# EIT Raw Materials Lighthouses:

## Responsible Sourcing, Sustainable Materials, Circular Societies

Initiation Document for the EIT RawMaterials Partner Interaction and Debate at the Expert Forum 2022

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## 1. EIT RawMaterials Lighthouses

Raw materials are the fundamental building blocks of our society and economy. If Europe wants to remain economically successful and become more resilient to external economical and geopolitical factors, it must stimulate a responsible raw materials sector, establish sustainable value chains of raw materials and advanced materials, and build up robust capacities for the Circular Economy—these are fundamental pre-requisites for the EU's Twin Transition and for achieving the ambitious climate neutrality targets.


Figure 1 **EIT RawMaterials is a leader in cross-value chain innovation.**

All EIT RawMaterials' activities and its project portfolio are aligned with three guiding strategic frameworks called Lighthouses[1]:

1. Responsible Sourcing
2. Sustainable Materials
3. Circular Societies

The Lighthouses are designed to help EIT RawMaterials prioritise its investment areas, optimise its partnership interaction, and collaborate with other European and global stakeholders. They provide a guide to achieving the three strategic objectives of EIT RawMaterials (and their respective targets),

[1] The first two Lighthouses were formerly defined as "Sustainable Discovery and Supply" and "Sustainable Materials for Future Mobility".

which are: i) securing raw materials supply, ii) designing materials solutions, and iii) closing materials loops.[2] Lighthouses can be updated and refreshed to embed key insights and learnings to represent a living, breathing framework. In that sense, Lighthouses reflect the EIT RawMaterials approach to structure its activities into large-scale and long-term coordinated innovation initiatives that address critical and specific raw materials challenges for Europe.

Lighthouses are used to:

- Align on identified innovation and education targets for the community, for example, technology development and education (state of the art, business opportunities, and training needs).
- Identify clusters or focuses of partner interests and projects, e.g., rare earth magnets and motors, battery materials, and lightweight design.
- Identify pressing industry topics for the Innovation Community's calls for proposals using EIT funding (particularly start-up calls and the KIC Added Value Activities (KAVA) call for proposals for education and technology upscaling projects).
- Forge significant connections with the EIT RawMaterials partner network through matchmaking events (e.g., Expert Forums, Innovation Hub events).
- Funnel EIT RawMaterials' funded activities to investors, particularly via the Raw Materials Investment Platform of the European Raw Materials Alliance (ERMA).

Table 1 **The EIT RawMaterials Lighthouses drive innovation and education initiatives for every element of the value chain to secure supply, create jobs, reduce carbon emission, maximise circularity and minimise harm to our environment. Several strategic value chains are considered.**

| | **Responsible Sourcing** | **Sustainable Materials** | **Circular Societies** |
|---|---|---|---|
| **Strategic technologies and value chains** | Batteries, fuel cells, magnets and motors, photovoltaics, electronics, lightweight design | | |
| **Thematic focus areas** | • Smart, data-driven targeting of ore deposits<br>• Mining and ore processing at the highest safety and environmental standards<br>• Social Licence to Operate | • Substitution of critical, toxic, and low-performance materials<br>• Resource-efficient materials design and processing | • Industrial Symbiosis<br>• End-of-Life product recycling<br>• Design for recycling and lifetime extension<br>• Traceability, sustainability, supply chain transparency |
| **EIT RawMaterials Strategic Objectives** | Securing raw materials supply | Designing materials solutions | Closing materials loops. |

[2] EIT RawMaterials Strategic Agenda 2021-2027

By integrating high-level innovation and education and by promoting our three approaches of responsible, sustainable, and circular raw materials value chains, EIT RawMaterials can significantly contribute to building a European industry that is strategically more autonomous, less exposed to supply chain risks, and is expanding value creation and job creation in emerging industrial sectors. These include the following value chains batteries, fuel cells and electrolysis, magnets and motors (e.g., wind turbines and traction motors), photovoltaics, electronics (incl. digital technologies), and lightweight design (see JRC 2021; Table 1). In addition, we identified the following categories for the future exploration, mining and processing sector: (1) Resource characterization, (2) Digital and automated mining, (3) Mineral processing, (4) Waste reduction and valorisation and (5) Sorting (see below, 6. EIT RawMaterials Project Portfolio).

The new Lighthouse approach makes it possible to quantitatively analyse the EIT RawMaterials project portfolio and partnership in terms of value chain clusters, new technologies, and related educational activities. Together with the partners, EIT RawMaterials aims to develop technology roadmaps, identifying the key trends and market needs, and to illustrate how the project portfolio and the innovation and education capacity of the Community can have an overall market impact.

## 2. EIT RawMaterials Partner Consultation and Co-creation Process

**The objective of this paper is to initiate the process of updating the EIT RawMaterials Lighthouses, i.e., to provide the framework for a EIT RawMaterials partner engagement and consultation process, which includes the following steps:**

1. May 2022: Lighthouse paper shared with EIT RawMaterials partnership as a pre-reading for the exchange at the Expert Forum; initial debate with EIT RawMaterials Innovation Hub Steering Committees
2. June 2022: Thematic debate at the EIT RawMaterials Expert Forum, Berlin, 27-29 Jun 2022; presentation of portfolio analysis, including the identification of gaps and investment opportunities
3. July 2022: Drafting of updated Lighthouse paper including the input of the Expert Forum debate

## 3. Lighthouse Responsible Sourcing

**Increasing safety – Reducing costs and environmental footprints – Improving efficiency**

The shift to net-carbon-neutrality and technology-driven innovation in the context of the EU Green Deal and the Twin Transition translates into increasing demands for critical and strategic raw materials. This increase in demand, combined with Europe's high import dependency, emphasises the need to act and address the responsible sourcing of primary and secondary raw materials outlined in the "EU principles for sustainable raw materials" published by the European Commission in 2021. Europe's clean, green, and digital future relies significantly on minerals and metals that should be sourced responsibly and managed sustainably along value chains. Boosting European exploration and mining efforts (from greenfield to post-closure) and strengthening processing capabilities for critical strategic raw materials are vital steps toward a more sustainable future. In this context, three approaches are at the core of the Lighthouse Responsible Sourcing:

i) achieving a more targeted and cost-effective exploration and quicker transition to mining operation; ii) reducing the environmental footprint of mining and processing; and iii) improving the efficiency of mineral and metallurgical processing.

Exploration and mining face significant challenges around establishing a Social Licence to Operate (SLO). The Lighthouse Responsible Sourcing can be instrumental here, engaging with stakeholders, including NGOs, and leading a constructive dialogue. These activities raise awareness and build trust, ultimately leading to increased acceptance for a renewed raw materials sector in Europe. Key areas that are regularly addressed within the scope of this Lighthouse are the Environmental, Social and Governance (ESG)-factors and the technical and economic challenges of the extractive sector.

