

The Nordic Supply Potential

of Critical and Strategic Raw Materials
Under a Twin Transition and Geopolitical Reordering



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Executive summary

The transition from a high-carbon to a low-carbon economy remains central to climate mitigation, but the context in which this transition unfolds has changed substantially since the 2021 perspective set out in the previous Nordic Innovation (NI) report (Eilu et al., 2021). In 2023, the concept of "strategic" raw materials was added to the previous classification of critical raw materials (Grohol & Veeh, 2023). What was previously mainly framed as a green energy transition can now be considered as a "twin transition", in which decarbonisation, digitalisation and defence jointly shape economic development (Figure A), while geopolitics increasingly affects access to minerals and metals, processing capacity, trade routes, and mineral and metal commodity prices (Figure B). Historical precedents demonstrate how direct this transmission can be; for instance, the 2010 Chinese rare earth element (REE) export restrictions triggered sharp REE price spikes, while the subsequent market reversal contributed to the collapse of Molycorp's Mountain Pass operation (Heffernan, 2015; IEA, 2025a). As a result, critical and strategic raw materials (CSRMs) are no longer only an industrial issue; they form a core component of economic security and technological competitiveness, and their increasing instrumentalisation in policy and geopolitics highlights the need for an important shift from passive supply concern to active strategic leverage (e.g., Carrara et al., 2023; EU, 2024a; Ufimtseva et al., 2024; IRTC, 2026).

Metals and minerals obtained from geological resources through mining are fundamental to industry and society. Since 2010 and the first Chinese cuts in REE export quotas, the industrialised world has become increasingly aware of escalating threats to its access to raw materials. This is particularly the case for those metals and minerals that are mainly produced in a few countries characterised by non-democratic governments or as being "brittle states" with regards to governance. The demand for many of these specific raw materials has increased dramatically during the last decade, mainly as a result of the broad introduction of new low-carbon-footprint technologies. Further to this, in 2023, the additional classification of "strategic" raw materials was likely prompted by the Russian invasion of Ukraine in 2022. This also led to increased importance being attached to raw materials with direct and critical applications for military technologies (Grohol & Veeh, 2023; IEA, 2025a; IEA, 2025b).



Against this transformed macro setting, the Nordic region is best understood as a selectively strong value-chain actor rather than a fully self-sufficient system (Eilu et al., 2021; Carrara et al., 2023; EU, 2024a). As summarised in Table A and Figure C, the region's relevance is concentrated in a specific portfolio of known critical and strategic raw materials whose industrial uses and European supply significance vary markedly between commodities. Notably, as also addressed in this report, the future discovery potential for new deposits of critical raw materials is large. The Nordic geological potential thus remains substantial, but strategic relevance depends on combining domestic capabilities with targeted international partnerships to address persistent gaps (EC, 2025a). In this sense, the central question is no longer whether resources exist, but whether they can be developed and coordinated at sufficient speed, scale and sustainability performance to reduce vulnerability in European supply chains.

Table A. Critical and strategic raw materials of high relevance in the Nordic region and their main industrial applications.

Cobalt	<i>Essential for many electrode types in Li-ion batteries; 100% of European mine production from Finland.</i>
Copper	<i>Critical and strategic under the Critical Raw Materials Act (CRMA); below the 2023 JRC criticality threshold. Electrification across generation, transmission, distribution and end-use: power cables and wiring, transformers, electric motors, charging infrastructure and renewable installations; also key for photovoltaic (PV) and information technology (IT)/digital infrastructure; approximately 52% of EU domestic supply at the extraction stage and 83% of EU domestic supply at the processing stage.</i>
Graphite	<i>Essential for electrodes in Li-ion batteries; nearly 90% of European mine production and several projects under development.</i>
Hafnium	<i>Superalloys; world annual production approximately 71 t (2016 estimate); Known resources in Greenland and Sweden.</i>
Lithium	<i>Li-ion batteries; no European mine production for batteries; battery-grade production under development in Finland; exploration projects in Sweden.</i>
Nickel	<i>Battery-grade nickel is critical and strategic under the CRMA; below the 2023 JRC criticality threshold. Stainless steel and battery value chains; relevant to electric-vehicle (EV) and stationary-storage deployment through high-energy-density Li-ion chemistries; approximately 64% of EU domestic supply at the extraction stage and 23% of EU domestic supply at the processing stage.</i>
Niobium	<i>Superalloys in power generators, turbines and superconducting magnets; 8% of globally known resources; no European mine production; 99% of European resources, mainly in Greenland.</i>
Platinum group metals	<i>Essential in fuel cell and hydrogen power technology, and extensive electronics applications; 100% of European mine production in Finland; 99% of European resources.</i>
Rare earth elements	<i>Magnets for electric motors and generators in vehicles and wind turbines; fuel cells and batteries; 9% of globally known resources; no European mine production. Major projects in Greenland, Sweden and Norway.</i>
Silicon metal	<i>Solar panels, semiconductors and silicon anodes in future Li-ion batteries; approximately 15% of European domestic supply.</i>
Strontium	<i>Ceramic ferrite magnets used in electric motors and generators; additional uses include glass/ceramics and drilling fluids; EU supply is 99.1% EU-sourced, while quantified known resources in the Nordic countries are in Greenland.</i>
Tantalum	<i>Capacitors and other electronics; no European mine production; 99% of European resources.</i>
Titanium	<i>Light-weight alloys for vehicles and electricity-related structures; 25% of globally known resources; 100% of European mine production in Norway; 90% of European resources.</i>
Vanadium	<i>Stationary redox batteries (large-scale energy storage); 10% of the globally known resources.</i>

Secure and resilient long-term supply chains of CSRM are essential for the economic security of any industrialised country, including the Nordic region and Europe, and for enabling technological leadership. In the context of the green energy transition, it is important to stress that recycling is far from sufficient to meet the increasing projected demand for CSRM (Hund et al. 2020; Schütte 2021; IEA 2024). Subsequent to the 2021 NI report, the IEA (2024) pointed out that there is a significant gap between the known supply and demand, for example, for copper and lithium: anticipated mine supply from announced projects meets only 70% of copper and 50% of lithium requirements. For copper, this shortfall needs to be seen with regards to the longer demand trajectory illustrated in Figure D, in which consumption rises from 2020 to 2050 under all three IEA policy scenarios: STEPS (Stated Policies Scenario), APS (Announced Pledges Scenario) and NZE (Net Zero Emissions by 2050 Scenario). Even the lower-demand case therefore implies continued growth driven by electrification, grids, industry and EV deployment (IEA, 2025a). These observations highlight the continued importance of and vital need for primary mining and the exploration and development of new sources for metals and minerals, particularly so regarding the CSRM.

This report thus updates the Nordic CSRM potential knowledge base in light of the Critical Raw Materials Act (CRMA), which introduced the strategic raw materials list in the 2023 CRMA documentation and formalised it in the 2024 regulation alongside the more concisely defined updated critical raw materials list (Grohol & Veeh, 2023; EU, 2024a). Section 2 introduces Table 2.1, summarising the commodities designated as strategic and critical under the CRMA and using this classification as a reference frame for the subsequent Nordic resource assessment. Our analysis examines how geopolitical policy action, in concert with this so-called twin transition, reshapes mineral market conditions and what this implies for Nordic resource development and strategic positioning. The report also illustrates the importance of companionability and secondary resources research in earlier NI-funded research.



Core drilling at the Fen REE-rich carbonatite, Norway. Photo: Henrik Schiellerup.

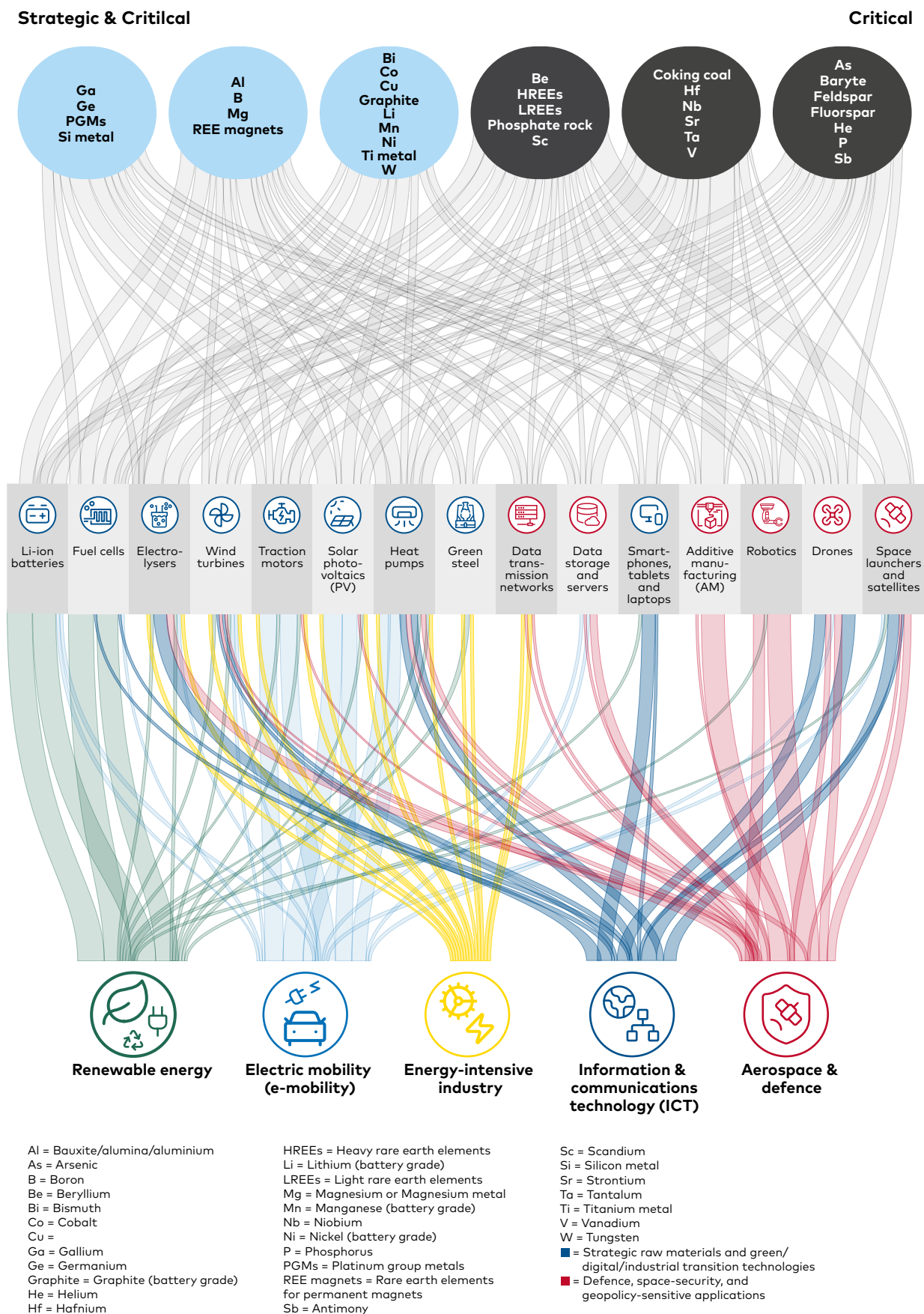
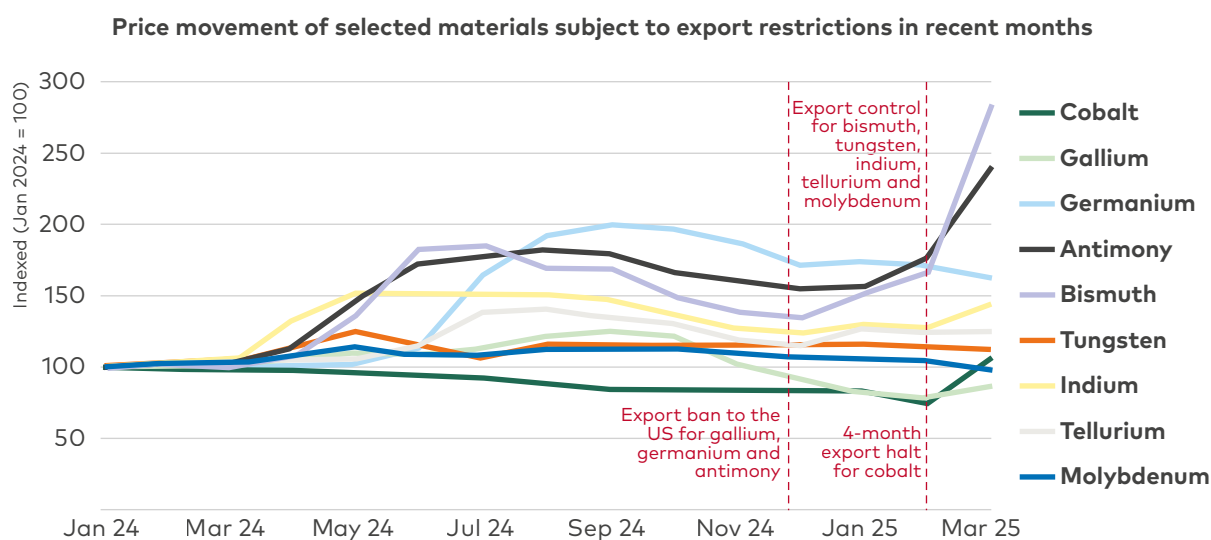


Figure A. Schematic representation of raw-material linkages across green-transition, digital and strategic-industry value chains, illustrating how multiple technology domains draw on overlapping mineral inputs. Adapted from Carrara et al. (2023).

The current policy environment is accelerating selected Nordic mining and processing projects that are considered strategically important. However, this should not be interpreted as unconstrained growth. Managing expectations is essential: long project lead times, high capital intensity, permitting complexity and infrastructure constraints mean that delivery is inherently phased. For this reason, environmental, social and governance (ESG) performance and carbon reduction must be treated as binding design conditions for development, not as downstream corrections, in line with the Paris Agreement and the European Green Deal policy direction (UNFCCC, 2015; EC, 2019).

This report's core contribution is to provide a structured synthesis of current knowledge on Nordic CS-RMs, identify critical data gaps and support evidence-based prioritisation for governments, industry and research institutions. By integrating geology, value chains and policy signals, it aims to support realistic strategic pathways.

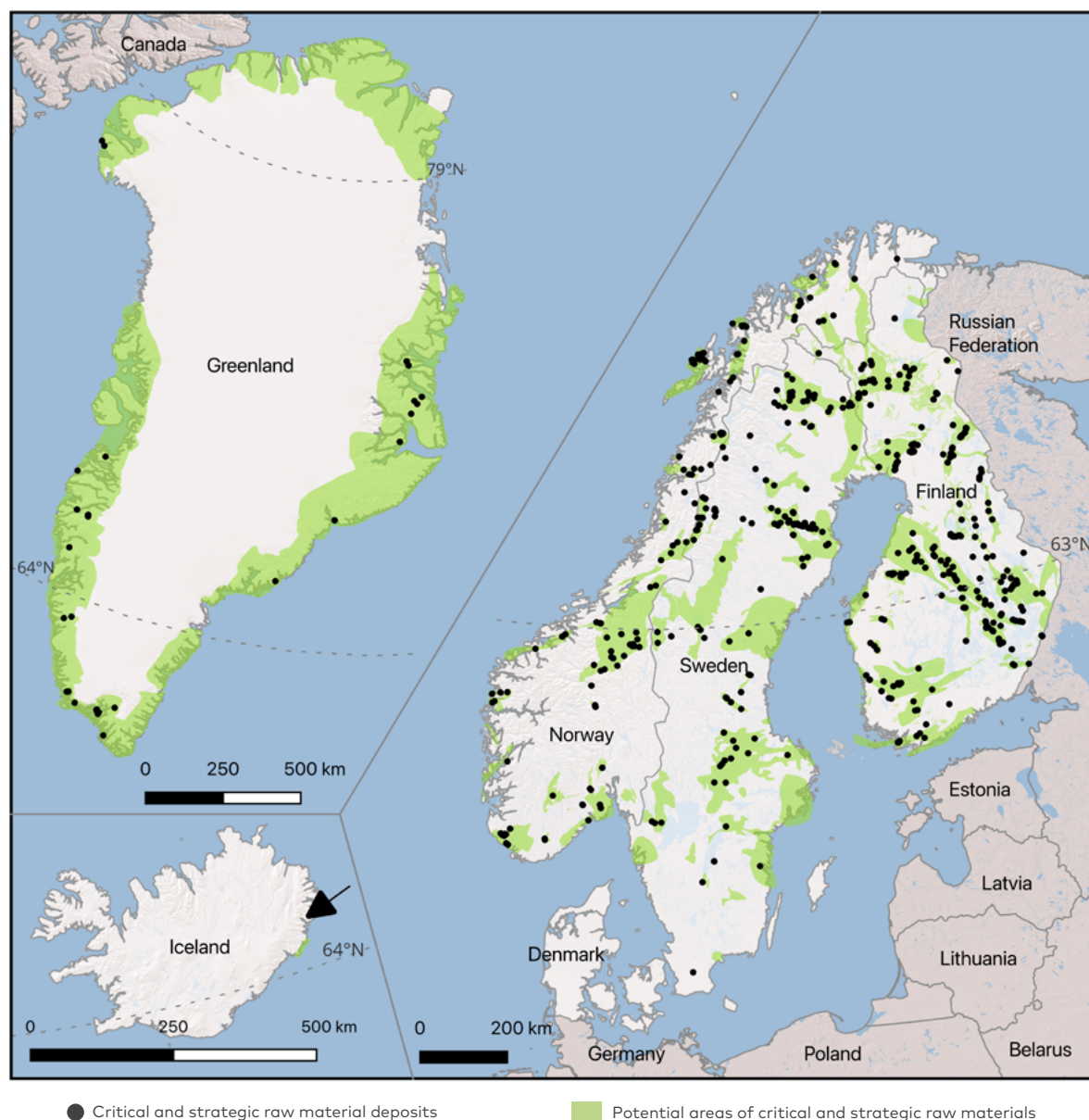


Sources: IEA analysis based on S&P Global and Bloomberg.

IEA. CC BY 4.0.

Figure B. Export restrictions on energy-related raw materials and recent price movements for selected metals and semi-metal tellurium (not presently classified as critical), illustrating how geopolitical constraints can rapidly transmit to commodity price volatility and broader supply-chain vulnerability/competitiveness risks. Adapted from IEA (2025a).

Known Resources of Critical and Strategic Raw Materials in the Nordic Countries



Finland		Greenland/Denmark		Norway		Sweden	
	Res. (t)*		Res. (t)		(t)		(t)
Antimony	2,555	Antimony	3,780	Beryllium	630	Antimony	23,005
Arsenic	2,400	Baryte	480,000	Cobalt	15,696	Arsenic	446,120
Beryllium	464	Beryllium	65	Copper	1,800,761	Bismuth	598
Cobalt	541,258	Copper	108,000	Coking coal	26,000,000	Cobalt	38,356
Copper	5,934,558	Feldspar/nepheline syenite	80,800,000	Fluorspar	984,000	Copper	10,925,000
Feldspar/nepheline syenite	910,000	Fluorspar	250,000	Graphite	20,376,344	Feldspar/nepheline syenite	110,000,000
Graphite	1,562,794	Gallium	27,000	Nickel	160,620	Fluorspar	2,828,000
Lithium	113,917	Graphite	6,000,000	Niobium	22,052	Graphite	15,617,500
Manganese	3,391,240	Hafnium	107,500	Phosphorus	52,864,000	Hafnium	6,741
Nickel	6,884,135	Lithium	235,600	Platinum group metals	4.25	Lithium	3,180
Niobium	122,381	Niobium	5,900,000	Rare Earth Elements	12,880,090	Manganese	8,560,000
Phosphorus	219,800,000	Phosphorus	11,456,025	Scandium	6.5	Nickel	3,253,868
Platinum group metals	890.2	Platinum group metals	575	Silicon metal	11,664,000	Niobium	38,500
Rare Earth Elements	169,067	Rare Earth Elements	33,749,590	Titanium	230,000,000	Phosphorus	58,900,000
Sandium	2,184	Silicon metal	2,797,860	Tungsten	2,701	Platinum group metals	0.485
Tantalum	499	Strontium	9,800,000	Vanadium	2,112,077	Rare Earth Elements	3,200,169
Titanium	24,100,000	Tantalum	916,000			Silicon metal	522,570
Tungsten	2,300	Titanium	11,914,325			Tantalum	68
Vanadium	1,100,000	Tungsten	26,030			Titanium	18,930,000
		Vanadium	179,000			Tungsten	1,770
						Vanadium	10,960,000

*Known resources, t = tonnes of contained metal / mineral.

Known critical and strategic raw material (CSRM) resources and areas with known or assumed potential for additional CSRM resources in the Nordic countries. Reported tonnages (t) are known resources in tonnes of contained metal or mineral, including both CRIRSCO-compliant and non-compliant resources and excluding assumed submarine resources; figures represent indicative estimates only. The Nordic CSRM potential should not be assessed from reported tonnages alone.

Figure C. Locations of deposits with known CSRM resources and areas with known or assumed potential for CSRM resources in the Nordic countries. The associated resource-potential area in Iceland is assumed to be very small and is hence indicated by a black arrow.

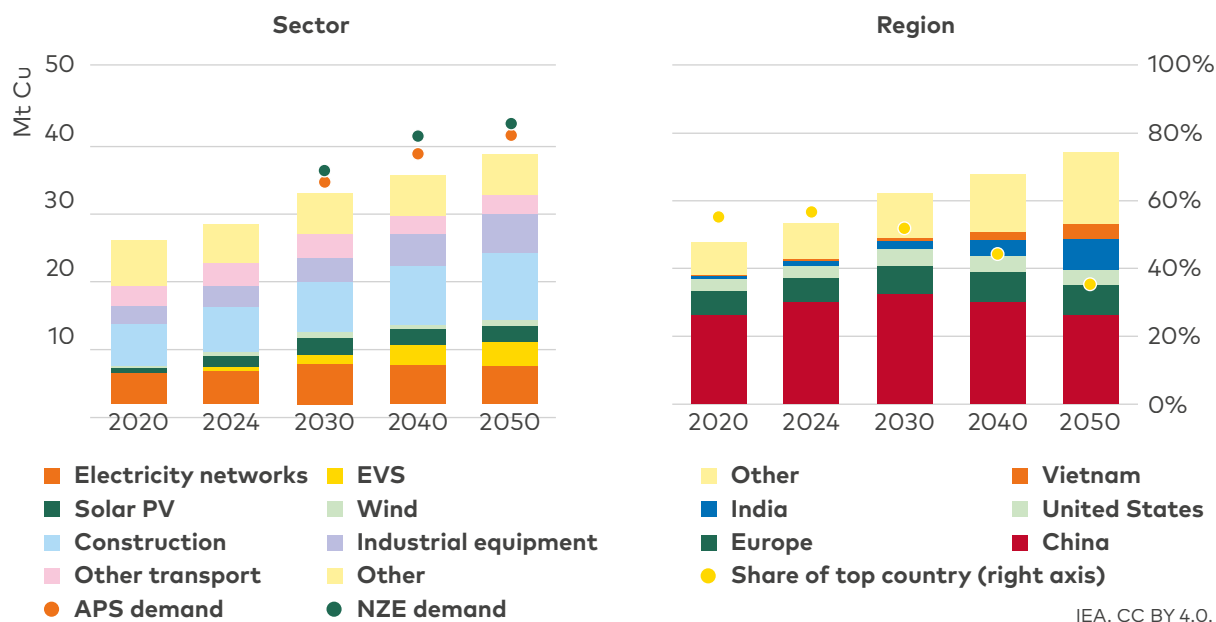


Figure D. Refined copper demand, excluding direct-use scrap, 2020–2050. The left panel presents sectoral demand in the STEPS (Stated Policies Scenario) as stacked bars in Mt Cu, with overlaid markers for total demand under the APS (Announced Pledges Scenario) and NZE (Net Zero Emissions by 2050 Scenario). The right panel displays the regional composition of STEPS demand, with stacked shares for China, Europe, India, the United States, Vietnam and other regions; yellow markers indicate the share of the largest demand country on the right-hand axis. Adapted from: IEA, Global Critical Minerals Outlook 2025.

Since the 2021 NI report, several actions to support and develop the proposed recommendations have been taken.

For **Recommendation 1** (primary resources and processing), Nordic work has advanced geological targeting, quantitative assessment of undiscovered potential and project-level pathways for mining and midstream build-out (Eilu et al., 2021; Jonsson et al., 2023; Rasilainen et al., 2023; EU, 2024a). However, much still remains to be done, such as gaining more knowledge on the occurrence and distribution of by-product or co-product metals, including but not limited to Bi, Co, Ga, Ge and Sb. The previously critical element In (indium) may also be included among these, as well as the potentially near-critical semi-metals Te and Se.

For **Recommendation 2** (secondary resources), the Nordic knowledge base has been materially strengthened through a multi-disciplinary research effort addressing secondary resources from field studies, process-oriented case studies and a value-chain perspective, together with national studies and inventories. The former work combined systematic geological, geochemical and geophysical investigations on mine waste and tailings with studies examining how CSRM partition across industrial residues and treatment stages (Feltrin et al., 2024).

