SCRREEN

Coordination and Support Action (CSA)

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www.scrreen.eu

SCRREEN Final Report

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Summary

SCRREEN Final Report

Approval

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2019-11-08 09:23:13	Mr. Stéphane BOURG (CEA)

SCRREEN

Solutions for CRitical Raw materials - a European Expert Network

Strengthening Europe's CRM Strategy

Solutions for CRitical Raw materials - a European Expert Network

38 MONTHS

30 PARTNERS

15 COUNTRIES

SCRREEN FINAL REPORT

NOVEMBER 2019

The SCRREEN project has received funding from the European Union's Horizon 2020 Research and Innovation Program under Grant Agreement 730227.

SCRREEN at a Glance

SCRREEN established a long-lasting EU Expert Network on Critical Raw Materials to meet its overall objective of strengthening the EU's Critical Raw Material Strategy. The objective was to lift barriers and ultimately boost the Creation of new markets in Europe, inducing job and wealth creation.

CRM knowledge portal launched

- **Responded to and addressed key CRM issues**
  Mining, processing, recycling, substitution and final applications in relation to crosscutting aspects (including policy, society, technology, standards and markets).

- **Analysed pathways and barriers for innovation**

- **Identified solutions for overcoming innovation barriers**

- **Studied the regulatory, policy and economic framework for the development of these technologies**

- **Convened and facilitated expert groups**
  Alongside informative, and targeted conferences, events and webinars to raise awareness, review and discuss key issues, deliverables and topics.

- **Communicated key CRM technical and strategic messages across Europe**

Contents

Contact Information

For enquiries about the SCRREEN project please contact the project coordinator via **contact@scrreen.eu**.

Disclaimer

This document is intended as a public-facing summary of SCRREEN project objectives, background context and the key outputs and results.

The information and content of this report is the sole responsibility of the SCRREEN consortium members and does not necessarily represent the views expressed by the European Commission, or its services.

While the information contained in the documents and webpages of the project is believed to be accurate, the author(s) or any other participant in the SCRREEN consortium make no warranty of any kind with regard to this material.

Individual project deliverable reports provide more detail and can be found at **scrreen.eu/results** (see Annex 1 for a complete list).

A Long-Lasting CRM Expert Network

> In 2011, 14 materials were identified as critical. In 2014 there were 20 and in 2017, 27. Some have been in this list because of their economic risk, some for their supply risk, some for both! And this based on a picture covering the previous last five years. If you are a researcher, an entrepreneur, a decision-maker with limited means/ resources, interested in investing to mitigate the CRM issues, the list by itself cannot not orient your choice. By proposing a state of the art on the value chains of these CRMs, by analysing the future trends that are foreseen based on market evolution or upcoming technologies and by highlighting promising innovative fields, SCRREEN can help you! To deliver this comprehensive review, SCRREEN relied on more than 150 experts who contributed directly (within the consortium) or indirectly (through their active participation in technical workshops). Now that the bases have been established, SCRREEN will continue to deliver expertise and advice to those who want to help the EU to face the CRM challenges!

Stéphane Bourg
Chef de Projet, CEA

A Historic Gathering of CRM Expertise

SCRREEN started in November 2016 with one ultimate goal - to create a long-lasting Expert Network on Critical Raw Materials. To do this, SCRREEN, uniquely, gathered together experts from 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 therefore acted as reference advisor in Europe for CRM strategy and served as an umbrella network providing a single voice to communicate CRM data, knowledge and to the highest level.

Developing The Network

The Network was developed to provide expert and independent assessment to the European Commission and all related stakeholders, with a focus on the 3 pillars of CRMs:

- Primary resources
- Secondary resources (recycling and recovery)
- Alternatives for substitution of elements/products/services

Six Expert Groups

The Expert Groups (EGs) were developed and convened throughout the project to assess the key strategies required to support the long-term sustainability of the network, covering:

- Market
- Governments & Policies
- Substitution
- Resources
- Circular Economy
- Production

Expert Network Collaboration

To deliver on the project's objectives, collaboration was fostered between experts within the network established by SCRREEN and delivered a holistic range of reports and insights within a range of thematic areas as summarised in figure 1.

Project Legacy

SCRREEN will 'live on' as long lasting network within a new structure in order to maintain continuity and to ensure that the expertise, knowledge and data generated by the experts will be exploited to further strength Europe's CRM Strategy.

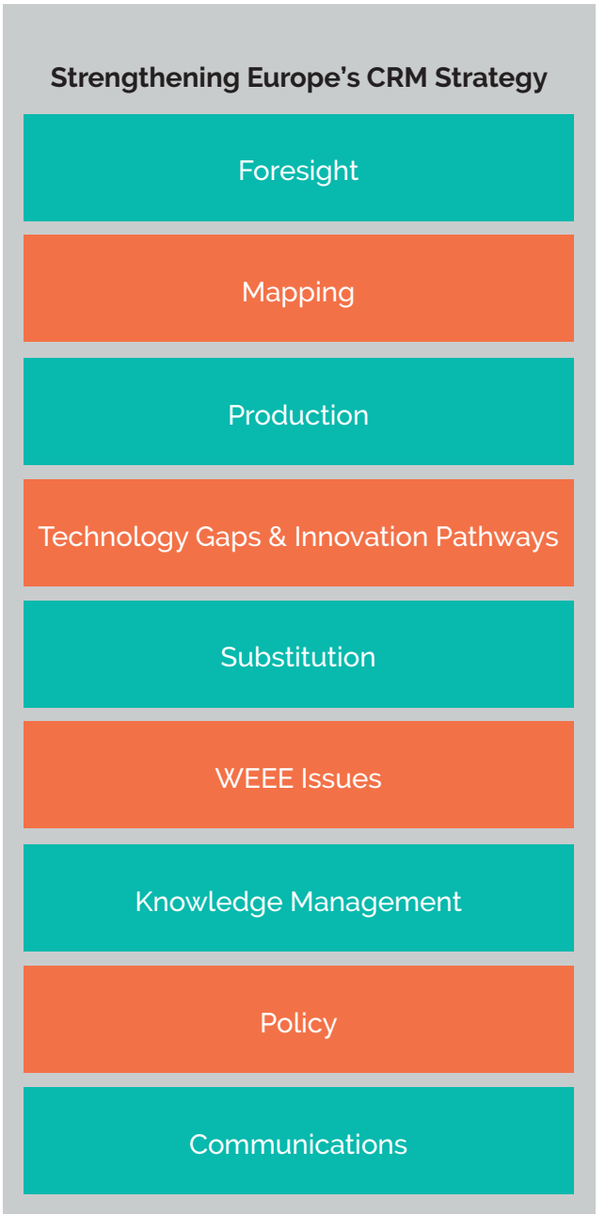

Figure 1. Strengthening Europe's CRM Strategy

Foresight

Dr. Luis Tercero Espinoza
Coordinator of Business Unit Systemic Risks, Fraunhofer ISI

Context

Ensuring a sufficient raw material supply to meet demand is an economic necessity. Knowledge on usage and future demand for CRM is an essential part of this. At the time that SCRREEN was launched, most known studies focused exclusively on CRM concentrations in vehicles, consumer appliances or in energy technologies addressing only a limited fraction of total CRM usage.

The objective of the 'Foresight' work was to provide an overview of present and future (to 2035) CRM markets in Europe. The starting point was the EU CRM List published in 2014 (accommodating the 2017 CRM List where feasible within the project timescales and budget).

