VERAM, for a sustainable and competitive future for EU Raw Materials

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Abstract. The project, VERAM “Vision and Roadmap for European Raw Materials”, aims to deliver a mapping of on-going initiatives on non-food, non-energy raw materials (including metals, industrial minerals, aggregates and wood) at European, Member State, and regional levels both from the Research and Innovation (R&I), industry, and policy perspectives. Moreover, based on a comprehensive gap analysis, VERAM will propose a common long term 2050 Vision and Roadmap in coordination and cooperation with all stakeholders across the value chain. For the first time, two European Technology Platforms (ETPs) together with their corresponding European Research Area Networks (ERA-NETs) are joining forces to develop a common roadmap.

1. The project

The Vision and Roadmap for European Raw Materials (VERAM) proposal answers to the Horizon 2020 call H2020-SC5-13d-2015, which looks for raw materials Research and Innovation (R&I) coordination. VERAM aims to provide the umbrella and coordination function for raw materials related R&I activities that address security and sustainability of supply from EU and non-EU sources and creates new synergistic effects due to linking of biotic and abiotic resource sectors. It intends to develop strategies to bring innovations to market and develop recommendations for future research and innovation related policy actions.

It is for the first time that two European Technology Platforms (ETPs) together with their corresponding European Research Area Networks (ERA-NETs) join forces to develop a common roadmap. The VERAM partnership is in fact constituted by the strongest possible representation of raw material sectors in Europe. It unites five European Technology Platforms (ETPs) and two European Research Area Networks (ERA-NETs), the newly established EIT Knowledge and Innovation Community (KIC) on Raw Materials. Since several of the partners of VERAM lack legal entity, they have chosen one of their members to act as the legal representative; this is the case of the two ERA-NETs and three of the five ETPs.
The ETPs have been established during the sixth Framework Programme as industry-led stakeholder fora to develop short to long-term strategic research and innovation agendas and roadmaps for actions at EU and national level.

The research agendas [1-5] and roadmaps produced by the ETPs and the relevant ERA-NETs form the basis for the so-called Strategic Implementation Plan (SIP) of the European Innovation Partnership (EIP) on RM. The SIP identifies actions to achieve the objectives of the EIP RM which includes improved coordination of research and innovation activities. It makes sense to involve the ETPs and ERA-NETs in an action to better coordinate the research and innovation activities as well as to evaluate the different ETP research agendas and roadmaps to identify synergies and gaps.

1.1. The project Consortium
The five ETPs in VERAM Consortium are: the European Technology Platform on Sustainable Mineral Resources (ETP SMR), which is also the project leader; the Forest-based Sector Technology Platform (FTP); the European Construction Technology Platform (ECTP), represented by Università Politecnica delle Marche (UNIVPM); the European Technology Platform for Sustainable Chemistry (SusChem), represented by the European Chemical Industry Council (Cefic) and the European Technology Platform on Advanced Materials (EuMaT), represented by the Vlaamse Instelling voor Technologisch Onderzoek (VITO).

The two ERA-NETs are: the Network on the Industrial Handling of Raw Materials for European Industries (ERA-MIN), represented by the National Centre for Scientific Research (CNRS), and the ERA-NET on wood material science and engineering (WoodWisdom.NET), represented by Fachagentur Nachwachsende Rohstoffe e.V. (FNR).

In addition, the VERAM consortium comprises RINA Consulting S.p.A. (RINA), Forschungszentrum Juelich GmbH (FZ Juelich), Tecnalia Research & Innovation (Tecnalia) and VTT Technical Research Centre of Finland Ltd. (VTT).

In VERAM, the biotic raw materials value chain is represented by both FTP and WoodWisdom.NET. In particular, FTP has 23 National Support Groups and deals with inventory, harvesting, processing, recycling and substitution of biotic raw materials. The forest-based sector in Europe comprises a wide variety of products and services, ranging from paper, packaging, tissue paper, furniture, carpentry and construction materials made from solid wood and wood-based panels to textile fibers, biofuels and special chemicals. Healthy and resilient forests are a prerequisite for a sustainable supply of raw materials as well as for other goods and services provided by forest ecosystems (including carbon sequestration, clean water, erosion protection, biodiversity, aesthetic landscapes and recreation).