For **Recommendation 3** (Nordic database development), substantial progress has been made through the integration of the Nordic Ore Deposit Database (NODD) and the Nordic Secondary Critical Raw Material Database (NSCRMD) into a shared architecture linking primary and secondary resource records. The 2024 Nordic secondary-resources programme reported 1,526 primary-resource records and 582 secondary-resource records, and coupled this database work with case studies on Grängesberg, Yxsjöberg, Løkken and Danish municipal solid waste incineration (MSWI) fly ash to test how geological, geochemical, geophysical and industrial-process data can be used to evaluate the CSRM recovery potential in waste systems (Feltrin et al., 2024). This report now includes dedicated summary sections (Sections 4.1–4.3) on the relevance of secondary resources and on the submarine resource potential in

Nordic waters, covering seafloor massive sulphides, manganese crusts and shallow-water ferromanganese concretions documented from the North Atlantic ridge system and the Baltic domain (e.g., Pedersen & Bjerkgård, 2016; Kaikkonen et al., 2019; González et al., 2023).

For **Recommendation 4** (demand and supply outlooks), EU and international foresight has improved scenario-based material demand and supply-chain analysis for transition technologies, providing a stronger planning basis under uncertainty (Carrara et al., 2023; IEA, 2025a).

A key update from this report is that geopolitics must now be embedded more directly in future planning, especially for **Recommendations 1, 2, 3 and 4**, because trade exposure, investment screening, strategic project designation and route reliability increasingly affect what is technically feasible and economically viable (EU, 2024a; Ufimtseva et al., 2024; EC, 2025b).

1 Introduction

Mineral and metal markets are influenced by a wide range of macro-level factors, including economic growth, technological change, energy prices, environmental regulation and trade relations. However, these drivers differ in duration and direct mechanisms. Some are cyclical and affect markets over short time horizons through price and investment swings. For example, lithium prices surged in 2021–2022 and then fell by more than 80% from 2023, mainly because supply expanded faster than demand as new battery-metal production rapidly came online; in parallel, EV growth slowed in some mature markets, partly linked to subsidy phase-outs or reductions, which tempered short-term demand momentum (IEA, 2025a). Other drivers are more persistent, operating (in some cases) over decades (e.g., population growth trends), reshaping demand profiles, supply-chain geography and policy frameworks (EU, 2024a). In the specific space of mineral value chains (MVCs), the long-term factors that currently appear dominant are the Twin Transition and Geopolitics.

In this report, the Twin Transition is defined as the coupled structural transformation in which decarbonisation (energy-system electrification, renewable deployment and efficiency) and digitalisation (data infrastructure, control systems, automation and digital services) advance jointly and mutually reinforce technology deployment, infrastructure investment and material demand (UNFCCC, 2015; EC, 2019; Carrara et al., 2023; IEA, 2025a). This coupling is analytically important, because digital systems are increasingly embedded in low-carbon energy and industrial systems, and mineral and metal demand is therefore shaped by the interaction of both transitions rather than by climate policy alone (IEA, 2021; Carrara et al., 2023; IEA, 2025a). Recent progress in large language model (LLM) artificial intelligence (AI) further has intensified this linkage: the IEA estimates global data-centre electricity use at about 415 TWh in 2024, with a base-case rise towards approximately 945 TWh by 2030, increasing pressure on grid adequacy and energy-security planning, and strengthening the case for firm low-carbon generation and the corresponding adaptation of uranium and fuel-cycle capacity (IEA, 2025c; WNA, 2025). A concrete US example is the Stargate platform linked to OpenAI, announced in Washington on 21 January 2025, with a stated intention to invest USD 500 billion over four years in AI infrastructure in the United States, including an initial USD 100 billion deployment, followed by a July 2025 expansion, with Oracle adding up to 4.5 GW of additional US data-centre capacity (OpenAI, 2025a; OpenAI, 2025b). The same trend is visible in the Nordic region, which is increasingly being treated as a preferred data centre destination because of its political stability, good air quality, cool climate, strong low-carbon power profile and, in some locations, electricity prices that remain among the lowest in the EU for non-household consumers. Key operators explicitly cite several of these factors in their Nordic investments: Microsoft's Finland data centre siting referred to the minimal risk and cool climate, Google's Hamina facility operates using 97% carbon-free energy and is being linked to district heating, Meta's Luleå campus matches its electricity use with 100% clean and renewable energy while achieving Leadership in Energy and Environmental Design (LEED) Gold and Platinum certification, and Green Mountain's hyperscale campus at Hamar in Norway is being developed on renewable power as one of the largest new data centre projects in the region (Microsoft, 2022; Green Mountain, 2023; Google, 2024; Meta, 2025). In parallel, this report uses Geopolitics to denote state-led policy action under geopolitical competition that directly affects MVCs, including strategic-project designation, trade diversification agreements, export controls, tariffs, foreign-investment screening, stockpiling and permitting acceleration (EU, 2024a; Ufimtseva et al., 2024; EC, 2025b; IRTC, 2026); key examples and implications are discussed in Section 2.3. Interpreted together as macro-drivers of global economies, the twin transition primarily acts through persistent demand expansion for transition technologies, while geopolitics primarily acts through supply-side governance, risk pricing and control over extraction, processing and logistics nodes. Their interaction defines the current macro regime for critical and strategic raw materials (Carrara et al., 2023; EU, 2024a; IEA, 2025a).

This interaction also needs to be understood in relation to physical scale. As illustrated in Figure 1.1, the most strategically consequential materials are not necessarily the largest by tonnage: within this selected

2025 production comparison, aluminium and copper dominate physical output across the wider system, while lithium, cobalt and rare earth elements occupy a much smaller share, yet carry disproportionate strategic importance because they are critically embedded in batteries, magnets, semiconductors and other high-dependence technologies (McNulty & Jowitt, 2021; National Minerals Information Center (USGS), 2026).

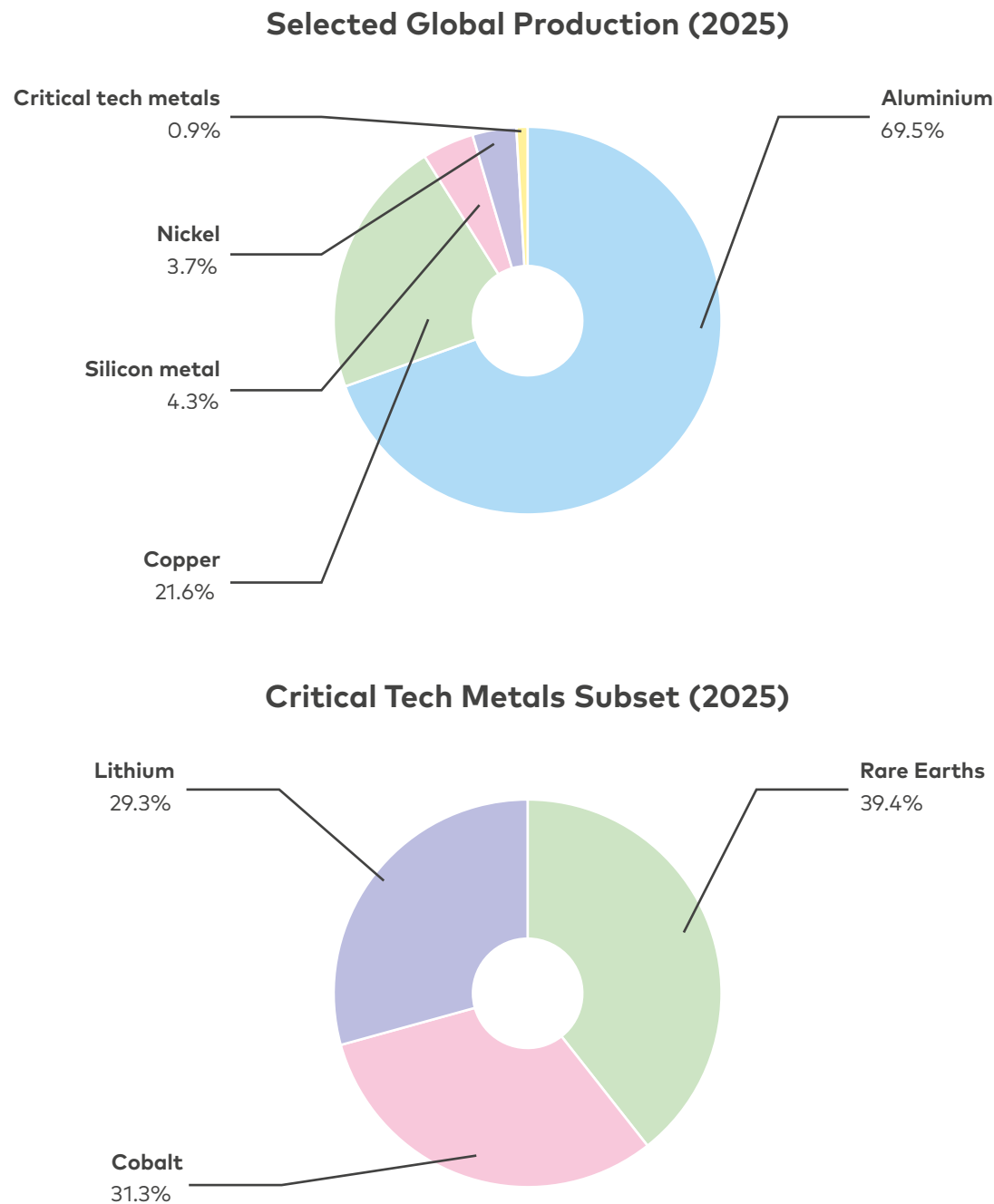


Figure 1.1. Relative shares of selected 2025 global production volumes and of selected critical-tech metals within the low-volume subset, illustrating why strategic importance is not well captured by tonnage alone. The global production pie chart uses official USGS world totals for aluminium smelter production (74.0 Mt), copper mine production (23.0 Mt), silicon metal production (4.6 Mt), nickel mine production (3.9 Mt) and aggregated lithium, cobalt and rare-earth-element mine production (0.99 Mt). The critical tech subset uses official USGS world totals for rare earth elements (390 kt, rare-earth-oxide (REO) equivalent), cobalt (310 kt, cobalt content) and lithium (290 kt, lithium content). Source data: National Minerals Information Center (USGS), 2026.

Concern about the security of supply of certain raw materials is not new; for several centuries, there have been periods of concern about the availability (and future supply) of important raw materials and products made from them. In the mid-19th century, Jevons (1866) warned that Great Britain could run out of coal due to the rapid increase in coal-driven industry. During the Cold War, there were concerns related to the Soviet Union's dominance in the production of many critical and strategic materials, particularly metals, and that this could result in a resource war (Szuprowicz, 1981). During the same period, South Africa dominated the world production of platinum group metals, chromium, vanadium and manganese while the country was under a trade boycott from many countries due to apartheid. Since the beginning of the 2000s, market liberalism and monopolization combined with geopolitical unrest, and raw material nationalism, has led to new concerns about access to necessary raw materials in the short and medium term. A central feature of the current situation is China's dominant position in both the primary supply and downstream processing of several important raw materials, including rare earth elements (REEs), tungsten and antimony.

Under this macro regime, both energy-system expansion and mineral demand growth are expected to remain structurally high, increasing pressure on exploration, mine development, processing, refining and recycling capacity (Carrara et al., 2023; Feltrin et al., 2024; IEA, 2025b). Accordingly, this report assesses the supply potential of the Nordic countries, covering Denmark, Finland, Iceland, Norway, Sweden and Greenland. For geological resource analysis, the principal focus is on the land area with substantial hard-rock mineral potential; Denmark is mainly treated as a non-hard-rock producer (limestone, chalk, salt, clay and aggregates) and is therefore not a major contributor to primary CSRM mine supply in this and similar assessments (Eilu et al., 2021). Consistent with the 2021 framing, the relevant land domain is approximately 1.63 million km² when excluding Denmark and the ice-covered part of Greenland (Finland 338,000 km²; ice-free Greenland 415,000 km²; Iceland 103,000 km²; Norway 324,000 km²; Sweden 450,000 km²), compared to about 4.33 million km² for the entire EU. This land scale aspect, combined with the long and complex evolution of the bedrock and its cover units, helps to explain the region's extensive mineral potential (Eilu, 2012; Eilu et al., 2021; Jonsson et al., 2023). Unlike the scope of the earlier report, this update includes a summary of current research on secondary resources as complementary supply streams, including tailings, waste rock, slags, process residues and municipal solid-waste-incineration ash, while confirming that primary mining remains essential for meeting transition-scale demand in the relevant time horizon (Feltrin et al., 2024; IEA, 2025a).

Overall, the Nordic supply potential for CSRM is very large but heterogeneous across commodities and jurisdictions, both in geological favourability and in data availability and maturity (Eilu et al., 2021). For example, metals central to e-mobility (cobalt, lithium and rare earth elements) are comparatively better constrained and in some cases already exploited, whereas several by-product metals (antimony, bismuth, gallium, germanium and indium) remain poorly constrained in terms of their geological distribution, processes of concentration, resource definition and recovery potential (Eilu et al., 2021; Feltrin et al., 2024). This data heterogeneity extends to secondary mining and metallurgical waste: Sweden currently retains leadership in the inventory of secondary resources, followed by Finland and Norway, indicating uneven regional readiness for future secondary-resource re-mining (Feltrin et al., 2024). Table 1.1 provides the consolidated list of CSRM and summarises available production and refining history used as the baseline for this report.

The project was led by Geological Survey of Finland (GTK), in collaboration with the following partner organisations: the Geological Survey of Sweden (SGU), Geological Survey of Denmark and Greenland (GEUS), Geological Survey of Norway (NGU), Faculty of Earth Sciences, University of Iceland (HÍ), Iceland GeoSurvey (ÍSOR) and the Ministry of Mineral Resources, Government of Greenland. The work was funded by Nordic Innovation under the Nordic Council of Ministers. All abbreviations and chemical element symbols used in this report are explained in Appendix 1.

Table 1.1. CSRMs with current (2026) mine, refinery and smelter production, resources and/or resource potential in the Nordic countries. Figures are in tonnes of metal or mineral unless otherwise stated in the underlying commodity summary. The table reflects the current commodity-summary set. It also includes copper, manganese and nickel, which are explicitly covered in this update because of their strategic or transition relevance. Basalt fibres are discussed separately as a short non-critical summary note rather than as a full commodity summary (Section 3).

Commodity	Mine production/ (t/y mtl/min)	Refinery and smelter production/ (t/y mtl/min)	Known resources ² / (t mtl/min)	Finland ³	Greenland ³	Iceland ³	Norway ³	Sweden ³
Antimony	0	0	29,300	Yes	Yes	No	Yes	Yes
Arsenic	0	0	449,000	Yes	Yes	No	Yes	Yes
Baryte	0	- ¹	480,000	Yes	Yes	Yes	Yes	Yes
Bauxite/ alumina/ aluminium ⁶	0	2,150,000	0	No	No	No	No	No
Beryllium	0	0	1,160	Yes	Yes	No	Yes	Yes
Bismuth	0	0	598	Yes	Yes	No	Yes	Yes
Cobalt	1,130	15,100	595,000	Yes	Yes	No	Yes	Yes
Copper	106,000	454,000	18,800,000	Yes	Yes	Yes	Yes	Yes
Coking coal	110,000	110,000	26,000,000	No	Yes	No	Yes	No
Feldspar/ nepheline syenite	420,000	383,000	192,000,000	Yes	Yes	No	Yes	Yes
Fluorspar	0	- ¹	4,060,000	No	Yes	Yes	Yes	Yes
Gallium	0	0	27,000	Yes	Yes	No	Yes	Yes
Germanium	0	0	Not quantified	Yes	Yes	No	Yes	Yes
Graphite ⁴	6,600	0	43,600,000	Yes	Yes	No	Yes	Yes
Hafnium	0	0	114,000	Yes	Yes	No	No	Yes
Helium	0	0	Not quantified	No	Yes	No	Yes	No
Lithium	0 ⁵	0	353,000	Yes	Yes	No	No	Yes
Magnesium metal	0	0	Not quantified for Mg metal	Yes	Yes	Yes	Yes	Yes
Manganese	0	490,000	12,000,000	Yes	No	No	Yes	Yes
Nickel	36,600	198,000	10,300,000	Yes	Yes	No	Yes	Yes
Niobium	0	0	6,080,000	Yes	Yes	No	Yes	Yes
Phosphorus	147,000	- ¹	343,000,000	Yes	Yes	No	Yes	Yes
Platinum group metals	1.95	5.560	1,470	Yes	Yes	No	Yes	Yes
Rare Earth Elements	0	0	50,000,000	Yes	Yes	No	Yes	Yes
Scandium	0	0	2,190	Yes	Yes	No	Yes	Yes
Silicon metal ⁴	1,000,000	364,000	15,000,000	Yes	Yes	No	Yes	Yes
Strontium	0	0	9,800,000	No	Yes	No	No	No
Tantalum	0	0	917,000	Yes	Yes	No	No	Yes
Titanium ⁴	390,000	21,600	285,000,000	Yes	Yes	Yes	Yes	Yes
Tungsten	0	0	32,800	Yes	Yes	No	Yes	Yes
Vanadium	0	0	14,400,000	Yes	Yes	No	Yes	Yes

1 For these commodities, smelter or refinery production is not relevant.

2 Includes both mineral resources according to current industry standards (as required by stock exchanges) and resources not according to such standards; the latter are often called historical resources. The figures are rounded to the lowest precision of the respective data available; hence, sums in this column are not the same as in detailed commodity summaries and CSRM tables.

3 Potential for additional discoveries. 'No' indicates no known indications of a commodity resource but does not mean there is no potential; comprehensive information is typically lacking. The resource potential of the seafloor is not included.

4 Presented figures for graphite, silicon metal and titanium may deviate somewhat from real production figures and can represent multi-year averages.

5 Lithium remains null in Table 1.1 because, although official Keliber/Sibanye-Stillwater updates published on 19 January 2026 state that cold commissioning and staged start-up of the Keliber project are underway in Q1 2026, and earlier company guidance indicated first-half 2026 production, no quantitative 2026 mine or refinery output statistics had been published by 12 March 2026.

6 Bauxite/alumina/aluminium reports the bauxite resource potential strictly as bauxite. No Nordic bauxite resources are counted here. Alternative alumina-bearing feedstocks such as anorthosite, feldspathic rocks and nepheline syenite are covered under feldspar/nepheline syenite. The processing figure records 2025 aluminium smelter production in Iceland and Norway.

2 Macro-drivers, criticality and geopolitics

2.1 Dominant macro-drivers

The two dominant macro-drivers introduced in Section 1 act on different parts of the MVCs. The green and digital transitions primarily reshape demand by redefining which materials are required, in which quantities and for which specific applications, while geopolitics mainly acts on the supply side by influencing where ores are mined, where metals are processed and refined, where raw materials are traded and how risk is managed through the diversification and control of midstream stages (Carrara et al., 2023; EU, 2024a; IEA, 2025a). In practice, these effects are reinforced by project durations and development intensity: most metallic mining projects are multi-year to multi-decade undertakings, require high up-front capital expenditure and must meet increasingly stringent ESG and permitting requirements before production can start (EU, 2024a; IEA, 2025a). The IEA illustrates this clearly for copper, where the current mine project pipeline indicates a potential supply shortfall of around 30% by 2035 because electrification is driving strong demand growth (IEA, 2025a). In addition, many CSRM are tied to major host commodities and by-product flows, meaning that expanding CSRM availability often depends not only on new mines but also on technological upgrading and expansion of smelting and refining capacity. In the Nordic context, this interaction between demand acceleration, supply concentration, long project lead times and processing constraints is central to evaluating realistic regional pathways for mining, re-mining and value-chain positioning (Valenta et al., 2019; McNulty & Jowitt, 2021; Jonsson et al., 2023; Feltrin et al., 2024). This report is therefore intended as a practical framework for orienting policy in this more complex strategic landscape.

2.2 Critical and strategic raw materials: continuity, criticality and CRMA framing

The Paris Agreement sets the long-term decarbonisation frame by requiring parties to keep global warming well below 2 °C, pursue 1.5 °C, and align development pathways with very low greenhouse gas emissions, with net-zero-type balancing of emissions and removals in the second half of the century (UNFCCC, 2015). In practice, this translates into accelerated electrification of transport, large-scale renewable deployment and grid expansion, which materially increases the demand for critical raw materials. Recent IEA scenario studies indicate that transition pathways are structurally mineral-intensive, with suggested strong growth in lithium, nickel, cobalt, graphite, copper and rare earth element demand under clean-energy deployment trajectories (IEA, 2021, 2025). At the EU level, research on CSRM by the European Commission's Joint Research Centre (JRC) has progressively moved from early criticality screening towards strategic technology and sector supply-chain forecasting, connecting climate and industrial policy to quantified materials demand, especially for batteries and EV value chains (EC, 2014; Bobba et al., 2020; Carrara et al., 2023). In this framework, EV transition pathways are a central demand driver for lithium, graphite, cobalt and nickel, while REEs become increasingly strategic via magnets for EV traction motors, as well as energy generation systems based on wind power. Their broader end-use diversity across digital, electronic, optical, health, biotechnology, AI and robotics applications is illustrated in Figure 2.2. A useful REE trajectory example is the IEA estimate that REE demand in energy applications may increase by roughly 3–7 times by 2040, depending on chosen technology mix and policy strength (IEA, 2021), a direction consistent with more recent supply-chain stress assessments and Nordic system analyses (Carrara et al., 2023). This interconnection between climate controls, demand forecasting and mineral value-chain constraints implies a structural transformation requirement in supply systems rather than incremental adjustment.

2.2.1 Critical raw materials and the logic of criticality

As defined by the EU, critical raw materials (CRM) are those raw materials that have a high importance to the industrial economy of the EU and whose supply is associated with a high risk of disruption, as specified by two parameters: economic importance (EI) and supply risk (SR). In 2024, the EU ratified the Critical Raw Materials Act (CRMA) and the fifth list of CRMs, including a new list of strategic raw materials (SRMs) (see Tables 1.1 and 2.1 in Section 2.2). The combined list of critical and strategic RMs is referred to as CSRMs in this report. This was based on an assessment of 83 individual materials dominated by metals and minerals. This updated list had already been presented in 2023 (Grohol & Veeh, 2023). A significant number of the thus classified CRMs are also fundamental for the technologies forming the core of the recently initiated green energy transition of our industry and society.

As previously stated, CRMs are defined as raw materials (RM) that both have a high economic importance (EI) and a large supply risk (SR) in the economy of a country or some other region under consideration (e.g., Blengini et al., 2020). To be classified as critical, a commodity must therefore be both in production somewhere in the world and consumed in the specific market that the criticality is assessed for. A CRM does not need to be expensive or have fundamental geological scarcity, even though several do meet these criteria. As explained below, the criticality of a raw material is determined by a combination of its geological distribution, geopolitics, trade statistics and economical parameters.

The EC has evaluated the EU's CRMs in 2011, 2014, 2017, 2020, and 2023 (Blengini et al., 2020; Grohol & Veeh, 2023), with the assessments documented comprehensively in summary reports spanning more than 2000 pages across several volumes. The US has also evaluated its CRMs in similar comprehensive studies and is consistently evaluating the issue (e.g., Schulz et al., 2017; Nassar & Fortier, 2021). Similar assessments have also been performed by many other countries, such as Russia, Canada, the UK and Australia (e.g., Chakmouradian et al., 2015). In this subsection, we explain the concept methods for defining CRMs and how they are ranked, following the methods used by the EC (EC, 2017).

2.2.2 Economic importance and supply risk

Economic importance (EI). The parameter EI aims at providing comparability and insight into the importance of a material for the EU economy in terms of end-use applications and the value added of corresponding EU manufacturing sectors in the Nomenclature of Economic Activity Codes (NACE) at the two-digit level. Economic importance is defined as follows:

$$EI = \text{Sum}[(A_s * Q_{ss}) * SI_{EI}]$$

where: A_s is the share of end use of the material in the NACE the two-digit level; Q_{ss} is the NACE two-digit-level value added; and SI_{EI} is the substitution index relative to economic importance. Thus, EI is calculated by multiplying the share of end use of a CRM in one sector with the value added (VA) for that sector, which is again multiplied by an index for substitution. This is repeated for each sector at the NACE two-digit level, and the aggregated EI for the particular CRM is calculated when all sectors are summed up.

Supply risk (SR). The parameter SR reflects the risk of a disruption in the supply of a specific raw material. It is based on the concentration of primary supply of raw materials from producing countries, considering their state of governance and trade aspects. Supply risk is defined by the European Commission as follows (EC, 2017):

$$SR = [((HHI_{WGI,t})_{GS} * IR/2 + (HHI_{WGI,t})_{EU \text{ sourcing}} * (1 - IR/2)) * (1 - EoL \text{ RIR}) * SI_{SR}]$$

where: HHI = the Herfindahl–Hirschman Index; WGI = the World Governance Indicator defined by the World Bank; t = trade agreements that can adjust the WGI; GS = global supply; EU sourcing = production inside the EU; EoL RIR = the end-of-life recycling input rate, which is the fraction of material that completes a full recycling cycle and replaces new raw materials in a fabrication process; IR = import reliance,

which equals (import - export)/(domestic production + import - export); SISR = a substitution index relative to the supply risk.

