Sustainable Materials and Technologies 15 (2018) 9–18

Contents lists available at ScienceDirect

Sustainable Materials and Technologies

journal homepage: www.elsevier.com/locate/susmat

# Improving supply security of critical metals: Current developments and research in the EU

Amund N. Løvik[a,*], Christian Hagelüken[b,c], Patrick Wäger[a,c]

[a] Empa, Swiss Federal Laboratories for Materials Science and Technology, St. Gallen, Switzerland
[b] Umicore, Hanau, Germany
[c] ESM Foundation, Bern, Switzerland

ARTICLE INFO

*Keywords:*
Critical metal
Raw Materials Initiative
Supply security
Recycling
Mining

ABSTRACT

According to the reports on critical raw materials for the EU, a raw material is considered critical if it has a high economic importance to the EU combined with high supply risk. Supply risk is considered to arise from a combination of several factors, namely a high concentration of production in countries with poor governance, limited material substitutability, and poor end-of-life recycling rates. A number of industry activities, policy initiatives and research projects have recently been initiated in Europe with the aim to secure an adequate supply of raw materials. In this article, we review such ongoing developments with a focus on publicly funded research projects on critical metals in Europe, and discuss their contribution to reaching the objectives of the Raw Materials Initiative as well as the more general goals of sustainability. We found that current research puts a strong emphasis on rare earth elements, being addressed in almost half of the identified projects. Other frequently studied metals include cobalt, indium and platinum group metals. The efforts are roughly evenly distributed between the three main domains of supply security measures: primary supply, secondary supply, and material efficiency and substitution, with a somewhat larger budget allocated to secondary supply. Current research is coherent with the aims of the Raw Materials Initiative in that it addresses primary production, recycling, and substitution as means to secure the supply of critical metals. However, the prioritization of certain metals, especially rare earth elements, is stronger than what seems justified by differences in *economic risk* (as a quantitative interpretation of criticality), and should perhaps be replaced by a more balanced distribution of funds. For example, more product-centric research considering a larger part of the materials cycle may facilitate recycling of a wider spectrum of metals. Particularly neglected metals and topics include beryllium, magnesium, recycling from end-of-life vehicles, design for recycling, and waste collection.

## 1. Introduction

### 1.1. Background

Modern society is characterized by its reliance on and relationship to technology. Technology and its progressive development are in turn dependent on an expanding palette of materials [1]. When the supply of raw materials is jeopardized, so are the benefits we reap from technologies, be it a clean energy supply, digital communication, or low-carbon mobility. Risks related to raw materials are considered especially important for the EU, due to its heavy reliance on imports and the importance of raw materials for European industry. In the past decade a plethora of policy initiatives, stakeholder platforms, industry activities and research projects has emerged as a response to increasing concerns over supply security of raw materials. In this article we review such developments on the EU level and discuss their capacity to meet the aims of the EU as well as their contribution to the more general goal of sustainability, in particular focusing on critical metals (CMs). We chose to focus on metals because they share many features related to supply security, such as integrated supply chains, similar production processes and the possibility of recycling from end-of-life products, while acknowledging that other raw materials (non-critical and/or non-metallic) may also have important, perhaps even higher risks associated with their supply.

*Abbreviations:* CM, critical metal; CRM, critical raw material; EIP, European Innovation Partnership [on Raw Materials]; EIT, European Institute of Innovation & Technology; ELV, end-of-life vehicle; EoL, end-of-life; FP7, 7th Framework Programme; H2020, Horizon 2020; KIC, Knowledge and Innovation Community; PGM, platinum group metal; PM, precious metal; PV, photovoltaic; REE, rare earth elements; RMI, Raw Materials Initiative; SIP, Strategic Implementation Plan [of the European Innovation Partnership on Raw Materials]; WEEE, waste electrical and electronic equipment

* Corresponding author at: Lerchenfeldstrasse 5, 9014 St. Gallen, Switzerland.
*E-mail address:* amund.loevik@empa.ch (A.N. Løvik).

https://doi.org/10.1016/j.susmat.2018.01.003
Received 19 July 2017; Received in revised form 20 November 2017; Accepted 27 January 2018
Available online 09 February 2018

