Council of the
European Union

Brussels, 18 January 2018
(OR. en)

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COVER NOTE

From:	Secretary-General of the European Commission, signed by Mr Jordi AYET PUIGARNAU, Director
date of receipt:	17 January 2018
To:	Mr Jeppe TRANHOLM-MIKKELSEN, Secretary-General of the Council of the European Union
No. Cion doc.:	SWD(2018) 36 final - Part 2-3
Subject:	COMMISSION STAFF WORKING DOCUMENT Report on Critical Raw Materials and the Circular Economy

Delegations will find attached document SWD(2018) 36 final - Part 2-3.

Encl.: SWD(2018) 36 final - Part 2-3

EUROPEAN
COMMISSION

Brussels, 16.1.2018
SWD(2018) 36 final

PART 2/3

COMMISSION STAFF WORKING DOCUMENT

Report on Critical Raw Materials and the Circular Economy

EN EN

4. DATA SOURCES AND MONITORING

4.1. Multi-sector data sources

4.1.1. The EU Raw Materials Information System including the CRM fact sheets

Securing undistorted supply of raw materials and, in particular, CRMs requires a sound and continuously updated knowledge base. In this context, and responding to a specific action of the 2015 Circular Economy Communication, the Commission is developing the EU Raw Materials Information System (RMIS)[1]. The first version (RMIS 1.0) was launched in March 2015. The advanced RMIS 2.0 version, launched in November 2017, is intended as a one-stop information gateway and knowledge service centre for non-energy, non-food primary and secondary raw materials.

Figure 6: Front page of the EC's Raw Material Information System (RMIS2.0)

RMIS 2.0 is to (a) support EU policy with tailor-made applications like the periodical Raw Material Scoreboard (see Section 4.2.1) and criticality assessments, and (b) help coordinate other EU level data and information on raw materials for the benefit of a variety of users. This will be made available directly in RMIS from different data sources. It will be facilitated by enhanced cooperation with Member States, industry representatives, and other stakeholders. Different functionalities of RMIS 2.0 will directly serve the implementation of the circular economy policy. Examples include Material Flow Analysis (MFA) and Material System Analysis (MSA, see below); information and data on secondary raw materials; contents on sustainability aspects and on research & innovation.

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[1] http://rmis.jrc.ec.europa.eu

RMIS 2.0 makes easily available and further exploitable the huge amount of information and data collected during the criticality assessments, which represent the background of the lists of CRMs. Such information and data is compiled and systematically organised in **raw materials factsheets** that provide ample information on each of the CRMs (and certain non-critical raw materials). The factsheets include information on supply from mining / harvesting, supply from recycling, trade, end-uses and related economic sectors, substitution, as well as supply chain analysis. Key facts and figures are collected and summarised on the front page of each factsheet.

4.1.2. Material System Analysis

In 2015, the Commission published a study[2] on Material System Analysis (MSA). It investigates the flows and stocks of 28 raw materials (26 individual CRMs plus aggregates and lithium) from "cradle-to-grave" across the entire material life cycle from resource extraction to materials processing, manufacturing and fabrication to use and subsequent collection, processing and disposal or recycling.

The 2015 MSA study provides an overview of data sources, with a specific examination of the Eurostat database on trade of goods from the viewpoint of its usability for MSA, a detailed methodology and a material system analysis for the 28 studied materials with data sources, assumptions and calculations and with main data gaps filled with experts' inputs gathered through direct consultations and organisation of workshops. It also contains recommendations for the maintenance and update of the MSA.

For each material, the MSA includes a Sankey diagram with material flows (as raw materials, components or products) illustrating entry (extraction, imports) and movement (production, consumption, exports) through the EU economy, additions to stock, and end-of-life disposal or recovery; and information on security of supply (country concentration) and substitutes.

By tracking materials throughout their full life cycle, the MSA can help to quantify potential primary and secondary sources and support the monitoring of their "level of circularity" in the EU-28. This is particularly important for CRMs for which public information on their trade is sometimes unknown, their uses have not been well documented, and their levels of recovery and reuse once discarded are generally low. An accurate assessment of global and EU-wide mineral resources must include not only the resources available in the ground (reserves) but also those that are present as stocks within the technosphere and become available through recycling. The data resulting from the 2015 MSA study provides an important base of background information from which security of supply and sustainable development pathways can be designed.

4.1.3. ProSUM

ProSUM[3] (Prospecting Secondary raw materials in the Urban mine and Mining waste) is a Coordination and Support Action funded by Horizon 2020 establishing a European network of expertise on secondary sources of CRMs. The project is providing data about stocks, flows, waste arisings and treatment of various product groups that are highly relevant as potential secondary sources of CRMs, i.e. waste electrical and electronic equipment (WEEE), end-of-life vehicles (ELVs), batteries and mining wastes.

Information concerning products placed on the market, product stocks and waste flows in the EU derive from both measured data, coherent estimates based on statistical

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[2] 'Study on Data for a Raw Material System Analysis (MSA): Roadmap and Test of the Fully Operational MSA for Raw Materials'. https://ec.europa.eu/jrc/en/scientific-tool/msa

[3] http://www.prosumproject.eu/

information, experts' assumptions and extrapolation. Quality level, uncertainty and error propagation of the gathered information are harmonised in order to provide high quality data in a centralised **Urban Mine Knowledge Data Platform**. Moreover, the data structure eases the regular update and maintenance of the information.

ProSUM has produced an EU-wide data platform providing user-friendly, seamless access to data and intelligence on secondary raw materials in various wastes. It provides centralised access to charts and maps and includes a search engine currently covering over 800 data sources and documents structured by the ProSUM project. This deliverable is key for the creation of a European raw materials knowledge base and it is contributing to the above-mentioned EU Raw Material Information System.

