SETTING STANDARDS FOR CRITICAL RAW MATERIALS

State of play and future prospects

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SUMMARY

As the EU seeks to secure access to Critical Raw Materials (CRMs), CRM-related technical standardisation has been gaining increasing policy attention. Technical standards are essential for the private sector to comply with emerging regulatory requirements, including those recently introduced by the Critical Raw Materials Act. They are also crucial for disseminating significant technological advancements in the CRM sector, notably on recycling, while ensuring their benefits are distributed fairly and sustainably. In the current highly competitive geopolitical environment, technical standards are also increasingly leveraged to favour domestic industrial interests and priorities.

This CEPS In-Depth Analysis examines the role, state and future prospects of CRMs-related standardisation from an EU perspective. It begins with an overview of the key benefits and actors in both the EU and global technical standardisation system. It then maps key recent developments and initiatives in CRM standardisation, in the EU and globally. Drawing on consultations with experts, it then identifies three fundamental risks and challenges – the limited participation of EU stakeholders and experts, specific content gaps in recycling and traceability, and a highly fragmented ESG standardisation landscape. Finally, it provides some policy recommendations to help address these challenges and to enhance the EU's role in CRM standardisation.

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INTRODUCTION

The race to secure access to Critical Raw Materials (CRMs) is in full swing. In recent years, expected rises in demand and increasingly evident vulnerabilities in supply chains have driven numerous governments worldwide to adopt wide-ranging policies to either reduce the risk of supply shortages, or to take advantage of large domestic resources for economic or geopolitical returns (Righetti & Rizos, 2024). In the EU, the Critical Raw Materials Act (CRMA), adopted in May 2024 after relatively swift interinstitutional negotiations, introduced key enhancements to the EU's policy framework on CRMs, including support for strategic projects, monitoring of supply chains, circularity, stockpiling or joint purchasing of CRMs. As the focus in the EU and other regions now shifts to implementing these measures, technical standardisation is emerging as yet another strategically important 'piece' of the CRM 'puzzle'.

The increasing relevance of standardisation in the CRM space stems from multiple factors. In jurisdictions like the EU that are introducing relevant new CRM-related regulations, the need for standards somewhat naturally derives from the private sector's need for a common framework for compliance. The accelerated pace of innovation in the sector has also amplified the need for common technical frameworks; renewed interest in and support for CRM-focused research, Development and Innovation (R&D&I) activities have indeed led to significant technological advancements in extraction, processing and recycling-related technologies, with the EU retaining a significant role as leading innovator in all CRM value chain segments (EPRS, 2024). In such a dynamic context, technical standards allow to codify, spread and further feed these innovations, while ensuring that their economic and societal benefits are shared in a fair and sustainable manner.

But what has perhaps been the main driver of growing attention to CRM standardisation, however, is the geostrategic impact of standards. In the global race for technological leadership, the ability to shape domestic standards as global benchmarks offers significant competitive advantage *vis a vis* other global players. This is well understood in the EU, which has long 'punched above its weight' in international standard setting[1]. Because of this, however, and in a context of heightened geopolitical competition, technical standardisation has been gradually shifting from a purely technical process of voluntary, private sector self-regulation to a competitive arena where governments adopt more assertive, interventionist approaches to pursue domestic political priorities

1 So much so that standards have often been referred to as a key – yet often overlooked – channel through which the EU exerts its regulatory influence over global markets (Fägersten & Rühlig, 2019; Pelkmans, 2024; Rühlig, 2021), a phenomenon known as the 'Brussels effect' (Bradford, 2020; Bradford et al., 2012).

(Fägersten & Rühlig, 2019; Rühlig, 2021, 2023; Zúñiga et al., 2024). And as the strategic importance of CRMs rises across policy agendas worldwide, they are becoming one of the contested 'battlegrounds' in the global standardisation arena.

Different governments have been moving in this direction. The trend has been notably driven by China, whose state-steered standardisation approach – emerging in initiatives like China Standards 2035 or the China Standardisation Outline – has manifested in both increasing assertiveness within international standard-setting organisations (SDOs) or by the *de facto* internationalisation of domestic standards via Belt and Road Initiative (Patrahau et al., 2020). In the US, the 2023 National Standards Strategy for Critical and Emerging Technology, also recognised the need to take a more proactive role in international standard development, particularly in a subset of technologies which also include those 'support[ing] increased sustainable extraction of critical minerals' (The White House, 2023). As discussed later in this report, the 2022 EU Standardisation Strategy has also placed significant emphasis on the need to align standardisation efforts to the EU's policy priorities, identifying CRMs as one of the 'standardisation urgencies' (European Commission, 2022a).

In this context, this CEPS In-Depth analysis assesses the role, state and prospects of CRMs-related standardisation in the EU and globally. It starts, in Section 1, by briefly describing the benefits of standardisation, the global and European standardisation systems and recent developments in the EU standardisation framework. Section 2 follows with a mapping of the current standardisation landscape for CRMs, describing recent initiatives. Section 3 then highlights, based on expert consultations, the major gaps and existing risks inherent in CRM standardisation activities, before Section 4 concludes with policy recommendations.

1. STANDARDS 101: BENEFITS AND ACTORS

1.1. THE BENEFITS OF STANDARDISATION

Although often overlooked, standards[2] are fundamental elements of the modern economy, permeating nearly every aspect of daily life. Two of the main international SDOs, the International Organization for Standardization (ISO) and the International Electrotechnical Commission (IEC), define a standard as '*[a] document, established by consensus and approved by a recognized body, that provides, for common and repeated use, rules, guidelines or characteristics for activities or their results, aimed at the achievement of the optimum degree of order in a given context*' (ISO/IEC, 2024). In other words, standards consist of in-depth, technical descriptions of how a certain product, process, or service should be manufactured, performed, or delivered and referred to by companies, consumers and public authorities alike.

The socio-economic benefits of standardisation have been widely documented in the literature. On a macro level, evidence indicates a positive impact on growth[3] driven primarily by an increase in labour productivity (Buts et al., 2020; Menon Economics, 2018; Vennerød et al., 2023). From a micro (firm-level) perspective, standardisation has been identified as offering strategic advantages such as improved market access, risk reduction and product quality improvement (European Commission, 2021b; Menon Economics, 2018). These benefits extend also to SMEs, despite the obstacles they sometimes face in directly participating in standard-setting processes (Miotti, 2009; Blind, 2022; Menon Economics, 2018).

The literature identifies several key mechanisms through which standards generate productivity gains. Standardisation increases **interoperability and compatibility** of processes, technologies and products (European Commission, 2021b; Menon Economics, 2018; Vennerød et al., 2023), meaning their ability to work together in a coordinated manner without the need for further adaptations. This allows producers to select among a wider range of harmonised supply sources, leading to greater cost-efficiency along supply chains (Vennerød et al., 2023). Product simplification and higher compatibility of components result in cost savings, thereby increasing a company's value (Miotti, 2009; European Commission, 2021b).

2 In this report, the word 'standard' refers to 'technical standard', meaning that developed by standardisation organisations and voluntary in nature (i.e., not mandated by regulation).

3 The contribution of standards to GDP growth is estimated to range between 15 and 28 % across European and North American countries (Vennerød et al., 2023). In Europe, one percentage increase in the stock of standards can bring about an increase in EU and EFTA of EUR 8.4 billion in gross value added over the following year (European Commission, 2021), though the estimated impact varies significantly across countries.

In turn, greater interoperability enables economies of scale and the building of positive network effects (Menon Economics, 2018), thereby fostering **international trade** (European Commission, 2021b; Vennerød et al., 2023)[4]. This has been particularly relevant in the process for EU integration, where the adoption of common EU standards in the 1980s allowed to overcome conflicting national standards and boosted cross-border exchanges (Miotti, 2009; Bjerkem & Harbour, 2020). Previous stakeholder consultations and surveys confirmed increased access to international markets as one of the main benefits of using standards (Miotti, 2009; European Commission, 2021b), though stronger benefits expectedly accrued for larger companies compared to SMEs (European Commission, 2021b).

Standards codify technology developments and best practices, thereby contributing to knowledge dissemination and incentivising **innovation** (Baron & Larouche, 2023; Blind, 2022; Vennerød et al., 2023). In highly standardised sectors, firms enjoy easy access to a common knowledge platform, which reduces the need to spend time and resources on independent R&D&I. By advancing firms to the technology frontier, standards put more of them in a position to further innovate. However, while effective in driving incremental innovation, standardisation might also entail the risk of limiting more radical technological advancements, as it pushes the industry toward lock-in effects (i.e., that standardised technological solutions tend to survive even when they become suboptimal) (European Commission, 2021b; Blind, 2022).

Standardisation also increases **market competition** through multiple channels. Firstly, standards reduce the variety of processes and products by promoting more uniform solutions. In turn, this enhances economic scalability and reduces prices (European Commission, 2021b; Blind, 2022; Vennerød et al., 2023). Further, the reduction in the variety of intermediate goods multiplies the number of compatible suppliers, generating productivity gains throughout the value chain and particularly in downstream stages (Blind, 2022). As products become increasingly similar, competitive pressure intensifies (Blind, 2022). Secondly, standards reduce information asymmetries, which helps level the playing field (Menon Economics, 2018). Indeed, when newcomers adopt widely recognised standards it helps them gain the trust of other market actors (European Commission, 2021b; Vennerød et al., 2023).

Quality assurance constitutes another channel for standards to impact productivity. Quality standards minimise manufacturing errors and investments in additional checks or safety measures, leading to costs savings (Blind, 2022; Menon Economics, 2018; Vennerød et al., 2023). Additionally, they often offer insurance against risky products or

4 For instance, Vennerød et al. (2023) estimate standardisation to have been associated with 9 % of sector-specific export growth in six Nordic countries between 1970 and 2019.

processes (Miotti, 2009; European Commission, 2021b). For large companies, such risk reduction is a crucial benefit of standardisation. Minimum quality requirements further enhance competition transparency by reducing information asymmetries between producers and consumers. In turn, stronger consumer trust leads to sales growth, which constitutes the main incentive to standard application for micro enterprises (Menon Economics, 2018).

Beyond the impacts on productivity, it is worth noting how through some of the above mechanisms standards bring broader social and environmental benefits. Indeed, standards generate positive benefits in terms of **safety and environmental safeguards** (Bjerkem & Harbour, 2020; Menon Economics, 2018; Vennerød et al., 2023). By enhancing product quality, safety and sustainability, standardisation improves consumers' experience, with positive ripple effects throughout the economy (Bjerkem & Harbour, 2020; Blind et al., 2012; Vennerød et al., 2023). Although there is no evidence of direct causal relationship between increased standardisation and lower environmental impact at the company level, it has been demonstrated that standards help companies in complying with complex regulations and ease verification processes for public authorities (European Commission, 2021b). Overall, broader social and environmental benefits of standardisation have been indicated to possibly exceed the impact on productivity gains (Bjerkem & Harbour, 2020)[5].

