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Report on Critical Raw Materials and the Circular Economy

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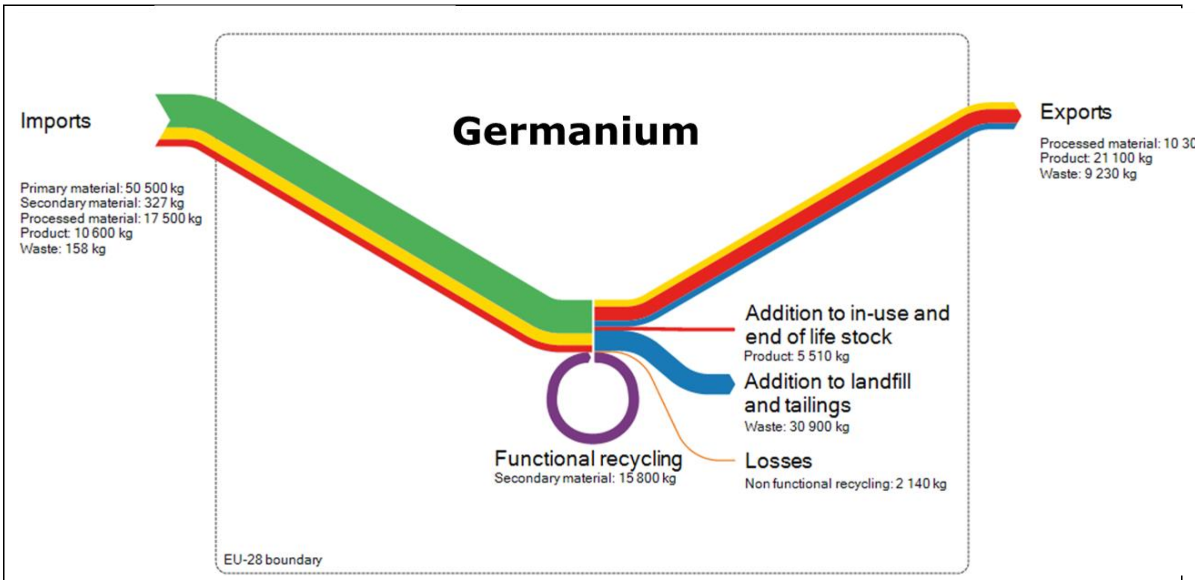
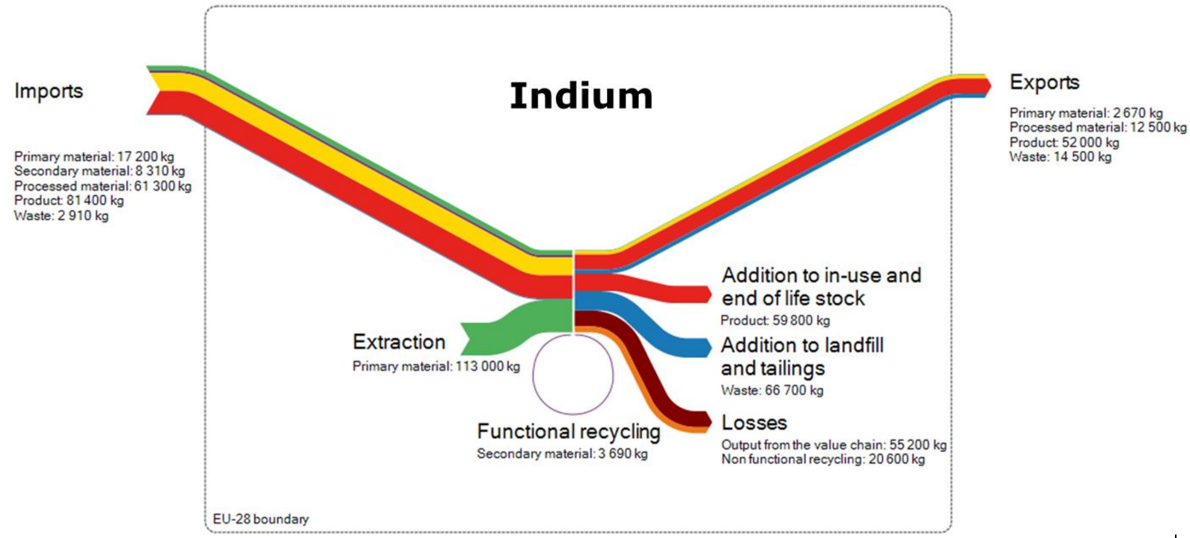
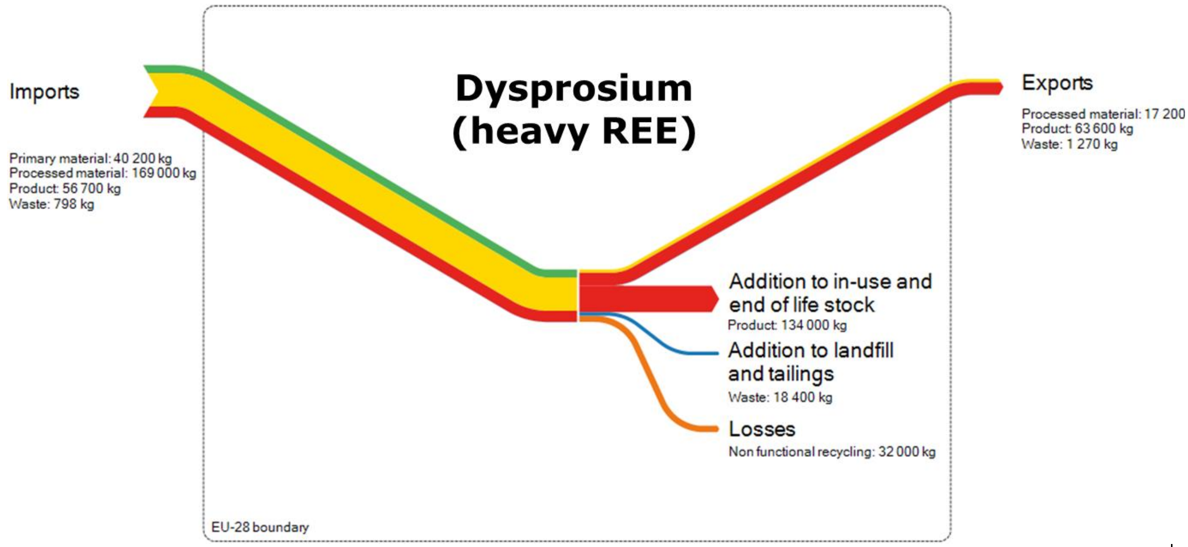

Germanium
Imports
Primary material: 50 500 kg
Secondary material: 327 kg
Processed material: 17 500 kg
Product: 10 600 kg
Waste: 158 kg
Exports
Processed material: 10 30
Product: 21 100 kg
Waste: 9 230 kg
Addition to in-use and end of life stock
Product: 5 510 kg
Addition to landfill and tailings
Waste: 30 900 kg
Functional recycling
Secondary material: 15 800 kg
Losses
Non functional recycling: 2 140 kg
EU-28 boundary

(b)


Primary material [t]
Secondary material [t]
Processed material [t]
Product [t]
Waste [t]
Output from the value chain [t]
In use dissipation [t]
Non functional recycling [t]


Indium
Imports
Primary material: 17 200 kg
Secondary material: 8 310 kg
Processed material: 61 300 kg
Product: 81 400 kg
Waste: 2 910 kg
Exports
Primary material: 2 670 kg
Processed material: 12 500 kg
Product: 52 000 kg
Waste: 14 500 kg
Addition to in-use and end of life stock
Product: 59 800 kg
Addition to landfill and tailings
Waste: 66 700 kg
Extraction
Primary material: 113 000 kg
Functional recycling
Secondary material: 3 690 kg
Losses
Output from the value chain: 55 200 kg
Non functional recycling: 20 600 kg
EU-28 boundary

(c)



(d)

For example, Figure 13 shows that currently only a small fraction of CRMs remains inside Europe's socio-economic system through functional recycling. For dysprosium (one of the heavy REEs), functional recycling is not observed at all. The potential to improve recycling of materials depends on various factors such as recycling infrastructure, market prices, possibility to disassemble products, and the amount of material becoming available from products reaching their end-of-life. In some cases, material flows are going to stock (e.g. when used in durable products) and they are not available for recycling for several years. This, however, is often the result of a continuous service of the materials to the society i.e. maintaining value within the economy, in line with the circular economy concept.

Lifetime of CRMs in EEE largely depends on the type of application and the end-use product. For example, lifetimes of REEs can vary from a few years (or even months) for lamps, up to decades in high efficiency motors. It is not possible either to generalise on the ease of disassembly (and hence of repair and re-use) of certain parts containing CRMs, since this depends on the type of product and even its brand. It is observed that the trend of miniaturisation of electronics is generally making disassembly of components increasingly challenging.

At the same time, the recycling of CRMs contained in EEE largely depends on the type of application and on the value of the raw materials. For example, precious metals in electronics (e.g. PGMs in printed circuit boards) are generally separated and recycled because this is economically viable[1]. On the contrary, the recycling of materials such as

[1] http://www.umicore.com/en/about/elements/

gallium, germanium, indium, silicon metal, and REEs is more challenging because of their disperse use in products[2].

Few data are available about the reuse of EEE. Reuse of EEE is generally not much established in the EU, except for some durable household products, e.g., washing machines and dishwashers, for which the reuse rate in certain EU countries can amount to 1% of the flow[3].

The ProSUM EU Urban Mine Knowledge Data Platform provides data on stocks and flows of secondary raw materials arising from different WEEE such as end-of-life screens, including end-of-life Cathode Ray Tube (CRT) TVs and monitors, Liquid Crystal Display (LCD) based TVs and monitors, laptops, and tablets[4]. The project has estimated the content of screens placed on the market and screen waste over time (see Figures 14 and 15). This includes the content of precious metals such as gold (Au) and silver (Ag) but also CRMs such as indium (In), neodymium (Nd) and palladium (Pd).

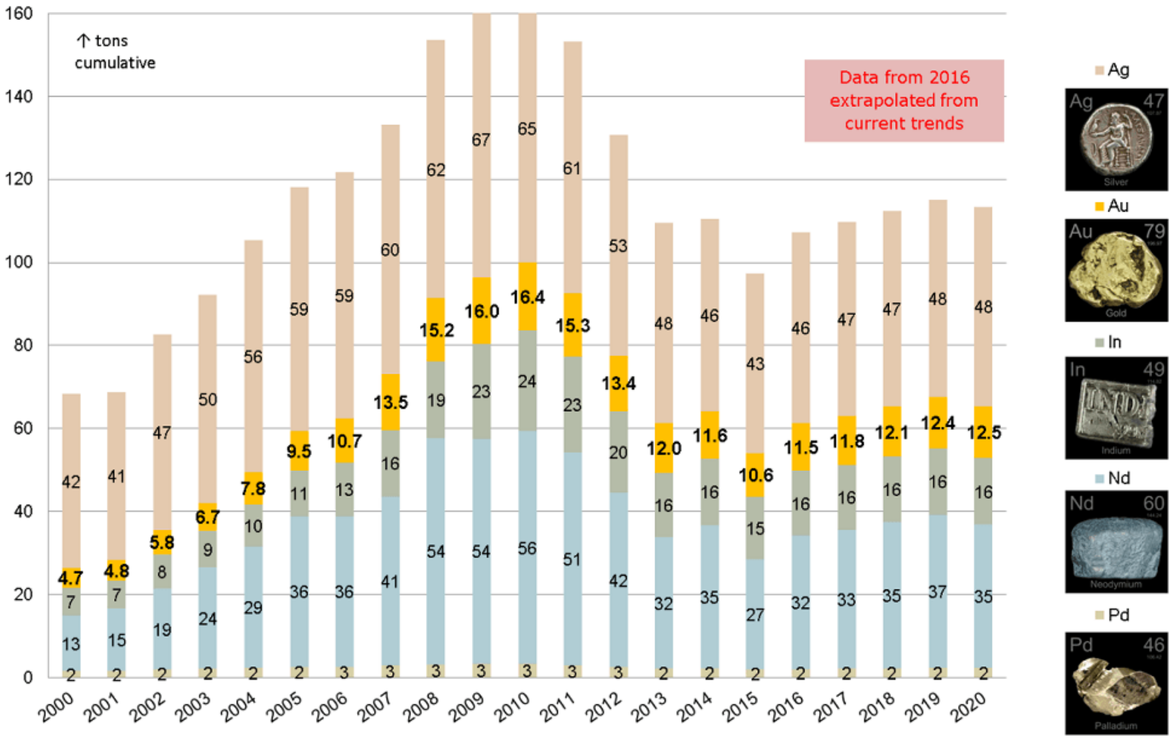


Figure 14: Selected precious metals and CRMs in screens placed on market 2000-2020, in tonnes (source: ProSUM project)

2 http://bookshop.europa.eu/en/feasibility-study-for-setting-up-reference-values-to-support-the-calculation-of-recyclability-recoverability-rates-of-electr-on-ic-products-pbLBNA27922/