The 3 building blocks of SCRREEN foresight activity were:

- A systematic overview of current use of CRM in the EU
- Original work to develop a compilation and analysis of major trends affecting demand for CRMs
- Original work to generate quantitative scenarios for future use of CRMs

Highlights

Current Use of CRMs

- Specification of the use of 31 critical materials in various sectors and applications.
- Presentation of 3 different views on European CRM use: an economy-wide overview; a bottom-up view on the CRM content of products; and the supply-chain perspective of CRM flows through Europe.
- Data added on the share of European value added of sectors that are dependent on CRMs - identifying sectors with both a high economic importance and a high dependence on CRMs (e.g. manufacturing of machinery & equipment.)
- Case studies of 8 selected critical raw materials, presented in disaggregated flows of CRMs in different phases of the European supply chain.
- Highlighted the importance of exploring material flows beyond the raw material stage as, in many cases, CRMs used in semi-finished and finished products in Europe are subject to import dependence.

Expert Contributions

Fraunhofer ISI , LGI, Leiden University, GTK, BGS, CRM Alliance

Current Use of CRMs – Conclusions and recommendations

- These 3 approaches could complement each other in shaping the foundation of a comprehensive knowledge base on the use of CRMs in Europe.
- They could also serve as a basis for further research on trends and future developments of the use and demand for critical raw materials.
- Expanding the knowledge base on CRM content of products would be an important step in closing the gap between bottom-up and top-down views on the use of critical raw materials.

Major trends affecting demand for CRMs

SCRREEN assessed the major trends affecting future demand for CRMs, based upon industrial applications and sectors. Demand drivers were assessed using a multi-perspective PESTEL framework, analysing consumer preferences, economics, technology, environmental factors, legal and political aspects.

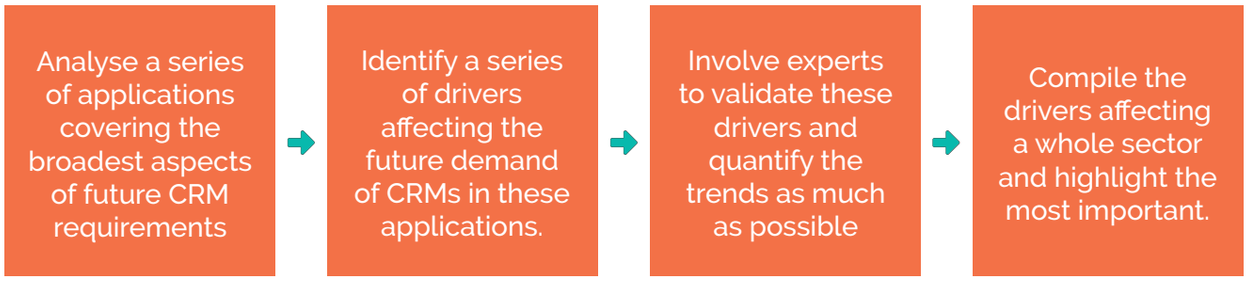

Figure 4. Summarised methodology used to assess major trends.

The resulting study covered 12 applications involving 20 CRMs.

Examples of data analysed to assess future trends:

	Energy	Electronics & Telecoms	Transport	Metallurgy	Chemical Industry	Agriculture	Other Industrial Applications
Number of Applications	18	14	13	12	11	2	26

Table 1 - Number of CRM-intensive applications by sector
Source: SCRREEN D2.2 Antoine Monnet et al (2018).

CRM	Application use in 2015 (t)	EU apparent consumption[1] (t)	% (R1)	Expected application use in 2035 (t)	% of expected use vs current EU total (R2)
Nd	390	1,000	40%	750	80%
Pr	130	230	60%	250	110%
Dy	80	180	40%	60	30%

Table 2 - CRM significance for wind power
Source: SCRREEN D2.2 Antoine Monnet et al (2018).

Major Trends - summary of sector findings

Energy
The development of wind power (involving rare earth elements) and domestic energy storage (mainly cobalt and natural graphite) is expected to drive up demand for CRMs.
The requirements related to the deployment of PV panels (mainly silicon, indium and gallium) should become less critical by 2035, due to material efficiency.
Important drivers to monitor in this sector include policies to further reduce CO_2 emissions, incentives for distributed power generation, power and storage requirements related to the deployment of electric vehicles (EVS).
Transport
The need to decarbonise mobility and reduce air pollution is closely tied to the emergence of hybrid and electric vehicles and the persistent dependence on autocatalysts for conventional combustion vehicles.
The deployment of EVs is expected to drive most of the growth of CRM requirements (mainly REE, cobalt and natural graphite) in this sector by 2035.
The search for better performing materials to replace existing ones, especially in terms of weight and performance in extreme conditions (ceramics for jet engines, Al-based alloys for car bodies), should also impact the sector, with tantalum, magnesium and niobium the main CRMs concerned.
Telecoms & Electronics
The global expansion of digital networks and services suggests that more people have access to the internet, so fuelling the need for connected equipment and fibre optics that Europe could produce and export. Therefore, the demand of CRMs in this sector should either level off (indium for screens), or keep increasing (REE, tantalum, palladium for electronic devices & appliances, Germanium for optic fibres).
Important drivers to monitor in the future include miniaturisation of components, measures against planned obsolescence and restrictions on exports of e-waste.
Agriculture
Global population growth (moderate in Europe) will foster the need for more efficient agriculture, thus increasing reliance on fertilisers and potentially encouraging European exports.
Various sources of phosphorous are likely to be considered (animal manure, but also sewage sludge and food waste chain) to reduce dependence on phosphate rock.
The emergence of precision agriculture, helped by new technologies and a drive for more sustainable agriculture, could improve the efficiency of fertiliser use.

Major Trends - recommendations

- **Further research is needed.** There is a lack of information on the main application of some CRMs (not covered in this study). It would be useful to investigate secondary applications of some CRMs when existing studies reveal a quickly growing application (e.g. storage application for cobalt and natural graphite). In these cases, even secondary applications could exacerbate the upward trend of demand.
- **A focus on some processing steps of the CRM value chain** could, in specific situations, provide valuable information, since the criticality of some CRMs depends on a specific form of product like high-grade silicon used for PV panels and electronic components.

Future use of CRMs in the EU

This activity completed the analysis loop and built on the findings from studies of current CRM use and major trends. Detailed projections for future demand of 14 CRMs were developed, forecasting until 2035 across their individual main applications. The CRMs used for projections were prioritised based on where:

- supply of the raw material is considered critical by the EU.
- demand for the raw material is influenced by at least one of the applications analysed under 'major trend' activity (with those affected by more than one major trend given priority).
- they have applications covering a high percentage of the overall current demand and are impacted by a major trend.
- they have applications expected to grow quickly due to overall demand in the near future.

Using this criteria, the following raw materials were chosen for further analysis: barytes, cobalt, gallium, indium, magnesium, niobium, the platinum group metals (PGM) palladium, platinum and rhodium, phosphate rock, the rare earth elements neodymium and dysprosium, tantalum and tungsten.

