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Materials & Products Taskforce

Embracing Circularity:

A Pathway for Strengthening the Critical Raw Materials Act

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Russia's war on Ukraine and the Covid-19 pandemic have highlighted Europe's high vulnerability – especially in the supply of raw materials, which today is largely import-based. In principle, the EU has the potential to become more independent. However, this would entail higher raw material prices, and mining activities inevitably encroach on nature and landscapes. Circular economy is the better alternative. It can help provide needed materials efficiently and keep extraction of primary raw materials to a minimum. If policymakers set a clear framework for this, it can be the basis for high security of supply and a greener and socially responsible economy.

Professor Dr Manfred Fischedick,
President and Scientific Managing Director of the Wuppertal Institute

Global competition is heating up around key materials and the climate is heating up in response to our carbon emissions, but by adopting a more circular economy Europe can turbocharge its response to both challenges in one go. As the EU negotiates its Critical Raw Materials Act, it should seize the opportunity to scale up circularity. European policymakers should look to learn from how leading businesses across sectors are already implementing a wide range of circular economy solutions in critical raw materials use, and facilitate the finance flows and flexible, targeted policies needed to take these approaches to scale – accelerating the EU's journey to climate neutrality and strategic autonomy.

Eliot Whittington,
Chief Systems Change Officer, CISL

Shifting to circular economy is vital in achieving a climate neutral and a more competitive EU by 2050. Enhanced circularity should also be applied to the growing usage of critical raw materials, given their essential role in the green and digital transitions. The EU's Critical Raw Materials Act is a welcome development, but it needs to go beyond the narrow focus on recycling, and it needs to be properly embedded into the broader industrial and sustainability strategy of the EU. Policymakers should aim to enable a systems-wide circular economy that fully harnesses the economic, environmental and social benefits of circularity – and this report provides essential recommendations on this matter.

María Mendiluce,
CEO of the We Mean Business Coalition

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Executive summary

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The global demand for critical raw materials (CRMs) has grown exponentially. These materials play a key part in the products we use every day. They are also vital for the green and digital transitions. In the coming years and decades, European Union (EU) economies will need increasing amounts of these materials to create products such as electric cars, solar panels and wind turbines.

However, **Europe's reliance on CRMs creates an uncomfortable dilemma – how can we secure the CRMs that we need when their extraction causes numerous environmental and social issues**. Industry must use these materials in the best way possible, to drive our transition towards a climate neutral EU by 2050 in a way that works for all citizens. Embracing a more circular economy could be a key strategy to address this complex problem.

The EU has been increasing its focus on the circular economy as a solution and enabler of the green and digital transition. The EU's Circular Economy Action Plan, which was launched in March 2020, provides wide-ranging legislations on, for instance, how to address greenwashing, create eco-design products and better repair our appliances.

The Critical Raw Materials Act (CRMA) is a forward-looking legislative proposal that aims to ensure a secure supply of the CRMs we need. The EU's dependency on China and vulnerability to recent geopolitical shocks such as Russia's war on Ukraine have brought the importance of the EU's strategic autonomy into sharper focus. The Act aims to increase domestic supply by setting a target: at least 10 per cent of the EU's annual consumption of raw materials is to come from domestic extraction. This will bring up environmental and social dilemmas, as it is essentially setting the path for mines to be opened or reopened in Europe.

An uncomfortable truth is that while Europeans may not want to see mines in our own backyards, we are not slowing down our consumption of products that require these CRMs. Furthermore, the fact that **we choose to import these products only from third countries is problematic as they are left to deal with the environmental and social consequences.**

As well as the proposal to increase internal extraction capacities and diversify our supply, **the draft CRMA also introduces a recycling target of 15 per cent which, if adopted, could be a positive step towards circularity**. Nonetheless, **circularity is far more than just recycling – it also involves looking at how to keep the value of materials in the system more effectively and for longer. This aspect of circularity is not addressed by the current CRMA proposal**. Shifting to a circular economy could also play a key role in reducing our carbon emissions and the amount of materials we consume by keeping value in the system for longer, and could also help to create socially just solutions.

While circularity alone will not solve the challenge of procuring CRMs, it could greatly support a transition to a climate neutral and sustainable economy. Building on evidence-based research, this report showcases the challenges, opportunities and business best practices of embracing more circular economy practices in CRM use, through the examples of three materials: aluminium (including bauxite and magnesium), lithium and rare earth elements (REE).

The report provides recommendations on how policymakers could enable the faster uptake of circular economy solutions:

Implement a more comprehensive circular approach within the CRMA, rather than focusing only on recycling.

Set a flexible approach towards circularity within the CRMA that recognises the need for a case-by-case approach.

Deploy forward-looking infrastructure to enable a systems-wide circular economy.

Set a clear overall vision on a European Industrial Strategy that combines circularity, carbon neutrality and further sustainability aspects.

Create more environmentally and socially sustainable supply chains by diversifying supply chains and promoting responsible mining practices.

Implement financial incentives and support schemes to ensure faster the commercial viability of a shift towards green technologies.

Business benefits of circular economy solutions

- **Supply risk mitigation.** By adopting strategies such as recycling, refurbishment and other circular practices, companies could reduce their reliance on global suppliers. This will mitigate the risk of supply shortages of primary raw materials.
- **Technology risk mitigation.** To reduce the risk of supply bottlenecks, companies could also aim to substitute CRMs with other materials, although this will typically come with some restrictions as well.
- **Costs reduction.** Recycling and other circular economy practices like reuse and refurbishment could save energy and the costs of primary raw materials while generating new revenue streams from end-of-life products.
- **New solutions.** Applying circular economy practices could lead to new business solutions. For instance, in the case of lithium, an extension of the service life of lithium-ion batteries could be considered in addition to the strategy of recycling.
- **Environmental, social and governance (ESG) performance.** The adoption of circular economy practices could play a crucial role in improving a company's ESG performance.
- **New markets and business lines.** The implementation of the above-mentioned practices could pave the way for completely new and more sustainable circular business models. For example, offering repair services, the introduction of product leasing and rental models, or the exploration of remanufacturing options could improve circularity, generate new revenues and reduce waste by extending product lifespans.

1. Introduction

The green transition is creating a rapid increase in demand for often-rare commodities such as critical raw materials (CRMs), many of which were of little economic importance just a few years ago. Europe is dependent on imports of many CRMs because it lacks domestic raw material deposits. In the case of other CRMs, economic, ecological and social reasons, or local opposition have halted extraction and processing in Europe. For example, Finland and Portugal have significant quantities of lithium, whereas Finland and Sweden have substantial quantities of cobalt.

CRMs are classified as materials that are critical based on **supply risk (in general, all restrictions on availability)** and **economic importance** in the European Union (EU). Strategies such as diversification of resources and increasing the EU's internal extraction could help to reduce the EU's strategic dependencies in a geopolitically challenging context. However, they do not adequately address concerns around a wide range of economic, environmental and social considerations, including how mining impacts local communities and natural habitats.

A circular economy could play an increasingly important role, by allowing the EU to keep a larger amount of materials within the system for longer. Circular practices also require a more deliberate shift towards a reuse model, which will play a key role in managing supply. To date, circular economy practices have not yet been scaled up with regards to the use of CRMs because of the lack of economic benefits and technical challenges. However, this situation is likely to change as businesses demonstrate the feasibility and economic viability of embedding more circular economy solutions in their CRM practices. Furthermore, a shift towards a circular economy is necessary to achieve the EU's climate neutrality objective.

The EU's Critical Raw Materials Act (CRMA) was published in March 2023. **The Act has the potential to drive the deployment of circular economy solutions in CRM use.** This Act includes the EU's fifth revised list of CRMs, covering 34 raw materials that have been identified as either critical or strategic for the EU's needs and have a wide range of applications. Many of these materials covered by the CRMA are essential for sectors such as renewable energy, the digital industry, defence or health. Furthermore, many of them have a high risk of supply chain disruption, mainly due to high dependence on a single supplier, representing a critical strategic dependency for the EU. For example, 24 of these raw materials are largely imported from China.[1]

1.1 Purpose and structure of the report

This study was carried out by the University of Cambridge Institute for Sustainability Leadership (CISL) in collaboration with the Wuppertal Institute for Climate, Environment and Energy. The report was commissioned by the CLG Europe's Taskforce for climate neutral and circular materials and products.[2]

This study focuses on the **key role the circular economy could play in the CRMA**. This study **draws from a diverse range of business perspectives** regarding the challenges and opportunities of implementing a circular economy for CRMs. The purpose of the report is to **underline how circular economy solutions could strengthen the security of supply of CRMs and accelerate the transition to a more sustainable European economy**.

The report aims to:

- Improve the understanding of businesses and policymakers about the current and future demand for CRMs and strategic raw materials in Europe, and how greater circular practices could support the green transition, bolster geopolitical autonomy and enable business innovation.
- Improve the understanding of businesses and policymakers about the key barriers to greater circularity concerning CRMs.
- Set out what policies and investments are required to make a more circular approach work in practice, and what preconditions would be needed to facilitate and incentivise their effective use.

The report is based on an **extensive literature review, a stakeholder workshop and additional interviews with business representatives**. The report features several **business case studies** to showcase the opportunities and how challenges can be overcome.

Section 2 provides background information on the three case studies in this report: lithium, rare earth elements (REE) and aluminium (including bauxite and magnesium). **Section 3** provides an overview of EU policies and regulations on CRMs and recent key EU circular economy proposals; it also includes some examples of strategies and proposals deployed by countries outside the EU (USA, UK and Japan). **Section 4** focuses on the aims and adoption of the CRMA in 2023, and further discusses the extent to which it is possible to achieve the targets set in the CRMA to ensure the secure supply of primary raw materials. **Section 5** lists the various challenges and opportunities for implementing circular economy practices from a business perspective and provides several case studies. In **Section 6**, the report concludes with a set of recommendations for policymakers aimed at facilitating the development of a thriving circular economy of CRMs in the future.

2. Background

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The significant increase in demand for raw materials has largely been driven by the green transition, as Europe focuses its efforts on shifting towards a climate neutral economy. Demand has also been intensified by Russia's war on Ukraine – which has accelerated the shift away from fossil fuels from Russia towards a massive expansion in renewable energy.[3]

2.1 What are critical raw materials (CRMs)?

The EU agreed an assessment methodology to define a raw material as **critical** in 2010.[4] The methodology has been revised many times, but since 2017 has been based on the two aspects of **supply risk (in general, all restrictions on availability)** and **economic importance**.[5] Criteria include 'substitutability', ie how easy it is to substitute the material, the rate of material recycling and the levels of supply risk.[6] If the calculated value of both aspects for the raw material lies above the defined threshold, the material is defined as critical.