3 http://publications.jrc.ec.europa.eu/repository/handle/JRC102632

4 More detailed information can be found on http://rmis.jrc.ec.europa.eu/?page=contributions-of-h2020-projects-236032

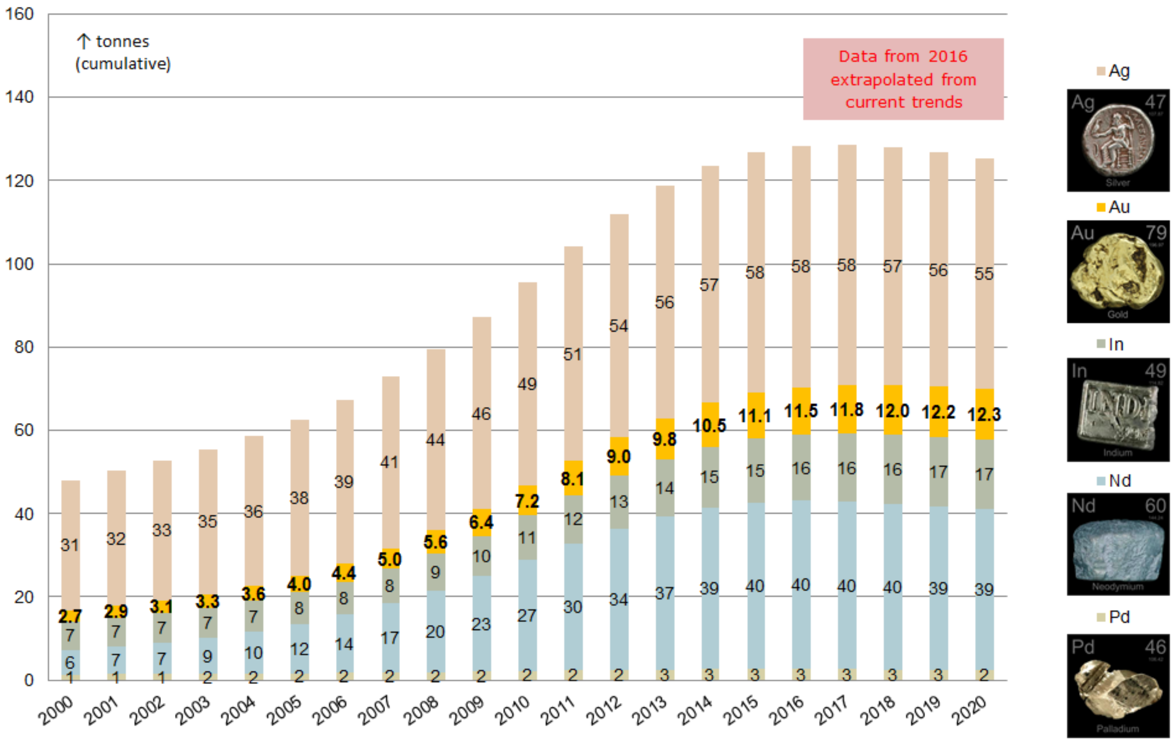


Figure 15: Selected precious metal and CRM content estimated in screen waste generated in the EU 2000 -2020, in tonnes (source: ProSUM project)

Data sources

No	Name and link/ref.	Scope			Reference period / date of publ.	Language	Free / subscription	Comments
		Subsectors	CRMs	Geographic area				
1	Eurostat[5]	WEEE	-	EU 28	2005-2014	English, German, French	Free	Data on WEEE collected and treated by Member States
2	ProSUM[6]	WEEE	All	EU 28	2015-	English	Free	Data on stocks and flows of secondary raw materials
3	Ecodesign preparatory study on enterprise servers[7]	Enterprise servers	All	EU 27	2014	English	Free	Example of preparatory study investigating the relevance of certain CRMs for the product group in question[8]
4	Review of Ecodesign preparatory study on fan[9]	Fans	Rare Earths	EU 27	2015	English	Free	Example of preparatory study investigating the relevance of rare earths for the product group in

5 http://ec.europa.eu/eurostat/web/waste/key-waste-streams/weee

6 http://www.prosumproject.eu/

7 https://bookshop.europa.eu/en/ecodesign-preparatory-study-on-enterprise-servers-and-data-equipment-pbET0415685/;pgid=GSPefJMEtXBSR0dT6jbGakZD0000SnCBUHBt;sid=dGYfUdVvKhofVY0Th7OB9rdKc7UZgnesCDY=

8 See also the JRC study on material efficiency aspects of servers: https://bookshop.europa.eu/en/environmental-footprint-and-material-efficiency-support-for-product-policy-pbLBNA27467/

9 http://www.eceee.org/static/media/uploads/site-2/ecodesign/final_report_fan_review_-_16_mar_2015.pdf

								question
5	Recovery of rare earths from electronic waste: an opportunity for high-tech SMEs. Study for the ITRE Committee IP/A/ITRE/2014-09.	EEE	REEs	EU28	2014	English	Free	

1.1.1. Existing EU policies

The Ecodesign Directive[10] addresses the potential negative impact that energy-related products can have on the environment. It does so by 'pushing' the market towards more energy efficient products as the worst performing ones are banned from the market. This Directive is complemented by the Energy Labelling Directive[11], which 'pulls' the market towards more energy (and resource) efficient products by informing consumers about their energy performance through the well-recognised and understood EU energy label.

The Ecodesign Directive provides an overall framework, while specific requirements are put in place for different groups of products that have, during their use, an impact on the energy consumption. These requirements are set after analysing the impact the products can have on the environment during their production, use and disposal or recycling.

The Ecodesign Working Plan 2016-2019[12], adopted as part of the Clean Energy for All Europeans package, sets out to give more support to measures seeking to improve resource efficiency, reparability, recyclability and durability. See Annex II for examples of CRMs discussed within Ecodesign preparatory studies.

The WEEE Directive 2012/19/EU has as its objective to contribute to sustainable production and consumption of EEE through, as a first priority, the prevention of waste and, in addition, by the preparation for re-use, recycling and other forms of recovery of waste of EEE, so as to reduce the disposal of waste and to contribute to the efficient use of resources and the retrieval of valuable secondary raw materials contained in EEE.

The WEEE Directive sets collection targets to be met over time. Until 2015 the target of 4 kilograms per inhabitant from private households applied, while a target of 45% of the average weight of EEE placed on the market in the three preceding years applies from 2016. From 2019, a target of 65% of the average weight of EEE placed on the market in the three preceding years, or 85% of WEEE generated in the year of reference, applies.

The WEEE Directive also requires that all separately collected WEEE undergoes proper treatment in order to avoid losses of valuable secondary raw materials. To this end, it sets recovery targets which are applicable per EEE category as set out in Annex V to the Directive. Annex VII to the Directive lays down minimum treatment requirements.

To assist relevant operators in fulfilling the requirements of the WEEE Directive, the Commission requested the European Standardisation Organisations to develop non-binding European standards for the treatment, including recovery, recycling and preparing for reuse of WEEE, reflecting the state of the art. The standards[13] have been largely finalised by CENELEC.

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10 Directive 2009/125/EC

11 Directive 2010/30/EU

12 COM(2016) 773 final

13 http://ec.europa.eu/environment/waste/weee/standards_en.htm

In order to support Member States in reaching the targets and the full implementation on the ground of the Directive, the Commission has initiated a targeted compliance promotion initiative, starting with assessing the implementation in Member States. Critical factors and obstacles to reaching the targets as well as good practices are being identified, to enable Member States to learn from each other and for further developing WEEE policies.

1.1.2. Circular Economy Action Plan

Additional emphasis is to be put on circular economy aspects in future product requirements under the Ecodesign Directive. In 2016, standardisation work was started within CEN/CENELEC following a request[14] by the Commission. The work includes the development of a general method to declare the use of CRMs in energy-related products. The results of the standardisation work are expected by March 2019.

To facilitate preparation for reuse and the environmentally sound treatment of WEEE, supporting the requirement in the WEEE Directive[15], the Commission initiated a dialogue between manufacturers of EEE and re-use operators and recyclers of WEEE with the aim to improve the exchange of information needed for preparation for reuse and treatment of WEEE. Following a first workshop in 2015, European associations representing the parties concerned are engaged in discussions about how to further operationalise these requirements, specifying information needs and communication channels etc. Initially, the focus of these efforts lies on information needed for the environmentally sound treatment of WEEE as far as dangerous substances and mixtures are concerned, but the scope should be broadened at a later stage to also cover information that will foster the preparation for reuse of WEEE (components) and the recycling of CRMs, and be aligned with the above-mentioned standardisation work.

The Action Plan, with a view to fostering increased recycling of CRMs, also includes the development of European standards for material-efficient recycling of complex end-of-life products such as WEEE. The Horizon 2020 project SCRREEN (see Section 3.4) is carrying out preparatory work on WEEE to this end, and a request from the Commission to the European Standardisation Organisations is underway.

As pointed out in the Action Plan, in order to raise levels of high-quality recycling, improvements are needed in waste collection and sorting. A new Horizon 2020 funded project called COLLECTORS[16] will map different WEEE collection systems in Europe, gain insight into the overall performance of systems and support decision-makers in shifting to better-performing systems via capacity-building and guidelines.

Finally, in order to foster high-quality recycling in the EU and elsewhere, the Action Plan sets out to promote voluntary certification of treatment facilities for certain key types of waste including WEEE. The Commission has launched a call for proposals under Horizon 2020 to this effect.[17]

1.1.3. Best Practices

- Using the Ecodesign Directive to improve the design of EEE so as to increase the recycling of CRMs. Several eco-design regulations are asking manufacturers to

[14] M/543, http://ec.europa.eu/growth/tools-databases/mandates/index.cfm?fuseaction=search.detail&id=564

[15] Article 15 of the WEEE Directive requires that producers provide information on different EEE components and materials, as well as the location of dangerous substances and mixtures in EEE which shall be made available to operators carrying out preparation for re-use and/or treatment operations.

[16] https://www.innovationplace.eu/project/collectors-waste-collection-systems-assessed-and-good-practices-identified/954

[17] https://ec.europa.eu/research/participants/portal/desktop/en/opportunities/h2020/topics/ce-sc5-08-2018-2019-2020.html

provide technical documentation of "*information relevant for disassembly, recycling or disposal at end-of-life*". More specifically, the regulation on ventilation units[18] requires "*detailed instructions (...) for the manual disassembly of permanent magnet motors, and of electronics parts*" that generally contain significant amounts of CRMs (in particular REEs). Several preparatory studies are addressing the use of CRMs and circular economy aspects, e.g. those on electronic displays or enterprise servers (see Annex II).

- Supporting the development of innovative recycling technologies for CRMs. The Commission has funded several research projects concerning the development of innovative solutions for the recycling of CRMs from EEE. For example, the RECLAIM project[19] led to the design and construction of an innovative plant for the recycling of yttrium and europium from spent fluorescent lamp powders. (See Section 3.6 for examples of on-going projects.)

1.1.4. Possible further actions

- Several recent preparatory studies under the Ecodesign Directive have come up with proposals of requirements to ensure an easier extraction at end-of-life of key components containing CRMs or proposals for declaring the content of some CRMs.
- Further explore with stakeholders the potential of new satellite technologies to better detect and tackle e-waste crime.

See also the Technological Roadmap to Near Zero Waste in WEEE[20] of the Horizon 2020 project NEW_InnoNet.

5.4 Batteries

(This section also covers to a certain extent batteries used in the automotive sector. For more information on such batteries, see Section 5.5.)

5.4.1 Data and data sources

There are three types of batteries: portable, industrial and automotive batteries. In the last decades, new battery chemistries have appeared on the market due to the development of new applications (e.g. electric vehicles, e-bikes). Depending on the battery chemistry, the main CRMs embedded in waste batteries are antimony, cobalt, natural graphite, indium and some rare earth elements (see Figures 16 and 17). Antimony is mainly use for lead-acid batteries, and its use has declined due to new battery technologies.[21] In contrast, in recent years the battery market has seen a relative increase in the amount of cobalt: from 25% of global end uses of cobalt in 2005 to 44% in 2015.[22] This is mainly related to specific Li-ion chemistries (e.g. Li-NMC suitable for new applications, see Figure 16). Concerning natural graphite, almost 10% of worldwide uses of graphite in 2010 was for the batteries sector.[23,24] In fact, graphite is widely used in several rechargeable and non-

[18] Commission Regulation (EU) No 1253/2014. http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32014R1253

[19] http://www.re-claim.eu/

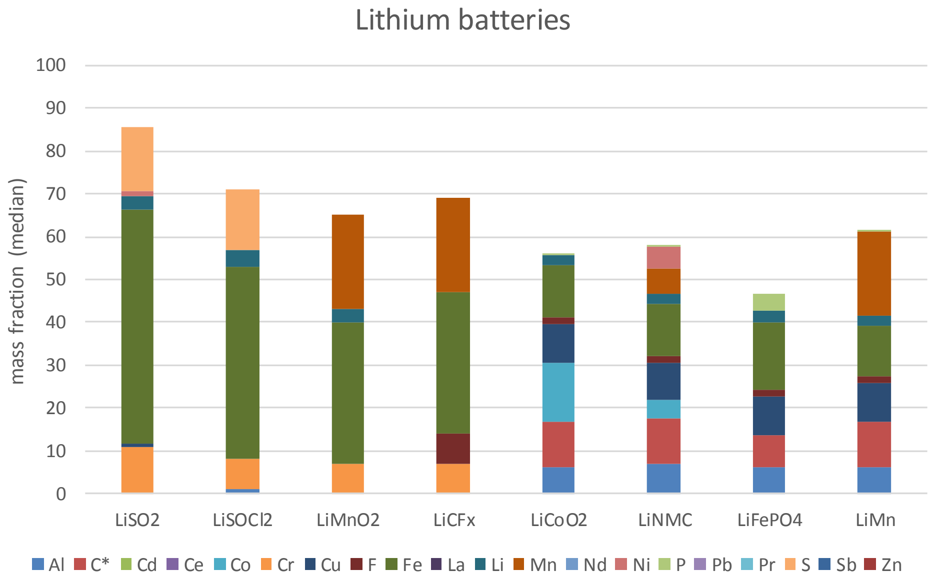
[20] http://www.newinnonet.eu/ReportsList.aspx

[21] EC, 2015. "Report on Critical Raw Materials for the EU critical raw materials profiles", available at http://ec.europa.eu/DocsRoom/documents/11911/attachments/1/translations/en/renditions/native

[22] 2017 CRM assessment

[23] EC, 2015. "Report on Critical Raw Materials for the EU critical raw materials profiles", available at http://ec.europa.eu/DocsRoom/documents/11911/attachments/1/translations/en/renditions/native

rechargeable batteries (both portable and industrial) as anode, for example in the quickly growing Li-ion battery market (see Figure 16).[25] From 2010 to 2017, alkaline batteries accounted for about 5% of indium consumption.[26] Finally, among rare earth elements, 10% of the worldwide lanthanum and 6% of cerium are used for NiMH batteries.[27]



* Graphite carbon

Figure 16: Elements embedded in Li-ion batteries according to specific chemistries (source: ProSUM project)