4.1.4. General sources

No	Name and link/ref.	Scope			Reference period / date of publ.	Language	Free / subscription	Comments
		Subsectors	CRMs	Geographic area				
1	EU Raw Materials Information System[4]	Various	All	EU and Worldwide	2015/2017	English	Free	
2	Criticality studies prepared for the European Commission[5]	Various	All	EU and Worldwide	2014, 2017 (updated every 3 years)	English	Free	
3	MSA study[6]	Various	CRMs (2014)	EU	2015	English	Free	
4	Sebastiaan, D., Mancheri, N, Tukker, A, Brown, T., Petavratzi, E., Tercero Espinoza, L. (2017): Report on the current use of critical raw materials[7]	Various	2014 list of CRMs	EU	2017	English	Free	
5	Marscheider-Weidemann, F., Langkau, S., Hummen, T., Erdmann, L., Tercero Espinoza, L., Angerer, G., Marwede, M. & Benecke, S. (2016): Rohstoffe für Zukunftstechnologien 2016. DERA Rohstoffinformationen 28; 353 S., Berlin. March 2016. [8]	Emerging technologies	Several	Germany	2016	German	Free	'Raw materials for emerging technologies 2016'
6	Graedel, T. E., J. Allwood, J. P. Birat, B. K. Reck, S. F. Sibley, G. Sonnemann, M. Buchert, and C. Hagelüken (2011): Recycling Rates of Metals – A Status Report. UNEP International Resource	All	Several	Worldwide	2011	English	Free	

4 http://rmis.jrc.ec.europa.eu

5 https://ec.europa.eu/growth/sectors/raw-materials/specific-interest/critical_en

6 https://ec.europa.eu/jrc/en/scientific-tool/ msa

7 http://scrreen.eu/wp-content/uploads/2017/01/SCRREEN-D2.1-Report-on-the-current-use-of-critical-raw-materials.pdf

8 https://www.bgr.bund.de/DERA/DE/Downloads/Studie_Zukunftstechnologien-2016.pdf;jsessionid=A996A13E9E2764B203496C746AB0D6D4.1_cid284?__blob=publicationFile&v=5

	Panel.							
7	EASAC policy report 29 (2016): Priorities for critical materials for a circular economy.[9]	All	All	World-wide	2016	English	Free	
8	ADEME (2010): Etude du potentiel de recyclage de certains métaux rares.	Various	35 metals inclu-ding Rare Earths	World-wide	2010	French	Free	
9	Schuler D. et al. (2011). Study on Rare Earths and their Recycling.[10]	Various	Rare Earths	World-wide	2011	English	Free	
10	Du X. and Graedel T. (2011). Global in-use stocks of the rare earth elements: a first esti-mate.[11]	Various	Rare Earths	World-wide	2011	English	Sub-scription	
11	ETC/SCP (2011). Green economy and recycling in Europe.[12]	Various	Several	Europe/ World-wide	2011	English	Free	
12	Hagelüken C. and Mes-kers C. (2010). Complex Life Cycles of Precious and Special Metals. Strüngmann Forum Re-port, Linkages of Sustainability. Edited by Thomas E. Graedel and Ester van der Voet.	Various	Several	Europe/ World-wide	2010	English	Sub-scription	
13	Gunn G. (2013). Critical Metals Handbook. John Wiley & Son.	Various	Several	World-wide	2013	English	Sub-scription	
14	UNEP International Re-source Panel (2010). Metal Stocks in Society: Scientific Synthesis	Various	Several	World-wide	2010	English	Free	

4.2. Monitoring progress

As mentioned in the introduction (section 1.2.2), there is no universally agreed definition of 'circular use' of raw materials. Even so, at EU level two interlinked means to monitor progress are presently available: the 'Raw Materials Scoreboard' and the ' Circular Economy Monitoring Framework '.

4.2.1. The Raw Materials Scoreboard

The Raw Materials Scoreboard is an initiative of the European Innovation Partnership on Raw Materials. The Scoreboard provides information on the EU's overall raw materials policy context. The first edition of the Scoreboard, published in 2016, consists of 24 indicators grouped into five thematic clusters.

The Scoreboard's thematic cluster on "Circular economy and recycling" consists of four complementary indicators: material flows in the circular economy, recycling's

9 http://www.easac.eu/fileadmin/PDF_s/reports_statements/Circular_Economy/EASAC_Critical_Materials_web_corrected_Jan_2017.pdf

10 http://www.oeko.de/oekodoc/1112/2011-003-en.pdf

11 Environmental Science and Technology, 45(9), 4096-101

12 http://scp.eionet.europa.eu/publications/2011_wp5/wp/WP2011_5

contribution to materials demand, management of waste electrical and electronic equipment (WEEE) and trade in secondary raw materials.

Two of these indicators are particularly relevant for CRMs. The indicator on recycling's contribution shows that for almost all CRMs the contribution of recycled materials to raw materials demand is small to negligible. The indicator on WEEE management, a waste stream that contains significant amounts of CRMs, further provides information on collection and recycling. It shows that the levels of collection, reuse and recycling of WEEE vary considerably across EU Member States, indicating a significant potential to improve resource efficiency.

4.2.2. The Circular Economy Monitoring Framework

The circular economy monitoring framework[13] is a set of 10 indicators that aim at assessing progress towards a more circular economy and the effectiveness of action at EU and national level.[14]

Several indicators included in the circular economy monitoring framework are relevant to CRMs, including the indicator on self-sufficiency for raw materials, the (sub)indicator on recycling rates of WEEE and the indicator on the contribution of recycled materials to raw materials demand (all three are also indicators in the Raw Materials Scoreboard).

Figure 7 presents the contribution of recycled materials to materials demand for a number of raw materials. It shows that even for materials for which overall recycling rates are relatively high, recycling's contribution to meeting materials demand is relatively low. This is because demand is higher than what can be met by recycling. In other cases, functional recycling is not economically feasible.