A responsible upstream raw materials sector requires advanced technologies and smart decision-making based on improved knowledge and data. This will increase efficiency and safety and reduce import dependency and the environmental footprints (emissions, waste such as tailings, water) of materials while significantly contributing to economic growth in the EU. Digitalisation acts as a natural connector among all segments of the value chain. It can help to gain a better, more holistic understanding of processes and life cycles—eventually leading to a truly Circular Economy that factors in all social, climate, and environmental costs (environmental life cycle assessment (E-LCA) and social life cycle assessment (S-LCA)).

## 3.1. Future exploration, mining, and processing technologies

Exploration, mining, and processing have one common denominator: Data. In traditional exploration, mining, and mineral processing, only a small fraction of the information and data collected along with the various steps and processes directly impact decision-making. If modern digital solutions are applied, double-digit efficiency improvements are achievable and positively impact safety, environmental footprint, and costs. Modern smart exploration, mining and processing operations collect vast amounts of data at each step along the value chain. Although data represents an incredible opportunity for increased resource efficiency, the challenge is to extract the relevant information and implement fit-for-purpose solutions.

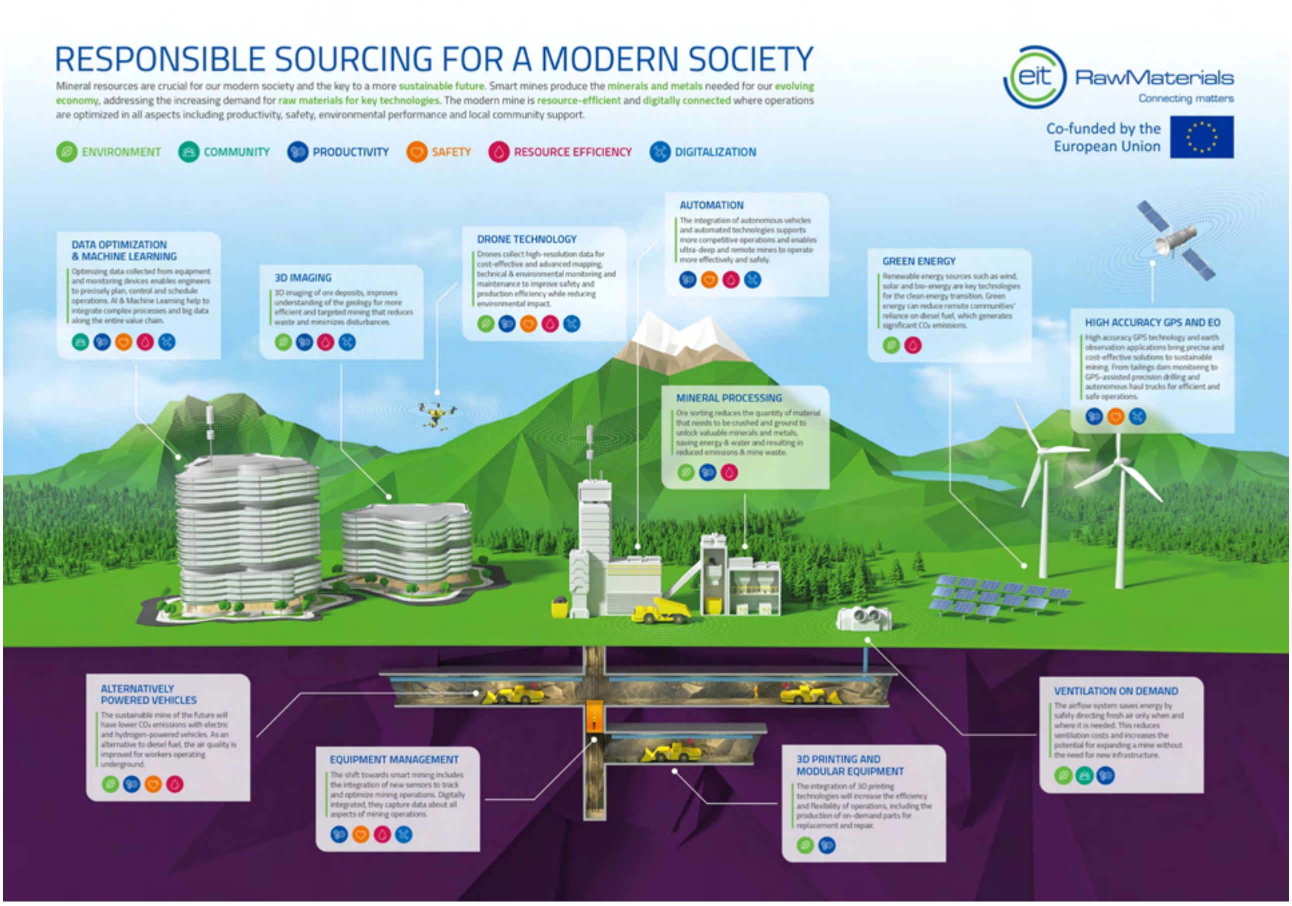


Figure 2 Responsible sourcing relies heavily on digital innovation and the interconnectivity and interoperability of data. Advanced models that build on multi-scale- and multi-method-data sources boost efficiency and safety in exploration, mining and processing while reducing the environmental footprint. Hence, they are critical prerequisites for more sustainably and responsibly sourced minerals and metals. Source: EIT RawMaterials, 2020

On top of this (r)evolution, the industry faces significant challenges in reducing its environmental footprint (including GHG emissions) as it is an energy-intensive sector. Life Cycle Assessment (including environmental and social aspects) and digital ledgers can help to record, trace, and balance all impacts to arrive at a more responsible and sustainable raw materials sector (see also Lighthouse Circular Societies).

## 3.2. EIT RawMaterials' value chain approach

While the impact areas listed in Table 1 address the key trends shaping the upstream raw materials sector as a whole, a more targeted approach emphasises specific commodities linked to strategic value chains that connect all three Lighthouses. This is where the EIT RawMaterials investment strategy is relevant.

The EIT Raw Materials Investment Strategy is a strategic value chain focus (see Introduction) that cultivates and promotes innovation that meets the EU's most pressing raw materials-related challenges and takes full advantage of the existing resource potential in Europe (see also Minerals4EU).

Six core raw material-focussed value chain strategies:

**Batteries:** Lithium, Co, Ni, Mn, and graphite (among other important elements) are essential building blocks for batteries. Currently, the EU produces only 1% of all battery raw materials worldwide[3], so the need to act is urgent. There is significant resource potential for all these commodities, and smart solutions that reduce the environmental impact and costs for exploration and mining operations can enable a competitive battery materials sector in Europe. Furthermore, processing facilities that apply leading-edge technology will play a vital role in decreasing dependency and improving efficiency in Europe's growing battery sector.