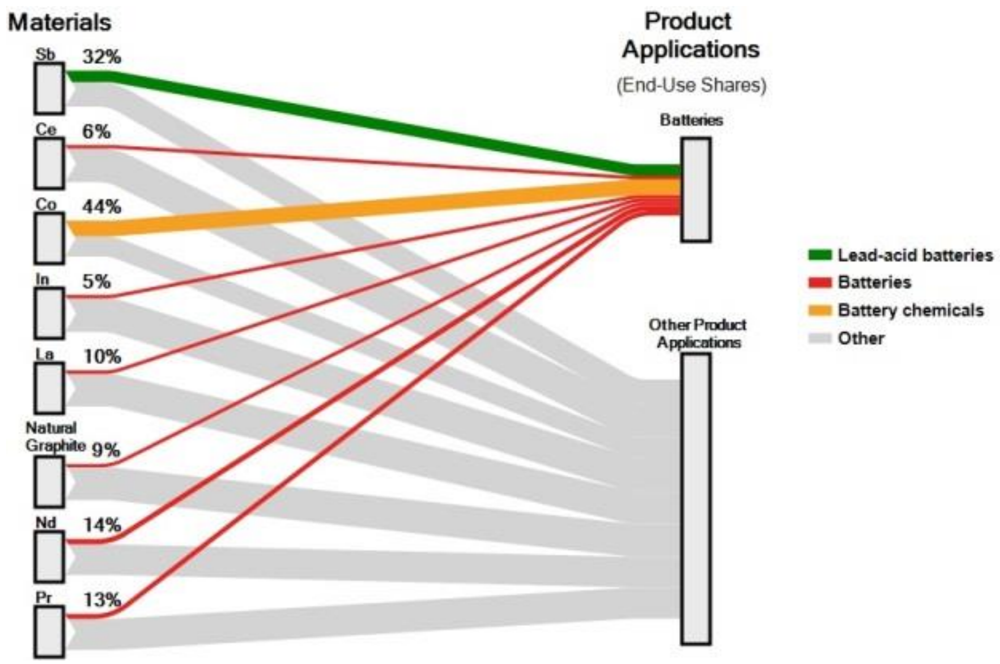


Figure 17: Flow of CRMs into battery applications according to the 2017 CRM assessment

[24] Labie R. et al. (2015). "Recuperation of critical metals in Flanders: Scan of possible short term opportunities to increase recycling", available at https://steunpuntsumma.be/nl/publicaties/recuperation-of-critical-metals-in.pdf

[25] EC, 2015. "Report on Critical Raw Materials for the EU critical raw materials profiles", available at http://ec.europa.eu/DocsRoom/documents/11911/attachments/1/translations/en/renditions/native

[26] Indium Corporation (2013), The Indium Market. 2017 CRM assessment

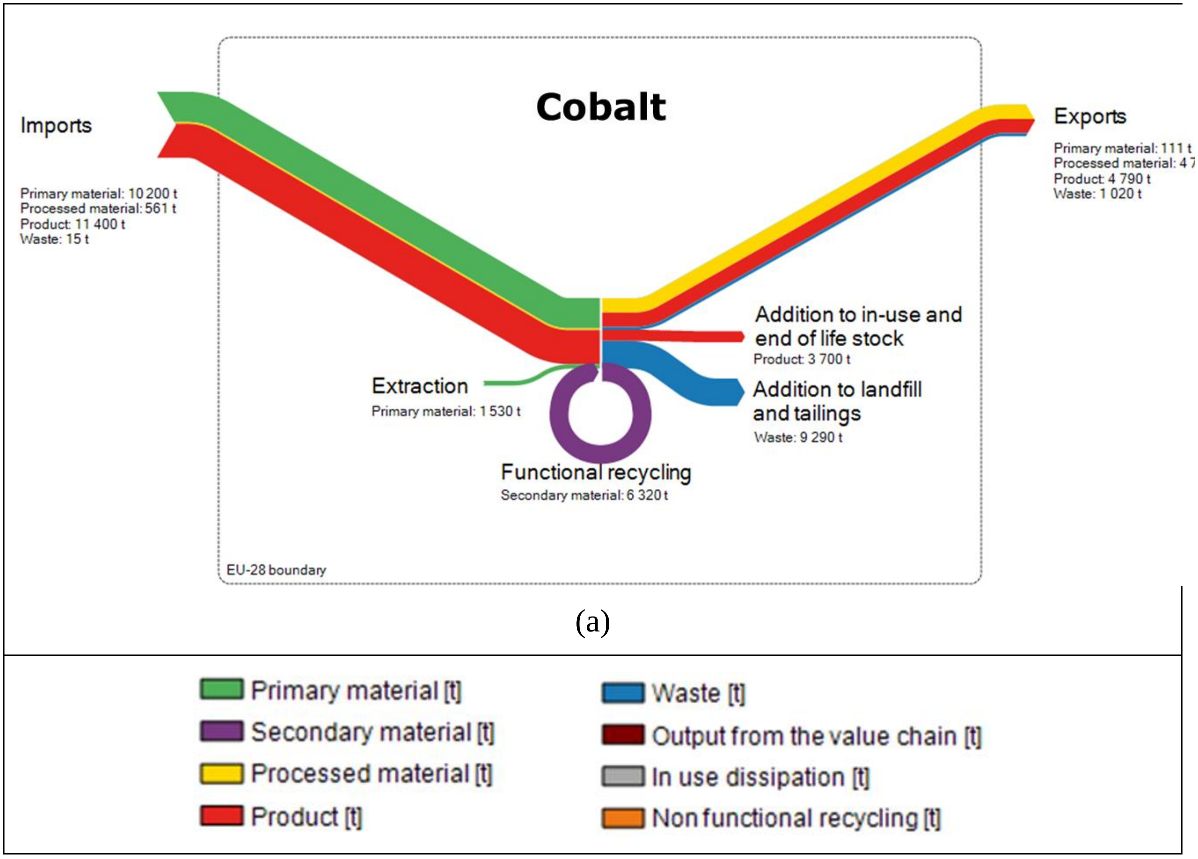
[27] 2017 CRM assessment

Actual collection rates of waste batteries depend on the battery technology/type (e.g. rechargeable/non-rechargeable batteries, Lithium/Ni-Cd batteries), on the lifetime of batteries, and on the end-use behaviour. For automotive lead-acid batteries, the collection and the recycling rates are much higher than for other batteries.[28]

Material produced from battery recycling can be used for the battery industry (e.g. cobalt) or steel and other industries, depending on the quality of the recycled material.

Recycling of cobalt mainly occurs thanks to the lower costs of the recovered cobalt compared to cobalt extraction from ores.[29] Recycling of graphite, on the other hand, is quite limited. In the recycling process of batteries, graphite is usually lost in the recovery processes. However, in hydrometallurgical processes, the recovery of graphite is possible.[30,31] Finally, the end-of-life recycling rates for lanthanum and cerium are below 1%.[32]

Figure 18: Simplified Sankey diagrams for materials used predominantly in the battery sector: (a) cobalt and (b) natural graphite. Values for the EU-28 expressed in t/year for the year 2012 based on the 2015 MSA study[33]



(a)

[28] IHS Consulting, 2014. "The availability of automotive lead-based batteries for recycling in the EU", available at www.eurobat.org/sites/default/files/ihs_eurobat_report_lead_lores_final.pdf

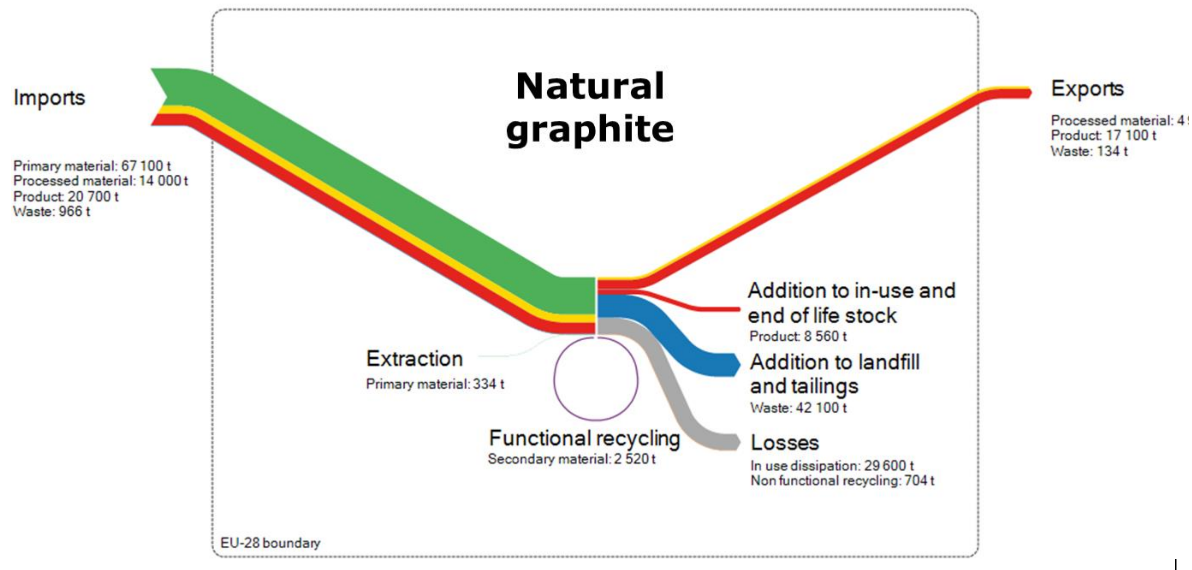
[29] EC, 2015. "Report on Critical Raw Materials for the EU critical raw materials profiles", available at http://ec.europa.eu/DocsRoom/documents/11911/attachments/1/translations/en/renditions/native

[30] EC, 2015. "Report on Critical Raw Materials for the EU critical raw materials profiles", available at http://ec.europa.eu/DocsRoom/documents/11911/attachments/1/translations/en/renditions/native

[31] Moradi, B. & Botte, G.G. J Appl Electrochem (2016) 46: 123. http://link.springer.com/article/10.1007/s10800-015-0914-0

[32] EC, 2015. "Report on Critical Raw Materials for the EU critical raw materials profiles", available at http://ec.europa.eu/DocsRoom/documents/11911/attachments/1/translations/en/renditions/native

[33] https://ec.europa.eu/jrc/en/scientific-tool/msa



(b)

Among the waste batteries flows, it is worth noting that the export flow of waste batteries to non-EU Member States is low; on the contrary, there is significant movement of waste batteries and accumulators between Member States.[34] However, batteries contained in EEE, especially rechargeable portable batteries, can enter in a second hand market outside of Europe.[35] Together with these waste flows, un-removed batteries from (W)EEE or batteries removed from WEEE but treated without recording their treatment contribute to increasing the data uncertainty.[36]

Data sources

No	Name and link/ref.	Scope			Reference period / date of publ.	Lan-guage	Free / sub-scrip-tion	Comments
		Subsectors	CRMs	Geo-graphic area				
1	Eurostat[37]	"Lead batteries", "Ni-Cd batteries", "Other batteries and accumula-tors"	No specific data on CRMs	Europe	2009-2015	English	Free	Data about recycling of batteries and accumulators

[34] Tsiarta et al., 2015, "Final Implementation Report for the Directive 2006/66/EC on Batteries and Accumulators", available at http://ec.europa.eu/environment/waste/batteries/studies.htm

[35] EPBA, 2015 "The collection of waste portable batteries in Europe in view of the achievability of the collection targets set by Batteries Directive 2006/66/EC", available at http://www.epbaeurope.net/documents/Reportontheportablebatterycollectionrates-UpdateDec-15-Exerpt.pdf

[36] EPBA, 2015

[37] http://ec.europa.eu/eurostat/data/database?node_code=env_wasbat

2	Eurostat[38]	Portable and batteries accumula-tors	No specific data on CRMs	Europe	2009-2015	English	Free	Data about sales and col-lection of portable bat-teries and accumulators
3	ProSUM[39]	Batteries	All	EU 28	2015-	English	Free	Data on stocks and flows of secondary raw materials
4	EPBA (Euro-pean Portable Batteries Asso-ciation)[40]	Portable batteries	No specific data on CRMs	Europe	1995 - 2014	English	Free	Data on col-lection rates in EU countries
5	Recharge (Eu-ropean Associ-ation for Ad-vanced Re-chargeable Batteries)[41]	Li-ion batteries	No specific data on CRMs	Europe	2006-2013	English	Free	Data about collection rates of portable batteries in Europe
6	EUROBAT (European Automotive and Industrial Bat-tery Manufac-turers) [42]	Automotive and indus-trial batter-ies	Antimony and cobalt	Europe	2011-2015	English	Free	Data about battery market volume. Considerations of antimony and cobalt in the report "Re-source Availa-bility of Metals used in Batteries for Automotive Applications".
7	EUCOBAT (European association of national collec-tion schemes for batteries)[43]	Portable batteries	No specific data on CRMs	Europe	2000-2012	English	Free	Data about the collection rate of portable batteries
8	EBRA Euro-pean Battery Recycling As-sociation[44]	Batteries' recycling	No specific data on CRMs	Europe	2009-2012	English	Free	Statistics about battery recy-cling
9	Darton Com-modities. 2016. Cobalt market review, 2015-2016[45]	All sectors with spe-cific data on Li-ion batteries	Cobalt	World-wide	2015-2016	English	Sub-scrip-tion	
10	Roskill: Natural and Synthetic Graphite Market Outlook (2015) [46]	All sectors with spe-cific data on Li-ion batteries	Graphite	World-wide	2015-2020	English	Free	

[38] http://ec.europa.eu/eurostat/data/database?node_code=env_waspb

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

[40] http://www.epbaeurope.net/pub_technicalSupport.html

[41] http://www.rechargebatteries.org/contribution-of-advanced-rechargeable-batteries-to-the-eu-agenda-and-initiatives-on-climate-energy-raw-materials-resource-efficienc/

[42] http://eurobat.org/brochures-reports, https://eurobat.org/statistics

[43] http://www.eucobat.eu/downloads

[44] http://www.ebra-recycling.org/releases

[45] http://www.dartoncommodities.co.uk/cobalt/

[46] https://roskill.com/market-report/natural-synthetic-graphite/

5.4.2 *Existing EU policies*

The Batteries Directive (2006/66/EC) establishes obligations for Member States to maximise the collection of waste batteries and accumulators, and to ensure that all collected batteries undergo proper treatment and recycling. To this end, the Directive defines targets for collection rates and for recycling efficiencies. The Directive is expected to achieve economies of scale in collection and recycling, as well as optimal resource saving.