In the 2010 assessment, which was published in 2011, 41 raw materials were reviewed, of which 14 were classified as critical.[8] This included bauxite and magnesium, which are used to produce alloys such as aluminium, which is a widely used material but is not listed as a CRM. Other critical materials included were cobalt, fluorspar, indium, the group of REE and tungsten. Since then, the list of CRMs has been updated every 3 years by the European Commission. With the 2023 CRMA, the Commission presented the most recent iteration of the EU's CRM list[9] (see Table 1). The list includes strategic raw materials, which are defined "based on the relevance of a raw material for the green and digital transition as well as defence and space applications".[10]

Table 1: List of critical raw materials (EU 2023)[7]

Critical raw materials *(strategic raw materials are in italics)*			
Antimony	Feldspar	Manganese – *battery grade*	Tantalum
Arsenic	Fluorspar	Natural Graphite – *battery grade*	*Titanium metal*
Baryte	*Gallium*	*Nickel – battery grade*	*Tungsten*
Bauxite	*Germanium*	Niobium	Vanadium
Beryllium	Hafnium	Phosphate rock	
Bismuth	Heavy rare earth elements	Phosphorus	
Boron – *metallurgy grade*	Helium	*Platinum group metals*	
Cobalt	Light rare earth elements	Scandium*	
Coking coal	Lithium – *battery grade*	*Silicon metal*	
Copper	Magnesium & *Magnesium metal*	Strontium	
Strategic raw materials that are not included in the CRM list			
		Rare Earth Elements for magnets (Nd, Pr, Tb, Dy, Gd, Sm, and Ce)†	

* In the EU's definition, scandium is not included in the group of HREE and is therefore listed separately
† Rare Earth Elements for magnets (Nd, Pr, Tb, Dy, Gd, Sm, and Ce) are not included in the CRM list, but are included in the strategic raw material list. Technically they can be classified as either LREE or HREE, but in the EU's definition, they are identified as a separate category

To illustrate the increasing demand for critical raw materials, **lithium is an interesting example**. It is a key component of batteries that is not easily replaceable, and demand in Europe is expected to be 12 times higher by 2030, and 21 times higher by 2050.[11] Globally, demand is expected to increase 90-fold by 2050.[12]

Other materials such as rare earth elements are also facing increased demands. REE are used in especially high quantities to create the permanent magnets that are used in electric motors and wind turbine generators. REE are also essential in the fluorescent materials that are used for energy-saving light bulbs and light-emitting diodes (LEDs). Thus, the phasing out of conventional light bulbs has also led to an increased demand.

The EU is highly dependent on a few supplier countries. For many CRMs, China is by far the most important supplier. This dependency, together with the global increase in demand, significantly increases the risk of supply chain disruptions. The exploration, development and establishment of new manufacturing and processing facilities is a long process. Even the implementation of a mining project, with proven deposits, can take 5-9 years[13] or even longer. Material efficiency, substitution and circularity are therefore key, particularly if they can be applied in the short term.[14]

In this report, **our case studies are lithium, REE and aluminium (as it contains bauxite and magnesium, which are on the latest CRM list)**. These materials have different applications, different sizes of known deposits and different production volumes. For some, production is highly concentrated in one or two countries, creating strong import dependencies, which circular solutions could help to reduce. Potential circular economy strategies for these materials include life extension, efficient use, limiting use, promoting alternatives where feasible and recycling. Although we have focused on only a few CRMs, learnings from these case studies will have practical applications for many other CRMs.

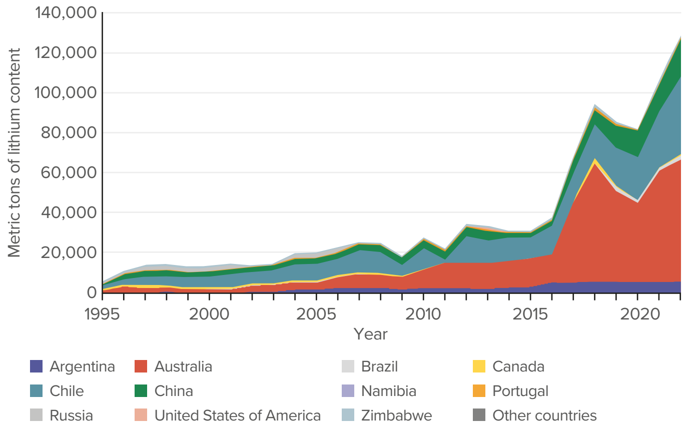
2.2 Lithium

Lithium plays a key role in batteries, notably in large traction batteries that are used for e-mobility. Because lithium has the lowest atomic mass of all metals and also the highest normal potential, it cannot be replaced by an equally effective material in batteries without increasing their weight substantially.

The increase in demand for lithium is particularly noticeable because it has few applications besides for batteries. Global demand and production was low until the recent shift towards greener technologies (Figure 1). At present, the EU's demand for lithium is met mainly (79 per cent) from Chilean sources, meaning a very high dependency.

Beyond additional mining, the large-scale recycling of lithium from batteries that are no longer usable for their intended purpose will be necessary in the future, even if further deposits are discovered as a result of rising prices and increased exploration.

Figure 1: Development of lithium production (source: United States Geological Survey[15])

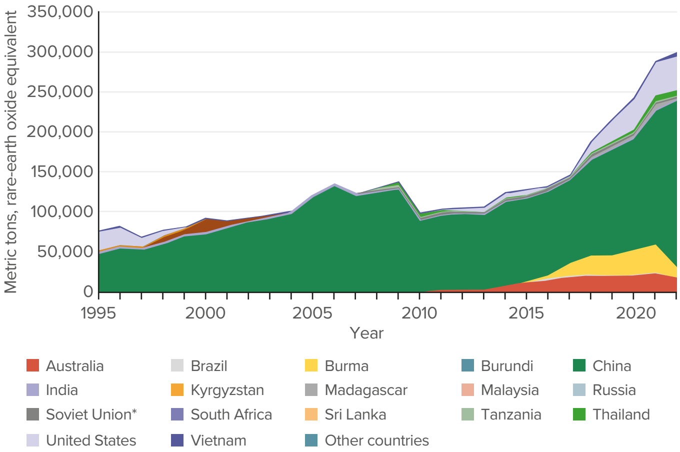


2.3 Rare earth elements (REE)

REE are a group of 17 chemical elements that are crucial components in many modern technologies, and particularly in the engines of electric vehicles and the generators of wind turbines. REE are **critical components in many clean energy technologies** because they help to make them more efficient, lightweight and durable. The 17 REE are scandium, yttrium and the 15 lanthanides (lanthanum, cerium, praseodymium, neodymium, promethium, samarium, europium, gadolinium, terbium, dysprosium, holmium, erbium, thulium, ytterbium and lutetium). These elements are called 'rare' not because they are rare in the traditional sense (ie that there is little available), but because they are typically not found in large concentrations or deposits in the earth's crust, which means they are rather difficult and expensive to mine and extract.

Light rare earth elements (LREE) and heavy rare earth elements (HREE) are used for making high-performance permanent magnets, which are used in high quantities in electric motors and generators. REE are also used as phosphors in energy-saving light bulbs and LEDs. **The demand for these REE has increased substantially** because of the expansion of renewable electricity and increased e-mobility use. To ensure it is viable, a well-functioning recycling system will need to collect substantial quantities of REE. This will require the clear identification of REE and an ability to separate them out from other materials.

Figure 2: Development of the extraction of rare earth elements (source: United States Geological Survey[16])



*consolidated for Soviet Union until 1999; split up into specific countries from 2000 onwards

Supplies of REE are highly dependent on Chinese suppliers (Figure 2). The risk of this relationship was notable when China significantly restricted its exports between 2010 and 2014, which led to a supply shortage and significant price increases (Figure 3).[17]

Figure 3: Price development of rare earth elements, adjusted for inflation (source: United States Geological Survey[18])

†Unit value in current U.S. dollars has been adjusted to the unit value in constant 1998 U.S. dollars.

2.4 Aluminium

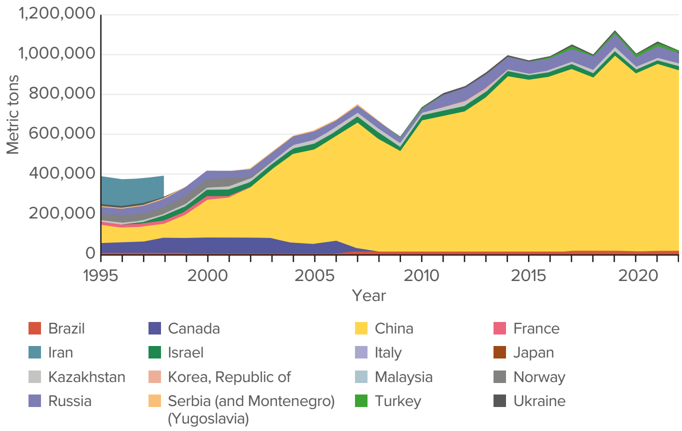
Aluminium plays an important role in the green transformation by reducing the weight of products to increase their efficiency. Aluminium is produced by an electrochemical process known as fused salt electrolysis. Bauxite and magnesium, both of which are CRMs, are crucial material inputs in aluminium production.

The recycling of aluminium is relatively advanced and already contributes significantly to reducing the environmental burden, as it significantly lowers energy consumption. Furthermore, unlike the primary production of aluminium, aluminium recycling does not produce fluorine emissions, which can cause considerable local environmental damage. However, Europe has almost no bauxite deposits (the most relevant origin of natural aluminium ore), because bauxite is mainly formed in tropical regions.[19]
Thus, there is a high dependence on supplier countries.

Aluminium is often used as an alloy – a metallic substance composed of two or more elements. An alloying element is a crucial chemical element that is added in small amounts to a base metal or another alloy to improve its properties, such as to increase its hardness and strength, or to create a new material with desired properties. Aluminium and its alloys are used extensively as building materials in manufacturing, consumer durables (refrigerators, air conditioners, cooking utensils), electrical conductors, automotive components and chemical- and food-processing equipment.

The most important alloying element for aluminium is magnesium. The EU and associated countries currently have no production of their own. Italy ceased magnesium production in 1992, France in 2001 and Norway in 2002.[20] As a result, today's demand for magnesium is almost exclusively covered by China (Figure 4). Although Russia, Ukraine and Turkey have mining and processing operations for magnesium, in the case of Russia and Ukraine, it is mainly used for titanium production, and is also not currently available to the world market because of the war. The supply from other countries is currently too small to be significant.

Figure 4: Development of magnesium production (source: United States Geological Survey[21])



The high dependency on Chinese supplies had a significant impact in 2021, as China cut back on magnesium production because of energy shortages, resulting in worldwide supply bottlenecks.[22]

3. CRM-related policies and regulations in the EU and selected non-EU countries (USA, UK and Japan)

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3.1 Overview of CRM policies and regulations in the EU

The Commission launched a first Raw Materials Initiative back in 2008, which pointed out the general need for a European raw materials strategy. This strategy was aimed at ensuring "access to raw materials from international markets under the same conditions as other industrial competitors", fostering the "sustainable supply of raw materials from European sources" and reducing the EU's consumption of primary raw materials by increasing resource efficiency and enhancing recycling.[23] As one of the follow-up actions of the initiative, a first list of CRMs taking into account environmental risks was published by the European Commission in 2011.[24] Together, **these initiatives formed the starting points for more policy measures focusing specifically on the circular economy and CRMs in particular**.

3.1.1 Evolution of the EU's CRM assessment lists (2011–20)

The EU's first list of CRMs was published by the European Commission in 2011.[25] In the next EU assessment of 2014,[26] the results were further defined by dividing the REE into the two groups of LREE and HREE. In the next iteration of the EU CRM assessment list (2017),[27] the methodology was further revised and adapted as a whole to distinguish the examination between the most critical points of the raw material production stages (extracting or processing). Furthermore, it included new factors for the calculation of supply risk and economic importance.[28]

Under the 2017 methodology, the results for the groups of REE and platinum group metals (PGM), which both consist of multiple raw materials, were available at the individual material level rather than at the group level for the first time. While the methodology and results of the assessment have been refined over time, the number of assessed, as well as critically classified, raw materials has also increased. **In the 2020 edition of the EU's CRM assessment,[29] the list included 30 raw materials, ie more than twice as many as appeared in the first list 9 years earlier.** For a detailed development of the lists, see Table 2 in Annex 1.

3.1.2 EU CRM action plan (2020)

The EU CRM action plan[30] outlines the EU's strategy for enhancing the resilience, sustainability and security of the CRM value chain. The document highlights the importance of CRMs to various industrial sectors and the EU's strategic autonomy in a global context. The communication proposes a comprehensive approach to increase the supply and diversification of CRMs, reduce the demand for CRMs and improve the circularity of CRMs. The first action was launching the ***European Raw Materials Alliance*** (ERMA) (see Annex 2).