**Magnets and motors:** Rare Earth Elements (REE) are critical components of permanent magnets and other high tech, low-carbon products, and sustainable technologies. Advanced exploration can help to ensure more precise targeting of this critical raw material, thereby reducing environmental impact and lowering costs for the successive mining and processing stages. The EU already has several known deposits with good potential for REE mining. However, REE deposits are often associated with radioactive elements (thorium, uranium) that naturally occur in REE-bearing minerals. Mitigating the risks around mining and processing radioactive material can alleviate environmental concerns and help to improve the acceptance of such mines and operations (SLO). Similar to the battery value

[3] European Commission, Critical materials for strategic technologies and sectors in the EU - a foresight study (2020), p. 19

chain, it is equally important to boost the REE processing sector because refining/processing is often an even narrower bottleneck for Europe's raw materials demands than the primary sourcing.[4]

**Hydrogen technologies:** The projected growth in fuel cell and electrolyser market uptake will have to be accompanied by a responsibly sourced, secure, and sustainable supply of several Critical Raw Materials (CRM) such as Platinum Group Metals (PGMs), cobalt, strontium, scandium, graphite, titanium, and REE and further strategic resources such as copper, nickel, and aluminium. Specifically, PGMs are essential for fuel cells. Only a handful of other elements have a higher geographic concentration (Herfindahl-Hirschman Index) and criticality index than PGMs (less than 1% are sourced from within the EU.[5] Hence, efforts to valorise residues and waste materials and extract these precious metals are indispensable. Additionally, these precious metals have discovery and development potential, specifically in Scandinavia and Greenland. The highly specialised exploration and mining approach requires expert know-how and innovative ideas to re-establish this sector in Europe.

**Lightweight Materials:** Magnesium plays a critical role in lightweight design materials. Although magnesium is abundantly available in brines and dolomitic rocks, it has a high criticality due to its geographic concentration in terms of extraction and processing, with most refined supplies (92%[6]) coming from China. More domestic processing capacities and a more diversified sourcing portfolio combined with increased efficiency to establish cost-effective sourcing alternatives are needed for magnesium.

**Photovoltaics (PV):** Boron, bismuth, gallium, germanium, indium, and silicon are critical raw materials linked to the photovoltaics sector. Other materials used to manufacture PVs include silver, arsenic, and selenium, which may come with a supply risk.[7] Today, the solar industry consumes up to 1500 t of silver worldwide.[8] Europe has significant resource potential for these elements, and they occur as accessory elements and by-products in a range of deposits (e.g., bauxite and zinc-ores). More efficient extraction of these elements from primary ores and waste materials, including tailings, could be an important step toward increased resource independence and a closer link to European PV manufacturers, especially since the demand for gallium, germanium, and indium is projected to

[4] Ibd.
[5] European Commission, Critical materials for strategic technologies and sectors in the EU - a foresight study (2020)
[6] Ibd.
[7] Gervais et. Al, Raw material needs for the large-scale deployment of photovoltaics – Effects of innovation-driven roadmaps on material constraints until 2050 (2021)
[8] Fraunhofer ISE, Aktuelle Fakten zur Photovoltaik in Deutschland (2022)

increase by over a factor of 10 by 2050.[9] Given the increased pressure to move to higher levels of renewable energy in the European energy mix, it is essential to act now to meet these demands in the foreseeable future.

**Electronics (ICT):** In addition to all critical and strategic elements that are relevant for the above value chains, tin, tantalum, tungsten, and gold – the so-called 3TGs – play an important role in the manufacturing of electronics. The 3TGs are at the core of the EU's conflict mineral regulation that came into force in 2021 (source) and aims (among other things) to ensure that EU importers of 3TG meet international responsible sourcing standards set by the Organisation for Economic Co-operation and Development (OECD). In this context, in addition to targeted exploration and resource efficiency, due diligence and traceability are pivotal aspects.

### 3.3. KAVA (EIT Raw Materials/KIC Added Value Activities) Topics

1. Exploration: data-driven decision making in the extractive sector related to one or more of the identified value chains
2. Mining and processing: responsible sourcing of materials related to one **or more of the identified value chains**
3. **Future exploration, mining, and processing technologies:**
    a. **Advanced and fully integrated exploration – smart targeting of ore deposits**
    b. **Future mining – Increase safety and reduce the environmental footprint of mining operations (from early operation to post-closure)**
    c. **Mineral processing – improve efficiency and reduce emissions and $CO_2$-footprint**

## 4. Lighthouse Sustainable Materials

The choice and design of pre-cursor materials, intermediates, and advanced materials significantly impact the overall resource efficiency, footprint, performance, and cost of a product.

This Lighthouse focuses on substituting critical, toxic, and low-performance materials, i.e., at the elemental, materials, and processing levels (Figure 3). Key technological approaches include modelling materials and processes, alloy development, microstructure engineering, and resource-efficient materials design and processing, including near-net-shape processing, e.g., 3D printing.

[9] European Commission, Critical materials for strategic technologies and sectors in the EU - a foresight study (2020)

Substitution is a disruptive intervention into an industrial ecosystem that comes with opportunities and risks. There is a need to consider that minerals and metals are extracted and processed within an ecosystem of industrial processes. Critical materials, in particular, are often produced as by-products of mass metals, where a cross-value chain perspective is needed (Figure 4). Substitutes can threaten existing business models, and mass production of new materials and disruptive technologies come with high costs for implementing new industrial production lines and infrastructure.

## 4.1. Additive manufacturing

A new level of design freedom and the possibility of true customisation are two factors supporting the impressive growth of additive manufacturing. Products are manufactured layer upon layer following a digital design. In the case of the additive manufacturing of metallic materials, the technology has shown to be capable of producing parts with unique and, in some cases, superior microstructures. Thus, in the case of metals, additive manufacturing has become a valid option for a growing number of companies worldwide. In terms of raw materials, the key advantage of additive manufacturing lies in producing near-net-shape, that is, as material-efficient as possible. In addition, complex geometries and gradient materials can be produced, that is, materials with changing properties across specific sections. The key challenges come with increasing production efficiency, lowering production cost, and tailoring the microstructure to achieve specific properties and functional capacities. Further challenges include the specific development of powder technologies, including the production of special alloys and metal powders from scraps and the development of multi-material solutions.

## 4.2. EIT RawMaterials' value chain approach

**Batteries:** EIT RawMaterials focuses on the emerging lithium-ion technology, although alternative technologies are not neglected. Indeed, until 2030, batteries for mobility will be mainly lithium-ion batteries. Alternative battery technologies might be suited for specific mobility niches (Li-S, Na-S) or are just in a conceptual phase (Li-air). The next generation will be 'solid-state Li-ion batteries. Innovation is focused on promoting innovation in suitable battery materials, particularly cathodes, anodes, separators, and electrolytes, and on better understanding the battery electro-chemistry and the physicochemical properties of the material interfaces. The ultimate goal is to develop batteries with a higher energy density, power, and longer lifetime.

