycling in the formal WEEE management system.
- Insufficient separation of KCE from other WEEE during collection, which requires sorting out KCE after collection to prevent dilution of CRMs in further processing;
- Lack of (detailed, quantitative) information and marking of key CRM components and their chemical composition; in particular relevant for NdFeB- magnets containing CRMs to differentiate them from other magnets.

In conclusion, this part of the research noted that CEWASTE would need to develop, in particular, technical requirements enabling the sound collection and sorting, and pre- and end treatment of KCE to enable the recycling of CRMs. In addition, new traceability and sustainability requirements could be needed as well to ensure the sound collection and processing where the collection, transport, handling and treatment of KCE are related to specific health, environmental and safety risks that are not yet covered in the analysed normative requirements. Eliminating or at least mitigating the identified obstacles would reduce the efforts to recycle the CRMs from the KCE and thus reduce the cost.

If EU member states and states outside the EU want CRMs to be recycled, it will be critical to establish a stable and reliable financing mechanism. Without such a financing mechanism, the recycling of CRMs from NdFeB-magnets, fluorescent powders, and in part from batteries, cannot be achieved.

3 Developing the Sustainability, Management, Technical & Traceability Requirements

Based on the result of the gap analysis (sub-section 2.4.2), the project took stock of the normative requirements defined in the existing relevant guidelines and standards in the field of electrical and electronic waste treatment and responsible sourcing of raw materials. Among others, the European Standards on Collection, Logistics and Treatment Requirements for WEEE (EN 50625 standard series) approved by CENELEC on 27th January 2014 were considered as the basis for development of the CEWASTE requirements. Where the existing requirements were not sufficient to meet the CEWASTE objective, new requirements on management, sustainability, traceability and technical issues related to CRM recycling were developed.

The following principles guided the development of the CEWASTE requirements:

- **Technological and economic feasibility:** To increase recovery and reduce losses of CRM and valuable materials, the selection of priority CRM or alloys for recovery as well as the final treatment technologies considers the technological processing, thermodynamic processes and economic limitations. Hence, it has been acknowledged from the outset that it is not possible to recover all CRM.
- **Optimal collection, sorting and removal:** Optimal collection, sorting and removal of equipment, components and fractions thereof containing CRM and valuable materials before further pre- and final treatment are a pre-condition for minimizing losses in the treatment processes chain.
- **Continuous improvement:** For reaching expected annual recovery goals and continuous improvement, a management system, with regular monitoring, is required that supports the implementation of the technical requirements and maximizes CRM recovery.
- **Auditability:** The CEWASTE requirements should be clear, coherent and measurable in order to facilitate substantiated assessment and confirmation of the level of compliance of the operations with the CEWASTE requirements.
- **Traceability:** This allows substantiated demonstration that waste products, components and fractions thereof can be tracked to ensure that their recovery has been undertaken in compliance with the CEWASTE requirements. This is only mandatory for waste lead-acid batteries and printed circuit boards.

While the first two principles are technology related, the third, fourth and fifth ones focus on organizational aspects.

The development of the CEWASTE requirements was an iterative process with several rounds of review and revisions based on the feedback received through a series of transparent and public stakeholder consultation process as well as performing pilot audits (see Section 6 for more details).

The CEWASTE requirements are for operators and facilities involved in the collection, pre-treatment and final treatment including related handling, sorting and storage of WEEE and waste batteries. The sub-sections that follow deal with the main sub-groups of the requirements and their focus. The CEWASTE Normative Requirements are available [here](#).

3.1 Management Requirements

These requirements specifically focus on managerial, environmental and social aspects.

Operators must have a functioning system that provides evidence of conformity with all applicable national and local laws and regulations, irrespective of where their operations occur. The system is supposed to cover labour regulations, discharge and air emission limits, waste transportation and disposal requirements, hazardous waste handling restrictions, noise limits during operation and national regulation on Occupational Health and Safety (OHS) and emergency requirements (e.g. protective clothing and equipment, safety features of machines and work posts, regular medical inspections, safety instructions and training and preventive measures).

In cases where local and national requirements are insufficiently developed or in cases where the operator and facilities have an exceptionally important transboundary impact, it is expected that the operator and facilities are aligned with international standards, conventions and protocols.

The operator and facilities are expected to meet the requirements of EN 50625-1:2014. If possible, operators and facilities will seek to reach a documented agreement regarding the implementation of the CEWASTE requirements throughout the supply chain.

The facilities' management system will cover the activities in scope of the CEWASTE standard. The operator and facilities will identify key elements of its operating environment, including its business network, stakeholders, customers and suppliers as well as its workers, the local community and environmental context, in which it operates, and to which sites they apply. The operator and facilities shall specify the responsibility, authority and interrelationship of all personnel involved. The operator shall define and document the range of waste handling activities (for example collection or treatment) and waste streams or materials relevant to CEWASTE.

The management team that has overall responsibility for the waste processing operations will have access to all resources required to implement the CEWASTE standard. Importantly, those management responsibilities as regards the treatment of WEEE, waste batteries and/or fractions thereof, waste management, and the transport and the handling of materials that exhibit hazardous properties need to be documented and communicated.

3.1.1 Risk management requirements

The operator will define, document and regularly review risk assessment procedures and activities. Risks relate to quality of recovery of CRMs, health and safety risks, fire and explosions and other emergencies. The operator will also have action plans including timetable, responsibilities and activities that mitigate risks.

Monitoring is an important mechanism to track progress against set objectives as well as to demonstrate and report on environmental, economic and social outcomes in an efficient, transparent and accountable manner. Operators and facilities will maintain an adequate monitoring system tracking, inter alia, progress on environmental, social and economic performance, critical risk factors and related responses at least for the risk points where the accidental release of poisonous solid, liquid and gaseous effluents is possible (including during transportation, treatment and disposal); and applicable natural disaster risks.

The operator shall have procedures in place to ascertain whether waste handling processes in scope of the CEWASTE certification attain the objectives or targets.

3.1.2 Documentation

EN 50625-1:2014 requires that, for at least three years, a record of data including input and output description, weight, origin and destination is maintained. A report of sub-contractors and sub-processors shall be kept. Operators and facilities will regularly monitor and report on compliance with the CEWASTE standard requirements and critical associated risks.

3.1.3 Communication

Communication is required to realize the full potential of a CEWASTE applied system. This can be particularly important during the initial steps when applying the CEWASTE standard. Therefore, stakeholders shall be informed about the possible challenges and environmental, economic and social benefits when implementing this standard. A stakeholder mapping exercise will specify the level of communication and awareness raising needed.

3.1.4 Management of personnel and resources other than personnel

The operator and facilities will ensure a safe working environment and will maintain a procedure for management of competencies of personnel involved in the processes covered by the CEWASTE standard and for management of the facilities, including, e.g., making the storage weatherproof, ensuring safe and controlled access.

