INTESA SANPAOLO
INNOVATION CENTER

INDUSTRY TRENDS REPORT

CRITICAL RAW MATERIALS

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CONTENTS

EXECUTIVE SUMMARY

This report delves into the detailed landscape of Critical Raw Materials (CRMs) within the European context, offering a thorough exploration of their state, supply chain vulnerabilities, and extraction's environmental and social impacts.

The analysis encompasses the regulatory framework, market dynamics, and the evolution of the European Raw Materials Initiative.

The study explores the diverse industrial applications of CRMs, with a specialized focus on strategic technologies in the rapidly evolving e-mobility sector. A detailed examination of this strategic sector, including advanced Li-ion battery technology, fuel cells, and traction motors, is provided. This section highlights the pivotal role CRMs play in driving innovation and sustainability within these fields.

The evaluation takes into account the critical role CRMs play in advancing e-mobility, emphasizing their impact on technology development, supply chain resilience, and overall sustainability in the transportation sector. The study explores the potential bottlenecks along the different steps of the supply chain by assessing the relevant supply risk and future demand for the main raw materials needed in the selected technologies, based on policy-relevant scenarios or market trends.

The report concludes with a forward-looking analysis, offering insights into the future prospects of CRMs. This section considers emerging trends, potential challenges, and opportunities that may shape the trajectory of CRMs in the years to come.

The findings and analyses presented herein serve as a valuable resource for policymakers, industry professionals, and stakeholders navigating the intricate landscape of CRMs within Europe.

STATE OF THE **ART**

In the contemporary global landscape, the speed and scale of the twin green and digital transitions has accelerated emphasizing the pathways of a green trajectory towards a carbon-neutral future and a digital transformation that seeks to drive technological advancements. These twin transitions serve as essential drivers for global strategies, highlighting the importance of resilience, sustainability, and technological superiority.

At the heart of these transitions lie the Critical Raw Materials (CRMs). CRMs are raw materials of high importance to the economy of the European Union (EU) and whose supply is associated with high risk. The term "critical" is introduced for raw materials that: (1) have a significant Economic Importance (EI) for key sectors while (2) suffering from high Supply Risks (SR) and (3), for which there is a current lack of substitutes.[1]

CRMs are vital for some of the most important technologies such as Electric Vehicles (EVs), energy storage batteries, and Light Emitting Diodes (LED) lighting. Their role is significant across various sectors, including defence, space, energy, transport, agritech, medicine, computing, and telecommunications.

The term "critical" was first used in 1939[2] in reference to raw materials in the military context. In those days, the American administration decided to build up a stock for 42 raw materials with military relevance[3].

Global overview

The terms critical materials and critical raw materials have no universal definition but are generally used to refer to metals and minerals which are of high economic importance to a particular industry, sector or spatial and are at risk of supply shortage. The extent to which a material is considered important or valuable is a socio-economic construct, which changes over time to reflect, among other factors, perceptions of current and future demand, the global political environment, and the state of technological.

Every country operates within a unique economic, technological, and geopolitical context, leading them to prioritize certain raw materials over others. As industries evolve and technologies advance, the demand for specific raw materials can surge, making them critically important for a nation's economic stability and growth. Consequently, most nations developed their own list of CRMs.

The USA developed a systematic approach in determining its list of critical minerals[4]. Using a two-stage screening methodology, the process starts with the early warning screening tool (Stage I). This initial stage evaluates a mineral's potential criticality using three main indicators: i) the vulnerability of supply chain, ii) the growth or decline in the mineral's production, iii) the overall behaviour and

1 Communication from the commission to the European Parliament and the Council - The raw materials initiative (2008)

2 B. Achzet, C. Helbig, "How to evaluate raw material supply risks: an overview" - Resour. Policy, 38 (2013), pp. 435-447

3 American Administration - Strategic and Critical Materials Stock Piling Act, Chapter 190, Enacted June 7, 1939

4 U.S. Geological Survey Releases 2022 List of Critical Minerals, United States Geological Survey (USGS), U.S. Department of the Interior, Federal Government of the United States, 2022

Source: Materias

changes within the market of the mineral. Data from the US Geological Survey (USGS) and other sources inform these indicators. The early assessment is then complemented by in-depth supply chain analyses (Stage II). Here, an inter-agency collaboration delves deeper into the factors identified during the first stage, refining the list of minerals (50 in 2022) deemed potentially critical.