Future Use – examples of projections for selected CRMs

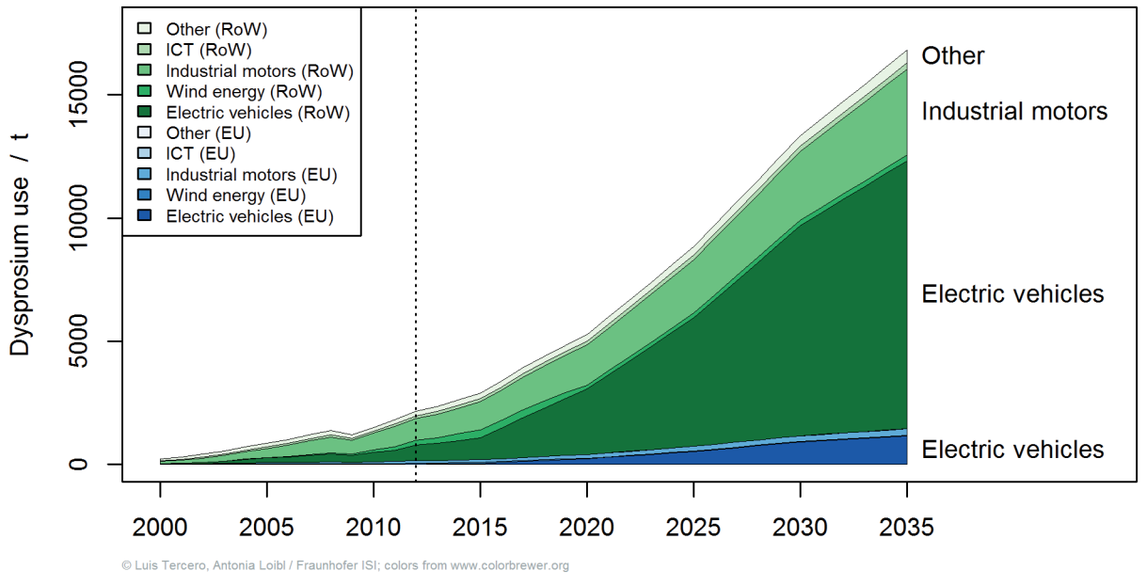

Figure 5. Neodymium demand for the main application sectors of permanent magnets with historical data until 2013 (indicated by the dotted line) and a demand forecast in the timeframe of 2013-2035 shown for Europe (blue) and rest of world (green).
Source: SCREEN D2.3 Dr. Luis Tercero Espinoza et al (2018)

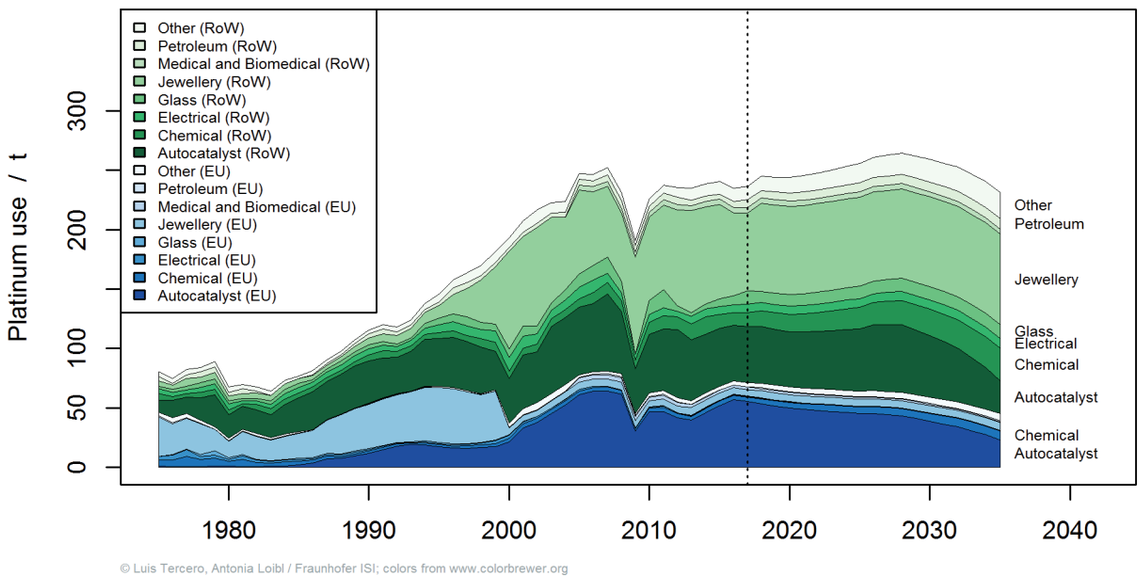

Figure 6. Platinum demand for the main application sectors of permanent magnets with historical data until 2017 (indicated by the dotted line) and a demand forecast in the timeframe of 2017-2035 shown for Europe (blue) and rest of world (green).
Source: SCREEN D2.3 Dr. Luis Tercero Espinoza et al (2018)

Mapping

> The main aim of the Mapping activity was to identify and quantify CRM resources in primary and secondary sources including mining wastes, industrial wastes, fabrication scraps, End of Life products and 'urban mines', according to the updated EU list of 27 CRMs published by the European Commission in 2017.
>
> We carried out a comprehensive identification and quantification of primary CRM resources in ore deposits in Europe. We focused also on secondary CRM resources, the main sources of which classified in materials such as mine wastes, industrial waste, fabrication scraps, End of Life products recycling and 'urban mines', which constitute old landfills and waste dumps in Europe.

Simon Michaux
Senior Scientist, GTK (Geological Survey of Finland)

SCREEN Activity

Identification & quantification of primary CRMs in Europe

Identification and quantification of secondary CRM resources in Europe

Challenges of locating, mining and extracting CRM resources

Context

To fully meet future CRM needs, metals and mineral products from primary sources will still be needed in the future. Most of them will continue to be imported from sources outside Europe; but others can, for political and economic reasons, be produced domestically. There are challenges to maintain a sustainable supply of primary CRM in Europe, including the development of innovative technologies addressing exploration of CRM to discover new potential deposits on land and offshore and mining technologies adapted to the treatment of primary mineral resources with increasing complexity and decreasing grade. There are also challenges relating to the supply of secondary CRM from mineral-based wastes (e.g. mining waste, processing tailing), including insufficient information about CRM compositions and volume characteristics in the mineral resources from primary ore deposits; a lack of systematic identification/mapping

of mining waste sites for future CRM extraction; and lack of a full inventory and range of metals to anticipate future demand.

For non-mineral based secondary resources (i.e. from reuse and recovery from waste products and metals), a sustainable supply of mineral products and metals for European industry requires more efficient and rational consumption, enhanced substitution and improved recycling.

Continuous reuse cannot alone provide the necessary quantities of CRM, due to recycling loss; the growing demand for CRM being higher than the rate of primary supply, recycled CRM production and finding new CRM sources and substitutions. Another main issue is the "metallurgical challenge" related to finding product and material groups with the highest potential for high-grade recovery of the CRM that are largely lost (e.g. indium, gallium, germanium, tantalum, rare earth elements).

Whilst it is unlikely that primary resources of CRM will become exhausted in the near future, access to those resources can be constrained by conflicting land uses or social acceptability issues.
Recycling CRM from secondary sources cannot supply the entire quantity that is needed to supply future demand. Although the EU is 100% import reliant for certain CRMs, such as beryllium, gallium or rare earths, for other CRM the EU can and does produce some of its requirements domestically, such as fluorspar, indium and tungsten.

Expert Contributions

GTK, BGS, GEUS, BGR, SGU, Amphos 21

Highlights

A detailed study into the Identification and Quantification of Primary CRMs in Europe was compiled by experts from the geological surveys of Finland (GTK), United Kingdom (BGS), Denmark and Greenland (GEUS) and Germany (BGR) using data from databases available in the EU countries and adding topical data on ore deposits and mineral resources wherever possible.

