SCRREEN

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Report on policy recommendations and stakeholder feedback

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Report on policy recommendations and stakeholder feedback

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SCRREEN

D 7.4 - REPORT ON POLICY RECOMMENDATIONS AND STAKEHOLDER FEEDBACK

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ACRONYMS AND ABBREVIATIONS

CAPEX	Capital expenditure
CEN	European Committee for Standardization
CENELEC	European Committee for Electrotechnical Standardization
CRM	Critical Raw Material
CSA	Coordination and support action
CZ	Czech Republic
D	Deliverable (of SCRREEN)
EEA	European Environment Agency
EEE	Electrical and electronic equipment
EC	European Commission
ELV	End of life vehicles
EoL	End of life
EOL-RR	End-of-life recycling rates
EU28	European Union (28 Member States)
EV	Electric vehicle
HREEs	Heavy Rare Earth Elements
HS	Harmonised system (UN Comtrade)
ICMM	International Council on Mining and Metals
ISO	International Organization for Standardization
JRC	Joint Research Centre (an EU science hub)
LUP	Land use planning
ML	Mining law
MS	Member state of the EU28
NEEI	Non-energy extractive industry
NIMBY	Not in my backyard
NGO	Non-governmental organization
NMPF	National mineral policy framework
OPEX	Operational expense
RIA	Research and innovation action
RMIS	Raw Materials Information System
RTD	Research, Technology, Development
R&I	Research and innovation
SLO	Social licence to operate
SRL	Substitution readiness level
TSF	Tailings storage facility
UNECE	United Nations Economic Commission for Europe
UNFC	United Nations Framework Classification for Resources
WEEE	Waste electrical and electronic equipment
WTO	World Trade Organisation

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CRMs symbols

Sb	→	Antimony
Be	→	Beryllium
Bor	→	Borates
Co	→	Cobalt (metal)
Coal	→	Coking coal
Cr	→	Chromium
Fl	→	Fluorite
Ga	→	Gallium
Ge	→	Germanium (metal)
Gr	→	Natural graphite (substance)
In	→	Indium (metal)
Mg	→	Magnesite, Magnesium
Nb	→	Niobium
Phos	→	Phosphate
PGMs	→	Platinum Group Metals
Si	→	Silicon metal
REE	→	Rare earth elements
LREE	→	Light Rare Earth Elements
HREE	→	Heavy Rare Earth Elements
W	→	Wolfram (Tungsten)

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ABOUT THE SCRREEN PROJECT

Since the publication of the first list of Critical Raw Materials (CRM) in 2010 by the Ad-hoc Working Group on CRM, numerous European projects have addressed (part of) the CRMs value and several initiatives have contributed to gather (part of) the related community into clusters and associations. This led to the production of important knowledge, unfortunately disseminated. Numerous databases have also been developed, sometimes as duplicates.

For the first time in the history, SCRREEN aims at gathering European initiatives, associations, clusters, and projects working on CRMs into a long lasting Expert Network on Critical Raw Materials, including the stakeholders, public authorities and civil society representatives.

SCRREEN will contribute to improve the CRM strategy in Europe by (i) mapping primary and secondary resources as well as substitutes of CRMs, (ii) estimating the expected demand of various CRMs in the future and identifying major trends, (iii) providing policy and technology recommendations for actions improving the production and the potential substitution of CRMs, (iv) addressing specifically WEEE and other EOL products issues related to their mapping and treatment standardization and (vi) identifying the knowledge gained over the last years and easing the access to these data beyond the project.

The project consortium also acknowledges the challenges posed by the disruptions required to develop new CRM strategies, which is why stakeholder dialogue is at the core of SCRREEN: policy, society, R&D and industrial decision-makers are involved to facilitate strategic knowledge-based decisions making to be carried out by these groups. A specific attention will also be brought on informing the general public on our strong dependence on imported raw materials, on the need to replace rare materials with substitutes and on the need to set up innovative and clean actions for exploration, extraction, processing and recycling.

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EXECUTIVE SUMMARY

This Deliverable is the last of SCRREEN´s Work Package 7 (Policy issues). Its overall objective is to develop policy, regulatory and stakeholder interaction recommendations to achieve targets set at the Raw Materials Initiative and improve the understanding of challenges around critical raw materials (CRMs) and the global value chains they are involved in. This report is based on previous project deliverables, recommendations from partner projects and feedback collected from SCRREEN consultation events (workshops, webinars, etc.). It is organized in 9 sections, each of which address a particular area that requires improvement. Each section is divided into background information, main issues and recommendations of future actions to be taken, mainly by the European Commission (EC) and its Member States (MSs), but also by other stakeholders (industry, minerals sector, recycling sector, etc.).

Given the increasing global competition for CRMs, the uncertainties posed by trade disputes and protectionism coupled with a high European CRM import dependence, ongoing EU diplomacy and trade policies with CRM producing countries remains a fundamental strategy to ensure a steady supply of such minerals to Europe. The EC has maintained a living CRM diplomacy strategy with many important CRM producers; yet, additional CRM-specific trade agreements with China (key CRM supplier) may be of use to avoid future potential impacts of protectionist measures. In terms of trade policy, we acknowledge that the EC is advancing in the right direction with the "Trade for all strategy" which calls for the inclusion of a chapter on energy and raw materials on all new free trade agreement (FTA) negotiations; however, it is not yet clear if CRMs will be given priority over other materials. Thus we recommend the EC continue stressing the need to treat CRMs as top priority in raw materials diplomatic actions, ensuring that CRMs are highly ranked in new trade agreements (e.g. new FTA).

Public data generation, sharing and management is an input of essential importance for all research work destined to orientate policy-making. Our results reveal that many CRMs have had few practical applications in the past and consequently the data available and our knowledge of them is very limited. We know relatively little about how their ores are formed and how to mine, process, use and recycle them in an effective, safe and sustainable manner. If existing and available, data on CRMs is insufficient due to lack of consequence and detailed stock-taking and reporting of CRMs in primary and secondary resources (mining waste, end-of-life products), insufficient knowledge about flows and stocks and non-harmonised data collected under different nomenclatures and formats across countries. Thus, it is crucial to advance on a pan-EU standardised and harmonised compositional and mineralogical characterisation of waste rocks, mining wastes, processing tailings, by-products, and metallurgical residues as well as standardised end-of-life products.

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To achieve such database it is recommended that further systematic surveys be undertaken in the EU to assess the potential for CRM resources in known deposits, mine wastes, tailings metallurgical residues and end-of-life products. This would involve detailed mapping and standardised reporting of volumes and grades of all potential resources. The Geological Survey of Sweden has already begun such a survey of mine wastes in Sweden (see details at Ladenberger et al. 2018). For primary resources, we believe that specific incentives are needed to attract CRM-targeted reconnaissance and exploration (drilling) work such as financial incentives or government-sponsored research to provide improved and expanded geoscience baseline datasets. Other factors that influence the framework conditions such as permitting efficiency, investment security and social acceptability need also be addressed (cf. D7.3 and related projects such as MIREU, MINLAND, etc.).

Furthermore, a more comprehensive and detailed identification of potential bottlenecks in CRM supply chains is necessary. We believe it is imperative to support the examination of both the level of consumption of individual CRMs within the EU Member States and of the processes involved along the entire supply chain in order to assess the geopolitical and other risks to supply. This needs to be complemented by in-depth commodity-specific studies of complete value chains carried out by experts from industry and academia. In the light of the continually changing levels and patterns of demand these studies should include consideration of future demand and supply scenarios to assist in the definition of appropriate technical or policy interventions. At the same time, good practice examples from Member States along the recycling chain such as the "price compensation mechanism" of ECODOM bringing solutions to recyclers should be further disseminated.

Besides supporting "end-of-pipe" solutions such as data generation (following standards) and new business models around recycling schemes and CRM recovery from mineral-based wastes, more efforts should be directed towards accelerating the implementation of the Eco-Design Directive (2009/125/EC) to facilitate new 'Design for Recycling' solutions for products, especially around those ones with high CRM recovery potential. We also recommend to revise the Eco-Design Directive and head it towards more systematically tackling material efficiency issues such as durability and recyclability.

Substitution remains one of the least advanced aspects within the EU RMI and one of the least present in the policies or strategies of EU MSs. We suggest to consider the possibility of advancing towards the creation of a Substitution Strategy for Europe whilst in parallel continue funding for R&I for developing greater and more secure recycling and recovery route for CRMs. Also we believe necessary to continue funding for investigating substitution options at the design phase of new products. This funding should be collaborative, involving industry and academic from across different disciplines, considering all forms of substitution. Likewise, work done so far on developing standards should continue whereas the EC could

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consider taking the lead in the creation of pan-European standards for the characterization of the properties of secondary CRM waste (WEEE, EoL batteries, etc.).

Mineral policies and strategies of EU MSs need to be regularly revised and updated. We believe the EC could encourage MSs to update the content and approach of their National Mineral Policy Frameworks (NMPFs) promoting the transitioning from a linear to a circular understanding of CRMs and their value chains. Such NMPFs should emphasize the importance of creating formal economic incentives for the industry, the minerals and recycling sector to collaborate and find new economic solutions to generate and share the necesary data and recover CRMs from by-products, mining waste and recycling streams.

Finally, we believe the SCRREEN project has within a relatively short period created a solid expert network on CRM value chains but that further cooperation of the network is needed during the coming years. Past initiatives such as the short-lived expert networks ERECON/EURARE have proven that longer horizons are needed to find collective solutions. In other words, the impact of those networks was limited in comparison to the invested resources. It will be important that the impact of such projects will be long-term which means that after the finalisation of such projects a prolongation of the developed network (stakeholders from EC/MS/companies etc.) should be envisaged. The impact should be measured too. The idea could be (besides voluntary acting) that financial means (project budget) could be taken into account from the coordinator for keeping the network alive.

According to its second-high level objective, SCRREEN is aimed at becoming a long-lasting Network. To reach this objective, a business plan that will allow the Network to exist and contribute to the EIP-RM SIP objectives on CRM after the end of the project is being formulated together with an activity plan for the Network. The network also is expected to guarantee the knowledge availability, transfer and use after the project (linked to JRC´s RMIS), and be able to support further initiatives, projects and programmes promoted by the EC. This umbrella network built on existing associations, initiatives, clusters, networks will bring together the main experts in CRMs, creating a permanent forum for policy makers, industry and society, sharing efforts and interests in raw material sector.

<u>Objectives of SCRREEN network follow-up</u>

Aiming to ensure secure and sustainable access to primary and secondary CRM resources, the possible follow-up of the SCRREEN project will be devoted to capitalise the work made during the project duration, by focusing the activity in terms of support to EU policies, organisation and animation of the expert community. In more detail, the long-lasting Network is expected to:

- Manage the lists of experts for sectors and materials, based on the knowledge gained during the project and the evaluation workshop, that will take place on 10-12th

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September 2019 in Brussels and where experts are invited to support the EU criticality assessment, via validation of data and data sources as well as exchange of knowledge for all the 83 screened materials.

- Improve and manage EU knowledge base on primary and secondary raw materials.
- Promote clustering and cooperation with other on-going projects and initiatives in RM sector.
- Animate the expert community, through organisation of related events, preparation of materials, positions papers, etc.
- Support the EC in policy making covering all the raw materials and their value chains as well as ensure support in relevant events organised by EC. Possible topics of interest can include: analysis of the future supply and demand of raw materials, policy and technological gaps, etc.
- Informing decision makers at EU and MS level, *i.e.* the producers and the users, defining possible new business opportunities and taking in account the relevance of all the social, environmental and economic issues on RM supply.

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1 INTRODUCTION

1.1 OBJECTIVES

This Deliverable is the last of SCRREEN´s work-package seven titled 'Policy issues'. Its overall objective is to develop policy, regulatory and stakeholder interaction recommendations, based on the evaluation of D7.3 which discussed the impact of policies, regulatory frameworks and (voluntary) standards on critical raw materials (CRMs) value chains at EU and national levels. This report follows-up previous WP7 deliverables (D7.1 & D7.2 & D7.3). Data and evidence were compiled gathering inputs from multiple stakeholders, received during meetings organized by the SCRREEN project (Input from Raw Materials Week 2018 and Berlin workshop December 2018 and SCRREEN webinar May 2019 with technical and regulatory experts) and from partner EC-funded relevant on-going and completed projects (MINLAND, MIREU, MINATURA2020, MSP-REFRAM, ProSUM, EuRare, FAME, etc.).

1.2 BACKGROUND

The EU has a **considerable CRM industry potential along the value chain**. This is illustrated in the Annual (EU-28) enterprise statistics by size class for special aggregates of activities (NACE Rev. 2), though not splitted in several CRM sectors (e.g. Manufacture of basic iron and steel and of ferro-alloys (C241), manufacture of basic precious and other non-ferrous metals (Code C244). For **CRMs that are found in the EU or can be recovered, an industrial chain needs to be identified, developed and protected**. Particularly, it is important to protect vulnerable value chains[1].

We strongly believe[2] that the complexity of the issues involved around CRMs and the importance of the economic/industrial stakes for the very future of the EU economy (which determines the well-being of its population) make it necessary to continuously develop and improve collective intelligence and knowledge related to minerals and metals, to inform policy-making at EU, national and regional levels. Minerals and metals were considered highly strategic assets for centuries up to the moment where globalisation emerged as a very convenient excuse for political relaxation in view of the utmost complexity of minerals and metals related issues, especially when observed from the sustainable development perspective. The **EU relies on free, undistorted global markets, to secure the imports of raw materials supplies vital to a huge number of downstream supply chains** and economic processes on which its economic and social well-being depend. This

[1] Cp. Swedish metals-producing Industry's associations (2013). National action for metallic materials. A STRATEGIC RESEARCH AND INNOVATION AGENDA, available at http://www.metalliskamaterial.se/globalassets/2-natverk/nationell-samling-kring-metalliska-material/pdf/national_action_for_metallic_materials_webb.pdf

[2] Following the statement of P. Christmann, made at the SCRREEN expert meeting in Rome (2018).