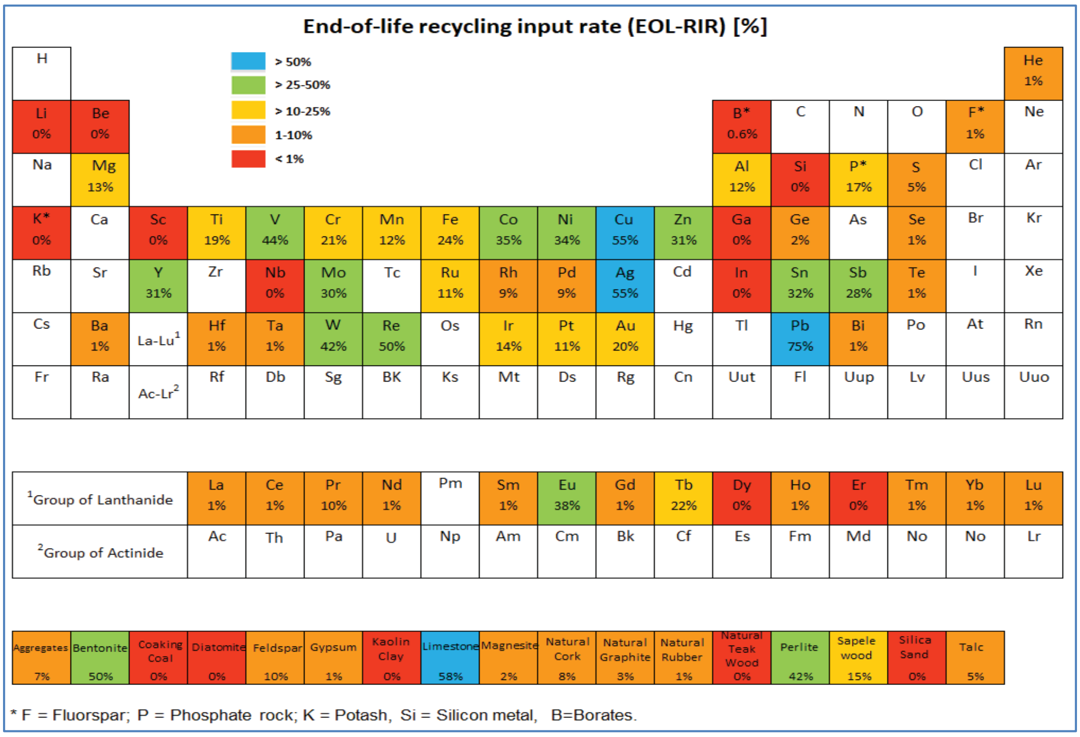

Figure 7: End-of-life recycling input rates (EOL-RIR) in the EU-28 (CRMs and non-CRMs)[15], [16]

[13] http://ec.europa.eu/eurostat/web/circular-economy

[14] As announced in the Circular Economy Action Plan, COM(2015) 614

5. KEY SECTORS (SUPPLY AND DEMAND OF CRITICAL RAW MATERIALS)

This section covers the main source of primary CRMs (mining) and other potential sources (mining waste and landfills), as well as the sectors where most CRMs are used, i.e. constituting the main sources of secondary CRMs (electrical and electronic equipment, batteries, automotive sector, renewable energy, defence industry, chemicals and fertilisers). (See also Annex I: Major applications of CRMs and information on recycling)

5.1. Mining

Extractive industries provide mineral raw materials that are essential to the downstream industries and economic sectors. Extractive industries provide, first of all, primary (critical) raw materials. In addition, mining waste provides a (potential) source of secondary (critical) raw materials.

5.1.1. Data and data sources

The inventory of the *primary* CRM deposits in the EU has been gradually built up in the Framework Programme 7 projects ProMine[17] and Minerals4EU[18] and also in the new Horizon 2020 ERA-NET GeoERA[19] driven by European geological surveys.

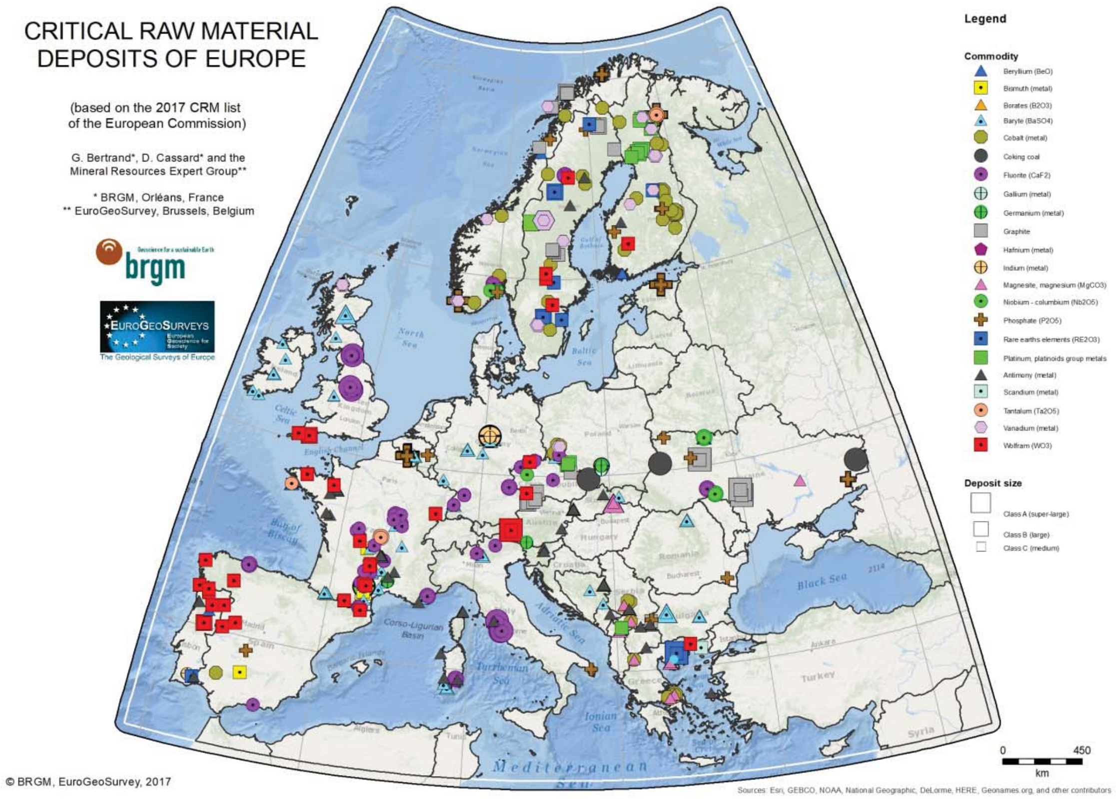

Figure 8: Map of CRM ore deposits in Europe

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15 Source: JRC elaboration based on the EU list of Critical Raw Materials (2017) and MSA Study (2015). The European Commission acknowledges the existence of data gaps and inconsistencies and has initiated a number of steps in view of future data improvement.

16 The 'end-of-life recycling input rate' (EOL-RIR) measures how much of the total material input into the production system comes from recycling of "old scrap". Elements in white indicate that no data or estimates are available from the 2017 EU criticality assessment.