3.2 Sustainability Requirements

The operator and facilities are to contribute to the well-being of the local community (can be also a city) and as a result can impact the overall regional development. The welfare of workers and the local community depend on functioning systems, such as safe handling of equipment and techniques for employees' health and productivity.

All point-source pollution and greenhouse gas emissions, including air, waste water and soil pollution will be reduced. Low-carbon technologies or energy efficiency measures will reduce greenhouse gas emissions.

Additionally, the protection of the natural environment is critical to the environmental and community well-being. The operators and facilities shall demonstrate an understanding of the potential impact of their activities and aim to limit their impact.

Community dialogue programs will create a common understanding of risks and benefits of WEEE and the application of the CEWASTE standard systems. Additionally, such outreach programs can be targeted to communicate sector-specific best practices of CEWASTE to facilitate further confidence and uptake of this standard throughout the entire supply chain.

3.3 Traceability Requirements

Traceability requirements included are based on the due diligence approach. They are mandatory only for waste lead-acid batteries and printed circuit boards and voluntary for the other KCE. This decision was made because these were the main KCE/KCC imported to the EU and it was important to create a level playing field by ensuring that recycling in their countries of origin was performed to the same minimum standards as the EU. Furthermore, the stakeholders and the CEWASTE Advisory Board emphasised the need to trace and control the critical environmental and social impacts associated to these two types of components. For printed circuit boards the traceability requirements are given in the CENELEC TS 50625-5 document by means of contractual obligations in the supply chain and by downstream monitoring requirements.

Requirements on traceability for items other than lead-acid waste batteries and printed circuit boards, and sustainability requirements on local communities' well-being and contribution to society have the status of recommendations.

3.4 Technical Requirements

Technical requirements that operators shall follow to recover CRM and valuable materials from KCE, KCC and fractions thereof are presented in this section. Technical requirements developed for the KCC based on the sufficient availability of evidence, experiences and national and European recommendations which contribute to advancements in this area.

For economic operators running final treatment operations, specific guidance is provided for fluorescent powders, waste batteries, magnets and printed circuit boards.

A graphic description is provided in Figure 4 which also highlights the CEWASTE scope, the flows that are not part of it and where they should be delivered to. This graphic navigates throughout the clauses that apply to specific KCE and KCC.

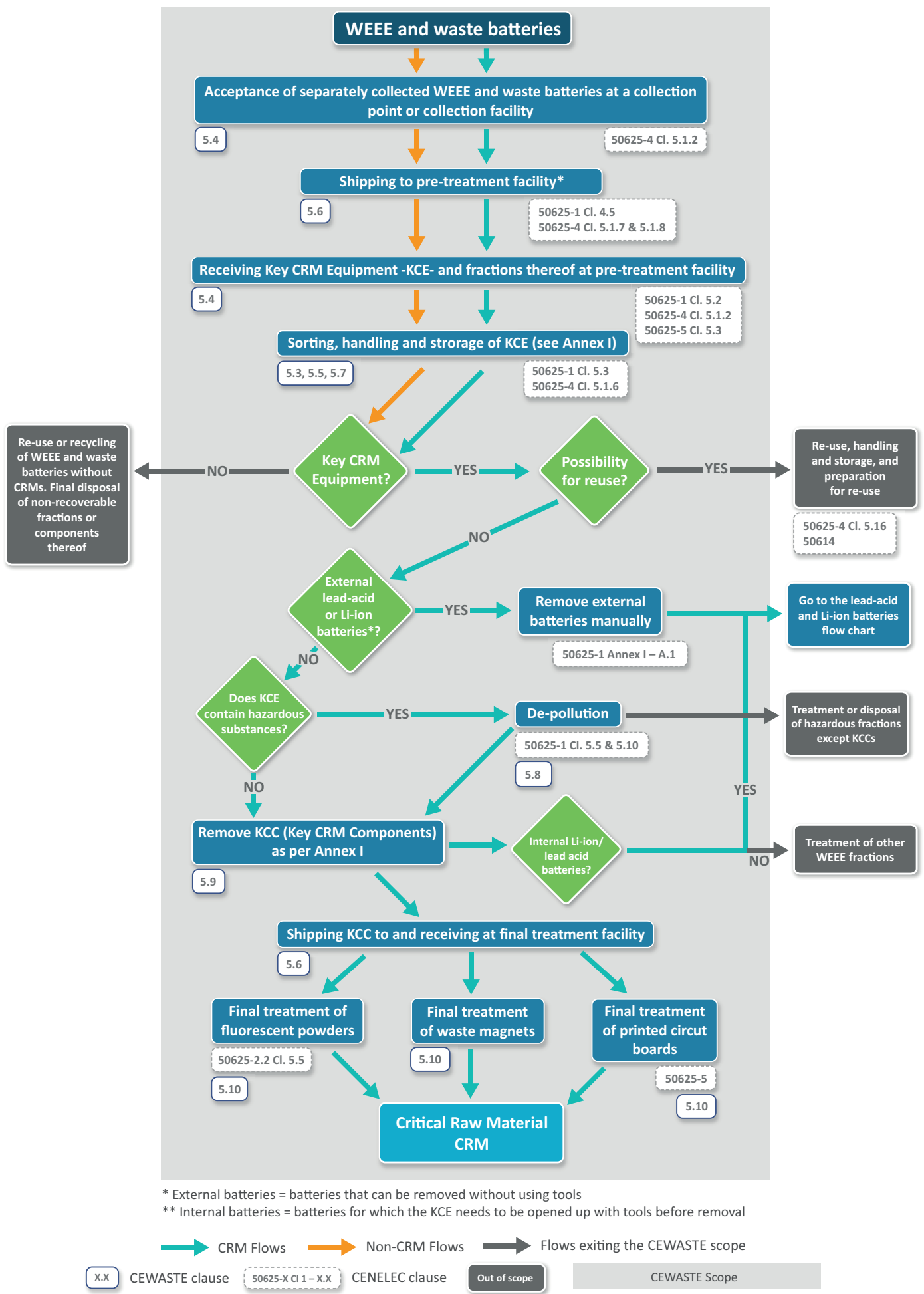


Figure 4 Navigation through technical requirements for key CRM equipment (KCE) and key CRM components (KCC)

4 The CEWASTE Assurance & Verification System

Even though recycling is one of the means to mitigate the criticality of CRMs, recycling rates of most of them are close to zero. Other sections in this report look at the current situation of CRMs contained in products, the feasibility of their recovery from waste and requirements that already support such recycling in existing standards. The normative requirements are supposed to enable CRM recycling, to create a level playing field for the operators along the end-of-life chain, as well as to improve the recycling of other valuable materials. However, for them to make a difference, they need to be complied with by operators of WEEE and batteries waste facilities.

The CEWASTE assurance and verification system seeks to attest the conformity of facilities that manage WEEE and batteries with the CEWASTE normative requirements, which aim to increase the recovery of CRMs as well as ensuring that processes which contribute to their recovery have a minimum level of sustainability. The assurance system therefore specifies the rules and procedures to be followed by actors involved in the implementation of the scheme, such as operators and certification bodies, whilst the verification system supports the auditing of facilities against the CEWASTE requirements, and preparation of auditors and operators for these audits. The rules describe the certification process in detail, referring to the application for certification, performance of the audit and the decision as regards conformity and certification.