The abiotic raw materials value chain, which comprises metals, minerals and aggregates, is represented by both ETP SMR and ERA-MIN. The European Technology Platform on Sustainable Mineral Resources (ETP SMR) unites stakeholders from industry, the research community, public authorities, the financial community, regulators, consumers and civil society to jointly develop a common vision. In particular, the European minerals industries involved include metal ores, industrial minerals, ornamental stones, aggregates, smelters as well as technology suppliers and engineering companies. The ETP SMR deals with exploration, extraction, processing, recycling and substitution of inorganic raw materials.

1.2. Objectives
Research and innovation activities in the area of primary and secondary raw materials - their use, reuse, and substitution - are dispersed between different players and supported by a variety of fragmented funding sources both on the EU and on Member States levels. The current situation is not optimal for unleashing the full innovation potential of the concerned value-chains. VERAM aims to create a critical mass by bringing together the stakeholders represented by the ETPs, the ERA-NETs, as well as the EIT KIC on Raw Materials.

The multi-disciplinary nature of research related to raw materials requires a coordinated multi-disciplinary approach on all levels. However, only around 15% of European publicly funded research is
coordinated jointly in the EU’s Research Framework Programme. The remaining 85% is funded via national or regional programmes. These funding programmes are very important but too often they unnecessarily lead to duplication of research efforts and they often lack the scope and depth required of the EU programmes. Incorporating as a part of the VERAM proposal’s partnership the two most central ERA-NET partnerships in the area of raw materials will help to mobilize and orchestrate the full 100% of European public research and innovation funding for the implementation of the 2050 roadmap envisioned.

The VERAM project aims to envelope all relevant aspects of non-food, non-energy raw materials related research and innovation, including metals, industrial minerals, aggregates and wood. It challenges the current compartmentalization into scientific disciplines and fragmentation into industry sectors to increase synergies and facilitate uptake of research results. In doing this, VERAM identifies the common interests, respecting also the individual visions of each stakeholder group in recognition of the specific conditions that they have to comply to.

It will provide an innovation reference point for the EIT Raw Materials (former KIC Raw MatTERS) and will coordinate the network of people involved in the EIP RM Commitments and in the proposals funded under Horizon 2020.

It will provide a web-based platform for identifying gaps and complementarities and bridge these. VERAM will also advise the European Commission and Member States on future research needs and policies to stimulate innovation and assist in overcoming the fragmentation in the implementation of the EIP RM Strategic Implementation Plan.

During its duration, VERAM will look for capacity building, transfer of knowledge, mutually beneficial information exchange. It will also encourage cross-fertilization between actions undertaken by different raw material industries and will speed-up exploitation of breakthrough innovations.

As one of the main deliverables of the proposal, a common long term 2050 Vision and Roadmap for the relevant raw materials will be presented. The vision and roadmap will also show the path to achieve the European Commission’s ambitious target of 80% reduction in CO₂ emissions by 2050.

In addition to the contributions to the requirements of the call, VERAM promotes innovation in the following ways:

- **Transparency.** A significant improvement in the exchange and use of the information available in the projects between the different stakeholders will be performed by mapping of ongoing research activities and research funding.
- **Visibility.** A higher degree of visibility to society, industry and policy makers for the innovation and research need.
- **Coordination.** Less risk of wasting resources on overlapping tasks and activities.
- **Complementarities.** Combining complementary research results and bridging detrimental technology-gaps by sharing of knowledge and cross-fertilization.
- **Critical mass.** A broader stakeholder base and critical mass for exploitation activities by bringing together ETPs and ERA-NETs relevant for the EIP-RM challenges.
- **Inclusion.** Involvement of the citizens, not only experts and industrial operators touched by the innovation in the field of Raw Materials, but extending the level of knowledge to the whole European people performed by stakeholder consultations.
- **Knowledge.** Easier access to information about national and international research and innovation projects through a web-based research and innovation portal.
- **Exploitation.** The funding-related “valley of death” for identified key innovation areas will be bridged by the incorporation of regional and national funding providers, as well as the support of the European Commission, in this way new business models and higher participation in innovation activities are expected.
- **Cooperation.** Improved mutual understanding and trust will ease the forming of future project consortia.
A successful execution of the VERAM proposal will help the society to reap the benefits of a growing circular economy and to address the Societal Challenges by a more sustainable and resource-efficient use of raw materials.