3.1.3 EU Critical Raw Materials Act, CRMA (2023)

European Commission President von der Leyen announced the EU **Critical Raw Materials Act (CRMA)** in her 2022 **State of the Union** speech.[31] In March 2023, the Commission published the proposal for the Act[32] and submitted it to the European Parliament and the Council of the European Union for further discussion and reconcilement.

The CRMA added a new list of **strategic raw materials** alongside the CRMs.[33] As well as nickel, these new strategic raw materials include copper, which has a well-diversified supply, but is difficult to substitute and is crucial for advancing the energy transition. The extended scope of raw materials that are of central strategic importance to the economy means that even higher demands must be placed on the security of supply.

For all strategic raw materials, the proposal sets targets to enhance the EU's own production capacities by 2030 (see Figure 5 on page 16):

- At least 10 per cent of the EU's annual consumption to be covered by domestic extraction capacity.
- At least 40 per cent of the EU's annual consumption to be covered by domestic processing capacity.
- At least 15 per cent of the EU's annual consumption to be covered by domestic recycling capacity.
- Not more than 65 per cent of the EU's annual consumption of each strategic raw material at any relevant stage of processing to originate from a single third country (diversification).[34]

The CRMA will **further reduce the timeframe for extraction permits within the EU to 24 months and for processing and recycling permits to 12 months**, to facilitate the faster build-up of production capacities.[35] Additional **public and private investments** will be made into relevant research and innovation projects along the value chain. The strategy aims to **diversify the suppliers of CRMs** through more strategic partnerships, while also closely monitoring the development of demand for CRMs. The CRMA also aims to improve the circularity and sustainability of CRMs. The Commission proposes **investing €200 million into Circularity Hubs** to increase the recovery and recycling of CRMs.[36] This investment is linked to the revision of the current End-of-Life Vehicles Directive,[37] which aims to facilitate more recycling and recovery facilities.

3.2 Recent key EU proposals on the circular economy

3.2.1 Circular Economy Action Plan, CEAP (2020)[38]

The CEAP, published in March 2020 by the European Commission, is a **comprehensive package of policy measures and initiatives aimed at promoting a sustainable and circular economy in Europe**. The CEAP fits within the wider aims of the European Green Deal.

The CEAP is **driven by environmental concerns but also aims to increase the competitiveness of European industry**, for example by reducing the dependence on raw material imports. The European Commission has put a specific emphasis on interlinking efforts to decarbonise the EU economy with the circular economy and digitalisation as enablers for new circular business models.

3.2.2 Ecodesign for Sustainable Products Regulation, ESPR (2022)[39]

The EU's proposal for a new ESPR, published in March 2022, aims to **establish a framework for improving the environmental performance of products throughout their life cycle**, with a focus on reducing their carbon footprint and resource use. The proposal includes requirements for product design and information provision to improve product repairability, durability and recyclability. It also includes minimum energy efficiency and resource efficiency standards for certain (still to be defined) products to encourage the use of sustainable materials and technologies.

With regard to CRMs, the proposal includes general measures for adopting more circular economy practices, for example by promoting the use of secondary raw materials, and for minimising the use of hazardous substances in products. It also includes provisions for extended producer responsibility, including measures to extend the lifetime of products, as well as requiring manufacturers to take responsibility for the end-of-life disposal of their products.

As a key element, the ESPR also introduces a **Digital Product Passport (DPP)**,[40] which would allow reliable traceability of product information over the whole life cycle, including potentially relevant details for CRM supply chains. By this means, the ESPR would offer, among others, the crucial legal basis for mandatory requirements, for example for the recyclability of products, and also for a potential ban of products that do not allow the recovery of the CRMs included in them.

Additional CRM-related EU strategies can be found in Annex 3.

3.3 Examples of non-EU CRM strategies and policies

Globally, there is a large dependence on imports of CRMs. Aside from the EU, other countries are also seeking to improve the security of their supplies.

3.3.1 US strategy on CRMs

The USA's efforts to secure the supply and increase the domestic production of CRMs are through the various actions of the Department of Defense (DoD). With the program of the Defense Production Act Title III, the DoD aims at "ensuring the timely availability of essential domestic industrial resources to support national defense and homeland security requirements".[41] In 2021, this title was awarded to Lynas Rare Earths Ltd, and led to the DoD investing $30.4 million[42] to establish domestic processing of LREE within the USA.

Further actions of the DoD include **the stockpiling of CRMs**, conducting technical studies to restore the domestic processing of HREE, and also funding the reopening and expansion of the old Mountain Pass rare earth mine in California. Through the Small Business Innovation Research program and the Rapid Innovation Funds, the DoD also supports smaller businesses with strategic investments, to accelerate the development of new REE processing technologies.[43]

Through the United States Geological Survey, **the government releases a critical mineral inventory**, similar to the CRM lists produced by the EU and the UK. The second, and most recent, list was released in 2022, and classifies 50 minerals as critical for the USA.[44] For a comparison of the US list of CRMs with the EU's list of 2023 and the UK's list of 2022, see Table 3 in Annex 1.

3.3.2 The UK's Critical Minerals Strategy

In 2022, the UK published its first strategy on CRMs in the policy paper *Resilience for the Future: The UK's Critical Minerals Strategy*.[45] The UK government's goal is clearly defined: "It is vital that we make our supply chains more resilient and more diverse to support British industries of the future, deliver on our energy transition and protect our national security".[46] The UK government aims to **increase domestic production while also collaborating with international partners to diversify supply**. The acceleration of domestic production includes the extraction of tungsten and lithium within the UK, and also the enhancement of the circular economy to "alleviate pressure on primary supply" through strategies like reuse, recycling and resource efficiency.[47]

One of the underlying goals of the investment strategy is to **reduce China's dominance of the CRM supply market**. Furthermore, the strategy includes the publication of a list of 18 raw materials that are considered critical for the UK. Apart from tellurium and tin, all of them are found in either the EU's critical or strategic raw materials list. Similar to the CRMA, the policy paper also includes a 'watchlist' of minerals that may become critical in the near future due to a changing market. All of the materials included in the watchlist are considered critical for the EU.[48] For a comparison of the UK's list of CRMs with the EU's list of 2023, see Table 3 in Annex 1.

3.3.3 Japan's strategy on CRMs

The Japanese government has set its focus on economic security. Japan created a new Economic Department in the National Security Secretariat in 2020, and passed the Economic Security Promotion Act in 2022, which gives economic security a higher priority than market efficiency.[49] The government considers it essential to secure supply chains from disruptions due to geopolitical conflicts to establish economic security. Japan aims to diversify the supply of CRMs away from China as its single most important supplier. Japan's strategy further includes the establishment of the Japan Organization for Metals and Energy Security (JOGMEC), which was created in 2004.[50] Although it is a government-independent administrative institution, JOGMEC pursues similar targets by aiming to ensure a stable supply of metal resources through stockpiling and investment programs. Through JOGMEC, Japan recently invested AU$200 million in the Australian mining company Lynas Rare Earths Ltd. The investment will be used to increase Lynas' LREE production and HREE separation; in return, Japan receives up to 65 per cent of the HREE dysprosium and terbium Lynas produces from the Mt Weld feedstock.[51]

4. Aims of the Critical Raw Materials Act (CRMA)

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The CRMA pursues various goals. One basic goal is to **increase the security of supply** of primary critical raw materials. As there is little mining and production of primary CRMs in the EU, European companies depend greatly on global suppliers. For instance, Chile and Australia together currently provide about 77 per cent of the global lithium supply.[52] In the case of REE, there is a high dependence on a single supplier country, as 85 per cent of LREE and 100 per cent of HREE are currently imported into the EU from China.[53] **The EU's strategies to achieve its goal of increasing the security of CRM supplies are building up its own raw material mining, processing and diversification of raw material sourcing.**

4.1 Embedding circular economy practices in the use of CRMs

The CRMA sets out a circular target for the first time at EU level. At least 15 per cent of the EU's annual consumption must come from recycled materials by 2030. Furthermore, the draft legislation sets out that Member States will have 3 years to adopt and implement national programmes around circularity. The programmes will include: increasing the collection of waste with a high CRM recovery potential; increasing the reuse of products and components; increasing the use of secondary CRMs; increasing the technological maturity of recycling technologies and promoting material efficiency and substitution; and ensuring the workforce is equipped with the skills needed.

This is a first, positive step in integrating circularity more directly into the debate around CRMs. Nonetheless, **the 15 per cent target is broad, and lacks a roadmap on how to achieve this by 2030**. The maturity of circular economy strategies varies greatly in different Member States, meaning that the success of national programmes will likely also vary. National programmes in some Member States may be relatively conservative, which will result in a slow transition towards circularity.

4.2 Build-up of raw material extraction capacities

The challenges of extracting raw materials in the EU are illustrated by the example of lithium. One of the largest lithium deposits in Europe is located at the Spanish–Portuguese border near the Spanish town of Cáceres. However, the development of the deposit is facing considerable societal resistance, as it is feared that mining will endanger Cáceres' status as a UNESCO World Heritage Site.[54] In May 2023, a permit for mining on the Portuguese side was granted. The company had previously agreed to changes in favour of the protection of water and biodiversity.[55] Other examples are the Jadar project in Serbia, which was stopped after strong protests,[56] and the Beauvoir Lithium Mining Project in Allier, France.[57]

Thermal waters could be another source of lithium. However, they are currently mainly intended for geothermal (district) heating. For example, large deposits have been found in the Upper Rhine border region between France and Germany,[58] which could, in theory, cover part of the European lithium demand. Although extraction is potentially economically viable, there is significant societal resistance[59] because of fears of the seismic consequences of the geothermal project planned, and because of its potential impact on the quality of water resources.

Despite the use of the term 'rare', deposits of REE are much more widely distributed worldwide than current production would suggest. At the beginning of 2023, the rare earth deposits in the northern Swedish iron ore deposits attracted considerable attention and raised hopes for greater European production capacity. However, although the deposits have been known about for a long time,[60] they have not been exploited so far. In June 2023, it was reported that the estimated size of the deposits of rare earth oxides was 1.3 million tonnes.[61] These REE deposits are located in the UNESCO World Heritage Site Laponia, which has a significant indigenous Sami population.

It is not yet clear whether the mining permit will be granted, given the environmental impacts, the opposition to mining, the rights of access to the land and reindeer grazing, and the risk of losing World Heritage status.[62] In addition, the economic viability of extraction is still not clear in this case. LKAB, the local Swedish mining company, is currently trying to develop a process to extract REE and phosphorus from the mining waste of its iron mines, with production expected to start in 2027. This could help to increase the economic viability of mining, because many CRMs are extracted as by-products and are often not economically recoverable on their own. It could also reduce the environmental impact and conflict with the indigenous population.

