# Materials for Energy Storage and Conversion
# A European Call for Action

A report by the Materials for Energy Storage and Conversion Cluster of the European Raw Materials Alliance

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A report by the Materials for Energy Storage and Conversion Cluster of the European Raw Materials Alliance.
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# Foreword

Climate change calls for a bold and swift transformation of the economy. With metals and minerals being key enablers of the European Green Deal and for the shift from a linear brown to a circular green economy, the challenge to secure the present and the exponentially growing future supplies of raw materials has been elevated to the very top of the political agenda.

The last 2 years have witnessed a sudden rise in geopolitical fractures and instabilities that has shaken Europe to its core. Now, unquestionably, Europe must grow its domestic capacities and develop raw materials into a major strength. In accordance with the REPowerEU Plan, a series of measures need to be implemented to speed up the green transition and spur massive investment in the raw materials sector to enable Europe's renewable energy growth ambitions. The proposed legislative framework outlined in the Critical Raw Materials Act, to which EIT RawMaterials and the European Raw Materials Alliance (ERMA) contributed their recommendations, sends a clear signal that momentum for developing raw materials as a strength in Europe is well underway.

**Bernd Schäfer**
CEO, Managing Director
EIT RawMaterials

In the context of the twin green and digital transition, Europe must anticipate and quantify the enormous raw materials investment needs that are necessary to feed the transformational requirements for electrification and energy storage. With the rise of solar, wind and fuel cell technologies, an increased volume of renewable energy will be produced, which will require huge quantities of raw materials and metals, many of which are critical and not found easily in Europe. Energy storage and energy conversion are important as the technology allows us to use energy when we need it, and when it is not being generated at any given moment. Many sources of energy, such as wind and solar power, are intermittent, meaning that they are not always available or consistent. Energy storage and conversion systems therefore help to support the variability of these sources and ensure that energy is available when needed.

This European Call for Action on Energy Storage and Conversion is the culmination of a highly open and inclusive process involving over 100 ERMA stakeholders, ranging from industry, public and private sector research and technology organisations, academia, and civil society.

More than ever, EIT RawMaterials and ERMA are committed to supporting Europe's swift and bold transition towards a circular economy by reducing our dependence on fossil fuels and mitigating the effects of climate change. Together with its 700 partners, ERMA has now developed two key actions for establishing world-leading strategic raw materials value chains in Europe, identifying almost 50 investment cases, with a total investment need exceeding €15 billion. If realised, many of Europe's raw materials needs could be sourced from within the EU by 2030.

On behalf of EIT RawMaterials and in deep recognition and gratitude of the immense and invaluable contribution of the ERMA stakeholder community in developing this Action Plan, I am proud to introduce the European Call for Action on Energy Storage and Conversion.

"I wish to thank the Task Force leaders and the over 100 individuals who have contributed to this document for their insight and dedication during the last two years. This Action Plan is the voice of the ERMA community. It outlines concrete and pragmatic actions and recommendations that, if followed through, will be a fundamental step towards achieving the ambitious goals of the Green Deal."

**Fabio Pegorin,** EIT RawMaterials, Action Plan Coordinator

"This action plan provides concrete recommendations to fulfill the ambitions outlined in recent EU policies. Together with the Cluster 1 Action Plan, it will be updated regularly to keep pace with the rapidly changing technologies and geopolitical and market conditions. It provides the baseline information and the concrete industry-led projects to support the European Commission with the definition and selection of projects of strategic importance. It highlights the vibrant capacity and diversity of the ERMA community."

**Massimo Gasparon,** EIT RawMaterials, representing the ERMA community

# Contents



# KEY FACTS

As part of the REPowerEU plan, the EU aims to bring over 320 GW of solar photovoltaics online by 2025 and almost 600 GW by 2030. These frontloaded additional capacities displace the consumption of 9 billion cubic metres of natural gas annually by 2027.

Batteries are expected to reach 965 GWh production in Europe by 2030. The mineral demand for battery storage-related materials is to increase drastically by 2040 compared to 2020. For manganese, nickel, cobalt, graphite and lithium, the projected estimates range between 7 and 40 times the 2020 demand by 2040 worldwide.

Recycling of battery materials could provide between 45 and 77 percent of the EU supply by 2050.

The REPowerEU programme aims at doubling the EU's 2030 domestic renewable hydrogen production target to 10 million tonnes, requiring in the region 80 GW of electrolysis, with an additional 10 million tonnes in imports.

REPowerEU aims at increasing the 480 GW target of wind power deployment by 20 percent by 2030 - set in the Fit For 55 package for a total of almost 600 GW.

The Critical Raw Materials Act proposed regulation benchmarks for domestic capacity by 2030: at least 10% of the EU's annual consumption for extraction; at least 40% of the EU's annual consumption for processing; at least 15% of the EU's annual consumption for recycling; no more than 65% of the EU's annual consumption from a single third country.

## Executive Summary

**THE CHALLENGE:** The ongoing Russian invasion of Ukraine has further highlighted the EU's dependence on Russian gas and vulnerability in the supply of raw materials that are essential for the twin transition. Forecasts of the demands of raw materials made before 24 February 2022 had to be updated in view of the need to accelerate this transition and find alternative energy sources – both from within and outside of Europe – to compensate for the loss of Russian gas and oil. Thus, the sustainable supply of raw materials has become imperative not only for the achievement of the EU Green Deal but, most importantly, to maintain the social stability and cohesion of the EU. As the energy transition gains momentum toward reaching the goal of net-zero carbon emissions by 2050, market projections expect between a seven-fold and a forty-fold overall increase in mineral and metal demands for clean energy technologies by 2040 following the International Energy Agency's (IEA) Sustainable Development Scenario (SDS). Complementary to growing EU domestic raw materials sourcing and diversified EU supplies, there is also the need for an overall energy storage capacity increase to support the ambitious targets of a clean and green EU economy. A considerable ramp-up of storage and conversion capacity within the sector must take place to further reduce fossil fuel dependencies, boost energy efficiencies and capture the existing recycling capabilities.

*"The production of graphite, cobalt and lithium may increase by nearly 500 percent by 2050, to meet the demand for clean energy technologies." Minerals for Climate Action - The Mineral Intensity of the Clean Energy Transition, World Bank Report, 2020*

With the unprovoked Russian invasion of Ukraine and the recent energy crisis, in past months European natural gas has been nearly 18 times as expensive as it was in 2019, causing titanic shifts to the raw materials supply and demand landscape, whilst jeopardising existing European energy-intensive metals industries. Necessary investments in the raw materials sector have been prevented by the absence of long-term supply contracts and off-take agreements. To bridge the compatibility of investments with long-term supply contracts, investment security and incentives must be created on the part of producers and customers. Today, there is limited primary production within the EU and, for some materials related to energy storage, the EU relies almost entirely on imports. There is also a significant lack of recycling facilities across Europe which, by 2050, could potentially become the main source for supplying an increasing demand for raw materials. To lead Europe out of this dilemma, European capacities must be built and promoted immediately without hesitation.

To address the most prominent and urgent raw materials challenges for Europe, the European Raw Materials Alliance (ERMA) has successfully established its second thematic Cluster on Materials for Energy Storage and Conversion. This Cluster follows the successful launch of the call for action on Rare Earth Magnets and Motors published in 2021, from which many of the recommendations made by ERMA have already been adopted in several important policy documents, and indeed have contributed to their content and concrete actions. To date, a rare earth pipeline has been de-risked and is estimated to be able to supply at least 20 percent of Europe's permanent magnet needs by 2030. According to the European Commission, ERMA's expertise has proven valuable for identifying gaps and regulatory barriers or bottlenecks that need to be addressed along the relevant supply chains, to assess investment needs, build project pipelines and mobilise investments in strategic areas and technologies, particularly in the area of the batteries supply chain.

In the context of the twin green and digital transition, this Action Plan focusses on anticipating and quantifying the enormous raw materials investment needs, necessary to feed the transformational requirements for electrification and energy storage. Importantly, it is the advancement of sophisticated new storage and conversion solutions that will be integral to the energy transition, and it is the very technologies like solar, wind and fuel cells that are required to convert or store energy which require high volumes of raw materials, many of which are critical and not within easy reach for Europe.

This Action Plan, 'Materials for Energy Storage and Conversion', highlights the implementation of specific and measurable actions by respective task forces that represent key stakeholders from industry, public and private-sector research and technology organisations, academia, and civil society. It presents the first clear execution roadmap for addressing the entire value chains, from exploration to recycling, supported by specific recommendations and actions across four primary strategic areas: Materials in Solar Energy, Battery Materials, Fuel Cells & Electrolysers and Alternative Energy Storage & Conversion.


Materials in Solar Energy


Battery Materials


Fuel Cells and Electrolysers

Alternative Energy Storage & Conversion

By means of an open and inclusive approach, the insights of all stakeholder groups were incorporated, and priorities were identified, focusing on the most strategically important and impactful actions to boost European energy conversion and storage in alignment with key EU initiatives. Such initiatives include the European Green Deal, the newly released Critical Raw Materials (CRM) Act, the Net-Zero Industry Act and Critical Raw Materials for Strategic Technologies and Sectors in the EU – A Foresight Study, supporting also the ambitious mission set within the Fit for 55 package (Versailles Declaration, Bentele Report) and the latest REPowerEU action plan.

**OUR RESPONSE**: To address these challenges, unlock potential and create synergies, more than 200 members from industry, research and technology organisations (RTOs), academia, and civil society present this Action Plan to highlight investments and opportunities, and address bottlenecks and gaps across the four primary Strategic Action Areas: (1) Materials in Solar Energy, (2) Battery Materials, (3) Fuel Cells and Electrolysers, and (4) Alternative Energy Storage and Conversion.

The recommendations and actions described in this action plan are designed to create **a more resilient, responsible, and sustainable energy storage and conversion sector** that can power the transition to a cleaner, greener, and more circular society. These recommendations are in line with those submitted by the ERMA and EIT RawMaterials communities is response to the consultation process for the CRM Act, which was released in March 2023. They, therefore, represent the views of over 700 stakeholders across EU and extra-EU industry, academia, research, NGOs, industrial associations and government organizations.

*"This Act will bring us closer to our climate ambitions. It will significantly improve the refining, processing and recycling of critical raw materials here in Europe. Raw materials are vital for manufacturing key technologies for our twin transition – like wind power generation, hydrogen storage or batteries." President of the European Commission, Ursula von der Leyen, 2023*

**Key actions listed under the CRM Act's proposal are the setting of benchmarks by 2030 for domestic capacities, and can be summarized as follows:**

- **at least 10% of the EU's annual consumption for extraction**
- **at least 40% of the EU's annual consumption for processing**
- **at least 15% of the EU's annual consumption for recycling**
- **no more than 65% of the EU's annual consumption from a single third country**

**The following table outlines the key deliverables for achieving a sustainable energy storage and conversion sector:**

### Materials in Solar Energy

- Increased access to raw materials for a strong EU PV panel manufacturing sector reaching 20 GW by 2025
- A strong EU circular solar industry with recovery of >2.000 t/GW of high-purity silicon by 2030
- Reduced carbon footprint of European panels production
- Reduce or substitute critical raw materials (CRM) in solar energy EU products
- Ensure a high collection rate to maximise secondary raw material production

### Battery Materials

- Strengthen the EU batteries ecosystem
- Reach a near 100 percent collection and recycling target for EV batteries
- Specific raw material needs to reach the 965 GWh/a goal: Si, Ni, LCE, Co, Mn, Graphite

### Fuel Cells & Electrolysers

- Build Europe's global innovation leadership in fuel cells & electrolysers, facilitating a less resource-intensive roll-out of the EU Hydrogen Strategy
- Increased potential for large-capacity energy storage facilities
- Achieve target of > 95 percent material recovery for PGMs, > 90 percent for Co and REE

### Alternative Energy Storage & Conversion

- Scaled up from GWh to TWh-scale energy storage capacity (geological cavities)
- Meet the energy use target of ca. 900 TWh of combined ocean/hydro/geo/air storage and conversion by 2030



While it is true that significant capacity exists within the EU, international partnerships need to be further developed to ensure diversification of supply and to address short-term as well as long-term gaps for some materials. Furthermore, most ERMA stakeholders identified permitting as one of the most crucial bottlenecks in the development of domestic resources and processing capacity. The CRM Act's intention to streamline and set a strict timeframe for permitting, in line with the recommendations made by the ERMA community, is a very welcome positive development.

As a result of the work of its two Action Plans, ERMA has identified almost 50 investment cases targeting materials for energy storage and conversion across Europe and beyond and a total investment need exceeding EUR 15 billion. If these projects were realised, up to 100 percent of Europe's needs for some materials could be sourced from the EU by 2030, which is a sure sign of the infinite potential for Europe that lies ahead.

## Market Development and Policy Context

New and advanced storage and conversion solutions are the cornerstones of the energy transition that is essential to limit global warming to 1.5°C above pre-industrial levels (1). The technologies to convert or store energy require a broad range of raw and advanced materials that are either critical because of geopolitical reasons or at risk of facing severe supply-demand gaps during the next few decades. Europe will need significant investment to secure the supply of these raw and advanced materials, as well as an effective policy framework to support these investments.

On 14 July 2021, the European Commission presented a package of climate-related legislative and policy actions known as the Fit for 55. This package aims to reduce EU greenhouse gas emissions by at least 55 percent by 2030 compared to 1990 levels (2). Apart from emission reduction, the Fit for 55 package includes concrete targets for energy storage and conversion, including electric mobility and renewable energy. Vehicles running on fossil fuels are expected to phase out as only zero-emission, new vehicles are expected to be sold from 2035 onwards. An overall target of 40 percent (increased now to 45 percent under the REPowerEU programme (3)) for energy from renewable sources is also set in the package, indicating a significant increase in wind and solar power capacity.