For the UK[5], the determination of mineral criticality hinges on its importance to the national economy. Two pivotal factors are considered: i) global supply risk determined using three indicators – production concentration, companion metal fraction, and recycling rate – ii) economic vulnerability that considers production evolution, price volatility, substitutability, global trade concentration, UK's import reliance, and the contribution to the UK's gross value-added. After evaluating these factors, the UK identified 18 minerals as critical for its economy.

Japan starts identifying critical minerals in 1984, by the Advisory Committee on Mining Industry under the direction of the Ministry of International Trade and Industry[6]. Although this list remained relatively constant over the years, Japan reassessed its stance in March 2020 with the "New international resource strategy". Recognizing the mounting significance of critical minerals for emerging technologies such as electric vehicles (EVs) and renewable energy equipment – especially considering carbon mitigation efforts – the latest strategy was informed by the lists of global powers like the USA and Europe. As a result, Japan highlighted 31 minerals as critical for its sustainable economic future.

In 2019, Australia presented its first official list of critical minerals and an accompanying national strategy. Initially recognizing 24 minerals, the list was updated in 2023 to include two additional elements, bringing the total to 26[7]. Australia's approach to determining this list involved comparative studies with other major economies, including the USA, EU, Japan, and India[8].

In this report, we mainly reference the EU's list of CRMs to ensure regional relevance and alignment with Europe's strategic priorities.

In a recent study[9], the European Union has conducted a comprehensive assessment to identify and update a list of CRMs. In this study, the strategic importance and supply risk of various materials that are essential for industries and technologies has been evaluated. The most recent list, published in 2023, comprises 34 materials that are considered critical due to their significance in various sectors, including the industrial, technological, and environmental domains (reported in Table 1).

5 Lusty et al. "UK criticality assessment of technology critical minerals and metals". British Geological Survey Commissioned Report, CR/21/120

6 Nakano, Jane. "Japan." The Geopolitics of Critical Minerals Supply Chains, Center for Strategic and International Studies (CSIS), 2021.

7 Critical Minerals Strategy 2023–2030, Australian Government Department of Industry, Science and Resources, June 2023

8 Report of the Committee on Identification of Critical Minerals - Ministry of Mines, India - June 2023

9 European Commission, Directorate-General for Internal Market, Industry, Entrepreneurship and SMEs, Grohol, M., Veeh, C., Study on the critical raw materials for the EU 2023 – Final report, Publications Office of the European Union, 2023, https://data.europa.eu/doi/10.2873/725585

Source: Materias

This list comprises 31 individual materials and 3 materials groups that include 10 heavy (HREEs) and 5 light (LREEs) rare earth elements, and 6 platinum-group metals (PGMs).

TABLE 1: LIST OF EU CRITICAL RAW MATERIALS (2023)

2023 LIST OF CRITICAL RAW MATERIALS (34)			
Aluminium/Bauxite	Copper*	**LREEs**	Scandium
Antimony	Feldspar	Magnesium	Silicon Metal
Arsenic	Fluorspar	Manganese	Strontium
Baryte	Gallium	Natural Graphite	Tantalum
Beryllium	Germanium	Nickel*	Titanium metal
Bismuth	Hafnium	Niobium	Tungsten
Boron/Borate	Helium	**PGMs**	Vanadium
Cobalt	**HREEs**	Phosphate rock	
Coking Coal	Lithium	Phosphorus	

*Copper and Nickel do not meet the CRMs criteria but are included in the list since they are considered Strategic Raw Materials (SRMs). An SRM is a raw material important for technologies that support the twin green and digital transition and defence and aerospace objectives.