The HHI can be explained as follows: in a market with one producer, the HHI is equal to $100^2 = 10,000$. In a market with, for instance, three producers with 50%, 30% and 20% market shares, the HHI would be equal to $50^2 + 30^2 + 20^2 = 3,800$. The HHI is therefore a very important factor that controls criticality. In reality, there are many trade agreements that, to a variable degree, modify the calculation of the EI and SR parameters.

From the explanations given above, criticality in general can be reduced with the following measures:

Reduction of EI: Develop technology that needs less of a CRM and find substitutions for the CRM. However, even if this is done, the consumption of many CRMs is expected to increase by ten-fold, as explained in Section 1.

Reduction of SR: The production of a CRM must take place in an increased number of countries (the HHI is then reduced, preferentially in countries with good WGI standings). Recycling, and in particular a full recycling cycle (end-of-life recycling), must also be increased.

2.2.3 CRMA list update and Nordic framing

From a Nordic perspective, the overall bedrock still holds extensive potential for CSRMs beyond its known base-, ferrous- and noble-metal endowment, while several less traditional CSRMs remain comparatively under-characterised in terms of distribution and deposit style (Goodenough et al., 2016; Eilu et al., 2021; Jonsson et al., 2023).

*Table 2.1. Updated CRMA 2023 classification of critical and strategic raw materials considered in this report update. Strategic raw materials under the CRMA are indicated in **bold**. HREE = heavy rare earth elements, LREE = light rare earth elements, PGM = platinum group metals.*

Antimony (Sb)	Baryte (BaSO ₄)	Bauxite/alumina/aluminium	Beryllium (Be)
Bismuth (Bi)	Borates (BO ₃)	Cobalt (Co)	Coking coal
Copper (Cu)	Fluorspar (CaF ₂)	Gallium (Ga)	Germanium (Ge)
Hafnium (Hf)	Helium (He)	HREEs	Lithium (Li)
LREEs	Magnesium metal (Mg)	Manganese	Graphite (battery grade)
Nickel (Ni)	Niobium (Nb)	PGM	Phosphate rock (PO ₄)
Phosphorus (P)	Scandium (Sc)	Silicon metal (Si)	Strontium (Sr)
Tantalum (Ta)	Titanium metal (Ti)	Tungsten (W)	Vanadium (V)

The 2026 update therefore uses the EU 2023/CRMA classification as the operative reference frame rather than the earlier 2020 list: manganese is now treated as critical, battery-grade nickel is critical and strategic under the CRMA, although it falls below the 2023 JRC threshold, and chromium and molybdenum remain close to, but below, the present EU threshold; indium, although included in the 2021 report, is not in the EU 2023 CSRM list and is therefore not carried forward as a main commodity summary in this version (Eynard et al., 2020; Grohol & Veeh, 2023; EU, 2024a). This operative material set is listed in Table 2.1, while Figure 2.1 displays the corresponding commodities in the updated EU economic-importance and supply-risk space.

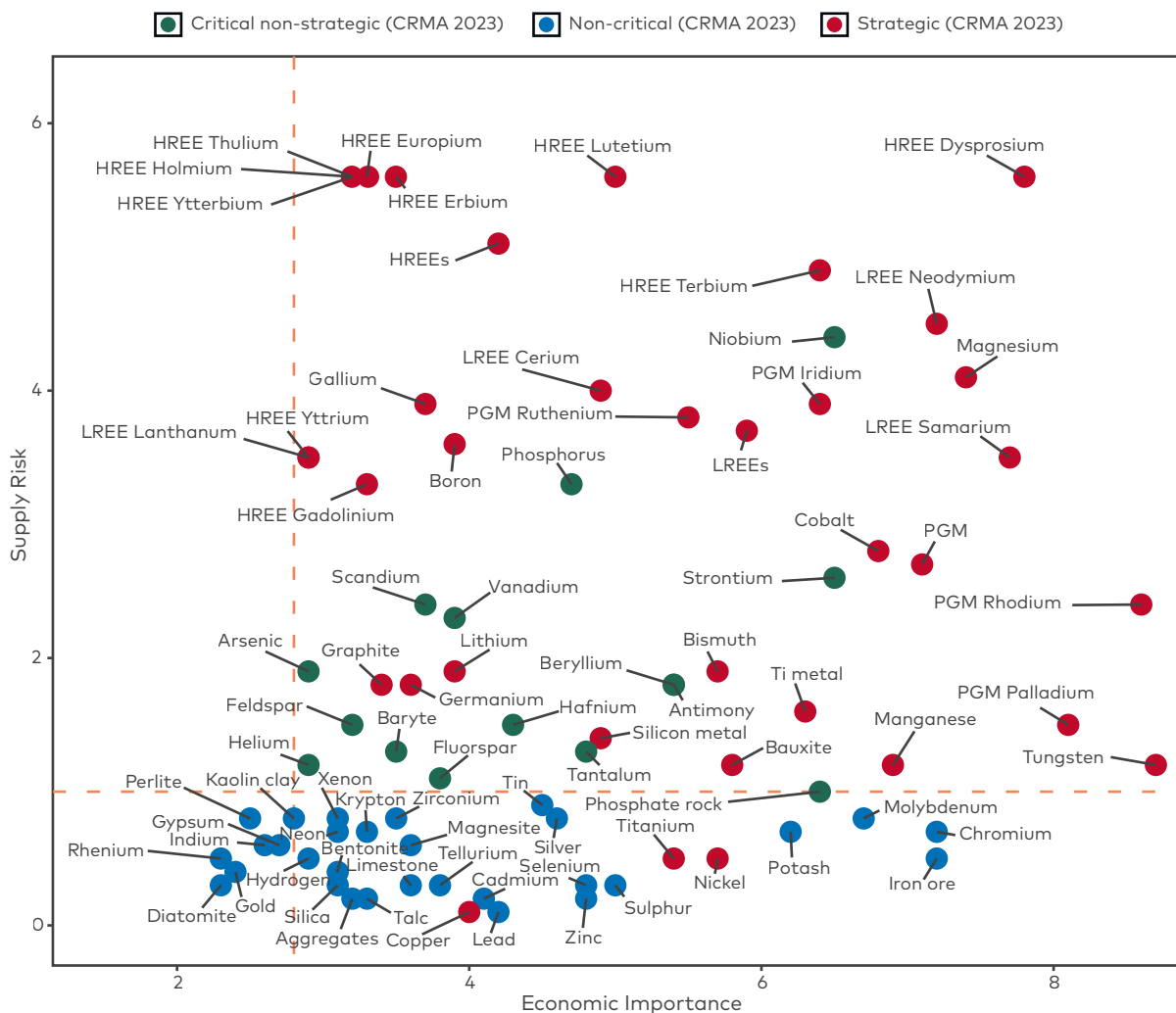


Figure 2.1. Plot of raw materials using the EU 2023 criticality-assessment data. The figure uses the 2023 Economic Importance (EI) and Supply Risk (SR) values and applies the EC rule of selecting the stage with the higher SR (extraction or processing). Materials are coloured as non-critical (blue), critical non-strategic (green) and strategic (red). For abbreviations, see Table 2.1. Data source: Grohol & Veeh (2023), Study on the Critical Raw Materials for the EU 2023.

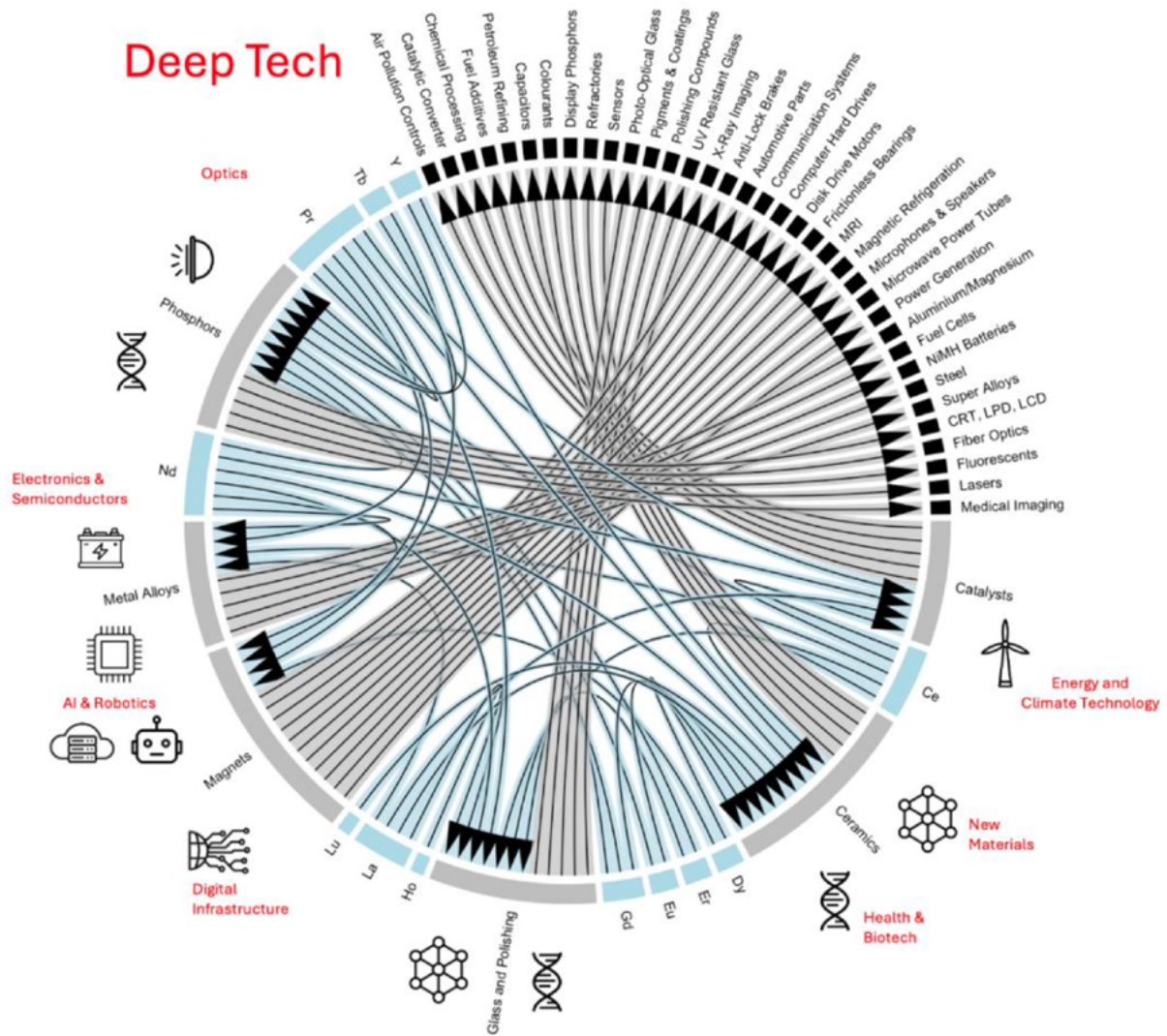


Figure 2.2. Rare earth element application network (chord-style representation), illustrating how individual REEs connect to a broad set of end uses across energy and climate technology, electronics and semiconductors, digital infrastructure, AI and robotics, optics, health, biotechnology and other science-based advanced technology domains labelled "Deep Tech" in the figure (VTT, 2019), emphasizing why the strategic importance of REEs extends well beyond magnets alone (co-developed, GTK-Technical Research Centre of Finland, VTT).

2.2.4 Strategic raw materials under the CRMA

Strategic materials are materials that are considered essential to a country's or region's national security and defence conditions. They can include natural-resource-based inputs such as oil, ores and industrial minerals, as well as processed materials, including aluminium, titanium, steel and other alloys, composite materials, plastics, polymers and ceramics. The concept of strategic raw materials is relatively new in Europe and is based on the metals being relevant for the green and digital transition and for space and defence applications. The following factors are taken into account to classify whether a raw material is of strategic importance: the extent to which strategic technologies utilise the raw material; the amount of a raw material used for manufacturing in the strategic technologies; expected global demand for relevant strategic technologies; and the relationship between expected resources, known exploitable reserves and the global consumption of a raw material. A raw material becomes more strategic when demand and production outpace supply capacity. Under the CRMA, strategic raw materials are linked to a set of measures intended to strengthen EU supply resilience across the value chain. By 2030, the EU aims to reach benchmarks of at least 10% of annual consumption from domestic extraction, 40% from processing, and 25% from recycling, while ensuring that no single third country supplies more than 65% of annual EU consumption of any strategic raw material at any relevant processing stage. The Act also supports Strategic Projects, national exploration programmes, and stronger monitoring and information sharing across the supply chain (Grohol & Veeh, 2023; EU, 2024a).

Further to these actions and constraints, recent EU policy reflects a bilateral strategy that links external sourcing diplomacy with internal industrial growth. Externally, the Union is expanding strategic raw-materials partnerships to diversify upstream access; by late 2025, the Commission reported fifteen partnerships with resource and transit countries (Feltrin et al., 2024; EC, 2025a). Internally, CRMA implementation combines financing support and time-bounded permitting (27 months for extraction; 15 months for processing, recycling and substitution) to accelerate projects across the full value chain (EU, 2024a; EC, 2025b). In the Nordic segment, designated projects illustrate this vertical logic: Sakatti (Finland), Keliber (Finland), Kolmisoppi (Finland), Nussir (Norway), LKAB's REE-P value-chain projects (Sweden) and Talga Natural Graphite ONE (Sweden) strengthen upstream extraction and primary production; ReeMAP (Sweden), Talga's planned anode-materials production in Sweden, Greenroc's planned AAM production in Norway and the Jervois Finland Cobalt Refinery Expansion reinforce midstream processing and refining; and Northcycle (Finland) together with the Fortum Battery Recycling Hydrometallurgical Plant (Finland) provide downstream circular recovery and secondary supply (Feltrin et al. 2024). Taken together, these projects demonstrate a policy-led attempt to connect exploration and mining, conversion/refining capacity and end-of-life material recovery within a less bureaucratic and more execution-oriented EU framework (EC, 2025b; EU, 2025a).

2.3 Geopolitics and the restructuring of MVCs

While green and digital transitions primarily reshape demand, geopolitics has become a dominant force in determining how mineral supply chains are organised and controlled. Under the earlier globalisation model, extraction, processing and manufacturing were largely organised according to cost efficiency and comparative advantage, which encouraged geographically dispersed and highly specialised value chains (IEA, 2025a). Recent assessments demonstrate that this architecture generated strong productivity gains but also high concentration risk at critical stages, especially refining and processing, where dependency on a small number of jurisdictions has become structurally significant for the EU and other advanced economies (Carrara et al., 2023; EU, 2024a; IEA, 2025a). New geoeconomic evidence indicates that major powers increasingly combine domestic industrial policy with alliance building, trade diversification, tariffs and targeted trade measures to reduce strategic exposure in mineral value chains (Guinea & Sharma, 2023; Ufimtseva et al., 2024; U.S. Trade Representative, 2024; EU, 2024b), while bilateral mineral diplomacy is also being used as a resilience instrument in wartime and post-conflict reconstruction contexts (Shaffer & Puig, 2025). Empirical work on mineral import dynamics further supports the structural linkage between clean-energy deployment and strategic raw-material dependence, reinforcing the

geopolitical salience of long-term access and trade security (Kilinc-Ata et al., 2023). In parallel, emerging scholarship demonstrates that geopolitical competition now extends beyond ore extraction to environmental liabilities and sovereignty questions associated with mine waste governance, broadening the definition of strategic control in resource value chains (Vivoda et al., 2025). Comparative regional cooperation literature also supports the underlying logic that external security pressures and corridor politics shape institutional responses and supply-route coordination over time (Rakhimov, 2010). As a result, mineral policy has shifted from pure market optimisation toward a security-informed model that combines diversification, strategic stockpiling and union-level project support, governance of key midstream nodes and the selective use of tariffs and trade-defence tools.

Copper, which is both critical and strategic under the CRMA, although below the 2023 JRC criticality threshold, provides a useful concrete example of this shift. The IEA's copper example illustrates that diversification is more advanced on the mining side than in refining. Planned mine projects are distributed across several jurisdictions, whereas refining remains more difficult to diversify, because capacity is concentrated in China and new or reactivated smelters require large capital investment, stable margins, energy, permitting and time. This means that additional mining options do not automatically remove downstream bottlenecks. This distinction between more geographically distributed mining options and downstream concentration is directly relevant to how diversification strategies should be interpreted in CSRM policy. At the same time, the broader CSRM pattern is not limited to copper alone: Figure 2.3 summarises top-three supplier concentration across selected raw materials globally to provide a rapid assessment of concentration and alternative key CSRM suppliers, with the underlying values listed in Appendix 4, Table B1, while Figure 2.4 provides a visual representation of mining-side diversification versus downstream concentration with the more detailed copper example from IEA (2025a).



REE-rich core from the Fen carbonatite, Norway. Photo: Henrik Schiellerup.

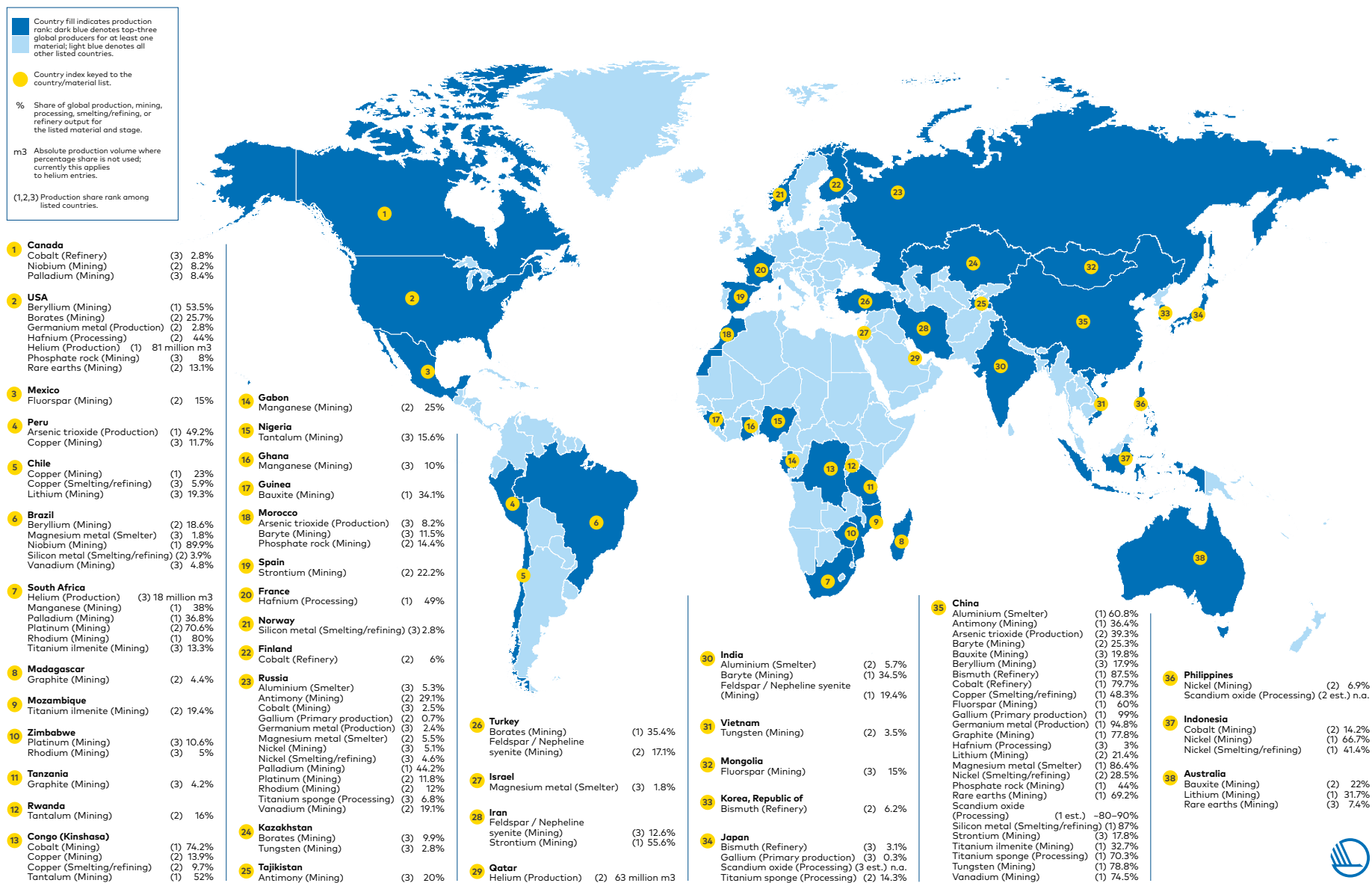


Figure 2.3. Top-3 country supplier map for selected critical raw materials, separating extraction and processing / refining where relevant, as a guide to trade diversification by showing whether dependence is near-monopolistic or whether credible second- and third-country supply options already exist. Data compiled from USGS Mineral Commodity Summaries 2026, BGS World Mineral Statistics, and the European Commission, Study on the Critical Raw Materials for the EU 2023. The underlying dataset is provided in Appendix 4, Table B1.

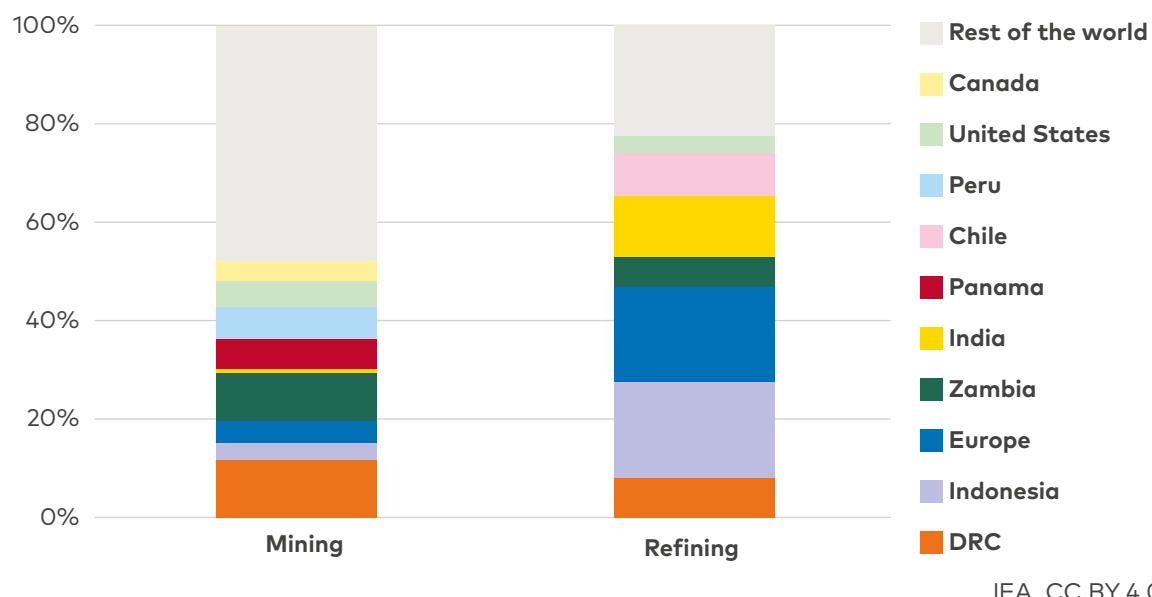


Figure 2.4. IEA illustration of the diversification potential in copper, showing that planned mining projects outside the largest supplier are more widely distributed than planned refining projects, where concentration remains much stronger. This serves as a useful model case for understanding the difference between upstream diversification and downstream concentration in strategic raw-material value chains. Adapted from: IEA, Global Critical Minerals Outlook 2025.

Diversification is only one aspect of a complex framework, consistent with the balance-of-power framing discussed by Ufimtseva et al. (2024). Some nations such as the US or regions such as the EU are pursuing a dual balancing strategy in critical raw materials: internal balancing through domestic production support and investment screening, and external balancing through alliance coordination to reduce reliance on China's extraction and processing (e.g., the US–Australia "critical minerals" partnership and the US–Ukraine strategic raw-materials partnership; USDOL, 2019; Guinea & Sharma, 2023; Shaffer & Puig, 2025). Foreign investment screening aims to prevent adversarial or high-risk actors from gaining control over upstream reserves, midstream refining nodes, logistics infrastructure or sensitive technology and data. By limiting control transfer rather than trade itself, screening is designed to preserve operational sovereignty and reduce the risk of supply disruptions or geopolitical escalation (Ufimtseva et al., 2024).

Recent Arctic developments illustrate how mineral supply, infrastructure and strategic coordination are becoming more closely linked. Investment screening now increasingly extends to ownership of major upstream assets, while transport and access are receiving greater policy attention as Arctic routes become more seasonally accessible. Reuters reported that a US spending bill earmarked USD 8.6 billion for Coast Guard icebreakers, while Russia–China oil shipments through the Northern Sea Route rose by 25% in 2024 to a record volume (Reuters, 2025b; CHNL, 2025). National Oceanic and Atmospheric Administration (NOAA) observations further indicate that continued sea-ice decline is increasing seasonal marine accessibility, with potential implications for logistics, infrastructure planning and corridor governance across the wider Arctic region (NOAA, 2025). Taken together, these developments demonstrate why geopolitics now influences mineral value chains at multiple stages, from project ownership and financing to refining, transport and recycling (Carrara et al., 2023; IEA, 2025a; IRTC, 2026).