4.1 Assurance

The project developed the principles underpinning the CEWASTE assurance system in accordance with ISO/IEC 17067:2013 (Conformity assessment — Fundamentals of product certification and guidelines for product certification schemes) and the [ISEAL Assurance Code of Good Practice](#), which is mainly geared towards the conformity of sustainability standards and related chain of custody standards, to secure a minimum consistency, rigour, competence, impartiality, transparency and accessibility, as well as the scope of the scheme, requirements against which relevant waste operators are to be certified, requirements for certification bodies, and procedures to be used by the conformity assessment bodies and in the certification process.

The requirements for Certification Bodies (CB) were developed considering the essential requirements of the standard ISO/IEC 17065:2012.

To attest the conformity of facilities with the CEWASTE requirements, the assurance system operates on three levels; i.e. (i) rules for registered CEWASTE Certification Bodies, (ii) rules to support the auditing of facilities, and (iii) rules to support the review of audit results and the certification decisions.

The CEWASTE scheme is applicable to the processes of collection, transport and treatment of WEEE and waste batteries. The general scope of the scheme is defined in the CEWASTE certification requirements against which conformity of operators is assessed, which is based on the type of facility being certified and the waste fraction being handled.

Operators' facilities seek certification against the CEWASTE requirements, which are part of the scheme rules. The scheme rules also foresee annual meetings of auditors to discuss the interpretation of requirements and the need for revision of the requirements of the verification system to ensure a homogenous implementation.

Requirements are included as to the registration of Certifications Bodies and the maintenance of registration.

The eligibility of auditors and the type of skills they must have to be accepted to the pool of auditors is also detailed.

The CEWASTE Assurance Tool and Manual for Operators is available [here](#).

4.2 Verification

In parallel to the assurance scheme, a verification system has been developed to support the certification processes. For example, to support the auditing of facilities against the CEWASTE requirements, auditing templates and tools have been developed to be used during audits. These are further accompanied by an Assurance manual for operators in the EEE and battery waste management sectors (providing guidance as to how to demonstrate compliance with the scheme requirements) and a Verification manual for auditors (providing additional background about the requirements to harmonize the assessment process).

To develop the verification system, existing verification systems of e-waste management facilities and raw material certification systems were analysed, inter alia WEEELABEX and SWICO. Such systems partly inspired the approaches adapted for verification of the CEWASTE requirements, particularly in relation to CENELEC EN 50625 requirements included in the CEWASTE standard. Experience of auditors was also taken into consideration for deciding on specific aspects of the tools developed in this system.

The verification system includes templates and Excel tools that have been designed to support the various procedures developed as part of the assurance system. Each of these is relevant at different phases of the certification process and addresses the various aspects of relevance at that stage. In general, certification includes the stages illustrated in Figure 5.



Figure 5 CEWASTE certification process flowchart

The tool for auditors includes a checklist and a manual. The checklist includes questions for each of the requirements. The auditor manual provides explanatory information and considerations for the assessment of conformity. Both can support the auditor during an audit through the provision of guidance information and clarification as to what level of performance is considered compliant and in what cases a major or minor non-conformity is to be identified. However, they are also useful for the preparation of audits and the final stage of assessing and deciding on the conformity of the requirements and the eligibility of the operator's facilities for certification.

The assurance manual allows operators to prepare themselves for the certification of their facilities. It can also be used by operators that would like to gain a better understanding as to these requirements to consider certification in the future. Aspects that the operator is to consider in preparing its facilities for certification and for the audit are detailed. For example, the type of documentation that is eligible as evidence of conformity in some cases, threshold levels in relation to measurable requirements, and aspects that need to be addressed in management plans.

The CEWASTE Verification Tool and Manual for Auditors is available [here](#).

5 Consultation & Testing the CEWASTE Scheme

A key part of the development of the CEWASTE certification scheme was the consultation and testing process. This enabled feedback from stakeholders, including operators at all stages of the collection and treatment process, and ensured the scheme reflects 'real world' opinions. There were several rounds of consultation on the documents detailing the scheme and a series of practical pilot audits that tested the scheme.

5.1 Consultation

Developing a widely accepted and mature certification scheme requires multi-stakeholder participation including key experts in a consultation process. CEWASTE stakeholders were identified along the entire value chain and invited to provide their feedback and comments to the project work and outcomes and to the draft version of the scheme. The ISEAL Assurance Code of Good Practice formed the basis of stakeholder participation activities.

To engage with stakeholders, the main stakeholder groups were identified and then invited to join a [Stakeholder Consultation Meeting](#) which was organized in October 2019 in Geneva. During this meeting the stakeholders and experts (including the CEWASTE Advisory Board) were given the opportunity to contribute to the design and content of the CEWASTE certification scheme, with a focus on the CEWASTE normative requirements. Comments received were assessed and where relevant integrated into the certification scheme.

In addition to the Consultation, a dedicated CEWASTE workshop was held as part of the [World Resources Forum Conference \(WRF\) 2019](#). This gave the project consortium the opportunity to hear stakeholders' perspectives on CEWASTE and related issues and to engage with the global WRF audience - high-level policy-makers, business leaders, NGOs, scientists and regional partners active in different areas of resource management.

Following these face-to-face consultations, the next step in the stakeholder consultation process was an online consultation open to the public. A draft version of the CEWASTE normative requirements formed the basis of this consultation. The first round of online consultation was launched in December 2019 and was open for two months.

From this consultation 278 comments were received including editorial comments as well as suggestions related to the technical or managerial parts of the document. Also, major questions on principles guiding the development of the requirements were raised. Out of the 278 comments raised, 243 were accepted and addressed in a revised version of the requirements document, 14 comments were not considered and 21 points remained open and were double-checked with feedback provided during the pilot audits.

A second round of online consultation was held in early 2021 after integrating the comments received from the pilot audits into a new version of the normative requirements. This round was limited to editorial comments only. Following this, the final version of the normative requirements was developed and published in April 2021.

Figure 6 shows the review and revision process followed by the project for the normative requirements.