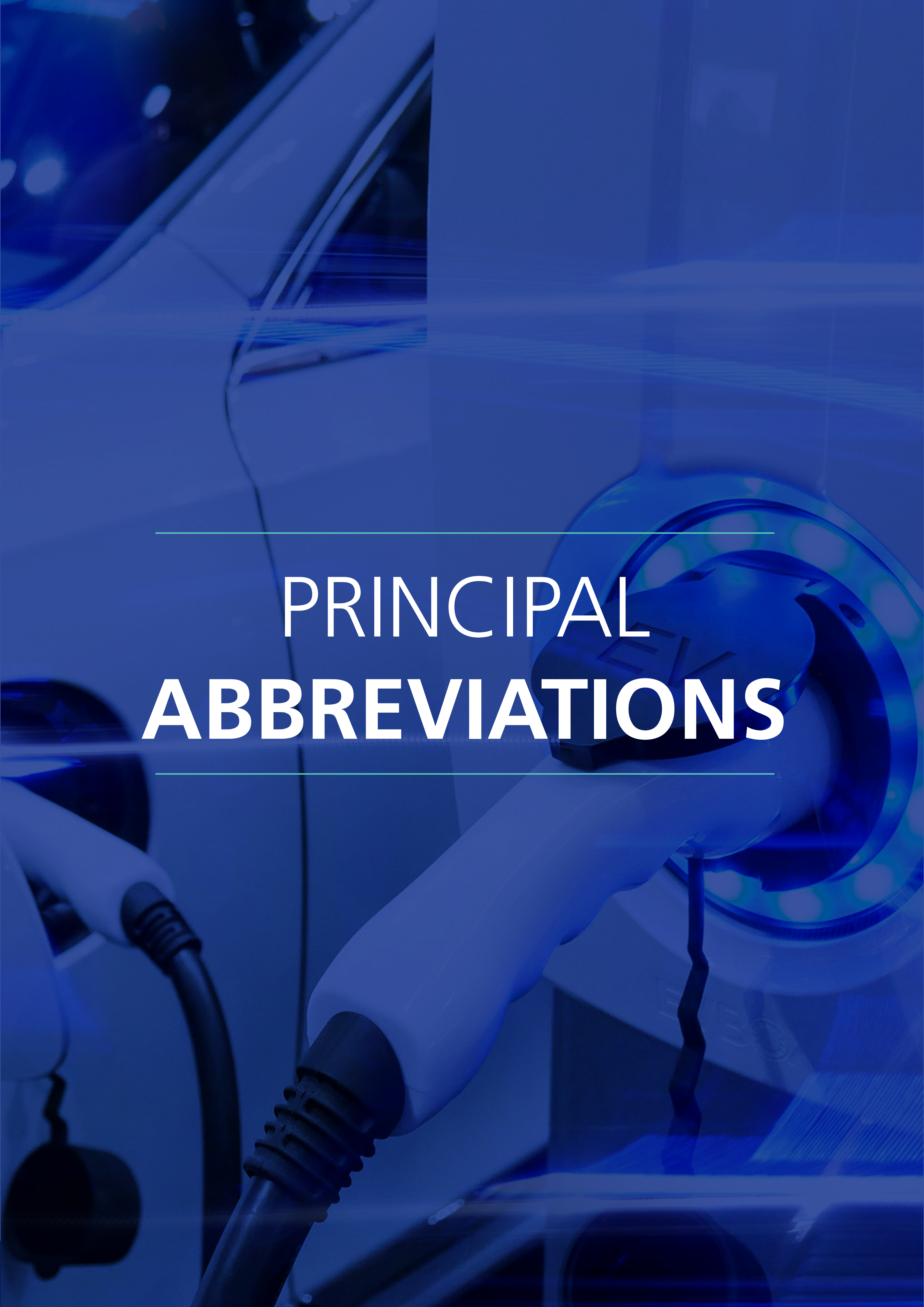
Source: Materias

The following Table 2 provides a brief overview of the 34 CRMs, specifying for each the production stage, the main global producer, the main EU sourcing countries and the selected uses.

TABLE 2: CRITICAL RAW MATERIALS OVERVIEW. SOURCE: STUDY ON THE CRITICAL RAW MATERIALS FOR THE EU 2023 – FINAL REPORT FROM EUROPEAN COMMISSION