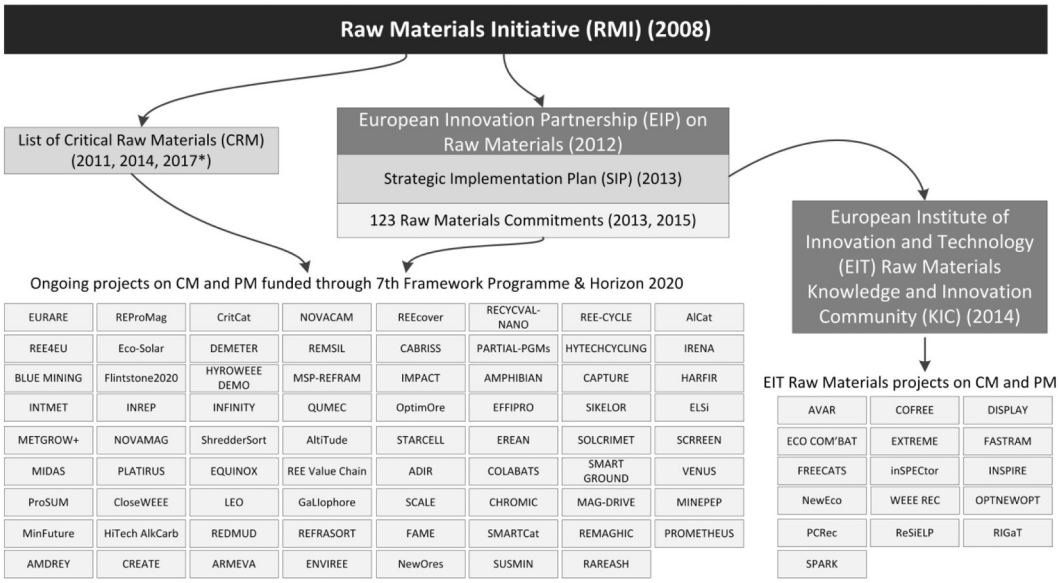


**Fig. 1.** Overview of research-related elements of the EU raw materials strategy, from the general Raw Materials Initiative to the more concrete actions of research projects. *The latest list of CRM is not taken into account here.

### *1.2. Initiatives, platforms and strategies in the European Union*

The Raw Materials Initiative (RMI), which was adopted in 2008, consists of a strategy to secure access to raw materials to the EU economy, and includes the following three "pillars": "1) ensuring that there is a fair and sustainable supply of raw materials from global markets; 2) ensuring that there is a sustainable supply of raw materials within the EU; 3) boosting resource efficiency and increasing the amount of recycling" [2].[1] The RMI, representing the EU's strategy and policy on raw materials, is implemented through the European Innovation Partnership (EIP) on Raw Materials, the funding of projects through the EU's research and innovation programmes, and the European Institute of Innovation & Technology's (EIT) Knowledge and Innovation Community (KIC) on Raw Materials, also known as EIT Raw Materials (see Fig. 1).

The European Innovation Partnership on Raw Materials is "a stakeholder platform that brings together representatives from industry, public services, academia and NGOs" with the goal to "provide high-level guidance to the European Commission, Members States and private actors on innovative approaches to the challenges related to raw materials" [4]. One of the main tasks of the EIP has been to translate the general aims of the RMI into description of research areas and proposed actions, which are documented in reports known as the "Strategic Implementation Plan" (SIP) [5,6]. Moreover, the EIP has had two calls for "commitments" in 2013 and 2015, whose goal is to mobilize industry, academia, government and other relevant stakeholders to respond to the recommendations of the EIP and enact the proposed actions. To be recognized by the EIP, the commitment must address at least one of the action areas, provide descriptions of the planned activities, indicate a budget and the extent of secured funding, as well as report annually to the EIP [7]. The EIP does not provide funding for the commitments and they are also not legally binding, but being recognized as a commitment can help secure funding through other channels, such as the Horizon 2020 (H2020) programme.[2]

An important input to the SIP was given through the previously established research agenda of the ERA-MIN programme [8], which proposed a list of research topics concerning the supply security of non-energy, non-agricultural raw materials. ERA-MIN and its successor ERA-MIN 2 are financed by the 7th Framework Programme (FP7),[3] H2020 and 21 national funding agencies, also including partners outside of Europe. In addition to establishing a network of the research community and defining research priorities, the ERA-MIN programme has funded 17 research projects through three calls in 2013, 2014 and 2015. ERA-MIN 2 will fund additional projects through calls in 2017, 2018 and 2019. Through the involvement of member state authorities, the ERA-MIN programme was instrumental in later securing support from national governments for the SIP.

The RMI has also led to increased funding for research on raw materials within the EU FP7 and H2020. Funding for projects dedicated to raw materials increased from € 180 m. in FP7 to € 600 m. in H2020 [4], thereby making up about 1% of the research and innovation funding of the EU. Many additional projects concerned with development of new materials and applications or improvement of existing technologies are also motivated by concerns related to raw materials.

In response to a proposed theme and action in the EIP SIP, the EIT established a so-called Knowledge and Innovation Community on Raw Materials [9] in 2014. EIT Raw Materials supports projects on start-ups, upscaling, innovation, internationalization and educational activities (e.g. developing Master and PhD programmes). It consists of a consortium of more than 100 partners from industry, academia and research organisations. Only the partners are eligible to apply directly for project funding, but third parties may obtain funding through participation in consortia. Fig. 1 illustrates the connection between the RMI, EIP on Raw Materials, EIT Raw Materials and ongoing research projects related to CMs.

In December 2015, the EU adopted the "circular economy package", which includes an action plan [10] as well as revisions to the general Waste Framework Directive [11], the Landfilling Directive [12], Packaging and Packaging Waste Directive [13] and the directives on Waste Electrical and Electronic Products, End-of-Life Vehicles and Waste Batteries [14]. The EU defines a circular economy as an economy "where the value of products, materials and resources is maintained in the economy for as long as possible, and the generation of waste minimised" [10]. The circular economy package carries forward many of the ideas from the RMI and the EIP-SIP, and includes critical raw materials as one of its priority areas. Within H2020, circular economy is

[1] The original communication from 2008 had a slightly different wording [3].
[2] Horizon 2020 is the EU's research and innovation programme for 2014 to 2020.
[3] The 7th Framework Programme was the EU's research and innovation programme for 2007 to 2013.