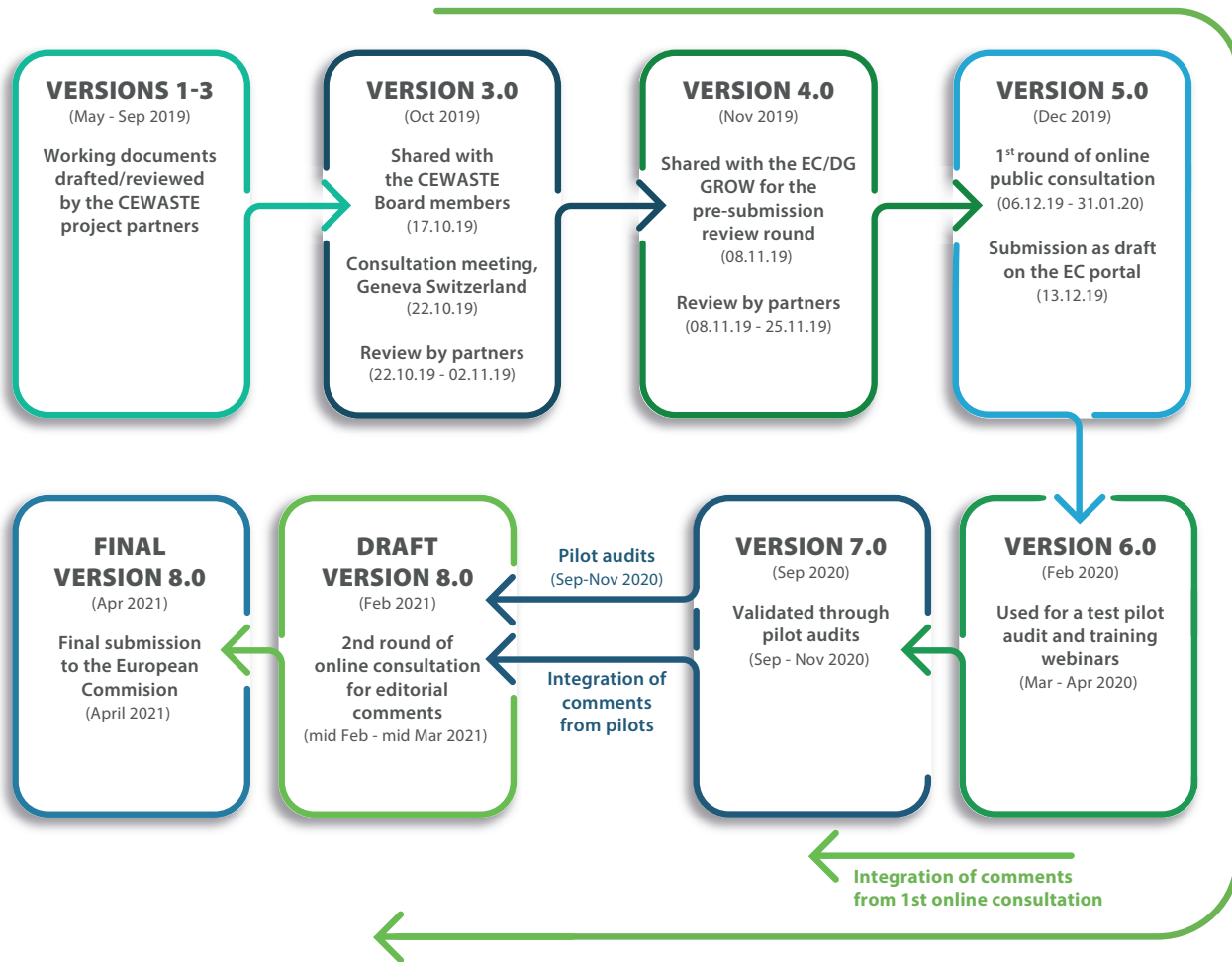


Figure 6 Review and revision round of the CEWASTE normative requirements

5.2 Pilot Audits

Between March and the end of November 2020, the project conducted 20 pilot audits to test the CEWASTE normative requirements and related assurance system and verification procedures. In addition, the pilot audits also assessed the readiness level of the audited operators against the management and technical requirements for recycling of CRMs. The feedback from the audits was used to update and revise the CEWASTE certification scheme.

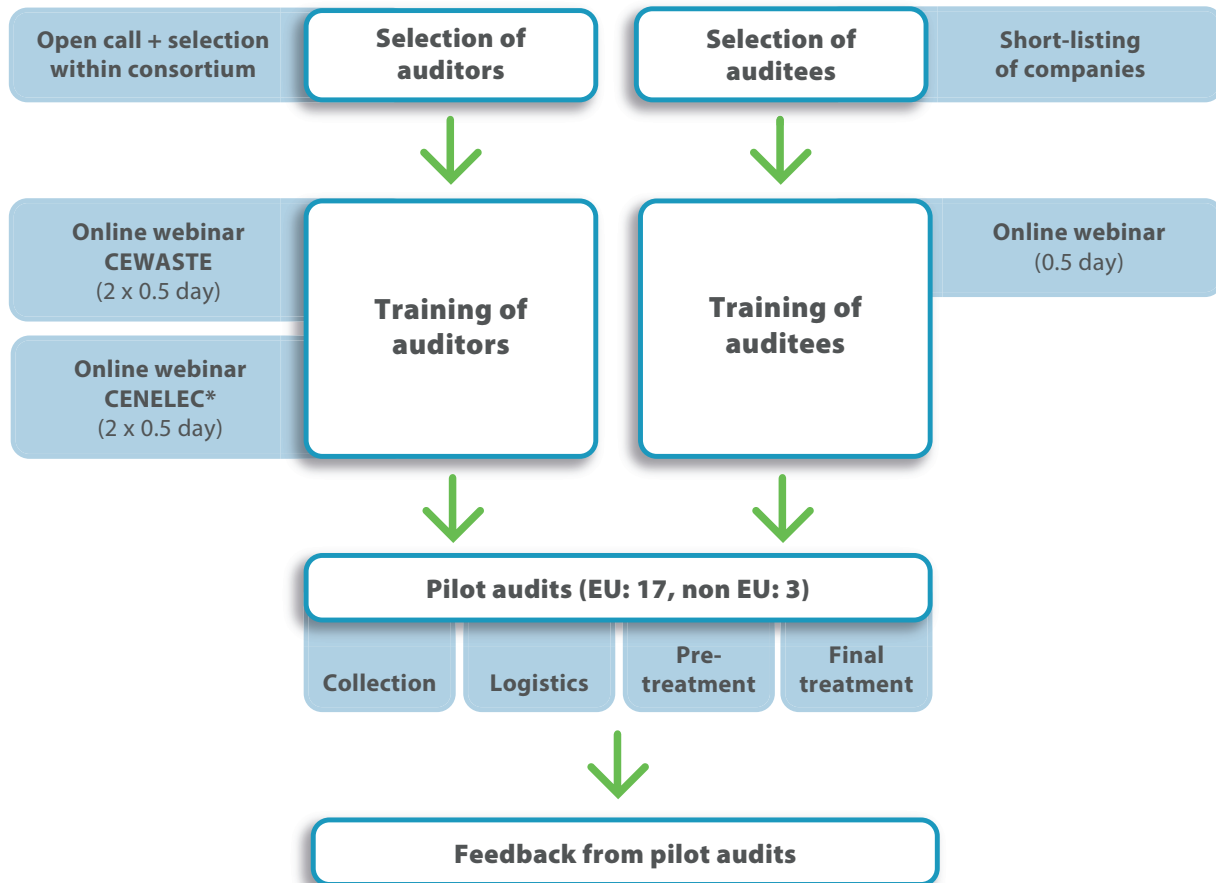
The operations targeted for audits were mainly selected from members of EERA (European Electronics Recyclers Association) and the WEEE Forum (International Association of Electronic Waste Producer Responsibility Organisations (PRO)), ensuring full coverage of the collection, logistics, pre-treatment and final treatment stages. Differences in size and geography of facilities were also considered along with other criteria to ensure that the applicability of the scheme was tested on a diverse range of organisations. (See the CEWASTE report [Validation Methodology for the Pilots](#) for more details about the planning process for the pilot audits).