Raw materials	Stage	Main global producer		Main EU sourcing countries		Selected uses
Aluminium/ Bauxite	Extraction	Australia China Guinea	28% 21% 18%	Guinea Brazil Greece	62% 12% 10%	Lightweight structures High-tech engineering
Antimony	Extraction	China Tajikistan Russia	56% 20% 12%	Türkiye Bolivia China	63% 26% 6%	Flame retardants' Defence applications Lead-acid batteries
Arsenic	Processing	China India Morocco	32% 25% 9%	China Morocco Bulgaria Germany Slovakia	44% 28% 11% 7% 2%	Medical applications Radiation protection Chemical applications
Baryte	Extraction	China India Morocco	32% 25% 9%	China Morocco Bulgaria Germany Slovakia	44% 28% 11% 7% 2%	Medical applications Radiation protection Chemical applications
Beryllium	Extraction	United States China Mozambique	67% 26% 4%	n/a	n/a	Electronic and communication equipment Automotive, aero-space and defence components
Bismuth	Processing	China Vietnam Japan	70% 18% 5%	China Belgium Thailand Laos	50% 26% 9% 5%	Pharmaceuticals Medical applications Low-melting point alloys Solid rocket propellant
Boron	Extraction	Türkiye United States Chile	48% 25% 11%	Türkiyea	99%	High performance glass Fertilisers Permanent magnets