17 http://promine.gtk.fi

18 http://www.minerals4eu.eu

19 http://geoera.eu

The production data of 63 mineral commodities from 168 countries are annually published by the Austrian Federal Ministry of Science, Research and Economy in the publication "World Mining Data"[20] with quality of data indication. The British Geological Survey also publishes similar information in their World Mineral Production annual publication. EU Materials System Analysis and CRM studies and fact sheets use this information (see Figures 1, 3, 5).

As regards *secondary* CRMs extracted or extractable from mining waste, at present there is no detailed database at EU or Member State level although recent EU-funded projects are addressing this lack of comprehensive data and information, in particular the ProSUM project (see section 4.1.3).

The MSA study (see section 4.1.2) depicts extractive waste in the EU using the following two parameters:

- “Extraction waste disposed in situ/tailings” is the annual quantity of the element in the extraction waste disposed in situ. This indicator refers to tailings (waste from extraction and if applicable preliminary step of processing made in situ);
- “Stock in tailings” is the quantity of the element in tailings in EU. This amount corresponds to the “extraction waste disposed in situ/tailings” accumulated over time.

A preliminary analysis from the MSA study on annual flows and stocks of CRMs in extractive waste over the last 20 years is reported in Figure 9. Quantities are indicative and mostly derived from mass balances and expert assumptions. Moreover, CRMs accumulated in tailings have likely undergone chemical and physical changes, which must be further evaluated under several aspects, in view of their possible recovery.

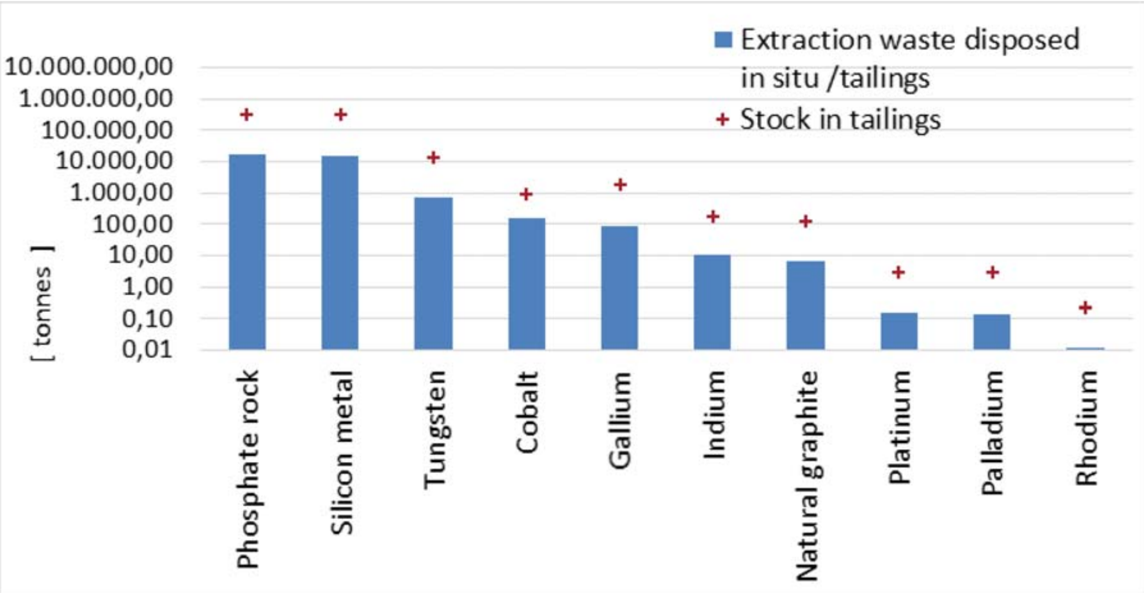

Figure 9: Amounts of some critical raw materials in EU-28 as “Extraction waste disposed in situ/tailings” and “Stock in tailings” (JRC elaboration based on MSA study (2015))

[20] http://www.world-mining-data.info

Data Sources

No	Name and link/ref.	Scope			Reference period / date of publ.	Lan-guage	Free / sub-scrip-tion	Comments
		Subsec-tors	CRMs	Geographic area				
1	Eurostat PRODCOM[21]	Mining	Some	EU 28	2004-2014	English	Free	Data on production of minerals and metals
2	Eurostat[22]	Waste of mining and quar-rying	-	EU 28	2004-2014	English	Free	Data on the gener-ation of hazardous and non-hazardous waste by country and sector. Consistency is limited due to differing reporting methods.
3	Minerals4EU	Mining and min-ing waste	All	EU 28	2014-2015	English	Free	Mining waste data based on a flow and stock model
4	MSA study[23]	Mining and min-ing waste	CRMs (2014)	EU	2015	English	Free	
5	ProSUM[24]	Mining Waste	All	EU 28	2015-	English	Free	Data on stocks of secondary raw materials
6	SMART GROUND[25]	Mining Waste	All	EU 28 (with focus on Italy as case-study country)	2015-	English		Improving knowledge on CRMs, including characterisation of mining waste deposits for CRMs

5.1.2. Existing EU policies

In 2008 the Commission launched a '**Raw Materials Initiative**'[26] complementing Member States' national policies on raw materials. This strategy has three pillars which aim to ensure:

- Fair and sustainable supply of raw materials from global markets;
- Sustainable supply of primary raw materials within the EU;
- Resource efficiency and supply of secondary raw materials through recycling.

The mining and quarrying sector, as well as the forestry sector, have a key role to play under each of these pillars.

The **Extractive Waste Directive** (2006/21/EC) provides for measures, procedures and guidance to prevent or minimise adverse effects on the environment and human health resulting from the management of extractive waste. Under this Directive, Member States are required to ensure that operators in the extractive industry draw up a waste management plan for the minimisation, treatment, recovery and disposal of extractive

21 http://ec.europa.eu/eurostat/web/prodcom

22 http://ec.europa.eu/eurostat/statistics-explained/index.php/Waste_statistics

23 https://ec.europa.eu/jrc/en/scientific-tool/ msa

24 http://www.prosumproject.eu/

25 http://www.smart-ground.eu/

26 http://ec.europa.eu/growth/sectors/raw-materials/policy-strategy

waste, taking account of the principle of sustainable development. This provision broadly follows the logic of circular economy.