**Hydrogen technologies:** The recent penetration of fuel cells (mostly proton-exchange membrane fuel cells, PEMFC) in the e-mobility field through the commercialisation of fuel cell cars by Asian car makers (Mirai by Toyota, iX 35 H2 by Hyundai, FCV Clarity by Honda) shows the starting point of the ramping up in numbers of such a vehicle fleet. Another striking example is the city of Paris, which targets 10.000 fuel cell-powered taxis and 20 hydrogen loading stations by 2024 (Bloomberg 2021). Polymer electrolyte fuel cells (PEFC) will be the fuel cell utilised in vehicles for years to come. In addition, solid oxide fuel cells (SOFC) are developed for auxiliary power units (APU) for trucks and maritime vessels. PEFCs are comprised of a cathode (active material, platinum on carbon or platinum-cobalt on carbon, possibly other bimetallic platinum compounds supported on carbon), anode (platinum on carbon), electrolyte (acidic perfluorinated polymer membrane), and bipolar plates (stainless steel). EIT RawMaterials innovation projects should focus on developing new technologies for synthesising the alternative nanostructured materials or low-platinum load catalysts, identifying suitable alternative membranes; building hydrogen fuelling technology, with a focus on electrolysers are particularly important.

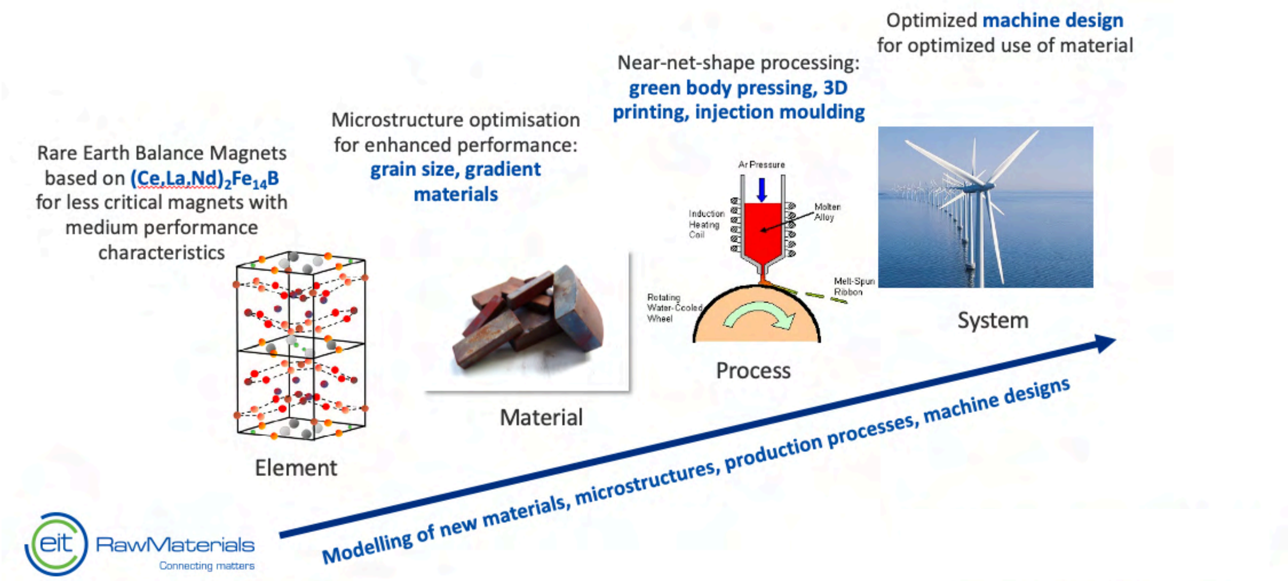


Figure 3 Different levels to approach the substitution of critical, toxic, and low-performance materials: the example of neodymium in permanent magnets of wind turbines. Images: Lewis – Jimenez-Villacorta 2013; Gauß et al. 2015; http://eresources.gitam.edu; Siemens.

**Magnets and motors:** High energy density rare earth permanent magnets enable the manufacturing of the most energy-efficient wind turbines as well as traction and servo motors. At EIT RawMaterials, innovation focuses on advanced processing and magnet manufacturing, i.e., alloy processing, new pressing and sintering technologies, injection moulding, 3D printing (near-net-shape production), and magnets with optimised microstructures (nano-grained materials). In addition, innovation projects that focus on the making of cerium and lanthanum containing magnets substituting neodymium as critical material are considered. The tailored design of e-drives for optimised use of magnet materials as well as emerging magnet technologies with the potential for disruptive change are other focus areas. For example, the upscaling of materials used in magnetic refrigeration technology has a high innovation potential.

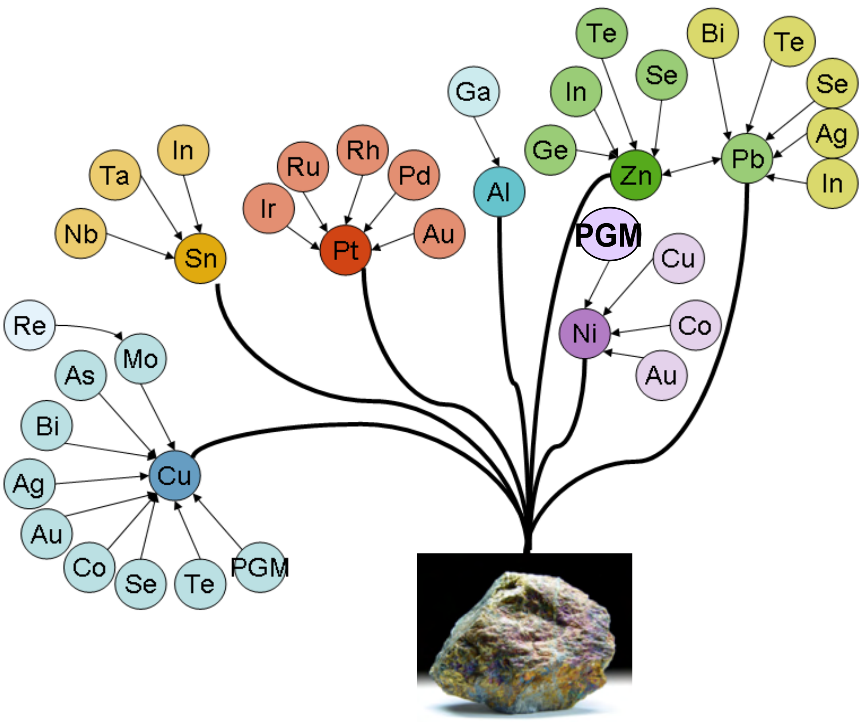


Figure 4 Raw materials (i.e., metals and other strategic elements) and particularly critical raw materials are often by-products. Eliminating one from the materials flowchart may influence the availability of another.[10]

**Photovoltaics:** Today, most photovoltaic modules are based on crystalline silicon wafers. The dominating materials are silicon, aluminium, and glass. Silicon and its manufacturing into wafers are considered critical by the EU. The current technological alternatives, so-called thin-film solar cells, may contain even more critical and toxic raw materials, including cadmium, tellurium, indium, gallium, and selenium.[11] EIT RawMaterials considers innovation projects that find suitable substitutes for these critical and toxic materials or significantly reduce their use per kW energy delivered. Innovation is also considered, for example, in reducing the use of costly metals in pastes for the metallisation of the cells (today mostly done by using silver, which can be replaced by copper and aluminium). Innovation projects that increase performance, thus reducing metal load per kW energy output, are also promoted by EIT RawMaterials.