Another possible deposit for REE, especially for highly critical HREE, is located in Kvanefjeld in Greenland,[63] which is an ecologically sensitive area. Currently, this rare earths project has stalled because the Greenland government has banned the related uranium mining in the area.[64]

Another challenge for increasing European production is the higher costs of these operations compared with non-European locations. Under current market conditions of international trade, raw material prices in the global market are still comparatively low and are far less instrumental in determining the total costs compared with processing costs, and especially energy costs as part of the processing costs. Although CRMs, such as magnesium and gallium, have been produced in the EU in the past, production has also been discontinued because of its lower relative profitability compared with international operations. A current example is the planned discontinuation of primary aluminium production by Speira AG at the Neuss site (Germany) in autumn 2023.[65]

4.3 Build-up of raw material processing capabilities

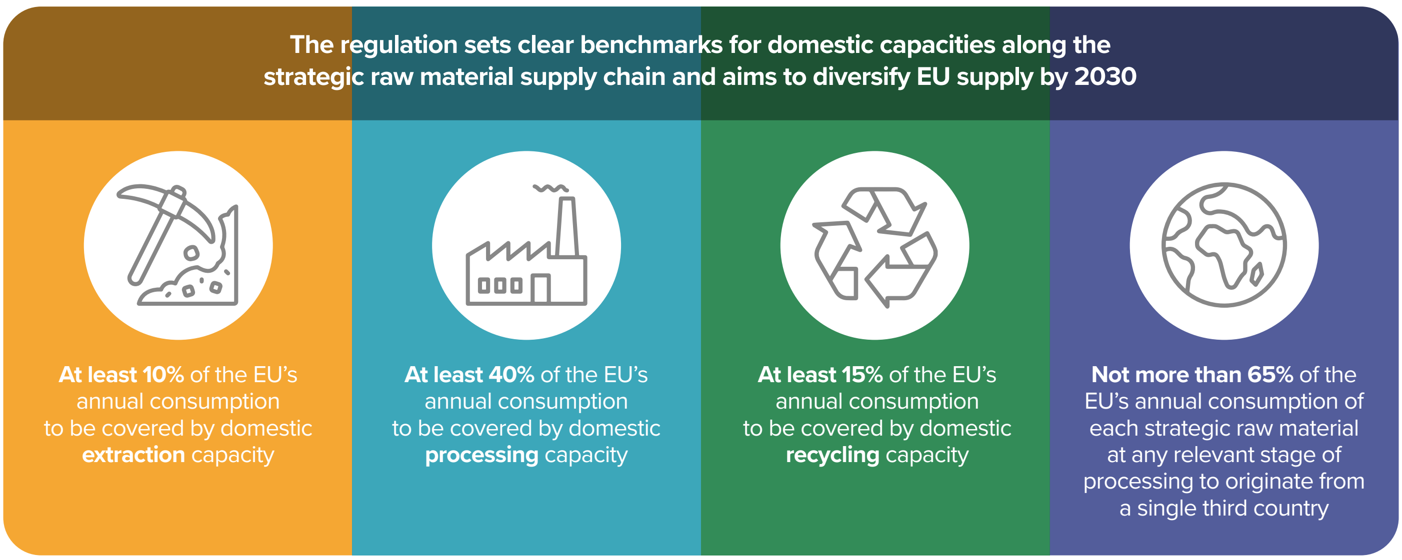
The processing of raw materials is often associated with significant challenges. As China, in particular, has achieved its market dominance far more through its processing capacities than through its own raw materials, there is a clear opportunity to significantly increase the EU's strategic autonomy. However, **this opportunity to build up processing capabilities is often made more difficult by the high energy prices and the desirably high, but more cost-intensive, environmental and labour standards in the EU**. An additional challenge is that the transport of the usually larger quantities of raw materials, compared with the smaller quantities of products, is associated with higher costs and a higher environmental impact, worsening competitiveness. Nevertheless, the existing primary production facilities in the EU, for example in the steel, aluminium and copper industries, show that the challenges associated with the transport of raw materials can incentivise innovation and efficiency, and create competitive advantages.

4.4 Diversification of supply

The diversification of supply countries is another important element that is being addressed by the CRMA. However, this depends largely on the existing and known deposits, their quality and the costs associated with their extraction. As China fulfils all three of these criteria in the case of REE, the country is the global main supplier of REE, for instance. But other countries could also play an important role in the future. In addition to strengthening the EU's self-sufficiency, countries such as Canada and Australia could play an important role, because they have very large raw material deposits in contrast to their comparatively small local manufacturing industries.

Besides the need for long-haul transport, **the main challenge is to prevent the displacement of other environmental impacts**. The EU should source these materials primarily from countries that have effective environmental and social protection measures in place and are committed to environmentally and socially sustainable mining and transport practices. In addition, the EU could support other countries with limited domestic capacities to develop environmentally and socially sustainable mining.

Figure 5: Key objectives of the Critical Raw Materials Act (source: own illustration based on the CRMA[66])



5. Business perspectives and views on CRMs and circular economy practices

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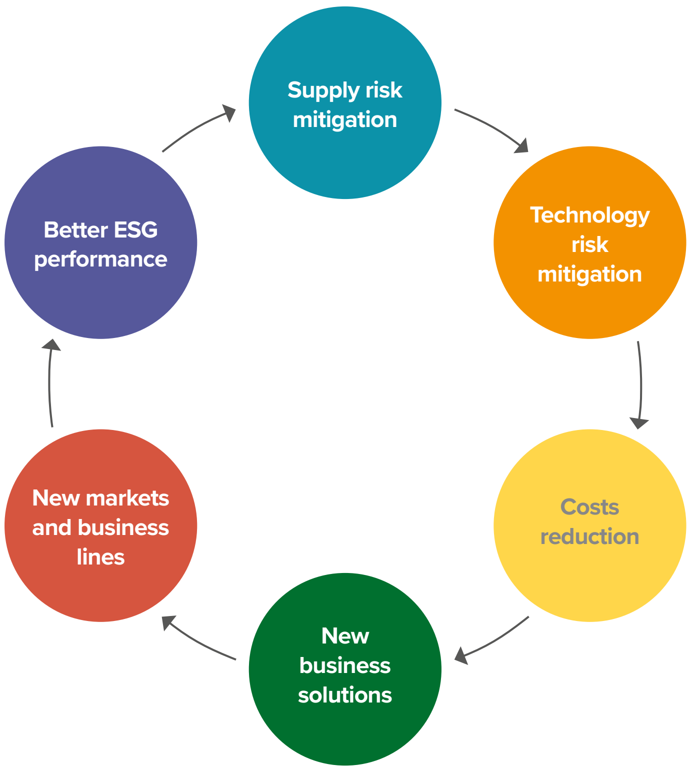
Implementing circular economy practices can provide a complementary or even an alternative opportunity for businesses. This means they become more independent of suppliers and more resilient against the risk of supply shortages. This section discusses the various challenges and opportunities for businesses when implementing circular economy practices in regard to CRMs.

The information contained in this section is based on literature research and primary research through an interactive workshop and various interviews with members of the CLG Europe's Materials and Products Taskforce, and also other identified company stakeholders along the value chains of lithium, aluminium and REE. The businesses represent the following sectors: aluminium, construction, lighting, automotive, IT, energy storage, material technology, packaging and recycling. The outcomes of the discussions are presented according to the Chatham House Rule.

5.1 Opportunities when implementing circular economy practices

While **the transition to 'competitive sustainability'**[67] comes with different challenges and requires adjustments and investment, it also opens up new paths for innovation, growth, cost reduction and sustainability. This section explores the opportunities that arise from implementing circular economy practices (Figure 6).

Figure 6: Opportunities in the circular use of critical raw materials (source: own illustration)



5.1.1 Business risk mitigation

By adopting strategies such as recycling, refurbishment and other circular practices, companies can reduce their reliance on global suppliers. This mitigates the risk of supply shortages of primary raw materials. Designing products for recycling allows companies to preserve the value of the materials used. It allows them to take advantage of new waste streams, increase recycling activities and their efficiency, and thus create a high-quality and responsible source of secondary raw materials.

To reduce the risk of supply bottlenecks, companies might also aim to substitute CRMs with other materials, although this typically comes with some restrictions as well. For example, aluminium can be replaced by steel in certain cases, but often with the trade-off of higher weights. In the case of a vehicle, the increase in weight would increase its fuel consumption.

Another example of material substitution is the replacement of lithium by using alternative battery technologies for applications where weight is a less important factor than in the transport sector. In addition to the long-established lead batteries, modern sodium-based batteries can be used to replace lithium-ion batteries. Both of these alternative battery types can be significantly cheaper than lithium-ion batteries, and do not contain CRMs or substances that are covered by the Restriction of Hazardous Substances Directive. However, they have a reduced storage capacity compared with lithium-ion batteries. Zinc batteries are another potential future alternative to lithium-ion batteries, but their use often requires toxic salts.[68] Customers and users must be willing to accept the restrictions associated with the use of these substitutes.

5.1.2 Business opportunities

Circular economy practices offer significant competitive advantages for businesses. If recycling strategies are considered at the product design stage, it may be possible to preserve the value of component materials right from the start.

Costs reduction. Recycling and other circular economy practices such as reuse and refurbishment save energy and the costs of primary raw materials, while generating new revenue streams from end-of-life products. The efficient use of CRMs in the manufacturing process can also lower the costs of primary resources. Particularly in the case of LEDs, but also in other applications where critical substances are used only in very small quantities, an important strategy is to use the substances as efficiently as possible and to extend their service life before resorting to costly recycling, which is associated with losses. Although more durability is quite effective at reducing costs, it might also lead to conflicts and trade-offs with other circular economy practices such as repairability or recyclability. Accordingly, this needs to be carefully optimised and balanced for each product.

New markets and business models. New and more sustainable circular business models, such as the offer of repair services, the introduction of product leasing and rental models, or the exploration of remanufacturing options could improve circularity, generate new revenues and reduce waste by extending product lifespans.

New solutions. Some example new solutions are presented:

- Magnesium, which is used as an alloying element of aluminium, is lost during the current recycling process because it is less noble than aluminium and is therefore oxidised. The lack of alternatives to replace magnesium in many applications means that new solutions need to be developed to reduce the demand for virgin magnesium. Extending the service life of end products is therefore an essential option here.
- For lithium, an extension of the service life of lithium-ion batteries can be considered in addition to the strategy of recycling. For example, optimised charging strategies can be used, as is already the case with notebook computers and smartphones, but there is also the possibility of their secondary usage for stationary applications, such as for solar electricity storage in the case of traction batteries that have lost only part of their capacity.[69,70]
- Implementing closed-loop systems fosters an innovation culture within businesses. This includes optimised product design and material use right from the design phase, the target-oriented development of new business models, and also optimised supply chain and logistics management. This culture of innovation enables companies to differentiate themselves in the market from competitors, and may create new revenue streams.
- The green transformation, in particular, calls for innovative solutions, as it requires the use of materials that previously had little significance. As a consequence, such innovations often lead to breaks in the material systems, at least in the beginning. New opportunities for recycling arise, and some substances may also be replaced by alternatives, for example for health reasons and to protect the environment. One example is lead and cadmium, the use of which is restricted by the Restriction of Hazardous Substances Directive,[71] and has resulted in the development of more powerful and sustainable solutions.

Environmental, social and governance (ESG) performance. Furthermore, circular economy practices play a crucial role in improving a company's ESG performance:

- **Environment.** By reducing resource consumption and waste generation, businesses can minimise their carbon footprint and overall environmental impact. Using secondary raw materials instead of primary raw materials reduces mining activities, and therefore has a positive impact, for example, on biodiversity. Furthermore, circular economy practices leverage energy savings that are necessary to reduce the EU's overall energy consumption.[72] For example, replacing primary aluminium with secondary aluminium can reduce energy consumption by 95 per cent.[73]
- **Social.** Embedding circular economy practices can support a just transition and address the negative social impacts of the use of CRMs. CRMs are usually mined in countries with little respect for human rights, and social regulation is much more restrictive in the EU than in other third countries and that contributes to waste leakage. Circular CRM practices under EU standards (including responsible sourcing and recycling) would significantly improve the social footprint of CRMs.*

*For more information, see the case study 'Sourcing CRMs responsibly: industry approaches'

- **Governance.** As well as the increasing regulatory pressure on reaching climate objectives, businesses feel pressure from customers, the public, the media, financial markets and investors. Demonstrating the demanded commitment to sustainability and environmental responsibility enhances a company's brand reputation and builds stronger relationships with customers and other stakeholders.

In this way, **circular economy practices further position businesses to meet current and future regulatory requirements related to sustainability**, such as upcoming legislation on mandatory environmental sustainability reporting for corporations. **This can reduce the risk of non-compliance and potential fines or penalties**. Many countries have set climate neutrality targets, and circular economy practices are vital for achieving these goals.

5.2 Challenges when implementing circular economy practices

This section explores the challenges that businesses face when implementing circular economy practices with respect to CRMs.

5.2.1 Regulatory barriers

Existing regulations may not always be conducive to circular economy practices, which can create barriers for businesses trying to implement them.