In 2015 only 9 Member States had reached the 45% target for collection of portable batteries established for 2016. However, recycling processes in most countries achieved the minimum levels of recycling efficiencies set by the Directive for lead, nickel-cadmium and other types of batteries.

The Directive requires the Commission to review the impact of its provisions on the environment and internal market as well as to evaluate some particular aspects, in relation to heavy metals, targets and recycling requirements. The Commission has launched an evaluation process intended to assess whether the Directive is delivering its objectives, considering also whether new uses of batteries and the new technologies and chemistries developed since its adoption in 2006 are duly addressed. Likewise, the coherence between the provision of the Directive and EU policies on Circular Economy and raw materials is being assessed.

As announced in the renewed EU Industrial Policy Strategy[47], the Commission proposed a second Mobility Package on 8 November 2017[48] following the 2016 Strategy for low emission mobility and the spring 2017 first Mobility Package[49]. The November 2017 package includes strengthened post-2020/2021 carbon dioxide standards for cars and vans and an Alternative Fuels Infrastructure Action Plan to support the deployment of an EU backbone charging infrastructure. Technologies based on batteries make a crucial contribution to the achievement of the objectives of these plans. How to foster better supply conditions for several CRMs is an important consideration in this context.

5.4.3 *Circular Economy Action Plan*

The Action Plan, with a view to fostering increased recycling of CRMs, includes the development of European standards for material-efficient recycling of complex end-of-life products such as batteries. A request from the Commission to the European Standardisation Organisations is underway.

5.4.4 *Best Practices*

- Improving the efficiency in the recycling of CRMs in batteries. In Europe, several recyclers have invested in research projects in order to increase the recycling efficiency including for CRMs.[50,51,52]
- *Projects for Policy* (P4P) is an initiative aimed at using research and innovation project results to support policy making. Several batteries projects[53] addressed issues

[47] COM(2017) 479

[48] https://ec.europa.eu/transport/modes/road/news/2017-11-08-driving-clean-mobility_en

[49] COM(2016) 501; COM(2017) 283

[50] http://www.recupyl.com/121-20-31-lithium-polymer-battery.html, http://recupyl.com/44-used-batteries-recycling-plant.html

[51] http://www.akkuser.fi/en/news.htm

[52] http://www.accurec.de/

such as life-time, re-use and recycling and contributed to policy recommendations.[54]

5.4.5 Possible further actions

- Promote suitable design for disassembly of WEEE so that batteries can be readily removed (see Section 5.3.5).

Further options are to be identified and assessed as part of the on-going evaluation of the Batteries Directive.

5.5 Automotive sector

5.5.1 Data and data sources

In the automotive sector, including conventional (combustion engine vehicles), hybrid (HEVs) and electric vehicles (EVs), several vehicle components contain CRMs. Some examples are graphite (in brake linings, exhaust systems, motors, clutch materials, gaskets and batteries), cobalt (in lithium-ion batteries especially for EVs), Platinum Group Metals (palladium, platinum and rhodium in auto-catalysts and particulate filters), niobium (as an alloying agent in high-strength steel and nickel alloys used in the body structure, engine system and structural components[55]) and Rare Earth Elements (in permanent magnets, auto-catalysts, filters and additives).[56,57,58]

About 14% of worldwide uses of graphite in 2011 refer to automotive parts.[59] In 2012, the share of EU demand of palladium for petrol engines was 69%, 70% of platinum was used for light duty diesel engines, and 80% rhodium for 3-way catalytic converters used to reduce tailpipe emissions from vehicles.[60] With respect to niobium, in 2012 44% of the EU demand was intended to the automotive sector.[61] Among the REEs, neodymium, praseodymium and to a lesser extent dysprosium and terbium are used in large high performance neodymium-iron-boron magnets for HEVs and EVs electric motors. These are also used in small electric motors and electronic sensors for the standard automotive industry including starter motors, brake systems, seat adjusters and car stereo speakers.[62] Moreover, lanthanum and cerium are embedded for example in nickel metal hydride (NiMH) batteries used in HEVs designs. Cerium is additionally used in auto-catalysts, which accounted for 35% of consumption in 2013.[63]

Although the internal combustion engine is likely to remain dominant in the short and medium term, the market for HEVs and EVs is expected to experience significant and

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[53] BATTERIES2020, MARS EV, EVERLASTING

[54] EC, 2017, "BATTERIES - A major opportunity for a sustainable society", https://ec.europa.eu/info/sites/info/files/batteries_p4p-report_2017.pdf

[55] Chalmers, 2013. “The Use of Potentially Critical Materials in Passenger Cars”, http://publications.lib.chalmers.se/records/fulltext/162842.pdf

[56] EC, 2015. “Report on Critical Raw Materials for the EU critical raw materials profiles”, http://ec.europa.eu/DocsRoom/documents/11911/attachments/1/translations/en/renditions/native

[57] http://www.criticalrawmaterials.eu/wp-content/uploads/CRM_InnoNet_transport-SCA_140514.pdf

[58] Roskill (2015). “Natural and Synthetic Graphite Market Outlook” and “Rare Earths Market Outlook to 2020”, https://roskill.com/market-reports/

[59] EC, 2015. “Report on Critical Raw Materials for the EU critical raw materials profiles”, http://ec.europa.eu/DocsRoom/documents/11911/attachments/1/translations/en/renditions/native

[60] EC, 2015. “Report on Critical Raw Materials for the EU critical raw materials profiles”, http://ec.europa.eu/DocsRoom/documents/11911/attachments/1/translations/en/renditions/native

[61] https://ec.europa.eu/jrc/en/scientific-tool/msa

[62] Roskill (2015). Rare Earths Market Outlook to 2020, 15th edition 2015

[63] Roskill (2015) . Rare Earths Market Outlook to 2020, 15th edition 2015

rapid growth over the coming decades. The CRMs embedded in vehicles are expected to increase proportionally. Cobalt, graphite, and rare earths employed in Li-ion batteries and electric motors are among the most targeted by increasing EVs demand (Figure 19).

Lithium-ion is the reference technology for EV batteries. Many different Li-ion chemistries are currently available[64] and are being tested to improve the performance and lower the battery costs. For example, in recent years Li-ion chemistries have shifted in favour of lower cobalt compositions. Natural graphite in turn is the reference anode material. In comparison to available alternatives, natural graphite had a market share of 64 % in 2014.[65]

Levels attained by the EV market in the EU in 2015 created a demand for batteries of 510 t and 8330 t for cobalt and graphite, respectively.[66] With regards to the rare earths for electric traction motors, in 2015, new EV's sold in the EU used about 50 t of neodymium, 16 t of praseodymium and 16 t of dysprosium while the demand for HEVs was around 33 t of neodymium, 11t of dysprosium and 11 t of praseodymium.[67]

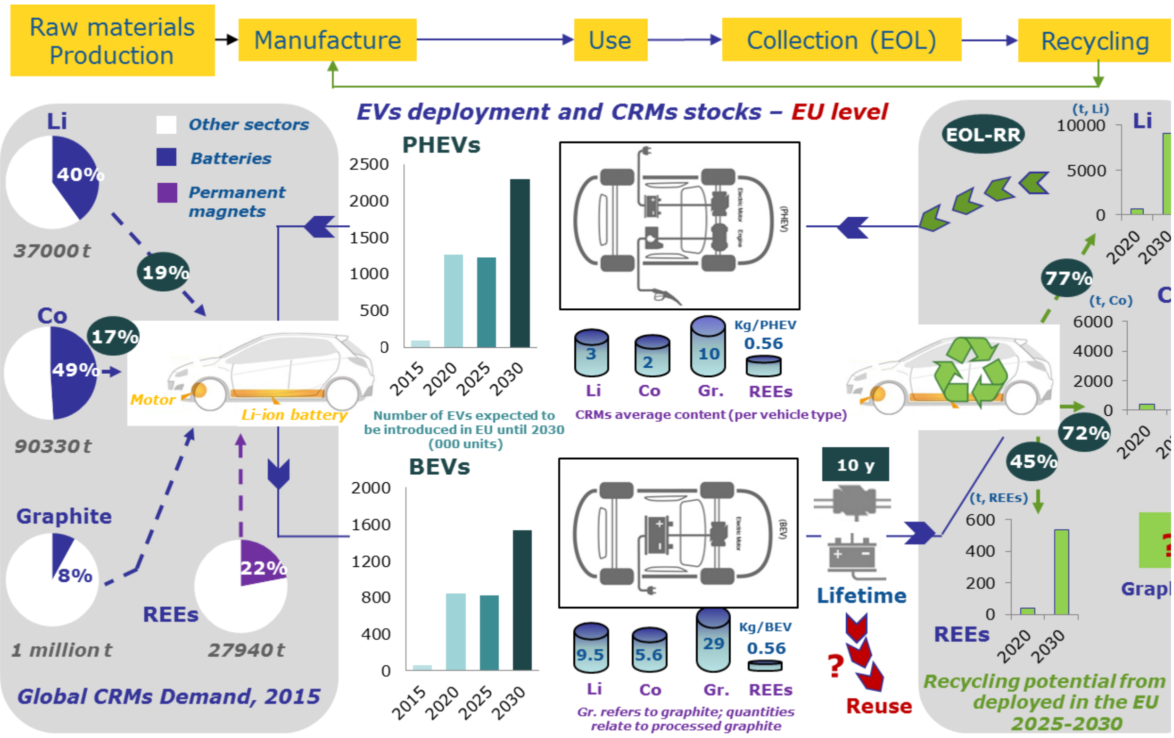

Figure 19: CRMs use in the EVs sector (battery electric vehicles (BEVs), plug-in hybrid vehicles, (PHEVs)) and potential flows resulting from recycling of EVs deployed in the EU[68]

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64 Li-ion chemistries available include: LCO (lithium-cobalt-oxide), NMC (lithium-nickel-manganese-cobalt), NCA (lithium-nickel-cobalt aluminium-oxide), LMO (lithium-manganese-phosphate) and LFP (lithium-iron-phosphate).

65 Available alternatives include: artificial graphite, mesocarbon microbeads, Si and Sn composites/alloys, and lithium-titanium-oxide, LTO.

66 JRC, 2016. https://ec.europa.eu/jrc/en/publication/eur-scientific-and-technical-research-reports/assessment-potential-bottlenecks-along-materials-supply-chain-future-deployment-low-carbon

67 JRC, 2016. https://ec.europa.eu/jrc/en/publication/eur-scientific-and-technical-research-reports/assessment-potential-bottlenecks-along-materials-supply-chain-future-deployment-low-carbon

68 Data sources are either explained in the text or given in JRC, 2016. https://ec.europa.eu/jrc/en/publication/eur-scientific-and-technical-research-reports/assessment-potential-bottlenecks-along-materials-supply-chain-future-deployment-low-carbon

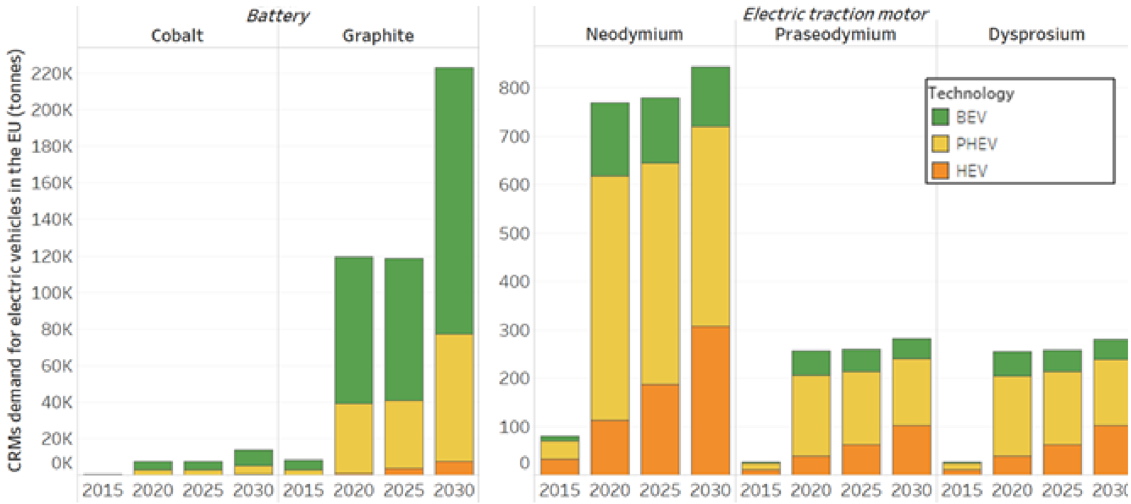


Figure 20: CRMs demand in the EU for the hybrid and electric vehicles segments[69]

Given the recent introduction of EVs on the European market, and taking into account the average lifetime of EV components (estimated to be approximately 10 years)[70], a significant number of EVs have not yet reached end-of-life. Large-scale recycling is not expected before 2020 and should only be more effective beyond 2025. Under current circumstances of low lithium and rare earth prices, high costs for technology largely untested at an industrial scale and the absence of substantial waste streams, the EU recycling infra-structure targeting EV batteries and electric motors is still weak.[71]

Currently, the material of most interest to Li-ion battery recyclers is cobalt. Specifically in the EV batteries sphere the recycling potential is significant as these batteries may be easier to collect if a dedicated system of return is established. However, specific challenges related to the declining use of cobalt in most appropriate Li-ion chemistries may make recycling unattractive, if economic practicality is not extended to the other materials such as lithium and graphite.[72] For example, whilst graphite anode materials are currently not recycled there are no obvious barriers to their recovery by hydrometallurgical and direct physical recycling processes.[73]

Regarding the rare earths contained in electric traction motors, although the current level of recycling from end-of-life permanent magnets is still very limited[74], several studies estimate the potential level of recycling of REEs to be around 40% in the next 20 years.[75]

The growth of the electric vehicle market could over time reduce demand for platinum, palladium and rhodium, though hybrid technology is still reliant on these catalysts to curb emissions. However, growth in the use of fuel cell catalysts could help to balance

69 Demand forecasts up to 2030 are based in penetration scenarios put forward by ERERT (European Roadmap for Electrification of Road Transport) for BEVs and PHEVs and on Avicenne Energy projections for HEVs. Details concerning the calculations are given in JRC, 2016. https://ec.europa.eu/jrc/en/publication/eur-scientific-and-technical-research-reports/assessment-potential-bottlenecks-along-materials-supply-chain-future-deployment-low-carbon

70 JRC, 2016 (as above) and references therein.

71 JRC, 2017, http://dx.doi.org/10.2760/6060

72 CEC, 2015. Environmentally Sound Management of End-of-Life Batteries from Electric-Drive Vehicles in North America.

73 Moradi, B. & Botte, G.G. J Appl Electrochem (2016) 46: 123. http://link.springer.com/article/10.1007/s10800-015-0914-0

74 Recovery of rare earths from electronic waste: an opportunity for high-tech SMEs. Study for the ITRE Committee IP/A/ITRE/2014-09.