To date, the policy response has dominantly been a selective reconfiguration rather than a full deglobalisation: diversification, friend-shoring (identification of politically trusted and strategically aligned partners) and regional processing are being prioritised alongside cost efficiency, while ownership and control of strategic nodes are actively managed through commercial partnerships, strategic-project frameworks and investment screening (EU, 2024a; Ufimtseva et al., 2024; EC, 2025a; EC, 2025b). Under high geopo-

litical stress, value chains may become partially fragmented, and historical patterns of state intervention suggest that control over processing capacity and export routes can function as leverage over supply and influences pricing. In this context, securing access to critical stages of the value chain becomes as important as securing geological resources themselves. The EU energy case is illustrative: despite a sharp reduction in dependence since 2022, Russian gas imports persisted in 2025, even as phase-out regulation advanced toward end-2027 deadlines (EC, 2025c). By analogy, CSRM policy is less about eliminating external dependence altogether and more about reducing single-country concentration to a strategically tolerable level.

Beyond trade, ownership and processing security, geopolitics also operates through defence-industrial requirements. Materials embedded in military platforms such as aircraft, naval vessels, armoured vehicles, missile systems, munitions, sensors, electronics and aerospace systems acquire an additional layer of strategic sensitivity, because supply disruption can directly affect defence readiness and industrial resilience. This balance-of-power logic can be condensed as presented in Table 2.2, which compares how the US and EU combine internal capability building with external de-risking and partnership strategies.

Table 2.2. Balance-of-power perspective on US and EU critical mineral strategies in geopolitical rivalry (Ufimtseva et al., 2024; EU, 2024a; Reuters, 2025a; EU, 2025a; EC, 2025b; Reuters, 2025c; EC, 2025a).

Actor	Strategic orientation	Strengthen own/allied capabilities	Weaken rival capabilities (primarily China exposure)
US	Internal balancing: domestic industrial strategy	Support domestic extraction, processing, refining and manufacturing via public incentives, defence-linked procurement and project financing.	Investment screening and trade/security tools to limit high-risk foreign control in critical-mineral assets and midstream nodes.
US	External balancing: alliance building	Build supply partnerships (trusted-partner sourcing, co-investment and offtake agreements) with allied countries.	Promote policy alignment among allies (investment screening/export controls/risk filters) to reduce rival leverage across shared supply chains.
EU	Internal balancing: strategic autonomy and verticalization	CRMA strategic projects, faster permitting timelines and support for extraction, refining, processing and recycling inside the Union; scaling circular and secondary supply, and defence applications.	Reduce structural dependency through internal diversification mandates, resilience benchmarks and governance of critical stages with high concentration risk.
EU	External balancing: strategic partnerships and trade diversification	Expand CSRM strategic partnerships with resource and transit countries; combine diplomacy, financing and industrial cooperation for stable inflows.	Lower single-supplier exposure through de-risking and diversified sourcing corridors rather than full decoupling (Guinea & Sharma, 2023; EU, 2024a).
EU	Comparative governance style versus US	Stronger regulatory-coordination model (single-market instruments, sustainability and traceability rules, coordinated strategic-project designation).	Less overt containment framing than the US; greater emphasis on dependency reduction, standards power and resilient market architecture.

In current CSRM policy, decentralisation refers to reducing the concentration risk by redistributing critical stages of the value chain across multiple jurisdictions rather than relying predominantly on China-centred extraction and midstream capacity (Carrara et al., 2023; EU, 2024a; IEA, 2025a). Geopolitically driven decentralisation is often framed in terms of cost, but its implications extend further: regional sourcing of mining, processing, refining and recycling in jurisdictions with stronger regulatory capacity can improve auditability, environmental oversight and social accountability, while greater regional control over midstream stages can strengthen traceability and reduce governance blind spots in long and often opaque supply networks (EU, 2024a; Feltrin et al., 2024; Liu et al., 2024; IEA, 2025a). It also changes the geography of energy and resource use. Shorter transport chains can lower fuel use and related emissions, but smaller or less specialised plants may need more energy to produce each tonne of material. For this reason, moving more of the processing stage of the value chain closer to Europe does not automatically reduce the overall environmental footprint if demand grows faster than improvements in efficiency, recycling and the management of lower-grade projects (Valenta et al., 2019; Lebre et al., 2020; IEA, 2025a). In this context, the Carbon Border Adjustment Mechanism (CBAM) is directly relevant, because it changes the carbon-adjusted cost of emissions-intensive intermediates entering the EU, reducing the advantage of high-emission production routes and strengthening incentives for lower-carbon regional sourcing where clean electricity and stricter governance are available (EU, 2023a; EU, 2024a). Decentralisation and friend-shoring should therefore be seen as defensive instruments offering an opportunity to increase transparency and sustainability of the mineral value chains.

2.4 Defence applications and strategic raw materials

The strategic importance of raw materials is not limited to the green and digital transitions. As demonstrated by Girardi et al. (2023), a substantial set of minerals and metals is also directly utilised in European defence manufacturing, where supply disruption has immediate implications for military readiness. Their study identified 40 critical and "soon-to-be" critical raw materials relevant to European defence applications and assessed them through a defence-specific risk framework that differs in important ways from the standard EU criticality methodology. In this framework, risk depends not only on how concentrated or geopolitically exposed the supply is, but also on how frequently a material is used across defence applications. This produces a defence-oriented ranking of materials that does not always match their position in energy-transition or digital-industry criticality assessments (Girardi et al., 2023), and it is included in this revised 2026 report to facilitate comparative analysis in the CSRM commodity summaries provided in Section 3.

One of the most important findings is that defence criticality is domain specific. The air domain is the most materially complex and risk-exposed, using all the materials considered in the study and relying heavily on aluminium, natural graphite, copper and titanium across aircraft, helicopters, missiles and associated electronics. Beyond this high-use core, air systems also draw on a broad tail of specialised electronics, sensor, propulsion and guidance elements, including cobalt, platinum, indium, vanadium, tungsten, tantalum, gallium, molybdenum, chromium, nickel, cadmium, yttrium, neodymium, germanium and beryllium. This breadth reflects the fact that air platforms combine lightweight structures, high-temperature engines, avionics, seekers, radomes, communications, guidance and missile subsystems in one tightly integrated system. The sea domain also carries high exposure, especially in vessels, submarines, propulsion systems, radars and weapons systems, with aluminium, copper, nickel, natural graphite and titanium forming a strong recurring set and cobalt, tungsten, chromium, molybdenum, platinum and vanadium adding a second layer linked to alloys, propulsion, corrosion resistance and sensor systems. Compared with air, the sea domain is less broad in specialised sensor and magnet elements, but it remains highly exposed through hulls, propulsion shafts, propellers, motors, radar, sonar and naval weapons. The land domain uses slightly fewer materials than the air one, but still depends on a broad mix that includes titanium, vanadium, molybdenum, chromium, nickel, copper and natural graphite in structural, mobility and weapons applications, together with a strong optoelectronic, navigation and communications signature expressed through beryllium, gallium, germanium, indium, tantalum, cadmium, yttrium and neo-

dymium in armoured vehicles, artillery, ammunition, communications systems and navigation equipment (Girardi et al., 2023). These differences reflect the structure of the platforms themselves: air systems combine the widest elemental diversity in one package, sea systems concentrate exposure in a somewhat narrower but very consequential marine-alloy and propulsion set, and land systems sit between the two, with a mixed vehicle-and-electronics profile. This contrast is summarised in Figure 2.5, in which the lettered matrices correspond to air, sea and land applications.

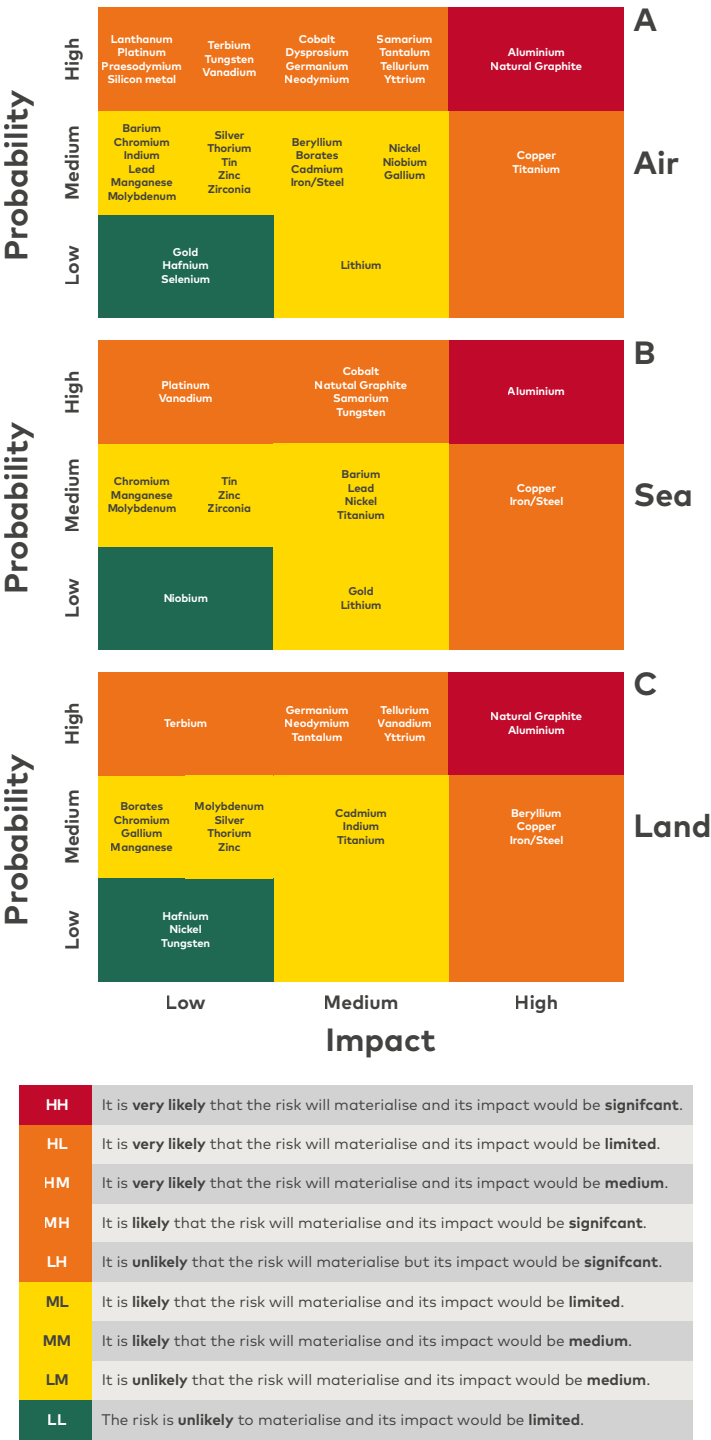


Figure 2.5. Defence-domain risk matrices compiled from Girardi et al. (2023): A = Air, B = Sea and C = Land. Here, Probability denotes the likelihood of supply disruption, while Impact denotes the operational significance of a material for the relevant defence domain. The different matrix patterns reflect differences in platform architecture, subsystem complexity and material-intensity profiles across domains, so disruption probability and impact do not distribute uniformly between air, sea and land systems. Modified after Girardi et al. (2023).

The defence ranking itself is instructive. Girardi et al. (2023) identify aluminium and natural graphite as very high-risk materials, because they combine high frequency of use with high probability of disruption. A second tier of high-risk materials includes several rare earth elements and associated magnet materials, as well as cobalt, germanium, silicon metal, tantalum, tellurium, tungsten and vanadium. By contrast, some materials often treated as strategically important in wider industrial debates appear as medium or low risk in defence, because their direct use is narrower, more substitutable or sourced from more diversified supplier bases. The report indicates that there is no single universal hierarchy of critical raw materials: the importance of a commodity depends on the sectoral system being considered.

The Dutch naval benchmark helps make this logic concrete at the platform level. In their 2024 Hague Centre for Strategic Studies (HCSS)/PricewaterhouseCoopers (PwC) study of the Air Defence & Command Frigate, abbreviated as LCF from the Dutch *Luchtverdedigings- en Commandofregat*, Patrahau and Girardi identify 29 raw materials likely to be used across the vessel's systems, of which 21 are on the EU's 2023 critical or strategic lists. The case study is important, because it demonstrates how a maritime platform with relatively strong EU/North Atlantic Treaty Organization (NATO) tier-1 supplier visibility still becomes vulnerable deeper in the chain: beyond tier 1, raw-material dependencies become much more difficult to track, while radar, communications, command systems, weapons systems and semiconductor-dependent subsystems retain exposure to gallium, germanium, silicon, palladium and a wider set of CSRM-intensive inputs (Patrahau & Girardi, 2024). In this sense, the naval example confirms that defence raw-material risk is not an abstract classification issue, but a procurement and readiness problem that emerges inside concrete European platforms.

Estimates used in European Commission Joint Research Centre (JRC) analysis further reinforce the magnitude of this issue. In the foresight work underlying the EU strategic-technologies assessment, current NATO fleets were estimated at roughly 20,700 active combat aircraft and 15,000 battle tanks, together representing around 81,000 t of titanium; the same assessment also reports approximately 415 kg of REEs used in an F-35-class aircraft (Figure 2.6) (Carrara et al., 2023). These numbers do not imply that defence outweighs civilian sectors by aggregate tonnage, but they do show why defence demand has outsized strategic importance relative to mass: comparatively limited quantities of titanium, magnet rare earth elements, semiconductors and specialty metals can still become acute bottlenecks for the manufacturing of aircraft, naval systems, sensors, missiles and systems for command, control, communications, computers, intelligence, surveillance and reconnaissance, known as C4ISR. For a broader material breakdown of military equipment and alloy requirements in the European defence industry, see also Pavel & Tzimas (2016).

CSRM like titanium and aluminium are essential for air defence.
Photo: Alva Bruun



Demand for strategic materials in NATO fleets

Aircraft and battle tanks, thousand tonnes

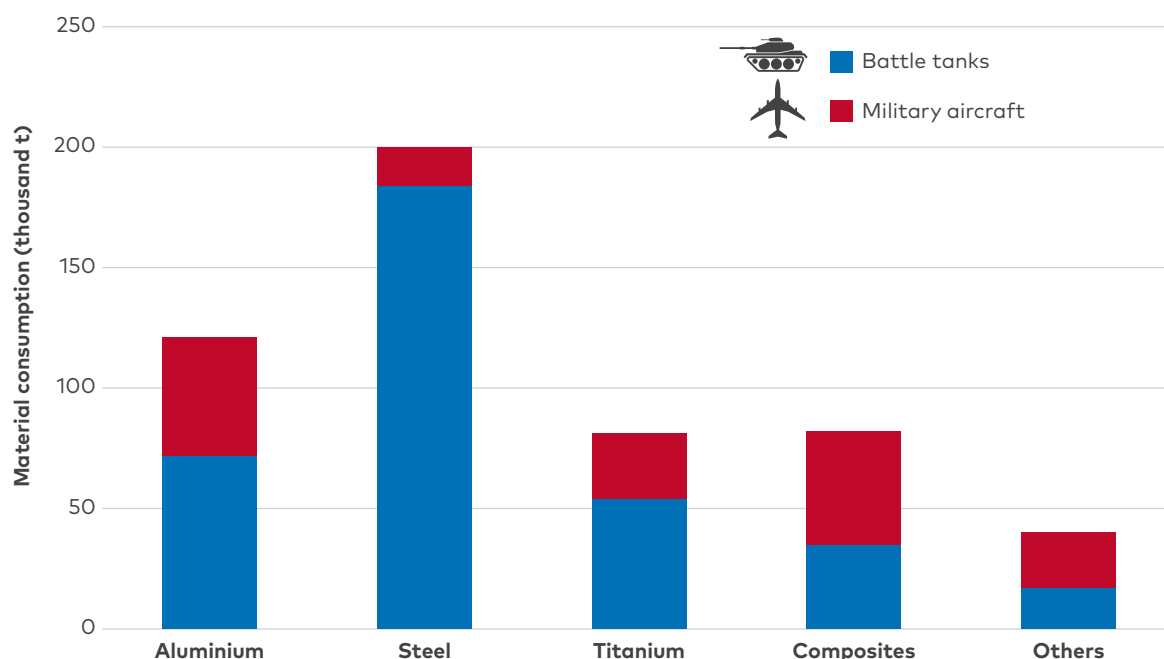


Figure 2.6. JRC estimate of structural-material demand present in current NATO fleets of aircraft and battle tanks, illustrating the particularly large roles of steel, aluminium, titanium and composites in military-platform mass requirements. Adapted from: Carrara et al. (2023), data on JRC analysis derived from Statista (2022a), Statista (2022b), and KPMG (2020).

Taken together, the EU/JRC supply-risk classification and the defence Probability × Impact classification form a useful comparison framework (see Section 3 tables). A first overlap group includes raw materials that are strongly flagged in both systems: natural graphite, Co, REEs, W, Ta, Si metal, Ti metal and PGMs all combine a criticality status or strategic concern in the EU framework with high or very high risk defence relevance (Carrara et al., 2023; Girardi et al., 2023; EU, 2024a). For this first group, recent geopolitics actions demonstrate why the overlap matters: restrictions on raw materials and processed inputs not only transmit to price volatility but can directly constrain defence-industrial availability when affected materials are used in magnets, batteries, shielding, electronics and aerospace systems. Reuters and official notices document this clearly through Chinese controls on graphite-related products, REE-related exports and tungsten-related items, alongside restrictions affecting gallium, germanium, antimony and bismuth (Reuters, 2025c; Reuters, 2025d; Reuters, 2025e; MOFCOM & GACC, 2025). A second group includes metals such as Cu and battery-grade Ni, which fall below the traditional JRC criticality threshold but are critical and strategic under the CRMA and remain highly important for defence manufacturing because of their broad functional use across electronics, alloys, motors and platforms (Girardi et al., 2023; EU, 2024a). A third group includes materials that are classified as critical in EU screening but show lower or less explicit defence salience, including Sb, As, baryte / Ba, Bi, feldspar, fluor spar, Hf, Li, Mn, Nb, phosphorus (P), Sc and Sr. For these materials, policy concern is driven more by industrial concentration, processing dependence, or clean-technology demand than by direct military exposure. This comparison helps distinguish materials that are simultaneously exposed in civil and defence systems from those whose strategic relevance is more sector-specific, adding an additional layer of prioritisation.

This is also where recent EU policy gives defence-driven strategic importance a harder institutional form. The CRMA formally placed strategic raw materials alongside critical raw materials in the twin-transition context (EU, 2024a), but EU defence policy now pushes in the same direction through instruments explicitly linked to capability gaps, ammunition production, joint procurement and defence-industrial readiness. Regulation (EU) 2023/1525 on supporting ammunition production under the Act in Support of Ammunition Production (ASAP) was designed to expand ammunition and missile manufacturing capacity inside the Union, while the 2025 White Paper for European Defence – Readiness 2030 and the Security Action for Europe (SAFE) instrument move further by linking defence investment, joint procurement and the reduction of strategic dependencies across areas such as ammunition and missiles, air and missile defence, maritime surface and underwater capabilities, drones, AI, electronic warfare and critical infrastructure protection (EU, 2023b; EU, 2025b). In practice, this means that the strategic nature of some materials is no longer merely inferred from geopolitical debate: it is being formalised through EU defence legislation and funding frameworks. Seen through the combined lens of the twin transition and defence readiness, strategic importance therefore becomes nearly as important as classical criticality, because materials with moderate criticality scores can still acquire high policy relevance once they are fundamental to priority defence capabilities and accelerated procurement programmes.

2.5 Nordic positioning in a geopolitically constrained world

Within this macro context, the Nordic countries occupy a distinctive position, because several reinforcing factors converge in one region: comparatively strong geological favourability for many EU critical and strategic raw materials (both primary and secondary), large and geologically diverse land and bedrock domains, an advanced mining and extraction sector, high institutional credibility and the potential to expand low-carbon-compatible extraction, processing and refining within stable policy frameworks (Eilu et al., 2021; Jonsson et al., 2023; Feltrin et al., 2024; EU, 2024a). What emerges from Sections 2.1–2.4 is that the Nordic strategic case is no longer driven by the twin transition alone. Electrification, digitalisation and AI-related infrastructure continue to accelerate demand, while geopolitics is reshaping trade routes, ownership structures and processing control, and defence adds a further layer of strategic urgency for several overlapping materials. At the same time, supply chains are increasingly shaped by ESG conditions, including growing requirements for environmental and human rights due diligence, which emphasise traceability, risk management and downstream accountability across mineral value chains (EU, 2024a; Ivic et al., 2021). In combination, these forces strengthen the case for Nordic supply chains connecting geological resources with traceable midstream capacity under comparatively strong governance, provided that ESG performance and carbon-reduction outcomes remain binding conditions for project advancement (Carrara et al., 2023; EU, 2023a; Girardi et al., 2023; Feltrin et al., 2024; EU, 2024a). For the Nordic countries, the key analytical question is therefore not only the quantity of known resources, but how far resource potential can be translated into resilient, low-carbon and strategically relevant value-chain capacity. Mapping resources, processing hubs, ownership structures and trade linkages is thus an operational requirement for prioritising investment and planning (Carrara et al., 2023; IRTC, 2026).

3 Production and resources of critical and strategic raw materials in the Nordic countries

In this section, we describe mine and refinery/smelter production and known and assumed resources of critical and strategic raw materials (CSRMs) in the Nordic countries. The section comprises individual CSRM commodity summary tables together with maps of known deposits, and mineral/metal-potential domains. The commodity summary tables (Sections 3.1.1–3.1.31) include global production and resources, Nordic production and resources, current and expected end uses, and data sources, while the corresponding maps are presented as Figures 3.1.1–3.1.28, where relevant, according to data availability. In this 2026 update, copper and battery-grade nickel are explicitly included, because they are listed as critical and strategic raw materials under the Critical Raw Materials Act (CRMA), while manganese is included as critical in the updated EU framework, with battery-grade manganese also classified as strategic under the CRMA (Carrara et al., 2023; EU, 2024a).

In these maps, red symbols identify active operations and green symbols identify closed operations where the mapped commodity is or was directly extracted or recovered; grey symbols identify active or closed sites where the operation status refers to another main commodity, and the mapped CSRM is only present as an unrecovered side stream, tailings component or other secondary/residual material.

Nordic information is primarily derived from national mineral-deposit databases and harmonised Nordic updates after Eilu et al. (2021), complemented by international statistics and market reporting; additional background tables are provided in Appendix 2, Tables A1–A5. Each commodity is covered in a dedicated subsection, with critical and strategic materials grouped under 3.1 and the non-critical material note retained under 3.2.

3.1 Critical and strategic raw materials

3.1.1 Antimony (Sb)

Antimony is a small-volume but strategically exposed metal used in flame-retardant compounds, lead-acid battery grids, lead alloys, semiconductors and specialty ammunition. It is commonly recovered from stibnite ores and as a by-product from polymetallic deposits, so supply expansion is constrained by both deposit availability and processing capacity. A highly concentrated global supply base is present, with China, Tajikistan and Russia prominent, while the EU has limited domestic production. For the Nordic region, the key issue is therefore not only resource occurrence but whether Sb-bearing polymetallic deposits and residues can support traceable by-product recovery across the value chain (Carrara et al., 2023; EU, 2024a; USGS, 2026).

Commodity	Antimony (Sb)	Data source
Uses of the commodity	<u>Main uses:</u> Flame retardants (43%), lead-acid batteries (32%). <u>Minor uses:</u> Lead alloys (14%), plastics (use as a catalyst in the production of PET and for heat stabilisers) (6%), glass and ceramics (5%). Pigments, lubricants and ammunition. <u>Defence uses:</u> Ammunition and selected military alloy applications; wider defence use is limited in the current source set. <u>Future uses:</u> Semiconductor industry. A cheaper alternative to indium–tin oxide compounds for LCD screens. Continues to be important, possibly increasing, in flame retardants. Use in car batteries may decrease if lead battery use decreases.	Latunussa et al. (2020)
Resources and potential in the Nordic countries	<u>Known resources (total):</u> 29,340 t Sb. <u>Finland:</u> Known resources: Orogenic gold–antimony deposits in western Finland contain 2,555 t Sb. <u>Greenland:</u> Known resources: 3,780 t Sb. Several Sb occurrences in central East Greenland associated with tungsten. <u>Norway:</u> Several silver and sulphide occurrences in the Caledonides are locally enriched in antimony, but without quantitative data, as yet. <u>Sweden:</u> Known resources: 23,005 t Sb. Additional potential exists in the Skellefte district and Bergslagen.	Lauri et al. (2018); Eilu et al. (2021); Eilu et al. (2022); Rosa et al. (2023)
Global production	110,000 t (mine production) (2025)	USGS (2026)
Main producing countries	China 36%, Russia 29%, Tajikistan 20%, Bolivia 4.5%, Myanmar (Burma) 4% (mine production)	USGS (2026)
Nordic concentrator, refinery and smelter production	No mine production (2025)	USGS (2026); Awe (2010)
Geopolitical and defence risk	EU/JRC view: critical in the current EU framework, with SR 1.8 at the extraction stage. Girardi et al. do not classify antimony as a strategic raw material for defence; its geopolitical role is instead evident through stockpiling and industrial-base measures, including USGS-reported National Defense Stockpile acquisition planning and 2025 US DPA funding for military-grade antimony trisulfide, against a concentrated global supply base.	Carrara et al. (2023), EU (2024a), Girardi et al. (2023), Reuters (2025e)



Figure 3.1.1. Locations of deposits with known antimony resources and areas with known or assumed potential for additional antimony resources in the Nordic countries.