2. The roadmapping process
The roadmapping process is a flexible technique that is used to support strategic and long-range planning. The approach provides a structured (and often graphical) means for exploring and communicating the relationships between evolving and developing markets, products and technologies over time [6]. The roadmapping process provides a way to identify, evaluate, and select strategic alternatives that can be used to achieve desired science and technology objectives [7].

Broadly, two cultures of roadmapping can be identified. The first is the technology roadmapping, in which roadmapping is approached as a normative instrument to identify relevant technologies and align them with explicit product plans and related action steps. In this culture, the roadmapping process is a systematic practice aimed at product development. The second is the emerging culture of strategy roadmapping, in which the roadmapping is perceived more as a dynamic and iterative process that produces weighed crystallizations of long-term vision, and short- to medium-term strategies to realize this vision. There, the roadmaps can be seen as knowledge umbrellas that depict a large-scale strategy picture of a system [8]. In this regard, the VERAM roadmapping process belongs to the second culture of roadmapping [9], which its graphical means is schematically given in Figure 1.

![Figure 1. A model of an ideal Roadmapping process for VERAM.](image)

3. The (preliminary) results

3.1. A common terminology
As indicated in the Strategic Implementation Plan for the EIP RM, terminology and reporting standards related to raw materials are heterogeneous throughout the EU member states [10]. Moreover, different areas within the raw materials sectors use different terminologies and classifications for raw materials and their properties. Since VERAM’s first objective is to facilitate information exchange, overcome fragmentation and promote cross-fertilization, a common terminology related to definitions of raw materials, their classification and concepts defining properties relevant for guiding research and innovation has been elaborated.

3.2. The current raw materials playing field

3.2.1. Definition of the raw materials playing field. Afterwards, the current raw materials playing field and the players involved have been defined on the basis of two main tasks:

- the identification of private, public and multi-stakeholder platforms and formal networks with a focus on raw material supply, and
• the identification of current sectoral and horizontal policies at international, EU and member states level that might considerably affect the future availability of raw materials for the European industry at any point of the value chain (exploration, mining, production, trade, consumption, collection, reuse, remanufacturing, recycling). In particular, for sectoral policies the main sectors taken into account were: construction and infrastructures, energy (in relation to materials used for generation and storage facilities, CRM), water, ICT, chemistry, bio-economy (excluding energy and food).

The work of selecting, gathering, and highlighting information has been carried out by considering already existing review documents, such as those produced by the Department for Environment, Food and Rural Affairs of United Kingdom [11] or by the European Environment Agency [12], and coming also from EU projects, such as the MIN-GUIDE [13] or the Intraw [14] projects, to report just a few of them.

The results have highlighted that depending on the country, policies are addressing different aspects in relation to raw materials. However, at global level the common trend is focused on the willingness of accelerating the transition of economies towards more sustainability and circularity, especially for those policy bodies issued more recently. In relation to raw materials, this tendency is expressed by setting the necessary frameworks to become more competitive and leader in their respective domains (i.e. mining, refining, metallurgy, manufacturing, construction, recycling and other end of life management options). At national level, policies seek to achieve a better integration of sectoral policies (i.e. biomass across food, feedstock, energy, bio-chemicals sectors).

Exploration of the raw materials playing field. After the definition of the current situation, the exploration of the raw materials playing field has been conducted. The analysis has focused on both abiotic and biotic raw materials about: (i) ongoing funding activities, (ii) patents and papers of 27 large European enterprises belonging to 13 industrial sectors (Glass and Ceramics; Cement; Steel; Aluminium and Alloys; Catalysis; Fine Chemicals; Bio-Plastics; Pulp and Paper; Automotive; Aerospace; Tyres; Electronics and Consumers Products; Automation), (iii) EU business enterprise research and development expenditure (BERD), and (iv) (possibly planned) opportunities at international, EU and member states level for initiatives that:

• explicitly aim to enhance the availability of raw materials, and
• are likely to affect such availability, either by supporting research and development (R&D) activities or by facilitating upscaling and implementation.