75 JRC, 2016 (as above) and references therein.

out some of this reduction in demand.[76] Concerning the recycling of platinum, palladium and rhodium, the auto-catalysts recycling is estimated to be between 50 and 60%.[77]

It is reported that the tyre industry uses up to 75% of natural rubber consumed in the EU. An average car tyre contains 15% natural rubber by weight and a truck tyre contains an average of 30%. The management of used tyres is relatively well organised in Europe. In 2015, 92% of used tyres (vs. 51% in 1996) were either reused as second-hand tyres, reconditioned through retreading, recycled or sent to energy recovery. However, tyre recycling is an open-loop recycling, meaning that tyre-derived rubber granulates are mainly recycled in other applications than tyres as current tyre devulcanization technologies are not selective enough to get the required high quality devulcanization.[78]

Data sources

No	Name and link/ref.	Scope			Refer-ence period / date of publ.	Lan-guage	Free / sub-scription	Comments
		Subsectors	CRMs	Geo-graphic area				
1	ProSUM[79]	Vehicles	All	EU 28	2015-	English	Free	Data on stocks and flows of secondary raw materi-als
2	Darton Commodities. 2016. Cobalt market review, 2015-2016[80]	All sectors with specific data on Li-ion batteries	Cobalt	Global	2015-2016	English	Availa-ble upon request	
3	Roskill: Natural and Synthetic Graphite Market Outlook (2015)[81]	All sectors with specific data on Li-ion batteries	Graphite	Global	2015-2020	English	Sub-scription required	
4	Roskill: Rare Earths: Global Industry, Markets & Outlook[82]	All sectors with specific data on per-manent mag-nets	REEs	Global	2015-2020	English	Sub-scription required	
5	Assessment of poten-tial bottlenecks along the materials supply chain for the future deployment of low-carbon energy and transport technologies in the EU: Wind power, photovoltaic and electric vehicles technologies, time	Low-carbon energy appli-cations (with specific chap-ters on EVs)	Cobalt, Graphite, REEs	EU	2015-2030	English	Free	

76 EC, 2015. "Report on Critical Raw Materials for the EU critical raw materials profiles", http://ec.europa.eu/DocsRoom/documents/11911/attachments/1/translations/en/renditions/native

77 EC, 2015. "Report on Critical Raw Materials for the EU critical raw materials profiles", http://ec.europa.eu/DocsRoom/documents/11911/attachments/1/translations/en/renditions/native

78 EC, 2017. "Study on the review of the list of Critical Raw Materials - Critical Raw Materials Factsheets", https://publications.europa.eu/en/publication-detail/-/publication/7345e3e8-98fc-11e7-b92d-01aa75ed71a1/language-en

79 http://www.prosumproject.eu/

80 http://www.dartoncommodities.co.uk/cobalt/

81 https://roskill.com/market-report/natural-synthetic-graphite/

82 https://roskill.com/product/rare-earths-market-outlook/

	frame: 2015-2030, JRC, 2016[83]							
6	Binnemans, Koen, et al. "Recycling of rare earths: a critical review." Journal of Cleaner Production 51 (2013): 1-22[84]	All sectors with specific data on permanent magnets	REEs	Global	2010-2020	English	Free	
7	Re-use and Second use of Rechargeable Batteries[85]	Li-ion Batteries	-	EU	2014	English	Free	
8	Battery Materials Analysis, EUROBAT[86]	Battery material analysis in the automotive batteries	Cobalt, Antimony, Graphite , REEs	EU	2009 – 2013	English	Free	
9	The Use of Potentially Critical Materials in Passenger Cars, Chalmers University of Technology[87]	Information of CRMs in automotive	Various	EU	---	English	Free	
10	Drabik and Rizos: "Circular Economy Perspectives for Future End-Of-Life EV Batteries" (forthcoming)	Li-ion batteries	Cobalt, graphite	Europe	Forthcoming	English	Free	Data on the impacts of collection and recycling rates

5.5.2 *Existing EU policies*

Directive 2000/53/EU on end-of life vehicles (the "ELV Directive") sets high targets required to be attained by the economic operators: 95% for reuse and recovery and 85% for reuse and recycling by an average weight per vehicle and year, as from 2015. Based on reporting so far, nearly all Member States have reached the earlier targets of 85% for reuse and recovery and 80% for reuse and recycling.

Directive 2005/64/EC on the type-approval of motor vehicles with regard to their reusability, recyclability and recoverability was adopted following the provision of Art. 7(4) of the ELV Directive to ensure that vehicle manufacturers design vehicles so that parts and materials may be reused, recycled or recovered once the vehicle comes to the end of its natural life. As a result, new vehicles may only be sold in the EU if they may be reused, recovered and recycled in line with the targets of the ELV Directive.

The Batteries Directive 2006/66/EC also applies to automotive and traction batteries.

5.5.3 *Circular Economy Action Plan*

There is one explicit reference to vehicles in the Circular Economy Action Plan: in the context of the EU Regulation on waste shipment[88], the Commission undertook to take further measures to help ensure that the Regulation is properly implemented stating that

83 https://ec.europa.eu/jrc/en/publication/eur-scientific-and-technical-research-reports/assessment-potential-bottlenecks-along-materials-supply-chain-future-deployment-low-carbon

84 http://www.sciencedirect.com/science/article/pii/S0959652612006932

85 http://www.rechargebatteries.org/wp-content/uploads/2014/04/RECHARGE-Information-Paper-on-Re-use-and-second-use-October-2014-v.14.pdf

86 http://www.eurobat.org/sites/default/files/resource_availability-final_long_version.pdf

87 http://publications.lib.chalmers.se/records/fulltext/162842.pdf

88 Regulation (EC) No 1013/2006 as amended by Regulation (EU) No 660/2014

high-value waste streams, such as end-of-life vehicles, will be targeted specifically, to prevent raw materials leakage.

As a first step, in the general context of ensuring compliance with the ELV Directive, a study was commissioned to assess the implementation of the ELV Directive with emphasis on end-of-life vehicles of unknown whereabouts, in the course of which a stakeholder workshop was organised and a public consultation[89] was carried out. It emerged that there is a broad and joint understanding among stakeholders that the current procedures need further improvement to keep track of vehicles and to improve the implementation of the requirement to issue and present a certificate of destruction. This includes addressing possible loopholes, for instance through requiring evidence on the vehicle's fate during a temporary de-registration and fining owners which do not provide statement of whereabouts for temporarily deregistered vehicles. The use of economic incentives - for instance fees or refund systems - to deliver end-of-life vehicles to authorised treatment facilities has also been discussed, inter alia, in the light of experience in some Member States.

5.5.4 Best Practices

- Vehicle manufacturers have established the International Dismantling Information System (IDIS)[90] compiling information for treatment operators of end-of-life vehicles to promote the environmental and economic dismantling and treatment and to help meet the targets set in the ELV Directive.
- To facilitate the control of shipments of end-of-life vehicles and to in particular set criteria enabling to distinguish between second-hand vehicles and waste vehicles, the Member States' Waste Shipments Correspondents have agreed Guidelines for Waste Vehicles[91], in use since 1 September 2011.
- Following the Commission's recommendations to address the problem of end-of-life vehicles of unknown whereabouts, a number of Member States have amended national legislation to ensure better control of registered vehicles and avoid deregistrations that are not linked to the legal treatment of end-of-life vehicles or the legal sale as second-hand vehicles.
- Some companies have begun investing in recycling of used EV batteries in Europe (e.g. Umicore in Belgium[92], Recupyl in France[93]). Some (like *Société Nouvelle d'Affinage des Métaux*, SNAM, and Umicore) have teamed up with car manufacturers (such as Toyota[94] and PSA Peugeot Citroën[95] and Tesla[96]), to collect and recycle batteries.
- A number of research initiatives and pilot projects have been developed for assessing the reuse of batteries that are no more suitable for EVs in energy storage applications. Batteries2020[97], Energy Local Storage Advanced system (ELSA)[98], ABattReLife[99] and Netfficient[100] are examples of EU-funded projects looking at the most suitable and

89 http://ec.europa.eu/environment/waste/elv/index.htm

90 http://www.idis2.com

91 http://ec.europa.eu/environment/waste/shipments/guidance.htm

92 http://www.umicore.com/en/industries/recycling/umicore-battery-recycling/

93 http://www.recupyl.com/104-batteries-the-future.html

94 http://www.gov.scot/Publications/2013/12/9124/5

95 http://www.snam.com/upload/actu/20151208%20PR%20PSA%20SNAM_A%20-%20version%20FS.pdf

96 https://www.tesla.com/it_IT/blog/teslas-closed-loop-battery-recycling-program

97 http://www.batteries2020.eu/

98 http://www.elsa-h2020.eu/

99 http://www.abattrelife.eu/

100 http://netfficient-project.eu/

sustainable second use applications for EVs batteries. Further calls are planned[101], requiring the consideration of the whole value chain including circular economy aspects.

5.5.5 *Possible further actions*

- Promote the adoption of labels or other tools for declaring CRM content in key vehicle components such as batteries and auto-catalysts, e.g. via standardisation.
- Request the development of European standards for material-efficient recycling of end-of-life vehicles including for CRMs.
- Provide further support to R&D and industrial-scale innovation activities for developing competitive recycling technologies focusing on materials which are currently not (or hardly) recycled, such as lithium, graphite and rare earths.
- Continue to monitor developments in the EVs market and carry out projections on related critical materials demand and stocks.
- Make national procedures on registration/deregistration more harmonised within the EU, foster exchange of information among Member States and ensure follow-up of the fate of the temporary deregistered vehicles.
- Encourage Member States to make use of economic incentives - for instance fees or refund systems - to deliver end-of-life vehicles to authorised treatment facilities.
- Make binding, if needed in a revised form, the Correspondents Guidelines No. 9 to the Waste Shipment Regulation.

See also the Technological Roadmap to Near Zero Waste in ELV[102] of the Horizon 2020 project NEW_InnoNet.

5.6 Renewable energy

5.6.1 *Data and data sources*

The markets for wind and photovoltaic (PV) energy technologies have been growing rapidly in recent years, and are expected to account for a large share of renewable energy growth in the coming years.

Wind and PV energy technologies rely on a variety of materials including six CRMs, namely neodymium (Nd), praseodymium (Pr), dysprosium (Dy), indium (In), gallium (Ga), and silicon metal (Si) (see Figure 21). The EU demand for these materials will evolve in future depending on the deployment rates of wind and PV energy technologies and the technology mix. For instance, most of the wind turbines currently installed in the EU do not use permanent magnet generators and thus do not require rare earths. However, the situation can significantly change in the next 10-15 years due to sizing up of the wind energy: introduction of large and more efficient turbines as well as more offshore wind power may entail a higher use of permanent magnets. The projected evolution in the EU demand for the six CRMs is given in Figure 22[103]. Big economies such as China and USA have ambitious plans for clean energy deployment, even if they may not depend to the same extent as Europe on offshore based deployment of wind power using permanent magnets. EU manufacturers could thus face more competition for the same material supplies.

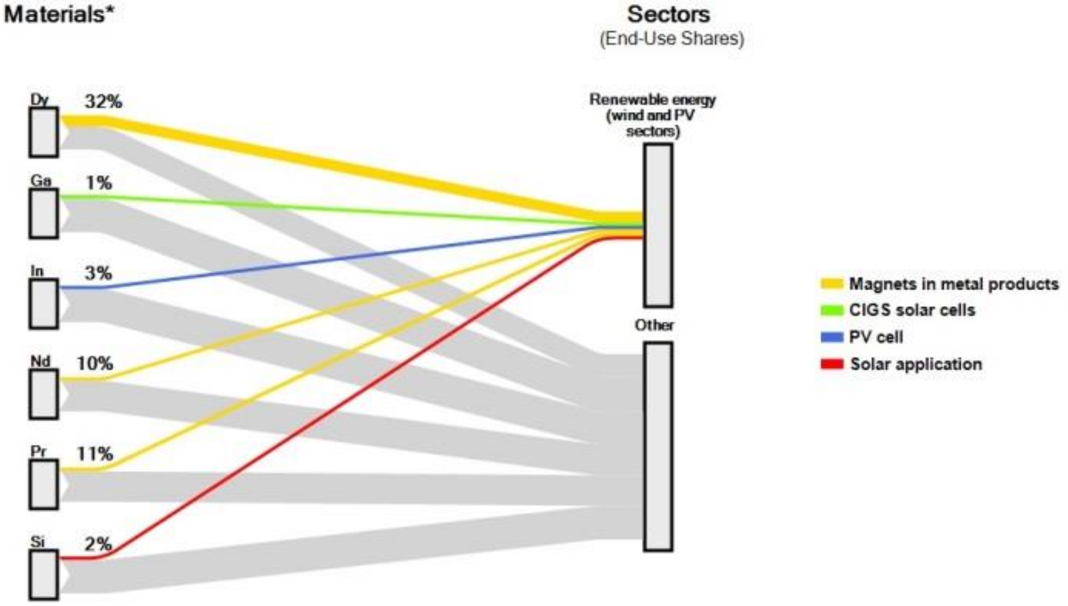
[101] https://ec.europa.eu/inea/en/horizon-2020/green-vehicles

[102] http://www.newinnonet.eu/ReportsList.aspx

[103] Silicon demand in Figure 22 denotes the amount of solar grade silicon required to achieve the PV deployment rates.