3.1.2 Arsenic (As)

Arsenic is mainly relevant as a by-product and processing issue rather than as a stand-alone mining target. It occurs in Cu, Pb, Zn, Au and Sn systems and is recovered or managed through smelter streams, commonly as arsenic trioxide. Uses are concentrated on compound semiconductors, glass, wood-preservative legacy applications, pesticides and specialty alloys, but toxicity and environmental controls strongly condition marketability. According to a mineral commodity summary from the USGS (MCS, 2026), production and trade remain limited and geographically concentrated. In Nordic resource assessments, arsenic is therefore prominent both as a potential minor commodity and as a deleterious element affecting ore processing, permitting and waste management (SCRREEN2, 2023; Carrara et al., 2023; USGS, 2026).

Commodity	Arsenic (As)	Data source
Uses of the commodity	<u>Main uses:</u> <i>GaAs and InGaAs are used in integrated circuits and semiconductors for various electronic applications such as telecommunications, photovoltaics and shortwave infrared technologies. The main use of arsenic in the EU is in zinc production, where it is used to remove impurities during electrowinning. It is also used as a decolouration agent in special glass production. Arsenic is used globally in herbicides, insecticides and wood preservatives, including chromated copper arsenate (CCA) for pressure-treated lumber, although such usage is restricted in the EU for consumer and environmental protection.</i> <u>Minor uses:</u> <i>Chemicals and alloys.</i> <u>Defence uses:</u> <i>Semiconductor and electro-optical materials used in specialised electronics, infrared and sensing applications, military radar.</i> <u>Future uses:</u> <i>Increased use in semiconductors, photovoltaics and other GaAs devices.</i>	SCRREEN2 (2023), USGS (2026)
Resources and potential in the Nordic countries	<i>Known resources (total): 448,520 t As.</i> <i>Finland: 2,400 t As in the Laivakangas Au area (Vesiperä); in addition, As is a minor potential commodity in several VMS and orogenic gold deposits and occurrences.</i> <i>Greenland: Resource potential unknown, considered limited. Occurrences of hydrothermal As mineralisation reported from central East Greenland Caledonides.</i> <i>Norway: Arsenic was mined in the late 19th and early 20th century and is present in several gold, cobalt and base metal deposits in Norway, including the Helgeland Nappe Complex. However, quantitative data on tonnages and grades are limited.</i> <i>Sweden: 446,120 t. Arsenic is present as a component (potential byproduct) in several gold and base metal deposits in Sweden, including the Skellefte district and Bergslagen. The closed Boliden mine was a very large previous producer.</i>	Stendal & Ghisler (1984), Rosa et al. (2023), GTK (2025), SGU (2026)
Global production	<i>61,000 t (arsenic trioxide)</i>	USGS (2026)
Main producing countries	<i>Peru 49%, China 39%, Morocco 8% (arsenic trioxide).</i>	USGS (2026)
Nordic concentrator, refinery and smelter production	<i>No Nordic production</i>	SCRREEN3 (2025)
Geopolitical and defence risk	<i>EU/JRC view: critical in the current EU framework, with SR 1.9 at the processing stage. Girardi et al. do not classify arsenic as a strategic raw material for defence; its geopolitical relevance is mainly through compound-semiconductor dependency and import exposure, because USGS notes defence-related GaAs integrated circuits have no effective substitute in many applications, and arsenic supply is tied to concentrated metal and trioxide trade flows.</i>	Carrara et al. (2023), EU (2024a), Girardi et al. (2023)



Figure 3.1.2. Locations of deposits with known arsenic resources and areas with known or assumed potential for arsenic resources in the Nordic countries.

3.1.3 Baryte (barium sulphate, BaSO₄)

Baryte is an industrial mineral whose high density, chemical inertness and whiteness make it important for oil and gas drilling muds, fillers, paints, plastics, rubber and radiation-shielding applications. Demand is therefore tied both to hydrocarbon drilling cycles and to industrial end uses. MCS 2026 identifies large global resources, but production is concentrated in a limited suite of countries, notably China, India, Morocco and Kazakhstan. Nordic baryte occurrences are strategically relevant where they can supply high-specific-gravity material with low impurity levels or where baryte occurs with base-metal systems, because quality and logistics often determine whether such a resource is economically feasible (Latunussa et al., 2020; Carrara et al., 2023; USGS, 2026).

Commodity	Baryte (barium sulphate, BaSO ₄)	Data source
Uses of the commodity	<u>Main uses:</u> <i>Weighting agent in drilling muds (60%), fillers (30%).</i> <u>Minor uses:</u> <i>Chemicals (9%), radiation shielding concrete, glass, bricks, tiles and other ceramics, and electronics and capacitors.</i> <u>Defence uses:</u> <i>Selected uses in electronics, armaments and propulsion-related systems at lower frequency than high-risk defence materials.</i> <u>Future uses:</u> <i>Demand remains strongly linked to oil and gas exploration and exploitation, and is thus expected to decrease in the long term. Increasing demand in the construction, electronics and automotive industries.</i>	Latunussa et al. (2020), USGS (2026)
Resources and potential in the Nordic countries	<u>Known resources (total):</u> <i>480,000 t baryte.</i> <u>Finland:</u> <i>Baryte has previously been produced from the Pyhäsalmi Cu–Zn mine. The surrounding area also has potential for baryte in VMS deposits.</i> <u>Greenland:</u> <i>Known resources: 480,000 t baryte. The 'Zebra Klint', Bredehorn, has overall resources probably in the order of several million tons.</i> <u>Iceland:</u> <i>Possible potential for deposits.</i> <u>Norway:</u> <i>Baryte is common in Pb–Zn VMS (Mofjellet) and Ag vein deposits (Bamble, Kongsberg) and the iron-rich parts of the Fen carbonatite. Former test mining at the hydrothermal Heskestad deposit in southernmost Norway.</i> <u>Sweden:</u> <i>Several deposits are known to contain baryte. The largest of these is the giant Aitik Cu–Au deposit. The others are small.</i>	Lauri et al. (2018); Eilu et al. (2022), Rosa et al. (2023)
Global production	<i>8.7 Mt baryte</i>	USGS (2026)
Main producing countries	<i>India 34.5%, China 25.3%, Morocco 11.5%, Kazakhstan 8%, Mexico 3.4%, Iran 3.4%.</i>	USGS (2026)
Nordic concentrator, refinery and smelter production	<i>None</i>	Idoine et al. (2022)
Geopolitical and defence risk	<i>EU/JRC view: baryte is represented through barium in the EU assessment, where it is critical with SR 1.3 at the extraction stage. Defence view: Medium risk at the barium level. Defence use is recognised, but the frequency of application and disruption exposure are lower than for high-risk classes.</i>	Carrara et al. (2023), EU (2024a), Girardi et al. (2023)

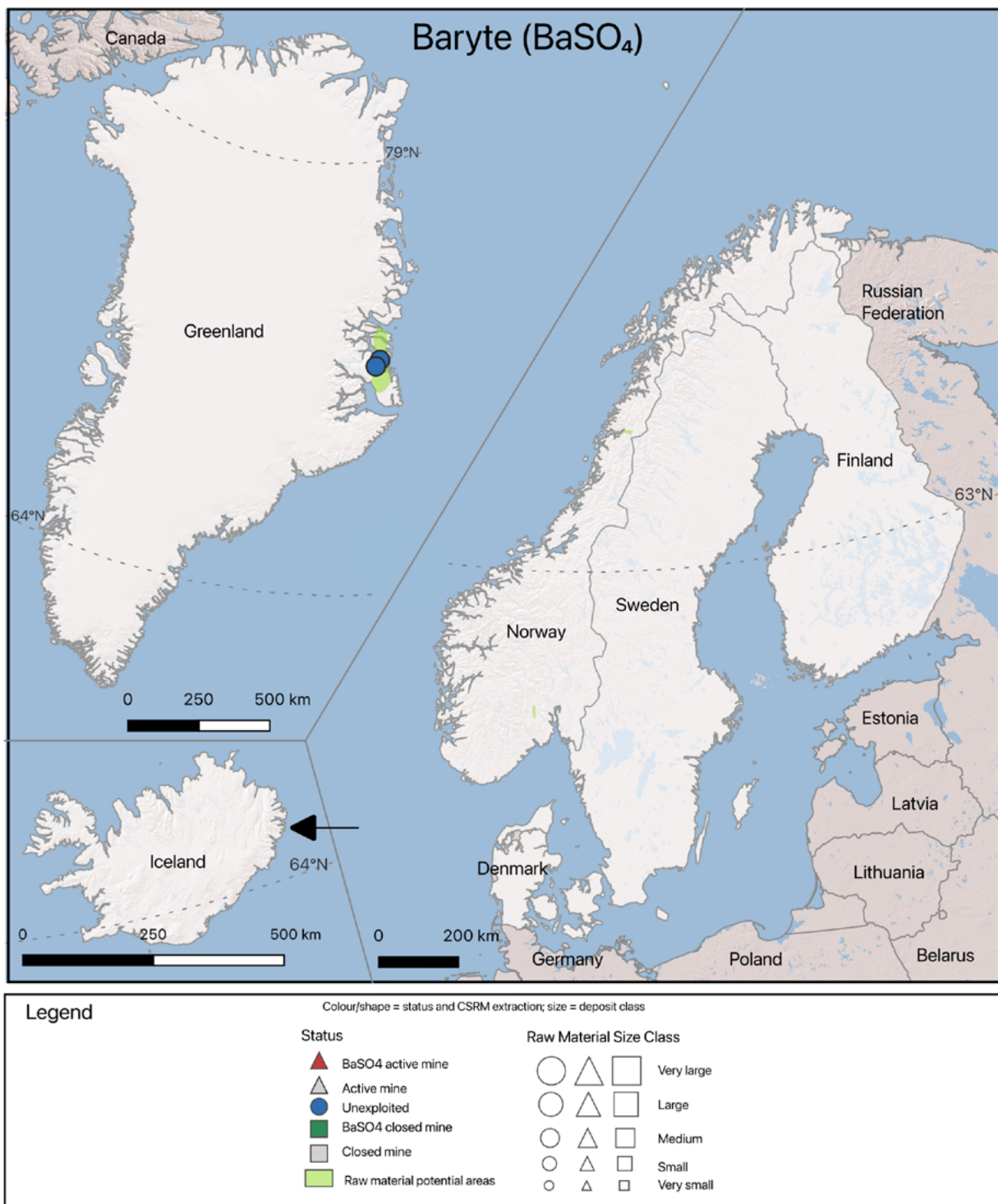


Figure 3.1.3. Locations of deposits with known baryte resources and areas with known or assumed potential for additional baryte resources in the Nordic countries. The associated resource-potential area in Iceland is assumed to be very small and is hence indicated by a black arrow.

3.1.4 Bauxite, alumina and aluminium (Al)

Bauxite, alumina and aluminium form a linked mineral-to-metal value chain. Bauxite is the main commercial source of alumina and aluminium, and it is also the main upstream source for some gallium recovery. Bauxite is mainly refined by the Bayer process to produce alumina, which is then reduced to aluminium metal by energy-intensive electrolytic smelting. Aluminium is light, corrosion resistant, electrically and thermally conductive, workable and highly recyclable. In the Nordic region, the main relevance is aluminium smelting, processing, recycling and possible alternative alumina-bearing feedstocks, especially in countries with low-carbon electricity (SCRREEN3, 2025; USGS, 2026).

Commodity	Bauxite, Alumina and Aluminium (Al)	Data source
Uses of the commodity	<i>Main uses: Aluminium is used in building and construction, automotive applications, transport equipment, packaging, high-technology engineering, consumer durables and electrical applications.</i> <i>Minor uses: Non-metallurgical bauxite and alumina are used in refractories, abrasives, high-alumina cement, aluminium chemicals, ceramics and related industrial products.</i> <i>Defence uses: Aluminium is a high exposure defence material because it is widely used in lightweight structural alloys, aircraft, naval and land machinery, military transport, electrical systems and equipment housings.</i> <i>Future uses: Demand is linked to lightweight transport, grid expansion, renewable-energy infrastructure, electric vehicles, batteries, solar technologies, and increased recycling.</i>	SCRREEN3 (2025); Carrara et al. (2023); Girardi et al. (2023)
Resources and potential in the Nordic countries	<i>No Nordic bauxite mine production is known. The Nordic relevance is mainly midstream and secondary resource based, through aluminium smelting, recycling, dross management and imported alumina processing, especially in Iceland, Norway and Sweden. Iceland is particularly important as a renewable-energy-based aluminium processing hub, with smelters at Reydarfjörður, Grundartangi and Straumsvík.</i>	SCRREEN3 (2025); USGS (2026); Feltrin et al. (2024)
Global production	<i>Bauxite mine production: 440 Mt in 2025. Alumina refinery production: 150 Mt in 2025. Aluminium smelter production: 74.0 Mt in 2025. SCRREEN3 reports 381.7 Mt bauxite production and 67.1 Mt aluminium production as 2019–2023 averages.</i>	USGS (2026); SCRREEN3 (2025)
Main producing countries	<i>Bauxite mining in 2025: Guinea 34.1%, Australia 22%, China 19.8%. Alumina refining in 2025: China 62.0%, Australia 11.3%, Brazil 7.3%, India 5.5%. Aluminium smelting in 2025: China 60.8%, India 5.7%, Russia 5.3%, Canada 4.5%.</i>	USGS (2026)
Nordic concentrator, refinery and smelter production	<i>Aluminium smelting is important in the Nordic value chain. In 2025, MCS reported aluminium smelter production of 750,000 t in Iceland and 1.4 Mt (from 7 smelters) in Norway. SCRREEN3 identified Norway and Iceland as important EU aluminium suppliers for the 2019–2023 period, with Norway supplying 16% and Iceland 8% of EU aluminium supply. Currently, Norway contributes around 40% of the EU demand for aluminium. Sweden also has aluminium processing and recycling capacity.</i>	USGS (2026); SCRREEN3 (2025); Feltrin et al. (2024); Hydro (2025); Proses21 (2026)
Geopolitical and defence risk	<i>EU/JRC view: bauxite is critical in the 2023 EU assessment, while bauxite, alumina and aluminium are treated as strategically important in the current EU policy framework. Defence view: aluminium is classified as very high risk in the JRC defence study, because it combines a high frequency of use across military platforms with exposure to supply disruption. The main supply-chain risks are the concentration of bauxite mining and alumina refining, the energy intensity of smelting, exposure to imported feedstock, and the sensitivity of aluminium production to power prices, sanctions, tariffs and industrial-policy decisions.</i>	Grohol & Veeh (2023); EU (2024a); Carrara et al. (2023); Girardi et al. (2023); USGS (2026)

3.1.5 Beryllium (Be)

Beryllium combines low density, stiffness, thermal stability and transparency to X-rays, giving it high value in copper–beryllium alloys, aerospace and defence components, electronics, telecommunications, X-ray windows and semiconductor equipment. The market is small, technically specialised and it is difficult to substitute without performance loss. MCS 2026 indicates that mine supply is dominated by a few producers, especially the United States, with additional production in Brazil, China and Nigeria. Nordic Be occurrences are therefore relevant as strategic optionality, but any future recovery would require strict health, environmental and processing controls, because beryllium dust and compounds pose serious occupational hazards (Latunussa et al., 2020; Carrara et al., 2023; USGS, 2026).

Commodity	Beryllium (Be)	Data source
Uses of the commodity	<u>Main uses:</u> Approximately 65% of the production of beryllium is used as copper–beryllium alloy. By industry sector: Electronic & telecommunications equipment (42%), transport and defence (44%). <u>Minor uses:</u> High-beryllium alloys (>40% Be) in electro-optical systems in the space and aviation industries. Pure Be metal: X-ray windows. Be metal applications consume on average 20% of the production. <u>Defence uses:</u> Copper–beryllium alloys, electro-optical systems, X-ray windows, and specialised aerospace and defence components. <u>Future uses:</u> Defence applications, nonmedical and industrial X-ray products, semiconductor processing equipment and new types of beryllium alloys.	Latunussa et al. (2020)
Resources and potential in the Nordic countries	<u>Known resources (total):</u> 1,159 t Be. <u>Finland:</u> Lithium deposits have Be as a potential byproduct. Estimated resources 464 t. <u>Greenland:</u> Estimated resources 64,858 t. Minor additional indications of Be resources. <u>Norway:</u> The Høgtuva area, where several small mineralisations occur within 8 km². Estimated resources 630 t (Bordvedåga deposit). <u>Sweden:</u> Small historic production from Kolsva, Perstorp and other localities. The Yxsjöberg deposit contains elevated concentrations of Be.	Jonsson et al. (2023), Gautneb et al. (2022), GTK (2025)
Global production	430 t (mining)	USGS (2026)
Main producing countries	USA 53%, Brazil 19%, China 18%, Nigeria 9%.	USGS (2026)
Nordic concentrator, refinery and smelter production	No Nordic production	
Geopolitical and defence risk	EU/JRC view: critical in the current EU framework, with SR 1.8 at the extraction stage. Defence view: High risk. Significant defence use across transport, optics, electronics and specialised alloys, with meaningful but not highest-tier disruption probability.	Carrara et al. (2023), EU (2024a), Girardi et al. (2023)

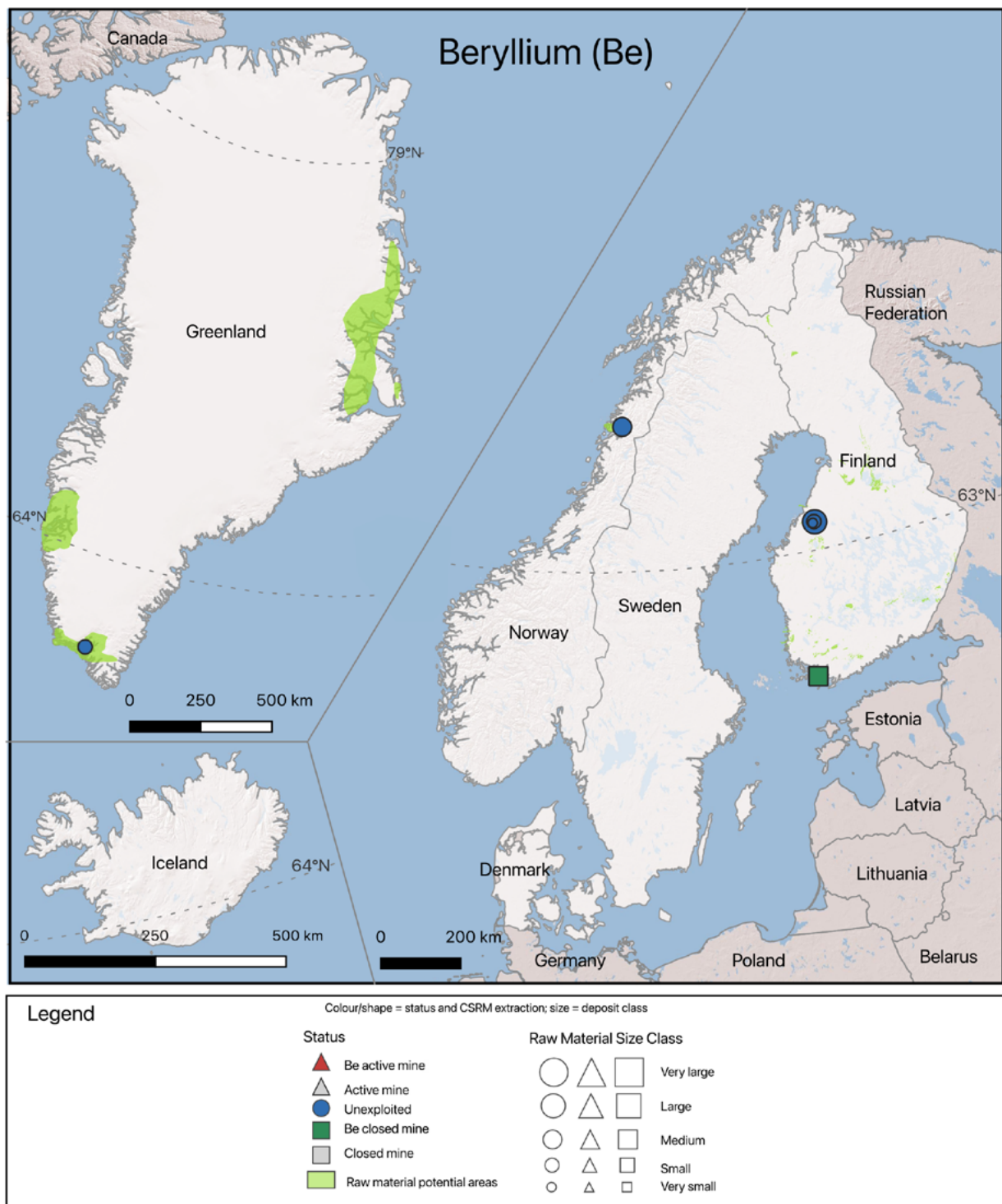


Figure 3.1.4. Locations of deposits with known beryllium resources and areas with known or assumed potential for additional beryllium resources in the Nordic countries.

3.1.6 Bismuth (Bi)

Bismuth is a comparatively low-toxicity heavy metal used in pharmaceuticals, cosmetics, low-melting alloys, solders, pigments and lead-substitution applications, including selected ammunition and shielding uses. It is rarely mined as a primary commodity and is commonly recovered as a by-product from lead, tungsten, copper and precious-metal processing. MCS 2026 reports refinery rather than mine production, underlining the importance of downstream recovery capacity and smelter integration. Because China dominates refined output, Nordic bismuth-bearing Au, Cu–Au, Pb–Zn and Te–Bi(–Au) systems may matter less as stand-alone deposits than as by-product opportunities from gold deposits or in polymetallic processing chains (SCRREEN, 2023; Carrara et al., 2023; USGS, 2026).