The Fit for 55 package requires a shift to a clean, green and, eventually, a net-zero emission energy economy, which inherently implies a significant increase in the demand for minerals and metals. Hence, a resilient European raw materials sector is the primary enabler of carbon emissions reduction. A transition away from a fossil fuel-based energy economy will, in the next decade, be based on energy conversion technologies such as solar, wind and fuel cells, as well as energy storage in various forms such as batteries and hydrogen (4)(5).

For the above-mentioned energy storage and conversion technologies to reach a sufficient level of investment that guarantees a 45 percent renewable share of the total European energy mix by 2030, it is critical to address strategic developments, technical innovation potentials, regulatory bottlenecks, environmental concerns, and civil society aspects.

*"Since 2010, the average amount of minerals needed for a new unit of power generation capacity has increased by 50 percent as the share of renewables has risen." International Energy Agency, 2021.*

Several EU initiatives and regulatory frameworks such as the European Green Deal, the Batteries Regulation, the New Industrial Strategy and the EU Taxonomy for Sustainable Activities have already set ambitious goals to which the ERMA stakeholder engagement process and investment platform can contribute and set additional tailor-made targets for the European raw materials sector. More recently, Russia's invasion of Ukraine triggered REPowerEU, a joint European action to make Europe independent from Russian fossil fuels well before 2030, thus increasing the urgency to secure the supply of materials required for the twin energy transition.

*"It is time we tackle our vulnerabilities and rapidly become more independent in our energy choices. Let's dash into renewable energy at lightning speed. Renewables are a cheap, clean, and potentially endless source of energy and instead of funding the fossil fuel industry elsewhere, they create jobs here." Frans Timmermans, Executive Vice-President for the European Green Deal, at the launch of REPowerEU on 8 March 2022*

While the EU material demand for energy storage and conversion is expected to grow significantly, many European mines will come to the end of their lifetime within the next 20 years (6). Domestic production of Copper, Nickel, and Zinc will be halved by 2040 unless prospecting efforts are significantly increased both in current operating mines and new deposits, while demand will grow at a much faster pace than ever before. If mine production in Europe is halved, then by 2040, European smelters would operate on only 10 percent European-sourced materials: the already long and vulnerable value chains serving the European industries would rely increasingly on foreign countries working to take global leadership by capturing natural resources used by European industries. To reverse these trends, and in response to the increasingly unstable geopolitical situation, the EU published the Net-Zero Industry Act and the Critical Raw Materials Act on 16 March 2023 (7)(8). These are arguably among the most significant policies released by the European Commission in recent times, and will be guiding documents for the materials and energy sectors in the foreseeable future.

These Acts demostrate that access to critical and strategic raw materials has now become a top priority for the EU. The Critical Raw Materials Act particularly highlights the importance of strengthening the domestic value chain, diversifying the EU's import of critical and strategic materials and better monitoring supply risks. The Critical Raw Materials Act is the culmination of a series of positive actions taken by the Commission and Member States, in full alignments with ERMA's joint efforts in terms of raw materials advocacy, consultation, and stakeholder mobilization

The sustainability of mining operations is also becoming an increasingly important matter. The achievement of sustainability undoubtedly requires control and operation of upstream activities and businesses with a responsible, smart, and innovative approach.

*"I believe that the reasons to explore sustainable mining in the EU are not only of economic and geopolitical nature. We also have a moral obligation." European Commissioner for Internal Market, Thierry Breton, at the Raw Material Summit 2021.*

The increased strategic importance of metals and minerals is reflected by a continuously growing list of critical raw materials (CRMs, published by the European Commission 2020 and updated in 2023). The expected increase in demand for several CRMs that are pivotal for the twin transition (green and digital) is evident in high compound annual growth rates (CAGR). The projected estimates for manganese, nickel, cobalt, graphite and lithium range between seven and fourty times the 2020 demand by 2040 worldwide.

The set of actions proposed in this Action Plan will have a profound impact on the European green energy and mobility industries in four distinct yet interrelated value chains. First, a more established and resource-efficient **solar energy sector** is instrumental in the shift toward clean and green energy. Europe has the potential to source many of the key raw materials (e.g., silicon) domestically. Increasing recycling efforts, backed by legislative actions and technology-driven advancement can unlock the full potential in this sector.

Second, a strengthened ecosystem will facilitate the installation of **battery materials processing** capacities, especially where other world regions would have a head start with standard technologies. In particular, the financing actions will render the investment cases for battery material processing more attractive (avoiding investment leakage), given the long lead times of such investments starting from the research and ideation phase to an investment that pays off. The neglect of these cases would have dire consequences. Competitiveness would be stifled on the grounds of sustainability where the EU would have a huge advantage over the rest of the world, and the likelihood of investment projects being implemented would be higher in other world regions where access to finance and raw materials (e.g., lithium salts) might find stronger support or fewer import hurdles.

Third, a strengthened ecosystem in the **fuel cell and electrolyser industry** is a key component of the proposed actions. This will lead to measurable impact in terms of cost reduction due to reduced costs in sourcing and production and improved synergies that drive the R&D efforts in this sector. Staying ahead of the competition is crucial in this emerging sector.

The **alternative energy storage & conversion** will benefit hugely from R&D-related actions that will translate into potentially significant GWh to TWh-scale energy storage capacities to cover the seasonal volatility of renewable energies and ensure strategic energy security. Decisive and timely actions in this sector have the potential to establish Europe as a world leader in the field. Advanced materials and storage and conversion solutions can furthermore lead to double-digit energy savings in the clean energy sector.

While we acknowledge that the increased use of **wind energy** is central to the European climate goals, questions regarding the raw materials related to wind power have been covered in previous work by ERMA in the Cluster 1 Action Plan on Rare Earth Magnets and Motors. A summary of the work can be found at the end of this Action Plan.

Most ERMA stakeholders identified permitting as one of the most crucial bottlenecks in the development of domestic resources and processing capacity. The uncertainty associated with the timing and outcomes of the permitting process introduces a very high level of risk for potential investors, thus preventing many otherwise viable projects from being implemented. Many European countries have no time limits for environmental permit handling, and different aspects of permit applications are often handled by different authorities that work independently. While it is absolutely crucial that that public be given the opportunity to scrutinize permit applications and appeal permit decisions, it is equally crucial that these processes be streamlined. The Critical Raw Materials Act's intention to streamline and set a strict timeframe for permitting, in line with the recommendations made by the ERMA community, is a very welcome positive development.

## ERMA Investment pipeline

To increase Europe's strategic autonomy in Materials for Energy Storage and Conversion, the EU will need to address the entire value chain. This involves the boosting of exploration, mining, separation, and processing and the building of a circular economy around materials for energy storage and conversion by advancing ecodesign requirements, waste collection, recycling activities. Today, there is limited primary production within the EU and for some materials related to energy storage, the EU relies almost entirely on imports. There is also a significant lack of recycling facilities across Europe which, by 2050, could potentially become the main source for supplying an increasing demand for critical raw materials.

As of May 2023, ERMA has identified over 50 investment cases targeting materials for energy storage and conversion across Europe and beyond and a total investment need exceeding EUR 15 billion (Figure 1). If these projects were realised, a significant percentage amount for some materials could be sourced from the EU by 2030, that is, significantly higher than today and, for some materials, even higher than the targets set in the Critical Raw Materials Act. This is illustrated in Figure 2, where global and EU demand and production data for 2020 are compared with forecasted global and EU demand data for 2030 for a selected group of critical and strategic materials.

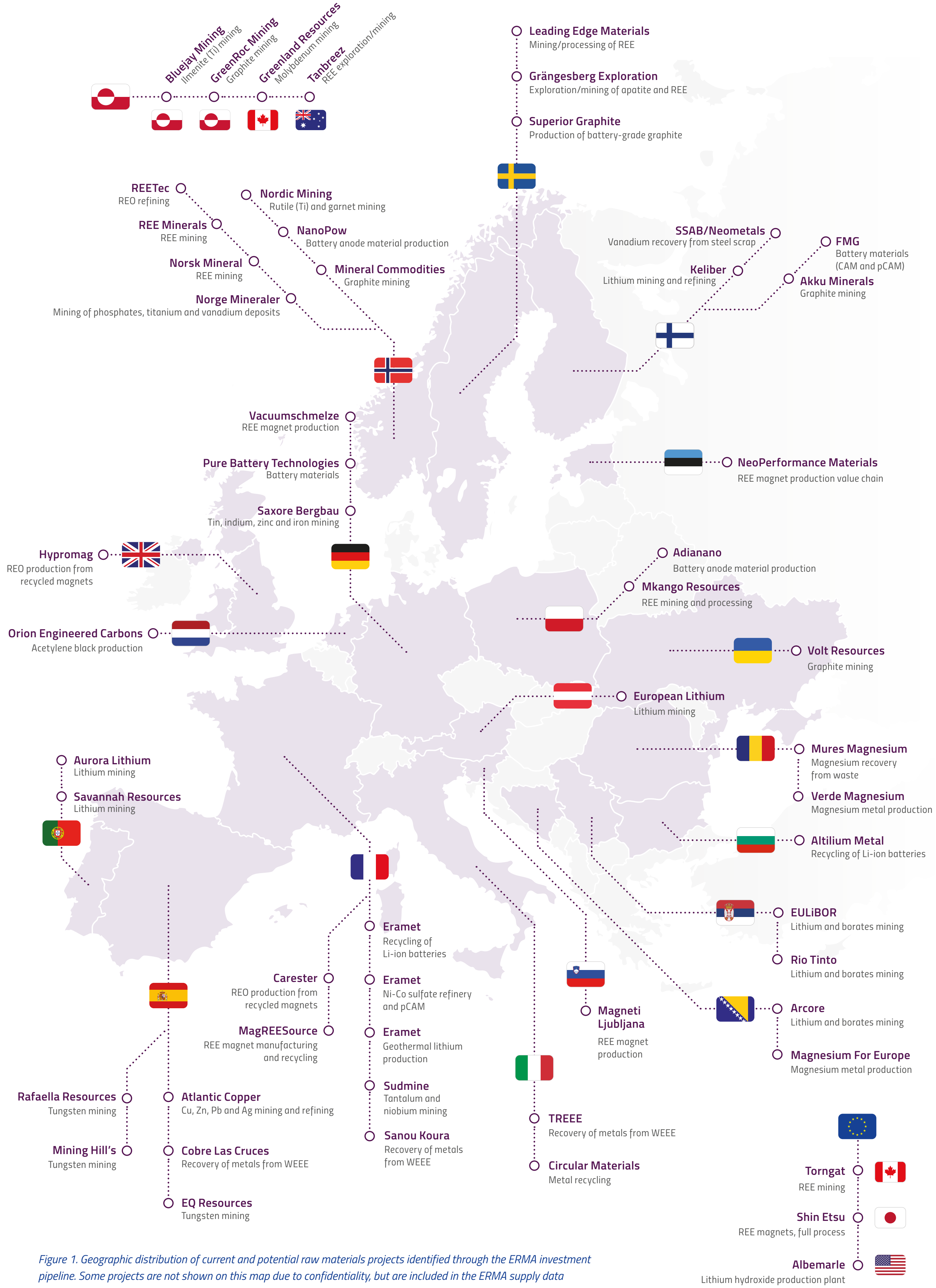



*Figure 1. Geographic distribution of current and potential raw materials projects identified through the ERMA investment pipeline. Some projects are not shown on this map due to confidentiality, but are included in the ERMA supply data reported in this document and in the high-level ERMA investment needs shown in Figures 2 and 4.*

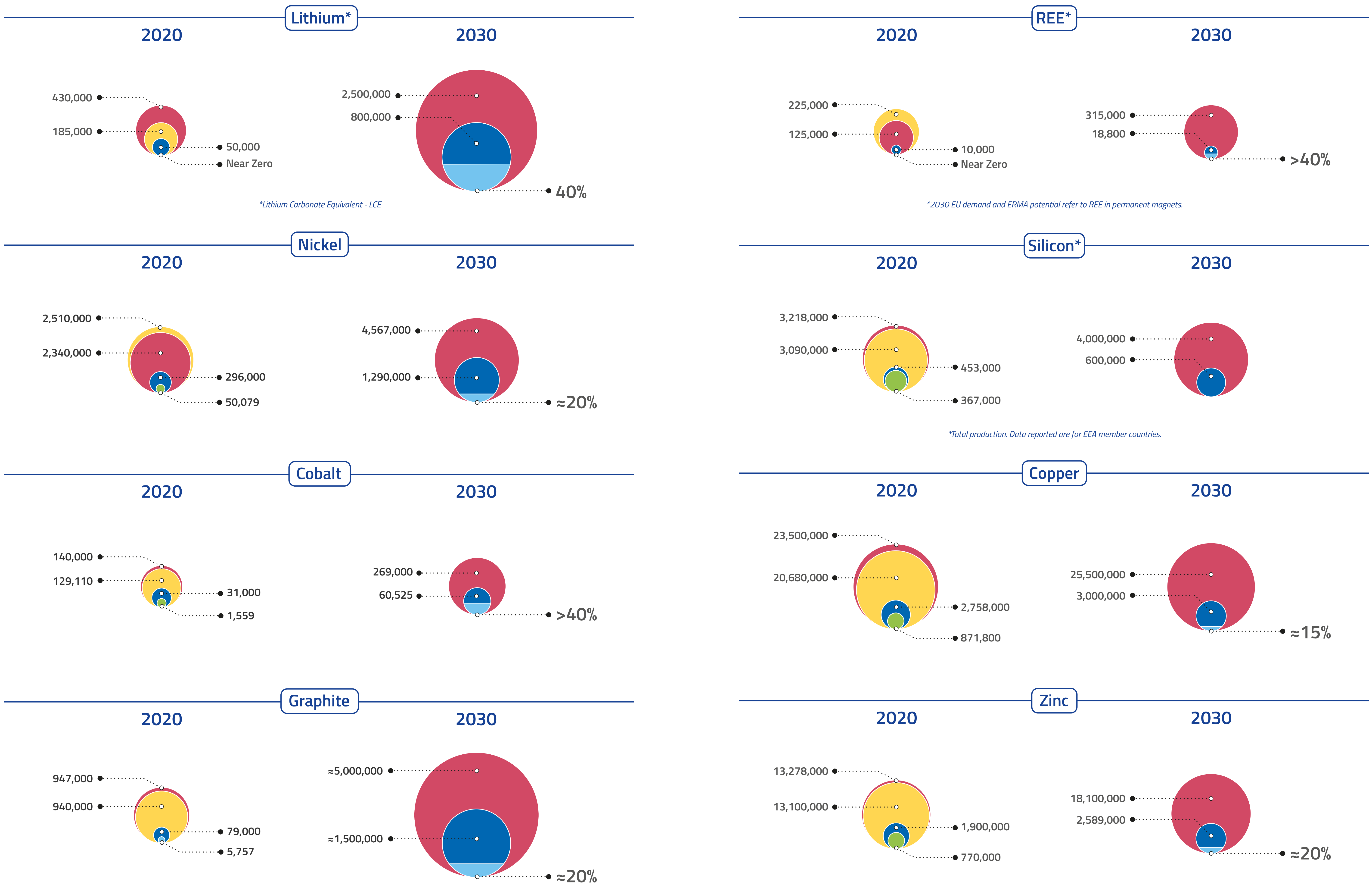



*Figure 2. Global and EU demand and production data for 2020, compared with forecasted 2030 global and EU demand and potential supply from projects identified through the ERMA investment pipeline, for a selected group of critical and strategic materials. All values in metric tonnes. Source: World Mining Data and other EIT RawMaterials internal and external sources.*