Several projects dedicated to permanent magnet recycling are either approved or under way in China[104]. Currently, there is no recycling of these rare earths in the EU. Up to 2030, most of the wind turbines will still be in operation (assuming a 30 years lifetime).

Recycling of Si, In, Ga from PV modules, alongside other raw materials such as glass, aluminium, copper and silver, has a high potential: more than 95% is claimed as an economically feasible recycling rate.[105] PV modules have a considerable lifetime - more than 25 years – meaning that this still young technology has generated little waste so far. Yet, the potential is huge: between 2 and 8 million tonnes of PV waste is estimated to be generated globally in 2030, increasing to 60-75 million tonnes by 2050.[106]



* Only a subset of all CRMs used in renewable energy sector is included.

Figure 21: Share of CRMs used in the renewable energy sector (wind and PV) (JRC Elaboration based on 2017 CRM assessment)

[104] Roskill, 2015. Rare Earths: Market Outlook to 2020, 15th edition 2015, London UK, ISBN 978 0 86214 618 4.

[105] BINE, 2010. Bine Informationdienst, Recycling photovoltaic modules, Projektinfo 02/10. http://www.bine.info/fileadmin/content/Publikationen/Englische_Infos/projekt_0210_engl_internetx.pdf

[106] End-of-Life Management, Solar Photovoltaic Panels, IRENA 2016 and IEA-PVPS; http://www.irena.org/DocumentDownloads/Publications/IRENA_IEAPVPS_End-of-Life_Solar_PV_Panels_2016.pdf

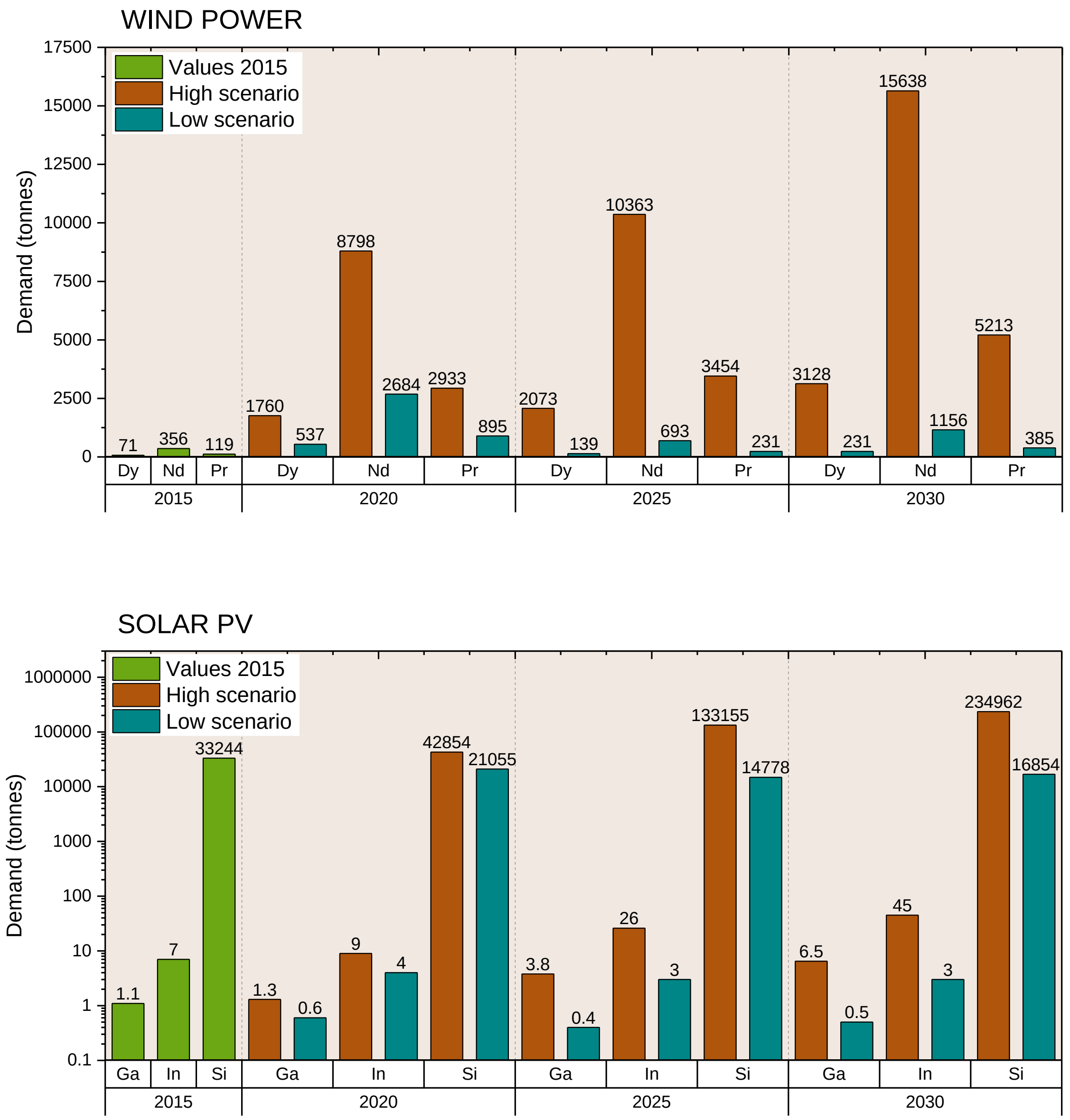


Figure 22: Projected evolution in EU demand for the six CRMs required in wind and PV sectors: existing low and high deployment scenarios considered. (Note that for the SOLAR PV diagram the scale is logarithmic.)

Data sources

No	Name and link/ref	Scope			Reference period / date of publ.	Language	Free / subscription	Comments
		Subsectors	CRMs	Geographic area				
1	Assessment of potential bottlenecks along the materials supply chain for the future deployment of low-carbon energy and transport technologies in the EU: Wind power, photovoltaic and electric vehicles technologies, time frame: 2015-2030,	Wind and PV	Nd, Dy, Pr, Si, In, Ga	Europe	2016	English	Free	

	JRC[107]							
2	Energy Transition and Demand for Raw Materials, The Hague Centre for Strategic Studies[108]	All	Various	Global	2017	English	Free	
3	Wind energy scenarios for 2030, A report by EWEA, the European Wind Energy Association [109]	Wind	Nd, Dy, Pr	Europe	2016	English	Free	
4	Solar Power Europe (SPE). European Photovoltaic Industry Association. Global Market Outlook For Solar Power / 2016 – 2020[110]	PV	Si, In, Ga	Europe	2016	English	Free	
5	EU reference scenario 2016. Energy, transport and GHG emissions. Trends to 2050, European Commission[111]	Wind and PV	Nd, Dy, Pr, Si, In, Ga	Europe	2016	English	Free	
6	Recycling of photovoltaic modules, BINE 2010[112]	PV	Si, In, Ga	Europe	2010	English and German	Free	
7	IRENA, International Renewable Energy Agency and Energy Technology System Analysis Programme. Solar Photovoltaic. Technology Brief; 2013[113]	PV	Si, In, Ga	Europe	2013	English	Free	
8	Roskill, 2015. Rare Earths: Market Outlook to 2020, 15th edition 2015	Wind	Nd, Dy, Pr,	Global	2015	English	Subscription	
9	Photovoltaic module decommissioning and recycling in Europe and Japan[114]	PV	Si, In, Ga,	Europe and Japan	2015	English	Free	
10	PV CYCLE[115]	PV	Si, In, Ga				Free	

107 https://ec.europa.eu/jrc/en/publication/eur-scientific-and-technical-research-reports/assessment-potential-bottlenecks-along-materials-supply-chain-future-deployment-low-carbon

108 http://www.rawmaterialsconference.nl/uploaded/docs/Raw_materials/Policy_Paper_Raw_Materials_04_09_2017.pdf

109 http://www.ewea.org

110 http://www.solarpowereurope.org

111 https://ec.europa.eu/energy/sites/ener/files/documents/20160713%20draft_publication_REF2016_v13.pdf

112 http://www.bine.info/fileadmin/content/Publikationen/Englische_Infos/projekt_0210_engl_internetx.pdf, http://www.bine.info/publikationen/publikation/recycling-von-photovoltaik-modulen/

113 http://www.irena.org

114 http://stud.epsilon.slu.se/7608/1/auer_a_150211.pdf

115 http://www.pvcycle.org

5.6.2 *Existing EU policies*

Renewable Energy is at the core of the Energy Union's priorities. The Renewable Energy Directive (2009/28/EC), setting European and national binding renewables targets for 2020, has been and will continue to be a central element of the Energy Union policy, in view of making the EU world number one in renewables. T**he EU as a whole is well on track to reach the 20% target by 2020.** However, some Member States will have to step up their efforts in order to reach their national targets.

The Commission's proposal for a revised Renewable Energy Directive[116] aims at further strengthening the European dimension of renewable energy policy, to make the EU a global leader in renewable energy and to ensure that the target of at least 27% renewables in the final energy consumption in the EU by 2030 is met.

The Ecodesign Working Plan 2016-2019 includes solar panels and inverters as a group of products that hold a significant potential for saving energy. A dedicated study will be launched for investigating this potential, but also looking at aspects supporting material efficiency issues such as durability and recyclability. These aspects should enable an efficient use of CRMs in solar panels and inverters.

5.6.3 *Best Practices*

- Sweden: Early adoption of mandatory recycling targets (under the WEEE Directive) for PV systems to encourage higher recycling and recovery rates.[117]
- The PV CYCLE association[118], established in 2007, collects PV waste for treatment free of charge, already recycling solar panels (mainly production scrap, panels damaged during delivery or installation or failed before reaching end-of-life) from Spain, Germany, Italy, Belgium, Greece and the Czech Republic.
- EU support to the development and demonstration of material efficient solutions for equipment used in wind (e.g. the Horizon 2020 project NEOHIRE[119] on the use of REE, Co and Ga in permanent magnets) and PV (e.g. the LIFE project FRELP[120]) energy technologies.

5.6.4 *Possible further actions*

- Examine whether the EU should develop a specific policy for eco-design of wind turbines (under the Ecodesign Directive) and/or their end-of-life management, in support of the manufacturing and recycling sectors concerned.
- Provide dedicated support to innovation and research actions fostering material efficient solutions in the use of CRMs in wind and PV energy technologies.

116 COM(2016) 767

117 Photovoltaic module decommissioning and recycling in Europe and Japan– current methodologies, norms and future trends, Master's Thesis • 30 HEC, Swedish University of Agricultural Sciences; http://stud.epsilon.slu.se/7608/1/auer_a_150211.pdf

118 http://www.pvcycle.org

119 http://neohire.eu

120 https://frelp.info

5.7 Defence industry

5.7.1 Data and data sources

The defence industry in Europe depends on a variety of raw materials, which are necessary to build a large spectrum of key defence capabilities. Thirty-nine raw materials have been identified as "important"[121] for production of high-performance processed and semi-finished materials (e.g. alloys, composites, etc.) needed for manufacture of a large variety of defence-related components and subsystems.[122]

Seventeen of these thirty-nine raw materials are evaluated in 2017 as CRMs[123] (Table 3).

Table 3: Critical raw materials (2017 list) used in the European defence industry, their role in defence industry and major end-use defence sectors (JRC source[216])

Critical raw material	Role in defence industry	Major end-use defence sub-sector
Beryllium	As an oxide and in various alloys with copper or aluminium to produce different components, for instance in fighter airframes, landing gears, connectors, electronic/optical systems for communication and targeting	Aeronautics, naval, electronics
Cobalt	Mainly in nickel-based superalloys for turbine, compressors and fans in fighter aircraft propulsion, and in electric motors (magnets) and batteries in combination with samarium and other elements (e.g. nickel or lithium)	Aeronautics, naval
Dysprosium	As a minor additive in high-powered neodymium-iron-boron (NdFeB) permanent magnets for electric motors, guidance, control systems, actuators and amplifications (e.g. voice coil motors and audio speakers, satellite communication)	Missiles
Gallium	Communication (e.g. transmitter) and electro-optical systems and on-board electronics as gallium arsenide and gallium nitrite; missile guidance	Electronics
Germanium	On-board electronics for inertial and combat navigation, IR tracking systems, binoculars (including night vision), GPS/SAL guidance system; canopy; as substrate in solar cells powering military satellites	Electronics
Hafnium	As oxide in electro-optical systems for radar and in a small percentage of superalloys for aircraft propulsion	Aeronautics, electronics
Indium	Laser targeting, sensors, identification equipment for IR imaging systems and inertial navigation as well as in on-board electronics for phased array radar	Electronics
Neodymium	Component of high-powered neodymium-iron-boron permanent magnets for a variety of applications: electric motors, guidance, control systems, actuators and amplifications (e.g. voice coil motors and audio speakers,	Aeronautics, space, electronics

[121] The term 'important' is used to denote materials with unique properties, necessary to fulfil the stringent requirements of defence applications.

[122] C.C. Pavel, E. Tzimas. JRC report: Raw materials in the European defence industry. EUR 27542 EN; doi:10.2790/0444.

[123] https://ec.europa.eu/growth/sectors/raw-materials/specific-interest/critical_en

	satellite communication, etc.); in lasers as neodymium: yttrium-aluminium-garnet crystals	
Niobium	Guidance section of missiles and in small quantities in composition of nickel super- alloys for high-temperature section of jet turbines	Aeronautics, missiles
Platinum	Thin coating of turbine blades (to increase thermal barrier) in combination with nickel and aluminium	Aeronautics
Praseodymium	In neodymium-iron-boron permanent magnets (usually in mixture with neodymium in a ratio Nd:Pr=4:1) with the same applications as for neodymium	Missiles
REEs (other[124])	Rather limited and specialised application in defence, such as magnets, radar (signal generation, surveillance and missile launch detection), lasers, sensors, other electronic components, phosphor (avionic display), heat-resistant superalloys and steel alloys	Aeronautics, electronics
Samarium	With cobalt in samarium-cobalt permanent magnets used in electric motors and diesel electric for propulsion, and electronic applications	Aeronautics, naval, electronics
Tantalum	Capacitors for on-board applications: binoculars, identification equipment/IR, inertial navigation, radars; in superalloys used in jet turbines and other propulsion systems; as a liner in shaped charges and explosively shaped penetrators	Aeronautics, electronics
Tungsten	Alloy element for ballast, warheads, shaped charges, throats, soldering, electrics, armour piercing and tank ammunition; also used in alloys in aeronautics for shells (arrowhead), fuselages, wings and turbine engines; tungsten carbide is essential for cutting machines	Aeronautics, land
Vanadium	Additive to improve the resistance to wear and deformation of steel; vanadium-containing alloys are used for the hull of submarines, in structural parts, engines and landing gear, but also in gun alloy elements, armour, fuselages and wings	Aeronautics, naval
Yttrium	Laser crystals for targeting weapons, finding and sight communication, electrolyte for fuel cells, phosphors for display screens, vision and lighting; in composition in equipment for signal generation, detection and surveillance, in thermal barrier coatings, and as alloying element for special steel grades	Electronics

The aeronautic and electronic defence sub-sectors are the major users of CRM (and the most vulnerable to potential material supply constraints).