Figure 7: Regulatory barriers (source: own illustration)

Regulatory barriers	• Waste leakage • Lack of policy signals to shift preference from virgin to recycled materials • Policy misalignment

Waste leakage. The research conducted showed that this is the most prominent issue businesses are facing regarding circular CRM practices. Current EU waste regulations[74,75] make it easier for businesses to ship end-of-life products outside the EU than to transport them to a recycling facility in another EU country. As a result, products that have a high recyclability value leave the EU market as waste and may return to the Single Market as recycled raw materials, rather than being recycled within the EU.

Until revised EU regulations come into force, end-of-life products are typically classified as waste rather than a valuable good. Overall, waste in the EU must be transported safely, without harming human health or the environment, and in accordance with the waste hierarchy. Waste transporters must also comply with the relevant international conventions, such as the Basel Convention,[76] which regulates the transboundary movement of hazardous waste. There is great potential for improvement in this space.

Lack of policy signals to shift preference from virgin to recycled materials. Currently, businesses do not have sufficient incentives to adopt recycled materials as their preferred input. Having a clear business case would be the most effective policy tool to increase business use of recycled materials. This could be achieved through a combination of supply- and demand-side policies. Some measures that could be implemented to create a solid market for recycled materials may include mandatory use of recycled content in products (a standard definition of recycled content would be required), green public procurement, green product labelling (substantiated with data), financial and/or fiscal incentives for recycled materials, or conversely putting a tax on virgin raw materials.

Policy misalignment. Traditional regulations, such as the Waste Framework Directive or the Waste Electrical and Electronic Equipment Directive, set a focus on reaching certain collection and recycling rates, but do not incentivise businesses to adopt more holistic circular practices like reuse, refurbishment, lifetime extension or waste prevention. Moreover, as seen in the Directive on End-of-Life Vehicles 2000/53/EC,[77] the requirements on recycling do not set a focus on quality, but on quantity, allowing downcycling of the material.

Chemical regulation may also affect business adoption of circular practices, because the level of impurity allowed in the melting of recycled materials may hinder the reuse of certain materials. Thus, it is important to ensure its alignment with circular policies to foster a functional circular economy.

Additionally, regulations related to product design or labelling may not yet provide clear guidelines on how to design products for circularity or communicate their sustainability credentials to consumers, as the more comprehensive circular economy practices for instance outlined in the ESPR have only recently started to take effect.

5.2.2 Challenges for business adoption

Figure 8: Challenges for business adoption (source: own illustration)

Challenges for business adoption	• Change in business models • Having a clear business case • Economic viability • Volume requirements to be competitive • Lack of value chain collaboration • Protection of business knowledge • Mindset shift • Lack of information • Logistical challenges • (Lack of) citizen engagement

Change in business models. Changes in business models are needed to truly implement circular economy strategies. For efficient recycling, material and alloy mixes have to be avoided whenever possible. This is an issue that must be considered not only during collection but also during product development. Companies need to rethink the initial design process to enable high-quality recycling, while allowing for the use of secondary materials with a lower quality or different specifications. This challenge calls for strengthened collaboration across the value chain and a shift towards circular design principles. But it can also be strengthened through product-as-a-service concepts that increase product responsibility.

Having a clear business case. Although circular business models offer the long-term possibility of reducing costs, the actual economic viability of implementing these practices remains a major challenge for companies. While ensuring the availability of high-quality materials and rethinking the design process, companies need to remain competitive and profitable in the market. The use of recycled materials in production processes depends, in addition to the required quality, largely on their price compared with the price of primary raw materials. Only when the raw material costs represent just a small part of the total production costs, can higher material prices be tolerated. For example, this is applicable in the case of magnets.

Economic viability. As well as being used as magnets, REE also have an important application as phosphors in LEDs, where they are used very efficiently in only very small quantities. Consequently, the content of REE in individual LEDs and small lighting products is very low, which means the concentration of REE in typical LED scrap is also very low.[78] Although this may be an area where technical improvements can be made to recycle REE in the future, it is unlikely to be particularly profitable unless a circular logic is adopted at the product design stage to facilitate the recyclability of REE (see the case studies in Section 5 for more details on how businesses are addressing this challenge).

Volume requirements to be competitive. The costs of recycling and reprocessing can be reduced through economies of scale, ie if larger quantities are available. This might be achieved by combining pre- and post-consumer materials in the recycling process. A further step may be to reduce or eliminate the export of CRM waste from the EU to third countries. However, countries such as China have a cost advantage over the EU in this area because of lower labour and energy costs. Without further regulatory incentives to ensure a level playing field, this factor will have an impact on the overall economic feasibility of circular economy practices in the EU.

Lack of value chain collaboration. The implementation of all circular economy practices can be complicated because of the complexity of the value chain. A company may need to work with its suppliers to ensure that raw materials are sourced sustainably and that components can be easily recycled or reused, thereby influencing supplier decisions, whereas the supplier has to meet the requirements of multiple customers. Therefore, it is particularly difficult to set targets for recycled content that go beyond the generally applicable regulations. Additionally, antitrust regulations must be considered in each co-operation, further complicating the implementation of circular practices.

Protection of business knowledge. While co-operation along the value chain is indispensable to enable an efficient circular economy, best practices and innovations are typically not shared to protect business intellectual property. This hinders innovation and the adoption of best practices in the rest of the industry. To scale up the adoption of new processes, a shift of mindset towards collaboration is needed. Calls for collaboration, such as those made by aluminium packaging producer Ball,[79] emphasise the need for a more collective approach to advancing circular economy practices, which should be encouraged by the regulatory framework.

Mindset shift. To scale up circular economy solutions, a mindset shift in business management is needed. Currently, it is still mainstream practice to prioritise individual competitive advantage thinking over more collaborative approaches. Companies need to engage in systemic collaboration, including public–private partnerships, to achieve a functional circular economy, as it is a societal challenge that requires systemic thinking and action.

Lack of information. The implementation of closed loops within a company or a sector where products are reused, refurbished or recycled requires a comprehensive understanding of the whole value chain and the composition of the product.[80] However, information about a product's composition is often lost in the value chain, hindering efficient circular economy practices. For instance, many different types of magnets exist and not all of them contain REE. Solutions such as labelling or DPPs aim to address this challenge by providing information on the product composition along the value chain.[81]

Logistical challenges. Circular business models often also face additional logistical challenges and associated costs when transporting post-consumer goods. While raw materials can be transported over long distances with comparatively few barriers, waste handling logistics have not been prioritised to the same extent. Companies therefore need to reconsider ownership and logistics management of their sold goods to overcome these challenges effectively.

(Lack of) citizen engagement. Citizen engagement plays a significant role in the successful implementation of circular economy practices. Consumers may be resistant to changing their purchasing habits or may not accept products made from recycled materials. Lack of awareness regarding the value of waste materials, such as electronics, can also hinder progress. Overcoming these challenges will require the strict safeguarding of the good quality of recycled products, the education of consumers about the importance of sustainability and circularity, and also the creation of incentives for more societal acceptance of circular products.

5.2.3 Technical challenges and limits of recycling

Figure 9: Technical challenges and limits of recycling (source: own illustration)

Technical challenges and limits of recycling

- Aluminium: material uniformity (sorting and lack of clean waste streams)
- Lithium: wide range of inputs
- REE: very demanding and costly separation process

The availability of high-quality secondary raw materials poses a major challenge to businesses, as recycling is the main circular strategy promoted under the EU CRMA to build more resilient supply chains. For example, recycling currently already contributes more than 35 per cent of the EU's demand for the CRMs vanadium, tungsten and cobalt.[82] However, because worldwide demand and production are still growing rapidly, there is not a 'steady-stock society'. Thus, the absolute quantities of available secondary raw materials do not meet the needs of the global economy, which sets natural limits to their share in production.

Furthermore, effective recycling requires materials that are easy to identify and sort. The easiest way to achieve this is by minimising the mixing of different materials at the product design stage. It is usually much easier to recycle pre-consumer materials than post-consumer waste because their composition is known and they contain no, or hardly any, impurities. In many cases, the availability of pre-consumer material is also significantly better, as appropriate collecting and recycling processes for pre-consumer material often exist.

Currently, the recycling of CRMs is partly hindered by various challenges including unintentional leakage or exporting of recyclable waste to countries outside the EU, inefficient use of CRMs in products by design and also by the lack of an effective collection of separate, clean waste streams and a local recycling infrastructure.

Aluminium

In the case of aluminium, recycling ideally takes place without any change in quality within the alloy groups (wrought alloys and cast alloys). The better the sorting quality, the easier this is. The ability to separate the materials is important. In many cases impurities appear in the course of the recycling processes due to the fact that some elements of components are not separable. This deteriorates the quality.

An important example for aluminium applications and aluminium recycling is **beverage packaging**. Because a further reduction in can weight is hardly feasible without affecting the stability of the packaging, the focus must be on ensuring the recycled material content is as high as possible. The proportion of recycled material has already increased significantly over the years, because aluminium is a very uniform material that is easy to recycle. However, for mechanical reasons, different alloys are still used for can bodies and lids, with the lid containing a significantly lower proportion of recycled material. Moreover, wider implementation of deposit return systems would help increase recycling rates and create closed loops. The possibility of using a uniform alloy could facilitate much better recycling, but is an unsolved challenge because of the different requirements for the lid.

Aluminium recycling also plays an important role for other products, but the variety of alloys used is manifold. It is particularly difficult to use heavily mixed post-consumer scrap, which either has to be sorted and processed by using costly advanced procedures, or processed into lower quality casting alloys. It is likely that the development of new and more cost-effective sorting technologies could improve the sorting quality and enable higher-quality recycling.

However, because the amount of available scrap will not be sufficient to cover the overall demand for aluminium in the foreseeable future, **there are usages for all qualities of recycled material, which will help to contribute to a reduction in environmental impact and a lower demand for raw materials. There is an obvious conflict of objectives here between recycling of the highest possible quality**, with the effort and costs required for this, and a continuing demand for the lower quality recycled material. Nevertheless, it remains important to improve the collection of aluminium scrap, and to use closed-loop recycling wherever possible. **Another challenge** in this context is the development of more tolerant alloys that allow the use of a higher proportion of recycled material and by-elements without compromising material performance.

Lithium

The recycling of lithium has hardly taken place so far, primarily because the highly material-intensive traction batteries that have recently been used in electric vehicles will only reach the end-of-life stage on a large scale in the coming years. With the continuation of current trends in the transport sector alone, lithium is very likely to become scarce and more expensive in the future, but at present it is still a fairly inexpensive raw material. Therefore, **battery recycling has so far not been made economical for lithium**, as it is still cheaper to buy virgin lithium than recycled lithium. However, **as demand is expected to significantly grow in the near future, this is likely to change**.

Furthermore, **the quantities of batteries produced and also the cathode material and cell chemistry are changing continuously**, and may vary for specific use cases. This means that recyclers will be faced with the challenge of having to deal with a wide range of inputs to achieve the best yields of secondary raw materials. The importance of the individual elements may also change, for example if fewer and cheaper cathode materials can be used, and thus their contribution to the recycling yield is reduced, recycling may become a subsidy business, as raw material prices are sometimes lower than those of recycled material. Nevertheless, because of its chemical properties, there is no general alternative to lithium for the high energy density batteries that are needed in the transport sector.

REE

As **the number of possible suppliers of REE is limited because of the lack of deposits**, the recycling of REE is an important option to reduce dependencies.

However, **several problems are associated with the recycling of REE:**

- The various REE differ only slightly in their chemical properties, which complicates their separation in the recycling process.
- REE form very stable compounds in rare earth magnets, which is why the overall processing is very demanding technologically and financially.[83]
- The separate collection of rare earth magnets is costly and only worthwhile for large magnets in wind turbines.

All of the factors listed here pose various challenges for creating a stable and economic supply of the high-quality materials that companies need if they are to use recycled materials in their production processes.