The waste management plan shall aim at preventing or reducing extractive waste production and its harmfulness, in particular by considering waste management in the design phase and in the choice of the method used for mineral extraction and treatment. It shall also encourage the recovery of extractive waste by means of recycling, reusing or reclaiming waste, where this is environmentally sound.

A study was commissioned by the Commission to gather data on the implementation of the Extractive Waste Directive in Member States, including on policies and practices regarding the reprocessing of extractive waste. The report of this study was published in July 2017[27]. A few Member States[28] indicated that a dedicated strategy (or guidance) has been adopted encouraging the reprocessing of extractive waste. In a number of Member States[29] there is no dedicated strategy or guidance but relevant provisions are included as part of the wider national policy on waste or resource efficiency. Hungary has commissioned an assessment to identify the quality, quantity and possible exploitation options of the secondary raw materials in the extractive waste facilities. Nevertheless, the study concluded that, overall, Member State policies on reprocessing of extractive waste are limited and focusing more on utilisation of inert waste materials in construction than on innovative reprocessing of waste and tailings to extract value associated with valuable substances and minerals.

5.1.3. Circular Economy Action Plan

As announced in the Circular Economy Action Plan, the Commission has started working on the development of a document gathering best practices in the field of extractive waste management plans. Since the entry into force of the Extractive Waste Directive in 2008, operators have submitted waste management plans as part of their permit applications. By now, as a result of the many years of experience with such plans, a substantial knowledge base should have been established across the whole of the EU, which should enable the identification of best practices that merit a more widespread implementation across the extractive sector. In July 2017, the Commission launched an open call for input to support the development of guidance documents in the field of extractive waste management plans including on aspects related to the circular economy. This document should be completed in 2018 drawing notably on practices in Member States. It will be complementary to the Best Available Techniques reference document (BREF) on the management of extractive waste, which is currently being revised.

Related to the action on best practices in the field of extractive waste management plans, the Circular Economy Action Plan also covers an action on sharing of best practice for the recovery of CRMs from mining waste (and landfills). A number of ongoing Horizon 2020 projects are relevant to this action.

5.1.4. Cooperation with advanced mining countries outside the EU

As part of EU Raw Materials Diplomacy[30], the Commission organised in Brussels in 2014, 2015 and 2016 workshops with advanced mining countries[31] on best practices on mining policies and technologies. Each workshop contained one or two sessions

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27 http://ec.europa.eu/environment/waste/studies/index.htm#extractive_waste

28 Belgium, Bulgaria, Ireland and Sweden

29 Austria, Croatia, Czech Republic, Estonia, Germany, Italy, Malta, Poland, Romania and Spain

30 https://ec.europa.eu/growth/sectors/raw-materials/specific-interest/international-aspects_en

31 Australia, Brazil, Canada, Chile, Mexico, Peru, South Africa and USA

dedicated to mining waste management, increasingly focusing on the economic potential of recovery of (critical) raw materials from mining waste. These workshops allowed a regular exchange of experiences between the EU and advanced mining countries. In addition, in 2015, the Commission organised an international conference[32] for exchange of good practices on metal by-products recovery, addressing technology and policy challenges, including regarding the recovery of several CRMs as by-products.

5.1.5. Best Practices

- Systems-integrated material production: Taking optimal account of the "companionality" of metals, i.e. the production of many critical metals is dependent on the production of carrier (base) metals. The picture below summarises the chemical and physical linkages between metals and the set of metallurgical processes that has been developed to accommodate these linkages. Base metals which are potential sources of CRMs can be seen as part of a systems-integrated metal production approach. It applies to both mining and recycling.

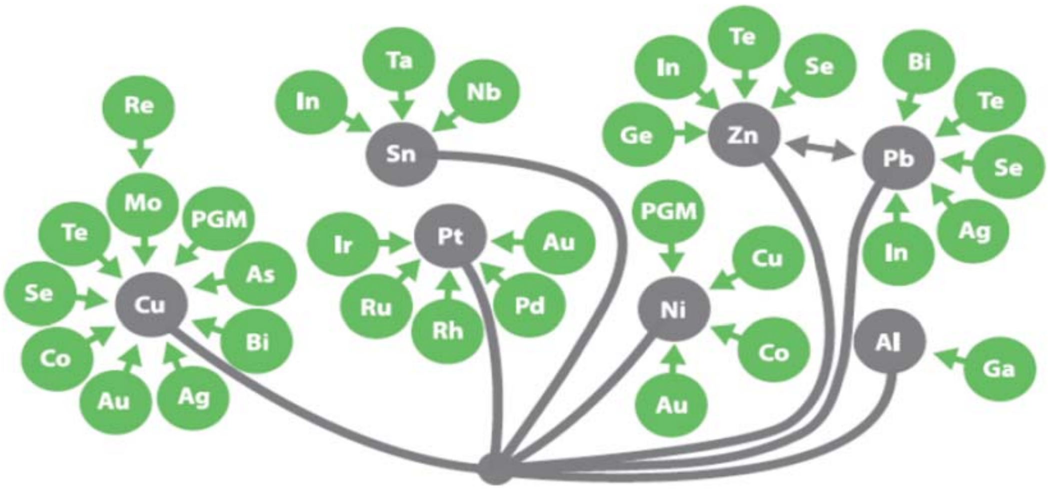

Figure 10: Sources of certain critical (and non-critical) raw materials (green) and their associated base metal (grey)[33]

- Developing a dedicated national (or regional) strategy, or guidance, for the reprocessing of extractive waste.[34]
- Benefiting from technological advancements, the Penouta mine in Spain re-started mining operations in 2011 processing extractive waste to extract tin, tantalum and niobium and other minerals obtained in co-production.
- The Horizon 2020 project SCALE[35] is developing a European scandium value chain through innovations which will allow the extraction of scandium from European bauxite residues.
- Improving the state of knowledge on extractive waste sites: the ongoing Horizon 2020 projects ProSUM and SMART GROUND are active in the area of data availability on CRMs in extractive wastes in view of a comprehensive pan-European

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32 https://ec.europa.eu/growth/tools-databases/eip-raw-materials/en/content/international-conference-%E2%80%9Cexchange-good-practices-metal-products-recovery-technology-and

33 Resnick Institute 2011

34 European Commission (2017): Assessment of Member States' performance regarding the implementation of the Extractive Waste Directive

35 http://scale-project.eu/

database on mining waste sites, which is currently missing.