Precise information on the type, composition and quantity of materials used in the European defence applications is limited mainly due to sensitivity reasons. Accurate information about the reuse of waste streams generated during production of high-tech components for defence applications, management of the end-of-life military products and recycling of materials from these products is not readily available either.

[124] Other REEs: cerium, erbium, europium, gadolinium, holmium, lanthanum, lutetium, scandium, terbium, thulium, ytterbium.

Overall, technological and economic barriers to recycle critical and scarce materials from defence industry could be expected. From an economic perspective, raw materials represent for some applications only a small fraction of the total value of the product (for example, the value of the materials contained in a jet engine may account for no more than up to 2 % of the engine cost[125]). Even though an alloy which is recycled from defence or civil applications contains valuable and high priced CRMs, the separation into its constituents might not be cost-effective.

In the aerospace industry recycling of materials from aircraft was not under a major consideration until recently and little information is currently available, in particular in official statistics. Now it has become a common practice to account for all metals used in the aerospace industry, for instance in the manufacture of a jet engine; any excess metal is fed into a closed-loop recycling operation.[126] Some publications argue that now the recycling rate of an aircraft has reached about 60 % and the aerospace industry is aiming to increase it to 80-90%.[127] Carbon fibre composite materials are becoming more popular in the aeronautic applications, such as jet fighters, and large industrial players (e.g., Airbus, Boeing, etc.) have already initiated programmes for recycling the carbon-fibre material. Aluminium, magnesium, titanium as well as steel are several materials which are currently recycled both from waste generated during the production of aircraft structure and engine components and from reclaimed components from retired aircraft. However, other CRMs such as rare earth elements are still recycled only in small quantities, mainly from permanent magnet scrap.

Data sources

No	Name and link/ref.	Scope			Reference period / date of publ.	Language	Free / subscription	Comments
		Subsectors	CRMs	Geographic area				
1	JRC report, Raw materials in the European defence industry; EUR 27542 EN; doi:10.2790/0444[128]	Air, Naval, Land, Space, Electronic Missile		EU	2016	English	Free	
2	US National Academy of Science, Managing Materials for a Twenty-first Century Military[129]	Military sector	Rare earth elements, beryllium	USA	2008	English	Free	
3	US Department of Defence, Strategic and critical materials 2015 Report on stockpile requirements[130]	Military sector	Various	USA	2015	English	Free	
4	Marscheider-Weidemann, F., Langkau, S., Hummen, T., Erdmann, L., Tercero Espinoza, L., Angerer, G., Marwede, M. & Be-	Emerging technologies	Several	Germany	2016	German	Free	'Raw materials for emerging technologies 2016'

[125] Strategic materials: technologies to reduce U.S. import vulnerabilities. Washington, DC: U.S. Congress, Office of Technology Assessment, OTA-ITE-248, May 1985: https://www.princeton.edu/~ota/disk2/1985/8525/8525.PDF.

[126] US National Academy of Science, Managing Materials for a Twenty-first Century Military. Washington, D.C. 2008, p. 89.

[127] A.P. Mouritz, Introduction to aerospace materials. Elsevier. May 2012, p. 560.

[128] https://ec.europa.eu/jrc/en/publication/eur-scientific-and-technical-research-reports/raw-materials-european-defence-industry

[129] https://www.nap.edu/catalog/12028/managing-materials-for-a-twenty-first-century-military

[130] https://www.hsdl.org/?view&did=764766

	necke, S. (2016): Rohstoffe für Zukunftstechnologien 2016. DERA Rohstoffinformationen 28; 353 S., Berlin. March 2016[131]							
5	MSA study[132]	Defence sector	CRMs (2014)	EU	2015	English	Free	

5.7.2 *Existing EU policies*

On 30 November 2016 the Commission adopted the European Defence Action Plan[133]. It sets out concrete proposals to support a strong and innovative European defence industry and defence capability priorities agreed by EU countries. It will do this by mobilising available EU instruments to ensure that the European defence industrial base is able to meet Europe's future security needs.

The main measures proposed are:

- a European Defence Fund to fund collaborative research projects as well as the joint development of defence capabilities, to be owned by EU countries, in priority areas;
- supporting SMEs through fostering investments in defence supply chains;
- ensuring Europe has an open and competitive single market for defence.

Security of supply is considered to be a cornerstone in the establishment of a genuine single market for defence. This is why the Commission will identify bottlenecks and supply risks linked to the materials that are needed for the development of key capabilities. This work, planned to take place in 2018, will build on the findings of a first study, undertaken by the JRC[134]. The outcome of the work may provide valuable inputs to future EU research programmes which could contribute to mitigating supply risks, for example through substitution of CRMs.

5.7.3 *Best Practices*

(No relevant best practice identified at this stage.)

5.7.4 *Possible further actions*

- Collect information about material supply chains for semi-finished defence products and determine whether the defence-based European industries are exposed to supply risks based on specific assessments.
- Provide support to collaborative defence research funding to mitigate supply risks linked to raw materials needed for the development of key defence capabilities by Europe's defence industry and to find solutions for improving resource efficiency, recycling and substitution of relevant raw materials.

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

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

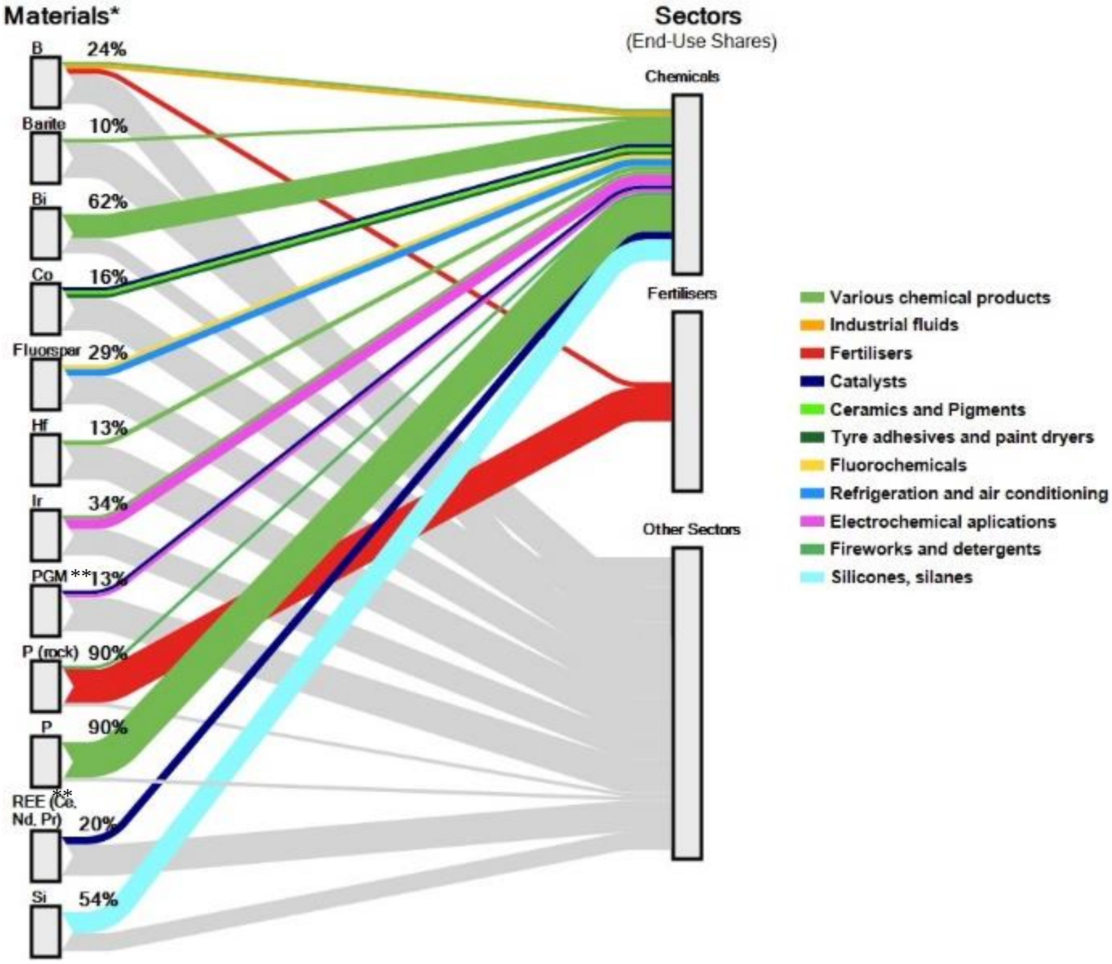
133 COM(2016)950

134 Pavel, C. and Tzimas, E., Raw materials in the European defence industry. Luxembourg, European Commission, joint Research Centre (JRC), 2016.

5.8 Chemicals and fertilisers

5.8.1 Data and data sources

The production of several chemicals and fertilisers in Europe relies on many CRMs (see Figure 23), such as: antimony, baryte; bismuth; borate; cobalt; fluorspar; hafnium; natural graphite; niobium; platinum-group metals (PGMs); phosphate rock; phosphorus; rare earth elements (REE); silicon metal; tantalum; tungsten; vanadium.



*Only a subset of CRMs used in chemicals and fertilisers are included. **Average share for: Pt, Pd, Rh, Ru in PGM (except Ir); Ce, Nd, Pr in REE. 'P (rock)' means phosphate rock.

Figure 23: Share of CRMs used in chemicals and fertilisers according to the 2017 CRM assessment[135]

The main applications of CRMs in the chemical and fertilisers sectors include their use in the production of catalysts, fertilisers, polymers, pharmaceutics and dyes. Examples include: 86% of phosphate rock is used in the production of fertilisers; 90% of white phosphorus is used in the production of detergents and other chemicals; 60% of bismuth is used in the manufacture of pharmaceuticals and other chemicals; and 54% of silicon metal is used for making silicones and silicates (final applications in e.g. shampoos, fixing materials and insulating materials).

[135] JRC elaboration based on data from the 2017 EU criticality assessment. The chemical and fertilisers sectors consists mainly in the NACE sectors C20 - Manufacture of chemicals and chemical products.

Chemicals containing CRMs are produced for a broad variety of other sectors, e.g. 43% of antimony is used in the production of flame retardant chemicals, which are incorporated in polymers used mainly in the electric and electronic equipment sector (see Section 5.3). Therefore, the overall importance of CRMs for the manufacturing industry is higher than what is presented in Figure 23.

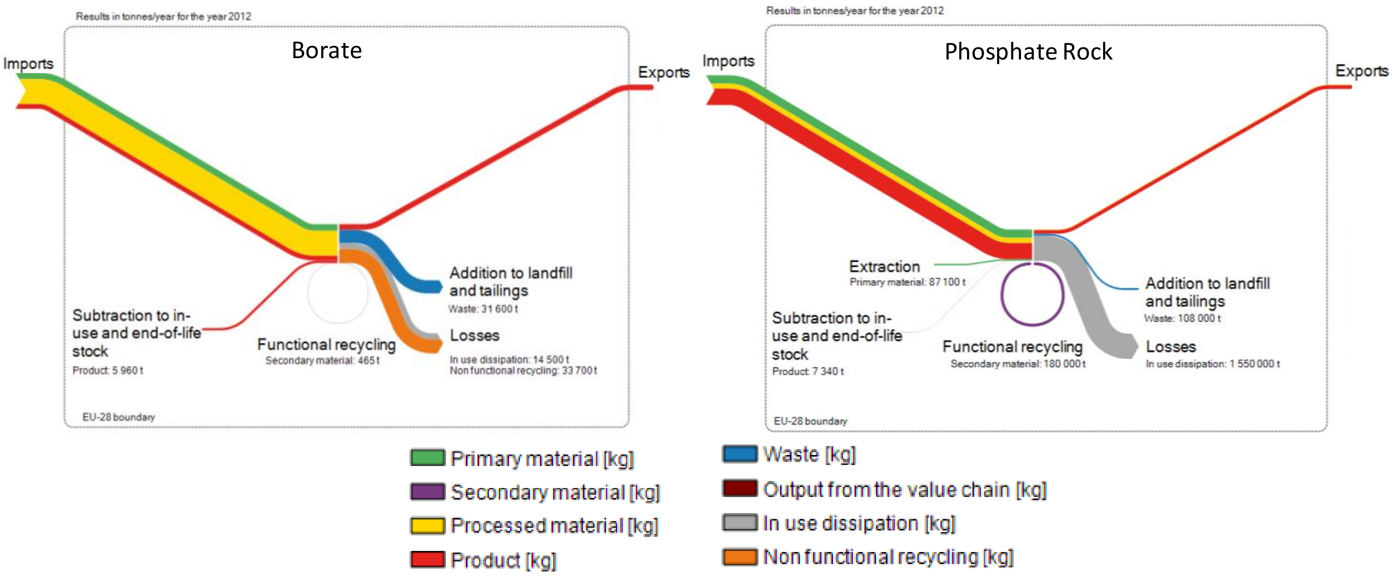


Figure 11: Examples of flows of CRMs used in chemicals and fertilisers based on 2015 MSA study

According to the MSA study[136], CRMs used in several chemical applications are lost to the environment due to dissipative use or to landfill. Examples of these losses include: natural graphite used in lubricants, silicones used in different chemicals, tungsten used in the production of catalysts and a large percentage of borates and phosphates used in fertilisers.