Commodity	Bismuth (Bi)	Data source
Uses of the commodity	<u>Main uses:</u> Chemicals, mainly pharmaceutical, animal-feed and cosmetics products (62%), low-melting alloys (28%) and metallurgical application and additives (10%). <u>Minor uses:</u> Coatings, pigments, electronics, food-processing equipment and pipe fittings. <u>Defence uses:</u> Lead-free ammunition and less-lethal projectiles, including as a lead substitute in shot. <u>Future uses:</u> Increasing demand in pharmaceuticals and solders, as well as semiconductors, thermoelectric materials, topological insulators and X-ray shielding-related applications.	Latunussa et al. (2020), USGS (2026), SCRREEN (2023), Khaki et al. (2025).
Resources and potential in the Nordic countries	<u>Known resources (total):</u> 598 t Bi (Sweden, Kankberg mine). Bismuth is not routinely assayed and reported in mineral resources statements. There are Cu, Cu–Au and Au occurrences that contain potentially recoverable bismuth, at grades probably in several tens of ppm Bi. <u>Finland:</u> Bi is reported as a minor commodity in the Petrovaara Cu–Au occurrence. <u>Greenland:</u> Bi is reported at the active Nalunaq gold mine, where gold mainly occurs as native gold and locally as maldonite (Au₂Bi). <u>Norway:</u> Several sediment-hosted Zn–Cu deposits with up to 100 ppm Bi (e.g., in Røros, Bleikvassli, Mofjellet); Cu vein occurrences in Telemark. <u>Sweden:</u> 598 t Bi reported; Kankberg Au mine produces a Te–Bi oxide product. Bi also reported as a by-product from the historic Boliden Cu–Au mine. Additional potential in existing gold deposits. Known from several other deposits, e.g., polymetallic skarns in Bergslagen, but without detailed data.	SGU (2022), Boliden (2023), Eilu et al. (2021), Grip and Wirstam (1970), Voigt and Bradley (2021), Eilu et al. (2024), Lauri et al. (2018), Jonsson (2020), Eilu (2012), Amaroq Minerals (2025)
Global production	Approximately 16,000 t refinery production; mine production not reported.	USGS (2026)
Main producing countries	China 87.5%, South Korea 6.3%, Laos 3.2% and Kazakhstan 1.2% (refinery production, 2025); Bolivia and Bulgaria each report about 50 t refinery production. Shares are approximate.	USGS (2026)
Nordic concentrator, refinery and smelter production	Glencore Nikkelverk has a sidestream of Bi-concentrate, but otherwise no reported Nordic Bi refinery production; within the EU, Bulgaria reports approximately 50 t refinery production.	USGS (2026)
Geopolitical and defence risk	EU/JRC view: critical and strategic in the current EU framework, with SR 1.9 at the processing stage. Girardi et al. do not classify bismuth as a strategic raw material for defence; its geopolitical role is a by-product and processing-concentration issue, strengthened by Chinese export controls and a refined market dominated by China rather than by diversified primary mining capacity.	Carrara et al. (2023), EU (2024a), Girardi et al. (2023), MOFCOM & GACC (2025)

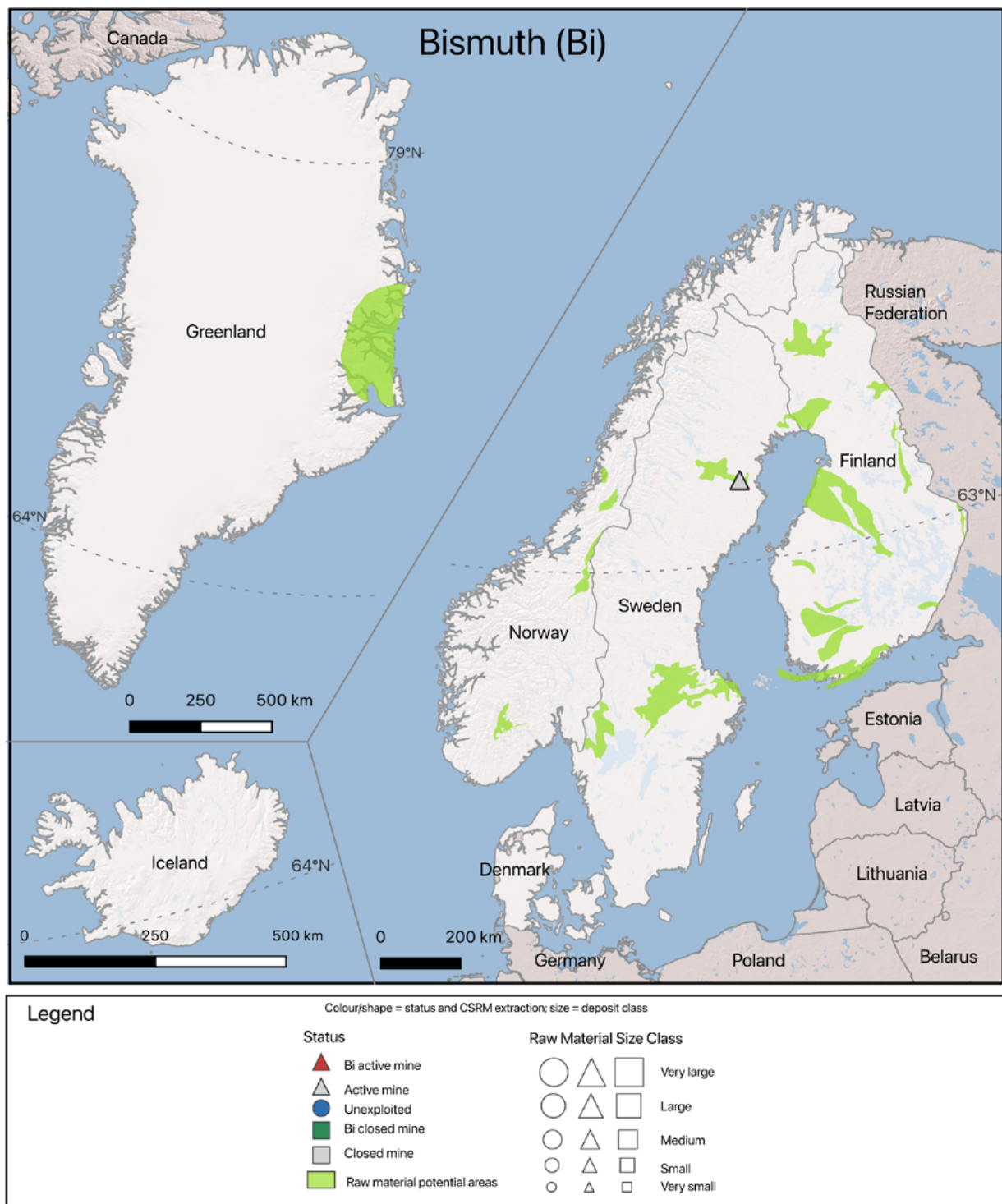


Figure 3.1.5. Locations of deposits with known bismuth resources and areas with known or assumed potential for additional bismuth resources in the Nordic countries.

3.1.7 Cobalt (Co)

Cobalt is a key battery and high-performance-alloy metal. It is used in lithium-ion batteries, superalloys, hard-facing materials, catalysts, pigments, magnets and defence-relevant high-temperature components. IEA assessments highlight cobalt as one of the metals most exposed to clean-energy demand growth and supply-chain concentration, while according to MCS 2026, mine production is dominated by the Democratic Republic of the Congo and refining is dominated by China. The Nordic region is unusual in Europe because Finland combines cobalt-bearing mines with refining capacity, giving the region both geological and midstream relevance. This makes Nordic cobalt important for battery, defence and supply-resilience policy (IEA, 2021; Carrara et al., 2023; IEA, 2025a; USGS, 2026).

Commodity	Cobalt (Co)	Data source
Uses of the commodity	<u>Main uses:</u> <i>Battery technologies, dominantly Li-ion batteries, superalloys, hardfacing, high-speed steel and other alloys.</i> <u>Minor uses:</u> <i>Catalysts for the petroleum and chemical industries; drying agents for paints, varnishes, inks, dyes, pigments, porcelain enamels; magnets and magnetic recording media; humidity indicators; vitamin B12 production.</i> <u>Defence uses:</u> <i>Superalloys, batteries, magnets and high-performance components in air, sea and land systems.</i> <u>Future uses:</u> <i>Increasing demand for Li-ion batteries.</i>	SCRREEN3 (2025), Cobalt Institute (2025), Slack et al. (2017)
Resources and potential in the Nordic countries	<u>Known resources (total):</u> 595,310 t Co. <u>Finland:</u> <i>Known resources 541,258 t Co. Assumed ('undiscovered') additional resources: 270,000 t Co. Kevitsa and Terrafame (Talvivaara) mines are the only Co-producing mines in Europe. Mineral resources at Terrafame Mine 1458 Mt @ 0.019% Co (as of 1.1.2020), Kevitsa: combined resources and reserves 274.6 Mt containing approximately 28,718 t Co (as of 31.12.2025).</i> <u>Greenland:</u> <i>Several Ni-Co projects are in progress, but no resource estimates on Co are available. Potential related to ilmenite-rich black sands and to conduit-type sulphide mineralisation.</i> <u>Norway:</u> <i>Known resources 15,696 t Co (mainly in Ni-Cu magmatic deposits).</i> <u>Sweden:</u> <i>Known resources 38,356 t Co. Several mines with historic Co production.</i>	Boliden (2026), GTK (2025, 2026), Rasilainen et al. (2017, 2020), Horn et al. (2021), Jonsson et al. (2023), Gautneb et al. (2022), Rosa et al. (2023)
Global production	<u>Mining:</u> 310,000 t (2025). <u>Refineries:</u> 250,000 t (2024).	USGS (2026), IEA (2025a)
Main producing countries	<u>Mining:</u> <i>DRC 73.1%, Indonesia 14%, Russia 2.4%, Madagascar, Australia and Philippines 1.2%, Canada 1.2%, PNG 0.9%, China, Cuba and Turkey 0.6%, US 0.1%. Refineries: China 78%, Finland 8%, Japan 2.3%.</i>	IEA (2025a), USGS (2026)
Nordic concentrator, refinery and smelter production	<u>Mining:</u> <i>Finland 1,008 t. Refineries: Finland 12,025 t, Norway 3,033 t.</i>	Tukes (2025), IEA (2025a), USGS (2026)
Geopolitical and defence risk	<i>EU/JRC view: critical and strategic in the current EU framework, with SR 2.8 at the extraction stage. Defence view: High risk. Defence use is material, and geopolitical supply exposure remains high because of concentrated and politically sensitive supply chains.</i>	Carrara et al. (2023), EU (2024a), Girardi et al. (2023)

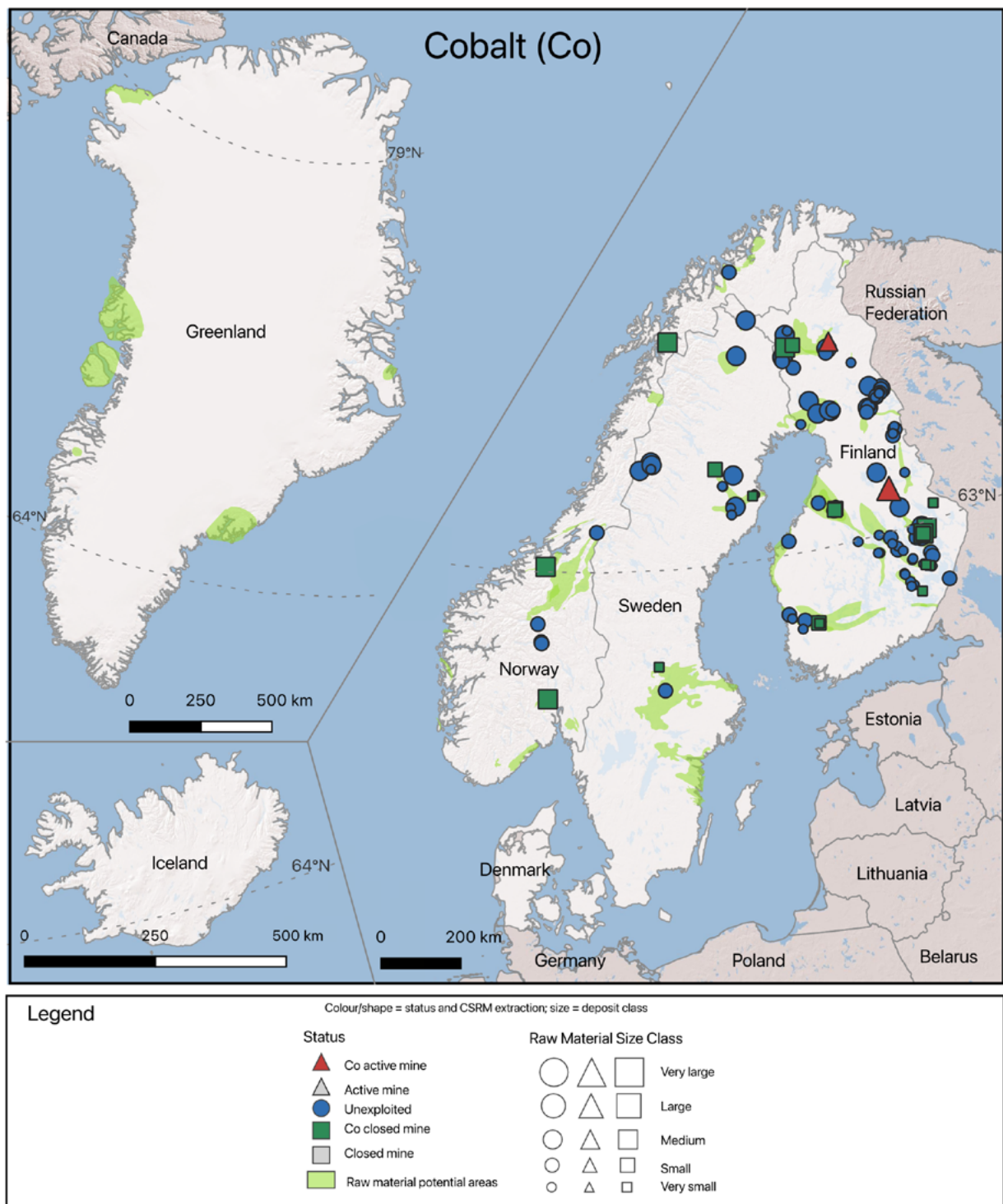


Figure 3.1.6. Locations of deposits with known cobalt resources and areas with known or assumed potential for cobalt resources in the Nordic countries.

3.1.8 Coking coal (C)

Coking coal remains critical because conventional blast-furnace steelmaking depends on metallurgical coke as both a reductant and structural support in the furnace. Its demand is therefore linked to steel, infrastructure, machinery and defence-industrial supply chains, even as low-carbon steelmaking routes are being developed. The IEA and SCRREEN assessments underline that steel demand remains large and that substitution away from coking coal is technically and capital intensive, rather than immediate. Nordic relevance is limited by the closure of Svalbard coal mining, but the remaining resource base records past regional supply potential and the strategic dependence of steelmaking on imported metallurgical coal (SCRREEN, 2023; Carrara et al., 2023; IEA, 2025b).

Commodity	Coking coal (C)	Data source
Uses of the commodity	<u>Main uses:</u> Coke is used in steel production (89% in blast furnaces). <u>Minor uses:</u> Production of carbides, base metal production, heat production, chemical industries. <u>Defence uses:</u> No direct defence-specific end use identified; metallurgical coal is a key input for coke and blast-furnace steelmaking, and steel underpins defence systems and defence-industrial supply chains. <u>Future uses:</u> Steel industries remain as the main user of coking coal (increased demand until 2030).	SCRREEN (2023)
Resources and potential in the Nordic countries	<i>Known resources (total): 26 Mt coking coal.</i> <u>Finland:</u> Unknown. <u>Greenland:</u> Unknown. <u>Norway:</u> 26 Mt coal resources, including material suitable for coking use. <u>Sweden:</u> Unknown (historic coal mining in Scania).	U.S. Energy Information Administration (2024)
Global production	940.3 Mt (mining), 630.9 Mt (processing).	SCRREEN (2023)
Main producing countries	Mining: China 53%, Australia 18%, Russia 9%, USA 6%. Processing: China 69%, Russia 6%, Japan 5%.	SCRREEN (2023)
Nordic concentrator, refinery and smelter production	Norway produced 110,000 t coal in 2025 (at Svalbard), partly for metallurgical and chemical industries in Europe. The last mine (Grube 7) closed on 30 June 2025.	Eurostat (2025), U.S. Energy Information Administration (2024)
Geopolitical and defence risk	EU/JRC view: coking coal is listed as a CSR in the EU 2023 framework, but the 2023 commodity summary does not report a fresh SR value; the earlier coking-coal assessment reported SR 1.2 at the extraction stage. Girardi et al. do not classify coking coal as a strategic raw material for defence; its geopolitical role is indirect but structural, because metallurgical coal underpins blast-furnace steel value chains and therefore links defence-industrial resilience to trade exposure, coal-quality constraints and the pace of low-carbon steel substitution.	Carrara et al. (2023), EU (2024a), Girardi et al. (2023)

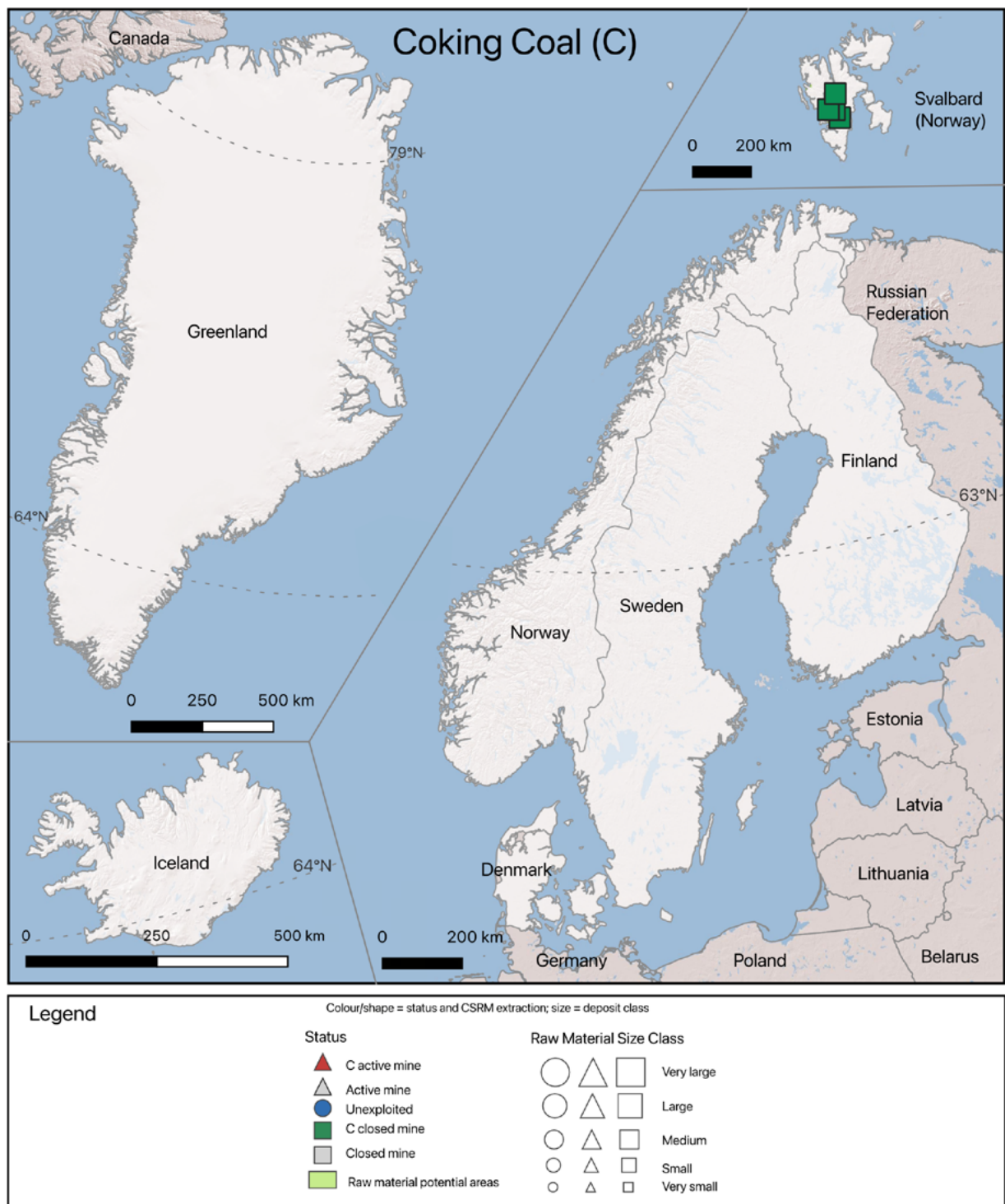


Figure 3.1.7. Locations of deposits with known coking coal resources and areas with known or assumed potential for coking coal resources in the Nordic countries.

3.1.9 Copper (Cu)

Copper falls below the 2023 JRC supply-risk threshold but is listed as a critical raw material in Annex II of the CRMA and as a strategic raw material in Annex I. It is a core transition metal for electrification across generation, transmission, distribution and end-use systems, including grids, transformers, cabling, electric motors, charging infrastructure and renewable installations (IEA, 2021; Eilu et al., 2021). Because of its high conductivity and broad use in energy infrastructure, copper demand is expected to increase strongly with transport, heating and industrial electrification (IEA, 2021). At the same time, construction and machinery remain major demand centres, so transition demand increasingly competes with established industrial uses (Valenta et al., 2019; Feltrin et al., 2024).

Commodity	Copper (Cu)	Data source
Uses of the commodity	<u>Main uses:</u> <i>Power cables and wiring; building (pipes, taps, valves, fittings, roof plates).</i> <u>Minor uses:</u> <i>Automobile parts; electric motors; heat exchangers and radiators; pressure vessels and vats; copper chips; coinage, cookware; antimicrobial applications; superconductors; jewellery.</i> <u>Defence uses:</u> <i>Wiring, motors, communications, radar, guidance systems, and broader on-board defence electronics.</i> <u>Future uses:</u> <i>Cables and wiring; electric motors; other uses in electric vehicles; various IT/digital applications; photovoltaic applications; building and infrastructure.</i>	Eynard et al. (2020); USGS (2026)
Resources and potential in the Nordic countries	<u>Known resources (total):</u> 18,768,319 t Cu. <u>Finland:</u> <i>Known resources 5,934,558 t Cu. Assumed ('undiscovered') additional resources at the regional scale estimated at 9,669,000 t. Largest deposit: Kevitsa mine, 371 Mt at 0.32% Cu.</i> <u>Greenland:</u> <i>Known resources: 108,000 t Cu. Assumed ('undiscovered') additional resources: 3,345,000 t Cu.</i> <u>Iceland:</u> <i>Minor potential in eastern Iceland.</i> <u>Norway:</u> <i>Known resources: 1,800,761 t Cu. Assumed ('undiscovered') additional resources: distinct additional potential in areas with closed mines or known resources. Largest deposit: Nussir, 60.7 Mt at 1.01% Cu.</i> <u>Sweden:</u> <i>Known resources: 10,925,000 t Cu. Assumed ('undiscovered') additional resources: in the Skellefte district 726,000 t and in the Caledonides 145,000 t Cu; other regions still lack such assessments. Largest deposit: Aitik mine, 3,065 Mt at 0.23% Cu (total tonnage including past production).</i>	Carranza & Sadeghi (2010), Stensgaard et al. (2011), Rasilainen et al. (2017), Bjerkgård et al. (2020), Eilu et al. (2021, 2022), Rosa et al. (2023), GTK (2025, FINODD)
Global production	23,000,000 t (mines); 29,000,000 t (refineries/smelters).	USGS (2026)
Main producing countries	<u>Mining:</u> <i>Chile 23%, DRC 14%, Peru 12%, China 7.8%, Russia 5.7%.</i> <u>Smelting, refining:</u> <i>China 48.3%, DRC 9.7%, Chile 5.8%, Japan 4.8%, Russia 3.3%.</i>	USGS (2026)
Nordic concentrator, refinery and smelter production	<i>Finland 28,866 t, Sweden 68,000 t (mines); Finland 169,775 t, Norway 18,279 t, Sweden 266,379 t (refinery and smelter).</i>	Boliden (2026), Eurostat (2026), Tukes (2025)
Geopolitical and defence risk	<i>EU/JRC view: below the 2023 JRC criticality threshold but listed as critical in Annex II of the CRMA and strategic in Annex I, with SR 0.1 at the extraction stage. Defence view: High risk. Copper is widely used across defence electronics, wiring, motors and guidance systems, but supplier diversification moderates the disruption probability relative to higher-risk classes.</i>	Carrara et al. (2023), EU (2024a), Girardi et al. (2023)

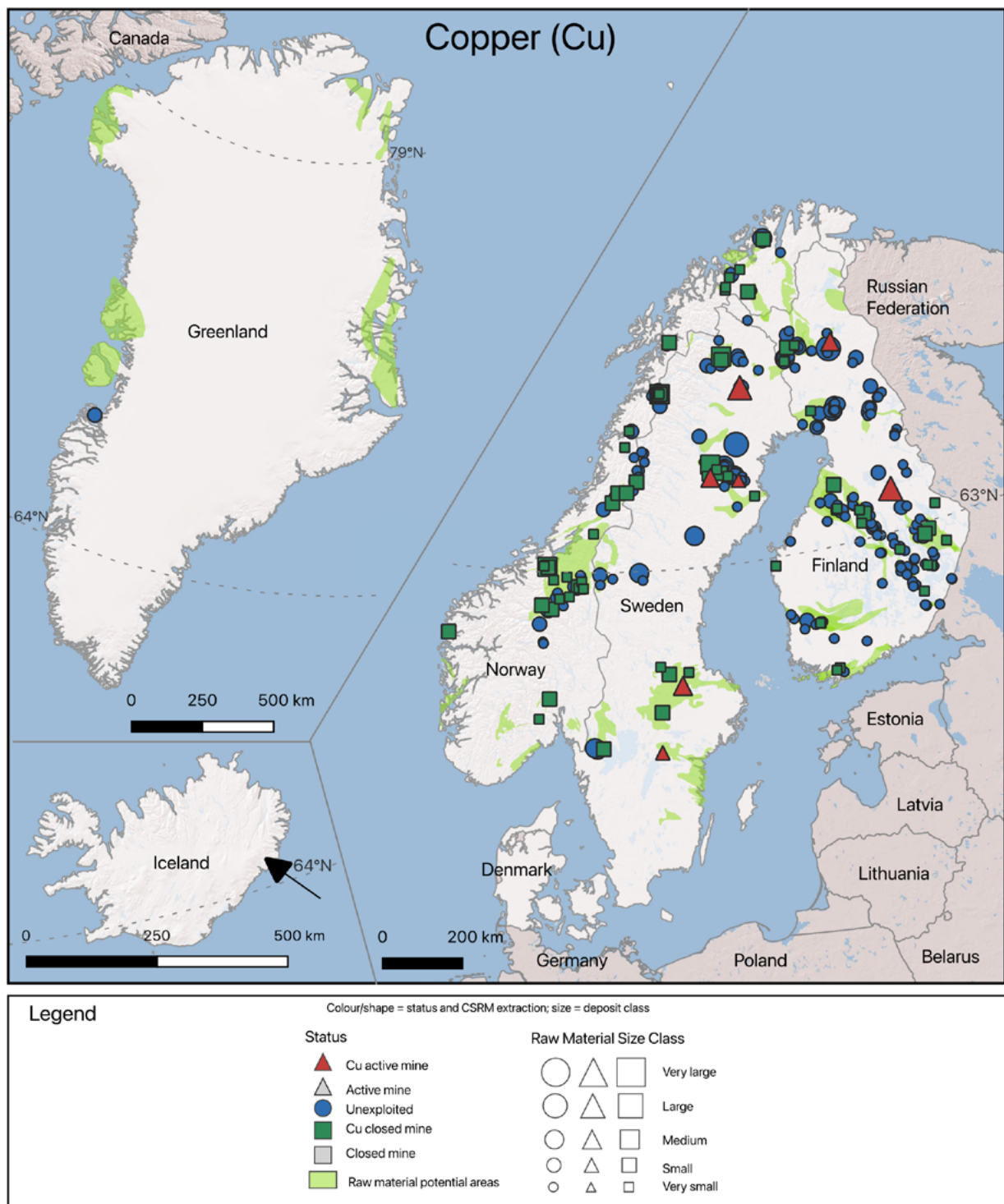


Figure 3.1.8. Locations of deposits with known copper resources and areas with known or assumed potential for copper resources in the Nordic countries. The associated resource-potential area in Iceland is assumed to be very small and is hence indicated by a black arrow.