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paradigm that was functional during the second part of the 20th century, due to the economic dominance of the 'Western' world, could be lethal to the EU in a multipolar world with resources and other forms of nationalisms developing while EU and its economic players are increasingly loosing the influence and power they had in the past.

In this context, the **fragmented EU lacks the legal basis and the political might to develop an industrial policy and to negotiate on equal terms with China**, a giant of 1.4 billion inhabitants with a clear industrial policy and well identified policy targets that are turned into actions that redefine the global material flows. Each of its Member States taken individually is way too small to play a major role in the new economic and social balances that will shape the XXIst Century. Minerals and metals related issues are complex, and this complexity is growing further when all technological, environmental, social and governmental issues are taken into consideration, something of essence if the 17 UN Sustainable Development Goals are to be met and if the threats to humanity that resources nationalisms are bearing.

This calls for a **permanent capacity to bring together the many stakeholders, within the EU and beyond its borders**, to develop collective intelligence on critical minerals related issues, and to define criticalities with major attention to foresight, as the international scene is evolving fast, and technologies that impact on supply and demand balance even faster. This collective intelligence is needed to address important issues such as policy, production, recycling, substitution and governance. The rich panel of diversified expertise and the mobilisation of collective intelligence that SCRREEN makes possible is of great value to better understand the complex issues around individual minerals and metals, and how they differ from one mineral/metal to another.

The EU has a considerable CRM industry potential along the value chain, as illustrated in the Annual (EU-28) enterprise statistics by size class for special aggregates of activities (NACE Rev. 2). **For CRMs that are found in the EU or can be recovered, an industrial chain needs to be identified, developed and protected**. Particularly, it is important to protect vulnerable value chains. The highly detailed production & trade databases like PRODCOM or the combined set of trade & production statistics in the EUROPROMS database could be used as a basis for analysis and identification of the European CRM value chain use. Potentially, such product-oriented databases could be combined with CRM use & content like developed in the PROSUM project.

Many of the CRM are mainly or only extracted as by-product of major metals or minerals of minor economic importance. These include bismuth, cobalt, gallium, germanium, hafnium, indium, REE, and scandium, which are produced together with gold, nickel, aluminium, lead, zinc, zirconium, phosphorus, and copper. For these commodities, the bottleneck of production is usually further up the value chain, that is, they typically are extracted from the mine in the ore, but are not recovered at the refineries or smelters due to the lack of

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economic incentive or simple technology. As a consequence, **policy support and initiation of projects targeting carrier metals may also be contributing to the domestic production of CRMs** (e.g. PGMs associated to copper-nickel ores) as long as miners have sufficient incentives to process those materials.

One of our key messages is that we need to promote National Mineral Policy Frameworks (NMPF) based on the following elements: a Mining Policy (targeting domestic mineral potential), a Circular Economy Policy and a Value Chain policy based on economic and industry analyses of CRMs conducted in cooperation with the industry.

With regards to national policy-making, we need to underline that, despite the considerable primary and secondary CRM potential in Europe, little attention has been devoted to CRMs in National Mineral Policy Frameworks (with some exceptions, see SCRREEN D7.2). In adittion, no concrete CRM policies imply less input in regulatory mining frameworks. There are no concrete CRM exploration provisions (e.g. giving priority to CRM-related concessions), which could support a company or facilitate CRM protecting (based on LUP). In the case of regulatory frameworks, CRMs are not appearing as a priority or special focus in the national mining laws which regulate primary minerals. Primary/secondary minerals require equal treatment i.e. a holistic policy approach.

Apart from that during the project we have agreed in the need of a **paradigm changeto include the value chain in the NMPF**. In this sense, it is important to make a distinction between a *mining* policy and a *minerals* policy. The minerals policy takes the mineral consumption approach into account, and strives for an integrated planning of the mineral resources available within a country´s territory (both primary and secondary). At this stage, it seems that the MSs are not considering this approach, and have separate policies to address primary and secondary (if such policies exist). However, the CRM value chain (up-/downstream) reflects the mineral consumption approach (production of CRM = domestic extraction + imports minus exports). Therefore: to satisfy the **CRM demand of any MS economy the CRM value chain needs to be taken into account with the whole picture**, i.e. we believe that any NMPF should make a smart integration of CRMs along the value chain as well take corporate policies and strategies into account. Another key message is that policies and legislation need to be updated and changed to better reflect the idea that value chains, e.g. of CRMs, need to transition from being considered linear to circular. Important point too is to **facilitate company investment security, streamline permitting and access to minerals** (LUP/SLO). Nowadays, industry, governments and many scholars alike still tend to think of metals value chains in linear terms; though circular economy approaches are increasingly becoming more important, still circular chains are on very early steps and far from dominating the CRM landscape. i.e. the idea that sustainability requires circularity still needs to be further promoted.

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The policy cycle (policy design, implementation and monitoring) relies on high quality data. CRM-safeguarding policies are constrained by the fact that the location and extent of resources within Europe is **poorly understood for most CRM in most countries**; which is also a consequence of the lack of specific CRM policies. This is due in large part to the limited availability of high quality geoscience data focused on CRMs in much of Europe. Consequently, there has not been sufficient CRM-focused exploration in the EU and this is the first essential stage in the value chain for all minerals. Additional geoscience research is required to provide a better understanding of regional geology, ore deposit genesis, mineralogy and deposit models to support exploration (and in this respect, sufficient policy support is needed). **Without exploration there can be no identification of mineral resources or reserves and protection via land use planning**, and therefore, no production of the mineral raw materials upon which the European industry depends.

Taking into account that CRM recycling is still at the technical cradle stage, the vast majority of 'green energy' metals must be provided by mining and ore processing in order to satisfy the current demand. Therefore, **efforts need to be taken to promote their primary production at the same time developing the recycling efficiency and other substitutions**. An efficient and safe waste management should be done by improving its transportation and tailings management, preventing any environmental contamination, and reusing waste as possible. Here a more global-push may be needed; now, only after Vale´s 2nd disastrous fatal accident in Brumadinho, did the ICCM react and decided to co-convene a mine tailings storage facilities review and create an international standard[3]. Something similar (of an international initiative, e.g. led by ICMM) would be welcome to push for the recovery of mining waste from TSF facilities. In this respect, waste should be always considered as a potential secondary resource. Mining should aim to recover all valuable metals and minimize waste. This calls for a concerted MP action i.e. considering appropriate primary/secondary CRM policies at the same time.

A **transition to a circular economy requires**: Better knowledge of waste flows as well as the knowledge of the composition of waste coming from EoL products to enable a more informed collaboration throughout value chain; eco-design facilitating dismantling, collection and separation; new processes for improving recovery and recycling; standardisation + certification of procedures for waste management / treatment facilities; development of policies on Member State level and of incentives facilitating adoptions of standards for recycling and recovery. The establishment of sustainable and efficient CRM value chains will also make a policy challenge for related current and future socio-economic, such as job creation, and environmental issues and activities, such as the transformation towards low-

[3] Cp. https://www.icmm.com/en-gb/news/2019/international-standard-for-tailings-dams; https://www.icmm.com/en-gb/news/2019/tailings-review

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emission transport and the production and storage of electricity from renewable energy sources.

1.3 REPORT OUTLINE AND METHODOLOGY

This Deliverable is structured in 10 Chapters, each addressing different issues of importance for the present and future supply of CRM for the European industry.

Each chapter is divided into three sections: Background, Issues and Recommendation. Inputs for each of the chapters were collected and summarised from the following secondary sources:

1. SCRREEN project Deliverables
2. Inputs from partners projects (MinLand, MIREU, MINATURA2020, MSP-REFRAM, ProSUM, ProMine, EuRare, FAME, MSP-REFRAM, Min Future, SMART-GROUND, ORAMA, etc.)
3. Existing literature used to update some of the results of SCRREEN project deliverables

Inputs were also gathered from stakeholder feedback during SCRREEN project meetings, including:

1. Raw Materials Week 2018
2. Berlin workshop December 2018
3. Brussels workshop on Enhanced Landfill Mining May 2018
4. SCRREEN webinar May 2019 with technical and regulatory experts

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2 EU CRM DIPLOMACY AND TRADE POLICIES

2.1 BACKGROUND

An important point, which is extremely critical, is the fact that parts and/or the whole value chain of several CRMs are moving to China and South-East Asia. For instance, the market for separated REE products is becoming smaller in Europe and even steps of further value adding down the value chain are done in China or other countries of Asia[4]. Another example is found in the global center of gravity for the production and use of some globally key metals such as steel which has moved towards Asia, i.e. China and India as emerging markets which are expected to account for an ever-growing share of the world's new car purchases. This trend is likely to continue and it is, for example, reasonable to assume that at least half of all passenger cars in the world will be produced in China within 20 years. Such a market development places major demands on the metal industry as a global supplier. Not least the great distance from the emerging markets is a challenge[5].

The following can be observed in the last years[6]: lack of investment and threat of shut down of active mines of CRMs; ambiguous attitude of major users of CRMs in Europe to invest in security of supply or supply resilience; exploration companies lack sufficient financing opportunities. In the case of some CRMs (REE, gallium, indium, etc.) this difficulty is compounded by the fact that markets do not exist for some critical raw materials (e.g. REE concentrates) and there are no exchanges on which standardised products can be traded, creating high entry barriers for aspiring miners. In other words, there are no markets (for instance) for mixed REE concentrates outside of China, and aspiring miners must either attempt to develop their own capital-intensive and technically complex separation plants or cooperate with existing facilities. Outside of China, such facilities currently exist only in France, Estonia, Malaysia, Japan and the USA.

Moreover, the establishment of a REE material supply chain from mine to market in Europe appears to need substantial and continuous political support, as a reliance on economic performance might be insufficient to maintain such a venture. Even if the EU would manage to step up primary extraction of CRMs, the next steps in the value chain often are concentrated outside Europe (e.g. beneficiation and making magnets as intermediates in the case of Nd). Enhancing EU supply hence does not necessarily mitigate supply risks since the primary materials will be still need to be processed elsewhere; moreover, there is no guarantee that REE produced will be supplied to the EU market. Put

[4] Tiess, 2014 [Treibacher AG]). (e.g. there is no market for NdMetal in Europe, customers purchasing already the Nd-Fe-B alloy and even the finished Magnets from China)

[5] Cp. Swedish metals-producing Industry's associations (2013). National action for metallic materials. A STRATEGIC RESEARCH AND INNOVATION AGENDA, available at http://www.metalliskamaterial.se/globalassets/2-natverk/nationell-samling-kring-metalliska-material/pdf/national_action_for_metallic_materials_webb.pdf

[6] Cp. SCRREEN D7.1; D3.3, available at http://scrreen.eu/results/

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differently, developing the CRM supply in Europe does not help if the next 2-3 tiers of the supply chain still are dominated by China.

Policies

The marginal nature of extraction markets implies that mining of some CRMs often takes place in poor, unstable regions, and via illegal practices. This leads to a high dependence on supply from regions subject to political crisis and the threat of a continued illegal supply of CRMs. Little still is known about the magnitude of illegal trade, routes and hubs of CRMs and the issue of unfair and illegal trade of CRMs remains unresolved. The EU is actively deploying strategic partnerships and raw material policy dialogues (bilaterally, regionally and multilaterally) with CRM supplying countries; although, the nature of the agreements is often of a broad nature and does not target specifically agreements for the supply of specific CRMs. In this respect, worthwile to mention, is the workshop on best practices on mining policies and technologies between EU and Australia, Brazil, Canada, Chile, Mexico, Peru, South Africa, USA – which was held on 12 & 13 June 2014[7].

At present, specific projects are being prepared, which will strengthen the EU's position with regard to raw materials and which will be endorsed by the European Commission under the Horizon 2020 programme. The European Commission pays increasing attention to the security of mineral commodities by EU Member States.

The importance of policy frameworks and the role of governments in the mineral sector is therefore one of the key drivers of the future development. However, there is room for improvement for bilateral agreements with some key CRM suppliers, e.g. with Morocco for phosphate rock or to further promote EU – Cooperation with Ukraine, which hosts a substantial CRM mineral potential[8], something acknowledged in the 3rd EU-Ukraine High Level group meeting (organised in Brussels in March 2019).

The EU trade policy is now advancing in the right direction with the "Trade for all strategy" which calls for the inclusion of a chapter on energy and raw materials on all new free trage agreement (FTA) negotiations; however, it is not yet clear if CRMs will be given priority over other materials.

At the same time there is still limited international cooperation or trade diplomacy focused on specific CRMs (e.g. phosphate, niobium). The raw material trade policy of the Commission is crucial for securing the CRM supply (trade policy is a matter of EC, foreign policy partly as well a matter of EC). Also the latest Joint Research Centre (JRC) report about visions of 2050 of the non-ferrous metals manufacturing states that *"There is a call for*

[7] All presentations are available at http://ec.europa.eu/growth/content/workshop-best-practices-mining-policies-and-technologies-0_en

[8] CRM potential in Ukraine is illustrated at http://geoinf.kiev.ua/M_R_2018_1.pdf.

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policy to further develop trade policies favouring a level-playing field, including enhancing transparency in the global pricing of raw materials, developing trade defence measures, and further negotiating free trade agreement to offset protectionism" (Dessart and Bontoux, 2017) .

The EU and the EC have considerably advanced the development of raw material trade policy and diplomacy – based on the Raw Material Initiative - with important CRM supplying countries, especially with China, which is the major CRM supplier to the EU. Although, with respect to China, there still is a considerable gap. In this way, we need to be aware that China is the largest CRM supplier compared with other countries supplying mostly one, or two CRMs, which also rises the question of CRM potential in those countries. China is still a dominant supplier of many CRMs, and the hybrid private-public nature of its operations will make it difficult to create competing supply under market conditions. One aspect to consider here are strategic plans of global powers such as the "Made in China 2025" masterplan.