Source: Materias



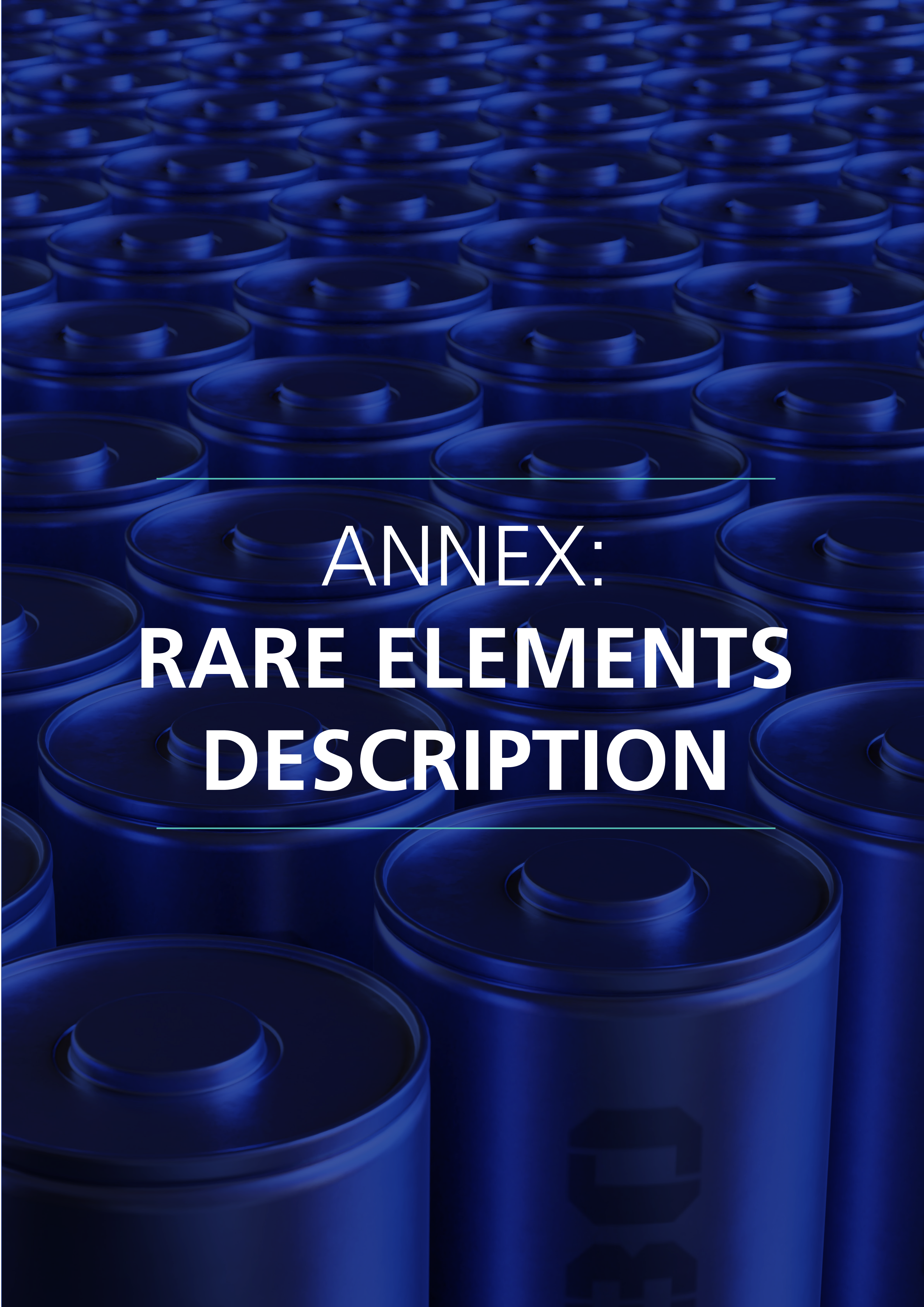
PRINCIPAL ABBREVIATIONS

ACIM	*Asynchronous Motor*	**HREE**	*Heavy Rare Earth Element*
BEVs	*Battery Electric Vehicles*	**IR**	*Import Reliance*
CRM	*Critical Raw Material*	**JRC**	*Joint Research Centre*
CRMA	*Critical Raw Materials Act*	**LED**	*Light Emitting Diodes*
EC	*European Commission*	**LFP**	*Lithium Iron Phosphate*
EESM	*Externally Excited Synchronous Machines*	**LIBs**	*Lithium-Ion Batteries*
EI	*Economic Importance*	**LME**	*London Metal Exchange*
EoL	*End-of-Life*	**LREE**	*Light Rare Earth Element*
EU	*European Union*	**LSCF**	*Strontium-doped Lanthanum Cobalt Ferrite*
EVs	*Electric Vehicles*	**LSM**	*Strontium-doped Lanthanum Manganite*
FCs	*Fuel Cells*	**MEA**	*Membrane Electrode Assembly*
GDLs	*Gas Diffusion Layers*	**NACE**	*Nomenclature statistique des activités économiques dans la Communauté européenne*
GDP	*Gross Domestic Product*	**NCA**	*Nickel-Cobalt-Aluminium oxide*
GS	*Global Supply*	**Ni-GDC**	*Nickel-Gadolinium Doped Ceria*
HHI	*Herfindahl-Hirschman-Index*		

Source: Materias

NiMH	*Nickel Metal Hydride*
Ni-YSZ	*Nickel-Yttria Stabilized Zirconia*
NMC	*Nickel-Manganese-Cobalt oxide*
NOx	*Nitrogen oxides*
NZIA	*Net-Zero Industry Act*
OECD	*Organisation for Economic Co-operation and Development*
PbA	*(Lead Acid)*
PEMFC	*Proton Exchange Membrane FCs*
PFSA	*Perfluorosulfonic Acid*
PGM	*Platinum Group Metal*
PHEVs	*Plugin Hybrid Electric Vehicles*
PMAR	*Permanent Magnet Assisted Reluctance Motor*
PMSM	*Permanent Magnet Synchronous Motor*
PTFE	*Polytetrafluoroethylene*
REE	*Rare Earth Element*
RIR	*Recycling Input Rate*
SCo	*Substitute Co-production*
SCr	*Substitute Criticality*
SI	*Substitution Index*
SI(EI)	*Substitution Index for Economic Importance*
SI(SR)	*Substitution Index for Supply Risk*
SOFC	*Solid oxide FCs*
SOx	*Sulphur oxides*
SP	*Substitute Production*
SR	*Supply Risk*
SRM	*Strategic Raw Material*
USGS	*US Geological Survey*
WEEE	*Waste Electrical and Electronic Equipment*
WGI	*Worldwide Governance Indicators of the World Bank*
WRSM	*Wound Rotor Synchronous Motor*

Source: Materias



ANNEX: RARE ELEMENTS DESCRIPTION

HREEs (Heavy Rare Earth Elements):