Auditors were drawn from the project consortium and externally, using personnel with experience of auditing relevant facilities for compliance with other, established, standards. Auditors were given a comprehensive introduction to the CEWASTE requirements, as well as the EN 50625 standard series

where auditors were not already well versed in this, through a series of online training webinars. (See the CEWASTE report [Training Materials for the Piloting Team](#) for more details about the training sessions).

Training was also provided to those organisations that would be subjected to an audit. This prepared them for the audit by familiarising them with the CEWASTE certification scheme as well as with the EN 50625 standards for those facilities that were not CENELEC certified.

Figure 7 provides an overview of the methodology for the preparation and planning of the pilot audits.



*auditees not certified according to EN 50625 also participated in the CENELEC online webinar organised for auditors.

Figure 7 Methodology for the preparation and planning of the pilot audits, as well as the plan for the online training sessions

The initial plan was to perform on-site audits, however, due to the COVID-19 outbreak in Spring 2020 and the general regulations for restricted movement of citizens in Europe (and other countries) some of the pilot audits had to be carried out remotely in a virtual format where the auditor connected with the operator online for the interview and/or tour of the plant. A total of ten physical and nine virtual audits took place, plus one audit being part physical and part virtual. Experience proved that virtual audits work well when verifying compliance against the management requirements whereas testing the technical requirements in a virtual format has its limitations and physical audits work better here.

As illustrated in Figure 8, audits were performed in ten European companies (in Belgium, Italy, Portugal, Spain and Switzerland) and in three companies outside Europe (in Colombia, Rwanda and Turkey). In some cases, more than one audit type (e.g. collection + pre-treatment) was conducted at the same company. There were 20 audits performed altogether:

- 4 - logistics requirements
- 3 - collection requirements
- 10 - pre-treatment requirements
- 3 - final treatment requirements

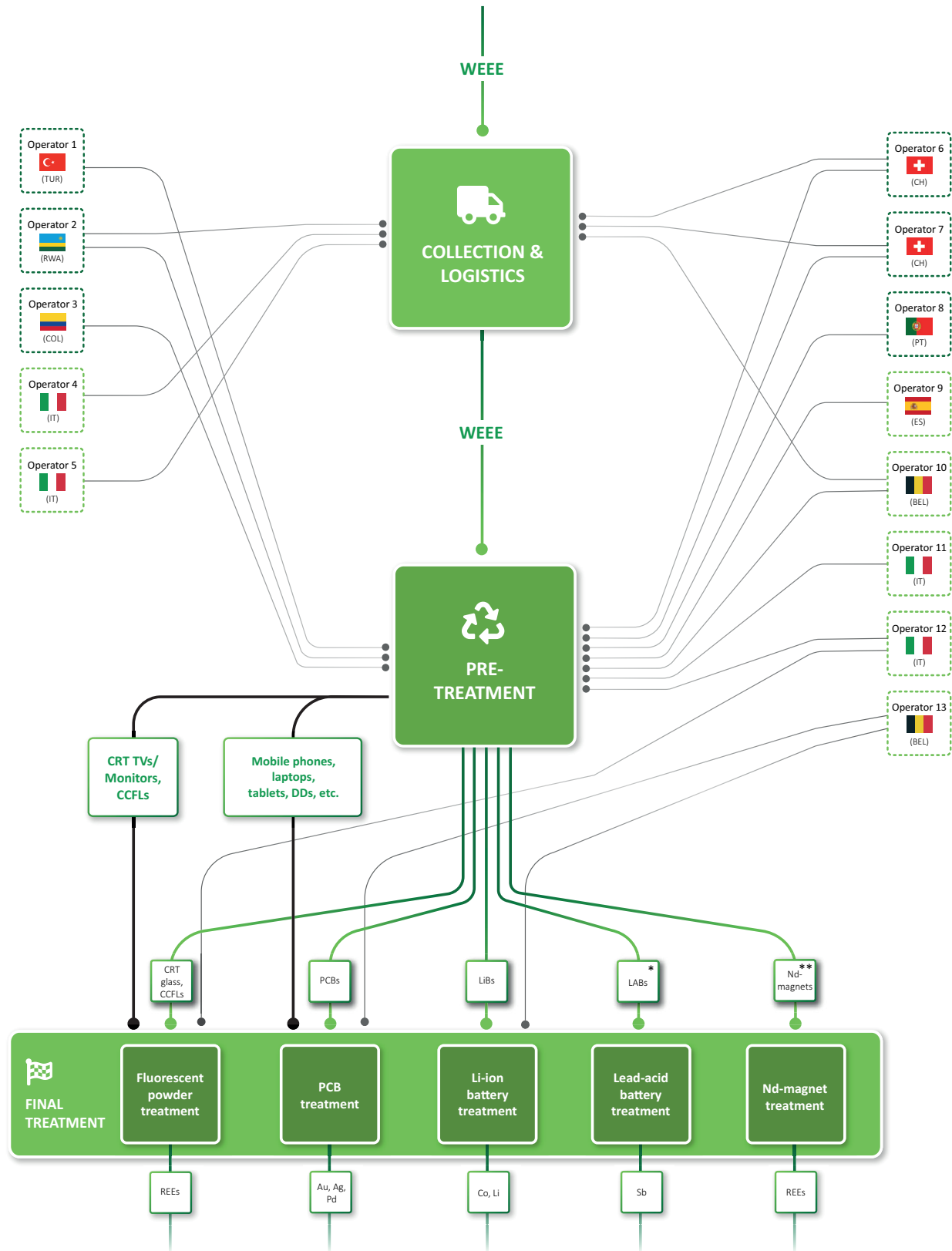
Due to the temporary closure of collection facilities caused by the pandemic, some audits had to be cancelled. To get feedback on the applicability and feasibility of the CEWASTE requirements related to collection, an additional questionnaire was prepared and sent out to relevant PROs to verify the collection related requirements.

During the pilot process, all comments and feedback from the auditor and the operators were documented. The auditors recorded more than 600 comments and these were reviewed by the CEWASTE team before being used to adapt the normative requirements, the assurance system and the verification procedures. Feedback from the pilot audits is available to view in the project report [Piloting reports and maturity level assessment](#).