A similar study was completed for the Identification and Quantification of Secondary CRMs in Europe. To do this SCRREEN also undertook a comprehensive review of available information in the public domain, including data and information from past and present projects such as Minventory, Minerals4EU, ProMine, EURARE, ProSUM, SmartGround and MICA.

A final exercise was undertaken around the Challenges of Locating, Mining & Extracting Resources. SCRREEN activity in this area reviewed generic issues that are experienced when studying the flows of CRM through the EU economy, for example the lack of consistency in the use of terminology and existing gaps in the availability of data that forms the essential knowledge base. Current mine production covers from 3 % to 40 % of the EU supply for those commodities that are produced from the mines. For some commodities the import dependency is 100 %, so there is a need for new exploration activities and opening of new mines in the EU28. SCRREEN insight within the mapping activity, reflects strong support for CRM exploration and extraction within the EU, as it shows the large potential for such raw materials to exist in potentially economic concentrations within the European bedrock.

Summary of Key Recommendations from Mapping Activity

The EU sustainable value chain and supply of CRM from primary and secondary resources requires:

- New geological, geophysical and geochemical data: focused on raw materials including CRMs are needed. Such new, in-depth data are lacking for most of Europe, and exploration is hindered in comparison with most developed countries.
- 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.
- Enhanced access to existing data on both primary and secondary resources to achieve high potential and new mineral deposits (e.g. CRM) also taking into account competing land-use.
- A functional EU database on CRM material flow analysis approaching real minerals and metals used by the EU.
- A practical life cycle database for all economically important minerals and metals containing CRM.
- Development of long-term supply of CRM and the analysis of industrial supply chains linking geological data to industrial products.
- Waste flow data that are commodity based.
- Waste to be categorised upon its resource potential.
- Mapping and prioritisation of the most relevant manufacturing areas such as product designers and metallurgists/ recyclers.
- Identification of the production residues containing CRMs for improved recycling, a selection of the most relevant residue streams for CRM recycling.
- Extracted CRM to be used as efficiently and economically as possible during manufacturing and throughout their entire life cycle and their dissipation during their use should be minimised.

Recommendations to improve knowledge on the reserves of CRM in end-of-life waste include:

- Adaptation of the waste and product statistics: the individual statistical categories usually include both products containing and not containing CRM.
- Track changes in the use of components and metals caused by product development: e.g. electronics in cars.
- Recycling of manufacturing waste: with recyclers required to publish detailed information on the quality and composition of recycled materials.
- Developing innovative recycling technologies for CRM from complex products: to improve the efficiency of material production and used throughout the whole supply chain up to the moment when waste becomes the resource needed by another process (e.g. redesign for recycling, collection and disassembly).

Production & Innovation

> Work within the 'Production' aspects of SCRREEN created a collective databank of the main existing production technologies for CRM from primary resources (mining), secondary resources (waste/scrap from processing and manufacturing activities), end-of-life products and historical waste (disposal areas). It also Identified the gaps in processing that limit 'closing the loop' for CRM recovery. Work within the 'Innovation' aspects of SCRREEN included looking at substitution, assessment is applicability and economics, developing a substitution readiness level and disseminating case studies around the theme.

Marjaana Karhu
Senior Scientist, VTT Technical Research Centre of Finland Ltd

Context

As signposted by the Raw Materials Initiative (RMI), primary and secondary resources as well as substitution options for raw materials are all strategies available to EU industry for mitigating risks associated with raw materials supply.

Substitution is the least advanced of these options. This is due to a number of reasons, including awareness of the different methods under the generic heading of substitution, and the potential for innovation that can result for considering this in the widest context.

Expert Contributions

MEFOS, VTT, GTK, IMN, Chalmers, KTN, CEA, TU Delft, Technalia, Idener, NTUA

Highlights – 'Production' Activity

For the Production aspect of SCRREEN activity, 3 main studies were produced:

- A detailed study into **Production Technologies of CRM from Primary Resources** was produced. Within this, the relevant production lines of 25+ CRMs, including production, applications, primary resources for production and main industrial actors, are identified. Flow sheets of mineral and metallurgical processing were analysed, and the main challenges related to CRM recovery techniques identified. Mining tailings and processing residues were also characterised.

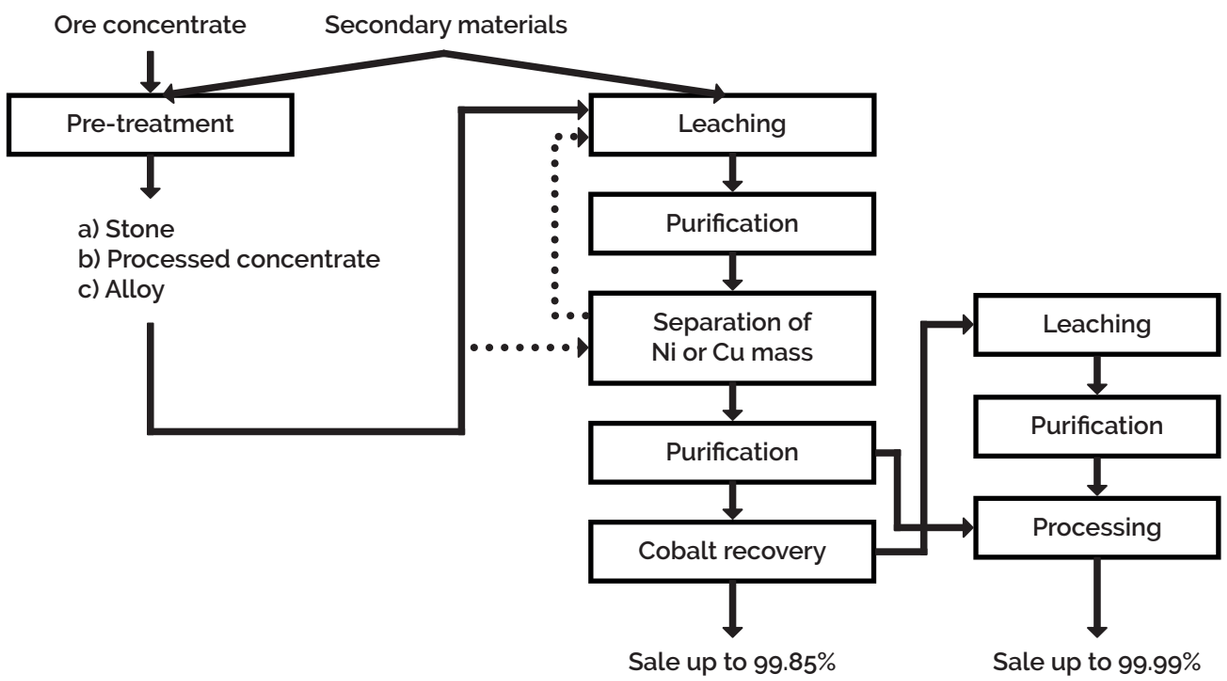

Figure 7. As an example for cobalt, the overall technological scheme of possible production stages. Source: SCRREEN D4.1. Dr Jason Yang et al (2018).

- A detailed study into **Production Technologies of CRM from Secondary Resources (including processing waste and historical waste, urban mines and manufacturing residues)**, covering 25+ CRMs. For each of the CRMs, a mix of critical information was identified and assessed, including:
  - Overview of global and regional material production.
  - Key actors in recovery and recycling and the available infrastructure.
  - State of the art production and recovery technologies.
  - Specific material challenges.
  - Alternative technologies.