Finally, from a **policymaker or legislator perspective**, standardisation benefits by lifting the burden of dealing with technical specifications at both the product and process level (Blind et al., 2012; Vennerød et al., 2023). Moreover, standards are found to generally facilitate compliance with regulations, especially legislative provisions related to sustainability or product quality (Miotti, 2009; European Commission, 2021b; Menon Economics, 2018). Such advantages provide arguments in support of public funding allocation to standardisation processes (Blind et al., 2012).

1.2. AN OVERVIEW OF THE GLOBAL AND EUROPEAN STANDARDISATION SYSTEMS

Standard setting involves a wide and heterogeneous system of actors and organisations. Standards are developed within SDOs, i.e. multistakeholder platforms where interested parties (manufacturers, consumers or other organisations) propose, discuss and ultimately agree on the content of standards. While the development of standards can be initiated by any of these parties, it is usually industry that takes the initiative, for instance when a new product enters the market. Importantly, standard setting is a bottom-up, consensus-based and participatory approach that relies on finding highest

5 The literature also highlights the relevance of standardisation with respect to sustainable development more broadly. Indeed, both European and ISO standards were found to be positively correlated with the UN's SDGs indicators (European Commission, 2021b; Blind, 2022).

common denominator across participating members in an iterative (hence typically lengthy) process. As such, the process fundamentally differs from – and de facto complements – the top-down approach of principles-based legislation. Typically, regulations set mandatory requirements, and technical standards provide a solution to achieve compliance with them. Unless explicitly mandated by law, standards are voluntary in nature, and participation in standard development is voluntary and not remunerated.

Standards can be developed at different levels. In the EU, the legal framework for standards[6] identifies four types of applicable ones: international, European, harmonised and national standards[7].

International standards are set by international standardisation organisations. The International Telecommunication Union (ITU), ISO and IEC are the main ones. Where IEC and ITU standardise specific sectors (electrotechnical and telecommunications, respectively) ISO stands out as the only one covering virtually all economic areas. ISO and IEC are member-based, with members being the national standardisation bodies (NSBs)[8]. Standards are developed within sector- or product-specific technical committees (TCs), each identified by a reference code (e.g. ISO/TC 61 'Plastics'). Each member organisation (i.e., the NSBs) decides which technical committees to be involved in, and to what extent (i.e. as active participant or as observer with commenting rights) based on national interests and/or priorities. New TCs can be set up based on an NSB initiative against emerging needs. Within a certain TC, draft standards are developed by active members and then circulated across all TC members for comments and feedback. This might happen for several rounds, until the group reaches a consensus. Finally, all NSBs are invited to vote on the final draft.

At EU level, European Standards (ENs) can only be developed by one of the three European Standardisation Organisations (ESOs): the European Committee for Standardization (CEN), the European Committee for Electrotechnical Standardization (CENELEC) and the European Telecommunications Standards Institute (ETSI). The structure of the three organisations mirrors that of the international organisations described above: CEN and CENELEC are associations bringing together the NSBs (CEN)

6 EU Regulation 1025/2012, Art. 2.

7 Beyond technical standards, two other types of deliverables can be produced by SDOs: technical specifications and technical reports. Technical specifications are normative documents used when there is a need for a standard but not yet enough consensus for a standard, as is often the case when a quick solution is required in areas of rapid technological development. Technical reports, on the other hand, are informative documents providing information on the technical content of future standardisation work, but do not establish binding technical requirements (ISO, 2024).

8 Being a UN Specialised Agency, ITU works slightly differently than ISO and IEC, offering memberships also to individual organisations (e.g. companies or universities). It also has a broader focus than standardisation only.

and the National Electrotechnical Committees (NECs) (CENELEC) of 34 European countries[9] as members. Their standardisation activities cover a wide range of sectors, with CENELEC focusing on the electrotechnical domain. Stakeholders can participate in their activities through their respective NSBs and NECs, which selects representative delegations for specific standardisation projects. ETSI focuses on standards for Information and Communication Technology (ICT)-enabled systems, applications and services. It comprises a far wider membership base, counting over 900 member organisations from 60 countries and 5 continents. Like ITU, ETSI members include private companies, research entities, governments, and public organisations, which can become directly involved in standards development without the mediation of NSBs or NECs.

Although most ENs are developed based on the initiative of industry, the European Commission can also issue standardisation requests ('mandates') for ESOs to develop **Harmonised Standards** (hENs). hENs are developed regular ENs but published in the Official Journal of the European Union and used by economic operators to demonstrate compliance with the requirements of EU legislation. The so-called presumption of conformity applies: if a certain product meets the requirements of the relative hEN, the product is presumed to conform to the certain EU legislation and has access to the Single Market. The use of hENs is voluntary, meaning that other technical solutions – including national, non-harmonised European or international standards – can be used by operators to demonstrate compliance with mandatory EU legal requirements. In these cases, however, the process to show compliance might be more cumbersome. About 20 % of European standards are developed as hENs upon a mandate of the European Commission (European Commission, 2024a, 2024b).

Box 1. The Vienna and Frankfurt Agreements

The relationships between ISO and CEN and between IEC and CENELEC are governed by the Vienna and Frankfurt Agreements, respectively. Their primary objective is to increase transparency, avoid duplication of efforts, and streamline the work of SDOs, thereby reducing the time required to produce standards. The Agreements recognise the primacy of international standards over national or regional ones, as stipulated in the WTO Code of Conduct, but they also acknowledge that the EU single market may require standards for which there is no recognised international need, or that are more urgently needed by the EU than at the international level. The Vienna agreement (ISO/CEN, 2001) outlines two modes of collaboration between ISO and CEN: under ISO leadership (which is the

9 EU-27, EFTA countries and United Kingdom, the Republic of North Macedonia, Serbia and Türkiye.

default and preferred option) and under CEN leadership (which is only permitted if there are reasons acceptable to non-CEN members of a specific TC, such as the European Commission's request for hENs).Cooperation involves the exchange of information, mutual representation at meetings, and parallel approval of standards at both the international and European levels. Similarly, under the Frankfurt Agreement (IEC/CENELEC, 2016), new electrical standards projects are jointly planned between CENELEC and IEC, but preferably carried at the international level. That is, when a new work item is proposed to CENELEC, CENELEC first offers it to IEC, and only if it (IEC) declines can CENELEC develop the standard (keeping IEC informed and allowing it to vote).

Finally, at national level, NSBs serve as the primary reference point for any interested party seeking access to the standardisation system, whether at national, European or international level. NSBs are responsible for adopting and implementing ENs as national standards. In cases where existing national standards conflict with newly adopted ENs, it is the responsibility of the NSBs to withdraw the conflicting national standards to ensure alignment with the European framework. During the development of standards within ESOs or at the international level, it is up to the NSB to disseminate draft standards to relevant stakeholders within their country and facilitate discussions to form a coherent national position. When adopted, an EN is implemented by NBS as a national standard in Member States (CEN-CENELEC, 2024). Figure 1 below provides an overview of global and European SDOs.

Figure 1. SDOs in global, EU and national standardisation systems

	General	Electrotechnical sector	Telecommunication sector
Global Level	ISO International Organization for Standardization	IEC International Electrotechnical Commission	ITU International Telecommunication Union
European Level	CEN European Committee for Standardization	CENELEC European Committee for Electrotechnical Standardization	ETSI European Telecommunication Standards Institute
National Level (example)	SIS Swedish Institute for Standards	SEK Swedish Electrical Standards	ITS Swedish Information and Telecommunications Standardization

Source: authors' own elaboration.

1.3. THE EUROPEAN STANDARDISATION STRATEGY AND EMERGING STANDARDISATION PRIORITIES

The importance of technical standards for the EU Single Market can hardly be overstated. Since the establishment of the European Economic Area in 1985 an the 'New Approach' to technical standardisation, the harmonisation of technical standards across Member States has been crucial in reducing barriers to cross-border trade and accelerating the process of EU integration. While subsequent policy cycles have fundamentally preserved the core principles of the EU standardisation policy, over time this has acquired an increasingly strategic significance and has been influenced by evolving policy priorities (Baron & Larouche, 2023).

The current legal and organisational framework of the European Standardisation System (ESS) is defined by Regulation 1025/2012, which consolidated and updated pre-existing EU legislations in a single instrument. Since the enforcement of the Regulation in 2013 there have been some notable updates and revisions to the EU standardisation policy. In 2016, for instance, the European Commission launched a Joint Initiative on Standardisation to increase the visibility of the benefits of standards and strengthen partnerships between the European Commission, ESOs and stakeholders. The same year, responding to a European Court of Justice case equating hENs to a provision of EU law, the European Commission introduced stricter requirements for the drafting of hENs, which eventually led to longer approval times (Bjerkem & Harbour, 2020).

The 2019-2024 political cycle also saw some significant new initiatives. During the first two years, key strategic documents such as the EU Green Deal, Digital Strategy and Industrial Strategy recognised the strategic role of standards in strengthening EU strategic autonomy and industrial competitiveness, as well as the need for the EU to be more assertive in SDOs (Bjerkem & Harbour, 2020). In 2021, the update of the 2020 Industrial Strategy further emphasised these points, announcing plans for a new standardisation strategy and for adjustments to the EU standardisation framework. Taking into account stakeholder feedback to an initial roadmap and MS recommendations[10], in 2022 the European Commission thus published a new **EU Strategy on Standardisation** (European Commission, 2022a).

The Strategy identified two major deficiencies with the current ESS: from an outward-looking perspective, the ESS was considered as not equipped to support the EU's competitiveness in the global context, particularly against increasingly decisive action from third countries to support their own competitive edge. From an inward-looking perspective, the strategy acknowledges the lack of flexibility, agility and focus of the ESS,

10 This was partly driven by pressure from some Member States, which in a non-paper circulating in 2020 (and presented for discussion at the Competitiveness Council of May 2021) were calling for a revision of the ESS.

which prevents it from properly and timely responding to – and even less driving – the dynamic innovation pace of emerging technologies, notably in the green and digital space. The Strategy therefore presented several actions aimed at addressing these challenges, including the creation of a High-level Forum (HLF) on European Standardisation and targeted amendments to Regulation 1025/2012 (see Box 2).