[10] Hagelücken and Meskers (2010), Complex Life Cycles of Precious and Special Metals, in: Linkages of sustainability (pp. 163-197), Volume 137

[11] EMIRI, Advanced Materials for Clean and Sustainable Energy and Mobility (2019); IEA, Designing New Materials for Photovoltaics: Opportunities for Lowering Cost and Increasing Performance through Advanced Material Innovations (2021)

**Electronics:** Critical materials used in electronics include, for example, indium in transparent conductive oxides, gallium and germanium in semiconductors, and tantalum in capacitors. All these materials' uses can be optimised by resource-efficient design and miniaturisation. Another approach is using printed electronics, using organic compounds as substitutes.

**Lightweight design:** In automotive applications, steel is by far the most popular and accepted material (about 60 % today). However, the dominance of steel in automotive will decrease, and new alloys, aluminium, and multi-material solutions will enter the market. Third generation steels are sometimes referred to as high-strength steels (HSS), ultra-high-strength steels (UHSS) or advanced high strength steels (AHSS).[12] There is a trend toward the development of new, innovative steel-based, lightweight sandwich and laminate materials. Cost-efficient manufacturing processes of these alternative lightweight materials are essential.

The widespread adoption of aluminium alloys requires a key innovation breakthrough: the key-performance characteristics of the material for application in the transport sector, i.e. specific and high-temperature strength, toughness, and durability, must be achieved not only by conventional alloying, that is, elements added to primary, highly energy-sensitive aluminium; but rather by the up-cycling of high-performance alloys from scraps for "next life applications" of greater value, higher quality, and improved environmental sustainability.

In the case of fibre reinforced polymers, cost reduction and a thorough understanding of the mechanical properties are the two key challenges hindering the large-scale adoption of the material. Effective numerical and analytical tools that predict performance and damage are important in this context. Key areas for innovation include cost reduction in the production of carbon fibres for load-bearing structures; bio-based fibres and matrices for secondary components; effective and automated manufacturing processes; joining and multi-materials development; and non-destructive damage detection and repair.

### 4.3. KAVA (EIT Raw Materials/KIC Added Value Activities) Topics

1. **Innovation in the substitution of critical, toxic, and low-performance materials related to one or more of the identified value chains**
2. **Additive manufacturing of materials related to one or more of the identified value chains, including powder development and microstructure engineering**
3. **Resource-efficient design of materials related to one or more of the identified value chains.**

[12] Frost & Sullivan, Overview of Automotive Powertrain, Chassis, Body, and Materials Roadmaps, 2025 (2016)

# 5. Lighthouse Circular Societies

The concept of a Circular Economy has recently gained traction in Europe as a positive, solutions-based perspective for achieving economic development within increasing environmental constraints. Raw, processed, and advanced materials from primary and secondary sources are the backbone of the economy. A radical shift is required from linear to circular thinking. End-of-life products, so-called "waste", must be considered as a resource for new product cycles. At the same time, losses and stocks of unused materials must be minimised and valorised along the entire raw materials value chains. In addition, business opportunities in strategically linking the processing of different materials' value chains must be considered to define the best circular solution from a systems point of view. This is defined as Industrial Symbiosis. Awareness of the benefits of closing material loops must be raised in society. The Circular Societies Lighthouse focuses on innovation and education related to industrial symbiosis, design for recycling and lifetime extension, end-of-life product recycling, as well as in the chain of custody (traceability, sustainability, transparency).

## 1.1. Circular Economy at EIT RawMaterials: Industrial Symbiosis, recycling, chain of custody

**Industrial symbiosis** is a systematic approach to a more sustainable and integrated industrial production system, identifying business opportunities that leverage underutilised resources, such as materials, energy, water, capacity, expertise, and assets. Industrial Symbiosis involves organisations operating in different sectors of activity that engage in mutually beneficial transactions to reuse waste and by-products, find innovative ways to source inputs and optimise the value of the residues of their processes.[13] The valorisation of non-scrap metal and mineral waste is gaining momentum. Both industry and academia invest in R&D to valorise valuable, so-called waste material streams and turn them into sources of secondary raw materials. Not only technological solutions could be considered but also other relevant non-technological aspects such as process and materials modelling, sharing process technology platforms, skills, and markets. Some of those relevant aspects could be considered in the Education, and Business Creation calls of EIT RawMaterials, but also in the collaboration with other relevant stakeholders.

**Product design for recycling and lifetime extension** are elements to save costs and resources. One good example of this concept is modular design, a useful strategy for making products easier to

[13] European Commission (2018), Cooperation fostering industrial symbiosis market potential, good practice and policy actions.

repair, remanufacture, and upgrade. At the same time, the development of new dismantling and sorting technologies will offer new design for recycling opportunities of products.

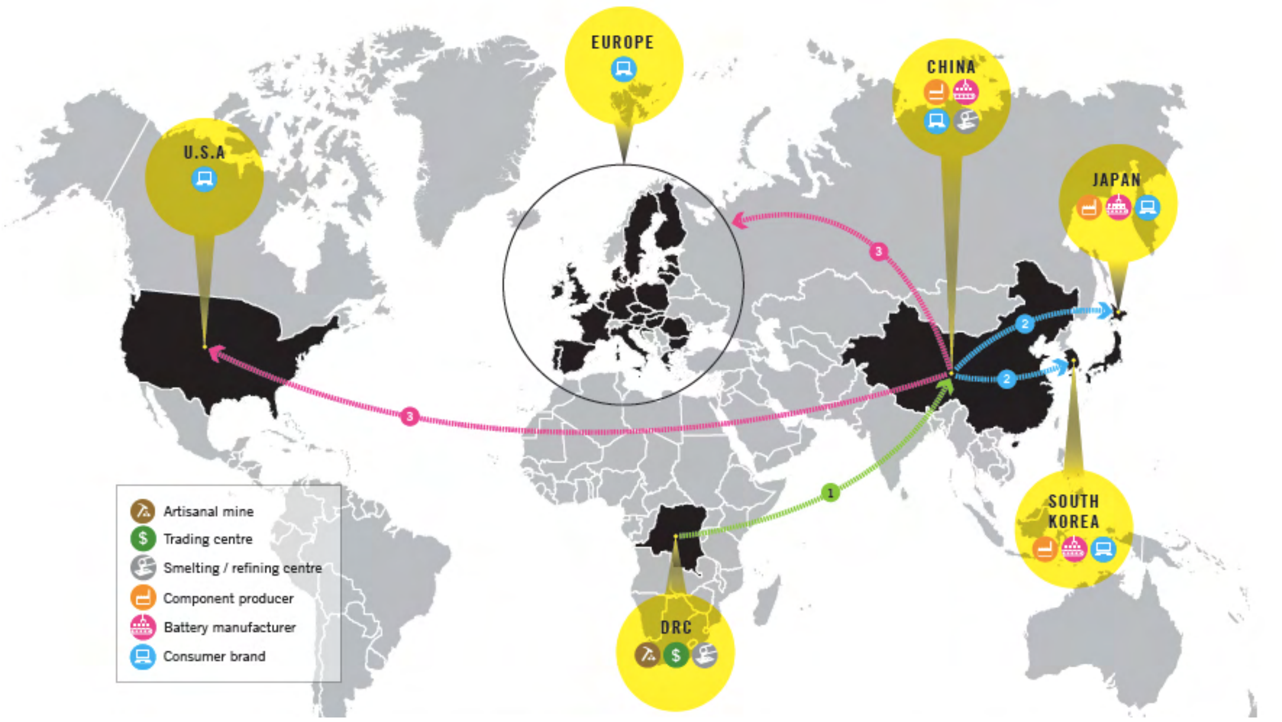


Figure 5 **Global trade and use of Cobalt from artisanal mines in the Democratic Republic Congo (DRC), which accounts for about 20-40 % of the metal produced in the DRC. Source: Amnesty International (2016), Human rights abuses in the Democratic Republic of the Congo power the global trade in cobalt)**