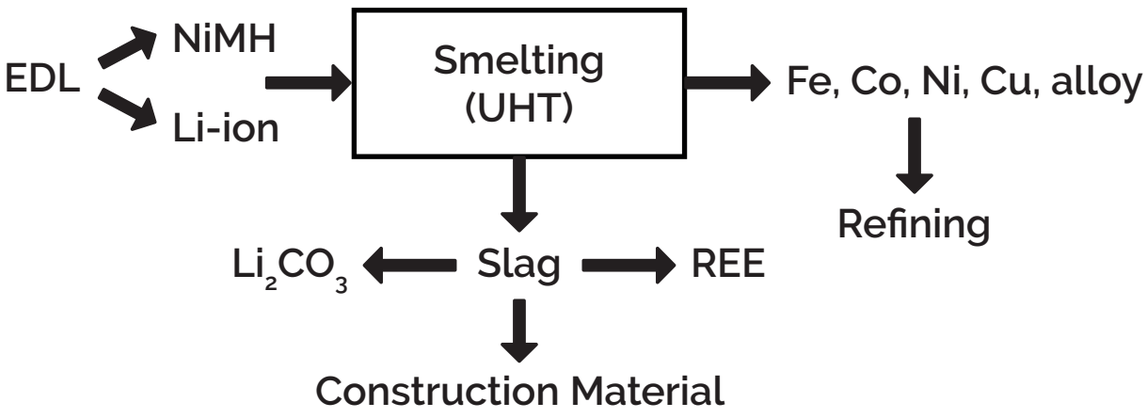

Figure 8. As an example for cobalt, one example of process flow sheet for recovery from secondary sources, Umicore process for recycling of rechargeable batteries.
Source: SCREEN D4.2. Pr. Lena Sundqvist Oeqvist et al (2018)

- A detailed survey of the **Environmental Trends and Circular Economy (CE) aspects of CRM** production. For each CRM, CE-related gaps were identified, including those that limit the performance of the processing chains, prevent closing the loop and act as barriers to zero-waste CRM production. Information was detailed on the processes, production, solutions and eco-design principles for closing the loop of raw materials in order to support the zero-waste point-of-view, resource efficiency and energy efficiency simultaneously were gathered. In addition, the aspects supporting CE were evaluated trying to resolve the identified challenges. Lastly, the environmental issues e.g. toxicity related to CRMs production were reviewed.

Highlights – 'Substitution' Activity

Substitution in the context of raw material criticality refers to the ability to achieve essentially the same function in a product or service by means other than the usual raw material. In simple terms, the availability of suitable substitutes can be seen as a reasonable way to avoid a "no-build" situation, in which particular products (and services requiring these products) cannot be delivered because of a bottleneck in raw material supply.

The key outputs of the work on substitution included:

- **Development of Substitution Profiles**: The table below illustrates the summary of 20 individual, detailed CRM substitutability assessments completed. N.B. a significant fraction of CRM demand is for applications where they play a key function not currently attainable by other means, or without being detrimental to competitiveness.

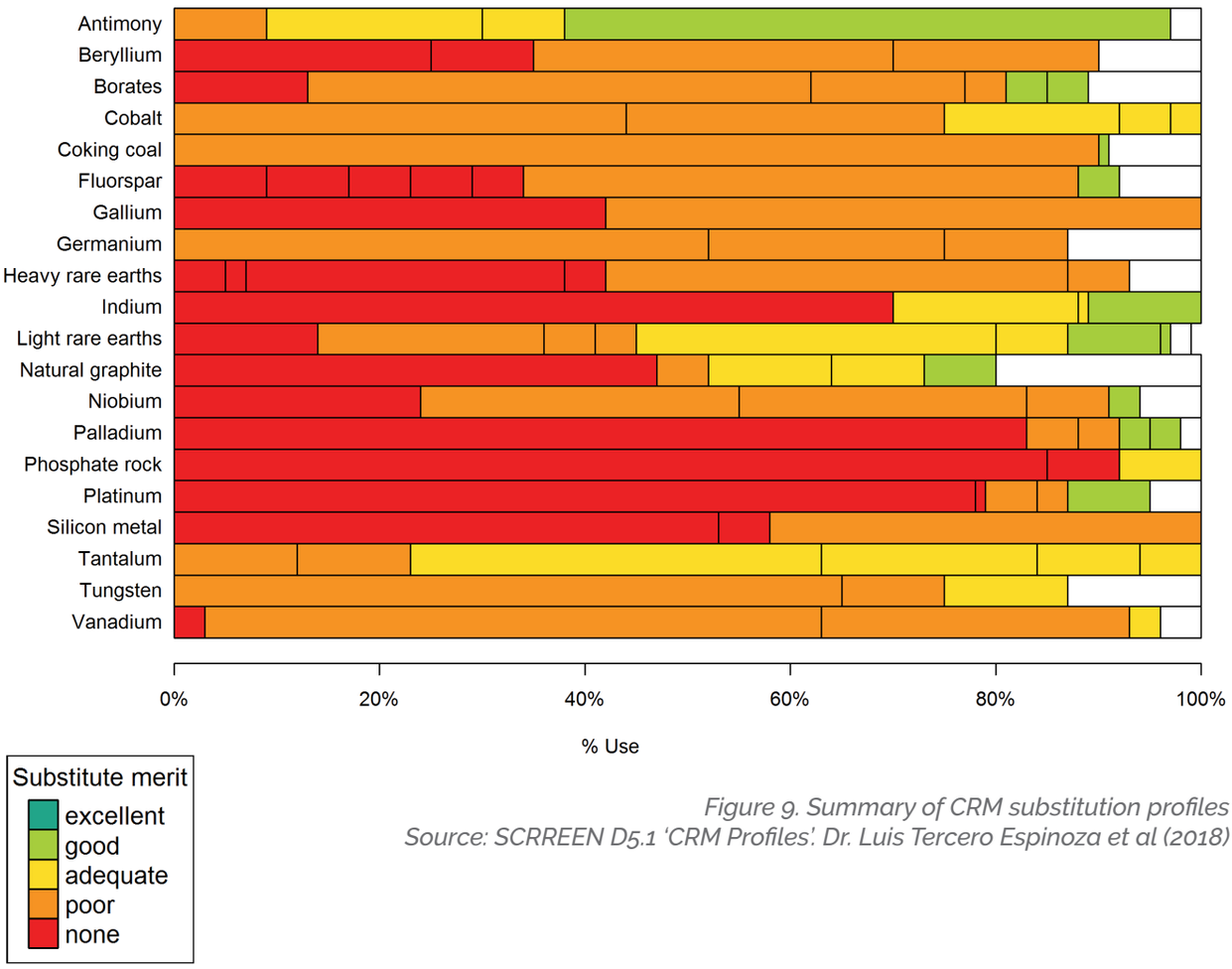

Figure 9. Summary of CRM substitution profiles
Source: SCRREEN D5.1 'CRM Profiles'. Dr. Luis Tercero Espinoza et al (2018)

- **Formulation of a proposed Substitution Readiness Level (SRL)**. N.B. the SRL was developed as a practical tool that could guide decision makers involved in considering CRM substitution solutions. The establishment of the SRL scale is inspired by other currently used scale such as the Technological Readiness Level and the Manufacturing Readiness Level.