Box 2. The EU Strategy on Standardisation

The EU Strategy on Standardisation foresaw 5 key sets of action to strengthen the ESS:

1) The creation of a **High-level Forum on European Standardisation**, which should: i) advise and assist the EC in identifying and anticipating future standardisation priorities and needs; ii) advise and support the European Commission in coordinating the representation of EU interests in international standard-setting fora; iii) ensure that EU standardisation activities are aligned with the EU policy objectives and iv) strengthen technical expertise and skill in standard setting activities. The forum brings together MS, NSB and ESOs representatives, as well as actors from industry and civil society, and works in close collaboration with existing experts' groups, including industrial alliances.
2) Amendments to **Regulation 1025/2012**, to adjust and modernise the governance of the ESS, particularly the internal governance and decision-making process of ESOs, to better represent SMEs, civil society and users in the standards-setting process (the amendments were adopted in late 2022).
3) The establishment of an **EU Excellence Hub on Standards** to coordinate internal standardisation expertise 'scattered within the Commission EU Agencies and joint Undertakings' to support the identification of standardisation needs, support the work on in standardisation of priority areas, monitor relevant international standardisation activities and support a newly Commission-appointed Chief Standardisation Officer.
4) The launch of a **'standardisation booster'**, to better connect EU R&D&I with the ESS. In practice, the booster consists of a platform that provides expert services to European research projects (e.g., Horizon Europe beneficiaries) to assist them valorise project results by contributing to the development or revision of standards. The platform has supported over 430 projects since its establishment.
5) The organisation of **Standardisation University Days** on standards, to boost academic awareness on standards and share good practices and anticipate the

need for standardisation experts in the future. A dedicated HE project, EDU4Standards, started in January 2024 with the aim of implementing this.

Building on the assessment of strategic dependencies of the 2021 Industrial Strategy, the Standardisation Strategy also identified 6 '**standardisation urgencies**', i.e. areas where '*standards are needed in the coming years to avoid strategic dependencies and to manifest the EU's global leadership in green and digital technologies*. Among these, standards for **CRMs** –and particularly 'standards to support the *recycling* of CRMs' – was highlighted as one of the key priorities of the Strategy, second only to Covid-19-related standardisation.

Since the publication of the Strategy, CRMs have consistently remained a priority in the annual work programmes on standardisation[11], reflecting the growing significance of CRMs in the broader EU policy agenda. Notably, in 2022 they were mentioned with a specific focus on 'CRMs for batteries and waste batteries', while in 2023 the work programme included a reference to the need for CRM standardisation along the entire value chain – from exploration to extraction, refining and recycling. The same heading appeared in the 2024 work programme, with an additional reference to the need to standardise the recycling of permanent magnets (see Table 1).

11 As per Regulation 1025/2012 in 2013, every year the European Commission publishes a Union work programme for European standardisation, outlining the key, concrete priority areas for the standardisation work of the year.

Table 1. Standardisation priorities of the work programmes for European standardisation, 2022-2024

	2022	2023	2024
1.	Review existing standards to identify needs for revisions or development of new standards to meet the objectives of the European Green Deal and Europe's Digital Decade and support the resilience of the EU single market.	Hydrogen infrastructure, support and storage.	Technologies for European high-performance computing and European quantum communication infrastructure.
2.	Covid-19 vaccines and medicines production.	Integration of solar electricity into the energy system – PV.	**Recycling of permanent magnets and exploration, extraction, refining and recycling of critical raw materials[12].**
3.	**Critical raw materials for batteries and waste batteries.**	**Exploration, extraction, refining, recycling of critical raw materials.**	EU Trusted Data Framework.
4.	Climate resilience of infrastructure and low-carbon cement.	Cybersecurity and accessibility requirements.	European Digital Identity framework.
5.	Hydrogen technologies and components.	Deployment of the digital product passport.	Ecodesign of air-to-air conditioning and heat pumps.
6.	Transport and storage of hydrogen.	Technologies for European high-performance computing and European quantum communication infrastructure.	Cybersecurity requirements for products with digital elements.
7.	Standards for the certification of chips in terms of security, authenticity, reliability.	Applying the Digital Services Act through technological means.	Hydrogen technologies and components.
8.	Smart contracts for data spaces.	Reliable exchange of data.	Electric vehicle charging infrastructure.
9.		Safety of heat pumps.	

Source: – European Commission (2022b, 2023b, 2024c).

12 More specifically, standards in this domain should be developed to: support [recycling] methods that are economically competitive with primary production; ensure that the recycling processes are environmentally friendly; recover neodymium in a form that is suitable for producing high-quality magnets; collecting and sorting used products containing neodymium magnets (European Commission, 2024c).

2. CURRENT STATE AND RECENT DEVELOPMENTS OF CRMS STANDARDISATION

Standardisation activities in the field of CRMs (or, more broadly speaking, in the minerals and metals sector) have substantially increased over recent years, driven by both commercial pressure – expansion of global CRMs trade – and new policy initiatives, both at EU and international level. In this Section, after providing an overview of the scope of metals and minerals' standards, we outline the recent developments on EU and international standardisation activities in this domain.

2.1. SCOPE OF METALS AND MINERALS STANDARDS

In the metals and minerals sector, standardisation typically centres around the following topics: classification and characterisation; chemical analysis; traceability and transparency; sustainability and ESG criteria. With time, and particularly in recent years, focus has gradually moved from more traditional, trade-oriented classification and testing to traceability, recycling and ESG matters. Below we briefly examine what each of these categories entails.

- Classification and characterisation. Standards in these areas provide a systematic classification and characterisation of materials based on their properties, composition, or intended use. Providing a commonly agreed categorisation system ensures consistency and uniformity in terminology and conventions across the industry, which in turns facilitates interoperability, communication, and regulatory compliance. These standards are at times defined as 'fundamental' and 'specification' standards (Patrahau et al., 2020). As an example, the United Nations Framework Classification for Resources (UNFC) is a widely recognised system classifying minerals, energy, and other resources (UNECE, 2019).
- Chemical analysis & testing. Alongside classification and characterisation, chemical analysis has traditionally been a strong focus of standard setting for the minerals and metals industry. This regards the specific measurements methods and techniques employed to ascertain / determine the composition and/or purity of a certain material. Different materials (or 'classes' of materials) typically require specific testing methods. These measurements are crucial because different industrial applications of a certain material might require very different levels of material purity. For instance, high-performance magnets used in, e.g. wind turbines, require high-quality rare earths compounds, while EVs batteries require

high-purity lithium[13]. Standardised testing methodologies are particularly important for supplier-purchaser relationships, because if both parties agree on the procedure for determining material content, there is more confidence in the transaction. As discussed in Section 1, using standardised testing methods provides assurance on the quality and composition of the material, saving time and resources otherwise spent on testing.

- **Traceability and transparency**. An emerging focus of metals and minerals standardisation, traceability refers to the ability to track the origins, processing and distribution of a material throughout all parts of the value chain, from extraction through to manufacturing or recycling. Traceability methods and tools allow anomalies and impacts throughout the chain (e.g., counterfeit components, environmental impacts) to be detected and appropriate preventive or corrective measures to be taken. Having uniform, standardised traceability methods in the industry provides the means to guarantee the quality and conformity of the material and facilitates exchanges of information across segments of the value chains. Several new s and mineral TCs include work streams on material traceability (see Subsections below).
- **Sustainability and ESG**. Like traceability, sustainability is another increasingly prominent focus of metals and minerals standardisation. In response to concerns over the environmental and social impact of the value chain – particularly upstream (i.e. mining) – and driven by an increasing body of legislation on the matter (see, for instance, EU sustainability and supply chain due diligence requirements), a growing number of sustainability standards or frameworks have been created for (and by) the industry to demonstrate responsible and sustainable mineral supply chains and compliance with regulations.
- **Recycling.** Another nascent area of standardisation within the minerals and metals sector focuses on the criteria for the environmental and technical requirements of recycling technologies. As indicated in Table 1, the recycling of CRMs, and particularly of rare earth permanent magnets, has recently become a key priority of standardisation in the EU. While the current standardisation framework largely overlooks this area (we will explore this gap at greater length in Section 3), notable new initiatives have been undertaken at both EU and international level, showcasing a growing ambition to upscale recycling capacity.

13 To stress the importance of chemical analysis standards in the minerals and metals sector, it is worth noting that China's proposal for an ISO technical committee on lithium in 2020 – which resulted in the creation of ISO/TC 333 Lithium – was a response to identified discrepancies between the material purities measured in Latin America – one of the main lithium import market for China – vis-à-vis those measured in China.

2.2. CRM STANDARDISATION INITIATIVES IN ISO

At global level, standardisation on metals and minerals primarily happens within ISO. ISO has been highly active in the minerals and metals sector since its inception in 1947, when ISO/TC 18 'Zinc and zinc alloys' and ISO/TC 26 'Copper and copper alloys' were created. The number of TCs has since multiplied, gradually including materials featured in the EU CRM list(s)[14]. Some of these TCs standardise on a specific mineral or metal (e.g. ISO/TC 18) whereas others focus on larger groups of materials (ISO/TC 183 on 'Copper, lead, zinc and nickel ores and concentrates') or on virtually all of them, though with a specific scope of application (e.g. ISO/TC 82 'Mining', or ISO/TC 323, 'Circular economy'). In the latter case, the TC and the standards it develops are defined 'material agnostic' (High-Level Forum on European Standardisation, 2024).

Over the last decade, two noteworthy TCs were established within ISO – both because of a proposal by China: ISO/TC 298 'Rare earth', created in 2015 and ISO/TC 333 'Lithium', created in 2020. Both TC/298 and TC/333 have a wide scope in terms of segments of the value chain covered, i.e. from primary to secondary production (High-Level Forum on European Standardisation, 2024). In terms of topics, ISO/TC 333 focuses on classification, and chemical analysis methods, while ISO/TC 298 also features workstreams on traceability and recycling. Importantly, both TCs address sustainability issues, and to avoid duplication and enhance coherence within the ISO portfolio, they have merged their respective sustainability working groups in a single joint working group – ISO/TC 298/JWG 6, headed by the US. This will result in one standard addressing sustainability for both RE and lithium. A new standard on sustainability across the entire lithium and rare earths value chains (i.e., including extraction, separation, conversion, recycling and reuse), is currently under development (ISO/AWI 24961) and expected for publication in 2027[15].

Another relevant TC is ISO/TC 82 'Mining', reactivated in 2013, which predominantly deals with technical specifications related to, e.g. mining equipment and machinery, mine structures and mine closure and reclamation management. This TC has also been recently expanding its scope to ESG issues along the mine life cycle, particularly within Subcommittee 7 'Sustainable mining and mine closure' (until October 2023 'Mine closure and reclamation management'). This expansion reflects the growing recognition of the broader impacts of mining activities beyond environmental ones only. Ongoing discussions on potential future standardisation work in the subcommittee include addressing social aspects of mining, especially regarding mine closure and the transition of land in the post-closure period. Additionally, there is a focus on developing

14 For an overview of ISO minerals and metals-relevant technical committees, please refer to Table 2.

15 For the list of published and upcoming ISO/TC 298 standards, please refer to Annex II.

methodologies for determining the economic value of mining waste, recognising that this waste could have potential future utility or value.

While minerals and metals have traditionally held a prominent position within ISO activities, the issue of *Critical* Minerals arose prominently in March 2021, when a **Strategic Advisory Group on Critical Minerals**[16] (SAG CRMI) was established. The SAG was established under Australian leadership with the mandate of analysing existing work of ISO in the field of CRMs, assess CRM market standardisation needs and priorities – particularly in the field of sustainability – and ultimately provide strategic advice on future work on critical minerals. Among its main findings – reported in Box 3 – the SAG reported a gap in ISO standards in some aspects of CRM value chains, including traceability, recycling and sustainability. However, it noted that for the latter there exists already a wide number of heterogenous voluntary standards developed by the industry (ISO, 2023).