2.2 ISSUE(S)

The mine production and refining of many CRMs is often concentrated in a few countries. This has the potential to introduce high levels of geopolitical risk, especially when the supplier countries are associated with resource nationalism, high levels of corruption, weak and unstable government, low standards of environmental protection or the involvement of child labour in mining. To cope with these risks, the EU keeps promoting strategic partnerships and raw material policy dialogues as part of an ongoing process to ensure a living raw materials diplomacy strategy.

EU legal actions against Chinese export restrictions and WTO rulings are a relevant issue. Given China´s position as a major CRM supplier to Europe, the imposition of export restrictions on CRMs implies a serious problem for European companies importing intermediate CRMs. In the past a problem was the levying by China of *export duties* on various kinds of CRMs, including antimony, chromium, cobalt, coke, fluorspar, graphite, indium, magnesia, yellow phosphorus, REEs, silicon metal, tantalum and tungsten, among others, and the imposition of quantitative restrictions, such as *export quotas*, applied to antimony, indium, and magnesia[9]. Those measures distorted the market and favoured Chinese industry at the expense of companies and consumers in the EU, in violation of general WTO rules and also of China's specific commitments from the time of its accession to the WTO. The EU was able to launch three legal cases against China´s export policies, from which two were successfully closed and the third one is under negotiation[10].

[9] European Commission (2016) "EU takes again legal action against export restrictions on Chinese raw materials", DG Trade, http://trade.ec.europa.eu/doclib/press/index.cfm?id=1530.
[10] Cp. also http://www.europarl.europa.eu/doceo/document/A-8-2018-0252_EN.html

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Raw materials subject of the third legal case against China include some CRMs. China's total exports of these products are worth around € 1.2 billion, one sixth of which goes into Europe. A first analysis suggests that removing the export duties imposed by China could allow an additional supply of these raw materials to the EU economy worth around €19 million, i.e. an increase of 9.2 %[11]. However, the real increase of China's supplies to the EU is likely to be much higher, if the other instruments that China is currently using to restrict its exports were also removed. The profiles of CRM´s with which the third legal case is concerned are summarised in a press release of the EC from the 19th of July 2016[12].

Even though export restrictions were lifted, in the last years the Chinese government has continued to limit domestic production of rare earth minerals, e.g. in the second half of 2018, an action which could be interpreted as a plan to constrain international exports and send prices for the critical materials higher, according to Adamas Intelligence[13]. For the second half of 2018, China's quota for rare earth separation and smelting was cut 36%. China's decision to limit domestic rare earth production to 45,000 tonnes for the second half of 2018 - announced in August and the lowest in more than five years - provides only enough supply for China's domestic buyers. The semi-annual quota had risen to 70,000 tonnes in the first half of 2018, 40 % higher than the first half of 2017. But that move was, according to Adamas, largely seen by analysts and electronics manufacturers as a step to legitimize black market production, with Chinese manufacturing consuming most of that supply.

While China is likely to attend to its own needs before exporting, increased exports would require the country to draw on already-low inventories of neodymium (Nd), prasesodymium (Pr) and dysprosium (Dy), used in electric vehicle motors. Again, according to Adamas, prices for one key rare earth mineral, PrNd Oxide, could increase by 10 % to 50 % within 2019, and is on track to double in price within next five years as demand outpaces supply. Chinese exports typically supply around 80 % of the globe's rare earth needs, about 156,000 tonnes annually. Still, exports tend to oscillate wildly from month to month[14].

2.3 RECOMMENDATION

Given the increasing strong competition at global level for 'green materials' (including CRMs) and the uncertainties posed by protectionism threats, we recommend the EC to treat CRMs (value chain) as top priority in EU raw material diplomacy and trade policies, ensuring CRMs

[11] European Commission (2016) "EU takes again legal action against export restrictions on Chinese raw materials", News release, 19.07.2016, http://trade.ec.europa.eu/doclib/press/index.cfm?id=1530, accessed 10.03.17.

[12] European Commission (2016) "EU takes again legal action against export restrictions on Chinese raw materials", Press release, 19.07.2016, http://europa.eu/rapid/press-release_IP-16-2581_en.htm, accessed 01.08.17. -

[13] Lewis, B., Scheyder, E. (2018). China cutting rare earth output, unnerving global manufacturers. October 24, 2018LONDON/HOUSTON (Reuters), available at https://www.reuters.com/article/us-china-rareearths-idUSKCN1MY2GZ

[14] Further information can be found at https://www.wto.org/english/news_e/pres19_e/pr837_e.htm, https://www.maritime-executive.com/article/world-trade-growth-slowing

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rank high in new trade agreements (e.g. new FTA negotiations) with important CRM trade partners (China, USA, Brazil, Russia, Morocco, Turkey, etc.).

At the same time we recommend the EC to continue and widen diplomatic actions with China focusing on CRM trade agreements, including consideration of illegal CRMs flows.

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3 CRM AND DATA ISSUE

3.1 BACKGROUND

Primary CRM resources are found in ore deposits where they occur either as main commodities or, perhaps more commonly, as by-products or companion metals. This causes a problem for data collection, as secondary commodities and companion metals are not commonly measured or even mentioned in the resource estimates of the deposits if they are not exploited as by-products. In addition to ore deposits that are or have been in production, CRM are present in mineral occurrences that are currently not economic for production or from which there is not enough data due to lack of investigation. Mineral occurrences lacking any kinds of resource estimates are much more common than ore deposits from which these estimates exist. Moreover, in mineral occurrences some CRMs (e.g., Ga, Ge, In, Sb, REE) are more commonly, but not always, present in minor to trace amounts than as main commodities, similarly to the ore deposits.

Properly identifying these CRM dependencies throughout the full supply chain is a challenge that cannot yet be met with the reports and databases that are currently available. However, expanding and linking existing Eurostat databases with knowledge in platforms like the JRC Raw Material Information System could be a first logical step into that direction. The main data sources for the primary resources are found in various databases that are at least to some extent downloadable from the websites of the geological surveys (FODD)[15] or of previous projects (ProMine, Minerals4EU, EURare).

The Eurostat Environmental accounts set contains imports-exports as well as domestic production data for a wide selection of (grouped) materials, including some CRMs and their ores, covering multiple years for each EU member state: "*The classification of material flows for domestic extraction of metal ores has been based on the chemical characteristic on the one hand, and on different classifications as practically applied by a range of potential data sources. On the 2-digit level metal ores are distinguished into two classes: iron and non-ferrous metals. The non-ferrous metal ores are further broken down into 9 material groups (3-digits)*" (European Commission, 2018).

Unfortunately, the material classification does not reach the level of detail required to identify extraction & trade of CRMs individually. Most CRMs are listed under aggregate indicators like 'other non-ferrous metals' or 'precious metals', which mix the non-critical materials like silver, in one category with critical materials like PGMs. Thus, in its current state, it becomes impossible to study the flows of CRMs individually. The non-ferrous metal ores are broken down into 9 material groups (3-digits). Due to the high importance of

[15] Cp. FODD (http://en.gtk.fi/informationservices/databases/fodd/)

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certain non-ferrous metals (critical raw materials) CRMs may be considered to further increase detail down to a 4-digit level in the future (European Commission, 2018).

3.2 ISSUE(S)

It is important to emphasise that many CRMs have had few practical applications in the past and consequently the data available and our knowledge of them is very limited. We know relatively little about how their ores are formed and how to mine, process, use and recycle them in an effective, safe and sustainable manner (Brown et al., 2018).

The main concerns about data quality include: the lack of standardised nomenclature for individual commodities; the variation in terminology used to describe mineral occurrences and deposits; and the lack of harmonised reporting of resources and reserves. Task 3.1 aimed to identify and quantifyprimary CRM resources in Europe and had to resort to a heterogeneous numbers of sources to collect the necessary data (see Table 1), with some databases product of projects without any update (e.g. ProMine database) (Lauri et al. 2018). In particular, because of different practices within individual countries and the lack of any reported resource and reserve data for many commodities, it is not possible to derive meaningful national or pan-EU totals for the resources or reserves of a particular CRM. Consequently, we have little idea of the potential availability of CRM that might be mined within the EU. Without high data quality (especially for CRMs), no optimal CRM policies for both primary and secondary CRMs can be developed.

The most important difficulty in obtaining comprehensive CRM-related data (production, flows, disposal, etc.) is that it is not generated for many minerals and thus cannot be collected by statistical agencies for global flow analysis. At a global level, and as highlighted also by findings of the MinFuture project[16], the monitoring of CRMs as part of the physical economy is hampered as open source trade data available at international agencies such as UN COMTRADE (global trade) does not provide individual data for CRMs. Under the UN Comtrade´s Harmonized System (HS), many CRMs such as niobium, indium, gallium, hafnium, niobium or tantalum are only reported in association with other substances, i.e. grouped. For instance, niobium, tantalum and vanadium are all reported together in Chapter 26 under the code '2615' (Niobium, tantalum, vanadium or zirconium ores and concentrates); the same for beryllium, chromium, germanium, vanadium, gallium, hafnium, indium, niobium (columbium), rhenium and thallium; all reported together under code '8112' (Müller et al., 2018).

Likewise, Eurostat statistics do not generally report on the use of individual CRMs (Tiess et al., 2018b, see Section 5.3). Some of the Eurostat data could be particularly useful for studying the use of CRMs in parts of the European supply chain, but, unfortunately, the

[16] https://minfuture.eu/index.html

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material classification does not reach the level of detail required to identify extraction & trade of all minerals respectively CRMs individually. Most metallic minerals are listed under aggregate indicators like 'other non-ferrous metals' which combine the non-critical materials like silver, in one category with critical materials like PGMs. Thus this renders the study of CRM flows individually impossible (Müller et al. 2018).

Even more difficult is to obtain data on production or recycling of CRMs hidden in traded manufactured or semi-manufactured goods (e.g. in WEEE), in alloys, in concentrates, in waste, in scrap or in end-of-life products. Given the difficulty in keeping track of those CRM flows, they are not individually identified and recorded in trade statistics.

A similar problem occurs with data on CRMs contained in mining waste, historically seen as potential source of pollution and not of economic benefit. Thus, currently Eurostat does not collect information about the accumulated amount of mining waste – the stock or the composition of the waste and since the waste amounts are merged at country level, the information becomes meaningless for metal exploration, including CRM exploration. To be useful, data on mining waste must be reported and accounted for on deposit level (Huisman et al., 2017). Another issue is that the limited data available are often dispersed amongst a variety of institutions, including governmental agencies, universities, non-governmental organisations and industries. When available, these data are often stored in databases or in analogue form, with their own non-standardised architecture and vocabulary, making any attempt of a compilation difficult and time consuming, besides potential problems in recognition as well as primary access (Ladenberger et al., 2018).

Finland provides a notable exception to the more general situation in the EU. In Finland there is a comprehensive and accessible geoscience database, underpinned by a modern, transparent and efficient mineral licensing system and a supportive regulatory framework, which account for its consistently high ranking among global destinations for exploration investment.

As highlighted in SCRREEN´s D3.2 (Ladenberger et al., 2018), main gaps in data availability on CRM in Europe are:

- Lack of consequent and detailed reporting of CRMs from/in primary resources;
- Lack of any consequent reporting of CRMs in secondary resources from mining waste or EoL products;
- No diversification of CRM contents in relation to the waste types;
- High losses of secondary raw materials before and within the recycling chain with existing recycling technology;

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- Insufficient knowledge about current and future potential availabilities of EoL products, about their flows through the recycling chain, and about final destinations;
- Neglecting exploration efforts which address specifically CRM mineral systems and resources.

Table 1. Data sources for primary CRM deposit data in Europe by country.

Country	Data Source to be used	Comment
Austria	Minerals4EU	no data, known deposits
Belgium	Minerals4EU	no data
Bulgaria	ProMine	
Croatia	ProMine	
Cyprus	ProMine	
Czech Republic	Minerals4EU	no data
Denmark	GEUS	
Estonia	ProMine	
Finland	Fennoscandian Database (FODD)	updated 2017
France	Minerals4EU	
Germany	ProMine	Collected from literature
Greece	Minerals4EU	Other documents and company data to be checked in addition
Greenland	GEUS	
Hungary	Minerals4EU	
Ireland	Minerals4EU	
Italy	ProMine	
Latvia	ProMine	
Lithuania	ProMine	
Luxembourg	ProMine	Limited number of deposits
Malta	ProMine	Limited number of deposits
Netherlands	Minerals4EU	Limited number of deposits
Norway	Fennoscandian Database (FODD)	updated 2017
Poland	ProMine	
Portugal	Minerals4EU	
Romania	Minerals4EU	no data
Slovakia	Minerals4EU	
Slovenia	Minerals4EU	no data
Spain	Minerals4EU	periodically updated from national DB (BDMIN)
Sweden	Fennoscandian Database (FODD)	updated 2017
Switzerland	Minerals4EU	
United Kingdom	Minerals4EU	no data, known deposits

Source: Lauri et al. (2018). Identification and quantification of primary CRM resources in Europe. SCRREEN, D3.1

3.3 RECOMMENDATION

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Public data on global and EU resources of CRMs from primary and secondary materials is generally not adequate to support policy making and investment decisions that will expedite CRM supply security for the EU. Consequently, research on many aspects continues to be required to orientate the development of optimal CRM policies. To date particular parts of the value chain of certain CRM, such as the REE, have received most attention. There is now a requirement to extend similar research to other CRM, especially those that underpin the development of clean energy and transport, such as cobalt and PGMs.

In order to improve our understanding of the value chains of individual CRM it would be particularly helpful to have better quantitative data to assess the EU material stocks and flows at each life cycle stage. New geological, geophysical and geochemical data focused on raw materials including the CRM are needed. Such new, in-depth data are lacking for most of Europe. Incentives need to be designed in partnership with the minerals sector so that companies implement cost-effective methods to keep track of material flows and account the quantities of CRMs involved in the production cycles, losses, and disposals.