1. Basic principle observed and reported for the substitution solution	**Lowest SRL:** Scientific research starts to move towards applied research. Examples could include paper studies and basic properties of the substitution solution that compare the current solution.
2. Concepts or applications of the substitution solution formulated	Shaping of the substitution solution starts, application could be identified. Examples are still limited to paper studies.
3. Proof of concept of substitution solution	Active R&D on the substitution solution are initiated. This includes laboratory studies to evaluate the substitution solution (check the provided function in comparison to the current solution to be replaced). Examples cover components that are not yet fully integrated nor representative.
4. Laboratory validation of the substitution solution	Components of the substitution solution are integrated in order to verify they can operate together. Examples include ad hoc integration of substitution solution at laboratory scale.
5. Validation in relevant environment of substitution solution	The maturity of the substitution solution grow significantly. Tests like comparison with the current solution are done at laboratory scale.
6. Demonstration in relevant environment of substitution solution	Substitution solution is tested in a relevant environment, meaning industrial (manufacturing) tools are available to make real this substitution solution. This is a major step forward for the substitution solution maturity. Examples cover prototype test in at least simulated operational environment.
7. Demonstration of substitution solution in operational environment	The substitution solution is tested at prototype scale to demonstrate its soundness and viability in an operational environment. At this stage the existence and the robustness of the substitution solution supply chain is assessed.
8. Full substitution solution qualified	Proof has been furnished that substitution solution brings the same performance than the original solution (to be substituted) at full scale. The functional specification for the substitution solution are fulfilled at the real scale. This scale represents the end of development stage.
9. Full substitution solution approved, accepted and deployed	**Highest SRL:** All the conditions for the large scale (e.g. industrial) deployment of the substitution solution are fulfilled: Readiness of the industrial tool to produce/provide cost competitive substitution solution, acceptance of ustomers to uptake solution. This is at least true for a substitution solution applied in a given specific sector, i.e. not generic since not applicable to all sectors to which substitution solution could apply.

Table 3. Source: SCREEN D5.2 'Substitution strategies guide for R&D&I'. E.Bouyer (2019).

- **Economic assessments undertaken for Substitution Trajectories:** including accumulators (electric cars and stationary energy storage); alloys (automobiles and aircraft); catalytic converters (vehicles); electrical components; permanent magnets (wind turbines / electric vehicles). The selected trajectories were analysed through their value chains, with a common methodology used, covering CRM availability: CRMs used in the application; economic risk due to (non) availability; economic relevance: statistical economic data analysis over the value chain; and the main actors (companies) identifying in the value chain.

Substitutive solution	Substitution mechanism	Development Stage	Parts of value chain affected	
			Fundamental effect	Less fundamental effect
Spinel™ (PGM-free catalyst)	Element	Laboratory	PGM producers, catalyst precursor producers, PGM recyclers	Converter manufacturers, automotive companies
Battery electric vehicles (no need for catalytic converter)	Application	On market	PGM producers, catalyst precursor producers, converter manufacturers, automotive companies, PGM recyclers	
Fuel cell vehicles (as above, but PGMs used as fuel call catalysts)	Application	On/Near market	Converter manufacturers, automotive companies	PGM producers, catalyst precursor producers, PGM recyclers

Table 4. Example trajectory – catalytic converter SCRREEN D5.3. Marjaana Karhu et al (2019).

- **Education of stakeholders across the CRM value chain and supporting dialogue between CRM key actors.** Substitution-focussed webinars and company interviews were delivered to introduce, discuss and review CRM substitution options with a range of industry, research and academic stakeholders. Of note, an online survey was completed backed up by 13 interviews with companies that are operating in key sectors and at different points in the supply chain (specifically, those with interests in alloys, magnets, batteries, electronic components and catalysts). The data from surveys and feedback from the interviews told us that:
  - The most common CRMs that organisations have experienced supply chain disruption in obtaining are: Heavy and light rare earths; PGMs; Cobalt; Indium. However this is often dependent on:
    - their position in the supply chain;
    - scale of operation;
    - current commitment to a particular technology; and
    - sector/ application focus.
  - Other materials that are not currently on the European Commission list of CRMs, but businesses told us are critical to their business include: Nickel, Lithium and Mica. Businesses also flagged a number of chemicals as critical due to the key role they play and the fact that they are now (or projected to be) subject to banning, or regulatory scrutiny.
  - The most common type of supply chain risk that organisations experience is sharp price rises and this is expected to get worse in the future, not better. Many companies are also concerned by changes in export/import and EHS regulations.
  - In order to mitigate supply chain risk, companies are working closely with suppliers and other partners to add a second source of supply. They are also active in R&D associated with recovery and recycling. Many companies, particularly those in emerging markets, are active in R&D associated with substitution.
  - A significant number of organisations have dedicated resource to mitigate CRM risk. However, there is an equal number of organisations that do not have any dedicated resource to manage this risk – further awareness raising activities could be helpful to this community.

WEEE Issues

Dr. Otmar Deubzer
Scientific Advisor, United Nations University (UNU)

Context

Many CRMs are used in electrical and electronic equipment (EEE), end of life of vehicles (ELVs) and in batteries. In EEE (and partially in ELVs), CRM contents and concentrations are low, in most cases far below 1 % where recycling might start becoming a real option (provided appropriate processing technologies are available). In all cases, separate collection and removal of WEEE, batteries and parts from ELV are a prerequisite for recycling. Low collection rates prevent the adequate treatment and thus reduce the recycling rates.

WEEE, electrical and electronic parts in ELVs and batteries are composed of a wide range of elements including CRMs that play a crucial role in the correct and efficient performance of the devices, with different quantities and materials concentrations depending on the expected application of the item components.

In order to address the growing concern of securing valuable raw materials for the EU economy, it is crucial to establish a robust value chain able to recycle these materials and limit the mining of primary resources. A deep understanding of the presence of CRMs in WEEE, ELV and batteries is essential so that targeted actions can be put into practice.

Expert Contributions

ECODOM, IMN, NTUA

Highlights

The expert partner group delivered detailed and wide ranging activities. IMN), ECODOM (the Italian take-back scheme for e-waste and batteries) and the United Nations University were involved in activities centred around:

- Identifying the types of CRMs in WEEE and the related options (and costs) of state of the art and current technologies available to recover and recycle WEEE – leading to the deliverable 'Prevalence, recyclability, cost and financing of CRM recycling from WEEE'.
- Reviewing regulations and standards on the WEEE issues in order to identify upgrade needs to help the recycling of CRMs – leading to the deliverable 'Upgrading regulations and standards to enable recycling of CRM from WEEE'.

Findings & Recommendations

The reports produced within the WEEE activities contain a multitude of useful and impactful data – more details can be found within the Deliverables listed within Annex 1 of this report.