Today, **the recycling of end-of-life products** is well-established in various industrial and consumer sectors in Europe. Both, economic incentives, as well as public policy regulations have proven to be key drivers in promoting recycling. Yet, whilst facing a fast technological change as well as exponential growth in the deployment of new technologies has made it difficult to ensure the extraction of valuable materials from so-called waste streams. Technology metals often found in minor amounts in functional materials and components have turned out to be difficult to extract under economically feasible conditions. Apart from effective policy measures, innovation in smart collection systems, optimised sorting, and dismantling, as well as efficient recovery technologies are vital to secure a sustainable supply or secondary critical raw material.

A **chain of custody** to prove the provenance of raw materials and advanced materials, as well as their social, environmental, and governance footprints, is vital for transitioning to a Green Economy that aims to leave no-one behind. A comprehensive understanding and documentation of materials' provenance and footprints will provide a competitive advantage for original equipment manufacturers from industries like automotive, energy, and machinery. It will enable sensitive sectors like aerospace and defence to build trust and to control information on technologies and assets. The implementation and interpretation phases should be supported by flexible tools and compatible datasets. Life Cycle Assessment databases need to be updated and maintained. Methods, tools, and data should be suitable to address different aspects and increase standards of sustainability. The Responsible Sourcing Lighthouse will particularly promote the flexible integration and implementation of different methods and tools, i.e., of stakeholders from across the value chains. This would be important for the application of sustainability assessment methods in different decision-making contexts and for addressing the needs of specific stakeholders and customers.

## 5.1. EIT RawMaterials' value chain approach

**Batteries:** The battery industry is forecast to grow exponentially in Europe. Building up battery recycling capacities is critical to treat the increasing volumes of waste batteries on the market and to secure Europe's position as a leader in the circular economy. Europe counts over two million EVs on its roads today, and this number is expected to reach seven to eight million by 2025. The EU's battery industry comes with massive demands for metal and mineral raw materials as well as clean and low-cost electricity. Hence, the industry is particularly receptive and heading for industrial symbiosis. For example, several battery cell manufacturing start-ups are located in regions with low-cost clean energy and rich raw materials resources (e.g., northern Europe). Design for recycling plays a particular role in finding the right materials and designs for automotive battery modules. Representing the highest value in EVs, battery modules will have to be dismantled in a (semi-) automated way. Real-time performance monitoring solutions of individual cells, for example, can help to exchange and repair in a targeted manner. The chain of custody is particularly relevant for sourcing battery-grade lithium, cobalt, nickel, manganese, and graphite, most of which are extracted and processed in the southern hemisphere and/or China (Figure 5).

**Hydrogen technologies:** PGMs are one of the key cost drivers in fuel cells and are highly resource critical (see above, Lighthouse Responsible Sourcing). In terms of recycling, the high intrinsic value of PGMs is a strong trigger for innovation in the respective recycling business. However, the extraction of other materials in fuel cells, particularly scandium, graphite and rare earths would have to be incentivised. Innovation in processing and separation will be key to substantiate value creation for both PGMs as well as technology metals.

**Magnets and motors:** High energy density rare earth permanent magnets enable the manufacturing of the most energy-efficient wind turbines as well as traction and servo motors. This key energy-intensive industry has almost disappeared from Europe. Since rare earths are often a by-product of other raw materials extraction processes, like those linked to phosphate and uranium processing, industrial symbiosis is a core aspect of various magnet value chains. Rare earth magnets are hardly recycled today. Technologies do exist, but the economics behind the collection, dismantling, and sorting do not exist.

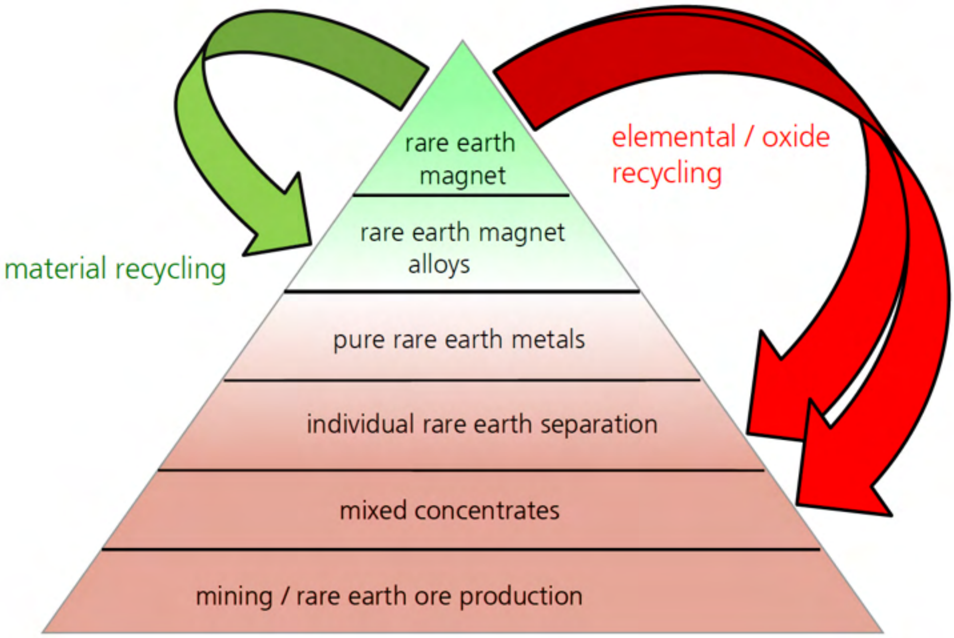


Figure 6 **Levels of recycling: the case of rare earth permanent magnets. Source: Gauß and Gutfleisch 2016.**

**Photovoltaics:** The number of photovoltaic panels placed on the EU market has risen sharply in recent years and is expected to grow strongly in the coming years. Assuming a 25-year lifetime for panels, total quantities of end-of-life photovoltaic panels in 2050 are anticipated to amount to 9.57 million tonnes. The main environmental problems linked with photovoltaic panels, if not properly disposed of, are the leaching of lead, cadmium, loss of conventional resources (primarily aluminium and glass), and loss of critical metals (silver, indium, gallium, and germanium). Advanced recycling technologies that enable a high level of materials recovery do exist. One example is the electrohydraulic fragmentation of panels that makes it possible to obtain separated materials fractions. These kinds of technologies would need to be upscaled and put into the market with a solid business case. In addition, innovation is needed in the processing of secondary silicon to meet specifications for wafer production. Alternatively, silicon from recycled PVs may be used in other technologies, particularly battery electrodes. Another key innovation trend is to explore various approaches for the lifetime extension of photovoltaic modules.