Having reviewed the readiness level of the audited operators to apply the CEWASTE requirements it can be concluded that they were found to have an adequate level of preparedness. Those requirements that posed a challenge to them could be divided into three categories:

1. The fulfilment of the requirement was not met as the overall process of CRM recycling has not been implemented because it is not economical. Only minor operational and organisational changes are required to implement CRM recycling.
2. The fulfilment of the requirement was not met as the overall process of CRM recycling has not been implemented because it is not economical. The changes can be made with medium level financial, organisational, work and time investment.
3. The accomplishment of the requirement was not fulfilled, and the process of CRM recycling has not been implemented due to lack of incentives and/or technology. In this case the main reason behind the requirement not being fulfilled was not the required extra investment but because the output material of the process was not marketable, due to lack of acceptors and/or lack of final treatment processes.

In most cases not meeting a requirement was due to case no. 1. i.e. non-compliance was simply due to the overall CRM recycling process not being economically feasible and therefore has not been implemented. With minor resources and changes the process of CRM recycling could be feasible. There were some examples of case no. 2. where resources required were estimated to be higher to achieve compliance. These were mainly related to traceability requirements, in some cases the separate sorting of CRM equipment and for some requirements for collection facilities. Case no. 3 was noted for final treatment operators processing fluorescent powders and pre-and final treatment operators for magnets.



* The volumes of LABs coming from WEEE are relatively small.
 ** The removal of magnets is being audited at pre-treatment facilities.

CCFLs - Cold Cathode Fluorescent Lamps **LIB** - Lithium-ion Battery
DDs - Disk Drives **PCBs** - Printed Circuit Boards
LAB - Lead-acid Battery **REEs** - Rare Earth Elements

Legend:



Figure 8 CEWASTE pilot audits with geographical distribution of operators along the value chain.

6 The Roadmap

The future sustainability of the CEWASTE certification scheme is by no means certain as external factors play a fundamental role in its widespread adoption. The roadmap considers these external factors and sets a course for the scheme in this wider context, outlining what must happen to ensure the efforts of the project will culminate in real impact.

6.1 The Wider Economic, Legislative and Technological Framework

There are a number of reasons why the recycling of CRMs is not commonplace, these centre on economics, legislation and recycling technology.

On the **economic** side, recycling is not economically attractive for most CRMs. This is due mainly to the huge capital costs involved in setting up the recycling process, low and volatile prices of CRM minerals and challenges to achieve high-quality secondary materials that are suitable to be incorporated into new products.

On the **legal** side, collection and treatment are required by the WEEE Directive, the Battery Directive (including the new proposal for the Sustainable Batteries Regulation) and partially by the ELV Directive. These directives, except for the proposal for the Sustainable Batteries Regulation, do not have specific requirements focusing on recovery of valuable materials or CRMs, and the overall mass related recycling target does not create drivers to ensure their recovery.

Some **technologies** are currently established for recovering CRMs, such as the recycling of palladium and other precious metals from printed circuit boards and recycling of antimony and cobalt from batteries. The recycling of REE from CRTs and fluorescent lamps could potentially be established if a stable investment climate and economic environment of the recycling operations is in place. Fluorescent powders are currently removed from lamps but not recycled for commercial reasons. Other technologies are new or being tested, such as the MSX and MtM technologies for magnets.

Other challenges related to the process of CRM recovery include:

- Difficulty in accessing components containing CRMs due to the design of products, their miniaturisation, the increasingly complex material mixtures in EEE, and knowledge gap of where CRMs are concentrated.
- Low concentration of CRMs in products, meaning more WEEE needs to be treated to obtain viable amounts. For example, to recover 100 t of fluorescent powder from lamps, 5,000 t of waste lamps are required.
- WEEE is generally mixed when collected because this is more cost effective and because there are few countries that have quality requirements in place for WEEE collection. This has the effect of increasing costs in downstream treatment, especially when components containing CRMs need to be removed.

Several solutions are proposed to ensure greater efficiency and to improve the feasibility of recovering CRMs. Each will not have an effect in isolation so they should be considered as a framework of solutions, where several need to be adopted in order to have a significant impact. Solutions having higher impact, likelihood of adoption or chance to stimulate changes at EU level have been clustered in 4 main themes in Figure 9.



Figure 9 Clustering of options to increase CRM recovery across EU

6.2 Ownership of the CEWASTE Scheme

To enable the certification scheme to be used following the end of the CEWASTE project an organisation needs to adopt it. The project has identified and analysed different WEEE treatment verification schemes to assess their suitability for this. The owners of these schemes are in the best position to become an accredited body for ensuring conformity verification in the short term for CEWASTE. These six companies were:

- [WEEELABEX](#)
- [R2:2013 Checklist](#)
- [e-Stewards](#)
- [Recycler qualification program](#)
- [EPEAT](#)
- [AS/NZS 5377-2013](#)¹⁵

The criteria used for identifying the company best suited for adopting the CEWASTE scheme were:

1. Coverage of activities; it is preferable that global services are provided.
2. Scope of the WEEE value chain covered. Verification experience covering the whole value chain from collection to final treatment for WEEE is expected.
3. Expertise in CENELEC requirements, as these are the basis of the CEWASTE standard. Having the ability to verify operations against CENELEC requirements will speed up the process of implementing the scheme.

¹⁵ Link to abstract only.

4. Accredited certification scheme.
5. Financial stability and good market penetration.

Of all the criteria noted, information on financial stability was the most difficult to collect. It is assumed that obtaining accreditation for the CEWASTE certification scheme will require an initial investment that will not be returned in the short term, given that the market for CRMs remains young and financial support may be required for ensuring the accredited body holding the CEWASTE scheme does not suffer financial difficulties. Alternatively, a scenario in which conformity with the CEWASTE standard becomes legally mandatory will radically change the situation, and the body holding the CEWASTE scheme would be required to be a front runner and adapt quickly for covering market needs.

Based on the assessment against the five criteria, the recommendation is that CENELEC should be the owner of the CEWASTE standard, while WEEELABEX should be the owner of the certification.

6.3 Key Points and Roadmap

The piloting of the CEWASTE requirements carried out during the project highlighted the following key aspects:

- Most of the pre-treatment and final treatment operators met most requirements, while for collection facilities the lack of implementation of the EN 50625-4 standard across Europe poses the biggest challenge.
- In those cases where requirements were not met, the main underlying cause was the current absence of the process aimed at ensuring recovery of fractions rich in CRM mainly linked to (i) absence of downstream market, or (ii) absence of financial incentives to recover the CRM. In the great majority of cases, minor to medium organizational and/or process changes could be implemented by the audited companies.

The adoption of CEWASTE is seen as a coherent step towards the achievement of EU goals around supply of CRMs and the recommendations for its adoption can be divided into three main groups: (i) pre-requisites for the adoption, (ii) conditions for success and (iii) roadmap.

6.3.1 Pre-requisites for adoption

The main pre-requisite for the adoption of the CEWASTE is to update the EN 50625 standards (Collection, logistics & treatment requirements for WEEE) to include best available technologies and to have resource efficiency integrated, followed by making the standards legally mandatory. Following this, the CEWASTE standards should also be made mandatory. As a voluntary standard it could only have a very minor impact because there would be minimal take up.