5.1.6. Possible further actions

- Improve the knowledge base by organising and reinforcing pan-European data acquisition, collection, and management at all levels on extractive waste sites (both legacy and active ones), on the mineralogical and elemental composition of the waste.
- Support the development of tools to assess feasibility and benefits (economic, environmental safety, etc.) related to the recovery of CRMs from mining wastes.
- Further support the development of technologies to efficiently extract CRMs from primary ores and extractive wastes.

5.2. Landfills

Many of Europe's landfills, which total number is estimated to exceed 500,000[36] represent a potential source of CRMs that may be recovered either from disposed waste electronic equipment or from certain industrial wastes containing CRMs.

5.2.1. Data and data sources

Eurostat[37] provides yearly statistics about the flows of municipal solid waste disposed in landfills. These statistics show a trend of reduction of landfilled waste from 144 million tonnes in 1995 to 61 million tonnes (-58%) in 2015 in the EU, representing 26% of municipal waste. In addition, statistics on total waste shows that its landfilling rate in 2014 was 47%, while the landfilling rate of waste excluding major mineral wastes was 27%.

No systematic collection of data specific to CRMs ending up in landfills is carried out and, subsequently, no precise statistics are currently available. Only rough estimates of the flows and amount of CRMs ending up in landfills are presently possible, such as those provided in the MSA study[38], through two parameters:

- "Annual addition to stock in landfill" that quantifies the amount of the element that is annually added to landfill (in the EU), including processing waste, manufacturing waste, products at end of life and recycling waste; and
- "Stock in landfill" that quantifies the amount of the element in landfill (in the EU). For the calculation of the stock, the study generally considers the amount of material accumulated in landfill over the last 20 years as a maximum level.

The estimated amounts of CRMs annually sent to landfills and the estimated accumulation in landfill over the last 20 years in the EU are plotted in Figure 11. Quantities are indicative and are mostly derived from mass balances and expert assumptions. Moreover, CRMs accumulated in landfills have likely undergone chemical and physical changes, which means that their possible recovery must be carefully assessed.

36 https://www.eurelco.org/infographic

37 http://ec.europa.eu/eurostat/statistics-explained/index.php/Municipal_waste_statistics

38 https://ec.europa.eu/jrc/en/scientific-tool/msa

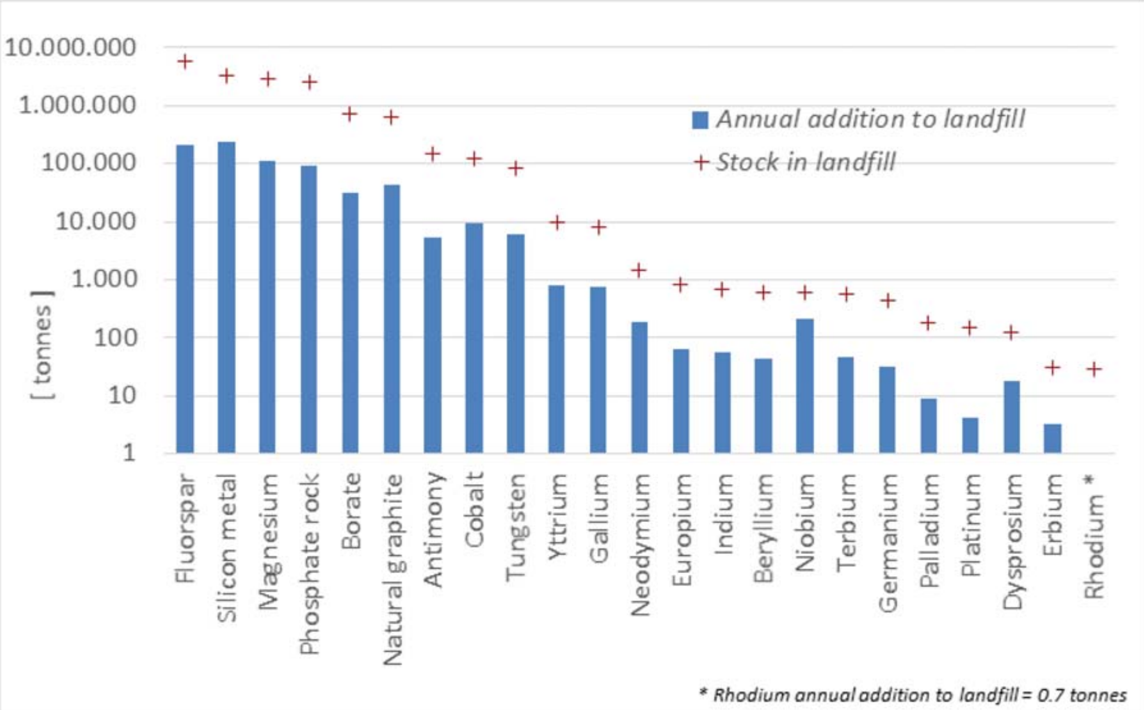

Figure 11: Amounts of CRMs as "Annual addition to stock in landfills in EU" and "Stock in landfill in EU" (JRC elaboration based on MSA study (2015))

A recent study[39] provided a first estimate of the concentration of CRMs in British landfills operating between 1980 and 2011 and receiving municipal, commercial and industrial waste. This study found that the overall concentration of CRMs in these landfills was about 380 mg/kg[40]. If these concentrations were generalised to the EU landfills, a rough estimated total content of for instance rare earth elements would be 470-520 thousand tonnes.[41] Larger amounts could be present considering also the landfills operating before 1980, but no detailed data are available on their composition.

The Horizon 2020 project SMART GROUND[42] fosters resource recovery in landfills (landfill mining) by improving the availability and accessibility of data and information on secondary raw materials present in landfills in the EU. The project will integrate all the data from existing databases and new information retrieved in a single EU databank.

39 Gutiérrez-Gutiérrez (2015), Rare earth elements and critical metal content of extracted landfilled material and potential recovery opportunities. Waste Management, (42).