5.3 Outlook

Overall, circular economy practices often require significant changes to existing business models because companies may need to address the availability of high-quality or alternative materials by fundamentally rethinking the design process, the logistics related to the reuse and recycling infrastructure, and the economic feasibility of such practices under current regulations. While the implementation of these practices can be challenging, it can also create new opportunities for businesses to build up more resilient business models, reduce costs and improve ESG performance. Nevertheless, it is a complex process that necessitates the collaboration of all stakeholders, including suppliers, producers, consumers and policymakers, to achieve a sustainable and profitable circular economy for CRMs.

5.4 Case studies

5.4.1 Complex challenges require comprehensive solutions: Volvo Cars' holistic approach to circularity

Today's cars contain around 50 different metals. It is not just electrification that is the reason for this. The current trend is for cars to become increasingly loaded with different options. The increased level of safety, comfort and digitalisation offered by vehicles contributes to the increased need for metals. Many of the 50 metals are present in very low quantities and are spread throughout the vehicle. This makes it difficult to recycle them when the vehicle reaches the end of its life. However, as the automotive industry transforms towards a more circular industry its recycling processes should improve.

Volvo Cars is committed to becoming a circular business by 2040, by maximising resource efficiency and decoupling resource use from business growth. To achieve this goal, Volvo Cars is implementing a holistic approach towards circularity, targeting both operations and vehicle design. The company aims to use higher amounts of recycled materials in its vehicles, and to design vehicles so that CRMs can be more easily recycled.

Volvo Cars is, for example, working on minimising its electric system by centralising vital electronic components and reducing the number of electronic components and cabling. The company is trying to cluster CRM-containing components and thereby make them easier to dismantle, and wherever possible designing components from a single material. It is also creating closed-loop recycling both for manufacturing waste and for components from its service units. Another key part of Volvo Cars' circular strategy is to identify partners that are leading the way in the recycling of CRMs.[84]

5.4.2 Design as a critical element for circular CRMs: Signify's efficient use of luminescent materials

Luminescent materials, also called fluorescent powders or materials, are used in illumination products: in LED lamps and luminaires, and also in low-pressure mercury discharge lamps. Mercury discharge lamps have a high recycling rate, exceeding 90 per cent. The glass is recycled and the toxic mercury recovered, but even though the fluorescent material can be recovered relatively easily, as it can be washed from the inside of the glass envelope, most of it is dumped because it is not economically feasible.

As mercury discharge lamps are now banned (in Europe), the amount of fluorescent materials used to make them will decrease with time. However, fluorescent materials are mostly used in LED-based illumination products, and their usage is set to increase in the coming years. In LED-based illumination products, the LEDs, which contain the fluorescent powders embedded in a silicone matrix, are usually soldered onto a printed circuit board.

Regarding recycling,[85] although methods exist to remove the LEDs from the circuit board, the huge variety of LED types means that it is difficult to reuse them. Removing the fluorescent powders from the LEDs and the silicone matrix is a far greater challenge than it is for discharge lamps; and even if it is possible, a mix of fluorescent materials is obtained, which is difficult to reuse as the exact mix varies from LED to LED because of differences in, for example, their colour temperature and colour quality.

Thus, a process will be needed to separate the different fluorescent materials.[86] This will be a costly process, which will only be feasible if the LEDs are adjusted at the design stage to allow for the easy removal of the fluorescent powders. Currently, the focus is on fluorescent materials that are based on the rare earth metal lutetium.

5.4.3 Replacing CRMs: Vianode's synthetic graphite – a giant leap to sustainable electrification[87]

By 2030, the EU aims to have at least 30 million electric vehicles on its roads.[88] One of the materials that is needed in large quantities for battery production is graphite, as it makes up about 50 per cent of the weight of the active materials in a lithium-ion battery. Vianode, a Norwegian company owned by Hydro, Elkem and Altor, set out to produce sustainable synthetic graphite to make a giant leap towards sustainable electrification.

Synthetic graphite can be obtained by the graphitisation of carbon sources, mainly coke, at high temperatures. Using low-sulphur coke (a minor by-product of oil refining) as a feedstock is an example of an industrial synergy: the primary alternative use of coke is combustion. Synthetic graphite is today the most common anode material and it enables increased range, faster charging, long service life and recyclability, and increased safety in electric vehicles. All of these features will support the faster adoption of electric vehicles and enable a well-functioning second-hand market for batteries.

Vianode has developed a revolutionary technology for the graphitisation process. By combining a closed and cleaner processing method with the use of renewable electricity from hydropower, this innovative technology helps to reduce CO_2 emissions by more than 90 per cent compared with conventional production. Compared with other anode materials, Vianode's anode material has an estimated footprint approximately 10 times lower – below 2 kg CO_2 equivalents per kg. Thus, Vianode's anode material is a key component for European cell manufacturers with ambitious sustainability targets. The efficient technologies and production process also contribute to reduced raw materials consumption.

This leap was made possible by specialised and proprietary expertise in high-temperature and closed production processing systems. The closed furnace technology reduces energy consumption by up to 50 per cent in the graphitisation part of production, compared with conventional production.

5.4.4 Sourcing CRMs responsibly: industry approaches

Given the often indirect nature of raw materials sourcing, brands are driven to take broad, collaborative industry approaches to promote and assure the responsible and sustainable sourcing of their materials. As most consumer-facing brands in the consumer electronics industry are downstream purchasers, the raw materials tend to enter the supply chain many levels above the brands' directly contracted suppliers.

For many brands, taking an industry approach to the responsible sourcing of raw materials is the only viable option. In the far upstream supply chain, at the mine level, brands are increasingly supporting the Initiative for Responsible Mining Assurance[89] to provide a credible and inclusive auditable standard for responsible mining that can, in turn, be relied upon by both downstream purchasers and regulators alike to verify the responsible and sustainable sourcing attributes of mined materials.

Similarly, the development and implementation of chain-of-custody standards and protocols will help stakeholders to track and verify certified material as it moves through the supply chain from one tier to the next. At the minerals processing level, which is widely considered to be the most significant choke point in material supply chains, the industry has coalesced around the Responsible Minerals Initiative[90] to conduct audits of smelters and refiners in high-risk minerals supply chains, to provide collective assurance for downstream purchasers that the raw materials sourced by their higher-tier indirect suppliers are, for example, 'conflict-free'.

5.4.5 Diversifying CRM sourcing: LKAB's circular innovation for the production of phosphorus and REE

LKAB operates the world's largest underground iron ore mines in the cities of Kiruna and Gällivare in northern Sweden. Here, more than 85 per cent of Europe's iron ore is produced. In addition to iron ore extraction and processing, LKAB is currently focusing on leveraging new technologies, innovative chemical processes, and circular methods to extract valuable REE and phosphorus. The REE and phosphorus will be extracted as by-products from the iron ore extraction, ie from material streams that currently end up as mining waste. The by-product nature of these materials makes their production less sensitive to the volatile markets often associated with CRMs and also less sensitive to market manipulation. Taking part in the creation of a European value chain for REE, LKAB plans to invest in new processing facilities directly adjacent to the mines, and to establish a unique circular industrial park by the Swedish coastal city of Luleå. The industrial park will be powered by fossil-free electricity, and produce the essential input materials required for its production processes.

As well as the important contribution from today's mining activities, there is potential for an exponential volume expansion as LKAB announced in January 2023 that Europe's largest known deposit of REE is in Kiruna (Sweden). LKAB submitted a concession permit application in June 2023[91] and, thanks to significantly higher grades, it may be possible to extract up to 10 times more strategic (REE) and critical (phosphorus) raw materials per tonne of iron ore as compared with the deposits that are currently mined by LKAB.

REE play a pivotal role in the production of electric cars and wind turbines – both key components of the green transition – and their supply chain is dominated by China. Whereas Russia has been a major supplier of phosphorus, which is a vital nutrient in the mineral fertilisers used in agriculture. As REE and phosphorus are included in the EU's list of 30 CRMs, LKAB's focus on their extraction could contribute significantly to increasing Europe's self-sufficiency in these vital resources.

For this project to succeed, LKAB is developing proprietary technology and is securing the prerequisites needed. However, more efficient permitting procedures are a key focus, given the complexity and time risk associated with this process historically.

By adopting circular economy principles and advanced technologies, LKAB is setting a precedent for other mining and mineral companies, and paving the way for a sustainable and resource-efficient future.

5.4.6 Collecting infrastructure as a key enabler for circular CRMs: Ball's approach to circular aluminium

As a global leader and innovator in the aluminium packaging industry, Ball remains committed to leading the development of low carbon, circular aluminium packaging solutions. The company's focus[92] is to reach net zero by increasing industry collaboration to new levels of detail, focus and transformation. The physical properties of aluminium provide an opportunity for decarbonisation to be achieved more quickly, and with lower abatement costs as compared with other packaging materials.

A key part of Ball's decarbonisation plan[93] is to achieve 90 per cent recycling rates, which will enable it to reach 85 per cent recycled content by 2030 in the regions where it operates – in Europe, the Middle East and Africa, its average recycled content is already 62 per cent. The key to achieving this target will be the development and implementation of modern deposit return systems (DRS) in Europe, which should increase collection rates from the current 73 per cent to more than 90 per cent by 2030. In most countries in Europe with existing DRS, recycling rates for cans are already at least 90 per cent. In Lithuania, where a DRS was introduced in 2016, the recycling rate increased from 45 per cent to 90 per cent within 5 years.[94] DRS enable the separate collection of clean waste streams and, ideally, recycling in a closed-product-loop scenario. Thus, it is possible to recycle aluminium over and over again in a can-to-can closed loop, with minimum losses, and as recycling rates increase, the need for primary material is exponentially reduced.

These developments will also incentivise further investments in Europe's capacity for can sheet rolling and remelting, which should address the risk of the leakage of aluminium into other markets and regions. The recycling of used beverage cans saves 95 per cent of the energy and 95 per cent of the CO_2 emissions required to produce the same amount of aluminium from a virgin source. It also ensures that other CRMs, like manganese and magnesium, which are present in the aluminium alloy are preserved in a closed product loop.

5.4.7 Recycling CRMs: Umicore battery recycling solutions[95]

Demand for batteries will grow exponentially, but it will be a struggle to source the large amounts of CRMs such as nickel, cobalt and lithium that will be needed to make them. Over the next decade, increasing numbers of lithium-ion batteries from electric vehicles will reach the end of their life, and significant amounts of production waste from cell and battery cell manufacturing will be generated. The recovery of valuable metals like nickel, cobalt and lithium by recycling production waste and end-of-life batteries enables their reuse as building blocks for new cathode materials, and also reduces the use of 'primary' CRMs extracted from mine concentrates.

Based on its extensive experience of recycling precious metals from very complex materials including electronic waste, Umicore has developed a unique recycling technology for rechargeable batteries. Umicore is a frontrunner with its industrial installation at its recycling plant in Hoboken near Antwerp, Belgium, which has an initial material input capacity of 7,000 tonnes per year. The pioneering technology implemented by Umicore combines a high-temperature treatment (pyrometallurgy), which melts the recyclables in a first process step, and a refining process step (hydrometallurgy), which extracts the valuable metals and recovers them in their pure forms so that they can be reused to manufacture new cathode materials. It is the most efficient and safest way to recycle the valuable metals and, as shown by a life-cycle assessment, has the lowest environmental impact. An industrial installation with an annual material input capacity of 150,000 tonnes is planned in Europe.

6. Conclusions and policy recommendations

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It is essential that the challenges and opportunities associated with the use of CRMs are addressed to achieve a green and digital transition. These materials are key components in many clean energy technologies, including electric vehicle batteries, wind turbines and solar panels. However, their supply chains are often concentrated in a few countries, creating risks of supply disruptions, price spikes, and social and environmental impacts.