Below is a summarised selection of key findings and recommendations taken from both studies:

- The electrical and electronic equipment (EEE) sector depends on several CRMs, including antimony, beryllium, cobalt, germanium, indium, platinum group metals (PGMs), natural graphite, rare earth elements (REEs), silicon metal, and tungsten.
- The recycling input rate of CRMs is generally low, with the exception of PGMs (well-established recycling process routes, high metal price, high recycling rates), and some other PGMs like cobalt from Li-ion batteries.
- Several factors influence the low recycling rate:
  - a lack of cost competitive sorting and recycling technologies, in combination with a lack of financing for CRM recycling.
  - the often lacking accessibility of CRMs in products. Since many of the critical materials are present at trace levels in entire WEEE, the accessibility and possibility to remove the components containing the CRMs is crucial to increase the concentration. Therefore, focused actions should be conducted to separate the targeted recycling processes.
- Mandatory recycling of CRMs is another robust solution to improve CRM recycling rates. In parallel, there needs to be incentives in place for the use of recycled CRM in new products, as well as a sound financing of the recyclers' additional efforts to enable the recycling.
- The recycling standards studied do not address CRMs – so the first step upgraded should be the introduction of CRM-specific stipulations to facilitate CRM recycling.
- A possible framework for driving the improvements could be made by PROs (Producer Responsibility Organisations). These are actors positioned between manufacturers and recyclers and could facilitate information sharing across both upstream and downstream value chains.
- The recommendations could deliver improvements in the eco-design of products and in the recycling of end of life products.
- There are three requirements that could bring significant improvement to the recycling industry:
  - **Separate CRM components.** By separating the components in an identifiable stream, it will be possible to concentrate the CRM in selected streams and facilitate the development of technologies focused on CRM recycling;

- **Monitor the downstream chain.** Monitoring information relating to downstream acceptor(s) of the fractions (and of the final treatment technologies) will verify if the CRM contained in the fraction monitored can be, or has been, recycled.
- **Set up recycling and recovery targets for CRMs.** This would be a challenging requirement to be met by recycling facilities.

- By improving eco-design standards to cover the lifecycle from the traceability of components, to product composition; to the facilitation of the dismantling activities, it will be possible to improve the recycling/ remanufacturing operations for CRMs.

Policy & Recommendations

Dr. Guenter Tiess
Managing Director of MinPol, Agency for International Mineral Policy

Context

The objective of the SCRREEN policy related activity was to:

- analyse challenges, gaps and opportunities in the policies, strategies, regulatory frameworks and standards governing CRMs in the EU and its Member States; and
- deliver suggestions and recommendations on which actions could be taken by the EU and stakeholders to contribute to achieving the targets set at the Raw Materials Initiative.

Expert Contributions

MinPol, WEFalck Scientific Advisory and Expert Services, Öko-Institut, WEEE Forum, Geokompetenzzentrum Freiberg e.V., AFNOR, KTN, ENEA, Fraunhofer ISI

Highlights

The expert network (and stakeholders) was brought together to deliver detailed CRM-relevant discussion, insight and studies around

- relevant business and policy issues
- standards, policies and regulatory frameworks
- the impact of these standards, policies and regulatory frameworks on CRM value chains including those for substitution
- identifying policy recommendations

More information on the background studies can be found using the links in Annex 1 of this report.

Policy Recommendations

SCRREEN headline policy recommendations are directed to the European Commission and its industry, plus the minerals, recycling and other stakeholders that need be involved in collaborative new solutions to achieve the objectives delineated in the Raw Materials Initiative and other policy instruments.

Policy recommendations will be discussed at Raw Materials Week 2019 and remain the cornerstone of further discussions within the EU CRM Expert Network and community.

Trade
Treat CRMs as top priority in EU raw material diplomacy and trade policies Ensuring that CRMs rank high in new trade agreements with important CRM trade partners (China, USA, Brazil, Russia, Morocco, Turkey, etc.).
Existing and further useful cooperation between Ukraine and the EU will extend the impact of SCRREEN Ukraine has strong CRM potential, for example having, currently, the only tantalum-niobium deposit in Europe.
Data & Analysis
Continue criticality assessments These provide early warning of potential supply risks of economically important raw materials.
Finance
Continue funding on: ➔ processes responsible for the formation of CRM bearing ores, ➔ improvement of exploration methods for the CRMs ➔ technology for their efficient recovery from ores, mining waste, processing waste and endoflife products. ➔ possible future importance of new material streams. ➔ new end-of-life product streams containing valuable CRM (e.g. electric vehicle batteries and fuel cells). Research into the recovery of CRMs from these sources should be assigned a high priority
Continue funding systematic surveys of CRM potential Including CRM resources in known deposits, mine wastes, tailings and metallurgical residues.
Fund (or co-fund with industry) studies of complete value chains at the product-level
Continue funding for long-lasting crm expert networks To maximise the impacts that these (often) short-lived networks (e.g. ERECON/EURARE) can achieve.

Research & Innovation
Identification of potential bottlenecks in CRM supply chains By examination of the level of consumption of individual CRMs within the EU Member States and of the processes involved along the entire supply chain.
Extend research to other CRM value chains Especially those that underpin the development of clean energy and transport, such as cobalt and Platinum Group Metals.
Improve quantitative data generation methods and standards from a material cycle perspective
Continue research and innovation to develop greater and more secure recycling and recovery routes for CRMs
Policy, Standards & Regulations
Direct more efforts towards accelerating the implementation of the eco- design directive Facilitate the generation of new design solutions for the 'Design for Recycling' concept.
Promote updates in the content and approach of member states national mineral policy frameworks To support transitioning from linear to circular understanding of the importance of CRMs for their own domestic value chains.
Continue supporting the work on developing standards Take the lead in the creation of pan-European standards for the characterization of the properties of secondary CRM waste (WEEE, EoL batteries, etc.).

Knowledge Management

> The SCRREEN Knowledge Management System is a powerful tool, based on two components:
> (i) the Data Management System (DMS), which uses a search engine 'tackling' all data, layers and documents delivered by the project and all external relevant documents including their metadata; and
> (ii) the Decision Support System (DSS) which is made operational by connecting the SCRREEN Knowledge Data Platform to the ontology-based MICA Raw Materials Expert System, specially updated for CRMs

Dr Daniel Cassard
Programme Scientific Coordinator French Geological Survey - BRGM

Context

The European Union Raw Materials Knowledge Base (EURMKB) and, at its core, the Raw Materials Information System (RMIS), identify and serve key information and knowledge needs of governments, business and research stakeholders. RMIS 2.0, developed by the Joint Research Centre (JRC - a Directorate General (DG) of the European Commission), includes a major chapter on critical raw materials and provides material factsheets of over 70 raw materials.

The aim of Knowledge Management in SCRREEN project was to organise global knowledge on CRMs in Europe and, through data integration and alignment to both the EURMKB and the EIP Raw Material Strategic Implementation Plan objectives, facilitate easy access to information, without duplicating existing databases.

A deep and extensive exercise of knowledge identification and measurement was carried out as the first step in knowledge management, leading to the production of a 'knowledge map'. This served as a preliminary map of all the knowledge generated during the project, and to help stakeholders find partners with knowledge in a specific CRM-related topic or material.

Expert Contributors

BRGM, IDENER, GEUS, GeoZS, JRC, LGI

Data Sharing

The knowledge mapping activity was used to support the development of data applications designed to share the best possible updated information, in an attractive and seamless way to end users, i.e. the European Commission, private decision- makers, academia and the general public

The design of a data sharing platform was developed through SCRREEN knowledge management activities, incorporating:

- A 'Diffusion System' and a 'Geospatial Portal' using search capability exploiting the Knowledge Base for non-structured data and metadata (aka the 'SCRREEN Data Management System') and also through a metadata catalogue of structured data.
- A dedicated search facility, developed to allow the JRC's RMIS 2.0 to exploit the SCRREEN Knowledge Base, with the development of an OpenSearch API (application programming interface), with synergies between SCRREEN and the Mintell4EU project of the GeoERA programme.
- Using the UrbanMinePlatform for SCRREEN applications , with an API developed demonstrating synergies between the H2020 ProSUM and SCRREEN projects.
- SCRREEN contributions to improve the MICA Mineral Resources Expert System (developed within the Horizon 2020 (H2020) MICA project) with the extension of the main ontology for CRM and concomitantly better connection of the MICA Expert System with the RMIS 2.0.