It is, therefore, important that more complete and reliable statistical data are collected, harmonised and made readily accessible. New data generation from operating mines or from old mining wastes needs to be approached from a material cycle perspective, i.e. acknowledging the difficulties but the importance in obtaining information on the amount available and potentially recoverable of CRMs. Based on new data collected and harmonised, a functional EU data base on CRM material flow analysis approaching real minerals and metals used by the EU is needed.

At the same time further funding should be made available to continue developing cost effective methods to conduct more detailed evaluations of resource potential in underexplored regions of Europe and the assessment (systematic, automatic sampling) of historic mining regions (brownfields and historical wastes) with new technology and concepts. As recommended in Ladenberger et al., (2018), it is crucial to advance on a pan-EU standardised and harmonised compositional and mineralogical characterisation of waste rocks, mining wastes, processing tailings, by-products, and metallurgical residues. Using modern analytical technologies it is possible to deliver accurate grades with respect to CRM. Along with grades, there is of course a need for detailed mapping of all stocks in brownfields of abandoned mining areas, as well as in operating mines, to be able to consider resource estimation and classifications issues. This is all essential information to be fed into newly developing business models which seek to exploit existing CRMs contained in mining wastes.

<u>Recommendations for improving data availability on primary and secondary CRMs in Europe (based on recommendation by Lauri et al. 2018 & Ladenberger et al. 2018)</u>

Ideally, the national geological surveys are the actors who collect and update all raw materials-related data in their country. The recommended actions include:

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- Agree with other responsible authorities on common criteria and formats for data collection and harmonisation (focus: CRMs) and based on that build national databases that are accessible through a web server and downloadable;
- In such direction, of main interest for geological survey is the pan-EU standardised and harmonised compositional and mineralogical characterisation of waste rocks, mining wastes, processing tailings, by-products, and metallurgical residues. Using modern analytical technologies it is possible to deliver accurate grades with respect to CRM. Along with grades, there is of course a need for detailed mapping of all stocks in brownfields of abandoned mining areas, as well as in operating mines, to be able to consider resource estimation and classifications issues.

- Update databases continuously (at least once a year)
- Build public-domain province databases in federal countries where the federal geological survey does not collect national mineral deposit data; such databases should be present for all provinces or states of a federal country
- Collect national data from other actors (universities, exploration and mining companies) working in the raw materials sector
    - Create new data (common system between companies and government) or re-convert and facilitate access to existing data on geological, geophysical and geochemical data focused on raw materials including the CRM. For that categorise waste data upon its resource potential, treat waste flow data on a commodity-base.
    - Engage in more detailed evaluations of resource potential in underexplored regions of Europe and revisiting of historic mining regions (brownfields and historical wastes) with new technology and concepts focusing on CRMs

Focusing on secondary CRM resources, map and prioritise most relevant manufacturing areas such as product designers and metallurgists/recyclers.

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4 CRM PRIMARY RESOURCES POTENTIAL IN EUROPE

4.1 BACKGROUND

Strong CRM potential exists in the EU: occurrences and deposits of all non-biotic CRM are known in the EU28 countries, Norway and Greenland. However, the location and extent of resources within Europe is **poorly understood for most CRMs in most countries** (Lauri et al., 2018); which also illustrates the lack of specific CRM policies, see chapter 3/D7.3). This is due in large part to the limited availability of high quality geoscience data focused on CRMs in much of Europe. Consequently, there has not been sufficient CRM-focused exploration in the EU and this is the first essential stage in the value chain for all minerals. Exploration is dependent on deposit models developed from knowledge of the processes that concentrate a metal or mineral in the crust and on the underlying regional geology. Such models are used by the exploration industry in conjunction with high quality, modern geoscience data to identify new exploration targets and to define the technology required to locate new resources. Without exploration there can be no identification of mineral resources or reserves and protection via land use planning, and therefore, no production of the mineral raw materials upon which the European industry depends.

The small quantities in which CRMs are normally used implies that a transparent spot market is non-existent, leading to intransparent markets dominated by bilateral long-term contracts. For several CRMs there are specialised markets served by minor mining companies who have difficulty in attracting risk capital and cannot survive price shocks easily. Certain CRM markets, particularly low volume ones, are inherently instable and volatile – innovative product technologies may reduce (e.g. LED) or enhance (e.g. electric vehicles) the need for CRMs suddenly.

Another important aspect lies in how global mineral supply chains function. Enhancing EU supply via development of domestic CRM-containing deposits does not necessarily mitigate supply risks since the primary materials will still need to be processed elsewhere, e.g. for intermediate products. Moreover, unless the right incentives or regulations are applied, there is no guarantee that the CRMs produced in the EU will be supplied to the EU market. In other words, **developing the CRM supply in Europe may not be enough if the next 2-3 tiers of the supply chain still are dominated by China or another non-EU country**[17]. The EC has early recognised the REE potential of Greenland and has already established a cooperation policy for increasing the participation of European exploration companies. Although there is the question, if the European market is sufficient for companies

[17] Tiess 2015, ERECON. Treibacher Industrie AG (Austria) - Using separated Rare Earth compounds for value adding. Identifies situation, where value chain moving to China / South East Asia. Market for separated products (e.g. Nd-Metal) becoming smaller in Europe.

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to sell their output, even if European exploration companies will have to find off-take arrangements with China.

4.2 ISSUE(S)

Further exploration efforts are required to obtain more precise, reliable ahd homogeneous resource data focused on primary CRMs, e.g. tonnage data under reliable standards. As previously mentioned (see Section 3 CRM and Data issue and SCRREEN D3.1, Lauri et al. 2018), reliable resource data for most commodities is generally very sparse and new data generated by exploration and mining companies is not collected in most EU Member States. Thus, there is a need for additional geoscience research to provide a better understanding of regional geology, ore deposit genesis, mineralogy and deposit models to support exploration. Likewise there is a need for reliable and homogeneous data that provides geologists and potential investors sufficient information to advance with feasibility studies that include CRMs (either as primary or secondary product of a mine operation).

Given the current limited economic motivation to explore for most CRMs at the present time, it is considered that some form of government support, e.g. policy attention or economic incentives, is required to promote further research into CRM deposit formation, to generate pre-competitive geoscience data and to incentivise exploration by the commercial sector.

In policy matters, as highlighted in SCRREEN´s D7.2, little attention has been paid to CRMs in national mineral policy frameworks: 8 years have now passed since the first publication of the CRM list by the EC in 2010. Focusing on CRMs, only a few countries have CRMs specifically included in their mining policies/strategies (leading to concrete policy actions), i.e. Austria, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Netherlands, Romania, Sweden and the UK. However, the level of focus differs among these countries: in the case of the UK Resource Security Action Plan CRMs are in the core focus, whereas in the cases of Germany or Finland CRMs are mentioned, but are not in focus. Moreover, existing mineral policy frameworks often do not employ a value chain approach but rather tend to focus on the traditional mining policy approach (an exception is the new mineral policy of the Czech Republic); for an effective and smart policy design it is necessary to have a thorough understanding of the entire supply chain of each CRM.

Exploration is without doubt the first step; yet, even if exploration data starts to be generated, it needs to be highlighted that finding an ore deposit and investigating it to the knowledge level that is required to justify the decision to advance towards feasibility/construction stages is a time and money-consuming process that may take even decades and requires previsibility and certainty. Currently, the same as for other non-CRMs, **investment security is not guaranteed** in various regions of the EU. Factors that render

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potential future investments insecure include the issue of slow, inefficient and unpredictable permitting procedures[18] subject to legal actions which may challenge permits already granted (cf. Norra Kärr case in Table 2 below). For instance, results of the 2018 Minex Forum survey determined that approvals for permitting presents the greatest challenge for developing greenfields projects in the Balkan region[19] which hosts deposits of REE, PGMs, magnesite, tungsten.

Other factors include increasing environmental activism (cf. Valtreixal case in Spain, see Table 2), social acceptability issues[20] including NIMBY attitudes and conflicting land uses[21]. Moreover, companies in Europe which have advanced with CRM projects have also faced financing difficulties, especially because the current European CRM mining scene is dominated by minor companies that have no access to **risk capital.** One recent example lies in the Hemerdon tungsten mine that re-opened in 2015, but was closed in 2018 due to financing issues (see Table 2 below).

Table 2: Overview of selected CRM projects, status and main development constraints.

Country and project name	Target mineral	Stage	Main constraining factor	History and status
Spain, Matamulas	REE	Stopped	Permitting	In 2017, the regional government of Castilla-La Mancha rejected Quantum Mineria´s request for obtaining an exploitation concession to start a REE project in Campo de Montiel based on a negative Environmental Impact Declaration. Reasons for the rejection were negative impacts on the biodiversity and on the water availability.
Spain, Valtreixal	Tungsten	Exploration	Environ-mental activism	The project is located within a Natura 2000 area, in concrete within a Special Protection Area (SPA) (Sierra de la Culebra). Even though under certain conditions Natura2000 areas can be compatible with extractive activities, some environmental NGOs claim the project incompatible with the area designation.
Sweden, Norra Kärr	REE	Pre-feasibility	Permitting	Deposit identified in 2009 and mining lease obtained in 2013. In 2016, a Swedish governmental review of a Supreme Administrative Court interpretation of the Swedish Mining Act led the Swedish Mining Inspectorate (SMI) to reassess four granted Mining Leases, including Norra Kärr´s. The SMI subsequently informed the company that the Mining Lease reverted from "granted" to "application" and requested supplementary information which the company supplied and which the SMI forwarded to County Administration Board") of Jönköping. On March 2019 such County submitted their opinion that more information is

[18] Discussed in the MINLEX project (MinPol, 2017).
[19] https://www.minexeurope.com/2018/survey-results/
[20] Discussed in MIREU (https://mireu.eu/)
[21] C.p. projects MINATURA2020 (https://minatura2020.eu/), MINLAND (http://minland.eu/project/).

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				required for them to support re-granting mining lease. The company initiated a Natura2000 permit application which may be influenced by a future mining operation. The Natura2000 permit application will be completed within the Swedish summer months (2019) and submitted to support the Mining Lease application. For granting of a Mining Lease in Sweden, conditions include that the SMI and County must be in agreement. For reference, when the Norra Kärr Mining Lease was granted in 2013, the SMI and the County were aligned in support of the Mining Lease granting.
UK, Drakelands /Hemerdon	Tungsten	Suspended	Financing	Operator bought the mine rights in 2007, the mine re-opened in 2015. The operator received a £2m loan in July 2018 but in October the company informed they had ran out of short-term capital and operations were shut down

Source: company´s websites. Updated June 2019.

4.3 RECOMMENDATION

In the face of a low level of global exploration spending targeted to CRMs, Europe should seek to pioneer a range of incentives seeking to take the lead in CRM-targeted exploration. As suggested in D3.3, the following incentives may be considered:

- government-sponsored research to provide improved and expanded pre-competitive geoscience baseline datasets, such as geology, geophysics and geochemistry, and research into the development of models for the formation of CRM deposits;
- reconnaissance exploration and drilling by government over prospective targets;
- financial incentives for exploration companies in the form of tax breaks or funding support for exploration activities focussed on CRM. Such exploration incentive schemes have enjoyed considerable success in the past in promoting exploration activity in Canada and Australia.

At the same time, future revisions of mineral policy frameworks need to focus on promoting and facilitating CRM-related exploration activities. Such policy frameworks should also be guided by future scenarios indicating commodities where demand growth may lead to potential supply problems.

Future EU-funded calls for projects and ongoing research seeking new technologies, business models, regulation of land uses and other organizational forms of tackling factors that hamper investment security needs to be re-direct the focus towards primary CRMs. In a growing international climate of trade disputes, the EU could strive to better communicate that investing in exploration and safeguarding well-known CRM-bearing primary deposits in Europe is the best way to ensure the future supply of CRMs to keep the European industry competitive.

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Based on ERA-MIN research, sustainable production of CRM could be achieved through investment in new innovations and technologies that:

• Reduce the loss of critical elements within residues and waste products during the entire life cycle;

• Have a minimal energy & water footprint and avoid the use of toxic and harmful chemicals during mining, refining and processing; and

• Reduce our dependence on primary CRMs through fostering end-of-life recycling and through substitution strategies.

This is backed up recent engagement activities with industry and research experts undertaken by KTN, which identified that further funding for R&I to "develop greater and more secure recycling and recovery route for CRMs" is deemed to be the most important collective action that should be taken to minimize CRM supply chain risk (KTN, 2019).

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5 CRM SUPPLY VIA BY-PRODUCTS

5.1 BACKGROUND

Many of the CRMs are mainly or only extracted as by-product of major metals or minerals of minor economic importance. These include bismuth, cobalt, gallium, germanium, hafnium, indium, REE, and scandium, which are produced together with gold, nickel, aluminium, lead, zinc, zirconium, phosphorus, and copper. For these commodities, the bottleneck of production is usually further up the value chain, that is, they typically are extracted from the mine in the ore, but are not recovered at the refineries or smelters due to the lack of economic incentive or simple technology. The by-product status of several CRM means that increased demand may not lead to increased CRM production because this is dependent on the economics of the main economic product (parent) rather than the daughter CRM.

The high level of commercial exploration activity undertaken for nickel-copper-PGM in Finland in recent years is testament to the importance industry gives to the availability of high quality geoscience data combined with robust mineral deposit models supported by substantial geological expertise in the Geological Survey of Finland (and which is a matter of strong minerals policy framework - the Finnish Mineral Strategy[22]). In order to achieve similar success elsewhere and shed more light on the CRM resource potential it is vital to have detailed geological knowledge of the most prospective target areas supported by substantial research on known European ore deposits.