Besides highlighting the forecasted EU demand in 2030 relative to current production, the figure shows that the ERMA cases identified to date can supply a very significant proportion of the EU demand. The values reported in Figure 2 are based on the current assumptions in terms of relative proportions of energy sources and battery types, as outlined in Figure 3. Figure 4 further shows that ERMA investments are distributed not only across Europe and among different materials, but also, most importantly, across value chains. This is in line with ERMA's strategy to build up capacity and skills across all stages of the value chain, from exploration to mining, processing, manufacturing and recycling. More investment cases will be submitted to ERMA in the coming months and years, potentially increasing the overall materials for energy storage and conversion production and recycling capacity in Europe across the various CRMs value chains.

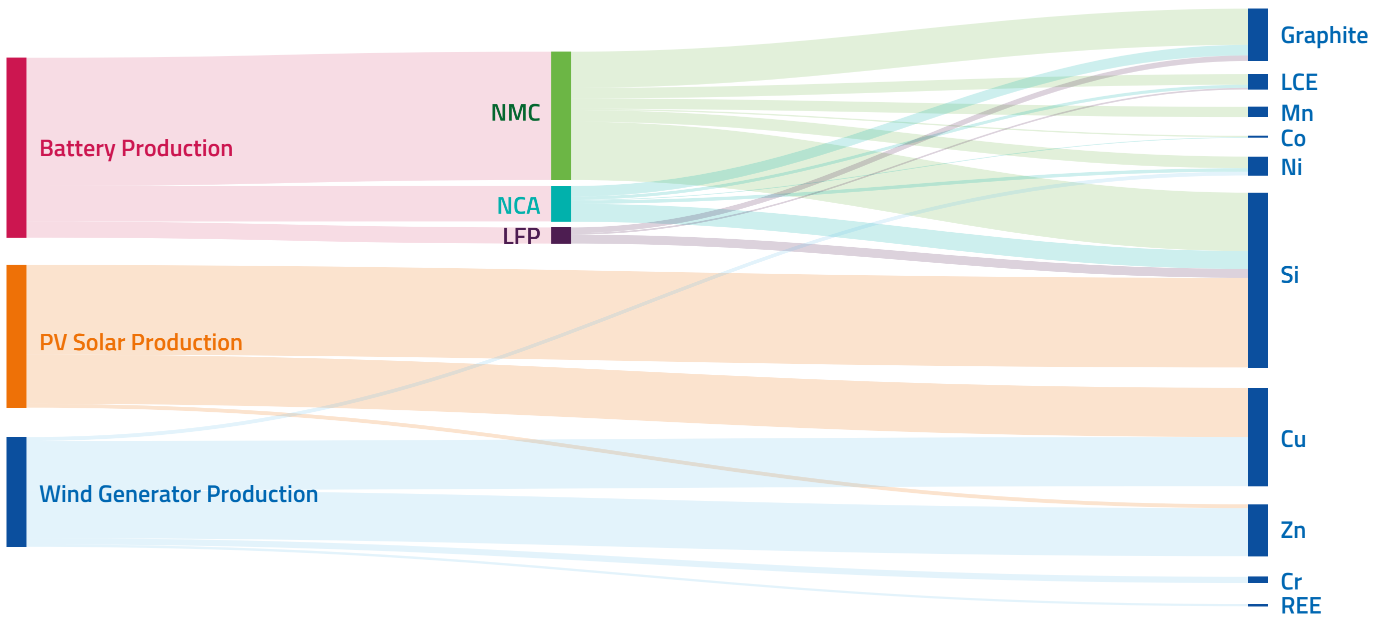



*Figure 3. Link between technologies used for energy storage and conversion and raw materials needs, based on current assumptions regarding the energy mix and battery chemistries (NMC - Nickel-Manganese-Cobalt; NCA - Nickel-Cobalt-Aluminium: and LFP - Lithium-Iron-Phosphate). The need of raw materials for the production of batteries will be affected significantly by the market share of specific battery chemistry mixes.*

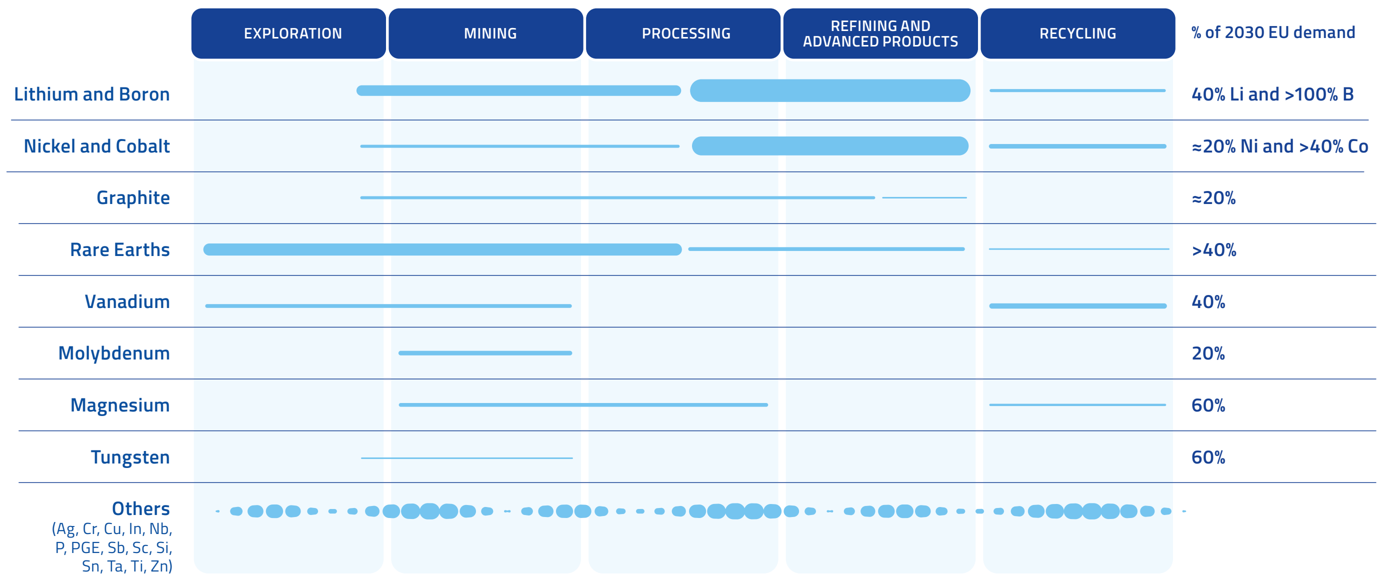



*Figure 4. High-level view of the distribution of ERMA investment cases for a selected group of critical and strategic materials across the value chains. The size of the bars is proportional to the investment needed for the various projects.*



## Access to raw materials and EU strategic partnerships

In recent times, raw materials have forcefully come to the attention of the public and policymakers. There is now an increased awareness of the risks associated with potential disruptions in the supply chains that underpin the EU's economic prosperity, social stability and safety.

While it is true that significant capacity exists within the EU, international partnerships need to be further developed to ensure diversification of supply and to address short-term as well as long-term gaps for some materials. International partnerships need to be developed in harmony and synergy with the support provided by the EU and Member States to develop domestic resources. In this context, ERMA is multiplying its international strategic partnerships and outreach activities, both in terms of membership and in the leadership of investment cases (Figure 5). In line with the European Commission's outreach strategy, ERMA is a key player in the partnership with Canada and has been a driving force in the Memorandum of Understanding between the European Union and Ukraine on a Strategic Partnership on Raw Materials. Other non-EU countries of strategic relevance for ERMA include Kazakhstan and Namibia, and several countries with partnerships in the pipeline (Greenland and Norway) or already announced (Argentina, Australia, Chile, Democratic Republic of Congo and Rwanda).

Besides its industry support for individual investment cases, ERMA is assisting the European Commission with the identification of emerging technologies and research topics that will restore the EU's know-how and innovation capacity. These include, among others, exploration, mining, processing, and recycling of materials used in solar energy, wind energy and hydrogen-related technologies.

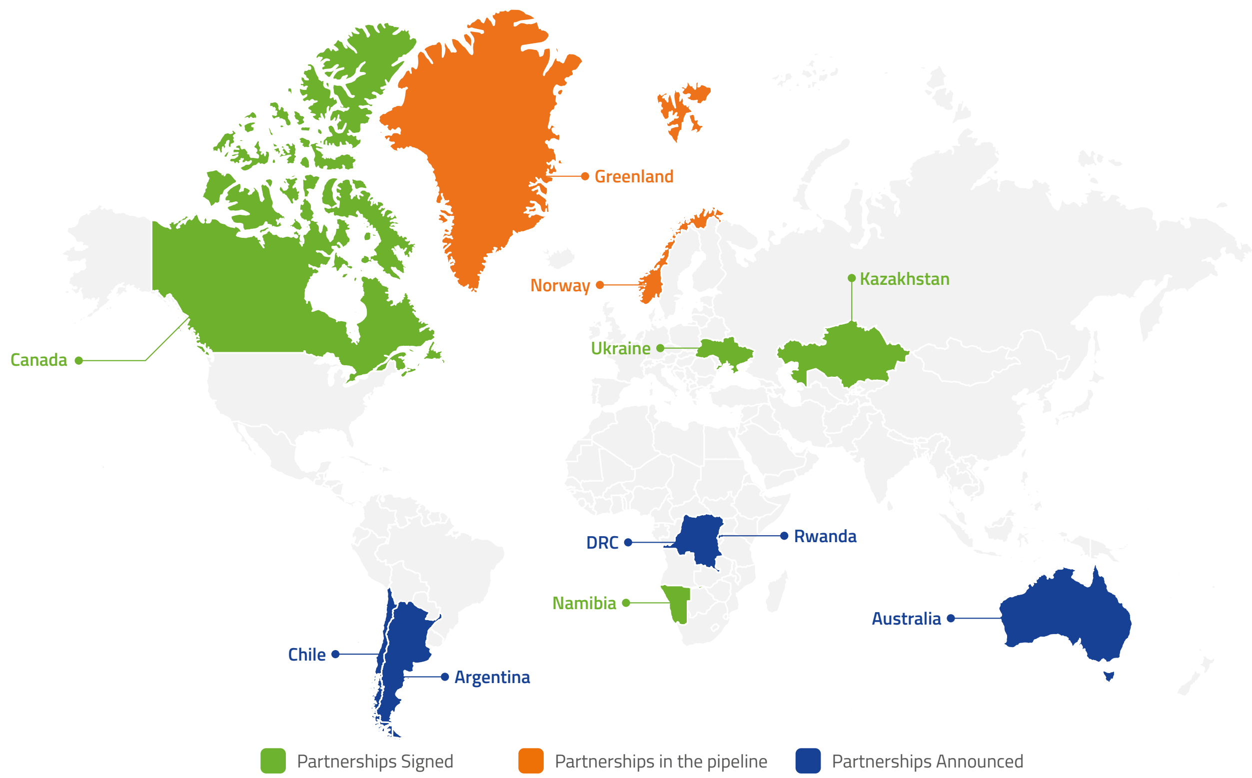



*Figure 5. Current and future EU-International strategic partnerships in the raw materials sector. Source: European Commission.*

## Action Plan Framework

This section presents the results of the stakeholder engagement and consultation process, in which a Task Force was established around each of the four selected technology areas within energy conversion and storage: Materials in Solar Conversion, Battery Materials, Fuel Cells and Electrolysers and Alternative Energy Storage and Conversion. In what follows, each technology area is described with respect to its raw materials supply-demand gaps, ERMA and its members' potential capacity to close those gaps, the required actions to be taken, and the broad impacts that can be expected as a result of taking these actions. Each of the four consecutive sections lists several macro action areas with a number of specific actions and impacts expected from the implementation of the specific actions. Within the macro action area, roles and responsibilities are identified and an overview of existing and relevant initiatives and projects is provided. The technology areas identified share the imperative need to **ensure secure and reliable access to raw materials for energy storage and conversion** through primary sourcing. The impacts delivered by the achievement of this imperative have direct consequences on the four technology areas.