To achieve a successful transition towards a more sustainable and resilient economy, decision-makers must take further steps towards improving the integration of circular economy solutions in CRM use, by building on the following learnings from case studies:

Implement a more comprehensive circular approach within the CRMA, rather than focusing only on recycling.

Currently, the CRMA is predominantly focused on increasing recycling rates. Although this is important, the implementation of a circular economy involves far more than increasing recycling rates. The EU's CRMA could be better connected with other climate, energy, digital, industry and circular economy policies in a holistic policy package. For example, more measures on energy and resource efficiency or life extension could be considered across the broader range of the circular economy package, and through the ESPR and other related policies for sustainable products. The recyclability, minimum lifetimes and warranties, durability, reusability and repairability of products could be even more effective at reducing the absolute demand for CRMs, increasing the security of supply and reducing environmental impacts. It is critical to align circular economy and sustainable product policies with the new proposals of waste regulations like the Waste Framework Directive and Waste Shipment Regulation.

Set a flexible approach towards circularity within the CRMA that recognises the need for a case-by-case approach.

Different material systems pose very different challenges and opportunities for the successful implementation of a circular economy. Accordingly, because the materials and their applications differ greatly, a 'one-size-fits-all' strategy that applies to all of them does not exist. The CRMA addresses important issues such as local extraction, local processing, local recycling and diversification of supply to ensure a secure supply of CRMs and the competitiveness of the EU economy. However, the objectives are often still formulated in rather general terms covering, for example, all CRMs, and do not take material differences and regional conditions in the EU and worldwide sufficiently into account. Thus, the CRMA should be expanded to cover additional circularity elements without being prescriptive on the exact measures required, as this would not be appropriate for different cases.

Deploy forward-looking infrastructure to enable a systems-wide circular economy.

Large quantities of primary raw materials will be needed for the initial build-up of stocks, which will cause a sharp increase in demand. However, the collection and recycling infrastructure also needs to be built up. For many CRMs, few collection, end-of-life-treatment and recycling facilities exist today. Although the Waste Electrical and Electronic Equipment and Waste Framework Directives already provide some initial incentives for the development of a more efficient recycling infrastructure, further ambitious measures are needed. An important basis for high-quality recycling is information about the composition of goods, and how to dismantle products and ensure their component materials accessible for high-quality recycling. All stakeholders along the value chain should be encouraged to co-operate, ie to exchange solutions, disseminate best practices and prevent problem shifting. This is an area where DPPs could be a valuable aid to enabling high-quality recycling.[96] It will also be necessary to promote the use of recycled materials through transparency and knowledge sharing.

Set a clear overall vision on a European Industrial Strategy that combines circularity, carbon neutrality and further sustainability aspects.

All additional EU regulation should promote circularity beyond recycling and also be better integrated with other targets, as traditional sector and topic-specific industrial policies are still not able to achieve this. In practice, this means integrating a circular economy more directly within different EU legislation, such as in the Green Deal Industrial Plan (GDIP), as a key driver to shift European industry towards circularity. Currently, circularity is barely mentioned within the GDIP, which is a very significant missed opportunity to harness the benefits that a circular economy could bring for European industry. A forward-looking approach towards a circular economy could lead to the EU becoming a world leader in circular technologies, which would build a competitive advantage globally for Europe. This, in turn, would lead to greater strategic autonomy and new business opportunities globally. Another example would be to create a greater link between energy savings policy and circularity. The revision of the Energy Efficiency Directive could be more clearly aligned to the CEAP to leverage the energy savings gained by keeping materials and products in the economy for longer.[97]

Create more environmentally and socially sustainable supply chains by diversifying supply chains and promoting responsible mining practices.

More international co-operation and co-ordination is needed to ensure a secure and sustainable supply of CRMs. Currently, the focus of the CRMA is on the security of supply; however, less attention is placed on how third countries are extracting these raw materials. It is vital that Europe ensures its supply chains are ethical, so that it does not simply outsource its social and environmental negative externalities. From a circular economy perspective, this will involve the investment in, and sharing of, innovative technologies with third countries, to ensure that innovative practices are not retained within the EU's borders. This will also mean working closely with local communities and ensuring responsible mining practices are implemented both inside and outside Europe.

Implement financial incentives and support schemes to ensure faster the commercial viability of a shift towards green technologies.

Suitable recycling processes will be important for securing the environmentally friendly, but also cost-effective, supply of CRMs. Given the high demand for CRMs, the current pace of change will not be fast enough to meet Europe's needs. The EU could speed up the transition towards green technologies by supporting early investments in innovative technologies. This will be key for improving the processing capabilities of Europe, alongside measures that enable demand for such recycled materials.[98]

Annex 1: EU, US and UK CRMs lists

Table 2: Development of the EU's lists of critical raw materials (CRMs) from 2011 until 2023 (CRMs added since the previous list are in green, and strategic raw materials in the 2023 list are in italics)

CRMs 2011[99]	CRMs 2014[100]	CRMs 2017[101]	CRMs 2020[102]	CRMs 2023[103]
Antimony	Antimony	Antimony	Antimony	Antimony
				Arsenic
		Baryte	Baryte	Baryte
			Bauxite	Bauxite
Beryllium	Beryllium	Beryllium	Beryllium	Beryllium
		Bismuth	Bismuth	*Bismuth*
	Borate	Borate	Borate	Boron – *metallurgy grade*
	Chromium			
Cobalt	Cobalt	Cobalt	Cobalt	*Cobalt*
	Coking coal	Coking coal	Coking coal	Coking coal
				Copper
				Feldspar
Fluorspar	Fluorspar	Fluorspar	Fluorspar	Fluorspar
Gallium	Gallium	Gallium	Gallium	*Gallium*
Germanium	Germanium	Germanium	Germanium	*Germanium*
		Hafnium	Hafnium	Hafnium
		Helium		Helium
Indium	Indium	Indium	Indium	
			Lithium	Lithium – *battery grade*
	Magnesite			
Magnesium	Magnesium	Magnesium	Magnesium	Magnesium & *Magnesium metal*
				Manganese – *battery grade*
Graphite	Natural Graphite	Natural Graphite	Natural Graphite	Natural Graphite – *battery grade*
		Natural rubber	Natural rubber	
				Nickel – battery grade
Niobium	Niobium	Niobium	Niobium	Niobium
	Phosphate rock	Phosphate rock	Phosphate rock	Phosphate rock
		Phosphorus	Phosphorus	Phosphorus

CRMs 2011[99]	CRMs 2014[100]	CRMs 2017[101]	CRMs 2020[102]	CRMs 2023[103]
	Silicon metal	Silicon metal	Silicon metal	*Silicon metal*
			Strontium	Strontium
Tantalum		Tantalum	Tantalum	Tantalum
			Titanium	*Titanium metal*
Tungsten	Tungsten	Tungsten	Tungsten	*Tungsten*
		Vanadium	Vanadium	Vanadium
Rare earth elements (REE)	Heavy REE (HREE)	HREE scandium*	HREE scandium*	HREE scandium*
	Light REE (LREE)	LREE	LREE	LREE
				Rare Earth Elements for magnets (Nd, Pr, Tb, Dy, Gd, Sm, and Ce)†
Platinum group metals (PGM)	PGM	PGM	PGM	*PGM*

* In the EU's definition, scandium is not included in the group of HREE and is therefore listed separately.
† Rare Earth Elements for magnets (Nd, Pr, Tb, Dy, Gd, Sm, and Ce) are not included in the CRM list, but are included in the strategic raw material list. Technically they can be classified as either LREE or HREE, but in the EU's definition, they are identified as a separate category.

Table 3: Comparison of the EU's last list of critical raw materials (CRMs) released in 2023 with the US and UK lists from 2022 (strategic raw materials in the EU's list are in italics)

EU list of CRM 2023[104]	US list of CRM 2022[105]	UK list of CRMs 2022[106]
Antimony	Antimony	Antimony
Arsenic	Arsenic	
Baryte	Baryte	
Bauxite	Aluminium	
Beryllium	Beryllium	
Bismuth	Bismuth	Bismuth
Boron – metallurgy grade		
	Cesium	
	Chromium	
Cobalt	Cobalt	Cobalt
Coking coal		
Copper		
Feldspar		
Fluorspar	Fluorspar	
Gallium	Gallium	Gallium
Germanium	Germanium	
Hafnium	Hafnium	
Helium		
	Indium	Indium

EU list of CRM 2023[104]	US list of CRM 2022[105]	UK list of CRMs 2022[106]
Lithium – *battery grade*	Lithium	Lithium
Magnesium & *Magnesium metal*	Magnesium	Magnesium
Manganese – *battery grade*	Manganese	
Natural Graphite – *battery grade*	Graphite	Graphite
Nickel – battery grade	Nickel	
Niobium	Niobium	Niobium
Phosphate rock		
Phosphorus		
	Rubidium	
Silicon metal		Silicon
Strontium		
Tantalum	Tantalum	Tantalum
	Tellurium	Tellurium
	Tin	Tin
Titanium metal	Titanium	
Tungsten	Tungsten	Tungsten
Vanadium	Vanadium	Vanadium
	Zinc	
	Zirconium	
Heavy rare earth elements (HREE) scandium* *Dysprosium (Dy), Gadolinium (Gd) and Terbium (Tb) listed under Rare Earth Elements for magnets†*	Dysprosium Erbium Gadolinium Holmium Lutetium Scandium Terbium Thulium Ytterbium Yttrium	REE
Light rare earth elements (LREE) *Cerium (Ce), Neodymium (Nd), Praseodymium (Pr) and Samarium (Sm) listed under Rare Earth Elements for magnets†*	Cerium Europium Lanthanum Neodymium Praseodymium Samarium	
Platinum group metals (PGM)	Iridium Palladium Platinum Rhodium Ruthenium	Palladium Platinum

* In the EU's definition, scandium is not included in the group of HREE and is therefore listed separately
† Rare Earth Elements for magnets (Nd, Pr, Tb, Dy, Gd, Sm, and Ce) are not included in the CRM list, but are included in the strategic raw material list. Technically they can be classified as either LREE or HREE, but in the EU's definition, they are identified as a separate category.

Annex 2: Regional and international initiatives

European Raw Materials Alliance (ERMA)

This strategy identifies raw materials as one of Europe's six strategic areas of dependency, and points out the need for an industrial alliance on raw materials.[107] The goal of the ERMA is to increase the EU's resilience in the value chains of REE and magnets, and is therefore aimed at funding and enabling relevant projects along the value chain. By 2030, the alliance promises to "increase the production of raw and advanced materials and address circular economy by boosting the recovery and recycling of critical raw materials"[108] and thereby sets a clear focus on circularity as one of the instruments to meet European supply. The alliance is led and managed by EIT RawMaterials, which was established in 2015, and forms part of the European Institute of Innovation and Technology.[109] Co-funded by the EU, the alliance is open to any relevant stakeholder, and includes more than 150 industrial and also non-industrial actors that are working together to secure the supply of raw materials and strengthen Europe's resilience.

Global Battery Alliance Action Partnership on Critical Raw Materials

The Global Battery Alliance (GBA) has launched the Critical Minerals Advisory Group (CMAG),[110] which will work with members across the value chain to ensure that critical materials are produced, sourced, processed, transported, manufactured and recycled in a responsible and sustainable manner that minimises environmental harm, respects human rights and creates benefits for stakeholders along the supply chain. The CMAG builds on the multistakeholder initiative implemented in 2020–21 under the Cobalt Action Partnership to introduce a range of macro-economic, social and governance issues related to the sourcing of critical minerals.

At the end of this members-led dialogue series, the GBA intends to have successfully mapped key issues pertinent to critical minerals within the battery value chain, prioritised issues based on their relevance to the GBA members involved and developed an action plan that enables the GBA to have a unique impact. In 2020–21, the GBA convened a comprehensive global stakeholder consultation process on the Artisanal and Small-scale Mining (ASM) Cobalt Framework as part of the Cobalt Action Partnership to immediately and urgently eliminate child and forced labour from the cobalt value chain, contribute to the sustainable development of communities and respect the human rights of those affected.