6.3.2 Conditions for success

There are three main conditions necessary for the achievement of a successful CEWASTE standard:

1. **Make the CENELEC standard legally binding.**

The cornerstone of the CEWASTE requirements is the EN 50625 CENELEC standards. Currently,

the CENELEC standards are only mandatory in a few EU countries and the experience in these countries is that the mandatory implementation creates a level playing field for all operators allowing fair competition in the regulated market.

It is unfortunate that the European Commission so far has not updated and made use of the possibility to make the standards mandatory by an Implementing Act¹⁶. By making the standards mandatory, large volumes of secondary raw materials can be prevented from being lost due to illegal disposal and trade as well as poor quality or irresponsible recycling. It is therefore important to make the EN 50625 standards binding at EU level to ensure proper implementation of CEWASTE.

2. Increase the collection rate of materials rich in CRM and in accountability.

At present, most CRMs are lost due to low collection rates. Therefore, policies must be put into practise that ensure increased collection of CRMs, especially for smaller products that are not currently being collected to anything like their full potential.

3. The normative references of the CEWASTE standard must be integrated into the EN 50625 standards.

After having analysed all standards that are available for the recycling of WEEE and waste batteries, the CEWASTE project has formed the opinion that the EN 50625 standards are the most state-of-the-art recycling standards. It is for this reason that most normative references in the CEWASTE standard are articles in the CENELEC standards. Furthermore, it is our recommendation that the CEWASTE standard should be integrated into the EN 50625 standards.

During the pilot audits, it became clear that those companies that were complying with the CENELEC standards were also compliant with all CEWASTE management, sustainability and traceability requirements. In instances where the economics of CRM recycling worked most of the CEWASTE technical requirements were being met, meaning that in these places the gap between existing recycling practices and the aim of CEWASTE to recover CRMs from the urban mine is small. Thus, if the economic drivers are in place, the changes needed to bridge this gap are minor.

6.3.3 Roadmap

The proposed roadmap for implementation of the CEWASTE standard is outlined below and summarised in Figure 10. The different solutions presented in Figure 9 can be implemented in different steps of the roadmap to achieve the increased recovery of CRMs and the best implementation of the CEWASTE standard.

- 1.** Make the CENELEC standard mandatory: Revise the CENELEC EN 50625 standards and update best available technologies to include aspects related to resource efficiency and make the CENELEC standard mandatory to ensure effective impact in CRM recovery and aligned to the EU's priorities.
- 2.** Incorporate the CEWASTE normative requirements into CENELEC's EN 50625 series.

¹⁶ Art 8.5 In order to ensure uniform conditions for the implementation of this Article, the Commission may adopt implementing acts laying down minimum quality standards based, in particular, on the standards developed by the European standardisation organisations.

3. Put into practice policies geared towards improving the collection of CRM-rich fractions, inter alia by concentrating CRM-rich fractions at collection stage and conducting awareness raising campaigns. This is expected to increase the supply of CRMs available for recovery.
4. Create market pull by promoting the use of secondary CRM via regulations requiring a minimum amount of recycled content in products, similar to what the [proposed Sustainable Batteries Regulation](#) aims to achieve.
5. Facilitate demand for CRM by creating a trading platform for recycled components or materials, thus easing the trade process for companies recovering CRMs.
6. Stimulate economic viability for recovery by means of policies and measures aimed at optimising the economic viability of CRM recovery processes, including dedicated incentive schemes for recyclers (or producers using secondary CRMs).
7. Stimulate research on effective technologies, and invest in research, development and technology for better and more efficient processes for recycling CRMs.

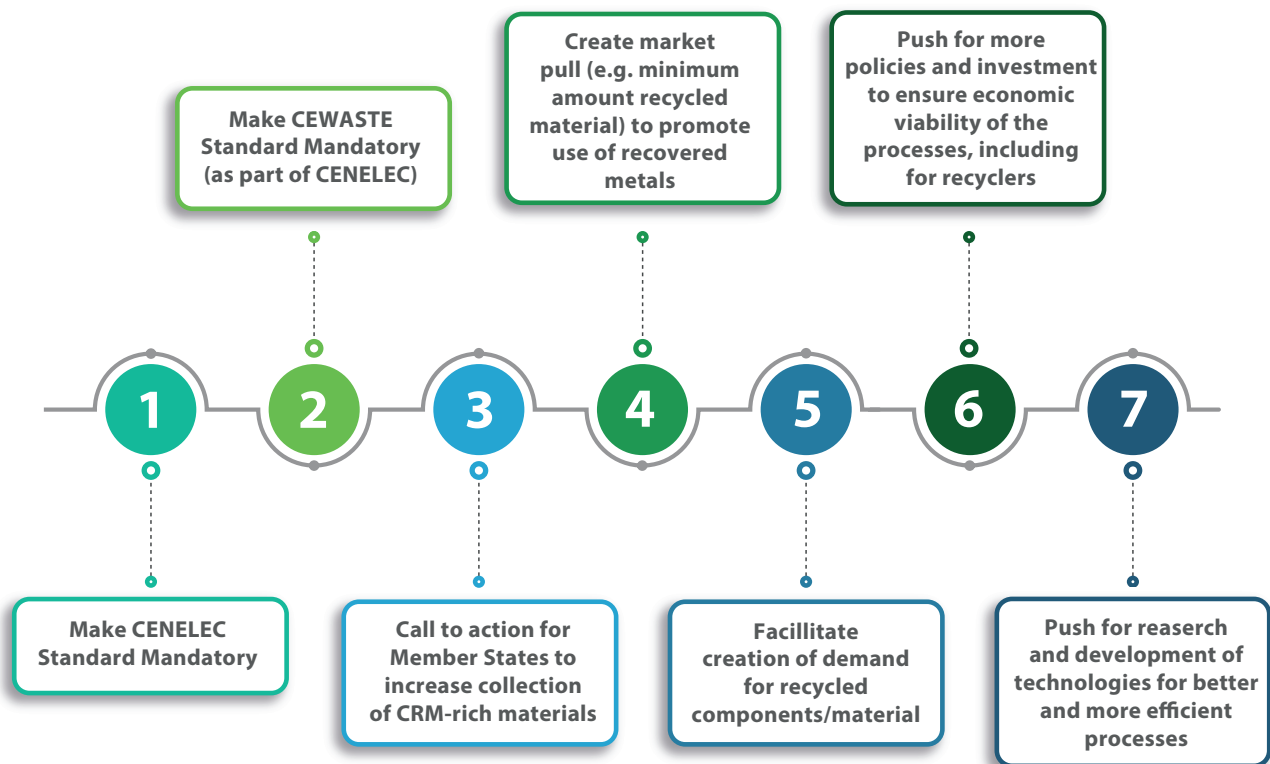


Figure 10 Roadmap for adoption of CEWASTE

7 Conclusion

CRMs are crucial to lifestyles and business competitiveness in Europe, but their supply is highly dependent on foreign countries. This is an issue of growing concern. Aiming to address this challenge, the CEWASTE project has delivered not only a set of normative requirements to foster the recycling of CRMs from Key CRM Equipment and Key CRM Components but also a verification and assurance scheme to attest conformity with those requirements. Various pilots and consultations have supported the development of the CEWASTE certification scheme.