Besides it is important to take a closer look at the processing technologies required to extract CRM as by-products or co-products that occur with other elements. The extraction of CRM from ore as by-products produces particular technological and economic challenges as the focus of the extraction process is on the main economic component, the parent material. For some metal groups, the PGM and REE, which are mined as co-products further separation and refining stages are required to produce the pure metals or intermediate products required by industry. These additional processing steps might place limits on the availability of some of these metals because of the restricted availability of the sophisticated processing capacity required. The production of PGM is an example for this.

This analysis of future demand trends make it clear that research into alternative European PGM sources and into new extraction technologies could contribute to securing the future PGM supply for import-dependent regions like the EU.

5.2 ISSUE(S)

[22] http://projects.gtk.fi/minerals_strategy/index.html

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The by-product status of several CRMs means that increased demand may not lead automatically to increased CRM production because this is dependent on the economics of the main economic product (parent) rather than the daughter CRM. In consequence, even though CRMs may be present in the ore extracted and the concentrate produced, they are not recovered at the mine site nor at the refineries or smelters due to the lack of economic incentives. This can lead to high levels of price volatility, which, when combined with the small size of the global market for many CRMs and the lack of transparency in such markets, it does not lead to increased investment in exploration, mining and extractive metallurgy of CRMs (Brown et al. 2018).

The by-product status of CRMs needs to be better considered in mineral policy frameworks (usually they are not).

5.3 RECOMMENDATION

Promote and/or fund further research to determine which potential economic incentives could be established to increase the possibility of recovering of CRMs at refineries or smelters. Of particular importance would be to develop the ability to swiftly increase production in response to sudden demand changes.

Research on alternative deposit types, on new genetic models, on advanced extraction methods and **more efficient by-product extraction might lead to increased CRM production within the EU and therefore contribute to minimising supply risks for European customers**.

The importance of CRM by-production needs to be better promoted for inclusion in the National Mineral Policy Frameworks of EU Member States so that MSs pay more attention as to how to incentivise by-production of their resources (e.g. via funding/incentives for by-product extraction technologies, etc.).

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6 CRM SUPPLY FROM MINING WASTE

6.1 BACKGROUND

Europe has a long mining and metallurgy history throughout which mining wastes (waste rock, tailings dams or sludge, back-filled, slag and ashes from smelters) have accumulated. Actually, in mining countries, the mining wastes constitute the largest part of society's total waste. Despite being an important residue, still little is known on how much waste is stored, how much could be recovered and under which conditions, etc. Answers to such questions are not an easy task as the data (if existing and available) is scattered among a variety of institutions including government agencies, universities, non-governmental organisations and industry and dispersed in different databases, formats and reports which is difficult to compare or aggregate. Part of the finished EU-funded ProSum project (2015-2017) aimed at collecting data on the amount and composition of stocks of mining waste and to create a dataset from which deposits with high levels of CRM could be identified. Results from the project revealed that across Europe there exist over 1600 open and closed mines which contain a substantial potential for CRM recovery (see Figure 1).

One of the reasons why CRMs were not considered a priority in mining waste is because mining waste has traditionally been regarded as an environmental problem; it is only in recent years that the economic potential has been recognized, e.g. as an additional source of revenue when conducting remediation activities. The previous lack of economic interest means there are lacking provisions in the mining/waste legislation (or simply no consideration in the policy framework of MSs). Results from the ProSum project indicated that a large amount of knowledge and information about mining waste is available but that information mainly concerns the raw materials that were in demand in society in the past, that is, iron, base metals and precious metals or environmentally hazardous elements such as arsenic, sulphur, cadmium and mercury, but not CRMs (Huisman et al., 2017).

As a consequence, only limited data exists on the amounts of mining waste (waste rock, tailings, waste sludge etc.) produced and accumulated in stocks (waste rock landfills, tailing and sludge dams). Results of the ProSum project also revealed that the status of knowledge on mining waste with special reference to CRMs is very heterogeneous and only a few countries have good data (Portugal) or partial data (France, Spain, Sweden), with the majority having no data on CRM contents (Ladenberger et al., 2018).

Some EU-funded projects are making valuable contributions to improve the sampling techniques to increase the data availability. The EU-funded project SMART-GROUND (http://www.smart-ground.eu/) created a digital platform that stores information that is structured and converted into searchable, downloadable and easy to process files. It allows the users to obtain rough estimations of waste remaining in mining and landfill sites,

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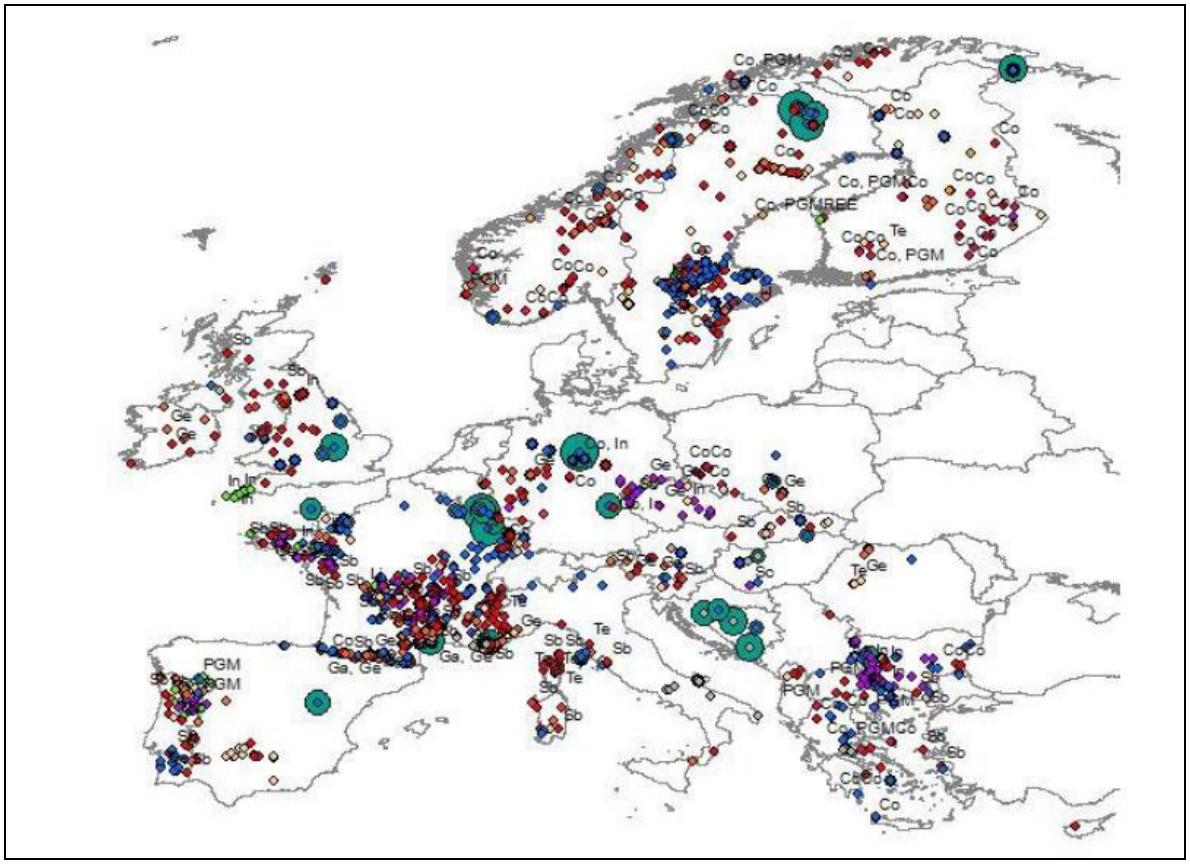
provided that sample data is available. At the same time the ORAMA project (https://orama-h2020.eu/) seeks to optimise data collection for primary and secondary raw materials by creating a system to transfer information stored at national level to the EU common information system. Other projects (e.g. BIORECOVER, INTMET[23], NEMO[24]) are working on new (biotechnology) methods to recover CRMs from mining wastes and landfills.

Figure 1: Map of Europe showing closed and operating mines.



Source: Ladenberger et al. 2018 (SCRREEN D3.2) based on ProMine and FODD. Note: the green circles represent the calculated amount of waste rock where the largest circles represent more than 500 Mt of waste rock. Diamonds represent smaller mines and the colours represent the type of ore; blue for iron and iron-alloy metals, yellow for precious metals, red for base metals, grey for bauxite, violet for energy metals (U) and green for special metals.

Despite the lack of a clear and precise per-country overview of the CRM potential in mining waste, there exist good practice examples across Europe of cases where recovery is already taking place, e.g.:

Recovery of tantalum and niobium (Penouta mine, Spain)

[23] https://www.intmet.eu/
[24] https://h2020-nemo.eu/

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The Penouta Mine (closed in 1985) was one of the most important tin mines in Spain. Mining in the Penouta deposit has been documented since 1906, but it was not extensively exploited until the 1970s when it was mainly worked to obtain cassiterite while Ta was obtained as a by-product. Extraction of ore was done via open pit specifically targeting the kaolinised leucogranite and those portions of the country rock which had been muscovitised and were soft enough to be extracted using free dig methods. Those materials were not milled and only fragments up to 2 mm in size were treated in the gravity plant so that a large amount of Sn and Ta-Nb minerals was not liberated from the hosting rock and was progressively accumulated in the tailing ponds, which have not been rehabilitated at all. As a consequence, sands from tailings reach similar grades as those of the original granite. Mining wastes still contain significant amounts of metals such as tin, tantalum, and niobium as well as significant quantities of industrial minerals (quartz, mica, feldspar, and kaolin) (Blengini et al., 2019).

A series of studies were conducted to assess the economic viability of recovering metals from mining wastes, including the authorisation of the project via the alignment with the Spanish law. The company conducted economic, environmental and social viability studies and as a result a gravimetric separation plant for the processing of wastes was constructed and started operating in early 2018 which leads to the obtaining of tantalum and niobium minerals. During the processing of tailings from waste-rock heaps and ponds of the old Penouta mine, around 1 % of tin, tantalum, and niobium concentrate is obtained, which is sold to international companies that process the raw material to generate intermediate compounds that serve to produce highly specific components.

The project not only allows the economic recovery of CRMs but also contributes to the recovery of an environmentally degraded area and boosts the economy in a rural environment (Blengini et al., 2019).

6.2 ISSUE(S)

Data related to raw materials, including CRMs, primary and from mineral-based wastes (mining and industrial) are only partially available in Europe. The limited data available are, however, often dispersed amongst a variety of institutions, including governmental agencies, universities, non-governmental organisations and industries. In the case of the latter, now defunct or historical industries and mines may have had documentation lost altogether since the cessation of production. When available, these data are often stored in databases or in analogue form, with their own non-standardised architecture and vocabulary, making any attempt of a compilation difficult and time consuming, besides potential problems in recognition as well as primary access.

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The problems regarding availability, quality, organization, accessibility and sharing of data are common. Solving these problems requires measures that address exchange, sharing, access and use of interoperable spatial data and services both at national and European levels. This is the aim of the INSPIRE Directive (2007, "Establishing an Infrastructure for Spatial Information in the European Community"), but its implementation in the Member States has just started and achieving those objectives represents a major challenge.

The EC has been for some years now increasingly raising attention to the issue of CRMs, e.g. the Final Circular Economy Package (presented in March 2019) contains a comprehensive report on the implementation of the Circular Economy Action Plan[25]. Under the plan a revised waste legislative framework entered into force in July 2018 which includes strengthened waste prevention and waste management measures, including products containing CRMs. Yet, despite such updates, as of today, one of the main issues at EU level is that there is still no EU legislation requiring the recycling of mining waste. An example of a good policy is that of the new Czech mineral policy which states that waste should be always considered as a potential secondary resource.

As previously mentioned, another important issue is the existence of sparse EUROSTAT statistics on mining waste (Ladenberger et al., 2018)[26]. This is because there is no obligation via EU legislation to collect data on mining waste, thus, there is no mining waste framework in MSs which requires collection of mining waste data. The observation made on the national inventories of mining wastes related to the implementation of the Mining Waste Directive (nowadays called the Extractive Waste Directive 2006/21/EC) showed that any compositional information provided are very limited and of uncertain quality[27].

The ProSum project initiated work on documenting and characterising mining waste in Europe but the work is far from being completed. The project developed guidelines for future work, a common database, and a new code list. Yet, as the project concluded, what is needed for a future improvement of the database is more complete characterisations of the thousands of mining waste sites in Europe. A complete characterization should include further sampling and modern multi-element analyses of the waste in order to identify CRMs, to estimate amounts and metal grades, and to better understand where they occur in nature. To achieve that new approaches are required for better sampling & characterization, mineral liberation, treatment of fine particles & reuse of all remaining materials.

Moreover, improvement is also needed on the access to the data in the ProSum website. The database allows nice visualisations of the data collected, but such information cannot be easily used for doing own analysis because the data itself and assumptions behind it remain

[25] http://ec.europa.eu/environment/circular-economy/pdf/report_implementation_circular_economy_action_plan.pdf

[26] Ladenberger et al. (Anna LADENBERGER (SGU), Nikolaos Arvanitidis(SGU), Erik Jonsson(SGU), Ronald Arvidsson (SGU), Susanna Casanovas (Amphos21), Laura Lauri (GTK)) (2018). Identification and quantification of secondary CRM resources in Europe, SCRREEN deliverable D3.2, available at http://scrreen.eu/results/

[27] ProSum project; SCRREEN D3.3.