**The key ERMA actions identified across the four technology areas are summarised below:**

**Continue to foster societal acceptance of mining projects across Europe**. This includes the roll-out of targeted public relations (PR) and information campaigns across Europe, the involvement of local communities in early-stage developments and communication actions on mining regulations and standards of responsible mining. Acceptance of local communities is one of the biggest hurdles for mining projects in Europe. The PR campaign requires time and resources that owners of smaller projects normally cannot access. This is a joint action between mining companies, supply chain stakeholder communities and Member States' public authorities. There is a need to create a normative process that the local stakeholders can refer to, with independent third parties mediating. As part of this process, a scientific board should be established, where a mining project proposal is reviewed for its social, environmental, and economic sustainability, including the voices of those not in favour of the project.

**Secure raw materials supply by facilitating the opening of new mines**, including access to investment by private and government co-funding. Where possible, national mining regulations should be updated to better support the raw materials needs of the Fit for 55 and REPowerEU targets.

**Increase EU recycling capacity through the development of new technologies** to their full potential by increasing the share of public funding channelled to Research and Innovation (R&I) on the circularity of materials for storage and conversion. Dedicated recycling and refining technologies should be developed to maximize recovery and cost-competitiveness and to reduce environmental footprint.

**Facilitate the diversification of raw materials supply by mobilising EU diplomacy (i.e., build strong relationships with resource-rich countries)**. EU manufacturers need access to raw materials to redevelop production in globally competitive conditions. This access should be secured, and resilience of the supply should be established, for instance in cases of major disruptions to the supply chain as seen during the COVID-19 pandemic and the Russian military invasion of Ukraine. Where necessary, the EU should support European manufacturers in diversifying their supply. To this end, a clear mapping of current supply locations of raw materials should be established as well as criticality mitigation strategies on a systemic level (e.g., trade agreements, secondary markets).



**Strengthen the transparency and sustainability of global solar supply chains, starting with silicon, from extraction to recycling**. End-users need better visibility of the origin and sustainability of the raw materials they use (for manufacturers) or that are in the end products (for EU developers). Therefore, we need to improve transparency in solar value chains. An industry-led initiative should be encouraged – for instance, with standard policies for sustainable procurement practice. The EU's upcoming initiatives on sustainable corporate governance and the SPI for Solar will support such increased transparency on value chains.

**Provide a highly skilled workforce across the energy storage and conversion sectors to reduce a most urgent skill gap**. Increasing green energy production targets not only imply an increase of demand for critical raw materials but also and as critically the demand for EU-based skills and competences. It is foreseen that the solar sector alone will require by 2030 over a million of people working in the field compared to just over 700,000 today. For the battery production alone 10 million jobs will be created by 2030; this is around the same employment for the entire automotive industry alone today.

**Develop and roll out digital tools to monitor material and waste flows throughout the whole value chain via Industry 4.0 approaches (e.g., IoT, blockchain)**. Data on materials needs to be further acquired on all life cycle phases, inclusive of the use phase, to evaluate raw material efficiency and circularity potential.

# MATERIALS IN SOLAR ENERGY

## Introduction

**THE CHALLENGE**: Solar energy is one of the crucial components for achieving the EU transition towards a low-carbon economy. According to the International Energy Agency (IEA), solar PV generation increased globally by a record 156 TWh (23 percent) in 2020 to reach 821 TWh (10). The solar PV market is set to continue growing exponentially, making solar PV the first installed capacity in Europe, according to the IEA.

As part of its Fit for 55 Package (2), the European Commission has proposed a 40 percent renewable energy target which would correspond to 497 TW of installed solar capacity by 2030 (11). This means a yearly average generation growth of 24 percent from 2020 to 2030, aligning with IEA estimates (International Energy Agency, 2021b).

Recently, the launch of REPowerEU by the European Commission, with a plan to make Europe independent from Russian fossil fuels well before 2030, has increased the need for a fast rampup of solar energy production capacity.

As part of the REPowerEU plan, the EU aims to bring online over 320 GW of solar photovoltaic by 2025 and almost 600 GW by 2030. These frontloaded additional capacities displace the consumption of 9 bcm of natural gas annually by 2027. Others believe that with the right framework, 1 TW of installed capacity is within reach (12)(13).

## Demand for Raw Materials in Solar Energy

The necessary annual growth rate will have a huge impact on the raw materials demand. Access to products manufactured with affordable and sustainable raw materials will be critical for the EU solar project developers. Some raw materials can heavily influence the costs of end products – for instance, silver represents 10 percent of the cost of an end module today – which means that an increase in the cost of silver can heavily influence the price of the end product. In addition, to ensure a coherent green transition and to respond to societal expectations, it will be critical to ensure that solar products are sustainable along the value chain.

As highlighted in the Updated Industrial Strategy and the Clean Energy Competitiveness report, Europe should reinvest in a sizeable manufacturing capacity for solar PV products, from polysilicon to module assembly. Most of the manufacturing value chain of solar panels takes place in China but Europe does have competitive advantages:

- Around 11 percent of PV silicon was produced in Europe and 15 percent of the PV market installations were made in Europe in 2020 (14).
- Europe's research and innovation, together with Japan and South Korea, leads the development of emerging technologies, such as heterojunction and perovskite technologies (15).
- Europe still has some production capacity along the value chain (ingots, wafers) as well as a diversified industrial ecosystem for module production.

A wave of reinvestment has started in Europe, with several cell and module factory projects reopening (e.g., Meyer Burger, Oxford PV, 3Sun Factory). The European Solar Initiative, an industrial alliance launched and endorsed by the Updated Industrial Strategy for Europe, has set an objective to re-establish 20 GW of manufacturing capacity, from polysilicon, ingots, wafers, and cells to modules, by 2025. To realise this objective, access to sustainable raw materials for EU domestic manufacturers must be secured to maintain a level playing field with global competitors.

## Investment

Global average annual solar PV investment needs to scale up by 68 percent by 2050 (USD 192 billion/year) compared to 2018 investment (USD 114 billion/year). For Europe, this represents USD 19 billion per year (16). Investment in solar PV can be made more attractive by (1) creating incentives and value chains in Europe, (2) stimulating innovation and entrepreneurship, (3) preserving and enlarging know-how through education, and (4) optimising reuse, recycling, and upcycling of recovered materials.

## Recycle, Reuse, Circular Design

Reuse of materials during the manufacturing process and recovery of materials in end-of-life products is a potential opportunity to increase access to materials while increasing the circularity of the solar PV industry. By 2050, there will be between 60 and 78 million tons of PV waste in circulation. Most materials can be recycled: 90 percent of a solar panel can be recycled according to the IEA-PVPS (17-19). Yet, the establishment of a proper and economically functioning recycling industry requires investing in recycling capacity and establishing a functioning remuneration framework.

## Skills

According to SolarPower Europe (20)(21), in order to meet the European Commission target of 40 percent renewables by 2030, the need for jobs in the solar sector will increase to between 742,000 to 1.1 million. More efforts are to be deployed in training the workforce with the necessary skills to meet the solar energy target.

## Alignment with existing initiatives and EU projects on Materials in Solar Energy

The **Solar Materials** task force benefits from the insights brought by its members which include four European industry associations of which two are solar industry associations: 1) **SolarPower Europe** (BE), 2) **PVThin** (BE). SolarPower Europe is the largest solar industry association gathering representatives from 40 national associations. Recently, it established the **European Solar Initiative**, an industrial alliance endorsed by the Updated Industrial Strategy for Europe. **PVThin** is an international not-for-profit association based in Belgium, which gathers companies from around the world on thin-film solar technologies and value chains. Its mission is to promote the social and environmental benefits of thin-film PV. These two associations have a strong role in educating policymakers and promoting the adoption of solar technology. Members of the task force are affiliated with these industrial associations. For example, the task force leader comes from **La Mia Energia** (IT), which is an Italian non-profit company formed by a group of SMEs. La Mia Energia is one of the Italian National Consortia for the recovery and recycling of end-of-life photovoltaic modules and is involved in defining guidelines for developing PV panel design and recycling. Other task force members include **9-tech,** a startup supported by EIT RawMaterials that is developing technologies for PV recycling; and **EUROALLIAGES** (BE), an association of European ferro-alloys and silicon producers with members connected to the solar industry such as **Elkem** (NO), **Ferroglobe** (SP), **PCC** (DE), and **RW Silicium** (DE). Other members, covering most parts of Europe, include **Fraunhofer ISE** (DE), Graphnest (PT), Innovando (IT), Oxford PV (UK), Recgroup (NO), ROSI Solar (FR), Tecnalia (SP), TREEE (IT), Ekolive (SL), as well as a senior advisor to the Dutch Ministry of Environment (NL).

## ACTION AREAS AND LINKED MACRO ACTIONS FOR SOLAR ENERGY

### ACTION 1: *Develop a Strategy for Revamping Solar Energy Manufacturing Activities in Europe*

Currently, several projects are aiming at rebuilding PV manufacturing capacities in Europe. However, investments remain limited, especially regarding ingot and wafer production. Even for polysilicon, the significant expansion of production in China threatens the market position of the EU (22). Bringing the entire value chain - from material extraction to processing in modules and end-of-life treatment - back to the EU requires a strong competitive edge and coordinated actions among all industry stakeholders.

### The Role of Member States

**Support a strong demand – an industrial strategy for the processing of raw materials in Europe**. Domestic mining and extraction activities can be reestablished only if there is a strong demand in Europe, meaning domestic manufacturing. The European Solar Initiative and the industrial alliance aimed at supporting the development of manufacturing projects in the EU have been endorsed by the EU and should be further supported.

#### The Impact

Ingot/wafers/cells production in Europe is currently 1% of the world production, and it is estimated to **increase to 14% by 2030**, according to the ERMA task force members. With the re-creation of the production chain ingot-wafer-cell-module, the task force believes that Europe is set to guarantee its future independence from the dominance of Chinese imports in the solar industry. Europe could secure 20 GWp by 2025 and 60 GWp by 2030 with EU-made PV panels.

**Increase PV manufacturing in the EU via investments and tax schemes**. Investments are required to build local PV manufacturing capacities. The ESMC believes that 75 percent of European PV installations should be manufactured in Europe, which amounts to about 60 GWp. There should be a tax relief incentive scheme to attract company relocation to Europe or measures to limit the import of materials that do not comply with sustainability KPIs, strengthen anti-dumping duties and encourage local production. The support (subsidies, tax initiatives, local content policy) should focus on the creation (or re-creation) of the value chain "polysilicon-ingot-wafer-cell-module" and PV-grade glass.

**Protect European producers**. Ensure fair competition from imported raw materials (e.g., silicon) and protect local producers from dumping practices. For instance, there are small companies working on PV in Europe (e.g., Photowatt) that should be supported to purchase European raw materials with a reduced carbon footprint.

**Develop skills and competencies for entrepreneurs, investors, workers, and researchers**. In alignment with the Ministries of Education within the member states, there must be support programmes to attract students to study solar energy technologies and professionals or companies to disseminate knowledge to students and professionals, while stimulating an entrepreneurial mindset in the sector. The needs of the solar industry sector should be well-known on a global scale. This, in the long run, will stimulate the development of advanced technology and solutions supporting business needs.



### The Role of the Banking Industry

**There is a need for significant reinvestment in solar PV manufacturing capacities, activating the European Investment Bank in particular, and through support on electricity prices.** A complete industrial strategy should be defined by the EU as part of the Solar Communication set to be published in 2023.

### ACTION 2: *Reduce or Substitute Critical Raw Materials in the Solar Energy EU Products*

### The Role of the R&D Community

**Improve the raw material efficiency of PV.** Raw material efficiency can provide both a cost advantage and improved sustainability to European PV modules. Measures aimed at increasing the efficiency in the use of raw materials (silicon, silver, aluminium), substituting toxic/critical/valuable materials (indium, lead, silver, gallium) with alternative materials that have comparable performance should be encouraged.

#### The Impact

Efficient recycling processes can recover at least 2 kilotons per GW of high-purity silicon from decommissioned solar panels by 2025. With an estimated five million tons of PV modules to recycle by 2030, an estimated 100,000 tons of high-quality silicon could be recovered. Similarly, recovering silver from used solar panels would reduce the economic and ecological impact (already in 2021, the PV market consumed 10 percent of the world demand for silver). Recycling thin film technologies can recover up to 90 percent of the semiconductor material for reuse in new modules and 90 percent of glass for reuse in new glass products.

**Improve raw materials recovery rate** (cost, sustainability) from conventional and emerging cell technologies (e.g., silicon, silver, indium, lead) and this includes the design of new technological approaches for dismantling, recycling, processing, and recovering raw materials.

### ACTION 3: *Ensure a High Collection Rate to Maximise Secondary Raw Materials Production*

Considering the growing PV waste volumes, the creation of a new Global Platform for EoL management, including tracking, collection, disposal, processing, raw materials recovery, and sales, is needed.

### The Role of Member States

**Coordinate across countries for more efficient collection, logistics, transportation, processing, and purification to optimise material recovery rate**. A centralized, EU-wide organisation with national representatives will coordinate and synchronise the yearly tons of collected, processed, and recovered raw materials, paving the way for the creation of new markets.

**Set objectives for recycling specific raw materials from solar panel waste**. Setting recycling quotas for recycling the critical and precious raw materials content (e.g., silicon, silver, cadmium, tellurium) to promote the development of a high-quality recycling infrastructure for PV modules that meet the strategic objectives of the EU.