Box 3. Assessment and recommendations of the ISO Strategic Advisory Group on Critical Minerals (SAG CRMI)

The work of the SAG was carried out from March 2021 to April 2023. The main assessments and recommendations, published in mid-2023 (ISO, 2023), focused on the following areas:

- **New CRM priorities and TCs**. Based on industry's consultation, the SAG defined a list of priority CRMs not yet covered within ISO, for which it recommended the establishment of a dedicated TC. These include Cobalt, Chromium, Graphite and Antimony. The new TC should primarily cover material-specific chemical analysis standards but also address 'material-agnostic' issues such as terminology, packaging, labelling and – crucially - traceability. The work on traceability should be based on the methodology developed as part of ISO/TC 298 'Rare earths'.
- **Chemical analysis techniques**: having reviewed existing chemical analysis techniques used for CRMs, the SAG recognised that it would be difficult to harmonise them and that it would not provide significant value to the industry. However, they did provide a list of 10 standards to be used as 'good practice models' for the development of chemical analysis standards for new materials, to enhance comparability. The establishment of a Critical

16 ISO defines critical minerals as 'an essential mineral or mineral-based resource necessary for a particular economic activity, whose supply is deemed to be at risk and whose absence would have detrimental consequences to a commercial entity and to the economic, environmental, security and social well-being of a country, common economic region or specific region' (ISO, 2024b). While not perfectly overlapping, this definition closely aligns with the EU definition of CRM and the two terms will be used interchangeably.

Minerals Coordination Committee (CMCC) was recommended to coordinate the work across several (existing and new) TCs on CRMs.

- **Recycling, traceability and ESG standards**: the SAG recognised a gap in ISO standardisation in the downstream part of the CRM value chain, particularly regarding sustainability, traceability and recycling. Regarding ESG standardisation, it noted that a significant number of ESG tools, guides and frameworks exist outside ISO. These tools are typically material-agnostic and extend across several supply chain segments, but rarely on the whole value chain. The SAG suggested that an International Workshop Agreement[17] (IWA) bringing together stakeholders and organisations developing or applying such standards should be set up within ISO for further discussions.

Building on the assessments and recommendations of the SAG (see Box 3), three significant initiatives were undertaken by ISO:

1) Following a proposal of the French National Standards Body AFNOR, ISO approved the creation of ISO/TC 345 'Specialty metals and minerals', including all of those identified by the SAG as priority CRMs not yet covered by ISO (antimony, beryllium, cobalt, chromium, graphite, niobium, platinum group metals, tantalum, vanadium, zirconium). ISO/TC 345 predominantly focuses on classification and chemical analysis. It does not feature workstreams on sustainability. The TC is led by AFNOR and started its activities in May 2024.
2) In August 2023, ISO established an **IWA on Sustainable critical mineral supply chains** (IWA 45:2024). The IWA is led by Standards Australia and is designed to assist stakeholders in understanding and demystifying the existing landscape of sustainability standards, tools, guidelines or frameworks available across CRM value chains, highlighting commonalities and divergences and assessing which are better suited to address their needs (ISO, 2024b). The conclusions of IWA 45, released in August 2024, are summarised in Box 4.

17 International Workshop Agreements (IWAs) are one of the recognised deliverables of ISO (together with international standards, technical specifications, technical reports and guides). An IWA consist of a document approved by consensus after a series of workshops held outside the ISO TCs structures and gathering the broadest range of relevant stakeholders. IWAs are set up to 'respond to respond to urgent market requirements', and can exist for a maximum 6 years, after which they are withdrawn or converted into another ISO deliverable (e.g., an international standard), based on market requirements (ISO, 2024).

3) Also in August 2023, the German National Standards Body DIN submitted a proposal to ISO for a Project Committee (PC)[18] on sustainable raw materials (now ISO/PC 348 'Sustainable raw materials'), which was approved shortly after. The German-led initiative aims to define horizontal criteria for sustainable production of all 'mineral, raw iron- and non-iron metals', with the intent of harmonising the wide range of existing sustainability criteria for raw materials. Like TC 333 and TC 298, the PC will be applicable to the whole value chain, i.e. from extraction to refining and product manufacturing, however, its actual focus has not yet been defined. The PC has been mandated by ISO to account for the results and insights of the IWA 45 (see Box 4).

Box. 4 Conclusions and recommendations of the IWA 45:2024 Sustainable critical minerals supply chains[19]

Published in August 2024 after a series of workshops held earlier in the year, IWA 45:2024 provided the following key recommendations:

- **Coordination and Cooperation:** Recognising the wide range of existing sustainability standards, the IWA stresses the need to avoid duplicating existing standards while addressing their gaps, including by enhancing cooperation among existing ISO TCs on critical minerals and between ISO and other SDOs.
- **Stakeholder Engagement:** IWA recommends promoting active participation of stakeholders, particularly under-represented and vulnerable groups, in the ISO standards development process, including through, e.g. dedicated listening sessions and by adopting equal and shared governance models.
- **Sustainability topic areas**: for sustainability standards to drive meaningful positive impact, IWA recommends they should prioritise transparency, robust conformity assessments and strong environmental and social requirements based on robust metrics and monitoring systems.
- **Future priorities:** the IWA suggests that future standards should focus on the technical and environmental aspects of circularity and end-of-life management, as well as traceability.

18 In ISO, PCs operate in the same way as TCs, with the only difference that they are solely mandated to develop one standard. After the standard is created, the PC is disbanded or transformed into a TC if there is a need for further standardisation within its scope (ISO, 2018).

19 ISO IWA 45:2024 is available for purchase at IWA 45:2024(en), Sustainable critical mineral supply chains.

2.3. CRM STANDARDISATION INITIATIVES IN THE EU

Although the ESS has a long history of active involvement in environmental sustainability, as well as mining and metals standardisation, activities in the CRM domain have been fairly limited. Several metal-specific TCs exist within CEN for non-critical raw materials such as aluminium (CEN/TC 132), copper (CEN/TC 133), nickel and ferronickel (CEN/SS M14) and steel (CEN/TC 459)[20]. However, there is only one active standard explicitly referring to CRMs, developed in the context of the CEN and CENELEC Joint Technical Committee on 'Material efficiency aspects for products in scope of Ecodesign legislation'(CEN/CLC/JTC 10), which defines a 'General method for declaring the use of critical raw materials in energy-related products' (EN 45558:2019).

Recently, however, CRMs have gained prominence in the EU's agenda and this has reflected in the EU's standardisation work. As discussed earlier, CRMs were included among the standardisation priorities of the 2022 EU standardisation strategy (European Commission, 2022a), and were mentioned as a key work item in all subsequent annual Union standardisation work programmes (see Table 1). Within the High-level Forum on European Standardisation, set up in January 2023 as requested by the EU Strategy on Standardisation, a dedicated Work Stream was established on CRMs under French leadership and supported by Cyprus, Denmark Germany, Italy, The Netherlands and Sweden.

The Critical Raw Materials Act (CRMA) has further accelerated CRM-related standardisation efforts in the EU. In the Staff Working Document accompanying the CRMA proposal, the European Commission emphasised the need to advance high-quality technical standards to '*help facilitate the creation of a transparent global market for critical raw materials*', acknowledging that European and international activity on CRMs has been limited and that the latter has been mostly led by non-EU actors. In the CRMA, Art. 44 states that: '*The Commission shall request the European Standardisation organisations to develop European standards or European standardisation deliverables to support the objectives of this Regulation'*.

While no formal standardisation requests related to the CRMA have yet been submitted to ESOs by the European Commission, there have been notable advancements in EU CRM standardisation since the publication of the CRMA. In March 2023, DIN submitted a proposal for a TC on rare earths to CEN, which was approved in June 2023 with the creation of CEN/TC-472 'Rare Earth Elements'. The TC aims to mirror and integrate in the ESS the work of ISO/ TC 298 'Rare Earth', but with a distinct emphasis on recycling,

20 Copper and nickel are currently not classified as CRMs but are considered as 'Strategic Raw Materials' due to their importance for strategic green and digital technologies (Carrara et al., 2023).

sustainability and traceability, to align with the provisions of the CRMA (see Subsection 2.4). The TC began its activities in November 2023.

Sweden's National Standards Body SIS has also been proactive in these efforts. In early 2024, SIS proposed a new TC, CEN/TC 477 'Sustainable production of raw materials from mining-related activities', as a mirror of the work of ISO/PC 348 and ISO/TC 82/SC 7. The TC, which was approved in April 2024, will cover the standardisation for sustainability aspects of the whole raw materials value chain from mining-related activities, thus including exploration, extraction, treatment, smelting, refining, other processing, recycling and mine closure and reclamation. Sustainability standardisation will include ESG aspects as well as carbon and environmental footprint, circularity, material efficiency and traceability.

In May 2024, the High-Level Forum (HLF) on European Standardisation published the conclusions and recommendations of its CRM workstream (High-Level Forum on European Standardisation, 2024). Here, the HLF highlighted the crucial role of standardisation in improving the transparency and efficiency within CRM value chains, benefiting all stakeholders in the EU and beyond. While acknowledging the recent promising initiatives at both EU and international (ISO) level, the Forum identified several areas – including most notably circularity and sustainability aspects – in need of further standardisation work (see Box 5).

Box 5. Conclusions and recommendations of the Critical Raw Materials Workstream of the High-Level Forum on European Standardisation

The High-Level Forum it recommended the following areas of intervention on CRM standardisation:

- **Characterisation and chemical analysis**
  - Implement ISO/TC 298 and ISO/TC 345 chemical analysis methods within the CEN system.
  - Develop standards on the characterisation and performances of secondary CRMs, particularly for permanent magnets.
- **Recycling of permanent magnets**
  - Implement a liaison with IEC/TC 68 'Magnetic alloys and steels'.
  - Identify or create a CEN technical committee for recycling processes.
  - Implement a link with research works by the EU's Joint Research Centre for environmental issue, possibly within CEN/TC 472 'Rare Earths'.
- **Traceability**

- Develop a standard on traceability within ISO/PC 348 and investigate the opportunity to implement it within the CEN system.
- Clarify the link with the EU digital product passport.

■ Environmental footprint & sustainability

- Support sustainability initiatives in ISO/PC 348 and ISO/TC82/SC7 and monitor other sustainability initiatives in the CRM sector.
- Implement a link with research works by the EU's Joint Research Centre on environmental footprint calculation methodologies.

■ Circularity

- Develop horizontal material efficiency standards for all products containing CRMs, based on Standardisation Request M/543 as well as other product-specific standards.
- Implement a link with the ongoing ecodesign preparatory study for product-specific measures on scarce, environmentally relevant and critical raw materials, and on recycled content.