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hidden (not accessible). As summarised by SCRREEN´s D3.2 main issues hampering an effective CRM supply from mining waste include:

- Insufficient information about CRM compositions and volumes in mineral-based wastes like for example mining waste such as dumps and tailings.
- Insufficient knowledge about mineralogical and geochemical behaviour of CRMs during mining and processing using physical and chemical methods.
- Insufficient information about the mineral-based character of residues, and their physical and chemical properties.
- Insufficient information about overall availability and resource potential of historic mining sites.
- Insufficient information about historical smelter locations and metallurgical wastes.
- Lack of systematic identification/mapping of mining waste sites for future CRM extraction.
- Lack of a unified system for classification of CRMs (e.g. UNECE/UNFC system) in various types of mining waste.
- Lack of specific methods of extracting metals and other valuable products from secondary, often heterogeneous sources.
- Uncertainties in regulations and permissions allowing new business models related to CRM recovery

As highlighted by colleagues of the KU Leuven[28], to make metal recovery from waste economically viable, there is need for:

- Cheap processes (low CAPEX/OPEX), able to compete with primary mining
- Flexible processes, able to deal with a broad range of compositions
- Streams with significantly high concentrations of valuable metals

6.3 RECOMMENDATION

Following recommendations outlined in Ladenberger et al., (2018), an EU sustainable value chain and supply of CRMs from primary and secondary resources needs:

[28] See presentation by J. Roosen at EIP workshop on enhanced landfill mining of CRMs (Brussels, 16 May 2018)

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- Further research directed to improving the methods to collect data on CRM composition and volumes in mineral-based wastes; nowadays, using modern analytical technologies it is possible to deliver accurate grades with respect to CRMs.

- Further efforts towards detailed mapping of all stocks in brownfields of abandoned mining areas, as well as in operating mines, focusing on identifying of streams with significantly high concentrations of valuable metals which could potentially render the CRM recovery economic. Also, existing data and information should be compiled, made available and further efforts should be directed to "bridging" and harmonising existing data among European countries.

- Investment into extraction process (flowsheet) that can render an extraction project economically attractive.

- Investment in the development of eco-friendly extracting technologies of CRMs from waste. Such technology developments can satisfy goals like waste reduction and reduced land use and they should become inherent objectives of the ecological part of every future mining/quarrying related activities. This can be actively incorporated into the remediation of historical mining sites and other inactive industrial facilities.

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7 CRM SUPPLY VIA RECYCLING

7.1 BACKGROUND

A sustainable supply of CRMs for the European industry requires improving their domestic recycling. Even though mining of primary CRMs will need to continue to cater for the growing demand, secondary CRMs have potential to cover larger parts of the demand. It is difficult to ascertain to what extent CRM recycling could cover the demand in the future; results obtained by previous projects addressing CRM secondary sources such as ProSUM and MSP-REFRAM showed that there are still significant gaps concerning the information on the content of CRM in end-of-life products such as vehicles, batteries, WEEE, etc., and thus their potential recyclability.

As a departure point, it needs to be clear that recycling is technically non-feasible (very difficult or impossible) for the following CRMs: coking coal, fluorspar, magnesite, natural graphite and phosphate rock. Coal once burned cannot be recycled, fluorspar is used in dispersive applications and its recycling becomes impossible, magnesite is predominantly used in the calcined form as magnesia and it cannot be recycled, a significant amount of material containing natural graphite is lost during use and cannot be recycled. Although phosphorus is recyclable, the input material phosphate rock is not recyclable (Tiess et al., 2018b).

Recycling of the remaining CRMs is possible with varying degrees of difficulty and success. Recycling barriers along the value chain start with the design of products. It is technically relatively easy to recycle base metals from simple products, but trends show that product manufacturing follows an increasing product complexity and metal heterogeneity (metals dissolved in each other) which renders recycling of trace components such as CRM much more difficult (UNEP, 2013). In other words, to avoid dissipative losses, there is a need for a change in how products are designed and how recycling systems are accordingly planned based on a good understanding of physics, thermodynamics and metallurgy so that products, components and recycling systems are designed departing from an concept of "design-for-recycling".

In parallel to product design change, besides increasing collection rates, new end-of-pipe solutions are needed, such as new metallurgical recovery techniques, e.g. recovery of palladium and platinum from electronic waste using selective laser sintering 3D printing (Lahtinen et al., 2018).

Another large problem in the value chain is the collection of post-fabrication (or post-consumer) scrap. Waste electrical and electronic equipment (WEEE) products contain a large numbers of CRMs. WEEE are currently considered to be one of the fastest growing

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waste streams in the EU, growing at 3 % to 5 % per year: between 2015 and 2016, the amount of EEE put on the EU market increased by 2.9 % from 9.8 million tonnes to 10.1 million tonnes. The recycling rate[29] of WEEE in the EU in 2014 reached 41 % in 2016[30] which means that many CRMs 'crucial to many electrical products' are lost, i.e. WEEE products do not get into the recycling stream. When considering the contribution of recycling to the EU demand for CRMs, this ranges from 0-44%. The WEEE directive is only focused on recycling targets and does not include recovery of CRMs.

Potential of CRM recycling

Taking into account that CRM recycling is still at the technical cradle stage, the vast majority of 'green energy' metals must be provided by mining and ore processing in order to satisfy the current demand. Information collected by UNEP show that the EoL-RR[31] of many CRMs is low, being lower than 1% for beryllium, borates, gallium, germanium, indium and REE, and 1 - 10% for antimony and tungsten. The only CRMs with an EoL-RR higher than 50% are chromium, cobalt, niobium and PGMs. Low EoL-RR are due to low efficiencies in collection / processing, technical limitations in recycling processes; in addition, primary material is abundant and low-cost (thereby keeping down the price of scrap).

7.2 ISSUE(S)

Collection and pre-sorting of CRM-containing waste needs to be improved, e.g. highlighting the importance of CRM recovery and avoiding the losses of valuable products to illegal and non-efficient recycling systems or being exported outside the EU.

A very important issue at the heart of recycling systems is the instability in the price of metals and of scrap. This is based on the assumption that recyclers are motivated and driven by the value of the recovered materials for which they get paid for. In this sense, the recovered material has to pay for all collection, dismantling, sorting and other recycling activities. Yet, often, recyclers encounter the problem of price volatility, which is specially detracting for smaller organizations, when scrap prices go down. Recyclers, like any other economic organizations, need previsibility, which sets the conditions for longer-term investments and continued increase and attainment of recycling targets. To cater for fluctuating scrap prices, a good example is the "price compensation mechanism" applied by the Italian household appliance recovery and recycling consortium ECODOM which has agreed with its partners to apply a price compensation mechanism to resolve the problem of low and inestable scrap prices (when primary raw materials are cheap, alternative good

[29] According to Eurostat, calculated multiplying the 'collection rate' with the 'reuse and recycling rate' (both defined in the WEEE Directive). Collection rate equals the volumes collected of WEEE in the reference year divided by the average quantity of EEE put on the market in the previous three years (both expressed in mass unit). The 'reuse and recycling rate' is calculated by dividing the weight of the WEEE that enters the recycling/preparing for re-use facility by the weight of all separately collected WEEE (both in mass unit).
[30] http://ec.europa.eu/eurostat/tgm/table.do?tab=table&init=1&language=en&pcode=t2020_rt130&plugin=1
[31] It indicates the percentage of a metal in discards that is actually recycled (see SCRREEN D7.1)

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quality secondary materials cannot compete). Thus, in its contracts with the treatment providers, ECODOM has introduced an indexing mechanism linked to the market value of the secondary raw materials: when this value rises, the Consortium pays to suppliers a lower amount; when the value goes down, the Consortium thus recognizes its suppliers a higher amount. The purpose of this mechanism is to ensure that these suppliers maintain a high quality standard, even in unfavorable market situations.

As highlighted by the International Resource Panel, there is a need for a realignment away from material (or metal) centric approaches towards product-centric ones. A focus on products discloses the various trade-offs between for example achieving weight-based policy targets and the excessive energy consumed in efforts to meet these targets (UNEP, 2013). The EU is heading in this direction with several Directives such as the Directive on End-of-life Vehicles (2000/53/EC), the WEEE Directive (2012/19/EU) and the Batteries Directive (2006/66/EC); yet, EU legislation with regard to recycling is currently focused on the amount of materials recycled (volume recycling), and has no focus on small flows of CRMs. Moreover, EU end of life legislation does not focus on specific collection and recovery rates for CRMs like cobalt. The WEEE directive is only focused on recycling targets and does not include recovery of CRMs.

Other issues which need to be addressed include the insufficient amount of information on CRMs which could be potentially recycled and the lack of disaggregated data on the use of CRMs (Eurostat).

Another existing challenge is to develop an EU policy sensitive to CRMs and their properties (covering the whole supply chain). Already in 2014 a proposal (COM/2014/0397 final) was made that in order to ensure security of supply of CRMs,[32] MSs should "*take measures to achieve the best possible management of waste containing significant amounts of CRMs in line with the waste hierarchy, taking economic and technological feasibility and environmental benefits into account. The measures contained in this Directive [WFD], e.g. the recycling targets for municipal waste and the ban on the disposal of metals, including metals present in discarded products, in landfills for non-hazardous waste will support the measures taken at national level*". It was also proposed that "*Member States should include in their waste management plans nationally appropriate measures regarding collection and recovery of waste containing significant amounts of critical raw materials*".

7.3 RECOMMENDATION

Further EU policy support is needed so that new Directive amendments explicitly make reference to CRMs, their importance and opportunities for improving their recycling taking

[32] In 2014 a proposal (COM/2014/0397 final) for amending the Waste Framework Directive (WFD), the 94/62/EC Directive on Packaging, the 1999/31/EC on the landfill of waste, 2000/53/EC on end-of-life vehicles, 2006/66/EC on batteries and accumulators and waste batteries and accumulators, and 2012/19/EU on WEEE[32], was presented and considerations in relation to CRMs were made.

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environmental, economic and technical (thermodynamics, metallurgical) aspects into account. At the same time, potential future Directive amendments (WEEE Directive, ELV Directive) could seek to focus the promotion of recovery of small CRM flows whereas end of life legislation could seek to focus on determining specific collection and recovery rates for strategic metals (CRMs) like cobalt.

The industrial implementation of the 'Design for Recycling' concept is still at its infancy globally. The EU needs to more strongly emphasize and incentivise the adoption of such concept working in partnership with the industry. On the legal side, the EU might further seek to orientate the Eco-Design Directive towards more systematically tackling material efficiency issues such as durability and recyclability (the focus so far has been on energy efficiency improvements). CRMs and their recycling potential under a product-centric approach might act as a central axis in the steering of this process.

Good practice examples from Member States along the recycling chain (collection, pre-sorting, sorting, disassembly/demanufacture) bringing solutions to recyclers should be further disseminated. Some of the main problems faced by recyclers nowadays include scrap price instability and the existence of illegal recycling streams which collect and inefficiently process valuable CRM-containing waste products. Examples of ECODOM in Italy and their 'price compensation mechanism' or France with a rigorous system of qualification of the collective systems in charge of collecting and processing WEEE can be mentioned.

Finally, greater knowledge is needed on the reserves of CRM in end-of-life waste. For that, as suggested in D3.2, the following actions would be welcome:

- Adaptation of the waste and product statistics: the individual statistical categories usually include both products containing and not containing CRM. In many cases the percentages of CRM may vary even in the same kind of products, e.g. tantalum in capacitors.

- Publicly available studies including reliable data on concentrations of CRM in end-of-life products.

- Track changes in the use of components and metals caused by product development, for example use of electronics in cars.

- Recycling of manufacturing waste (new scrap): require recyclers to publish detailed information on the quality and composition of recycled materials.

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8 CRM SUBSTITUTION

8.1 BACKGROUND

Substitution in the context of raw material criticality generally refers to the ability to achieve the same function in a product or service by means other than the usual raw material. Substitution act as an important mitigation strategy to overcome the potential disruption in the supply of CRMs: it covers the partial substitution (minimization of CRM) to the complete substitution (full replacement) (Bouyer, 2019). A well-known example of partial substitution was the substitution of Pt by Pd in automobile catalysts in the mid-1990s when the expensive Pt was partially substituted by the then less expensive Pd. This led to a large increase in Pd demand and caused a reversal of the Pt to Pd price ratio; combined with supply restrictions on Pd exports from Russia, an all-time high of the Pd price was reached in 2000[33].

Based on intelligence gathered during SCRREEN and CRM_InnoNet (see KTN, 2019), we have identified the following drivers for business considering substitution as a strategy to mitigate CRM supply chain disruptions: sharp price rises in CRMs (which can be caused by changes in supply/ demand or geopolitical issues, etc); CRMs which are (or likely to become) subject to regulations (e.g. environmental or health-safety regulations) and therefore banned; development of novel materials that bring about improved performance and therefore differentiation in the marketplace[34]. Four different substitution strategies have been identified: Substance for substance, Process for process, Service for product & New technology for substance.

Despite some well-known examples, in general substitution remains a complex factor as it is influenced by many variables and because of constant fluctuation in material use in response to technological innovation, market forces, economic development, etc. To be considered feasible, substitution should, ideally, meet these conditions: (i) the substituted material should perform equal to or better than the substance it is replacing; (ii) it should make sense economically (the cost of the substitute material and of the manufacturing process should remain competitive); and (iii) it should be effectively scalable (Pavel et al., 2016). At the same time, substitution should avoid replacing one CRM by another, which is often a risk as various CRM belong to the same group of elements (see metal linkages wheel).

In Tercero Espinoza et al., (2018) an examination was made of substitution options available for selected CRMs. A review of 5 key criticality studies revealed substantial differences as to how each country and/or organization in charge of the study assesses criticality and

[33] Hagelüken & Meskers (2009), "Complex Life Cycles of Precious and Special Metals", in: Graedel, T.E., van der Voet, E. [Eds.] Linkages of Sustainability, 163–97, The MIT Press Scholarship Online, http://mitpress.universitypressscholarship.com/view/10.7551/mitpress/9780262013581.001.0001/upso-9780262013581-chapter-10, accessed 17.05.17.
[34] Etienne Bouyer (CEA), SCREEN expert group meeting Rom 2018.