Existing reports and/or studies on the effectivity and efficiency of EU and national funding programs have been analysed considering their impact on raw materials security of supply and the factors of success. Within the industrial sector, the consortium has mapped the current situation, trends, needs, long-term strategies, evolution and development aspects, oriented to grant the availability of raw materials at high level. Strategic aspects have been delivered in order to sum up in synergistic way to the research roadmaps and to highlight the congruence and differentiations. The raw materials R&I landscape has been analysed with regard to strength and weaknesses considering the coverage of sectors, raw materials and value chains.

The exploration of the raw material playing field has revealed that the current R&I programmes cover most relevant raw materials, industry sectors and value chain sections at EU and international levels. The R&D in the business enterprise sector in Europe is very heterogeneous and only three member states (Germany, France, and United Kingdom) hold 68% share of the total R&D. The research topics addressed in Europe and oversea are very similar, meaning that the international cooperation should be pushed in order to join efforts to solve common problems. Moreover, a more efficient R&D funding could be achieved if further funding for market access is provided.

3.2.2. The web-based portal. During all the activity of research, collection, and analysis of the current situation of EU raw materials sectors, a research and innovation raw material (R&I RM) portal has been created and implemented with all the collected data. The web-based portal, accessible at www.veram.eu, ensures the relevance and usefulness of the project results and constitutes a systematic, dynamic, open,
and proactive platform for the entire stakeholder community, aiming to facilitate the sustainable coordination of the European R&I on raw materials. This platform defines and promotes the most adequate decision-making process/good governance and communication. Currently, the portal populates approximately 130 research projects, 1200 organizations, 75 funding agencies, 71 calls for proposals and 164 publications.

3.2.3. Possible future scenarios. The relevance of ongoing European R&D efforts has been investigated under three possible future scenarios (European stagnation, global scarcity and ethical value driven innovation) [15] for different material intensive industrial sectors and technology areas. These scenarios were identified through a four steps process, which includes:

- a brainstorming workshop, conducted within the Consortium, and the translation of the archetypical images of future [16] into the context of VERAM project by answering to the question “What do the architypes mean from the perspective of raw materials (e.g. demand, availability, development needs, industrial expectations)?”;
- scenario formulation, applying the “Futures triangle method” [17,18], for which a plausible future (or futures) is created by analysing the interaction of the three forces: barriers (weight of history), drivers (push of the present), and compelling forces (pull of the future). Moreover, literature survey was carried out to strengthen the scenario storylines;
- scenario impacts were analysed in terms of opportunities and threats for both biotic and abiotic raw materials;
- finally, a report of the outcomes was written.

3.3. The 2050 Vision and Roadmap for European raw material research

3.3.1. The 2050 Vision for European raw material research. The results of both collection and analysis of data, together with the scenarios formulations, represented the first step for the development of the 2050 Vision and Roadmap for European raw material research.

From the background information, global outlook and regional/national ambitions coming from the gap analysis, the 2050 society and megatrends have been defined [19-21]. These global trends bring new societal challenges, that have the potential to boost the demand for products that make use of innovative technologies requiring R&I, such as the Key Enabling Technologies (KETs). In particular, KETs belonging to 65 innovation fields were considered for the VERAM project, since they are closely related to Raw Materials, belonging to 11 domains: Electronics and Communication Systems; Chemical Processes, Chemicals, Chemical Products and Materials; Manufacturing and Automation; Energy; Transport and Mobility; Construction; Mining, Quarrying and Extraction; Environment; Health and Healthcare; Textiles; Agri-food.

Matching all inputs, Europe by 2050 will be characterized by the transition towards a low-carbon economy, due to a number of circumstances, including climate change; population growth and the widening gap between social classes; the depletion of resources and the consequent demand of sustainable sourcing; and the mass customization and technological changes and innovations.