3.1.10 Feldspar & nepheline syenite

Feldspar and nepheline syenite are industrial minerals mainly used as fluxes and alumina-alkali sources in glass, ceramics, fillers and related mineral products. Their criticality is less about scarcity than about consistent quality, low iron content, logistics and reliable access for energy-intensive downstream industries. MCS 2026 reports a broadly supplied global market, but local deposits remain important, because transport costs and product specifications can dominate economics. In the Nordic context, feldspar and nepheline syenite are also relevant, because the alkaline and granitic systems that supply these industrial minerals may hold additional CSRM potential, even when feldspar or nepheline syenite is the main saleable product (e.g., Jonsson et al., 2023; Carrara et al., 2023; USGS, 2026).

Commodity	Feldspar & nepheline syenite	Data source
Uses of the commodity	<u>Main uses:</u> Glass, ceramics, sanitary ware and insulation. <u>Minor uses:</u> Various types of fillers and extenders, dental material. <u>Defence uses:</u> Indirect use in technical ceramics and electrical insulation components; relevance is mainly through glass and ceramics rather than a commodity-specific defence end use. <u>Future uses:</u> Glass and fiberglass uses expected to increase, due to increases in automobile and solar panel glass industries. Anorthositic feldspar and Al raw material. CO₂-free white cement.	Eynard et al. (2020), USGS (2026)
Resources and potential in the Nordic countries	<u>Known resources (total):</u> approximately 191.7 Mt quantified feldspar, anorthosite and nepheline syenite resources. <u>Finland:</u> Known resources 910,000 t at Rosendal (1.3 Mt @ 70% feldspar). <u>Greenland:</u> 21.8 Mt anorthosite inferred resource at Majoqqap Qaava; 27 Mt indicated + 32 Mt inferred anorthosite resource at Qaqortorsuaq/White Mountain. Additional potential in anorthosites in SW Greenland and NW Greenland. <u>Norway:</u> Before WWII, many hundreds of feldspar mines were in operation in Norway from granitic pegmatites. Present endowment is unknown. Europe's biggest nepheline syenite mine has been in operation in N. Norway since 1960. Remaining resources are confidential. <u>Sweden:</u> Many quarries with historic feldspar production from granitic pegmatites. Present feldspar resources are unknown, but significant potential is assumed. The Norra Kärr deposit has an inferred resource of 110 Mt @ 65% nepheline syenite. Further potential for nepheline syenite exists in some other alkaline rocks. National mineral occurrence databases: www.gtk.fi, www.sgu.se, www.ngu.no.	Hudson Resources (2018), SRK Consulting (2021), Greenland Anorthosite Mining (2023), Rosa et al. (2023), GTK (2025, FINODD)
Global production	31 Mt (mines)	USGS (2026)
Main producing countries	India 19.4%, Turkey 17.1%, Iran 12.6%, China 11.9%, Italy 7.1% (mining).	USGS (2026)
Nordic concentrator, refinery and smelter production	Finland 22,678 t; Greenland, no data found; Norway 360,000 t; Sweden, production figures are not available.	WMD (2026); Sibelco (pers. com.)
Geopolitical and defence risk	EU/JRC view: feldspar is critical in the current EU framework, with SR 1.5 at the extraction stage; nepheline syenite is not separately scored in this dataset. Girardi et al. do not classify feldspar or nepheline syenite as strategic raw materials for defence; their geopolitical role is best treated as low-intensity industrial resilience, because supply security depends on quality-controlled glass and ceramic feedstocks, import concentration in some markets and regional logistics rather than a defence-specific bottleneck.	Carrara et al. (2023), EU (2024a), Girardi et al. (2023)

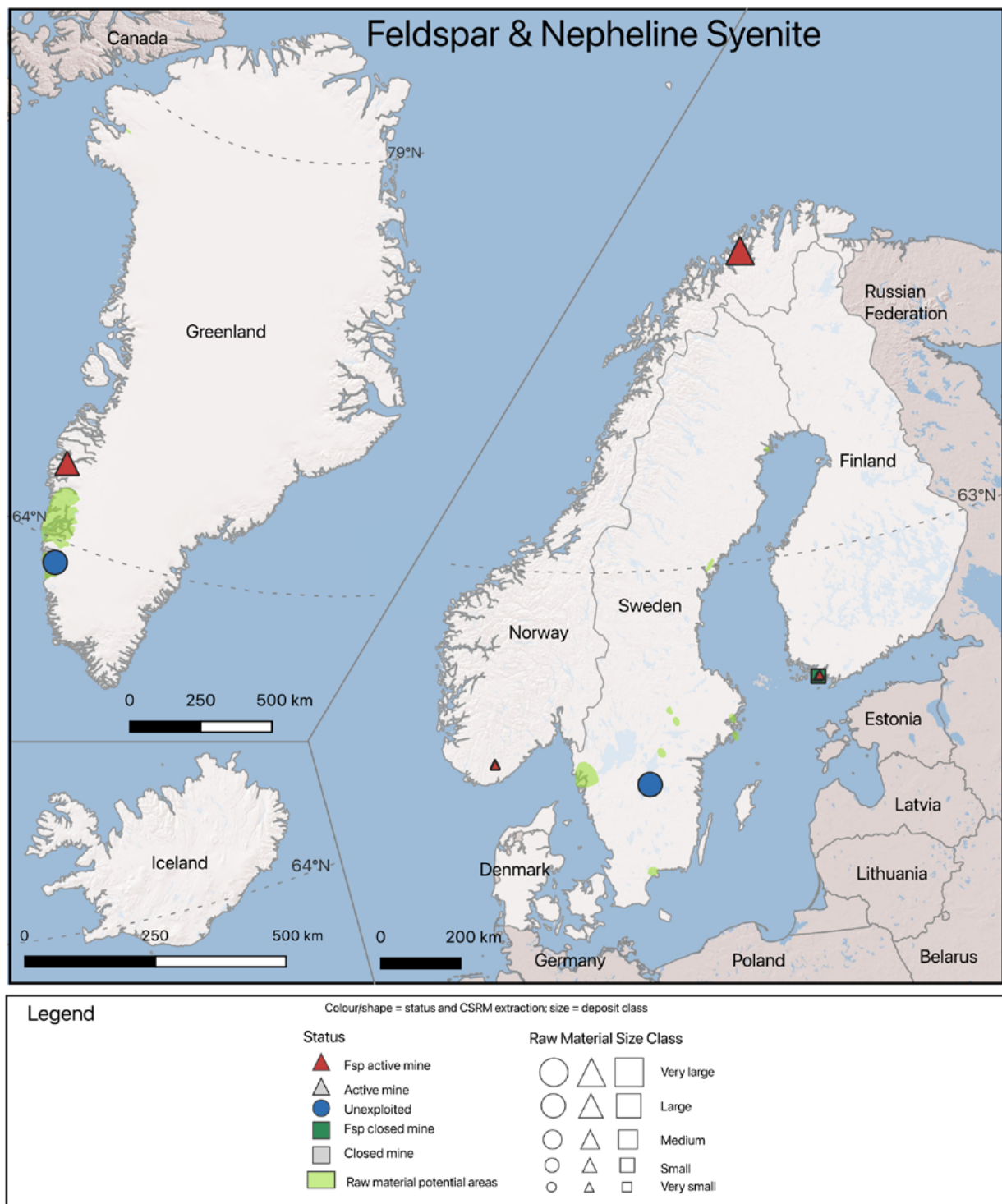


Figure 3.1.9. Locations of deposits with known feldspar and nepheline syenite resources and areas with known or assumed potential for feldspar and nepheline syenite resources in the Nordic countries. Although EU criticality applies to feldspar, nepheline syenite is included because it is an important Nordic feldspathic industrial mineral for glass and ceramic raw-material supply, with significant Norwegian production and additional Swedish resource potential.

3.1.11 Fluorspar (fluorite, CaF₂)

Fluorspar is the main mineral source of fluorine (F) and is essential for the production of hydrofluoric acid, aluminium smelting, steelmaking, fluorochemicals, refrigerants, polymers and emerging battery-electrolyte applications. Acid-grade fluorspar is particularly strategic because it feeds chemical value chains rather than only metallurgical flux uses. MCS 2026 identifies abundant geological resources but concentrated mine supply, with China, Mexico, Mongolia and South Africa among the major producers. The Nordic relevance lies in known fluorite occurrences and in by-product or co-product potential within alkaline, carbonatite and hydrothermal systems, but market entry strongly depends on the grade, deleterious elements, the processing route and access to chemical customers (Fulton & Miller, 2006; Latunussa et al., 2020; Carrara et al., 2023; USGS, 2026).

Commodity	Fluorspar (fluorite, CaF ₂)	Data source
Uses of the commodity	<u>Main uses:</u> <i>The three principal markets for fluorspar are: acid, metallurgical and ceramic, with their specific grades and quality parameters. The former two are commercially called "acidspar" (60% of demand) and "metspar" (25% of demand), respectively.</i> <u>Minor uses:</u> <i>All fluorine-bearing chemicals. Ceramics: The addition of 10–30% of fluorspar in glass and ceramic products produces a white opaque and opalescent effect in glass and enamels. Elemental fluorine in organic synthesis, and is necessary in the production of uranium hexafluoride, the starting material for separation of uranium isotopes in nuclear fuel production.</i> <u>Defence uses:</u> <i>Uranium fuel-cycle chemicals, including uranium hexafluoride production, and fluorochemical processing.</i> <u>Future uses:</u> <i>Applications and uses of fluorspar will remain stable, except there is a major push to substitute fluorine used in many industries (especially in the air conditioning and refrigerator sector) for more environmentally friendly options. The future demand for fluorspar is assumed to grow.</i>	Fulton & Miller (2006), Latunussa et al. (2020), USGS (2026)
Resources and potential in the Nordic countries	<u>Known resources (total):</u> <i>approximately 4.24 Mt fluorspar/fluorite.</i> <u>Finland:</u> <i>No known resources or resource potential.</i> <u>Greenland:</u> <i>At Kvanefjeld, there are large fluorine resources of villiaumite (NaF). The Ivittuut deposit has 250,000 t fluorspar. Several other fluorspar occurrences are known, but their resources have not been assessed.</i> <u>Iceland:</u> <i>Possible potential for deposits.</i> <u>Norway:</u> <i>Approximately 30 registered deposits of fluorspar, the largest being Lassedalen, with resources of 4 Mt ore at 24.6% fluorite.</i> <u>Sweden:</u> <i>2.828 Mt. The Storuman deposit has 27.7 Mt at 10.21% fluorite. The other known deposits are historical closed mines from which no resource estimates are available.</i>	GME (2018), Lauri et al. (2018), Rosa et al. (2023); Tertiary Minerals plc (2012)
Global production	<i>10.0 Mt fluorspar</i>	USGS (2026)
Main producing countries	<i>China 60%, Mexico 15.1%, Mongolia 15%, South Africa 4.1%.</i>	USGS (2026)
Nordic concentrator, refinery and smelter production	<i>No production</i>	
Geopolitical and defence risk	<i>EU/JRC view: critical in the current EU framework, with SR 1.1 at the extraction stage. Girardi et al. do not classify fluorspar as a strategic raw material for defence; its geopolitical role is chemical-chain leverage, because fluorspar is the entry point to hydrofluoric acid and fluorochemical value chains that support metallurgy, electronics and other strategic industries, while production and processing remain geographically concentrated.</i>	Carrara et al. (2023), EU (2024a), Girardi et al. (2023)

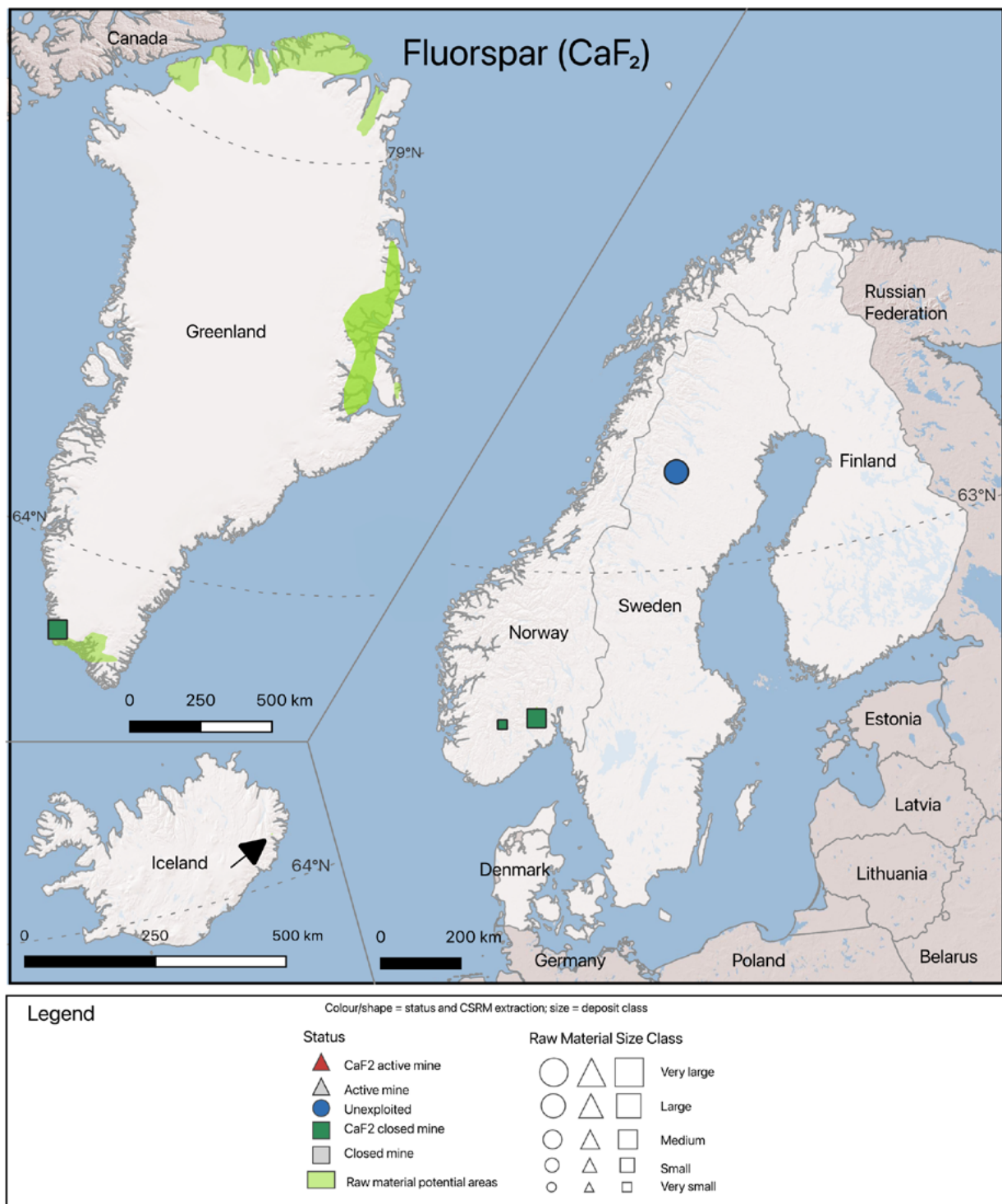


Figure 3.1.10. Locations of deposits with known fluorspar resources and areas with known or assumed potential for fluorspar resources in the Nordic countries. The associated resource-potential area in Iceland is assumed to be very small and is hence indicated by a black arrow.

3.1.12 Gallium (Ga)

Gallium is a high-technology by-product metal mainly recovered from bauxite processing and, to a lesser extent, zinc processing. It is essential for gallium arsenide and gallium nitride semiconductors used in LEDs, radio-frequency electronics, power electronics, photovoltaics, radar and defence systems. The IEA highlights semiconductor and clean-energy supply chains as increasingly exposed to mineral and processing concentration, while according to USGS MCS 2026, gallium production is highly dependent on a small number of refining jurisdictions. The Nordic gallium potential is therefore mostly a processing and residue question, linked to bauxite alternatives, zinc circuits, alumina products and trace recovery from suitable industrial streams (Latunussa et al., 2020; Carrara et al., 2023; IEA, 2025a; USGS, 2026).

Commodity	Gallium (Ga)	Data source
Uses of the commodity	<u>Main uses:</u> <i>Semiconductor wafers in integrated circuits, LED lighting.</i> <u>Minor uses:</u> <i>CIGS solar cells, displays, low temperature melting solders and alloys, laser diodes, optoelectronic devices.</i> <u>Defence uses:</u> <i>Semiconductors, radar, communications, and electro-optical systems in advanced defence electronics.</i> <u>Future uses:</u> <i>Radio frequency devices, LED and solar cell uses expected to increase. Demand in integrated circuits expected to remain steady.</i>	Latunussa et al. (2020), USGS (2026)
Resources and potential in the Nordic countries	<u>Known resources (total):</u> 27,000 t Ga. <u>There are presently no primary gallium ores in the Nordic countries (or elsewhere in the world).</u> <u>Greenland:</u> <i>The only known resource in the Nordics, at Skaergaard: 27,000 t Ga.</i> <u>Resource potential:</u> <i>Zinc-dominated sulphide ores across Fennoscandia and Greenland are possible sources, but few have been analysed for gallium.</i>	Lauri et al. (2018), Jonsson & Högdahl (2019), Eilu et al. (2021), Rosa et al. (2023)
Global production	<u>Refinery production:</u> 900 t Ga (mine production unknown).	USGS (2026)
Main producing countries	<i>China 99.0%, Russia 0.7%, Japan 0.3%, Gallium is extracted as a by-product of aluminium production, and some is produced from the residues of zinc production.</i>	USGS (2026)
Nordic concentrator, refinery and smelter production	<i>There is a potential to produce, but apparently no recovery.</i> <u>Iceland:</u> <i>Ga₂O₃ content in imported alumina varies, but typical values are 0.006 to 0.008% (w/w). Total import of alumina was ~1.6 Mt in 2024 for three smelters.</i> <u>Norway:</u> <i>Norsk Hydro AS had, for a short period (late 1960s), a plant aimed at the production of 200 kg Ga/year as part of purification of aluminium. In addition, the fly ash from coal-fired power plants is another possible source.</i>	Pers. comm. from Icelandic Al refineries (2026); Huhtelin (2022)
Geopolitical and defence risk	<i>EU/JRC view: critical and strategic in the current EU framework, with SR 3.9 at the processing stage. Defence view: Medium risk.</i> <i>Used in selected defence electronics and electro-optical systems, but with lower application breadth than higher-risk materials.</i>	Carrara et al. (2023), EU (2024a), Girardi et al. (2023), Reuters (2025e)

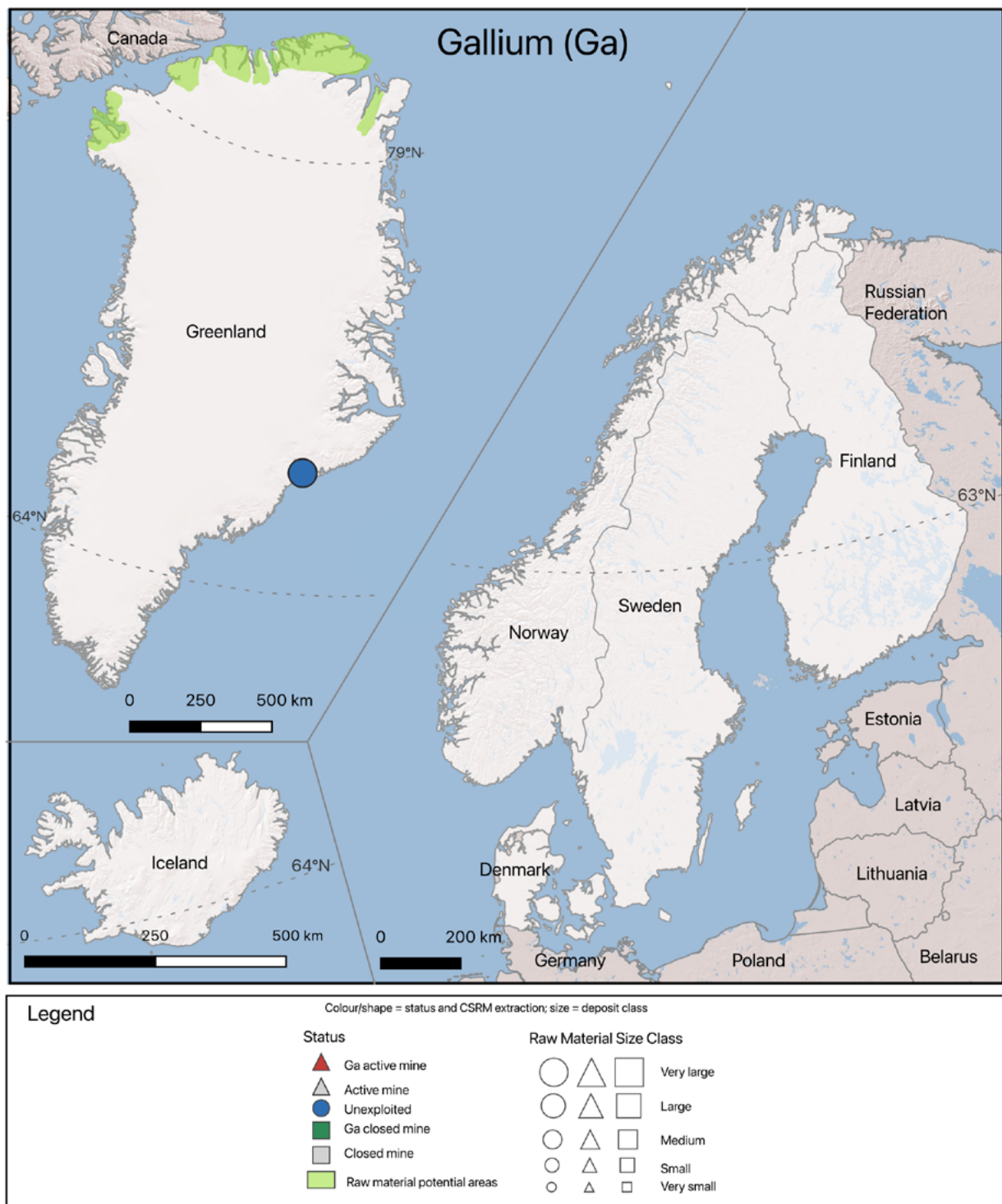


Figure 3.1.11. Locations of deposits with known gallium resources and areas with known or assumed potential for gallium resources in the Nordic countries.

3.1.13 Germanium (Ge)

Germanium is a by-product metal mainly recovered from zinc ores and certain coal or fly-ash streams. It is used in fibre optics, infrared optics, polymerisation catalysts, high-efficiency solar cells, electronics and defence-relevant sensing systems. Because primary germanium deposits barely exist, supply depends on host-commodity production, residue handling and specialised refining. MCS 2026 indicates a narrow production base and continuing exposure to processing concentration. For the Nordic countries, germanium should therefore be assessed in Zn-rich systems, coal-related residues where relevant, and smelter or recycling streams, rather than as a conventional stand-alone resource target (USGS, 2023; Carrara et al., 2023; IEA, 2025a; USGS, 2026).