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determines the level of substitutability. Despite the heterogeneity in scope and assessment methods, a broad interpretation of results reveals that a significant fraction of CRMs demand is for applications where they play a key function not currently attainable by other means or without being detrimental to competitiveness, e.g. due to large losses in performance (see Tercero Espinoza et al. 2018, Fig. 2 and Fig. 3). In other words, many CRMs were assessed as very difficult to substitute by most of the revised studies, such as beryllium, cobalt, chromium, indium, manganese, rhenium, REE and tungsten. As found in Tercero Espinoza et al., (2018), the majority of substitutes is currently in the research and development stage, and market ready solutions are scarce. In contrast, others were assessed as easier to substitute or with little additional cost such as diatomite, potash or titanium.

The global value chain of products containing CRMs needs to be well understood in order to find potential spaces for CRM substitution efforts in Europe. On a global scale, in many industries, European companies operate at the end of the value chain and import most of their semi-finished products from outside Europe. A direct implication of this is that some direct substitution measures are beyond the influence of the European producers. Medium and large companies have the option of working around this by transferring part of their production to countries with abundant supply of materials. This trend has considerably weakened Europe's industrial base and increased its dependence on imports, including CRMs (Calleja et al., 2015).

As a result of a broad literature revision, the SCRREEN project identified that at present, there are no comprehensive quantitative data on the substitutability of raw materials because too many parameters can influence the degree to which a critical material is substituted. Similarly, there is no consensus in the attribution of substitution and substitutability in criticality assessments. As a consequence, the SCRREEN project partners worked on developing an indicator to approach the substitutability of CRMs. Partners seeked to answer the question not only if it is possible to substitute but rather if it is feasible and how much effort it takes to make it. For that a substitution readiness level (SRL) indicator (and scale) was proposed that allows to follow the maturity of the solution and that also measures the remaining effort to be done to make the substitution solution possible and real. The SRL, a sector and application-specific indicator, can help actors all along the value chain to take the right decision in due time to select a substitution solution according to specific market and sector constraints. Policy makers could become users of such SRL for deciding whether to support a breakthrough substitution solution versus another one (e.g. a less disruptive) according to the benefit it could bring and the expected time to market (Bouyer, 2019).

Another tool developed and implemented in the SCRREEN project was a methodology to assess substitution trajectories in order to identify the relevance of CRM substitution for the European economy. The trajectories of accumulators (electric cars and energy storage

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applications), alloy in transportation sectors, catalytic converters, electrical components in permanent magnets were assessed by CRM availability, economic relevance and availability of substitution solutions (see Karhu et al. 2019).

8.2 ISSUE(S)[35]

As highlighted by the CRM_InnoNet project, despite the EU efforts for addressing the CRM challenge, a strong pan-European substitution strategy is still missing in the current political landscape. At the Member State level, our results show that no mineral policy or strategy addresses CRM substitution as one of the primary goals. In the EU, only Germany and France, and to some extent the Netherlands and the UK, have issued strategies covering CRM substitution (Tiess et al., 2018a). Likewise, there is a limited number of European governments who have a clear critical materials policy linked to product design and development (Peck et al., 2015).

The development of substitutions (new substances, processes, services or technologies) is, in the eyes of developers, a long-term risky investment often higher than optimizing existing processes and known technologies. This is compounded by materials price volatility which acts as deterrent to R&I as companies shy away from investing when rates of return are highly uncertain (Calleja et al., 2015). Price volatility also acts as an incentive (or disincentive) for companies to invest in researching for substitutes: an example is the case of cobalt, used in the cathode material of Li-ion batteries, and the most critical material to be substituted. Given cobalt´s high market prices, there exist commercial incentives for this metal to be substituted; in contrast, natural graphite, the key component on the anode side of the batteries, has no similar price incentives that motivate substitution research (Karhuu et al., 2019).

Despite the topic of eco-design (of product or process) is becoming increasingly important and more widely recognised, a persistent problem is the adoption of an eco-design approach, i.e. the literature indicates that there is little engagement from product designers on the subject of critical materials and product design (Peck et al., 2015). In this sense, there exists potential to promote ways to make CRM substitution to become a key part of the eco-design approach, so that materials science is closely linked to product design.

Substitution of CRMs is generally regarded as replacing one material for another thus considered a topic for materials science only. However, to take substitution solutions from discovery to market and doing so rapidly, it is essential to link the parts of the value chain as well as the research base with the industrial sectors. Europe needs to create the environment where materials science, product design, engineering and business models are

[35] This section is largely based on findings by CRM_InnoNet network compiled in the report by Calleja et al. (2015).

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not regarded as separate entities, but come together in the innovation process (Calleja et al., 2015).

Another issue which needs attention is the lack of alignment between industry and policy cycles, which makes it difficult to prioritize and focus on certain CRMs. Depending on the sector, there may be very different time cycles related with CRM substitution. On the one hand, there are very short technology innovation cycles and a framework of criticality that changes quite rapidly; on the other hand, there are long-term oriented policy cycles. The raw material production sector, i.e. mining sector, has very long term cycles. When changes in the industry occur (i.e. regulation on substitution, products manufacturing etc.), the mining/production sector will not respond rapidly and supply of CRM may continue over several years after substitution policies have been put in place (Calleja et al., 2015).

Investing in substitution is seen as a high-risk undertaking, both in terms of increased Capital Expenditure (CAPEX) and the duration of the full innovation cycle (typically ten years or more). There is also uncertainty whether a material classified as CRM today will remain a CRM in the future, i.e. sudden changes in the political climate could render investment in R&I in substitution unprofitable. Furthermore different industries and sectors have their own priorities for criticality, not always in alignment with the current CRM list (Calleja et al., 2015). Likewise, there is a lack of incentives for companies to consider CRM substitution as a viable business opportunity.

Another issue which hampers more substitutive solutions is the fact that R&D in materials is data-rich, yet data generated generally does not enter the open domain. Additionally there is a lack of advanced computational tools for data evaluation and modelling. Sector transfer of learnings is generally non-existent (Calleja et al., 2015).

Finally, we should highlight that the image of substitution should change from being a challenge to an opportunity for the market, also in terms of sustainability.

8.3 RECOMMENDATION

All organizations involved in promoting R&I for substitution in the EU would certainly welcome a specific substitution strategy for Europe. Such a strategy would need to be appliances (or product)-focused and address cross-sectorial challenges, such as bottlenecks along the CRM supply chain, especially intermediate products, which are vital for strategic sectors (e.g. those essential for the energy transition in the current context). Examples include accumulators in electric cars, alloys in transportation sectors, catalytic converters and permanent magnets in wind turbines and transport vehicles (see assessment of trajectories for these examples at Karhu et al. 2019). It also needs to address common opportunities, such as options for accelerating material innovation.

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Moreover, an EU substitution strategy should seek to overcome the common perception that substitution is a substance-for-substance activity and that it mainly concerns materials science. The strategy should make it clear that developing successful substitution solutions requires a cross-disciplinary approach and effective knowledge transfer between academia & industry as well close links to cross-cutting issues like resource efficiency and eco-design.

The strategy also needs to be based in the understanding that substitution of CRMs by process or application innovations are long-term oriented and conditioned by various factors which influence risk (price volatility, lack of coordination between developers, etc.).

To speed up the time to market of new solutions, the collaboration of industry and academia is essential. At the same time there is a need for new instruments for sharing knowledge on CRM substitution RTD outcomes and business opportunities while protecting competitiveness in strategic industrial sectors (Calleja et al., 2015). In this sense, we recommend the SCRREEN-project SRL indicator be tested to see whether it is deemed useful by developers and policy-makers alike.

We also recommend to find new ways to promote and orientate manufacturing companies towards eco-designs. A higher level of cooperation between designers, material scientists and companies is required for accelerating material innovation and the market uptake of solutions. Such recommendation is based on the expectation that the integration of materials science with product design at early stages in the manufacturing process will result in increasing efficiency and shortening the time of developing new solutions for the substitution of CRMs.

We finally suggest the EC to consider extending the funding for R&I programmes for fundamental materials science and for applied research into application (or product)-focused CRM alternatives e.g. via the EIT Raw Materials (KIC) which we believe is a powerful instrument to support demonstrator and incubator activities.

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9 VOLUNTARY STANDARDS

9.1 BACKGROUND

As defined in Regulation 1025/2012/EU on European standardisation, a voluntary standard is a technical specification, approved by a recognised standardisation body, for repeated or continuous application, with which compliance is not compulsory. Voluntary standards make things work. They give world-class specifications for products, services and systems, to ensure quality, safety and efficiency. They are instrumental in facilitating national, regional, European and international trade.

During the SCRREEN project, the AFNOR partner identified standards (published and under development/revision) useful for the SCRREEN project. These standards are elaborated at European (CEN and CENELEC) and international (ISO and IEC) levels, and few ones developed at national levels. Branch standards and company standards were also considered.

Standards for primary (mined) CRMs

At international level AFNOR found few specific standards dedicated to CRMs in particular ISO standards. ISO created in 2016 a technical committee (under the responsibility of China), the ISO/TC 298 Rare Earth, dedicated to the standardization in the field of rare earth mining, concentration, extraction, separation and conversion to useful rare earth compounds/materials (including oxides, salts, metals, master alloys, etc.) which are key inputs to manufacturing and further production process in a safe and environmentally sustainable manner. The ISO/TC 298 Committee is developing standards on:

- ISO/WD 22453 Rare earth -- Elements recycling -- Method for the exchange of information of rare earth elements in by-products and industrial wastes
- ISO/WD 22451 Rare earth -- Elements recycling -- Measurement method of rare earth elements in by-products and industrial wastes
- ISO/AWI 23664 Traceability of rare earths in the supply chain from mine to separated products
- ISO/AWI 22928 Measurement method for magnet scraps containing rare earth elements
- ISO/CD 22450 Rare earth -- Elements Recycling --Communication formats for providing recycling information on rare earth elements in by-products and industrial wastes

In ISO/TC 207 Environmental management, a new standard is under development, ISO/WD 14009 Environmental management system: Guidelines for incorporating redesign of products

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and components to improve material circulation. This document presents guidelines for the strategies of material circulation, in particular the use of CRM and their recyclibility.

ISO/TC 45, is in charge of the standardisation of methods for testing and analysis of raw materials for use in the rubber industry.

Also in ISO, a new Technical committee was created in 2018 on circular economy to develop requirements, frameworks, guidance and supporting tools related to the implementation of circular economy projects. CRMs will be an aspect in this structure.

Standards for secondary CRMs

Few voluntary standards are existing for secondary raw materials. At European level, voluntary standardization works are under development by CEN/CLC/JTC 10 Energy-related products - Material Efficiency Aspects for Ecodesign, in particular in terms of terminology, durability, upgradability, ability to repair, facilitate re-use, use or re-used components, ability to re-manufacture, recyclability, recoverability, recycling, use of recycled materials, documentation and/or marking regarding information relating to material efficiency of the product. Two standards present a real interest for CRMs:

- prEN 45555 (under development) General methods for assessing the recyclability and recoverability of energy-related products: this document present an assessment method dedicated to CRMs.
- EN 45558:2019 General method to declare the use of CRMs in energy-related products. The main intended use of this document is to provide a mean for information on the use of CRMs to be exchanged up and down the supply chain and with other relevant stakeholders, in order to ease their reuse and recycling.

Previous initiatives include the WEEE-Labex launched as the culmination of a research project run by the WEEE Forum to design a set of standards respect to the collection, sorting, storage, transportation, preparation for re-use, treatment, processing and disposal of all kinds of WEEE and to put in place a process of monitoring companies through audits conducted by auditors (Campadello et al. 2019).

At CENELEC level work is ongoing according to the Mandate 518 for preparing standards (Standards Series 50625 and 50614) along the value chain (Collection, Transport, Re-use and Treatment) of WEEE (Campadello et al. 2019).

9.2 ISSUE(S)

With regards to voluntary standards, there are only a few standards dedicated specifically to primary CRMs, and these are international ISO standards. There exist other standards not

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dedicated to CRMs but which include the thematic and are applicable, e.g. on terminology, sampling techniques, measurement and characterisation of CRMs as trace elements in raw materials, and horizontal standards (environmental management, social responsibility).

At European level, we are facing a void in terms of the organization of the collection of CRMs and the characterisation of their properties as secondary CRMs are not standardized. Future standardization works could be based on works performed for other raw materials such as aluminium and copper. A main barrier is the separation between a secondary raw material and wastes. A clarification and a better distinction should be provided in order to improve the collection and valorization of such raw materials.

Another issue is that a few voluntary standards exist for secondary raw materials (developed under m518 mandate), and some are under development (under m543 mandate) (AFNOR, 2018).

Standardised procedures for waste characterisation, separation and treatment are needed, especially for any products and applications, such as WEEE, EoL batteries, etc. New regulatory framework and possible incentives can boost the transition towards the adoption of standards at large scale. Focusing on the WEEE issue, during the project it was identified the need for upgrading regulations and standards to enable CRM recycling from WEEE. Based on that a strategy was developed within the SCRREEN project (see Campadello et al. 2019).

9.3 RECOMMENDATION

The availability of standardised data on the composition and volume of CRMs in products and in mineral-based wastes is of utmost importance for any economic anaylsis and for the policy-making cycle. Standards play a key role in ensuring quality and interoperability of the data collected.

Given that nowadays Europe faces a void in terms of the organization of the collection of CRMs which results in a non-standard characterisation of secondary CRMs, we recommend the EC to continue supporting the work on developing standards (e.g. under m543 mandate) but also to lead the creation of pan-European standards for the characterization of the properties of secondary CRM waste (WEEE, EoL batteries, etc.), seeking to resolve the issue of what separates a secondary CRM from waste, among other non-resolved technical issues.

Concerning WEEE, multiple specific technical and management recommendations are available at Campadello et al. (2019) for improving standards dealing with WEEE recycling (CENELEC, R2 standard, Eco-design standards) which we believe should be communicated for discussion with those organisations responsible for developing the standards.