1. **Erbium (Er):** A silvery-white metallic element with atomic number 68, used in fiber optics and nuclear reactors.
2. **Dysprosium (Dy):** A metallic element with atomic number 66, often used to enhance the performance of neodymium-based magnets in high-temperature conditions.
3. **Europium (Eu):** A soft metallic element with atomic number 63, primarily used in phosphors for television screens and fluorescent lamps.
4. **Gadolinium (Gd):** A silvery-white metal with atomic number 64, used in magnetic resonance imaging (MRI) contrast agents and in certain types of electronic components.
5. **Holmium (Ho):** A metallic element with atomic number 67, primarily used in medical and scientific equipment.
6. **Lutetium (Lu):** A silvery-white metal with atomic number 71, used in petroleum refining and in certain types of electronic equipment.
7. **Terbium (Tb):** A soft gray metal with atomic number 65, used in phosphors for LCD displays and in solid-state devices.
8. **Thulium (Tm):** A soft, silvery metal with atomic number 69, used in certain electronic equipment and medical applications.
9. **Ytterbium (Yb):** A metallic element with atomic number 70, used in stress sensors and as a dopant in fiber optic cables.
10. **Yttrium (Y):** A silvery metal with atomic number 39, used in phosphors for television screens and in superconductors.

Source: Materias

LREEs (Light Rare Earth Elements):

1. **Lanthanum (La):** A soft, silvery-white metal with atomic number 57, used in high-capacity batteries and in the production of certain types of glass.
2. **Cerium (Ce):** A silvery-white metal with atomic number 58, widely used in catalytic converters and in glass polishing compounds.
3. **Praseodymium (Pr):** A soft, silvery metal with atomic number 59, used in various alloys and in the manufacturing of permanent magnets.
4. **Neodymium (Nd):** A soft, silvery metal with atomic number 60, essential in the production of high-strength permanent magnets used in many electronic devices.
5. **Samarium (Sm):** A hard, silvery metal with atomic number 62, used in certain types of nuclear reactors and in the production of specific magnets.

PGMs (Platinum Group Metals):

1. **Iridium (Ir):** A hard, brittle, and dense metal with atomic number 77, often used in spark plugs and in the manufacturing of certain types of high-temperature crucibles.
2. **Palladium (Pd):** A shiny, silvery metal with atomic number 46, widely used in catalytic converters, electronics, and dental alloys.
3. **Platinum (Pt):** A dense, malleable, and ductile metal with atomic number 78, known for its resistance to corrosion, used in jewelry, catalytic converters, and various industrial applications.
4. **Rhodium (Rh):** A rare, silvery-white metal with atomic number 45, used in catalytic converters and for its reflective properties in mirrors and jewelry.
5. **Ruthenium (Ru):** A rare transition metal with atomic number 44, used in electronics, catalysts, and some types of jewelry.
6. **Osmium (Os):** As the densest and hardest of the group, osmium is often alloyed with other PGMs such as Platinum and Iridium. Osmium also is an excellent conductor of electricity and an effective oxidation catalyst. Common applications for osmium include fuel cells and forensic science.

Source: Materias

ABOUT INTESA SANPAOLO INNOVATION CENTER:

Intesa Sanpaolo Innovation Center is the company of Intesa Sanpaolo Group dedicated to innovation: it explores and learns new business and research models and acts as a stimulus and engine for the new economy in Italy. The company invests in applied research projects and high potential start-ups, to foster the competitiveness of the Group and its customers and accelerate the development of the circular economy in Italy.

Based in the Turin skyscraper designed by Renzo Piano, with its national and international network of hubs and laboratories, the Innovation Center is an enabler of relations with other stakeholders of the innovation ecosystem - such as tech companies, start-ups, incubators, research centres and universities - and a promoter of new forms of entrepreneurship in accessing venture capital. Intesa Sanpaolo Innovation Center focuses mainly on circular economy, development of the most promising start-ups, venture capital investments of the management company Neva SGR and applied research

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ABOUT MATERIAS

Materias is an innovative SME aiming to create new businesses, supporting the development of innovative solutions in the advanced materials sector and accelerating their market entry. Materias invests in science-based new ventures supporting the most promising technologies to overcome the “Death Valley”, through the connection of the research world with industrial companies.

The company operates on scientific knowledge-based technologies, which require more costs and risks than digital innovations. The work carried out by Materias has allowed the scouting of over 1.100 ideas in the advanced materials sector, going from life science, civil engineering, food-tech to industrial engineering.

The development of applied research projects and the management of intellectual property has allowed the company to increase its value and strengthen its intangible assets by feeding the technology database and the patent portfolio. Materias has created an innovation ecosystem that has allowed the company to come into contact with excellent public and private research Centers of international relevance.

The ecosystem has generated a valuable contribution in terms of technology transfer and first industrialization in partnership with universities and Public Research Centers.

Published: January 2024