Develop a coordination group that keeps track of activities concerning the circularity of products and components containing CRMs.

Beyond the above initiatives, it is worth highlighting how the increasing efforts in EU CRM standardisation have also been reflected at the international level within ISO. Indeed, two of the above-mentioned recent initiatives in this domain within ISO, i.e. the creation of ISO/TC 345 'Specialty metals and minerals' and of ISO/PC 348 'Sustainable raw materials', are led by EU national standards bodies (Germany's DIN and France's AFRNOR, respectively).

Table 2. List of metals and minerals' TCs in ISO and CEN/CENELEC

Org.	Code	Name	Scope	Secretariat	Creation year	N. active standards
CEN	TC 132	Aluminium and aluminium alloys	Classification; Chemical analysis	AFNOR (France)	1994	134
CEN	TC 133	Copper and copper alloys	Classification; Chemical analysis	DIN (Germany)	1988	97
CEN	TC 262	Metallic and other inorganic coatings, including for corrosion protection and corrosion testing of metals and alloys	Classification; Chemical analysis	BSI (UK)	1994	166
CEN	TC 459	European Committee for Iron and Steel Standardization (ECISS)	Classification; Chemical analysis	AFNOR (France)	2019	0
CEN	TC 472	Rare Earth Elements	Chemical analysis; Traceability; Sustainability; Recycling	DIN (Germany)	2023	0
CEN	TC 477	Sustainable production of raw materials from mining-related activities	Traceability; Sustainability; Recycling	SIS (Sweden)	2024	0
CLC	JTC 010	Energy-related products - Material efficiency aspects for ecodesign legislation	Classification; Traceability; Recycling	NEN (Netherlands)	2016	9
IEC	TC 068	Magnetic alloys and steels	Classification	DKE (Germany)	1968	27
ISO	PC 348	Sustainable Raw Materials	Traceability; Sustainability; Recycling	DIN (Germany)	2023	0
ISO	TC 017	Steel	Classification; Chemical analysis; Sustainability	JISC (Japan)	1947	319
ISO	TC 026	Copper and copper alloys	Classification; Chemical analysis	SAC (China)	1947	27
ISO	TC 027	Coal and coke	Classification; Chemical analysis	SABS (South-Africa)	1947	105
ISO	TC 079	Light metals and their alloys	Classification; Chemical analysis	AFNOR (France)	1953	112
ISO	TC 082	Mining	Classification; Sustainability	DIN (Germany)	1955	64
ISO	TC 102	Iron ore and direct reduced iron	Classification; Chemical analysis; Sustainability	JISC (Japan)	1961	82
ISO	TC 132	Ferroalloys	Classification; Chemical analysis	SAC (China)	1969	69
ISO	TC 155	Nickel and nickel alloys	Classification; Chemical analysis	AFNOR (France)	1973	31
ISO	TC 183	Copper, lead, zinc and nickel ores and concentrates	Chemical analysis	SA (Australia)	1983	28
ISO	TC 207	Environmental management	Classification; Traceability; Sustainability	SCC (Canada)	1993	69
ISO	TC 298	Rare Earth	Classification; Chemical analysis; Traceability; Sustainability; Recycling	SAC (China)	2015	12
ISO	TC 308	Chain of custody	Classification	NEN (Netherlands)	2016	1
ISO	TC 323	Circular economy	Classification; Traceability; Sustainability; Recycling	AFNOR (France)	2018	4
ISO	TC 333	Lithium	Classification; Chemical analysis; Traceability; Sustainability	SAC (China)	2020	0
ISO	TC 345	Specialty metals and minerals	Classification; Chemical analysis	AFNOR (France)	2023	0

2.4. THE CASE OF RARE EARTHS AND PERMANENT MAGNETS

In the context of CRM standardisation, rare earths (RE) and RE-based permanent magnets deserve particular attention. RE permanent magnets – one of the largest end-use sectors of RE – are critical components of several green and digital technologies such as IT devices, EVs and wind turbines, and their demand is expected to rapidly expand due to increased adoption of these technologies. Because of highly concentrated global production and high import dependency, however, RE currently rank among the CRMs with the highest supply risk for the EU (Carrara et al., 2023; European Commission, 2023a). Although recent discoveries of RE deposits (IRIS, 2024) and new RE refining initiatives (fDi Intelligence, 2024) in Europe offer promising long-term prospects for reducing import dependency and supply risks, the absence of meaningful upstream production capacity has led the EU to explore alternative sourcing options, notably recycling. Indeed, previous assessments have shown that recycling of RE permanent magnets could potentially contribute significantly to EU demand by the early 2030s (Rizos et al., 2022). Over recent years, the EU has demonstrated its interest, support and increasing leadership in the development of recycling technologies for permanent magnets through several R&D&I projects, such as INSPIRES[21].

With recycling technologies rapidly approaching the commercial stage, it is important to establish supportive regulatory frameworks to help recycling businesses overcome existing economic, logistical, or technical barriers. Crucially, Rizos et al. (2022) identified two key prerequisites for the success of EU-based RE magnet recycling were: the definition of a uniform labelling systems for end-of-life appliances using magnets, and the gradual introduction of recycling quotas for magnet manufacturers. EU legislators have recently acknowledged these needs, and in the absence of existing permanent magnet-specific product policies (as in the case, for instance, of batteries), included two RE permanent magnet recycling-specific articles in the CRMA: Art. 28 on traceability and recyclability, which mandates labelling requirements for product manufacturers of selected permanent magnet-containing products; and Art. 29 on recycled content, which sets minimum requirements for recycled material in new permanent magnets placed in the market (see Box 6). These provisions clearly build on the precedent set by the recently revised regulatory frameworks for ecodesign and batteries (Rizos & Urban, 2024).

21 Other (ongoing or concluded) EU projects on RE recycling include REMANANCE, SUSMAGPRO, REproMAG, SecREEts, EREAN, REEcover, REE4EU, REMHub, REEPRODUCE, REEsilience.

Box 6. Permanent magnet provisions in the CRMA

In the CRMA, Art. 28 and 29 set rules to support the uptake of permanent magnet recycling operations in the EU. Their main provisions are briefly outlined below.

- Art 28 'Recyclability of permanent magnets'
  - Two years after the European Commission defines the label format, manufacturers placing certain appliances (including e.g. wind energy generators, industrial robots, motor vehicles, heat pumps, washing machines, tumble driers, microwaves, vacuum cleaners or dishwashers) in the market will need to add a **label** indicating the presence and, if any, the type of magnets embedded in the appliance. Further, the appliance should bear a **data carrier** reporting specific information on, e.g. the magnet's weight, location, chemical composition, use of coatings, glues, additives and on how to easily access and remove them.
  - By November 2025, the European Commission will adopt an **implementing act** defining the **format** for the labelling system (meaning the above obligation will be enforced as of November 2027 at the latest).
- Article 29 'Recycled content of permanent magnets'
  - By May 2027 or 2 years after the European Commission defines the calculation method (whichever is later), manufacturers of the appliances indicated in Art. 28 will have to make publicly available the **share of recycled** neodymium, dysprosium, praseodymium, terbium, boron, samarium, nickel and cobalt used in permanent magnets heavier than 0.2kg.
  - By May 2026, the European Commission will adopt a **delegated act** to define the **rules** for the calculation and verification of recycled content.
  - After the entry into force of the delegated act, and by no later than December 2031, the European Commission will adopt **delegated acts** to establish minimum **recycled content requirements** for permanent magnets incorporated in the product categories indicated above.

As discussed in Section 1, when novel technologies enter the market the development of technical standards is a key step to codifying such technological advancements into industry's practices, as well as to possibly guide the definition of technology-specific rules and to provide a clear framework for the industry to comply with them. In the case of RE permanent magnet recycling, whereby Articles 28 and 29 of CRMA provide general requirements for magnet manufacturers and users, they also clarify that the specifics of these requirements will be defined by the European Commission in upcoming

implementing and delegated acts. These, in turn will likely refer to existing technical standards in defining these requirements, particularly regarding the labelling system mandated by Art. 28 (Art. 34 of the CRMA explicitly states that delegated acts adopted to supplement the Regulation will, among others, '*refer to technical standards to be used in relation to the data carrier and unique product identifier referred to in Article 28*').

Hence, as also highlighted in the 2024 EU annual working programme on standardisation (European Commission, 2024d), developing a system of technical standards for permanent magnet recycling has become a key priority to support provisions set forth by the CRMA. And it is in this framework that CEN launched TC-472 'rare earth elements' in November 2023. While the main role of CEN TC-472 is to reflect and incorporate the efforts of ISO/TC 298 on a global scale, the committee will initially concentrate on creating harmonised standards to aid the industry in adhering to the regulations outlined in Articles 28 and 29 of the CRMA. While the European Commission has not officially issued standardisation requests to ESOs regarding RE magnet recycling and/or traceability to date, an ad hoc working group on RE magnet labelling kicked-off its activities in the context of CEN TC-472 in November 2024.

3. GAPS AND CHALLENGES IN CRM STANDARDISATION

This section outlines gaps and challenges in CRM standardisation from an EU perspective, drawing primarily on insights gathered through consultations with experts in the field of CRM standardisation[22].

3.1. LIMITED TECHNICAL EXPERTISE DEDICATED TO CRM STANDARDISATION

A significant challenge related to CRM standardisation, as acknowledged by the European Commission (2022) in the Standardisation Strategy, lies in the **difficulty in systematically mobilising European stakeholders – particularly technical experts – for standardisation activities**. This issue was confirmed by interviewees, who highlighted that stakeholder engagement in standard development can be especially challenging in the metals and minerals sector. This is caused by three main factors:

1) First, the lack of clear short-term incentives for the private sector to participate in standardisation activities. Participating in standardisation requires dedicated expertise and a significant investment in terms of time and resources. Standardisation work is voluntary and not remunerated (often requiring the payment of a fee) which makes it unattractive. Additionally, experts noted a generally limited awareness or understanding of the strategic importance of standardisation among European stakeholders, particularly in the CRM space. In the private sector – and especially among SMEs – standardisation is often perceived as an administratively complex and time-consuming activity, disconnected from daily operations. If companies do not recognise and account for the strategic significance and long-term economic and social benefits of standardisation – a fundamentally private sector-driven activity – the whole economy tends to underinvest in standardisation. Additionally, in some sectors, e.g. the rare earths industry, the absence of industrial clustering initiatives and difficulties channelling standardisation needs to SDOs was noted to exacerbate the problem.
2) Second, the EU's relative lack of technical experts in the minerals and metals sector, stemming from long-term outsourcing metals production and having only recent entry into some value chains (e.g. lithium or rare earth)[23], results in fewer specialised professionals available for standardisation work. Compared to global actors such as China, Canada, Australia, or Japan, the EU has fewer experts from

22 In total, 11 interviews were conducted in the period between January and July 2024 with representatives from national and international organisations as well as industry and academia. For the list of interviewees and the questionnaire used, please refer to Annex I.