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10 EU FRAMEWORK CONDITIONS

10.1 BACKGROUND

The EU framework conditions for a substantial increase in investments on domestic mineral developments in Member States are still in need of further consolidation. The European investment climate for mineral development projects (primary/secondary CRMs) still remains unfavourable by the lack of a strong policy framework at EU level (top-down instrument). This indicates the need of strong communication between the EC and the Member States in further efforts to coordinate and foster Member States to discuss and find common solutions to the key issues that prevent the minerals sector (and specifically investments towards CRMs) from achieving a level playing field in the EU´s internal market. Unlike for other technology alliances (e.g. space technology, remote sensing, nuclear research, etc.) little effort has been made to set up structures for a cross-European provision of CRM.

A key message that we need to underline in relation to national policy-making is that, despite the considerable primary and secondary CRM potential in Europe, little attention has been devoted to CRMs in National Mineral Policy Frameworks (NMPF, with some exceptions, see Tiess et al., 2018a). Such frameworks are in need of analyses of minerals consumption, particularly (but not only) CRMs.

10.2 ISSUE(S)

When comparing the extensive mapping of minerals vs company policies, we believe that in general the company policies / value chain is neither connected with the NMPF, or only partly. Examples like the Austrian Raw Material Alliance and the German Raw Materials Alliance[36] are exemptions. The reason for this are diverse: first, mining policies are not considering/allocating specific CRM roles (this would require a connection with the value chain because of the specific CRM features); second, mining policies are not considering the Mineral Consumption Analysis approach (cp chapter 2 at Tiess et al., 2018a). Finally, a mineral policy would need to take into account the (specific features of CRM respectively the) value chain as well corporate goals and strategy. A good example case is the CZ New Mineral Policy (2017) which is based on mineral consumption analyses and which is considering primarily and secondary CRMs equally.

Another key message is that no concrete CRM policies imply less input in regulatory mining framework. There are no concrete CRM exploration provisions (e.g. giving priority), which could support a company or facilitate CRM protecting (based on LUP). In the case of

[36] However, the German Alliance does not exist anymore as it went bankrupt

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regulatory frameworks, CRMs are not appearing as a priority or special focus in the national mining laws which regulate primary minerals.

At the same time, no mining law (ML) is allocating CRM as a special group i.e. is allocating special rules for exploration/extraction/processing of CRMs as well special roles with respect to the land use planning law (no priority zones for CRMs in LUPs and environmental law). The MLs are allocating general roles for mineral resources i.e. how to explore/extract minerals. We would like to bring up again the Norra Kärr project in Sweden[37]. Exploration activities might be less dependent on stable political and institutional conditions than long term mining activities, but as they are the first step towards raw materials extraction stable conditions are particularly desirable to ensure that exploration expenditure can be securely linked to mine development, if results are favourable. This does not only include political conditions like internal and/or international conflicts, but also the legislative framework related to the licensing of exploration and mining activities. Permitting bodies such as mining authorities have to be consistent, knowledgeable if companies are to be confident enough to invest in that country. Regional and governmental institutions involved in the process of permitting procedures have to backed by modern and reliable mining laws. All aspects that are important in setting up a mining business have to be clearly regulated and the process should be transparent to both the mining company as well to other stakeholders.

Further investments towards CRM exploration and/or exploitation are hampered by various factors, among them the lack of social licence to operate (SLO). An increasing threat is given in the growing power of NGOs and networks of organised civil society against mining. There is a mismatch of the financial strength between those fighting mining and promoting mining. Over-optimistic emphasing of the circular economy paradigm may undermine the publics' and political decision makers' awareness of the need of primary production of raw materials, including CRMs. In Greece, for instance, a potential conflict in the development of a mining project is related to the often expressed "lack of trust" of the local communities, ecological organisations and other stakeholders regarding the actual compliance of the mining industry with prevailing environmental rules and regulations. The non-issuance of a "social license" is often the cause for the significant delays in the development or even the annulment of new mining projects in Greece. The constraints encountered in permitting of new mining projects in Greece during the last decades are in contradiction with the recently published National Strategy for the Development of Mineral Resources (2012) that fully supports the Sustainable Development of Mineral Resources (MinPol, 2017).

Mineral policy / Securing access to CRM via land use planning

[37] See chapter 2.

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Mineral planning policy is part of the NMPF and focusses on securing the access to CRM via land use planning management. The partner project MINLAND[38] has been studying the situation in the EU and has determined that safeguarding of minerals in land use planning is mandatory in Sweden, Norway, Poland, Italy and Hungary, but not in Finland, Spain, Portugal (but protection of exploitation and exploration permits are mandatory). In spite of that, there is no special safeguarding tool for CRM employed in any of the cases revised in the MINLAND project (cf. MinLand/D3.3).

10.3 RECOMMENDATION

Policy, at EU and Member State level, continues to play a decisive role in supporting R&I to diversify the different paths through which Europe´s industry can remain competitive and innovative by ensuring a steady supply of CRMs. Global demand for raw materials, including CRMs, is growing rapidly, driven by population growth, urbanisation, improving standards of living, the application of new technologies and policy actions on matters such as climate change and environmental protection.

In the EU, Member States need to devote more attention to CRMs in the NMPFs. For that, **knowing the mineral consumption status and potential future demand, i.e. which CRMs are needed and for which applications, is the departing point for any mineral policy**. Thus, such knowledge is needed alongside the forecasting of future raw material demand which is always very challenging given the inherent uncertainties relating to the level of demand, the market shares of individual technologies and material intensities. In a range of scenarios evaluated by Fraunhofer (Marscheider-Weidemann et al., 2016) major increases in demand for several CRM, especially those that are obtained as by-products, were indicated. It is essential to continue to evaluate future scenarios in order to identify those commodities where demand growth may lead to potential supply problems and to identify appropriate solutions which might involve increased CRM production from primary or secondary sources or the development of substitutes.

At the Member State level, when designing new National Mineral Policy Frameworks, Member States should avoid separating primary and secondary CRM, but should seek to **apply a value chain approach**, focusing on products and services where CRMs play an important role. This may entail a paradigm shift in many countries where mining and mineral policies are often dissociated from recycling and substitution policies.

Member States need to encourage further exploration. Given the low level of global exploration focussed on CRM consideration should be given to promoting such activities in the EU. A range of incentives should be considered to encourage this, including:

[38] http://minland.eu/

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- government - sponsored research to provide improved and expanded geoscience baseline datasets, such as geology, geophysics and geochemistry, and research into the development of models for the formation of CRM deposits;
- reconnaissance exploration and drilling by governments over prospective targets;
- financial incentives for exploration companies in the form of tax breaks or funding support for exploration activities focussed on CRMs. Such exploration incentive schemes have enjoyed considerable success in the past in promoting exploration activity in Canada and Australia.

Another important recommendation for Member States is that CRMs need to become a priority in their land use planning. The SCRREEN project management has been cooperating with the MINLAND partners in order to bring this aspect forward in the agenda. We suggest the EC to keep supporting this initiative so that further promotion reaches towards MS´s land use planning priorities.

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11 SUMMARY OF RECOMMENDATIONS

We hereby summarise a number of recommendations arising from the previous chapters. Recommendations are mainly directed to the European Commission and its Member States, but also apply to the industry, the minerals and recycling sector as well as to other stakeholders that need be involved in collaborative new solutions to achieve the objectives delineated in the Raw Materials Initiative and other policy instruments.

- **Treat CRMs as top priority in EU raw material diplomacy and trade policies**, ensuring CRMs rank high in new trade agreements with important CRM trade partners (China, USA, Brazil, Russia, Morocco, Turkey, etc.). Continue and widen diplomatic actions with China focusing on CRM trade agreements.

- **Improve quantitative data generation methods and standards from a material cycle perspective.** Continue funding and coordinating the creation of a much needed EU database on CRM material flow based on new data and data collected and harmonised. Data should be available in detail, downloadable and serve the purpose of better understanding the composition and volume of CRMs in primary and secondary resources available in the EU MSs.

- **Continue criticality assessments**. Criticality assessments remain an important tool to provide early warning of potential supply risks of economically important raw materials. Such assessment should continue to be carried out regularly using, wherever possible, more complete and higher quality datasets for quantifying the criticality indicators. Close cooperation with the industry is key.

- **Continued funding research on the processes responsible for the formation of CRM - bearing ores, on the improvement of exploration methods for the CRMs and on the technology for their efficient recovery** from ores, mining waste, processing waste and end - of - life products is essential. It is important also to consider the possible future importance of new material streams. For example, there may be a requirement to mine and extract CRM from new or 'unconventional' deposit types, or from mining and processing wastes that have not previously been exploited. This may involve treatment of lower grade ores, possibly with mineralogy that differs from those typically worked, or with elevated contents of deleterious elements, such as arsenic or uranium. New end-of-life product streams containing valuable CRM will become available in increasing amounts in the future as new technologies become more widely used, for example electric vehicle batteries and fuel cells. Research into the recovery of CRMs from these sources should be assigned a high priority.

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- **Continue funding systematic surveys of CRM potential**: it is recommended that further systematic surveys be undertaken in the EU to assess the potential for CRM resources in known deposits, mine wastes, tailings and metallurgical residues. This would involve detailed mapping and standardised reporting of volumes and grades of all potential resources. The Geological Survey of Sweden has already begun such a survey of mine wastes in Sweden (see details at Ladenberger et al. 2018).

- **Fund (or co-fund with industry) studies of complete value chains at the product-level**. Criticality assessment should continue to be followed up by in-depth commodity-specific studies of complete value chains carried out by experts from industry and academia. In the light of the continually changing levels and patterns of demand these studies should include consideration of future demand and supply scenarios to assist in the definition of appropriate technical or policy interventions.

- **Identification of potential bottlenecks in CRM supply chains**: examination of both the level of consumption of individual CRMs within the EU Member States and of the processes involved along the entire supply chain is needed in order to assess the geopolitical and other risks to supply. Potential bottlenecks in the supply chains of individual CRMs can thus be identified and appropriate mitigation strategies developed.

- **Direct more efforts towards accelerating the implementation of the Eco-Design Directive** to facilitate the generation of new design solutions for the the 'Design for Recycling' concept, especially around those chains with high CRM recovery potential. Revise the Eco-Design Directive and head it towards more systematically tackling material efficiency issues such as durability and recyclability, as well as evaluate the possibility of advancing towards a Substitution Strategy for Europe.

- **Extend research to other CRM value chains following REE example:** Public data on global and EU resources of CRMs from primary and secondary materials is generally not adequate to support policy making and investment decisions that will expedite CRM supply security for the EU. Consequently, research on many aspects continues to be required. To date particular parts of the value chain of certain CRM, such as the REE, have received most attention. There is now a requirement to extend similar research to other CRMs, especially those that underpin the development of clean energy and transport, such as cobalt and PGMs. While the exploration, mining and extraction stages of the material value chains are of fundamental importance, it is stressed that the other life cycle stages of individual CRM also need to be fully assessed to ensure security of supply.

- **Promote updates in the content and approach of the National Mineral Policy Frameworks** of Member States transitioning from linear to circular understanding of the importance of CRMs for their own domestic value chains. Emphasize the importance

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of creating formal economic incentives for the industry, the minerals and recycling sector to collaborate and find new economic solutions to recover CRMs from by-products, mining waste and recycling streams.

- **Continue funding for R&I for developing greater and more secure recycling and recovery route for CRMs**. Also continued funding for considering investigating substutiton options at thr design phase of new products. This funding should be collaborative, involving industry and academic from a across different disciplines, considering all forms of substitution.

- **Continue supporting the work on developing standards** (e.g. under m543 mandate) and take the lead in the creation of pan-European standards for the characterization of the properties of secondary CRM waste (WEEE, EoL batteries, etc.).

- **Continue funding of long-lasting CRM expert networks**: Available initiatives such as the short-lived expert networks ERECON/EURARE have proven that longer horizons are needed to find collective solutions. In other words, the impact of those networks was limited in comparison to the invested resources. It will be important that the impact of such projects will be long-term which means that after the finalisation of such projects a prolongation of the developed network (stakeholders from EC/MS/companies etc.) should be envisaged. The impact should be measured too. The idea could be (besides voluntary acting): financial means (project budget) could be taken into account from the coordinator for keeping the network alive.

  According to its second-high level objective, SCRREEN is aimed at becoming a long-lasting Network. To reach this objective, a business plan that will allow the Network to exist and contribute to the EIP-RM SIP objectives on CRM after the end of the project is being formulated together with an activity plan for the Network. The network also is expected to guarantee the knowledge availability, transfer and use after the project (linked to JRC´s RMIS), and be able to support further initiatives, projects and programmes promoted by the EC. This umbrella network built on existing associations, initiatives, clusters, networks will bring together the main experts in CRMs, creating a permanent forum for policy makers, industry and society, sharing efforts and interests in raw material sector.

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12 OBJECTIVES OF A FOLLOW-UP PROJECT

Aiming to ensure secure and sustainable access to primary and secondary resources, the possible follow-up of the SCRREEN project will be devoted to capitalise the work made during the project duration, by focusing the activity in terms of support to EU policies, organisation and animation of the expert community. In more detail, the long-lasting Network is expected to:

- Manage the lists of experts for sectors and materials, based on the knowledge gained during the project and the evaluation workshop, that will take place on 10-12th September 2019 in Brussels and where experts are invited to support the EU criticality assessment, via validation of data and data sources as well as exchange of knowledge for all the 83 screened materials.
- Improve and manage EU knowledge base on primary and secondary raw materials.
- Promote clustering and cooperation with other on-going projects and initiatives in RM sector.
- Animate the expert community, through organisation of related events, preparation of materials, positions papers, etc.
- Support the EC in policy making covering all the raw materials and their value chains as well as ensure support in relevant events organised by EC. Possible topics of interest can include: analysis of the future supply and demand of raw materials, policy and technological gaps, etc.
- Informing decision makers at EU and MS level, *i.e.* the producers and the users, defining possible new business opportunities and taking in account the relevance of all the social, environmental and economic issues on RM supply.

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