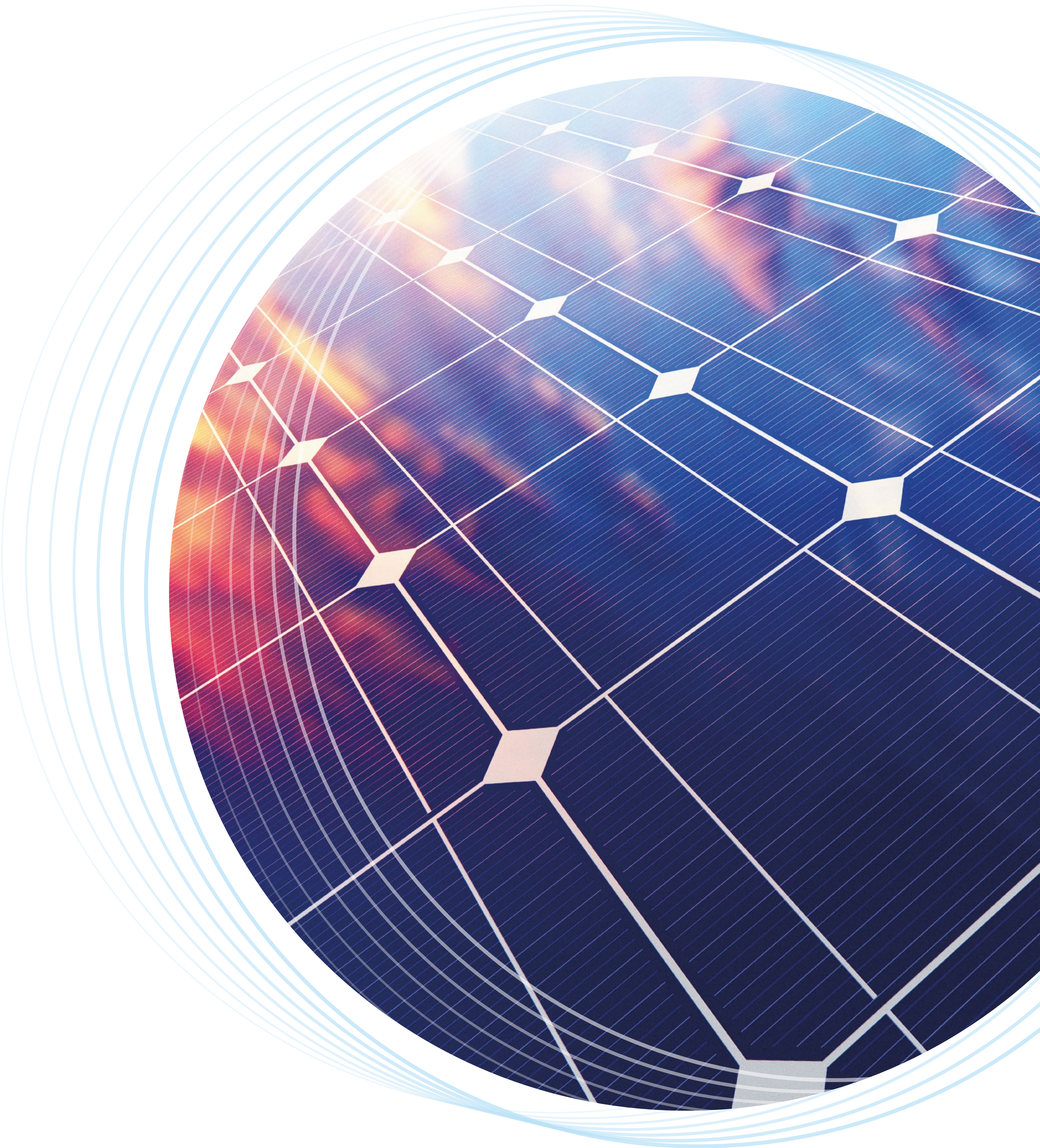
## The Impact

The recovery of raw materials (e.g., glass, plastic, silicon, cadmium telluride, copper, aluminium, silver, etc.) from PV will generate a plethora of new businesses, enhancing the value chain of the global solar market. New business includes smart logistics with data-driven platforms and Industry 4.0, as an enabler for energy and material recovery tracking, simplifying future energy target increases. As a secondary effect, the increase in the number of EU-located stakeholders will drive an increase in the demand for future investments to retain the value chains.

**Need for a global alliance for solar recovery with national representatives**. Organisation and coordination of an EU-wide global alliance are needed, involving stakeholders and national representatives at various levels in the value chain from production to management of EoL. Consolidation and further development of the Extended Producer Responsibility (EPR) schemes should rely on the "polluter pays" logic, whereby the producers cover the cost of collection and recycling of their end-of-life panels.

## The Role of the European Commission

**Standardise the quality of traded secondary materials to enhance recycling**. There is a regulatory gap when it comes to the definition of a homogeneous quality assessment of recycled materials to be used as a secondary raw materials source. In this context, a foundation for a labelling/code focused not only on the energy class of the modules but also on waste traceability (to ensure supply at the PV panels' recycling facilities) would be beneficial. Furthermore, the sector should focus on the eco-design of PV to enhance recycling efficiency and work on replacing the use of fluor-based polymers as a back sheet with recyclable fluor-free polymers.



# BATTERY MATERIALS

## Introduction

The Fit for 55 package includes a phase-out of fossil fuel-driven cars. In 2030, new passenger cars sold in the EU should demonstrate a 55 percent reduction in CO2 emissions relative to the 2021 baseline, and in 2035 all new cars sold in Europe should be zero-emission vehicles (23). This policy change will further increase the demand for battery-driven vehicles and raw materials used in the batteries and powertrains of these vehicles.

The currently dominant battery in the car industry is the lithium-ion battery (LIB), with a global production capacity expected to grow at a CAGR of 16.5 percent from 631 GWh in 2020 to 2912 GWh in 2030. An even higher CAGR of 32.7 percent is expected for the industry in Europe, with announced projects expanding the capacity from 57 GWh in 2020 to 965 GWh in 2030 (24). The estimates for European capacity growth have changed drastically within only one year: in December 2020, the Batteries Europe Strategic Research Agenda had projected the European capacity to reach 443 GWh by 2030. Regardless of the European share of the battery production market, the International Energy Agency's Sustainable Development Scenario (SDS) base case projects the mineral demand for battery storage-related materials to increase drastically by 2040 compared to 2020. For manganese, nickel cobalt, graphite, and lithium the projected 2040 estimates range between eight and forty times the 2020 demand.

Over the next decades, technology developments and investments will affect the predominant cathode and anode chemistries and, therefore, the specific battery raw materials need and forecast. There is a consensus coming from automotive battery roadmaps that identifies lithium-ion (Li-ion) as being the predominant battery model implemented in mobility over the next few decades. Currently, there are three main candidates which are considered winning chemistries for electric mobility: lithium-nickel-manganese-cobalt (NMC); lithium-nickel-cobalt-aluminium oxides (NCA); and lithium-iron-phosphate PO4 (LFP). The high-Ni NMC is expected to dominate but other chemistries will still be in production (Figure 2). In addition, some legacy chemistries such as lithium-ion manganese oxide (LMO), lithium-titanium-oxide LTO and lithium cobalt oxide LCO would remain to a very minor extent (9)(25). A new generation of Li-ion batteries with silicon/graphite composite anode and nickel-NMC cathode are also being researched. An additional uncertainty in the battery raw materials demand is presented by the introduction of solid-state batteries and other lower TRL solutions, which could partly or fully replace lithium, nickel and cobalt with alternative, more abundant materials. LIB chemistries, however, are expected to be in high demand until at least 2030 (25).

To support this ambitious development path, the European authorities need to ensure a level playing field in which this industry can successfully operate. These conditions include promoting feedstock (batteries and associated materials, production scrap) retention within European Union Borders; high collection rates (and avoiding leakage and export to lower standard facilities); and support for early-stage industry operations through financial mechanisms. These two major conditions will enable the recycling industry to fully scale up, close the supply chain loop and reduce dependence on imports into the EU. In addition, a strengthened effort in R&D is necessary for Europe to consolidate its supply leadership of new generations of batteries and develop new materials.

## Alignment with existing Initiatives and EU projects on Battery Materials

For **battery materials**, ERMA strongly complements the work done by the European Battery Alliance (EBA), the Batteries Europe European Technology and Innovation Platform, the PPP Batteries Europe Partnership, and the Battery 2030+. The EBA work has been important in supporting the establishment of battery gigafactories announced to be built in Europe within this decade. The raw material needs of these gigafactories are vast, and in focusing primarily on the raw and advanced materials mining, processing and secondary sourcing, the ERMA Battery Materials task force complements the past work of other initiatives, particularly by resolving regulatory hurdles and bringing investment into the upstream value chain for batteries. On a practical level, alignment is reached through the representation of the EBA in the Battery Materials Task Force, as well as the Task Force members being active in the different other battery initiatives in Europe.

1 Calculation based on projected mix of battery chemistries in 2030 (Yugo & Soler, 2019; International Energy Agency, 2021) and their material intensities per energy unit.
Anode estimates based on 1,2 kg/kWh graphite and 0,12 kg/kWh silicon (52).



## ACTION AREAS AND LINKED MACRO ACTIONS FOR BATTERY MATERIALS

### The Impact

A more attractive investment case for battery material processing that would lead to reduced investment leakage and mitigate risks related to private investments will unlock the potential to contribute up to a 50 percent share of the European lithium-ion battery raw material and advanced material needs from European sources **by 2030**.

## ACTION 1: *Facilitate Access to Finance for Battery Materials Projects Across the Value Chain*

### The Role of ERMA and its Stakeholders

As of May 2023, the ERMA investment platform pipeline collected a number of cases targeting the reduction of the supply-demand gap for specific battery materials (Figure 1).

Even with the low scenario of 443 GWh by 2030, increased efforts are needed for Europe to maintain its raw materials base for the battery industry. In addition to increasing the primary production of battery materials, the battery recycling industry needs to be ramped up. The European battery recycling industry will not only have the potential to provide a significant supply necessary for the energy transition in Europe but will also act as a standard for safe and sustainable treatment solutions for end-of-life LIB (26). It is estimated that by 2030 roughly 25 GWh (134 kt) of batteries will be available for recycling in the EU, equivalent to 16 percent of the global volume of LIB available for recycling (27). This figure is still very modest when compared to either of the capacity scenarios for LIBs to be produced in Europe in 2030. The large discrepancy is due to a significant quantity of LIBs that have not reached the EOL. Only 18 GWh and 50 GWh of LIBs will have reached the EOL in 2025 and 2030, respectively.

### The Role of ERMA and EIT RawMaterials

**Jointly establish a combined European Raw Materials Fund to support all project stages from exploration to Prefeasibility Studies (PFS), Definitive Feasibility Studies (DFS) and operations**. The fund requires support from EU and member state policy levels, including a combination of equity and quasi-equity instruments, grants, loans, guarantees and tax incentives. Grants, equity funding and loan guarantees should be made available to junior mining companies and for early-stage, high-risk projects that have not yet reached PFS. Existing financing tools such as untied export credits from European states to projects dedicated to raw materials produced for the European market should be used. A support agency similar to KORECO or JOGMEC should be established to run the operation. This should include the creation of a front-loading finance mechanism, regardless of the status of the environmental permits because it is generally very difficult to get project funding before environmental permits are in place, and this makes it extremely challenging for small companies to develop their projects.

### The Role of the European Commission

**Bring mining, refining, and recycling activities into the Sustainable Finance Taxonomy to meet the 2030 and 2050 climate goals as defined in the European Green Deal**. Strong support from the European Commission is needed to demonstrate the sustainable performance of the European mining, processing and recycling industries. Strong emphasis should be put on developing common criteria for sustainability in mining to be considered sustainable investment objects.

**There is a need for promoting alignment and allocation of topics in Horizon Europe and other EU funding programmes**. This includes early-stage screening and definitive feasibility studies (DEFs) that should be supported by Horizon Europe. In addition, focus regions should be identified in cooperation with third-party mining associations such as MirEU and the Council of Mining and Metallurgy in Europe.

**Promote technical and financial collaboration for the development of refined cobalt products in the Democratic Republic of Congo (DRC) for EU battery production**. In addition to focusing on EU soil, there is also an opportunity to enable the development of further refining stages in the DRC which could feed directly into EU battery production. One of the main benefits would be a significantly reduced carbon footprint as the DRC's energy grid is hydro-powered, compared to the predominant Chinese production which is fossil-fuel based. This would also fit with a 'just transition' approach, allowing the DRC to benefit more from the electric vehicle revolution via positive socio-economic impacts related to the introduction of refining operations in the form of direct and indirect employment. Close technical collaboration and partnerships with battery production companies would allow refined DRC cobalt products to be optimised for EU battery production.

## ACTION 2: *Development of Governance in Third Countries*

### The Impact

Secure sustainable DRC cobalt for Europe by ensuring higher scrutiny on supply chain actors involved in sourcing through ASM (artisanal and small-scale mining) and defining responsible ASM practices.

### Governance in third countries and Strategical Partnerships

**Support efforts to develop more responsible, artisanal and small-scale mining (ASM) (i.e., on-the-ground ASM initiatives; finalisation of an ASM Framework) to improve social acceptability of DRC cobalt**: Given the importance of the DRC for the supply of battery materials, promotion activities should include material mined in the DRC. There are several programmes and activities underway to address systemic challenges in the DRC, to which ERMA may wish to contribute.

Foremost are the environmental and social concerns related to cobalt mining, particularly those from the 9 percent of DRC production, which is estimated to come from ASM, which is partly associated with child labour and human rights abuses. Various organisations have made progress in supporting the ASM sector to adopt better environmental and social practices, such as the Fair Cobalt Alliance (FCA) which is working directly with ASM miners. There is also a need for an agreed ASM Framework which is recognized by the supply chain, the DRC authorities and stakeholders, to define 'responsible ASM' practices and to enable independent verification of ASM operations. In 2021 there was good progress in developing this framework via the efforts of the Fair Cobalt Alliance (FCA), the Responsible Minerals Initiative (RMI) and the Responsible Cobalt Initiative (RCI) working with the Global Battery Alliance.

**Promote efforts to increase uptake of refiner audits against 'OECD Guidance' aligned standards, through DRC regulation or other mechanisms**: A complementary action which is widely deployed in mineral supply chains is third-party assurance of refiners against a standard which is aligned with the OECD Due Diligence Guidance for Responsible Supply Chains of Minerals from Conflict-Affected and High-Risk Areas (the OECD Guidance), for example, the RMI standards. Cobalt extraction in the DRC includes a crude refining step for the production of cobalt hydroxide. Compulsory audits for all crude cobalt refiners in the DRC would ensure much higher scrutiny of supply chain actors involved in sourcing ASM and promote efforts to ensure more responsible ASM.