23 The shortage of skilled workforce in the minerals and metals sector in the EU has been already acknowledged as a major hurdle in and of itself for the industry – see Righetti & Rizos (2024).

both industry and academia that can be involved in standard development. Given the absence of short-term returns for companies highlighted above, the limited human resources tend to prioritise the core business operations rather than standardisation activities. Long-term, experts also noted that the problem may worsen by a generational change, due to active standardisation experts leaving the field and the likely increasing need for technical standardisation in the metals and minerals sector.

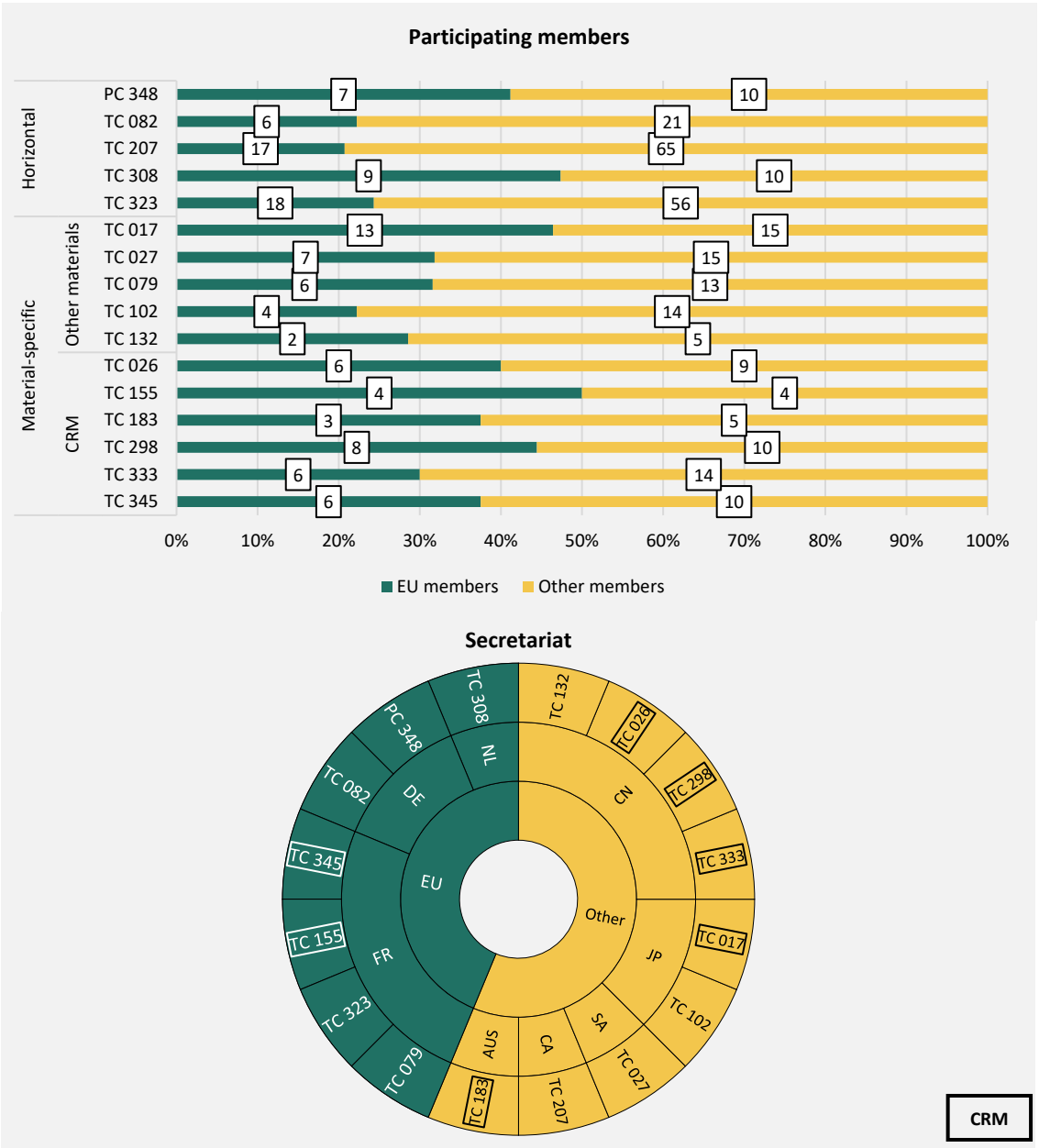
3) Third, the broadening and fragmented landscape of metal- and mineral-related standardisation workstreams at both European and international level – recently expanded as a result of the various new initiatives outlined in Section 2 – further stretches the already scarce technical expertise, diluting the capacity for Member States to actively participate in the numerous working groups. Indeed, interviewees highlighted that the same experts participate in both ISO and CEN TCs, because of thematic overlaps. This challenge is particularly acute for smaller countries, where NSBs struggle to mobilise adequate financial and human resources to follow all these activities. In this context, the absence of a platform or a mechanism to monitor and oversee all different workstreams and possibly coordinate EU efforts was noted as a significant gap.

The **limited engagement of EU stakeholders in standardisation,** whether caused by insufficient incentives, lack of awareness or other constraints, **risks resulting in poor representation of EU interests on international standard-setting platforms at global level**. Consulted experts noted that if EU stakeholders fail to engage adequately in international SDOs such as ISO, where other international players are instead taking an increasingly assertive approach, this could lead to a disadvantageous position for the EU and its industry. In fact, a lower number of involved experts may hinder the ability to effectively engage in technical discussions, and hence evaluate and amend standardisation proposals from other countries. While acknowledging an important change of pace from EU actors in terms of involvement in CRM standardisation, both at EU level and in international settings, interviewees held that engagement of some EU Member States – including some with a significant stake in the metals and minerals sector – remains limited. Therefore, it is crucial to have as many EU Member State representatives as possible.

Looking at the membership composition of the metals and minerals-relevant TCs outlined in Table 2 of the previous Section (Figure 2, top), the EU appears to be well-represented. Notably, EU Member States exceed 35 % of the total participating (voting) members of

all but one CRM-specific TCs (i.e., TC 333 'Lithium')[24], and hold the secretariat for almost half of considered TCs which gives responsibilities over procedural decisions in the standard development process (Figure 2, bottom).

Figure 2. Number of participating EU Member States and secretariat of metals and minerals TCs at ISO.



Source: own elaboration based on ISO.

24 For a draft to be approved, DIS and FDIS ballots require that at least two thirds of the voting P-members in the Committee that developed the Standard vote positively, and no more than one quarter of all of the voting NSBs vote negatively.

3.2. CONTENT GAPS IN CRM STANDARDISATION

When asked about potential standardisation gaps along CRM value chains, experts recognised that the **standardisation framework is well-developed in the upstream segments (i.e., primary production), but presents notable gaps in downstream areas**. As discussed in Section 2, aspects such as the characterisation and chemical testing of primary raw materials have long been a core subject of technical standardisation, primarily to support international trade of mineral commodities. Hence, only limited standardisation gaps were identified upstream. These included certain CRMs not yet covered (e.g., scandium, which is covered at CEN but not ISO level), innovations in extraction technologies (e.g., mining automation) and certain sustainability aspects of raw materials value chains (the latter being however largely standardised by the industry outside the realm of a standardisation organisation, as further discussed below). Nevertheless, in line with the conclusions of ISO's Strategic Advisory Group on Critical Minerals (see Box 3), experts pointed out that technical standards remain somewhat underdeveloped in certain downstream areas, and particularly on recycling and traceability.

Recycling technologies for CRM-containing products such as batteries and permanent magnets have advanced significantly in recent years (Righetti & Rizos, 2024). As exemplified by the INSPIRES project, having long prioritised and significantly supported innovation efforts in CRM recycling, the EU has been at the forefront of these advancements. With new recycling technologies and processes moving towards commercialisation, experts highlighted a growing need to standardise them to ensure consistency and efficiency across the industry. As discussed in Section 2, standards are particularly required in the field of RE permanent magnet recycling, to sustain the provisions on recyclability and recycled content of permanent magnets set by Artt. 29 and 29 of the CRMA. In this context, experts also noted that the EU has a strategic interest not only in supporting innovation, but also in advancing and potentially leading global standardisation efforts in CRM recycling by identifying and sharing EU best practices within international standardisation platforms. Indeed, experts cautioned that if European stakeholders fail to adequately address this new area of standardisation, it may eventually misalign with European interests. This need extends to areas beyond the recycling process itself such as ecodesign principles, which is also essential for effective recycling.

In addition to recycling, material **traceability** emerged as another critical area requiring further standardisation. Currently, the opaque nature of the CRM markets complicates the tracking of materials along the supply chain, hindering transparency and information sharing across operators (Burkhardt et al., 2020). Interviewees highlighted the necessity of establishing standardised traceability methods such as labels, digital product passports

or other information interfaces to enable more effective tracking of materials, which is particularly important for recyclers. Here too, the EU has been driving regulatory and technological advancements, for example in the batteries domain. The EU Batteries Regulation, which entered into force in August 2023, introduced the requirement for new batteries to carry a digital product passport as of 2027. This tool – the first of its kind globally – aspires to become a key enabler for the sharing of product-related data among supply chain actors on origins, chemical composition, carbon footprint, as well as recycling and disposal aspects (Rizos & Urban, 2024). As discussed in Section 2, the CRMA introduced similar provisions for rare earth permanent magnets, mandating manufacturers to use labels signalling the presence and type of magnets, along with a data carrier reporting information on origin, weight, chemical composition, and on access and safe removals.

Although advancements in CRM recycling technologies and traceability tools are not yet fully codified into technical standards, some progress is being made. In ISO, TC/298 'Rare Earth' is the only material-specific TC with dedicated working groups on recycling and traceability, as others (e.g., TC/333 'Lithium') focus more on characterisation and chemical analysis aspects. In the recycling WG of ISO TC/298, it is worth noting advancements in the context of ISO/AWI 24457, a work item approved in March 2024 which is set to specify key terms and processes, as well as technical, energy and environmental recycling for recycling RE permanent magnets. In the area of traceability, focus has been predominantly on quality assurance, enhanced safety and pollution prevention. However, there has been no emphasis on complying with the labelling system requirements set by Art. 28 of the CRMA (see Section 2). At the EU level, as discussed in Section 2 CEN/TC 472 is to mirror and integrate ISO/TC 298 work into the ESS, while possibly covering some other gaps (e.g., on labelling). Importantly, in July 2024, the European Commission issued a standardisation request to ESOs regarding the digital product passport, in support of requirements set by the Battery Regulation.