Critical Raw Materials Knowledge Data Platform (EU-CRMKDP)

The EU-CRMKDP, i.e. the SCRREEN Knowledge Data Platform (KDP) and its 'Document Management System' (DMS) are connected to the MICA Expert System, thus creating the SCRREEN Decision Support System (DSS).

The platform incorporates:

- all available data/information related to CRMs from mining activities and from the urban mine (through the link with the ProSUM KDP); and
- results of comprehensive studies related to substitution, future demand, policy and technology recommendations for improving both production and substitution, mapping and treatment issues related to WEEE and EoL products, and knowledge gained over the last years, allowing end users to easily view and exploit these data, and combine them.

Figure 10. CRMKDP spatial viewer

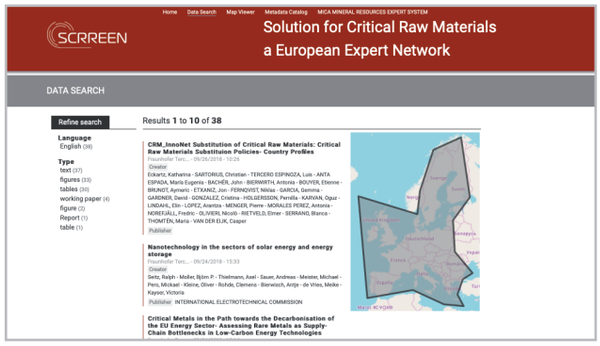

Figure 11. Results of a search request

All of which means that the CRMKDP launched by SCRREEN is a powerful, effective and sustainable system designed to facilitate data updates and maintenance and allowing users access to data on the whole CRM resources value chain and providing a visual, geographic and searchable CRM knowledge database.

Communication

Marco de la Feld
Project Manager and Business Developer, ENCO srl

Catalysing And Illuminating SCRREEN Activities

A host of informative and innovative communications activities were fulfilled to support the project's purpose. The project was highly prominent in CRM-related events, from hosting important conferences within EU Raw Materials Week, to presenting on activity across Europe. A series of webinars were provided to update stakeholders on the policy and innovation activity coming out of the project. All the project communication activities served to inform a critical mass of stakeholders about high impact challenges and opportunities.

CRM Superpowers Campaign

Clearly, the importance of CRMs in the European Union cannot be understated and that securing reliable and unhindered access to raw materials is important for the EU. To emphasise this, an innovative and highly successful online campaign was developed, targeted at the general public to raise awareness on CRMs and their importance in their daily lives.

The 'Superpowers of New Critical Raw Materials' campaign shed light on the different forms which critical raw materials take in general day-to-day life. 12 visuals were created to spread the message about the wide range of opportunities CRMs deliver, from their use in cars and wind turbines to solar panels and smartphones. Easily digestible visuals (in 6 languages) were shared on social media, covering themes highlighting the way that CRMs are used in all the technologies that are essential for the energy and digital transition and crucial to the development of machinery and devices that are now completely integral to facilitating our daily lives.

Figure 12. Example visuals from the CRM Superpowers campaign.

SCRREEN - What's Next?

Stéphane Bourg
Chef de Projet, CEA

Since 2011 and the first European CRM list, the number of materials to be screened, and the number of materials acknowledged as critical, has grown continuously. If a part of the data used in the assessment comes from exiting databases such as EUROSTAT, a lot of information is split over an increasing number of publications, reports, and small databases that are not easy to access and difficult to assess. Moreover, the data covers a wide field of topics, from mining to substitution, from production to market, from environmental to societal perspectives and from biotic to abiotic materials. Only an agile and flexible network, relying on a wide range of experts convened with purpose can support the European Commission in such an exercise. This is what SCRREEN did in September 2019 by organising a three day validation workshop in collaboration with DG-GROW and the JRC. This is what SCRREEN intends to develop further post-project completion.

Project Legacy

A continuing and long-lasting SCRREEN Network is planned to 'live on' past the official project end date of December 2019. A refreshed and re-structured expert network would:

Manage the lists of experts for sectors and materials: based on the knowledge gained during the project and on the outputs from the EU criticality assessment evaluation workshop held in September 2019.

Improve and manage EU knowledge base on primary and secondary raw materials.

Promote clustering and cooperation with other on-going projects and initiatives in the raw materials sector.

Animate the CRM expert community: through organisation of related events, preparation of materials, positions papers.

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.

Inform decision makers at EU and Member State level, i.e. the producers and the users: defining possible new business opportunities and taking into account the relevance of all the social, environmental and economic issues on raw materials supply.

Annex 1 – List of key SCRREEN deliverables

The information contained in this report is necessarily a summary of the extensive activity undertaken and data generated by the SCRREEN project. Detailed deliverable reports are publicly available summarised in the table below.
Find them at: **http://scrreen.eu/results/**

Theme	Ref	Title
Foresight	D2.1	Report on the current use of critical raw materials
	D2.2	Report on major trends affecting future demand for critical raw materials
	D2.3	Report on the future use of critical raw materials
Mapping	D3.1	Identification and quantification of primary CRM resources in Europe
	D3.2	Identification and quantification of secondary CRM resources in Europe
	D3.3	Challenges of locating, mining and extracting CRM resources
Production	D4.1	Production technologies of CRM from primary resources
	D4.2	Production technologies of CRM from secondary resources
	D4.3	Circular Economy and zero waste aspects and business models of production
Options and Strategies for Innovation	D5.1	CRM profiles
	D5.2	Substitution strategies guide for R&D&I
	D5.3	Report on the economic assessment of substitution trajectories
	D5.4	Report on the delivery of case studies and webinars
Technology Gaps/Barriers & Innovation Pathways In CRMs Value Chain	D6.1	Technological gaps inhibiting the exploitation of CRMs primary resources
	D6.2	Technological gaps inhibiting the exploitation of CRMs secondary resources
	D6.3	Technological gaps hindering uptake of CRMs substitution in industrial application
	D6.4	Roadmap and innovation pathways for technology development in CRMs value chains to unlock primary and secondary unexploited resources and introduce substitution solutions in industry

Theme	Ref	Title
Policy	D7.1	Report on relevant business and policy issues for Europe pertinent to CRMs
	D7.2	Report on (voluntary) standards, policies and regulatory frameworks in Europe relevant to CRMs
	D7.3	Impact of (voluntary) standards, policies and regulatory frameworks on CRM value chains including those for substitution
	D7.4	Report on policy recommendations and stakeholder feedback
Waste Electrical And Electronic Equipment (WEEE) Issues	D8.1	Prevalence, recyclability, cost and financing of CRM recycling from WEEE
	D8.2	Upgrading regulations and standards to enable recycling of CRM from WEEE
Knowledge Management	D9.1	Results of the knowledge identification survey
	D9.2	Preliminary version of the EU-CRMKDP
	D9.3	Final version of the EU-CRMKDP
Communication	D10.2	Dissemination & Exploitation Plan
	D10.5	SCRREEN Final Report
	D10.8	Report on engagement with the general public and recommendations for future actions

SCRREEN

Solutions for CRitical Raw materials - a European Expert Network

Project Partners

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