## ACTION 3: *Improve European Innovation and Technology Capacity on Battery Materials*

### The Impact

Identify the gaps in battery raw materials production capacities across the value chain, allowing for optimised production and off-takes.

### The Role of ERMA

**Create an environment that encourages mining and battery metal processing companies to work with R&I**. Support the development of new sustainable mining technologies, ensure that the projects at different stages (Exploration, PFS and DFS) are supported by appropriate new technologies, and bring together industry across the value chain. The latter is particularly important to small and medium-sized European companies that need to secure economies of scale and off-take agreements.

### The Role of the European Commission

**Innovation ecosystems should be created and prioritised in Horizon Europe, to enable different companies to work together for a common goal**. The ecosystems should focus on graphite, alloys, and special and base metals such as lithium, nickel, cobalt, manganese, silicon, and copper. Investment in public research centres is an integral part of such ecosystems. Stepping up R&D efforts in battery material processing is both crucial and urgent.

**Overcome the lack of regulatory framework supporting digitalisation to ensure the quality and traceability of battery products when delivered to cell or battery producers**. Support systems for R&D, both through Horizon Europe and within regional and member states, should be streamlined and focused on new raw and active material development for higher energy density, faster charging, reduced cost, low carbon footprint and increased safety.

## The Role of Member States

Include battery materials in a new Important Projects of Common European Interest IPCEI for raw materials for the European Green Deal. Promote research on low carbon raw materials for batteries.

## ACTION 4: *Address the Regulatory Framework for Battery Materials*

### The Impact

Harmonised standards may allow European battery materials producers to demonstrate their sustainability performance as a unique selling point, thereby increasing competitiveness based on willingness to pay for sustainably produced battery materials.

Mitigation of conflicting policy objectives, leading to better integration between battery material processing and the objectives of the European Green Deal.

### The Role of the European Commission

**Fit for purpose standards for mining are proposed as one of the key solutions in battery regulation**. The lack of a single certification scheme and a single due diligence mining standard in Europe needs to be addressed. These should be linked to the Sustainable Development Goals. A harmonised tracing system agreed upon across the EU should be introduced and implemented.

**The current Harmonised System (HS) Code system should be reviewed particularly for anodes and anode materials**. In preparation for the implementation of the Batteries Regulation, specific criteria (including manufacturing criteria and labels) and KPIs for the Batteries Regulation should be defined. In this regard, the term "EU manufacturing" should be better defined for raw materials in order to promote full battery value chains in Europe.

### The Role of Member States

**Implementation of a tax incentive system (e.g., reduced VAT) for eco-friendly batteries**. Incentives should focus on higher recycled content within batteries and extend mandatory targets and requirements for recycled content within portable batteries.

Horizontal guidance on value chain sustainability criteria should be promoted. The guidance should be based on recognised international standards and include a horizontal certification scheme for producers that is considered sustainable, based on product benchmarking and an integrated performance and sustainability standard. This action will incentivise adherence to environmental and value chain sustainability criteria.

**There is a need for shifting the view on the hazardous properties of raw materials towards risk control and risk management**. Within horizontal regulatory frameworks (e.g., exposure limits), this action helps decrease regulatory burden, reduces the risk to human health and supports the uptake of battery production and especially recycling for materials where there are no feasible substitutes. This would also bring the cost factor into REACH/CLP reviews by enabling competition without jeopardizing the safe use and control of risks in applications.



## ACTION 5: *Ensuring a Level Playing Field in International Competition*

### The Impact

A smart mix of trade measures leads to reliable, sustainable, and fair access to raw materials, reduces dependence on third-country processing and increases the competitiveness of already existing processing capacities.

Increased likelihood to attract investment cases for Europe, in competition with other regions in the world where finance and raw materials (e.g., Li-salts) have traditionally been strongly supported and that face reduced regulatory barriers.

### The Role of the European Commission and Member States

**Strong requirement to align import duties and tariff exemption regimes with the overarching policy objective of increased EU strategic autonomy**. Imports by Member States must be subject to the same requirements throughout the upstream chain as in the EU, such as the import of products from countries with a CO2 energy mix worse than the EU/EFTA average.

**Establish clear and stringent battery second life requirements and criteria Including equivalent recycling conditions and traceability measures for batteries**. Clear and stringent requirements and criteria for second-life applications and export of both end-of-life batteries (with or without associated cars), and dismantled cells/modules/black mass should be introduced. This includes rules (e.g., WEEELabex) for recycling facilities to approve transborder shipments of batteries and associated materials. Strict control and monitoring (through tracking digital systems and battery passports) of end-of-life cars and battery exports for second life purposes or recycling is needed.

## ACTION 6: *Ensure a High Collection Rate to Maximise Secondary Raw Materials Production*

In December 2020, the European Commission released a document with a proposal for updating the EU regulation concerning the handling of end-of-life batteries "Batteries Regulation" as part of the European Green Deal. While this regulation aims at setting collection and recycling targets, new and more stringent technical and legal obligations will be imposed in the future.

*"The proposal for a regulation concerning batteries and waste batteries, which would replace the 2006 Batteries Directive, would govern the entire battery lifecycle. It would establish mandatory requirements for sustainability (such as carbon footprint rules, minimum recycled content, performance and durability criteria), safety and labelling for the marketing and putting into service of batteries, and requirements for end-of-life management. It would also introduce due diligence obligations for economic operators sourcing raw materials. The proposed regulation could provide a blueprint for further initiatives under the EU's sustainable product policy, aimed at making sustainable products the norm." A new EU regulatory framework for batteries. European Parliament, March 2022.*

## The Impact

Increase the profitability of existing battery recycling plants due to larger material volumes available for treatment and the creation of fertile ground for the creation of new businesses.

## The Role of Member States

**Address regulatory gaps** in order to reach near-100 percent collection and recycling target for EV batteries and reduce illegal dismantling and export of End-of-life Vehicles (ELVs) in and from the EU.

**Promote measures to limit tax evasion** and financial damage to Member States' economies due to illegal dismantling and unregulated labour.

## Governance in Third Countries and Strategic Partnerships

**Internationally align, simplify, and slim down the rules for waste shipments and facilitate conditions for importing waste for recycling**: Beyond the alignment of the new battery regulation with the existing waste shipment regulation and the waste framework directive, battery recycling would benefit from a better international alignment of the waste catalogues and waste shipment requirements. The optimal recovery and use of secondary raw materials are now often hampered by complex and sometimes conflicting requirements. Facilitating the transportation of secondary battery recycling streams will enable the steady and responsible recycling of battery materials and increase secondary raw material production.

# FUEL CELLS AND ELECTROLYSERS

## Introduction

Fuel cells are electrochemical devices that convert chemical energy stored in fuels directly into electric energy and heat. They are highly reliable and long-lasting and are composed mainly of solid parts containing valuable critical raw materials (e.g., PGMs). Coupled with renewable energy sources, they contribute to the energy mix in an environmentally friendly and permanent way, as they eliminate the costs associated with handling and storing toxic materials like battery acid or diesel fuel. Fuel cells and electrolysers do not, however, currently contribute significantly to the EU's energy mix. In 2019 only 2 percent of the total EU energy share was provided by these technologies. The sector is currently undergoing a transformative change toward mass commercialisation and will provide an attractive, clean energy solution once applications reach market maturity. Over the next few decades, hydrogen will contribute significantly to the global energy supply and can help the EU to reach its Fit for 55 targets. According to projections, by 2050, hydrogen-powered energy production will abate 560 Mt of CO2 (28).

As stated in REPowerEU (3), a key goal for the green European hydrogen sector is to have a production capacity of 10 million tonnes of renewable hydrogen by 2030 and to import10 million tonnes by 2030. The overall global capacity for hydrogen fuel cells and electrolysers is forecast to be at 300 GW by 2030. By 2050 the total EU energy share of hydrogen electrolysers is foreseen to be 13-20 percent (in 2019, this value was 2 percent) with a total EU market value of around EUR 820 billion and 5.4 million associated jobs (29)(30). The Fit for 55 energy use forecast (industry share) for fuel cells and electrolysers is 817 TWh by 2050 (31).

The projected growth in fuel cell and electrolyser market uptake will have to be accompanied by a responsibly sourced, secure, and sustainable supply of a number of CRMs such as PGM (platinum, palladium), cobalt, strontium, scandium, graphite, iridium, titanium and REE and further strategic resources such as copper, nickel, and aluminium. Based on a study by German-based DERA (32), Scandium and Iridium demands will increase globally by a factor of 7.9 and 5, respectively by 2040 compared to 2018 levels (Sc: 9.1 t (2018), Ir: 6.8 t (2018)) based on the SSP1 sustainability scenario closest to Fit for 55 goals (2). According to the European Commission, platinum demand in the fuel cells and electrolysers sector will decrease toward 2030 and increase by a factor of 1.5 by 2050 compared to the 2020 baseline (across all applications) of 39 t platinum (refined stage) (33). This is based on the expectation that progress in catalyst technology will enable a reduction of PGM loadings at comparable or improved catalyst performance (Pt loadings have been reduced significantly in Proton Exchange Membranes (PEM) - Fuel Cells (FCs) over the past 20 years), similar to what has been achieved in mobile emissions catalysts. Considering, however, that fuel cell-powered vehicles need approximately ten times more PGMs than a regular Internal Combustion Engine (ICE) (33), this increase in demand may even accelerate if the technology is widely adopted.

Of the overall 63.9 tonnes of European Pt-demand (2012-2016 data), 74 percent (47.3 t) are used in autocatalysts. The corresponding figures for Pd are 59 t of EU demand with 82 percent (48.4 t) for autocatalysts. While 40 percent of processed materials (e.g., polymers and composites) for FC and 25 percent of components (e.g., catalysts and membranes) come from within the EU-27, the primary sourcing of CRMs such as Pt and the actual assembly of fuel cells is where the EU is trailing behind, with 5 percent and 1 percent respectively (34-39). With a scenario of 50 percent share for PEM, cumulative PGM demand over 2023 to 2030 for 40GW will be around 4.5 t of platinum (40) and between 4 t to 14 t of iridium (depending on the rate of thrifting achieved). The Iridium supply is, however, seen as the most critical factor (global supply is 7 to 8 t/y) (41)(42).

FUEL CELL PASSENGER VEHICLES (EU)
**3.7M**

FUEL CELL LIGHT COMMERCIAL VEHICLES (EU)
**0.5M**

FUEL CELL TRUCKS AND BUSSES (EU)
**45,000**

FUEL CEL TRAINS (IEA)
**570**

*Figure 6: Forecast for fuel cell-powered vehicles in the EU by 2030 (9).*

Hydrogen has the potential to power vehicles and decarbonise heavy stationary equipment, building on existing technology and infrastructure. Over 40 million vehicles are projected to be hydrogen-powered in the EU by 2050 (MDS and HDS) (17).

Sustainable industrial processes and materials recycling are of vital importance for the EU ecosystem. The existing state-of-the-art metal recycling processes have not yet been commercially applied in the stream of fuel cells, while preliminary research studies have proved that the existing processes are not sustainable due to high energy consumption and environmental footprint. Recycling of PEMFC and electrolyser components need to be seen holistically and not only from the metal's perspective. Besides Platinum and Iridium, the PEM technology uses membranes made of fluorinated polymers that have value and should be reused, if possible. Public funding can help to develop processes and build up recycling ecosystems that support sustainability targets.

A key aspect in the recycling of fuel cell equipment is component dismantling and pre-treatment. This is important as fuel cells must be precisely designed for the high-specification membrane electrode assemblies (MEAs) containing the PGMs. In addition, a broad collection network for end-of-life products needs to be established to ensure a continuous feed supply and an uninterrupted production process. It can therefore be expected that any significant amounts of recycled materials from end-of-life fuel cells will not be available before 2030. There are currently more than 30,000 fuel cell cars on the roads worldwide, with the respective market to be valued at 2 billion EUR (2020), with a projected CAGR of 40 percent between 2020 and 2026. As a fuel cell car contains 30-60 g of Pt, it is estimated that recycled materials worth more than 50 million EUR can be obtained in the future, allowing for potential recycling businesses to be operated and be profitable in the long term (31-38).

Based on November 2021 figures, current ERMA investment cases may supply up to 1100 kg of PGM for the fuel cells and electrolysers sector. In addition, ERMA cases can close supply-demand gaps for graphite and nickel.

## Alignment with Existing Initiatives and EU Projects on Fuel Cells and Electrolysers

The ERMA Cluster on Raw and Advanced Materials for Energy Storage and conversion offers good synergies with other current initiatives in Europe. For **fuel cells and electrolysers**, ERMA is connected with the European Clean Hydrogen Alliance through Hydrogen Europe (HE). The Alliance supports the ambitious REPowerEU plan and its objective to domestically produce 10 million tonnes of renewable hydrogen by 2030 which would require around 110 GW input electrolyzer capacity (3). This will be achieved by implementing a pipeline of investment projects for scaling up clean hydrogen, identified by the industry and the other stakeholders across the EU-wide hydrogen value chain.

The clean hydrogen investment pipeline, presented on November 2022, provides an estimated capacity of renewable hydrogen production of 62.5 GW by 2030. It further aims to give visibility to the foreseen hydrogen projects, mobilise the needed investments, provide additional focus to EU and national funding instruments, facilitate matchmaking among the stakeholders and raise awareness on the regulatory and administrative bottlenecks that should be tackled to meet the EU hydrogen strategy ambitions.

## ACTION AREAS AND LINKED MACRO ACTIONS

### The Impact

Emergence of new (and consolidation of existing) technology players (SMEs, start-ups) addressing the criticality of raw materials for hydrogen (H2) technologies, thus facilitating a less resource-intensive roll-out of the EU H2 Strategy through an accelerated industrial capacity build-up and a reduced and more competitive market introduction. Technology development should address the increased potential for large-capacity energy storage facilities, as well as increased sustainability of energy storage solutions.