The CEWASTE consortium believes that the responsibility of undertaking actions to increase recycling of CRMs lies with various actors in the value chain; it is a societal challenge. Considering this, the relevant authorities must make the recovery of CRMs economically viable.

CEWASTE recommends that:

- Legislation should require recovery of specific CRMs.
- Supplementary market incentives should stimulate, as much as possible, the use of secondary CRMs in new products.
- Financial or fiscal incentives should be used to spur the economic viability of recovering CRMs and using secondary CRMs.
- Platforms where demand for recycled components, materials and CRMs meets supply should be promoted.
- Actors involved in the collection of e-waste should raise awareness of the importance of recycling of CRMs.
- PROs should consider consolidating fractions of CRM-rich products in adequate quantities (“clustering”) to make recycling attractive.
- Actors in the value chain should be in the position to access information on the CRM rich components, thereby making monitoring of actual recycling of CRMs easier.
- The relevant authorities should do a better job at enforcing rules around transboundary shipment of CRM-rich fractions outside the EU and the respect of technical standards along the value chain.
- The CEWASTE normative requirements must be integrated into the EN 50625 series and the whole set must be made legally binding.
- The sector needs more targeted investments in research and development of new technologies.

Annex 1 - Consortium

World Resources Forum Association – Coordinator

The World Resources Forum Association (WRFA) is an independent non-profit international organization that serves as a platform connecting and fostering knowledge exchange on resources management amongst business leaders, policy-makers, NGOs, scientists and the public. WRFA has an international reputation for its flagship conference, the World Resources Forum (WRF).

www.wrforum.org

Oeko-Institut

Oeko-Institut is a leading independent European research and consultancy institute working for a sustainable future. Founded in 1977, the institute develops principles and strategies for realising the vision of sustainable development globally, nationally and locally. Work is organised around the subjects of Chemicals Management and Technology Assessment, Energy and Climate, Immission and Radiation Protection, Agriculture and Biodiversity, Sustainability in Consumption, Mobility, Resource Management and Industry, Nu-clear Engineering and Facility Safety as well as Law, Policy and Governance.

www.oeko.de

European Electronics Recyclers Association

EERA is a non profit organisation which represents and promotes the interest of recycling companies that are treating waste from electrical and electronic equipment. Its membership includes 35 specialist recycling companies (pre- processors and end- processors) across 23 countries in Europe.

www.eera-recyclers.com

WEEE Forum

The WEEE Forum is the world's largest multi-national centre of competence as regards operational know-how concerning the management of waste electrical and electronic equipment (or 'WEEE', for short). It is a not-for-profit association of 43 WEEE producer responsibility organisations across the world and was founded in April 2002. Through exchange of best practice and access to its reputable knowledge base toolbox, the WEEE Forum enables its members to improve their operations and be known as promoters of the circular economy.

www.weee-forum.org

Austrian Standards

Austrian Standards International – Standardization and Innovation is the recognized standardization body in Austria, a non-profit service organization founded in 1920 and part of a national and international standardization network: i.e. the Austrian member of the European Committee for Standardization CEN, the International Organization for Standardization ISO and the European Telecommunications Standards Institute ETSI. Austrian Standards International cooperates with OVE which is the responsible for standardization in the electrotechnical field being member of CENELEC and IEC.

www.austrian-standards.at

SGS Fimko Oy

SGS Fimko Oy belongs to the world's leading inspection, verification, testing and certification company SGS. With more than 95 000 employees, SGS operates a network of more than 2400 offices and laboratories around the world. SGS Fimko Oy has been operating in Finland since 1924 and today employs about 120 professionals in six locations. SGS Fimko Oy provides diverse inspection, testing, verification and certification services and holds Notified Body status as well as several accreditations.

www.sgs.com

Sofies

Sofies provides strategic sustainability consulting, project management and services. Using an integrative approach based on industrial ecology, Sofies successfully addresses growing environmental and socioeconomic challenges. It is a Geneva-based international group, with branches in Zurich, UK and India, with a unique expertise in WEEE management and policy-making. Sofies has a track record in 25+ countries across Europe, Asia and Africa.

www.sofiesgroup.com

United Nations University

The United Nations University (UNU) is as a UN Organization a global think tank and postgraduate teaching organisation headquartered in Tokyo hosted by Japan. The Sustainable Cycles (SCYCLE) is a Programme hosted by the UNU Vice Rectorate in Europe based in Bonn, Germany. Its activities are focused on the development of sustainable production, consumption and disposal patterns for electrical and electronic equipment, as well as other ubiquitous goods. UNU-ViE SCYCLE is leading the way in global quantification of e-waste product flows, with more detailed e-waste generated/arising analyses carried out in individual EU Member States, such as the Netherlands, Belgium, France, Italy, Romania and the Czech Republic.

www.unu.edu and www.scycle.info

ECOS

ECOS is a non-profit organisation working to promote environmental aspects in the development of standards and specifications at European and international level, especially those produced in support of EU environmental laws and policies. ECOS' mission is to influence the development of ambitious strategies to reduce and control sources of environmental pollution, and to promote resource and energy efficiency, environmental health and sustainable development.

www.ecostandard.org



Annex 2 - Advisory Board

Name of organization	Country	Name of assigned person
Agence de l'Environnement et de la Maîtrise de l'Energie (ADEME)	France	Erwann Fangeat, Rachel Baudry
Aluminium Stewardship Initiative (ASI)	Australia	Fiona Solomon, Marieke van der Mijn
CENELEC TC111x Environmental Standards (CENELEC)	Germany	Christian Dworak
Colombian Institute of Technical Standards and Certification (ICONTEC)	Colombia	Juan Sebastián Salazar, Erika Lucia Urrego Ortiz
International Union for Conservation of Nature (IUCN)	Switzerland	Giulia Carbone
DG Joint Research Center (JRC)	Italy	Fabrice Mathieux, Fulvio Ardente
Public Waste Agency of Flanders (OVAM)	Belgium	Marleen Dirckx, Tom Van Troyen
Regional Environmental Center (REC Turkey)	Turkey	Rifat Ünal Sayman
Southern African e-Waste Alliance (SA-EWA)	South Africa	Susanne Yvonne Karcher
Swiss Federal Institute for Materials Science and Technology (Empa)	Switzerland	Heinz Böni, Patrick Wäger
Umwelt Bundesamt (UBA)	Germany	Regina Kohlmeyer
WEEELABEX	Czech Republic	Richard Toffolet, Petr Novotny
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