**Electronics:** Europe's ambition to re-build a semiconductor industry, using private as well as public funding, presents a significant opportunity to establish the most sustainable and environmentally friendly production facilities in the sector. These and other electronic components require sourcing critical materials like silicon, gallium, germanium, and the 3TGs – tin, tantalum, tungsten, and gold. European industry and civic society would greatly benefit from innovation and education to increase the transparency and traceability of raw materials value chains.

Waste electric and electronic equipment (WEEE) is the fastest growing waste stream in the EU, and less than 40% is recycled, with big differentiation between EU Member States. The efficient collection, sorting, dismantling, and processing of WEEE would provide a robust, sustainable provision of secondary CRMs in Europe.

**Lightweight design:** High strength steels, aluminium alloys, and composite materials have very different challenges regarding industrial symbiosis, materials design, recycling, and sustainability. A Circular Economy of steels and aluminium alloys is well established in terms of recyclability. Transparency and sustainability standards in the supply of critical raw materials, e.g., niobium, chromium, tungsten, and magnesium, are of concern. New opportunities for Industrial symbiosis emerge in the context of Green Steel and the use of clean hydrogen as a reducing agent. Composite materials face the challenge of cost-efficient recyclability and the end of the product life cycle, particularly regarding the use of thermoset materials.

## 5.2. KAVA (EIT Raw Materials/KIC Added Value Activities) Topics

1. **Industrial symbiosis: turning waste resources into valuable input for one or more of the identified value chains or improving a business case in these value chains by turning waste into secondary resources for other industries.**
2. **Design for recycling and lifetime extension: Optimise materials and products' design to create a business case for one or more of the identified value chains.**
3. **End-of-life product recycling**
4. **Chain of custody (traceability, sustainability, transparency).**

# 6. EIT RawMaterials Project Portfolio Analysis

## 6.1 Ongoing investments

The EIT RawMaterials upscaling project portfolio currently comprises 47 projects (58 more projects with KAVA 9), with a slightly larger share of Circular Societies related projects compared to those related to Responsible Sourcing and Sustainable Materials (Figure 7). This is also related to the budgets: Sustainable Materials and Responsible Sourcing related projects represent a dedicated budget of €45M and €40M, respectively, whereas €65M are dedicated to projects in Circular Societies.

The battery value chain clearly stands out in terms of the overall investments committed. Considering the exponentially growing battery materials market demand in Europe and worldwide, there is a huge innovation and investment potential for EIT RawMaterials, i.e., along the full value chain. All the other value chains have similar dedicated budgets, i.e., between €9M and €15M.

## 6.2 Gaps

A comprehensive analysis of the impacts achieved so far as well as open gaps and investment opportunities is subject of the partner co-creation process and debate at the Expert Forum 2022. At this stage, the following gaps have been identified:

Responsible Sourcing: Apart from the battery value chain, none of the targeted value chains comprise dedicated projects for the responsible sourcing of primary raw materials, representing a clear gap. This is of particular concern, considering the EIT RawMaterials target of opening at least one new mine in Europe by 2027.[14] In the technology-focussed category that was defined as “Future exploration, mining, and processing technologies”, projects related to resource characterisation, digital and automated mining, and mineral processing dominate the portfolio. The challenge will be to use those technologies to achieve at least one major ore discovery in Europe by 2027.[15]

Sustainable Materials: In the case of photovoltaics and electronics, the EIT RawMaterials project portfolio does not cover materials design projects, reflecting the limited European industrial capacity in these two sectors. Whilst there are materials design projects in the battery value chain, none of

[14] EIT RawMaterials Strategic Agenda 2021, p12
[15] EIT RawMaterials Strategic Agenda 2021, p12

them currently focus on solid state batteries, which has been defined as a target in the EIT RawMaterials Strategic agenda.[16]

Circular Societies: Projects related to "Design for Recycling" are missing. This is because the EIT RawMaterials partnership comprises only comparatively few downstream industry partners designing and selling products, i.e., OEMs, for instance, in electronics, automotive, and equipment manufacturing. The other key gap relates to projects in supply chain tracing, transparency, and sustainability; for instance, projects related to innovation and business development in Life Cycle Assessment.