In order to face this future, the EU raw materials sectors will need to:

- provide and improve sustainable supply and use of primary, secondary and renewable RMs throughout the value chains;
- strengthen the EU economy by decreasing import dependencies and ensure base load supply trough diversification at source;
- embrace digitization, manage technical and practical applications of digitization in the sector, and revolutionize traditional value chains, business models and processes;
- develop and implement improved and better adapted measurable scientifically based values/indicators/standards associated with sustainability through the whole value chain where needs have been identified using newly developed data management systems;
• improve scientific and technical dialogue along and across business lines, exchanging experiences, advancing and leveraging good practices;
• increase the cross-disciplinary integration between academia and business for identification and development of new, cross-sectorial value chain opportunities.

For all the above-mentioned reasons, by 2050 it can be envisaged that the EU resources sector will:
• contribute to the gross domestic product and economic growth by providing EU market leadership in technology exports worldwide;
• contribute to the resilience of the EU industrial landscape and society through continually more advanced surveys of the EU landmass and marine environment, increasingly automated industrial processes, optimized valorisation of available resources, optimized use of resources and reduced consumption, increased recovery of materials and backflow into the economy and developing environmental footprint assessments of the full life-cycle of materials and products;
• addressing legacies and public acceptance through remediation of the EU’s existing legacy sites for future use.

3.3.2. The 2050 Roadmap for European raw material research. On the basis of the results obtained by the gap analysis, the creation of the 2050 Vision, and the stakeholders’ consultation, carried out through an online survey and focused on the collection of their personal vision for the raw materials sectors, a first draft of the 2050 Roadmap was produced.

The VERAM R&I Roadmap for 2050 comprises four pillars (already identified in the Vision document): supply, processing, closed loops and markets & applications. Each pillar is divided in different RIAs, for a total of ten. The content of the four pillars and the ten RIAs is reported below.

**Pillar I (Supply) – Fostering a sustainable raw material supply to feed all value chains:**
- RIA 1.1: New exploration and harvesting technologies for sustainable supply;
- RIA 1.2: Mobilizing an increased RM supply from EU sources.

**Pillar II (Processing) – Resource efficient processing, refining and converting of raw materials:**
- RIA 2.1: Development of resource efficient processing, refining and converting technologies;
- RIA 2.2: Minimization and valorisation of production residues.

**Pillar III (Closed loops) – Maximizing material closed loops:**
- RIA 3.1: Increasing collection, sorting, separation and detection efficiencies;
- RIA 3.2: Recycling technologies adapted to complex, durable, miniaturized and material efficient products;
- RIA 3.3: Developing and integrating assessment methodologies for balancing recycling costs and benefits.

**Pillar IV (Markets & Applications) – Raw materials in new products and applications:**
- RIA 4.1: Substitution of (critical) materials in new technology and energy applications;
- RIA 4.2: Development of new bio-based products;
- RIA 4.3: Development of new material applications and new markets.

The content of both pillars and RIAs are not definitive and will be updated and integrated by an interactive process that will endure throughout the project’s life and that will ultimately produce the 2050 Roadmap for European raw materials.

4. Expected impacts
The outcomes of the VERAM project are expected to contribute towards the following impacts:
• develop a coordinated EU policy on raw materials research, innovation and technological developments to raise investor confidence and improve financing mechanisms;
• promote more efficient use of resources by preventing unnecessary overlaps in technology related to innovation activities;
• create cross-sectorial and cross value chain research through joint ETP, ERA-NETs and other stakeholders and national activities;
• provide opportunities for exchange of Best Practice amongst Member States;
• accelerate uptake of ground-breaking technologies;
• review research and innovation results achieved, forecast directions for future research and assist in reviewing the EIP Raw Materials Strategic Implementation Plan;
• identify synergies between individual initiatives at EU and national level;
• improve raw materials policy and access to their utilization;
• help reduce Europe’s external supply dependency and foster a more efficient use of resources to improve the competitiveness of European industry;
• develop a common long term 2050 vision and R&I roadmap for European raw materials.

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