For borates and phosphates, the sources of secondary materials are biogenic wastes (e.g. manure or other animal by-products, bio- and food wastes, wastewater)[137], for which recycling is considered as functional (see Figure 24) because it replaces primary boron and phosphorus. The recycling of phosphorus rich wastes can also help prevent water eutrophication.

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

137 Schoumans, OF, Bouraoui, F, Kabbe, C, Oenema, O, van Dijk, KC. Phosphorus Management in Europe in a Changing World, 44, 180–92, 2015.

Data Sources:

No	Name and link/ref.	Scope			Reference period / date of publ.	Language	Free/ subscription	Comments
		Subsectors	CRMs	Geographic area				
1	Eurostat: data on P gross balance[138]	Fertilisers	Phosphorus	EU 28	2006-2015	English	Free	Data on P gross balance, including consumption of fertilisers, P inputs and removals from soil
2	Eurostat: data on chemical production[139]	Chemicals	-	EU 28	1995-2015	English	Free	Chemical production statistics (PRODCOM), NACE 2 sector 20
3	LUCAS: Land Use/ Land Cover Area Frame Survey[140]	Land Use/ Land Cover	Phosphorus	LUCAS Soil Survey 2009/2012 : EU 27 2015: EU 28	2009/ 2012 and 2015 Next soil survey in 2018	English	Free	Information on physical and chemical properties of topsoil (0-20 cm) in the EU, including concentration of Phosphorus
4	FAO Statistics on fertilisers[141]	Various (including Fertilisers)	Phosphorus	World	2002-2014	English	Free	Information on fertilisers flows.
5	Van Dijk et al., 2016 [142]	Various (including Fertilisers)	Phosphorus	EU 27	2005	English	Free	Phosphorus flows in EU-27 and its Member States, including food and non-food production, consumption, and waste.

5.8.2 *Existing EU policies*

The existing Fertilisers Regulation (No 2003/2003) ensures free movement on the internal market for fertiliser products belonging to one of the product types included in Annex I to the Regulation. Such products may be labelled 'EC-fertilisers'. Companies wishing to market products of other types as EC-fertilisers must first obtain a new type-approval through a Commission decision amending that Annex. Around 50% of the fertilisers currently on the EU market, including virtually all fertilisers produced from organic materials, such as animal or other agricultural by-products or recycled bio-waste from the food chain, are currently not included in the Annex.

138 http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=aei_pr_gnb&lang=en

139 http://ec.europa.eu/eurostat/web/prodcom/overview

140 http://ec.europa.eu/eurostat/web/lucas/overview

141 http://www.fao.org/faostat/en/#data

142 van Dijk, KC, Lesschen, JP, Oenema, O. Phosphorus Flows and Balances of the European Union Member States, Science of The Total Environment, 542, 1078–93, 2016.

5.8.3 Circular Economy Action Plan

The Commission undertook in the Circular Economy Action Plan to propose a revised EU Regulation on fertilisers, so as to facilitate recognition of organic and waste-based fertilisers in the single market and thus encourage the recycling of bio-nutrients as fertilising products in the circular economy.

On 17 March 2016, the Commission proposed a Regulation[143] to harmonise EU rules for products derived from organic waste and by-products and to provide rules for the safe recovery of nutrients into secondary raw materials; when organic waste fulfils strict rules, it can become a component of CE-marked fertilising products with unrestricted access to the single market.

5.8.4 Best Practices

- The recycling of CRMs from spent catalysts used in the chemicals sector: In 2012, the European Catalysts Manufacturers Association produced general guidelines for the management of spent catalysts that can be applied for recycling CRMs.[144] PGMs recycling from catalysts used in chemical processes achieves recycling rates of 80-90%.[145]

5.8.5 Possible further actions

- Support the development of new or optimisation of existing chemical processes and/or technologies that enable/enhance the safe recycling and/or reuse of CRMs.

6 Conclusions and Outlook

As set out in the Circular Economy Action Plan of 2015, this Report provides key data sources, suggests a number of best practices and identifies options for further action, in order to ensure a coherent and effective EU approach to CRMs in the context of the transition to a circular economy. The possible further actions presented in the report (see Annex III for an overview) are to be further assessed before deciding whether or not they should be implemented by the Commission.

The Commission welcomes the views of Members States and stakeholders on this report, and will use the Raw Materials Supply Group (a Commission expert group) and the European Innovation Partnership on Raw Materials, as well as other relevant (specific) forums to consult on further measures to be taken so as to properly address issues in relation to CRMs in the transition to a circular economy.

143 https://ec.europa.eu/transparency/regdoc/rep/1/2016/EN/1-2016-157-EN-F1-1.PDF

144 ECMA, Ecma Guidelines For The Management Of Spent Catalysts, 2012.

145 Hagelüken, C, Recycling the Platinum Group Metals: A European Perspective, Johnson Matthey Technology Review, 56, 29-35, 2012.

Annex I. Major applications of CRMs and information on recycling (JRC elaboration based on the 2017 CRM study and on the MSA study 2015)

CRM	Major applications	Recycling	
		End-of-life recycling input rate	Recycling from products at end-of-life
Antimony	Flame retardants; Lead acid batteries; Lead alloys	28%	Secondary antimony is mainly recovered from lead-acid batteries
Baryte	Weighting agent in oil and gas well drilling fluids or “muds”; Filler in rubbers, plastics, paints & paper; Chemical industry	1%	Little baryte is recovered at drilling sites
Beryllium	Electronic and telecommunications equipment; Transport and Defence (Vehicle electronics, Auto components, Aerospace components)	0%	Beryllium is not recycled from end-of-life products
Bismuth	Chemicals; Fusible alloys (low-melting alloys) & other alloys; Metallurgical additives	1%	Bismuth is difficult to recycle because it is mainly used in many dissipative applications, such as pigments and pharmaceuticals.
Borates	Glass (insulation); Glass (excl. insulation); Frits and Ceramics; Fertilisers	0.6%	Borates can be replaced by secondary sources from the recycling of biogenic waste flows such as food and vegetal waste, manure and sewage sludge
Coking coal	Base metal production	0%	The end-of-life recycling input rate for coking coal is estimated to be zero
Cobalt	Battery chemicals, Superalloys, hardfacing/HSS and other alloys; Hard materials (carbides and diamond tools)	35%	Cobalt-bearing end-of-life scrap can be in the form of used turbine blades or other used parts from jet engines, used cemented carbide cutting tools, spent rechargeable batteries, magnets that have been removed from industrial or consumer equipment, spent catalysts, etc.
Fluorspar	Solid fluoropolymers for cookware coating and cable insulation; Refrigeration and air conditioning; Steel and iron making; Fluorochemicals; Aluminium making and other metallurgy	1%	Although fluorspar itself is not recyclable, a few thousand tons of synthetic fluorspar are recovered each year during uranium enrichment

CRM	Major applications	Recycling	
		End-of-life recycling input rate	Recycling from products at end-of-life
Gallium	Integrated circuits; Lighting	0%	The rate of recovery of gallium from end-of-life products is close to zero and this is due to the difficulty and cost to recover it from highly dispersed items
Germanium	Optical fibres; Infrared optics; Satellite solar cells	2%	Only a small amount of germanium is recycled from old scrap of IR optics such as used mobile phones
Hafnium	Base metals; Machinery parts; Chemical products; Optics	1%	It is likely that little to no post-use recycling is being carried out currently, given its contamination in the nuclear industry and the low percentage content in super alloys
Helium	Cryogenics; Controlled atmospheres; Welding; Pressurisation and purging; Semiconductors, optic fibres; Balloons	1%	Helium used in large-volume applications is seldom recycled
Indium	Flat panel displays; Solders	0%	Very little old scrap is recycled worldwide because of minor indium concentrations in final products, a lack of appropriate technology, or low economic incentives compared to recycling costs
Magnesium	Transportation; Packaging; Desulphurisation agent	13%	In the EU, a large share of magnesium is used as an alloying element in the production of aluminium alloys and derived applications. Most of end-of-life magnesium scrap is recycled as part of the aluminium value stream. Magnesium alloys are entirely recyclable once they are collected from end-of-life products
Natural Graphite	Refractories for steelmaking; Refractories for foundries	3%	Efforts toward recycling post-consumer products containing natural graphite are dampened by oversupply and low prices. There is some recycling of used refractory material
Natural rubber	Automotive	1%	End-of-life recycling is limited either due to contamination issues or due to the impossibility to recycle the application
Niobium	Steel (structural, automotive, pipeline)	0%	The amount of niobium physically recovered from scrap is negligible

CRM	Major applications	Recycling	
		End-of-life recycling input rate	Recycling from products at end-of-life
PGMs	Autocatalyst; Jewellery; Electronics	11% *	The high value of PGMs makes their recycling attractive. The majority of the recycling volumes come from the recycling of spent automotive catalysts and electronics
Phosphate rock	Mineral fertilizer; Food additives	17%	Phosphate rock can be replaced by secondary sources of phosphorus from the recycling of biogenic waste flows such as food and vegetal waste, manure and sewage sludge
Phosphorus	Chemical industry applications	0%	
REEs (Heavy)	Phosphors: lighting, displays; Magnets; Chemical (other)	6% *	Recycling of REEs is often difficult because of the way they are incorporated as small components in complex items or as part of complex materials. The processes required for recycling are energy intensive and complex
REEs (Light)	Magnets; Glass Polishing; FCCs; Metallurgy	7% *	
Scandium	Solid Oxide Fuel Cells; Al-Sc alloys	0%	No recycling circuit is known for scandium in end-of-life products
Silicon metal	Chemical applications; Aluminium alloys	0%	Silicon metal is not currently recovered from post-consumer waste. Most chemical applications are dispersive, thus not allowing for any recovery. There is research on recycling of silicon wafers, however it has not yet materialised in marketable solutions
Tantalum	Capacitors; Aerospace; Sputtering targets; Mill products; Carbides	1%	Tantalum can be recovered from end-of-life capacitors and spent sputtering targets
Tungsten	Mill and cutting tools; Mining and construction tools; Other wear tools	42%	Recycling of tungsten in high speed steel is high. On the other hand, recycling in applications such as lamp filaments, welding electrodes and chemical uses is low because the concentration is low and therefore not economically viable
Vanadium	Ferrovanadium; Tubes and pipes; Turbines and electromotors	44%	Two kinds of secondary vanadium scrap can be discerned: steel scrap, recycled along with the vanadium content, and spent chemical process catalysts

* average values

Annex II. Examples of CRMs discussed in Ecodesign preparatory studies

Year of conclusion	**Preparatory study on:**	**Details**
2007	Space and combination heaters	The study mentions the use of PGMs in catalytic combustion
2007 (review on-going)	Personal computers and servers	The initial study discussed the content of silicon in computers. The on-going revision study specifically mentions the EU CRMs and it analyses their content in the products (based on research conducted by JRC)
2010	Sound and Imaging Equipment	The study discusses the content of silicon in the products
2007 (review on-going)	Televisions / electronic displays	The initial study discusses the content of indium (as ITO) in the products. Potential measures on the declaration of indium were discussed in the review process (based on a research conducted by JRC)
2007	Linear and compact fluorescent lamps	The study discusses the presence of some materials such as REEs, gallium and indium
2007 (review on-going)	Domestic washing machines	The review study discusses the content of REEs in motors
2007 (review 2017)	Domestic dishwashers	The review study specifically mentions the EU CRMs and it discusses the content of REEs in motors
2007	Simple set top boxes	The study discusses content of silicon metal in products
2007	Domestic lighting; incandescent, halogen, LED and compact fluorescent lamps	The study discusses the content of some CRMs (such as gallium and indium) in the products.
2008	Electric motors	The study mentions some REEs used in high performance motors
2009	Room air conditioning appliances, local air coolers and comfort fans	The study discusses the content of REEs and their relevance for high efficiency motors
2009	Directional lighting: luminaires, reflector lamps and LEDs	The study discusses the content of some CRMs (such as gallium and indium) in the products
2011 (review 2015)	Ventilation fans in non-residential buildings	The review study discusses the content of REEs and the relevance of their recycling
2014	Uninterruptible Power Supplies	The study mentions the use of some CRMs (such as gallium, cobalt, silicon) to improve efficiency
2014	Electric Motors and Drives	The study discusses the use of some REEs in high-performance magnets
2015	Power cables	No CRM was found relevant for this product group
2015	Enterprise servers	The study specifically refers to CRMs and is a first example of a study which assesses the content of CRMs in the products (based on research conducted by JRC)
2015	Light Sources	The study specifically refers to the CRMs and is a first example of a study which specifically assesses the content of CRMs in the products

Annex III. Overview of possible further actions by sector and EU policy area

Sector / policy area	EU industrial and raw materials policy	EU environment policy	EU research and innovation policy	Other EU policies
General		Workshop for Member States on CRMs under the Waste Framework Directive.		
Mining	Improve pan-European data acquisition, collection and management on the composition of mining waste; Develop tools to assess feasibility of recovery of CRMs from mining wastes.		Development of technologies to efficiently extract CRMs from primary ores and extractive wastes.	
Landfills	Promote the recovery of CRMs from landfills.			
Electrical and electronic equipment	Under the Ecodesign Directive, consider requirements on easier extraction at end-of-life of key components containing CRMs or declaring the content of CRMs.	Explore the potential of new satellite technologies to detect e-waste crime.		
Batteries	Promote suitable design for disassembly of EEE so that batteries can be readily removed.			
Automotive sector	Promote labels or other tools for declaring CRM content in key vehicle components; Request the development of European standards for material-efficient recycling of end-of-life vehicles including for CRMs; Monitor developments in the EVs market and carry out projections on related CRM demand and stocks.	Encourage Member States to use economic incentives to deliver end-of-life vehicles to authorised facilities; Make the Waste Shipment Correspondents Guidelines No. 9 binding.	Development of recycling technologies focusing on materials which are currently not recycled.	Make vehicle registration/ deregistration more harmonised and foster exchange of information among Member States.
Renewable energy	Include eco-design of wind turbines under the Ecodesign Directive.		Research and innovation actions for efficiency in the use of CRMs in wind and PV energy.	

Defence industry	Collect information about material supply chains for defence products and examine possible supply risks.		Research on materials needed for key defence capabilities to improve their resource efficiency, recycling and substitution.	
Chemicals and fertilisers			Development /optimisation of chemical processes or technologies for safe recycling or reuse of CRMs.	