3.3. FRAGMENTATION OF ESG STANDARDISATION FOR CRM

While the areas of recycling and traceability appear insufficiently standardised, the opposite holds true for ESG criteria. Here, as also evidenced by the conclusions of the ISO SAG (Box 3) and the recently published ISO IWA 45:2024 (Box 4), a broad and heterogeneous landscape of standardisation frameworks exists for the metals and minerals industry to adhere to[25]. Many of these standards have been developed by

25 Some of the most widely implemented standards include those developed by the Initiatives for Responsible Mining Assurance (IRMA), the Mining Association of Canada's Towards Sustainable Mining (TSM), the International Council on Mining and Metals (ICMM), the Copper Mark or the Global Reporting Initiative (GRI). For an extensive overview of ESG reporting schemes and standards frameworks for metals and minerals value chain, please refer to BGR (2022) or the mapping carried out in the context of the ISO IWA 45:2024.

voluntary standards and certifications organisations or in the context of industry-led initiatives (i.e., outside the remits of SDOs) over the past decade. This has come in response to increasing pressure and scrutiny from consumers and investors for more responsible sourcing (Deberdt et al., 2024), new legislative and regulatory requirements (see, for instance, those set by the CSDDD and CSRD) as well as commitments at the highest political levels to high ESG standards compliance in CRM sourcing[26]. While positive overall, this trend has resulted in significant fragmentation in ESG standardisation, with the different frameworks reflecting or being influenced by specific geographical, material, and political considerations and preferences. Indeed, significant differences exist among them in terms of scope (with some focusing on, e.g. specific materials, value chain segments or 'E', 'S', or 'G' aspects), level of ambition, audit quality, governance structure, levels of stakeholder engagement and transparency (BGR, 2022; International Energy Agency, 2023).

Table 3. Non-exhaustive list of sustainability standards for mineral commodities

Responsible organisation	Sustainability standard	Commodities (Minerals and/or Products)
Aluminium Stewardship Initiative	ASI Performance Standard; ASI Chain of Custody Standard.	Aluminium
Initiative for Responsible Mining Assurance (IRMA)	The Standard for Responsible Mining	All mineral resources
International Council on Mining and Metals (ICMM)	Sustainable Development Framework (SDF)	All mineral resources
International Finance Corporation (IFC)/World Bank Group	Performance Standards on Environmental and Social Sustainability	All mineral resources
Responsible Jewellery Council (RJC)	RJC Code of Practices (COP) RJC Chain of Custody Standard (CoC); RJC Code of Practices (COP) Standard.	Gold, Silver, PGM, Diamond
Responsible Minerals Assurance Process (RMAP)/Responsible Minerals Initiative (RMI)	RMAP Mineral Supply Chain Due Diligence Standards; ESG Standard	All mineral resources
Responsible Steel	The Responsible Steel Standard	Steel

26 Calls for high ESG standards in CRM sourcing were recently made in the context of the UN Secretary-General's Panel on Critical Energy Transition Minerals (2024), as well as at both the G7 (2023) and G20 (2023) level. The Minerals Security Partnership (MSP), a collaboration initiative of 14 countries and the EU aimed at catalysing public and private investments in CRM supply chains, also places the commitment to high ESG standards at the core of its mandate.

The Copper Mark	The Criteria Guide for the Risk Readiness Assessment; Joint Due Diligence Standard (Cu, Pb, Ni, Zn)	Copper (+ lead, nickel, zinc and their by-products)
Towards Sustainable Mining (TSM)/The Mining Association of Canada (MAC)	TSM Protocols and Frameworks	All mineral resources
World Gold Council (WGC)	Responsible Gold Mining Principles (RGMPs)	Gold
CERA 4in1 / DMT GROUP	CERA 4in1 Performance Standard (CPS)	All mineral resources

Source: BGR (2022). For a more comprehensive overview of sustainability standards and reporting schemes for critical minerals value chains, please refer to ISO (2024b).

According to interviewed experts, the complexity of the ESG standardisation landscape generates confusion and uncertainty within the industry, increasing the burden on companies that might be unsure about what scheme better suits their operations and objectives. Further, lack of consistency across ESG frameworks in terms of, e.g. definitions, methodologies or form of measurements may limit governments and civil society organisations' ability to effectively monitor and compare industry's ESG performances (International Energy Agency, 2024). As also recently noted by another ISO IWA, ISO IWA 45:2024 on Environmental, social and governance (ESG) implementation principles, this complexity poses a risk to of undermining trust in these schemes and diluting their market signal function, ultimately discouraging investment and engagement in ESG by organisations.

This fragmentation has led some to call for more uniform ESG criteria. Indeed, some experts pointed to ESG and sustainability as areas with significant margins for higher harmonisation and convergence. Several initiatives have recently emerged for this purpose. At the industry level, the Consolidated Mining Standard Initiative (2024) aims to consolidate the voluntary responsible mining standards of the initiative's partners[27] into a single global one. Frameworks like the Copper Mark have recently expanded their material focus (The Copper Mark, 2022), and others like ICMM have established 'equivalency benchmarks' (ICMM, 2020) to align with other existing standards. ISO has also been increasing consolidation and harmonisation efforts, such as in the context of ISO TC/298 JWG 6 – which covers both lithium and rare earth sustainability, and most notably with the recently established ISO PC-348 'Sustainable Raw Materials', a Germany-

27 Involved partner organisations include ICMM, The Copper Mark, the Mining Association of Canada and the World Gold Council. The objective of the initiative is to launch the new standard in 2025.

led initiative which is set to define a uniform set of ESG criteria for all (non-energy) raw materials centred around the EU principles for sustainable raw materials (European Commission, 2021b).

Although there are advocates for greater harmonisation in ESG standards, not all experts agree with this viewpoint. Indeed, experts showed conflicting views on the opportunity and need to set up yet another workstream on ESG standardisation, even if for harmonisation purposes, due to the large number of already existing ESG frameworks. These new initiatives, some argued, risk adding further complexity to the already crowded landscape and may further stretch the already limited human resources available for standardisation work. Furthermore, some cautioned that harmonisation exercises, even if well-intentioned, could result in a compromise at the 'lowest common denominator' among existing frameworks. Indeed, narrowly focused standards might indeed be effective precisely insofar as they focus attention and resources on specific issues, materials, geographies or value chain segments. Finally, aligning ESG criteria might turn out to be a complex process in and of itself. Indeed, experts noted the harmonisation efforts might prove particularly challenging content-wise, as different countries might have significantly different understanding, preferences, or simply regulatory requirements on ESG criteria – for example in terms of their scope and strictness. As a result, gaining global consensus on a common set of ESG criteria may face resistance from some countries, making widespread acceptance and adoption challenging[28].

28 It should be noted that Art. 30 of the CRMA gives the possibility for all developers of certification schemes in the area of CRM sustainability ('scheme owners') to apply to have their scheme recognised. If recognised, the scheme can be used by Strategic Project promoters to certify the projects' sustainability. For the scheme to be recognised, it needs to fulfil the requirements laid down in Annex IV of the Act, which include: being subject to multistakeholder governance, provide for an objective and independent monitoring and verification system, having a site-level auditing system and covering certain minimum environmental and social risk categories. Currently, no schemes have been officially recognized under Article 30 by the European Commission, which will define need the template to be used by scheme owners to apply for recognition by May 2027.

4. CONCLUSIONS AND RECOMMENDATIONS

As countries implement and refine their CRM policies, it is becoming increasingly important for them to also step up efforts in CRM-related technical standardisation. This has been recognised by the EU, where the 2020 EU Strategy on Standardisation listed CRM recycling as a standardisation urgency and CRM-related activities – whether at the extraction, processing and recycling level – have systematically appeared as a key priority in the Annual Union Work Programme for European Standardisation since 2022. Developing technical standards is crucial to disseminate the significant innovations that have occurred in the CRM space, notably on recycling, while also ensuring environmental safeguards and increasing transparency in CRM markets. In the EU, harmonised standards will also be necessary to support operators in complying with specific requirements of the CRMA, such as those related to the recycling of permanent magnets.

While in recent years numerous new CRM-related standardisation initiatives have emerged, both at EU and international level, gaps and challenges still persist. A first key issue is the risk of weak participation of EU stakeholders in standard-setting activities, particularly within international platforms like ISO. Although long and broadly acknowledged, this is of particular concern in the minerals and metals sector, as only a few Member States appear to have or mobilise sufficient experts and to be actively involved. Further, increasing CRM-related standardisation workstreams risks stretching already limited resources. For the EU to succeed in technical standardisation, it is essential to incentivise stakeholders – particularly technical experts to participate and contribute, especially in emerging technologies like CRM recycling ones. On the international stage, effective representation of EU Member States in CRM-related TCs is crucial to safeguard the EU's interest, particularly as other global actors adopt increasingly assertive approaches.

In terms of content areas, conversations with experts revealed gaps in the CRM of recycling and traceability. Recycling technologies have undergone significant advancements in recent years, but these innovations have not yet been codified in technical standards. Similarly, growing calls for greater CRM market transparency underscore the need for widespread adoption of traceability methods and tools, which have also significantly advanced in recent years. In both domains, recent initiatives within ISO and CEN – described in Section 2 – show a growing interest in advancing technical standardisation. These efforts offer promising prospects for addressing these gaps. Having increasingly supported and regulated technological developments in both CRM recycling and traceability, the EU is well positioned to meaningfully contribute to these efforts, and potentially lead standardisation workstreams at global level. To achieve this and to ensure that EU industry priorities, best practices and regulatory requirements are

reflected in international markets, EU stakeholders should ensure sustained and effective engagement through robust representation within relevant ISO TCs.

Lastly, the landscape of ESG standards for CRM appears to be highly fragmented, creating uncertainty for the industry and potentially hindering the ability to track and compare ESG performances along CRM value chains. Several industry-led initiatives have sought to consolidate some existing sustainability frameworks, and ISO has also made significant steps in this direction by establishing the dedicated ISO/PC 348 'Sustainable Raw Materials'. However, opinions diverge on the need for greater harmonisation of ESG standards, with some experts arguing that harmonisation initiatives could further complicate an already crowded landscape. Some also warned that harmonisation might end up diluting existing ESG standards to a lowest common denominator, undermining the effectiveness of narrowly focused frameworks that address specific issues or regions. Additionally, aligning ESG criteria globally was also seen as inherently challenging due to differing national preferences, regulatory requirements, and varying interpretations of ESG scope and stringency. These differences may complicate consensus-building and hinder widespread adoption of harmonised standards.