40 In particular, it was reported that the concentration of REEs (Sc, Y, La, Ce, Pr, Nd, Sm, Eu, Gd, Tb, Dy, Ho, Er, Tm, Yb, Lu) was 220 ±11 mg/kg, PGMs; concentration of PGMs (Pt, Pd, Ru) was 2,1 ±0,2 mg/kg; concentration of other metals (Li, Ln, Sb, Co) was 156 ±7 mg/kg. Concentration of other valuable metals (such as Cu, Al, Ag, Au) in such landfills was 6,6 ±0,7 g/kg.

41 Estimations provided by the SMART GROUND project

42 http://www.smart-ground.eu

Data sources

No	Name and link/ref.	Scope			Reference period / date of publ.	Language	Free / subscription	Comments
		Subsectors	CRMs	Geographic area				
1	Eurostat[43]	Municipal waste statistics		EU 28	1995-2015	English	yes	Data on municipal waste generated and treated in the EU. It includes statistics on waste landfilled.
2	Eurostat	Total waste statistics		EU 28	2004-2014	English	yes	Data on total waste generated and treated in the EU. It includes statistics on waste landfilled.
3	MSA study[44]	Various	CRMs (2014)	EU 28	2016 (updated every 3-5 years)	English	yes	Flows of materials landfilled estimated for 28 raw materials (including all the CRMs identified in the CRM study of 2014)
4	EURELCO[45]	Landfills	All	EU 28	2014-onward	English	yes	European network for enhanced landfill mining, including data collection and presentation
5	SMART GROUND[46]	Landfills	All	EU 28 (with focus on certain case-study countries)	2015-2018	English	yes	Data on secondary raw materials, including characterisation of landfills for CRMs

5.2.2. *Existing EU policies*

Rules are in place in the EU, such as Directives 2008/98/EC on waste[47] and 1999/31/EC on the landfill of waste[48], to ensure that environmental and human health risks posed by landfill operations are mitigated and subsequently eliminated. However, it should be noted that landfills or tipping sites no longer in operation as of the entry into force of the first EU Waste Framework Directive in 1977 are not subject to EU environmental and public health protection rules.

5.2.3. *Circular Economy Action Plan*

The Circular Economy Action Plan acknowledges that landfills could be a source for recovering critical raw materials. It contains an action on sharing of best practice for the recovery of CRMs from landfills (and mining waste). A number of ongoing EU-funded projects are relevant to this action.

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43 http://ec.europa.eu/eurostat/statistics-explained/index.php/Municipal_waste_statistics
44 https://ec.europa.eu/jrc/en/scientific-tool/msa
45 https://www.eurelco.org/infographic
46 http://www.smart-ground.eu/
47 OJ L 312, 22.11.2008
48 OJ L 182, 16.7.1999.

5.2.4. Best Practices

- EU network for landfill mining: The EURELCO[49] (European Enhanced Landfill Mining Consortium) is a Raw Material Commitment recognised by the European Innovation Partnership on Raw Materials. It supports technological, legal, social, economic, environmental and organisational innovation in the area of 'enhanced landfill mining' i.e. safe exploration, conditioning, excavation and integrated valorisation of (historic, present and/or future) landfilled waste as both materials - including CRMs - and energy.
- Investigation and characterisation of landfills in the EU e.g. through the on-going SMART GROUND Horizon 2020 project (see above).

5.2.5. Possible further actions

- Examine options for promoting the recovery of materials (and energy) from historic and present landfills under economically viable conditions.

49 http://www.eurelco.org/mission

5.3. Electrical and Electronic Equipment

5.3.1. Data and data sources

The electrical and electronic equipment (EEE) sector depends on a variety of CRMs including antimony, beryllium, cobalt, germanium, indium, platinum group metals (PGMs), natural graphite, rare earth elements (REEs), silicon metal, and tungsten (Figure 12).