## ACTION 1: *Develop Advanced Materials for Fuel Cells and Electrolysers*

### The Role of Member States

**Improve the cost and speed of development of novel materials by facilitating access to pilot lines for the development and characterisation of novel materials**. This includes the mapping and assessment of pilot lines available in the EU for the development and characterisation of novel materials, including component design, to maximise the benefits of critical raw materials and optimise their usage. This can lead to the setting up of a network (virtual centre) of accessible pilot lines (private pilot lines and pilot lines partly or wholly funded with public resources).

**Decrease the risk of the EU lagging behind in terms of technology development and building up of industrial capacity**. Similarly to the Hy2Tech IPCEI ensure that the forthcoming IPCEI scheme projects on advanced H2-related technology materials receive proper attention in funding terms, and that specific IPCEIs are promoted from both member states and the EU.

### The Role of the European Commission

**Improve the cost and speed of development of novel materials by increasing the share of public funding channelled to R&I on materials**. Through EU Horizon Europe, make sure that the Clean Hydrogen Joint Undertaking features R&I calls on advanced materials such as the setting up of a European interregional partnership on advanced materials for H2 technologies.

**Improve the developmental speed rate for standardisation and characterisation of novel materials to enable material comparison and accelerate market uptake**. This is to be achieved through the assessment of characterisation methods and tests most commonly used, and the definition of harmonised EU protocols.

### The Role of EIT RawMaterials and the R&D Community

**Decrease the content of CRMs in fuel cells and electrolysers by 30 percent by 2030 through higher elemental efficiency and new PGMs composition as for the KPIs provided MAWP of the Clean Hydrogen Partnership.**. This is achieved by encouraging industry and RTOs to collaborate through public funding initiatives and by promoting EU-wide access to critical R&D infrastructure and talent.

**In the context of metal hydrides and liquid organic hydrogen carriers (LOHC) for improved hydrogen storage, including solid-state storage**. Development and characterisation of (a) metal hydrides for hydrogen storage: interstitial hydrides (e.g., iron-titanium-based), high-entropy alloy hydrides with high hydrogen capacity, complex hydrides including magnesium-, aluminium- and boron-based hydrides with transition and rare-earth metals; and (b) LOHC. Synthesis and characterisation of novel compounds, optimised hydrogen storage capacities, thermodynamics and kinetics with alloying and use of additives. Testing of complete systems with electrolysers and fuel cells.

**Advanced materials for hydrogen storage (i.e., polymer coatings)**. Research on protective sol-gel oxide coatings limiting hydrogen permeation through polymer materials. Know-how is the answer to the problem of hydrogen permeation through the vessel/container (polymeric liner), especially at higher pressures (e.g., 70 MPa or 700 bar). Hydrogen can be stored as compressed gas in high-pressure (~ 70 MPa) tanks. Storing hydrogen in tanks causes a problem of hydrogen permeation through the tank walls, especially in the case of long-term storage. The maximum range of permeation is determined by industry standards, e.g., in the case of power supply systems for passenger cars it is less than 6 Ncm3 per hour of hydrogen per litre internal volume of the container (Commission Regulation EU No 406/2010). Hydrogen permeation is an important issue both in individual (passenger cars) and industrial applications (hydrogen transport, storage, energy conversion), especially from the safety point of view, because of the high explosiveness of the air-hydrogen mixture.

## ACTION 2: *Develop a Legal Framework for Fuel Cells and Electrolysers*

### The Impact

Contribution to technology competitiveness of existing and emerging value chain industrial players.

**Stimulate incentives via a legal framework on the collection, reuse, and recycling of EOL H2 technologies (fuel cells and electrolysers), to focus on the recovery of CRMs**. Increase collection targets and meaningful EPR obligations (create a scale for EOL-waste processing, the economic viability of 'urban mining'). This can be achieved by solving regulation gaps on the definition of high-quality, end-of-recycling targets, and by establishing traceable, auditable, and ambitious minimum processing standards (yields, environmental and social performance) to avoid low-quality recycling.

**Ensure sustainability and social responsibility of the Hydrogen (H2) economy by promoting the shift towards responsibly and ethically sourced CRMs**. Encourage the mining of local resources to develop local supply chains, alongside best practice third-party assurance of responsible mining practices, for example, metals mark, stewardship initiatives, TSM and via the Initiative for Responsible Mining Assurance (IRMA), as well as by engaging in local, regional, and country partnerships to promote economic development in host regions.

**ACTION 3:** *Develop Networks and Guidance*

### The Impact

Strengthened ecosystem of players (co-innovators) along the value chain and increased innovation performance of industrial players and research organisations (also via the optimisation of pilot lines - less idle time)

### The Role of ERMA and its Stakeholders

**Improve EU-wide dialogue within the community and with policy/decision-makers on issues related to supply risk for hydrogen technologies**. Leverage the existing ERMA membership by increasing the basis of contributors that ensure value chain completeness with upstream and downstream industrial players and by ensuring a strong presence of research organisations that interface with other parties beyond the EU.

## ALTERNATIVE ENERGY STORAGE & CONVERSION

The combined global energy use for geo and air storage and conversion is projected to be 525 TWh for 2030 and 911 TWh for 2050. For hydro and ocean energy, this forecast is lower but still significant with 362 TWh and 451 TWh, respectively, for 2030 and 2050. In 2020, 1.6 TWh were produced through the ocean power generation and the production from this source in the Net Zero Scenario is projected to 27 TWh in 2030 (43). The IEA estimates a total raw materials (combined minerals and metals) demand for other low-carbon power generation, including alternative energy storage and conversion such as geothermal and wave energy, of around 1.3 Mt per annum in 2040 (28). While these figures are undoubtedly significant, members of the Alternative Energy Storage and Conversion task force concluded that they did not have sufficient information on actual materials needs, technology challenges and further developments to make meaningful recommendations.

Policies and legislative incentives are likely to remain the most common options to boost innovation and commercialisation in Alternative Energy Storage and Conversion. In alignment with the European Green Deal, EU Alternative Fuels Infrastructure Directive, EU Energy Efficiency Directive and the EU Renewable Energy Directive, the EU supports research and development in alternative energy storage and conversion through a variety of funding schemes such as the Horizon Calls and the Connecting Europe Facility (CEF), which is a key EU funding instrument to promote growth, jobs, and competitiveness through targeted infrastructure investment at a European level.



## WIND ENERGY AND RARE EARTH ELEMENTS (ERMA Cluster 1)

Wind energy is one of the central pillars of the EU energy transition and the European Green Deal. Within ERMA, the issue of raw materials supply to the wind power value chain has been partly covered by ERMA Cluster 1 in its Action Plan on Rare Earth Elements, Magnets and Motors (44). A brief summary of the conclusions outlined in this document is reported below.

According to the targets defined in the Fit for 55 document, wind energy generation capacities in the EU are expected to more than double by 2030, i.e., to grow from 180 GW to 451 GW. During this period, the first generation of wind turbines deployed on a large scale will reach their end of life, thus, will have to be replaced. This exponential growth represents a disruptive innovation change that goes beyond the energy market itself. Key bottlenecks that are widely acknowledged relate to securing grid stability and accelerating the permitting process for installing new turbines as well as refurbished ones. The materials' dimension of the exponential growth in wind energy requires heightened focus in the political debate. Wind turbines need large amounts of sustainable strategic materials, particularly concrete, steel, copper, and fibre-reinforced composites. In addition, many turbines use rare earth permanent magnets in the electric generators of the turbines, particularly in offshore wind farms.

The EU demand for rare earth permanent magnets in the wind energy sector will grow from 7,000 tonnes in 2020 to 21,700 tonnes by 2030. Sustainable access to these materials is at high risk because 98 percent of the current EU demand is met by imports from China. There is a lack of supply chain diversification, lack of transparency, and lack of social and environmental standards. The EU rare earth and magnet industry has been declining over the last 20 years, even though high energy density permanent magnets are needed more than ever, i.e., for the use in the energy and automotive sectors, but also in electronics, robots, and various domestic and industrial appliances. In this context, the ERMA Cluster Rare Earth Magnets and Motors has developed an Action Plan that can be summarised in four key recommendations (ERMA 2021):

1. European policymakers will need to create a level playing field: the cost of EU production within the segment of rare earth magnets and motors is intrinsically higher than the Chinese production cost, which is massively lowered by a set of direct and indirect state subsidies and lower social, labour, and environmental standards. Furthermore, trade facilitations, such as unilateral tax exemptions, discriminate against European and other global competitors.
2. European OEMs will need to consider a potential commitment to buy a significant percentage share of rare earth materials from European producers. The downstream industry would gain a significant advantage by diversifying its supply chains, securing access to local suppliers, maintaining local access to materials knowledge for future motor designs and test facilities as well as supporting the development of capacities for a circular economy of electric motors.
3. The EU will need to make sure that end-of-life products (and waste materials) containing rare earths stay in Europe by introducing and implementing regulations and standards that facilitate the reprocessing and recycling of these products.
4. There is a unique opportunity to trigger large private investments in the emerging European rare earth value chain by matching funds. For this reason, the EU and its Member States should pull all financial levers including state aid, such as a dedicated Important Project of Common European Interest (IPCEI).

## List of Acronyms

| | |
|---|---|
| AESC | Alternative Energy Storage and Conversion |
| BEV | Battery Electric Vehicle |
| CAGR | Compound Annual Growth Rate |
| CAM | Cathode Active Materials |
| CRM | Critical Raw Materials |
| DFS | Definite Feasibility Study |
| EIP | European Innovation Partnership |
| EOL | End of life |
| EPR | Extended Producer Responsibility |
| ERMA | European Raw Materials Alliance |
| ESG | Environment, Society, Governance |
| ETS | Emissions Trading System |
| EU | European Union |
| ESMC | European Solar Manufacturing Council |
| FC | Fuel Cells |
| GW | Gigawatts |
| HEV | Hybrid Electric Vehicle |
| ICE | Internal Combustion Engine |
| IPCEI | Important Projects of Common European Interest |
| IRMA | Initiative for Responsible Mining Assurance |
| JRC | Joint Research Centre |
| KPI | Key Performance Indicator |
| kWp | Kilowatts Peak |
| LCA | Life Cycle Assessment |
| LCE | Lithium Carbonate Equivalent |
| LIB | Lithium Ion Battery |
| LOHC | Liquid Organic Hydrogen Carriers |
| M&N | Matchmaking & Networking |
| mt/y | Million Metric Tonnes per Year |
| pCAM | Precursor Cathode Active Material |
| PEFCR | Product Environmental Footprint Category Rules |
| PFS | Pre-feasibility Study |
| PGM | Platinum Group Metals |
| PHEV | Plug-in Hybrid Electric Vehicle |
| PV | Photovoltaic |
| R&D | Research and Development |
| R&I | Research and Innovation |
| REE | Rare Earth Elements |
| REO | Rare Earth Oxides |
| REACH | Registration, Evaluation, Authorisation and Restriction of Chemicals |
| CLP | Classification, Labelling and Packaging |
| RTO | Research and Technology Organisation |
| SDS | Sustainable Development Scenario |
| SLO | Social License to Operate |
| STEPS | Stated Policy Scenario |
| TF | Task Force |
| t | Metric Tonnes |
| t/y | Metric Tonnes per Year |
| TW | Terawatts |
| VAT | Value Added Tax |
| WEEE | Waste Electrical and Electronic Equipment |



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Map indicating the countries of origin of the European partners that contributed to the stakeholder consultation process. The work was organised in dedicated taskforces. In addition, the Cluster benefited from international participation (see Appendix).

## Appendix. Members of the ERMA Cluster Materials for Energy Storage and Conversion

### Industry, Financial Organisations, Business Organisations

| COUNTRY | ORGANISATION |
| --- | --- |
| Australia | Argosy Minerals Limited |
| Australia | Cobalt Blue Holdings Limited |
| Australia | Core Lithium |
| Australia | Eclipse Metals Ltd |
| Australia | Elementos Limited |
| Australia | Greenfields Exploration Ltd |
| Australia | Mineral Commodities Ltd. |
| Australia | Neometals Ltd |
| Australia | Renascor Resources Limited |
| Australia | Resource Mining Corporation Limited |
| Australia | Syrah Resources |
| Australia | Volt Resources Limited |
| Australia | Eclipse Metals Ltd |
| Australia | WALKABOUT RESOURCES LTD |
| Austria | MinPol |
| Austria | Proman Management GmbH |
| Belgium | Comet Traitements SA |
| Belgium | DEME Group - Global Sea Mineral Resources NV |
| Belgium | Kreab |
| Belgium | SQM Europe NV |
| Belgium | Umicore |
| Belgium | Solvay |
| Bulgaria | Kibela Minerals AD |
| Cameroon | Africa Raw Materials Market Ltd. |
| Canada | Auxico Resources Canada |
| Canada | Canada Nickel Company Inc. |
| Canada | Euro Manganese Inc. |
| Canada | Fortune Minerals Limited |
| Canada | Global Energy Metals Corporation |
| Canada | Leading Edge Materials Corp. |
| Canada | Nextsource Materials Inc. |
| Canada | Sherritt International Corporation |
| Canada | WT&C Innovates Inc. |
| Czech Republic | ČEZ Group |
| Czech Republic | DIAMO, state enterprise |
| Czech Republic | Geomet s.r.o |
| Denmark | Grundfos Holding A/S |
| Estonia | Up Catalyst |
| Finland | Akku Minerals Oy |
| Finland | Finnish Minerals Group |
| Finland | Fortum |
| Finland | Hycamite TCD Technologies Ltd. |
| Finland | Keliber Oy |
| Finland | Metso Outotec |
| Finland | Nordic Nickel Ltd |
| Finland | ROVJOK |
| France | Adionics |
| France | BlueSolutions |
| France | BNP Paribas |
| France | Catura Geoprojects |
| France | Eramet |
| France | Fonroche Géothermie |
| France | GEOLITH |
| France | Imerys |
| France | iUMTEK |
| France | Nanomakers |
| France | Nidec Corporation |
| France | Orano |
| France | Pragma Industries |
| France | Renault |
| France | ROSI |
| France | Saft |
| France | SUDMINE |
| France | Veolia |
| France | Verkor |
| France | Vermilion REP SAS |
| France | WEEECycling |
| Germany | AMG Lithium GmbH |
| Germany | Aurubis AG |
| Germany | Birla Carbon |
| Germany | Coftech GmbH |
| Germany | Cronimet Holding |
| Germany | DEM - Deutsche E Metalle AG |
| Germany | Deutsche Lithium |
| Germany | DGWA GmbH |
| Germany | DMT |
| Germany | ESy-Labs GmbH |
| Germany | G.E.O.S. Ingenieurgesellschaft |