Based on the analysis in this paper, the following recommendations are proposed:

R1. Mobilise and coordinate stakeholders for CRM standardisation activities

To ensure efficient and effective representation of EU stakeholders in CRM standardisation activities, engagement needs to be primarily strengthened at Member States level. Here, NSBs play a key role in fostering participation and in raising awareness on the strategic importance of standardisation for CRM and beyond. Adopting or updating dedicated national strategies and programmes on standardisation – currently only existing in a few of Member States – could also facilitate this process, for instance by including forms of financial incentives (e.g., participation grants) for technical experts and other stakeholders to encourage participation in the standards development activities. Further, to coordinate efforts across the several emerging CRM-related standardisation workstreams, CEN could consider establishing a dedicated committee akin to the Critical Minerals Coordination Committee recently created within ISO. This operational committee would complement the strategic / advisory role of the CRM workstream of the High-Level Forum on Standardisation. It would provide a platform for officers from different CRM-relevant CEN TC-s to enhance coordination and communication, prevent duplication of work and, where feasible, promote consolidation of CRM-relevant standardisation efforts to reduce participation burdens and ensure robust engagement. Finally, the EU could make more use of exiting clustering platforms, such as the European Raw Materials Alliance (ERMA), for standardisation purposes. Adding standardisation workstreams within these platforms, for example, would help

channel stakeholders' requirements and needs to SDOs, highlight gaps in the standardisation framework and streamline information sharing.

R2. Strengthen the link between the EU research and education on CRM and standardisation

The mobilisation of EU stakeholders for CRM standardisation should notably include researchers and innovators. The growing number of EU-funded R&D&I projects in the field of CRMs can provide valuable technical knowledge and expertise to the EU standardisation work. Strengthening the link between the EU R&D&I framework and the ESS is crucial to ensure that research outputs translate into relevant standards and that standardisation considerations are integrated into research activities from the outset. The recently launched 'Standardisation Booster' is an example of a tool that can be used to enhance this connection but whose potential, as evidenced by the limited number of CRM-focused projects supported, remain underutilised. Introducing reward systems for university researchers involved in standardisation (e.g., by providing university credits) could also help to strengthen these synergies. Finally, leveraging existing EU R&D&I capacity should be complemented by initiatives aimed at training new professionals on standardisation. Building on existing efforts under the Standardisation Strategy, such as the Standardisation University Days, the EU could promote CRM-focused standardisation education and training through the integration of curricular activities in existing programmes (e.g., in the context of the recently launched European Raw Materials Academy) or through new dedicated vocational and education training programmes.

R3. Advance EU-level standardisation on permanent magnets recycling

Although, based on the Vienna Agreement, standardisation activities – including on CRMs – should preferably be led at the international (ISO) level. The strategic priority and urgency placed by the EU in some specific areas may justify leading some (or advancing parallel) standardisation workstreams at the EU (CEN) level. As underscored by the 2024 Union Work Programme for European Standardisation, one such high-priority – high-urgency area for the EU is recycling of rare earth permanent magnets. With the CRMA putting forward new requirements on the labelling (Art. 28) and recycled content (Art. 29) for new magnets placed in the market (see Subsection 3.4), the European Commission will now need to define the specifics of these requirements by means of delegated and implementing acts, relying on existing technical standards to enable industry compliance. Regarding the labelling requirements, considering the absence of existing workstreams within ISO and the short timeframe available for the European Commission to define technical specifications (the rules will need to be published by November 2025), advancing EU-level standardisation in this area within CEN TC-472 is

justified on urgency grounds[29]. While an ad hoc working group on RE magnet labelling has already been established within CEN TC-472, this would still benefit from a formal standardisation request from the European Commission (similar to what was recently done in the case of batteries for the digital product passport) to provide clear guidance and encourage strong stakeholder engagement throughout the value chain.

R4. Ensure broad consensus on harmonised ESG standards for CRM

The fragmented landscape of ESG standardisation for CRM value chains requires a certain degree of harmonisation to improve clarity and transparency in CRM markets. Converging towards a uniform, comprehensive and broadly recognised ESG standardisation framework would also support price differentiation with non ESG-compliant alternatives in the market and help establish a distinct, marketable product[30]. Given ISO's global recognition and established multi-stakeholder governance, the ISO/PC 348 initiative represents an ideal platform where ESG harmonisation efforts could converge. For an initiative like this to succeed despite potentially differing opinions on the scope and strictness, the secretariat should work to establish the widest possible consensus among international partners and the private sector. This requires identifying reasonable commonalities among existing ESG standards, whilst also avoiding to the extent possible 'lower common denominator' outcomes. In line with the recommendations of ISO IWA:45, ISO/PC 348 should primarily focus on addressing existing gaps, ensuring equitable and balanced participation in the process and promoting coordination with other workstreams and/or organisations. While not directly involved in the work of ISO/PC 348, the European Commission[31] could foster discussion and rally support around ISO/PC 348 in international fora, such as the G7 and the MSP Forum, where the need to advance ESG-based pricing across raw materials is also being recognised. Finally, in order to maintain alignment with standards and promote accountability within companies, it will be crucial to have rigorous and independent verification systems in place.

29 Given the tight timeline, other swifter forms of CEN outputs such as a CEN technical reports or a CEN technical specification could be initially considered instead of full-blown harmonised standards to provide certainty to the industry. Concerning the rules for the calculation and verification of recycled content for permanent magnets (Art. 29 CRMA), considering the longer timeline available for the European Commission to define technical specifications and the ongoing standardisation work in this area in ISO in the context of ISO/AWI 24457, we do not argue for the need to advance EU-level standardisation. However, we recommend EU to Member States to actively engage in the context of the 24457.

30 As shown by the recent attempt of the LME to introduce a 'green' nickel contract, the limited understanding of market participants as to what ultimately qualifies a material (in that case, nickel) as 'green', and the broad range of certification options with varying scopes and metrics are among the main challenges preventing the creation of a 'green (nickel) market' .

31 The European Commission is a Category B liaison member of ISO PC/348, meaning it is given access to reports on the work of a technical committee or subcommittee but it does not actively contribute to it.

ANNEX I

For this study, the research team conducted 11 consultations with professionals with expertise and/or relevant experience in CRM-related standardisation. Semi-structured interviews where employed to elicit information. The list of guiding questions used during consultations is provided below, and the list of experts is provided in Table A.1.

Consultation questions

- How do you assess the existing situation in terms of EU (CEN) and global (ISO) standardisation of CRMs, and/or more specifically of rare earth elements?
- Why are standards important in the CRMs/rare earth elements domain (e.g., to improve / facilitate circularity, supply chain transparency, facilitate international trade etc.)?
- In which segment of CRMs / rare earth elements value chains do you see the greater need for standardisation and why? Which present challenges can standards help to address?
- Can the EU take a greater role in the development of standards for CRMs / – elements?
- What role can EU Member States and the industry play in this domain? Could you provide some specific recommendations or best-case examples?

Table A.1. Interviewed experts

Organisation category	Title
Academia	Scientific Director
Industry	Director Innovation
Industry	Chief Executive Officer
Academia	Researcher and Lecturer
Government/Intergovernmental organization	Policy Officer; Policy Officer
Government/Intergovernmental organization	Advisor
Standards development organisation	Technical Advisor
Standards development organisation	Development Officer
Standards development organisation	Project manager; Project manager
Standards development organisation; Government/Intergovernmental organization	Head of International; Director Strategy and Senior Advisor
Standards development organisation	Programme Manager

ANNEX II

Table A.3. List of ISO/TC 298 standards

Code	Year	Title	Status	Theme
ISO 22444-1:2020	2020	Rare earth — Vocabulary — Part 1: Minerals, oxides and other compounds	Published	Classification
ISO 22444-2:2020	2020	Rare earth — Vocabulary — Part 2: Metals and their alloys	Published	Classification
ISO 22450:2020	2020	Recycling of rare earth elements — Requirements for providing information on industrial waste and end-of-life products	Published	Recycling
ISO 22453:2021	2021	Exchange of information on rare earth elements in industrial wastes and end-of-life cycled products	Published	Recycling
ISO/TS 22451:2021	2021	Recycling of rare earth elements — Methods for the measurement of rare earth elements in industrial waste and end-of-life products	Published	Recycling
ISO 22927:2021	2021	Rare earth — Packaging and labelling	Published	Traceability
ISO 23664:2021	2021	Traceability of rare earths in the supply chain from mine to separated products	Published	Traceability
ISO 23596:2023	2023	Rare earth — Determination of rare earth content in individual rare earth metals and their compounds — Gravimetric method	Published	Testing & analysis
ISO 23597:2023	2023	Rare earth — Determination of rare earth content in individual rare earth metals and their oxides — Titration method	Published	Testing & analysis
ISO 22928-1:2024	2024	Rare earth — Analysis by wavelength dispersive x-ray fluorescence spectrometry (WD-XRFS) — Part 1: Determination of composition of rare earth magnet scrap using standardless XRF commercial packages	Published	Recycling
ISO 24544:2024	2024	Rare earth — Recyclable Neodymium iron boron (NdFeB) resources — Classification, general requirements and acceptance conditions	Published	Recycling
ISO 24181-1:2024	2024	Rare earth — Determination of non-rare earth impurities in individual rare earth metals and their oxides — ICP-AES — Part 1: Analysis of Al, Ca, Mg, Fe and Si	Published	Testing & analysis
ISO/AWI 24961	n/a	Rare earths and lithium sustainability across the value chain : concentration, extraction, separation, conversion, recycling and reuse	Under development	ESG and sustainability

ISO/AWI 24457	n/a	Specifications for recycling of neodymium iron boron sintered permanent magnets	Under development	Recycling
ISO/AWI 19456	n/a	Determination of rare earth impurity contents in individual rare earth metals and their oxides — Inductively coupled plasma mass spectrometry Part 1: Determination of rare earth impurity contents in individual La, Ce, Pr, Nd, Sm metals and their oxides	Under development	Testing & analysis
ISO/AWI 24468	n/a	Praseodymium-neodymium metal	Under development	Testing & analysis
ISO/DIS 24548	n/a	Rare earth — Determination of moisture content in rare earth products — Gravimetric method	Under development	Testing & analysis
ISO/DIS 5976	n/a	Rare earth — Determination of loss on ignition in rare earth products — Gravimetric method	Under development	Testing & analysis
ISO/DIS 17887	n/a	Traceability of rare earths in the supply chain from separated products to permanent magnets	Under development	Traceability

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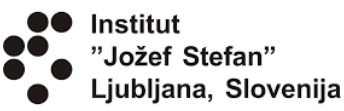
ABOUT INSPIRES

Intelligent and Sustainable Processing of Innovative Rare-Earth Magnets

INSPIRES is a project co-funded by the EU that aims to recover and supply rare earths within the EU through radical innovations in the recycling of permanent magnets (PMs) focusing on one of the most readily available sources: home appliances. INSPIRES will optimise methods at industrial scale for sustainable extraction, recycling and use of recycled magnets in new motors. For more information about the project, see: https://www.inspires-magnet.eu/.

The consortium includes leading partners in the development of recycling strategies of PMs, real-life scrapping and waste logistics practitioners, electric motor and white good manufacturers, and sustainability (DTU) and circular economy experts (CEPS). Together the consortium covers the entire magnetic circular supply chain: home appliance recoverers and dismantlers (SUROVINA, ZEOS), NdFeB recyclers (HSPF, CSIC, CNR, JSI), recycled magnet producers (KOLEKTOR), motor developers (DOMEL), home appliance end users (GORENJE).

List of partners



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