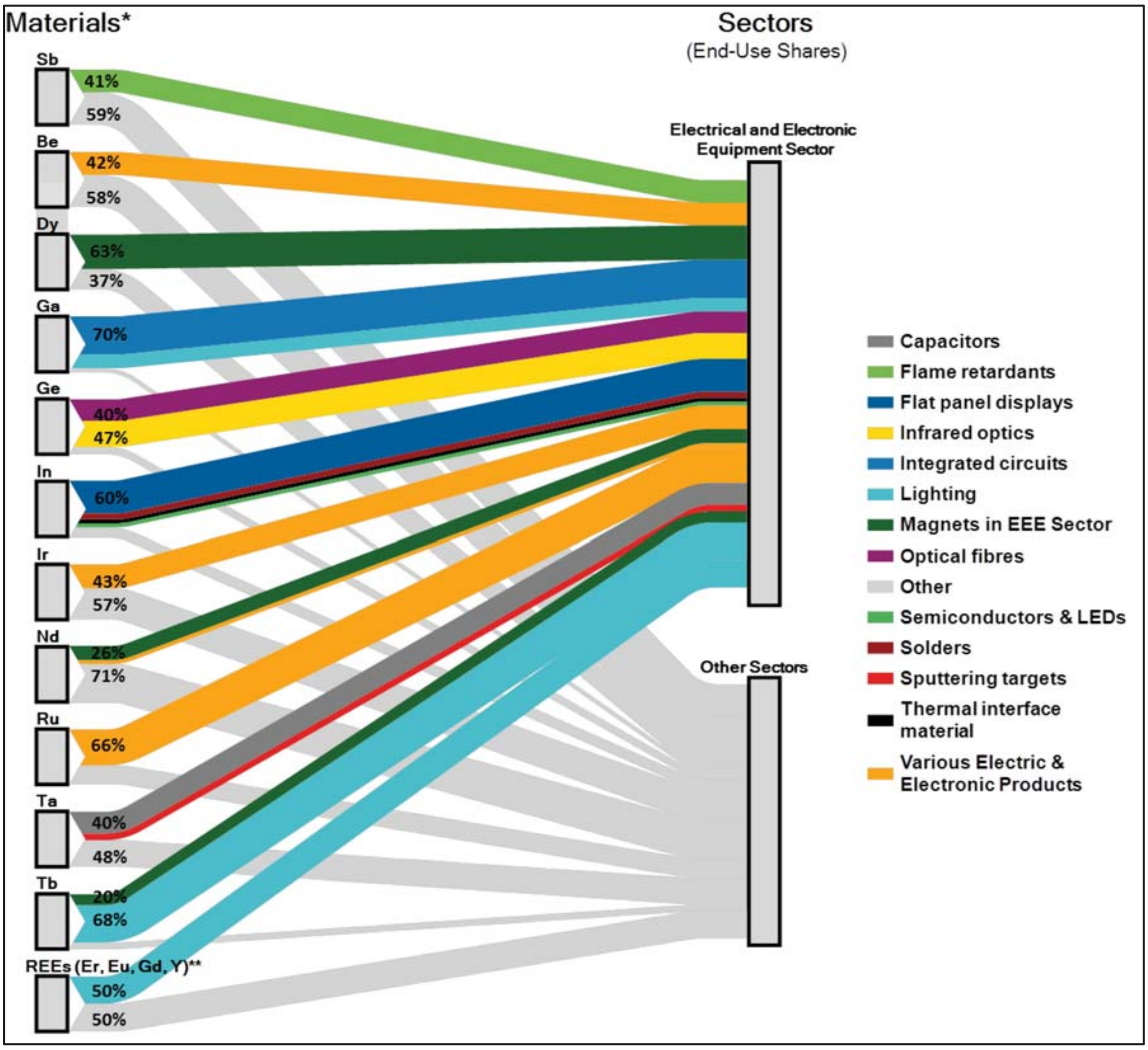


Figure 12: Share of CRMs used in the electric and electronic sector according to the 2017 CRM assessment[50]

* Only a subset of CRMs used in the EEE sector are included. Additional CRMs linked to the EEE sectors include Ce, Co, Fluorspar, Hf, He, La, Mn, Natural rubber, Pd, Pt, Pr, Rh, Sm, Si, W, and V.
**Average share for Er, Eu, Gd, and Y.

For example, gallium finds widespread use in integrated circuits and light emitting diodes (LEDs) for lighting. Other important product application associated with the EEE sector includes, e.g., magnets, flat screen displays, and optical fibres. Figure 12 also shows that the EEE sectors are the major user of gallium (95% of the element is used in

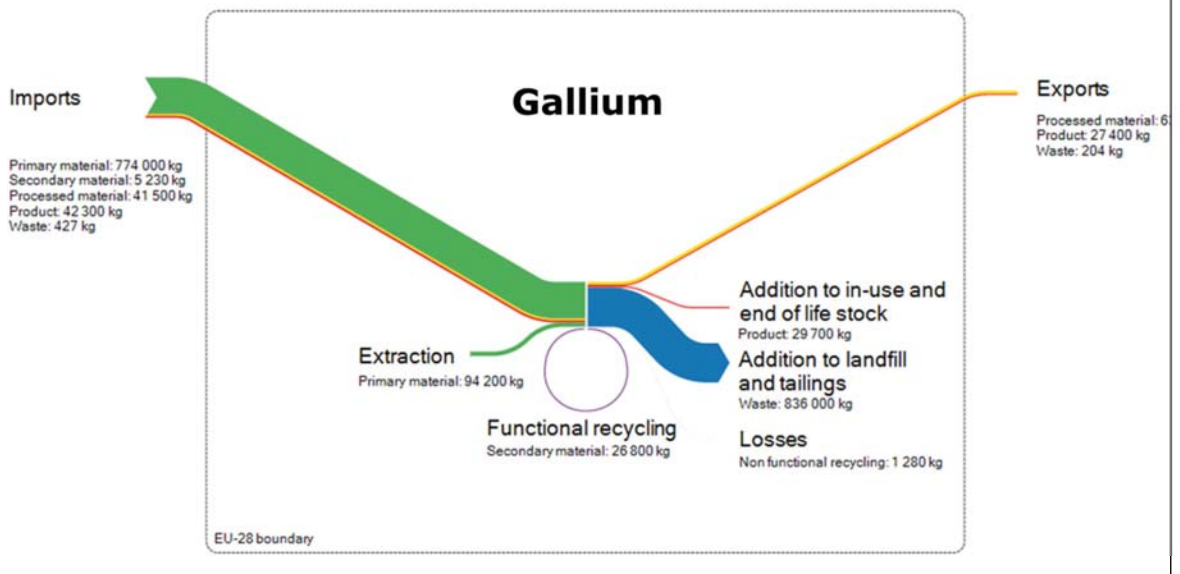
[50] JRC elaboration based on data from the 2017 EU criticality assessment. The EEE sector consists of two NACE sectors (C26 – Manufacture of computer, electronic and optical products and C27 – Manufacture of electrical equipment). The share of Sb in flame retardants used in the EEE sector is estimated at 96% (http://www.oakdenehollins.com/media/316/WRAP_01_316_IMT002_CRMs_in_the_UK_Summary_FINAL_0.pdf). The fraction of Nd, Pr, Dy, and Tb in magnets used in the EEE sector is based on a global average figure given in Du and Graedel. Global Rare Earth In-Use Stocks in NdFeB Permanent Magnets. Journal of Industrial Ecology 2011, 15 (6), 836–843.

the EEE sectors), germanium (87%), indium (81%), and several REEs (e.g., used in lighting applications).

Some flows of CRMs reach indirectly EEE, and these flows are not always captured by statistics. For example, 52% of the overall flow of antimony is used to produce flame retardant for plastics[51], afterwards used to manufacture EEE. Additional information of these flows is necessary to capture the final uses of CRMs. This implies that the relative relevance of EEE for certain CRMs can be even higher than shown in Figure 12.

For CRMs used predominantly in the EEE sectors (i.e., gallium, germanium, indium, and dysprosium (as an example of a heavy REE[52]), Figure 13 provides an indication of the amounts of secondary materials functionally recycled to contribute to EU demand in 2012 (see purple coloured Sankey line).

Figure 13: Simplified Sankey diagrams for materials used predominantly in the EEE sector: (a) Gallium (b) Germanium (c) Indium and (d) Dysprosium. Values for the EU-28 expressed in t/year for the year 2012 based on the 2015 MSA study[53]



(a)

51 Antimony is generally applied as a synergist (antimony trioxide) for brominated flame retardants used into EEE.

52 Heavy rare earth elements are important constituents of tri-band phosphor lighting used for linear fluorescent tubes and compact fluorescent lamps, as well as CCFL LCD backlights for flat panel displays.

53 https://ec.europa.eu/jrc/en/scientific-tool/msa