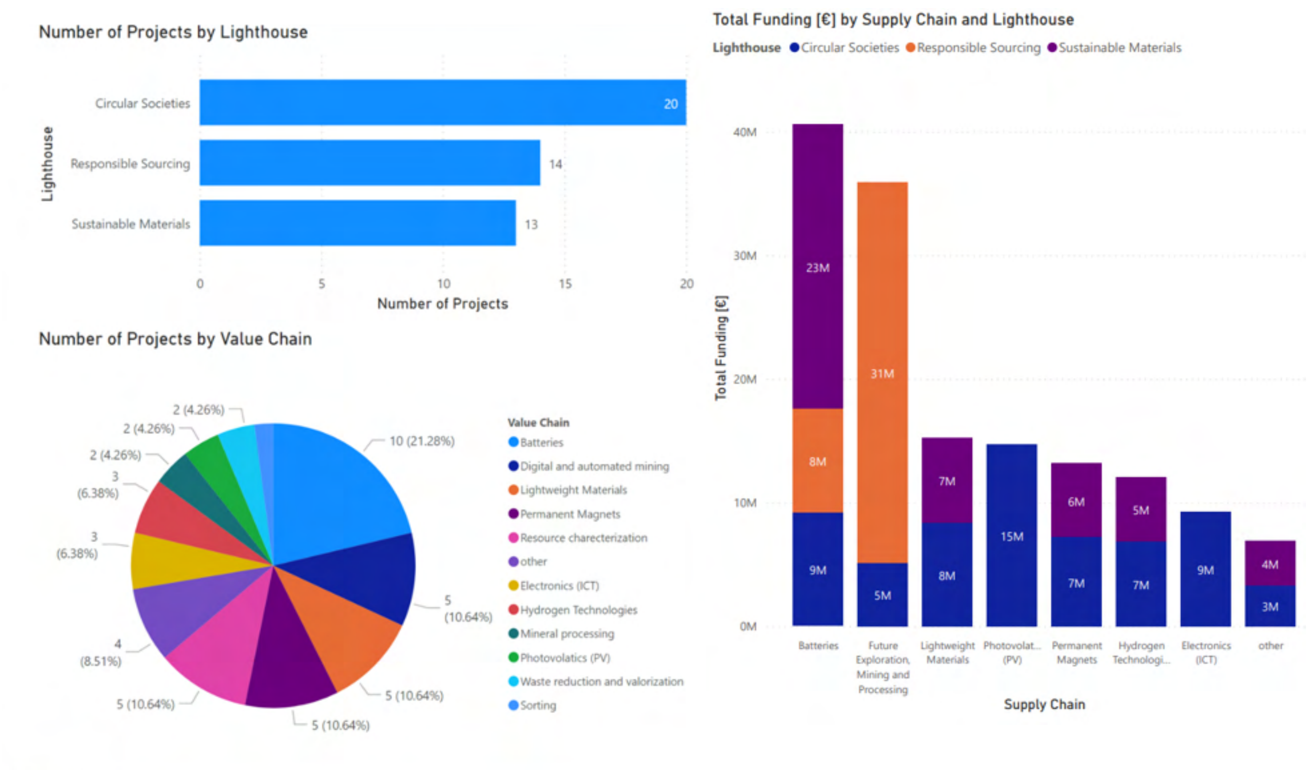


Figure 7. Overview of ongoing (current) upscaling projects categorised by Lighthouses and value chains. The bar summarising the budgets related to Future Exploration, Mining, and Processing Technologies represents projects in Resource Characterisation (€11M), Digital and Automated Mining (€12M), Mineral Processing (€7M), Waste Reduction and Valorisation (€3M), and Sorting (€3M). These projects and related technologies can serve various different kinds of value chains. Budgets refer to total funding, including partner co-funding.

[16] EIT RawMaterials Strategic Agenda 2021, p13

Table 2 **The EIT RawMaterials education projects related to specific value chains.**

| **Learning Level** | **Mining & Processing of battery materials** | **Battery production** | **Collecting, dismantling, and recycling** |
|---|---|---|---|
| **Basic** | EBBC | | Innomat |
| **Advanced** | iTarg3T<br>DMS School | | Recycle my Phone<br>AMIR |
| **Expert** | BattValue<br>EBBC | EBBC | EBBC |

| **Learning Level** | **Mining & Processing of Magnet materials** | **Magnet production** | **Collecting, dismantling, and recycling** |
|---|---|---|---|
| Basic | IRTC-Training | | CRM-ELV |
| Advanced | SinReM | | Recycle my Phone<br>AMIR |
| Expert | IRTC-Training | IRTC-Training | IRTC-Training |

| **Learning Level** | **Mining & Processing of Fuel Cell materials** | **Fuel cell production** | **Collecting, dismantling, and recycling** |
|---|---|---|---|
| Basic | IRTC-Training | | |
| Advanced | SinReM | Alpe | |
| Expert | TrainCall | TrainCall | TrainCall |

| **Learning Level** | **Mining & Processing of Lightweight materials** | **Lightweight materials production** | **Collecting, dismantling, and recycling** |
|---|---|---|---|
| Basic | | | LightRight |
| Advanced | | | |
| Expert | | | LightRight 2.0 |

# 7. Processes

## 7.1. Matchmaking

The EIT RawMaterials Lighthouses are closely linked to the matchmaking events of the Knowledge and Innovation Community, such as the annual EIT RawMaterials Summit, the Expert Forum, and the Raw Materials and Circular Economy Expedition (RACE). The first two events gather the community around core topics of the Lighthouses, which are directly linked to specific strategic value chains (see also Table 1). The partners of the Innovation Community inform and debate the current status of R&D efforts, education, industry needs, the policy framework and funding opportunities to accelerate start-ups as well as innovation and education projects.

## 7.2. Acceleration and education

The EIT RawMaterials calls for proposals for technology upscaling and education (KAVA calls) as well as the Start-up Accelerator and Booster calls, use the Lighthouse themes to define call topics and to co-develop the EIT RawMaterials project and start-up portfolio. This is done in collaboration with the Raw Materials Academy and its partner organisations. The portfolio strategy is aligned with the structure of the European Raw Materials Alliance, which also builds on a value chain perspective.

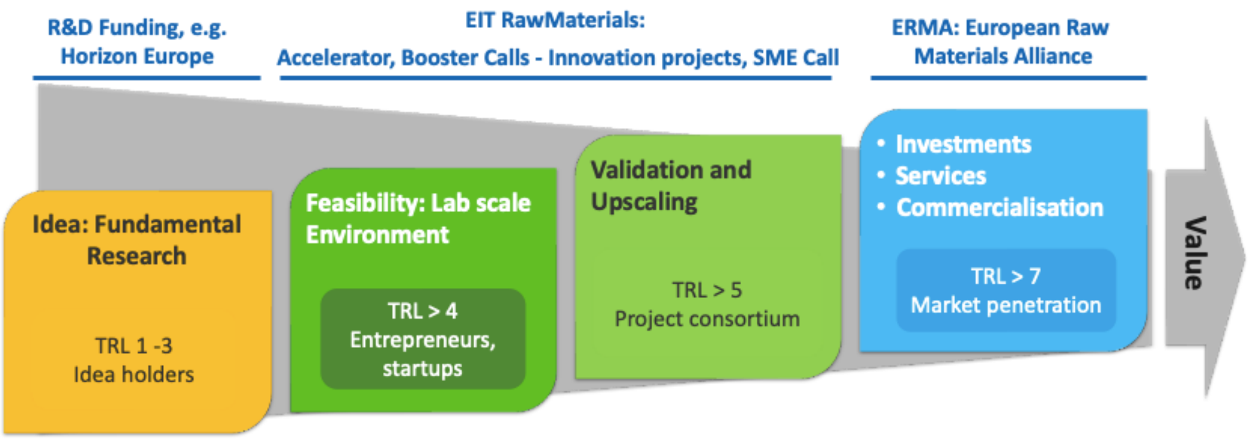


Figure 8 **The EIT RawMaterials innovation funnel bridges the gap between idea and market.**

### 7.3. Collaboration and alternative funding

The EIT RawMaterials Lighthouses are also used to define and develop the Business Intelligence capacity of EIT RawMaterials used for consultancy services towards policymakers such as the European Commission and industry. Until today, a budget of €1.3 millions of external funding has been raised by the Innovation and Business Intelligence team (primarily through Horizon Europe funding).

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# List of Abbreviations

| | |
|---|---|
| AHSS | Advanced high strength steels |
| CRM | Critical Raw Materials |
| DRC | Democratic Republic Congo |
| E-LCA | Environmental life cycle assessment |
| ERMA | European Raw Materials Alliance |
| ESG-factors | Environmental, Social and Governance-factors |
| HSS | High-strength steels |
| KAVA | KIC Added Value Activities |
| KIC | Knowledge and Innovation Community |
| PEFC | Polymer electrolyte fuel cells |
| PGMs | Platinum Group Metals |
| RACE | Raw Materials and Circular Economy Expedition |
| REE | Rare Earth Elements |
| S-LCA | Social life cycle assessment |
| SLO | Social Licence to Operate |
| SOFC | Solid oxide fuel cells |
| UHSS | Ultra-high-strength steels |
| WEEE | Waste electric and electronic equipment |