International Minerals Security Partnership (MSP)

The US-led Minerals Security Partnership was announced in 2022,[111] and its members include Australia, Canada, Finland, France, Germany, Italy, Japan, the Republic of Korea, Norway, Sweden, the UK, the USA and the EU. The partnership is aimed at building robust supply chains for CRMs while also protecting the environment. Partner countries have announced investment in various international projects along the supply chain and in the development of recycling technologies.

Public-Private Alliance for Responsible Minerals Trade (PPA)

Another example of a multisectoral partnership formed by the US government and other stakeholders to build resilient CRM supply chains is the Public-Private Alliance for Responsible Minerals Trade (PPA).[112] Administered by the non-profit organisation RESOLVE, the alliance comprises various governments, stakeholders along the supply chain, civil society organisations and foundations. Since 2012, the alliance has been operating to establish supply chains that are free of conflict for minerals, such as tin, tantalum and tungsten in the Democratic Republic of the Congo and Great Lakes region of Central Africa.

UNECE Framework for Critical Raw Materials

The United Nations Economic Commission for Europe (UNECE) is supporting Member States to ensure a sustainable, ethical supply of CRMs for the transition to a net zero economy.[113] CRMs in this context are minerals that are essential, for example, for digitalisation, renewable energy technologies and electric vehicles. For this purpose, the UNECE has developed a framework for CRMs, including a social contract, a sustainable finance framework, a sustainable resource management system, supply chain traceability, and strategic environmental assessments to mitigate negative impacts and identify sustainable solutions. The aim is to align CRMs with the United Nations' Sustainable Development Goals.

OECD Inventory on Export Restrictions on Industrial Raw Materials

The Organisation for Economic Co-operation and Development (OECD) seeks to support more sustainable policies, including the topic of raw materials that are critical for the green transition.[114] Based on its Inventory on Export Restrictions on Industrial Raw Materials,[115] the OECD recently published a Trade Policy Paper,[116] providing a comprehensive assessment of data on production and international trade with a focus on raw materials that are critical for green technologies. Additional work in this area is envisaged and will include an annual update of the Inventory, the associated online data visualisation tool and an analytical report that will follow up on the topic.

IEA Critical Minerals Policy Tracker and database

Following the 2022 Ministerial Communiqué[117] of the International Energy Agency (IEA), a Working Party was created by IEA members to work on the availability, security and responsible sourcing of energy-specific critical minerals and materials. A key development in this regard is the IEA Critical Minerals Policy Tracker,[118] which is based on the IEA report *The Role of Critical Minerals in Clean Energy Transitions*[119] and also its World Energy Investment and World Energy Outlook reports. This tracker tool is intended to help policymakers create new critical mineral policies for supporting supply reliability and resiliency, promoting exploration, production and innovation, and also encouraging sustainable and responsible practices. In May 2023, the IEA's Policies database on critical minerals[120] for the green transitions listed 214 policies and initiatives worldwide.

IRENA Collaborative Framework on Critical Materials for the Energy Transition

In March 2022, members of the IEA's International Renewable Energy Agency (IRENA) launched a Collaborative Framework on Critical Materials for the Energy Transition.[121] The platform aims to exchange knowledge and best practices, and to co-ordinate actions to ensure that the scarcity of minerals and materials does not threaten the accelerated deployment of renewable energy. The platform will develop strategies to de-risk the supply of critical materials, enhance understanding of the market situation and raise acceptance for new, more sustainable mining projects. The framework builds on IRENA's analytical work, including a technical paper entitled *Critical Materials for the Energy Transition*,[122] and responds to members' requests for an international dialogue platform on critical materials.

Annex 3: Legislation, strategies and policies related to critical raw materials

Additional CRM-related legislations

Conflict Minerals Regulation (2021)

The Conflict Minerals Regulation[123] came into effect on 1 January 2021. This regulation is a binding legislative act of the EU which aims to ensure that minerals and metals entering the EU do not contribute to human rights abuses or environmental damage. The regulation requires EU importers of tin, tantalum, tungsten and gold to conduct due diligence on their supply chains. The aim of this due diligence process is to identify and address the risks of adverse impacts linked to their sourcing, including forced labour and human rights abuses. The regulation establishes a full framework for whole supply chain reporting and disclosure, and also for certification and recognition schemes for responsible sourcing.

Overview of other EU strategies and policies affecting CRMs

European Green Deal (2019)

The European Green Deal[124] is a comprehensive set of overarching policy initiatives and measures introduced by the European Commission in 2019 to ensure the EU climate is neutral by 2050, and to transform the EU's economy into a sustainable and resource-efficient one. It states that net zero greenhouse gas emissions will be achieved by 2050, and that economic growth must be decoupled from resource use.

New European Industrial Strategy (2020)

The new European Industrial Strategy[125] is a set of policies and initiatives introduced by the European Commission, also in March 2020, to support the competitiveness and resilience of the EU's industrial sector in the digital age. The strategy focuses on investing in strategic technologies in key areas such as 5G, artificial intelligence, cloud computing and cybersecurity, and also on the development of strategic value chains, such as green hydrogen and electric vehicles.

It aims to support a sustainable industrial transition by promoting the circular economy, improving resource efficiency and reducing greenhouse gas emissions. It also introduced the principles for strengthening the EU's strategic autonomy by securing the supply of clean and affordable energy and raw materials, and for creating lead markets for related clean technologies.

EU Batteries Directive (2020)

In late 2020, the proposal for the EU Batteries Directive[126] was published to establish circular economy practices for rechargeable industrial batteries and electric vehicle batteries with an internal storage capacity above 2 kWh, and to reduce their negative environmental and social impacts throughout all life-cycle stages. This covers, for example, the carbon footprint or the recycled content, but also additional sustainability information on the battery composition, including CRMs.

The Batteries Directive was also presented by the Commission as a 'blueprint' for future product regulations, especially with regard to the focus on the actual recovery of CRMs instead of input-based recycling quotas. For the required traceability of product data – and for the first time in an EU regulation – a product-specific DPP is expected to be used as a 'battery passport'.

Fit for 55 package (2021)

The EU's Fit for 55 package[127] is a set of proposed legislative measures introduced by the European Commission in July 2021, aimed at achieving the EU's target of reducing greenhouse gas emissions by at least 55 per cent by 2030, compared with 1990 levels. The package is another key component of the EU's Green Deal and its broader strategy for a sustainable and climate neutral economy. The Fit for 55 package includes a wide range of policy measures, which also address the topic of CRMs in several ways.

The Fit for 55 package also includes measures to increase funding for research and innovation in areas such as low carbon technologies, sustainable industrial processes, and the recycling and recovery of CRMs. These measures aim to develop new technologies and solutions that could reduce the use of CRMs or replace them with more sustainable alternatives. As part of its ongoing raw materials diplomatic activities,[128] the EU has also established dialogues and partnerships with countries and regions that are major producers of CRMs, to ensure a secure and sustainable supply.

EU Global Gateway (2021)

Launched by the EU in July 2021, the EU Global Gateway[129] is a platform aimed at creating mutually beneficial partnerships with emerging markets and developing economies. In particular, it will support smart, clean and secure links in the digital, energy and transport sectors, and also strengthen health, education and research worldwide.

The EU Global Gateway could also address the topic of CRMs by providing information on their availability and accessibility in different countries and regions, and also on the regulatory frameworks that govern their extraction, production and trade. The platform could promote the responsible sourcing and sustainable supply chain management of CRMs (eg for battery and renewable hydrogen production), by providing guidance and resources that will support the identification and mitigation of the risks associated with CRM use, and also the adoption of best practices for responsible sourcing.

The Versailles declaration (2022)

The Versailles declaration[130] is a statement that has been adopted by the EU and its Member States, and also Canada and Japan. The declaration affirms the signatories' commitment to strengthening multilateralism and co-operation in the face of global challenges such as climate change, health pandemics and geopolitical tensions.

The declaration highlights the importance of innovation, sustainable development and the green transition, and emphasises the need to ensure the resilience and security of critical supply chains, including CRMs. The signatories have committed to working together to promote the sustainable and responsible sourcing of CRMs, to improve their availability and accessibility, and to support research and development of alternative materials and technologies.

REPowerEU plan (2022)

The EU's REPowerEU plan[131] is a strategy to increase renewable energy production and consumption in Europe, and also a direct reaction to Russia's war on Ukraine. The plan aims to reduce greenhouse gas emissions and accelerate the transition to a carbon neutral economy by increasing the share of renewable energy in the EU's energy mix. The REPowerEU plan is relevant for CRMs as it promotes the use of renewable energy technologies such as wind and solar energy that rely on CRMs. The plan could also present significant resource benefits over fossil fuel technologies. Furthermore, the included target for more energy efficiency could also reduce the overall demand for energy generation systems that are dependent on CRMs.

European Chips Act (2022)

The European Chips Act[132] is an EU initiative aimed at strengthening the EU's semiconductor industry and reducing its dependence on imports from non-EU countries. The initiative was launched in February 2022 as part of the EU's broader Digital Strategy to ensure that Europe is fit for the digital age with artificial intelligence, the Internet of Things, 5G networks and green technologies. The European Chips Act is relevant for CRMs as semiconductor manufacturing relies on several CRMs, including REE, lithium and cobalt. By promoting the development of advanced semiconductor technologies and manufacturing processes in Europe, the initiative aims to reduce the EU's dependence on these materials and ensure their sustainable sourcing and use.

Green Deal Industrial Plan, GDIP (2023)

On 1 February 2023, the European Commission presented the EU's GDIP[133] with the target to increase the general competitiveness of European industry, to support a rapid green and digital transformation, and to strengthen the EU's strategic autonomy.

The GDIP seeks to establish a supportive environment for the scaling up of the EU's manufacturing capacity with special focus on net zero technologies and related products needed to meet the EU's climate targets. On an international stage, Russia's war on Ukraine also brought a sharper focus to geopolitics, which is also reflected in the GDIP. Regarding CRMs, the GDIP recognises their importance for several sectors, such as renewable energy, batteries, electric vehicles and semiconductors. It highlights the need to ensure sustainable and resilient access to raw materials, including through responsible sourcing, substitution and recycling.

The GDIP proposes several actions, including supporting the development of sustainable supply chains and promoting circular economy principles to reduce dependence on primary raw materials. It also proposes the creation of a Critical Raw Materials Club to bring together raw materials consumers and resource-rich countries, and also additional Clean Tech/Net-Zero Industrial Partnerships to ensure global security of supply through a competitive and diversified industrial base.

Net Zero Industry Act, NZIA (2023)

The proposal for the NZIA,[134] published by the commission in March 2023, aims to establish a comprehensive framework for achieving net zero greenhouse gas emissions from industry by 2050. The Act proposes measures to support the transition of industrial sectors to a more sustainable, low carbon future, by providing financial support for research, innovation and skills, improving the regulatory framework and enhancing international co-operation. For this purpose, the Act proposes to accelerate the deployment of renewable energy sources, such as wind and solar, in industrial processes. Furthermore, it proposes measures to promote resource efficiency and circularity, including the use of secondary raw materials and the reduction of waste.

Directive on common rules promoting the repair of goods (2023)

In March 2023, the European Commission adopted a proposal on common rules promoting the repair of goods[135] with the aim of reducing waste and benefiting consumers. The proposal includes a new 'right to repair' for consumers within and beyond the legal guarantee, which requires sellers to offer repair services and producers to inform consumers about such repair services. An online matchmaking repair platform will connect consumers with repairers and sellers of refurbished goods, and a European Repair Information Form and quality standard for repair services will be developed to improve transparency and quality. The proposal aims to make it both easier and more cost-effective for consumers to repair goods, boosting the repair sector and incentivising sustainable business models.

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