## Industry, Financial Organisations, Business Organisations

| COUNTRY | ORGANISATION |
|---|---|
| Germany | H.C. Starck Group GmbH |
| Germany | Heraeus Holding GmbH |
| Germany | J&C Bachmann GmbH |
| Germany | Materion Corporation |
| Germany | senata GmbH |
| Germany | SGL Carbon GmbH |
| Germany | Showa Denko Materials (Europe) GmbH |
| Germany | Vulcan Energy Resources |
| Germany | Vulpes Lithium GmbH |
| Greece | AMEN NEW TECHNOLOGIES |
| Greece | MONOLITHOS Catalysts & Recycling Ltd |
| Greece | ORYKTON Consulting MON.I.K.E |
| Greece | PCN Materials IKE |
| Greece | Vlysis |
| India | Epsilon Advanced Materials Pvt Ltd |
| India | Ziptrax CleanTech Pvt Ltd |
| Ireland | Resource 500 Fevti Ltd |
| Ireland | TCM Research |
| Italy | 9-Tech |
| Italy | Breton SpA |
| Italy | Circular Materials Srl |
| Italy | Enel Spa |
| Italy | Eni Spa |
| Italy | ERION |
| Italy | GlobEco Srl |
| Italy | Innovando Srl |
| Italy | Italmatch Chemicals |
| Italy | La Mia Energia Scarl |
| Italy | MBN nanomaterialia SpA |
| Italy | Particular Materials Srl |
| Italy | Sangraf Italy Srl |
| Italy | Stam Srl |
| Italy | TREEE Srl |
| Mauritania | Suricate Minerals (Suricate sarl) |
| Morocco | Managem |
| Netherlands | Circularise B.V. |
| Netherlands | Durapower Technology Group B.V. |
| Netherlands | Fairphone |
| Netherlands | IHC Mining B.V. |
| Netherlands | Stellantis |
| New Zealand | CarbonScape |
| Norway | Bergen Carbon Solutions AS |
| Norway | Elkem |
| Norway | Hydro |
| Norway | Norge Mineraler AS |
| Peru | CHASKA INTERNATIONAL MINING SAC |
| Poland | Adianano |
| Poland | Elemental Holding SA |
| Poland | Jastrzebska Spolka Weglowa S.A. (JSW S.A.) |
| Poland | SGPR.TECH |
| Portugal | Graphenest |
| Portugal | Lusorecursos Portugal Lithium S.A. |
| Romania | Verde Magnesium |
| Slovakia | ekolive s.r.o. |
| Slovenia | Magneti Ljubljana d.d. |
| Slovenia | Reusable Technologies, d.o.o. |
| South Africa | Bunengi Group |
| South Africa | Manganese Metal Company |
| Spain | A3 AMBIENTAL SL |
| Spain | Economía Recursos Naturales, S.L. (ecoNatura) |
| Spain | INNCEINNMAT SL |
| Spain | Infinity Lithium Corporation Limited |
| Spain | KEROGEN ENERGY, S.L. |
| Spain | Lithion Iberia Cluster sl |
| Spain | MATSA |
| Spain | Pasek España SAU |
| Sweden | Big Rock Exploration AB |
| Sweden | EMX Scandinavia AB |
| Sweden | LTU Business AB |
| Sweden | Superior Graphite Europe Ltd. |
| Switzerland | ARCORE AG |
| Switzerland | Belenos Clean Power Holding |
| Switzerland | Boliden |
| Switzerland | Glencore Nikkelverk AS |
| Switzerland | Li-Cycle |
| Switzerland | MINESPIDER AG |
| Switzerland | MTO - Nornickel group |
| Switzerland | Resource Invest AG |
| Switzerland | The Swatch Group Research & Development Ltd |
| Ukraine | LLC "ZAVALIVSKIY GRAPHITE" |

## Industry, Financial Organisations, Business Organisations

| COUNTRY | ORGANISATION |
|---|---|
| Ukraine | MINE EXTRACTION LLC |
| United Kingdom | Anglo American |
| United Kingdom | Bluejay Mining Plc |
| United Kingdom | Ferroglobe |
| United Kingdom | Fibre Technologies Ltd |
| United Kingdom | ICD Europe Ltd |
| United Kingdom | Less Common Metals |
| United Kingdom | nmcn |
| United Kingdom | Oxford PV |
| United Kingdom | Johnson Matthey Plc |
| United States | Albemarle Corporation |
| United States | Controlled Thermal Resources |
| United States | Metalex Commodities Inc |
| United States | MP Materials |
| United States | Refacture, Inc |
| United States | USA Rare Earth LLC |
| Zimbabwe | Prospect Resources Ltd |

## Government Organisations

| COUNTRY | ORGANISATION |
|---|---|
| Australia | Australian Trade and Investment Commission (Austrade) |
| Australia | Government of Western Australia |
| Canada | Natural Resources Canada |
| Canada | Québec Government |
| France | French Ministry for the Economy and Finance |
| Greenland | Ministry of Mineral Resources and Justice, Government of Greenland |
| Italy | Italian Ministry of Environment and Energy Security |
| Netherlands | Netherlands Enterprise Agency (RVO) |
| Poland | Polish Ministry of Climate and Environment |
| Spain | Spanish Ministry for the Ecological Transition and Demographic Challenge |
| Turkey | Turkish Energy, Nuclear and Mineral Research Agency (TENMAK) |
| Ukraine | Ministry of Energy of Ukraine |
| Ukraine | State Service for Geology and Subsoil Use of Ukraine |

## Association / Civil Society Organisation / NGO

| COUNTRY | ORGANISATION |
|---|---|
| Belgium | CEFIC |
| Belgium | Cobalt Institute |
| Belgium | Cycling Industries Europe |
| Belgium | ECGA - European Carbon and Graphite Association |
| Belgium | EMIRI - the Energy Materials Industrial Research Initiative |
| Belgium | EUROALLIAGES |
| Belgium | EUROMOT - European Association of Internal Combustion Engine and Alternative Powertrain Manufacturers |
| Belgium | Euromines - European Association of Mining Industries, Metal Ores & Industrial Minerals |
| Belgium | Eurometaux - European Association of Metals |
| Belgium | European Aluminium |
| Belgium | European Association for Coal and Lignite AISBL (EURACOAL) |
| Belgium | European Lithium Institute eLi |
| Belgium | International Raw Materials Observatory |
| Belgium | RECHARGE |
| Belgium | SolarPower Europe |
| Belgium | The International Thin-Film Solar Industry Association - PVthin |
| Canada | Canada EU Trade and Investment Association |
| France | European Cluster of Ceramics (Pôle Européen de la Céramique) |
| France | Polymeris |
| France | A3M - Alliance des Minerais, Minéraux et Métaux |
| France | EPMA - The European Powder Metallurgy Association |
| France | Rare Earth Advisory (REA) |
| Germany | DeepSea Mining Alliance e.V. (DSMA) |
| Germany | Fraunhofer-Gesellschaft |
| Germany | HESSE & ASSOCIATES |
| Germany | IPA - International Platinum Group Metals Association e.V. |
| Germany | Verband der Automobilindustrie e.V. (VDA) |
| Germany | WirtschaftsVereinigung Metalle |
| Greece | PROMEA - The Hellenic Society for the Promotion of Research and Development Methodologies |
| Italy | Adaci – Associazione Italiana Acquisti e Supply Management |
| Italy | FISE UNICIRCULAR |
| Norway | Battery Norway |
| Portugal | Cluster Portugal Mineral Resources |
| Portugal | Quercus - ANCN |

## Association / Civil Society Organisation / NGO

| COUNTRY | ORGANISATION |
|---|---|
| Spain | CONFEDEM - CONFEDERACIÓN NACIONAL DE EMPRESARIOS DE LA MINERÍA Y DE LA METALURGIA |
| Ukraine | Ukrainian Association of Geologists |
| United Kingdom | Vanitec Limited |
| United Kingdom | Fauna & Flora International |
| United Kingdom | Sazani Associates |

## Universities and Research Institutes

| COUNTRY | ORGANISATION |
|---|---|
| Australia | Source Certain |
| Austria | Montanuniversität Leoben |
| Belgium | Ghent University |
| Belgium | VITO - Vlaamse Instelling voor Technologisch Onderzoek |
| Denmark | Geological Survey of Denmark and Greenland |
| Finland | Geological Survey of Finland (GTK) |
| Finland | Lahti University of Technology LUT |
| Finnland | University of Oulu |
| France | BRGM - French Geological Survey |
| France | CEA - French Atomic and Alternative Energy Commission |
| France | France Industrie |
| France | Université de Lorraine |
| Germany | bifa Umweltinstitut GmbH |
| Germany | Helmholtz-Zentrum Dresden-Rossendorf |
| Germany | Karlsruhe Institut of Technology |
| Germany | TU Bergakademie Freiberg |
| Ireland | Irish Centre for Research in Applied Geosciences (iCRAG) |
| Italy | ENEA - Italian National Agency for New Technologies, Energy and Sustainable Economic Development |
| Italy | FONDAZIONE BRUNO KESSLER (FBK) |
| Italy | Politecnico di Milano |
| Italy | Università degli Studi di Milano |
| Italy | University of Milan Bicocca |
| Netherlands | TU Delft |
| Norway | Institute for Energy Technology (IFE) |
| Norway | SINTEF |
| Poland | Institute for Chemical Processing of Coal (IChPW) |
| Poland | KGHM Cuprum sp. z.o.o. |
| Poland | Sieć Badawcza Łukasiewicz - Instytut Metali Nieżelaznych |
| Poland | Wrocław University of Science and Technology |
| Portugal | INEGI |
| Romania | National R&D Institute for Nonferrous and Rare Metals - IMNR |
| Slovenia | Geological Survey of Slovenia |
| Spain | CETIM |
| Spain | CRM Group |
| Spain | EURECAT |
| Spain | Fundación Gómez Pardo |
| Spain | Fundación TECNALIA Research & Innovation |
| Spain | IMDEA Nanociencia |
| Spain | Polytechnic University of Catalonia (UPC) |
| Sweden | KTH Royal Institute of Technology |
| Sweden | Luleå University of Technology |
| Ukraine | Institute of Geology, Taras Shevchenko National University of Kyiv |
| United Kingdom | British Geological Survey |

## About EIT RawMaterials and the European Raw Materials Alliance (ERMA)

Minerals, metals and advanced materials are key enablers of the green and digital transition. Raw materials are critical to preserving the global competitiveness of the EU's most strategic economic sectors. They are fundamental for the EU to develop its strategic autonomy and to re-industrialise key European ecosystems. Today, only a fraction of the most critical and strategic raw materials is produced in Europe. This can be changed by adopting a circular economy, through innovation in recycling, the use of advanced materials, substitution, more efficient processing, sustainable mining, and wider exploration.

**EIT RawMaterials** is the leading European raw materials partnership and was set up to advance Europe's transition into a sustainable economy. Its mission is to secure a supply of sustainable raw materials, close materials loops and design product solutions to ultimately develop raw materials into a major strength for Europe. To achieve this, EIT RawMaterials drives innovation, education and entrepreneurship within the raw materials sector. By providing a collaborative environment for disruptive and breakthrough innovations, it connects partners from industry, academia, research, and investment. It also invests in the future generation of innovators for the raw materials sector through initiatives ranging from the education of school students to higher qualifications for industry professionals.

Established in 2015, EIT RawMaterials is the largest network in the raw materials sector worldwide with over 300 members representing the entire raw materials value chain, from exploration to mining, processing, substitution and recycling. The association is legally independent and is bound to the EIT (European Institute of Innovation and Technology, a body of the European Union) by the Framework Partnership Agreement. Activities are facilitated through the six regional innovation hubs: Innovation Hub West in Leuven, Belgium; Innovation Hub North in Luleå, Sweden; Baltic Sea Innovation Hub in Espoo, Finland; Innovation Hub East in Krakow, Poland; Innovation Hub South in Rome, Italy; and Innovation Hub Central in Metz, France. Its headquarters are in Berlin, Germany.

**eitrawmaterials.eu**

EIT RawMaterials is the managing body of **ERMA** – the European Raw Materials Alliance. ERMA's vision is to secure access to critical and strategic raw materials, advanced materials, and processing know-how to make EU industrial ecosystems more resilient. The alliance brings together all relevant stakeholders, including industrial actors along the entire value chain, Member States and regions, trade unions, civil society, research and technology organisations, investors and NGOs. It provides an independent forum for discussion and analysis, as well as a mechanism for translating potential projects into actual activities and infrastructures that will contribute to creating long-lasting added value and jobs for Europe.

Together with its 700 international partners, ERMA has developed two key action plans for establishing world-leading strategic raw materials value chains in Europe. As a result of ERMA's work, over 50 investment cases have been identified, within and outside of the EU, with a total investment need exceeding 15 billion euros. If realised, many of Europe's raw materials needs could be sourced from within the EU by 2030.

ERMA was established in 2020 as part of the European Commission's Action Plan on Critical Raw Materials and the publication of the 2020 List of Critical Raw Materials.

**erma.eu**



The European Raw Materials Alliance (ERMA)
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**Disclaimer**

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EUROPEAN RAW MATERIALS ALLIANCE | ERMA

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