Commodity	Germanium (Ge)	Data source
Uses of the commodity	<u>Main uses:</u> <i>Fibre optics 40%, infrared optics 47%.</i> <u>Minor uses:</u> <i>Electrical equipment, solar cells, polymerisation catalysts, LEDs.</i> <u>Defence uses:</u> <i>Infrared optics, sensors, night-vision-related systems, and specialised defence electronics.</i> <u>Future uses:</u> <i>Solar cells (CIGS), IR and fibre optics.</i>	Latunussa et al. (2020); USGS (2022); Marscheider-Weidemann et al. (2021)
Resources and potential in the Nordic countries	<i>Known resources (total): not quantified.</i> <i>There are presently no primary Ge ores anywhere in the world. Ge was extracted from leaching of zinc refinery residues in Finland from imported ore in significant amounts at least up to 2015, when 13 t Ge was produced from imported raw materials. Since 2016, Ge production in Finland has been minimal. Resources in the Nordic countries are unknown. Ge is recorded from zinc occurrences in North Greenland, with up to 0.05% Ge in sphalerite. Finland, Norway and Sweden: possibly minor potential.</i>	Eilu et al. (2021); Lauri et al. (2018); Jonsson & Högdahl (2019); Rosa et al. (2023)
Global production	<i>140 t (refinery production). Mine production not known.</i>	USGS (2023); USGS (2026)
Main producing countries	<i>Commercially in only a few countries, including the United States, Belgium, Canada, China, Germany and Russia, with China being the leading producer of germanium. Because most producers do not publicly report germanium production, global production data are limited. Substantial germanium-rich deposits, including tailings sites, that are in operation or active development are in China, Congo (Kinshasa), Russia and the United States. Additional such potential in Namibia.</i>	USGS (2026)
Nordic concentrator, refinery and smelter production	<i>No production.</i>	
Geopolitical and defence risk	<i>EU/JRC view: critical and strategic in the current EU framework, with SR 1.8 at the processing stage. Defence view: High risk. Germanium is used in defence optics and electronics and is exposed to elevated geopolitical and supply-chain concentration risk.</i>	Carrara et al. (2023), EU (2024a), Girardi et al. (2023), Reuters (2025e)

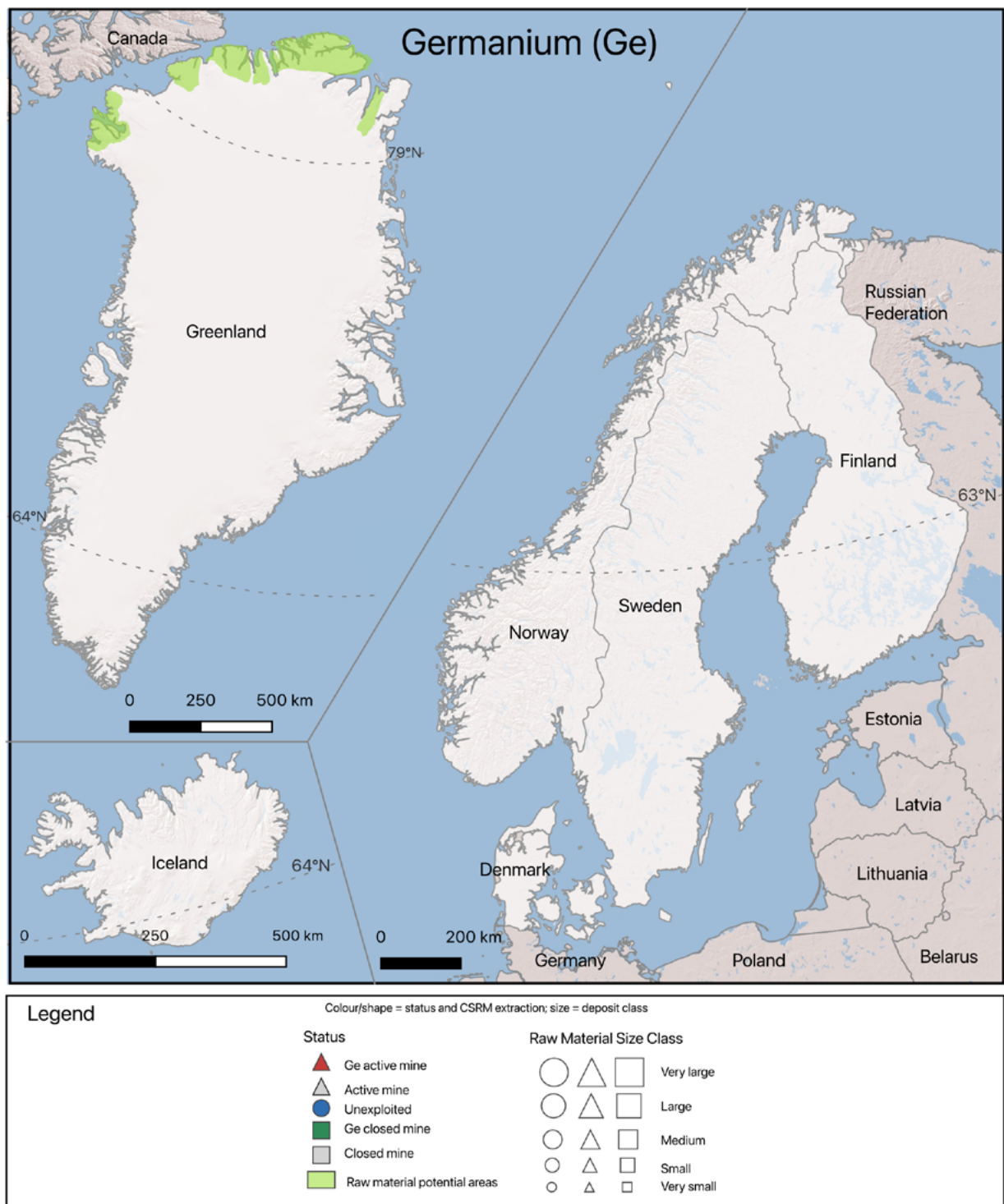


Figure 3.1.12. Locations of deposits with known germanium resources and areas with known or assumed potential for germanium resources in the Nordic countries.

3.1.14 Graphite

The industry commonly classifies natural graphite into three main groups: flake, amorphous and vein graphite. Flake graphite accounts for approximately 50% to 60% of total natural graphite output (approximately 58% of world production) and is the primary source of graphite for lithium-ion battery applications, which require spherical graphite particles produced through specialised grinding, chemical purification and coating of high-quality natural graphite (EC, 2020; Eilu et al., 2021). Amorphous graphite output accounts for roughly 40% to 50%, and vein graphite for less than 1% (EC, 2020). The market value and end-use suitability of graphite deposits are strongly influenced by the flake size and carbon content, with flake graphite concentrate typically ranging between 85% and 97% graphitic carbon (EC, 2020). Battery-grade graphite requires high-purity (>99.95 wt% C) spheroidal particles with sizes in the range of 10–25 µm for effective operation (Kaikkonen et al., 2022). The CRMA also identifies synthetic anode grade graphite as a critical raw material.

Commodity	Graphite	Data source
Uses of the commodity	<u>Main uses:</u> <i>Li-ion batteries, electrodes, foundry industry, refractory materials, metallurgical industry.</i> <u>Minor uses:</u> <i>Shapes, friction products, lubricants, pencils.</i> <u>Defence uses:</u> <i>Propulsion systems, on-board electronics, armoured-platform components, and ammunition guidance-related applications.</i> <u>Future uses:</u> <i>Refractories for the steel industry remain the dominant market. Graphite is the second largest component in Li-ion batteries, and this use has seen a rapid increase in recent years, a trend that is expected to continue. Li-ion batteries demand a spherical-type graphite produced by specialized grinding of high-quality natural graphite deposits. Large-scale fuel cells, modular nuclear reactors (PBNRs), and vanadium redox batteries are additional future uses.</i>	Latunussa et al. (2020), USGS (2026)
Resources and potential in the Nordic countries	<u>Known resources (total):</u> <i>43,556,294 t graphite. Finland 1,562,794 t, Norway 20,376,000 t, Sweden 15,617,500 t, Greenland 6,000,000 t.</i> <u>Finland:</u> <i>Several flake graphite and extensive amorphous graphite occurrences probably contain several Mt of fine-grained graphite.</i> <u>Greenland:</u> <i>Historical mine production and known resources suggest additional major potential.</i> <u>Norway:</u> <i>Approximately 70 registered graphite occurrences in four main graphite provinces.</i> <u>Sweden:</u> <i>At least eight graphite deposits and occurrences are known.</i>	Lauri et al. (2018), Thrane & Kalvig (2018), Beowulf Mining (2019), Stinton et al. (2021), Gautneb et al. (2020), Talga Group (2023), Rosa et al. (2023)
Global production	<i>1,800,000 t (mining).</i>	USGS (2026)
Main producing countries	<i>China 78%, Madagascar 4.4%, Tanzania 4.2%, Brazil 3.6%, Mozambique 3.3%, Russia 1.4%.</i>	USGS (2026)
Nordic concentrator, refinery and smelter production	<i>Norway: 6,600 t (mining), 2,000 t synthetic anode graphite (Vianode produces ca. 2 ktpa of synthetic anode graphite, upscalable to c. 60 ktpa)</i>	USGS (2023), Vianode (2026)
Geopolitical and defence risk	<i>EU/JRC view: natural graphite is critical and strategic in the current EU framework, with SR 1.8 at the extraction stage.</i> <i>Defence view: Very high risk for natural graphite. It combines very wide defence use with very high disruption probability under concentrated global supply chains.</i>	Carrara et al. (2023), EU (2024a), Girardi et al. (2023), Reuters (2025d)

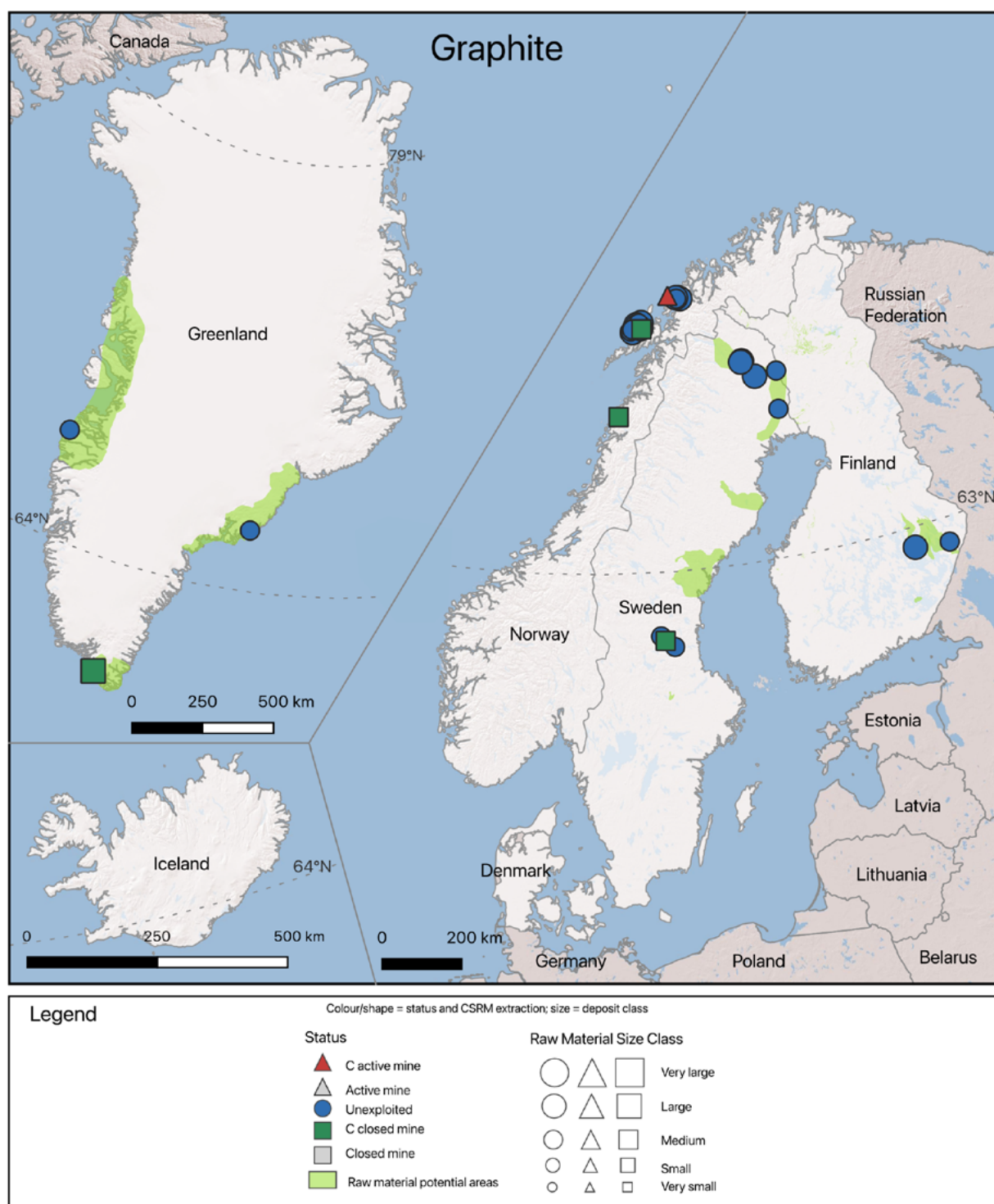


Figure 3.1.13. Locations of deposits with known graphite resources and areas with known or assumed potential for graphite resources in the Nordic countries.

3.1.15 Hafnium (Hf)

Hafnium is almost entirely linked to zirconium mineral processing, because it substitutes for zirconium in minerals such as zircon and baddeleyite and must be separated for nuclear-grade zirconium production. Its uses include superalloys, control rods, plasma cutting, microelectronics, high-temperature ceramics and selected defence systems. MCS 2026 does not provide world primary production data, which reflects the opacity and by-product nature of the market. Nordic hafnium relevance is therefore tied to Zr-rich deposits and heavy-mineral systems rather than independent Hf ores. Resource evaluation should focus on zirconium mineralogy, Hf/Zr ratios, separability and whether downstream zirconium processing could support by-product recovery (Latunussa et al., 2020; Carrara et al., 2023; USGS, 2026).

Commodity	Hafnium (Hf)	Data source
Uses of the commodity	<u>Main uses:</u> <i>Superalloys.</i> <u>Defence uses:</u> <i>Electro-optical systems and phased-array radar applications.</i>	USGS (2026)
Resources and potential in the Nordic countries	<i>Known resources (total): 114,241 t Hf. There are no known ores with Hf as a major commodity in the Nordic countries or elsewhere in the world.</i> <i>Greenland: Known resources 107,500 t.</i> <i>Sweden: Known resources 6,741 t.</i> <i>Resource potential: A potentially very large resource at Sokli, Finland. Potential in all Zr-rich mineral resources in the Nordic countries.</i>	Short et al. (2015), Lauri et al. (2018), Latunussa et al. (2020), Eilu et al. (2022), Jonsson et al. (2023), Rosa et al. (2023)
Global production	<i>World primary hafnium production data were not available in USGS Mineral Commodity Summaries 2026. SCRREEN2 estimated annual hafnium production from zirconium ores at about 71 t in 2016, used as the average for 2012–2016.</i>	SCRREEN2 (2024); USGS (2026)
Main producing countries	<i>France and USA are the major hafnium producing countries, with a combined share of more than 85% globally in 2019. France is the major world producer, from imported raw materials, and the only one in the EU, with approximately 35 t; China and India have low-volume domestic production.</i>	SCRREEN2 (2024); USGS (2026)
Nordic concentrator, refinery and smelter production	<i>None</i>	
Geopolitical and defence risk	<i>EU/JRC view: critical in the current EU framework, with SR 1.5 at the processing stage. Defence view: Low risk. Defence applications exist, but overall use is relatively limited, and disruption probability is assessed as low.</i>	Carrara et al. (2023), EU (2024a), Girardi et al. (2023)

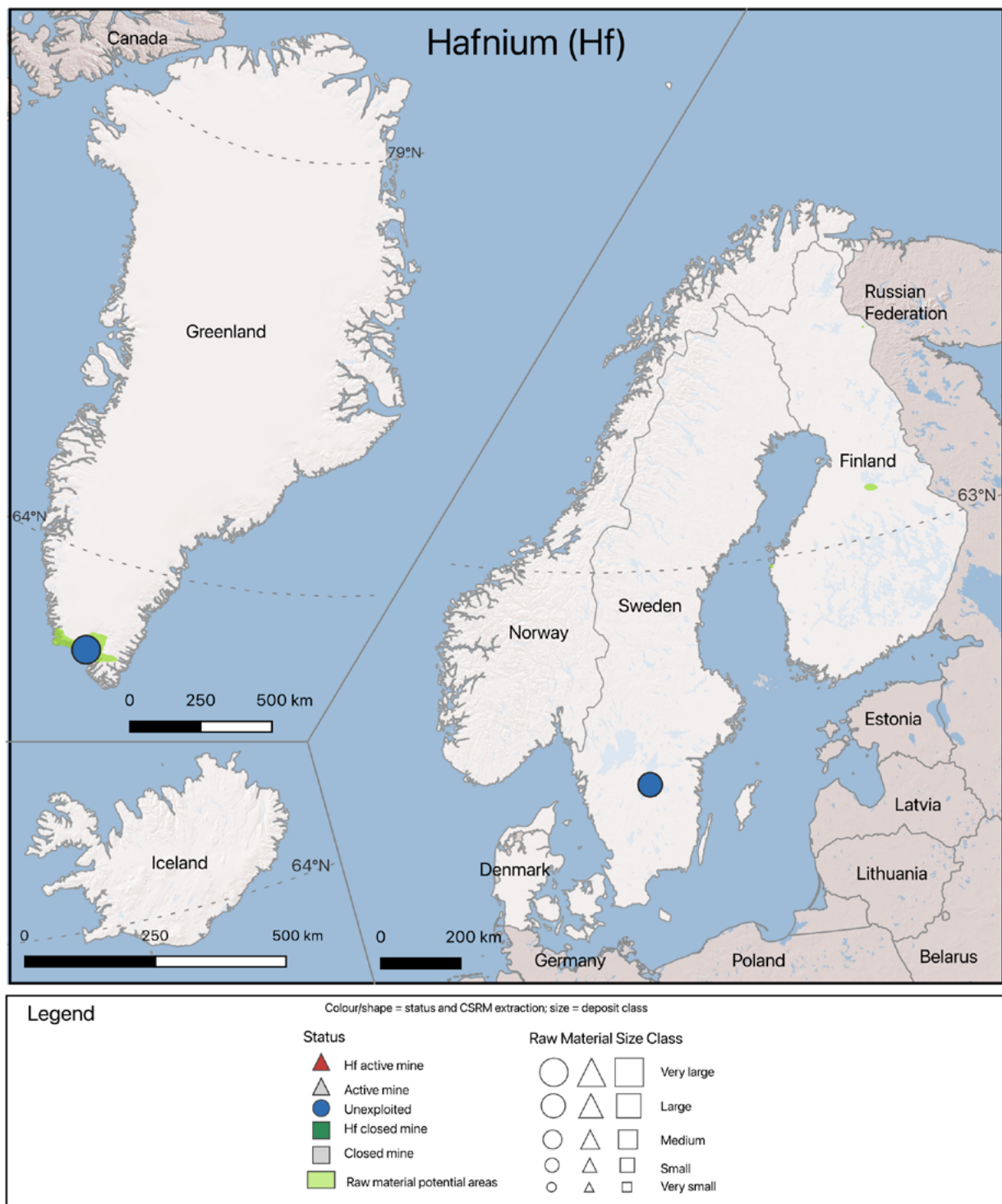


Figure 3.1.14. Locations of deposits with known hafnium resources and areas with known or assumed potential for hafnium resources in the Nordic countries.

3.1.16 Helium (He)

Helium is a non-renewable noble gas mainly recovered from natural-gas systems where it has accumulated geologically. Its low boiling point and chemical inertness make it indispensable for cryogenics, MRI and NMR systems, semiconductor manufacturing, fibre optics, leak detection, welding atmospheres and aerospace applications. MCS 2026 indicates global production concentrated in a few gas-producing countries, creating recurring vulnerability to field outages and liquefaction bottlenecks. Nordic potential is unconventional and poorly quantified, but reported helium in Greenland hot springs, Danish geothermal wells and Finnish deep groundwaters indicates that screening of gas compositions may be warranted where geological traps or deep fluid systems are present (Persoz et al., 1972; Carrara et al., 2023; Rosa et al., 2025; USGS, 2026).

Commodity	Helium (He)	Data source
Uses of the commodity	<u>Main uses:</u> <i>Cryogenics, i.e., as a cooling medium for superconducting magnets in magnetic resonance imaging (MRI) scanners and in nuclear magnetic resonance (NMR) spectrometers, as well in aerospace.</i> <u>Minor uses:</u> <i>Because of its very unreactive nature, helium is also used to provide an inert protective atmosphere for fibre optics and semiconductor manufacturing, and for arc welding. Helium is also used to detect leaks in a variety of industrial settings. In addition, Helium is used as a lifting gas in balloons, weather balloons and airships.</i> <u>Defence uses:</u> <i>Cryogenic systems, controlled atmospheres, leak detection, aerospace support, and specialty laboratory functions relevant to defence and dual-use infrastructure.</i>	USGS (2026)
Resources and potential in the Nordic countries	<i>Known resources (total): not quantified. Helium is known to occur in hot springs in East and South Greenland (with concentrations of 1–2% of the gas fractions), but no potential reservoirs have yet been identified, and no resource estimates have been published. In Denmark, helium up to 2.26% has been reported from the Margrethholm-1 geothermal well, although this remains an occurrence/potential indicator rather than a resource estimate. In Finland, helium has been documented in deep groundwater, drill holes and mines, indicating exploration potential, but no confirmed resource estimate was identified.</i>	Persoz et al. (1972), Pulsar Helium (2023), Rosa et al. (2023), Rosa et al. (2025)
Global production	190 million m ³ .	USGS (2026)
Main producing countries	USA (42%), Qatar (33%), and Algeria (5.8%).	USGS (2026)
Nordic concentrator, refinery and smelter production	<i>No confirmed Nordic helium production was identified. Norway and Denmark produce natural gas, whereas Finland has no domestic fossil natural gas production and relies on imported gas plus domestic biogas/biomethane.</i>	IEA (2023), USGS (2026)
Geopolitical and defence risk	<i>EU/JRC view: critical, not strategic in the current EU framework. Girardi et al. do not classify helium as a strategic raw material for defence; its geopolitical role is linked to concentrated natural-gas-derived supply, liquefaction and storage bottlenecks, and high-purity gas dependence, with USGS also noting aerospace demand and helium-3 use in neutron detectors.</i>	Carrara et al. (2023), EU (2024a), Girardi et al. (2023)



Lithium-bearing tourmalines (elbaite), Varuträsk pegmatite, Sweden. Photo: Martiya Sadeghi.

3.1.17 Lithium (Li)

Lithium is central to lithium-ion batteries for electric vehicles, stationary storage and portable electronics, while established other uses include ceramics, glass, greases and specialty chemicals. IEA scenarios identify lithium as one of the fastest-growing clean-energy metals, with demand strongly tied to battery deployment and grid-scale storage. MCS 2026 indicates rapid mine-supply growth, but a concentrated production base led by Australia, China, Chile and Zimbabwe, with refining especially concentrated in China. Nordic relevance is high, because Finland is advancing the Keliber mine-to-chemicals project and Greenland and Sweden host additional granitic pegmatite potential, making lithium a practical regional supply-chain opportunity (IEA, 2021; Carrara et al., 2023; IEA, 2025a; USGS, 2026).

Commodity	Lithium (Li)	Data source
Uses of the commodity	<u>Main uses:</u> Batteries (approximately 88%), ceramics and glass (approximately 4%), lubricating greases (approximately 2%), mold flux powders in steel continuous casting. <u>Minor uses:</u> Air treatment, pharmaceuticals, polymer production, primary aluminium production, rubber and thermoplastics, light-weight metal alloys, drilling mud and other industrial uses. <u>Defence uses:</u> Li-ion batteries for electric motors and propulsion systems across aircraft, ships, submarines and missiles. <u>Future uses:</u> Demand in batteries, especially EVs and energy-storage systems, is expected to increase strongly.	Warren (2016), USGS (2026)
Resources and potential in the Nordic countries	<u>Known resources (total):</u> 352,697 t Li. <u>Finland:</u> Known resources 113,917 t Li. Assumed ('undiscovered') additional resources: 510,000 t Li. The Keliber project's Syväjärvi mine began operations on 11 February 2026, while the broader project remained in staged commissioning during 2026. <u>Greenland:</u> Known resources 235,600 t Li. The resource potential is much higher than what the known resources suggest. <u>Norway:</u> Resources unknown, probably small (in pegmatites). <u>Sweden:</u> Known resources 3,180 t Li. Potential resources are probably reasonably large, but no assessments have been published.	Kunzendorf et al. (1982), Rasilainen et al. (2018), Gautneb et al. (2020), Eilu et al. (2022), Rosa et al. (2023), Electrive (2026), Sibanye-Stillwater (2026)
Global production	290,000 t, calculated to lithium metal (excludes U.S. production). No statistics available on the production of refined lithium.	USGS (2026)
Main producing countries	Australia 31.7%, China 21.4%, Chile 19.3%, Zimbabwe 9.7%.	Latunussa et al. (2020), USGS (2026)
Nordic concentrator, refinery and smelter production	<u>Finland:</u> The Keliber project's Syväjärvi mine began operations on 11 February 2026, while the broader project remained in staged commissioning during 2026.	Electrive (2026), Sibanye-Stillwater (2026)
Geopolitical and defence risk	<u>EU/JRC view:</u> critical and strategic in the current EU framework, with SR 1.9 at the processing stage. <u>Defence view:</u> Medium risk. Diffuse use in defence battery systems gives it medium impact, but the present disruption probability is assessed as lower than for more concentrated materials.	Carrara et al. (2023), EU (2024a), Girardi et al. (2023)

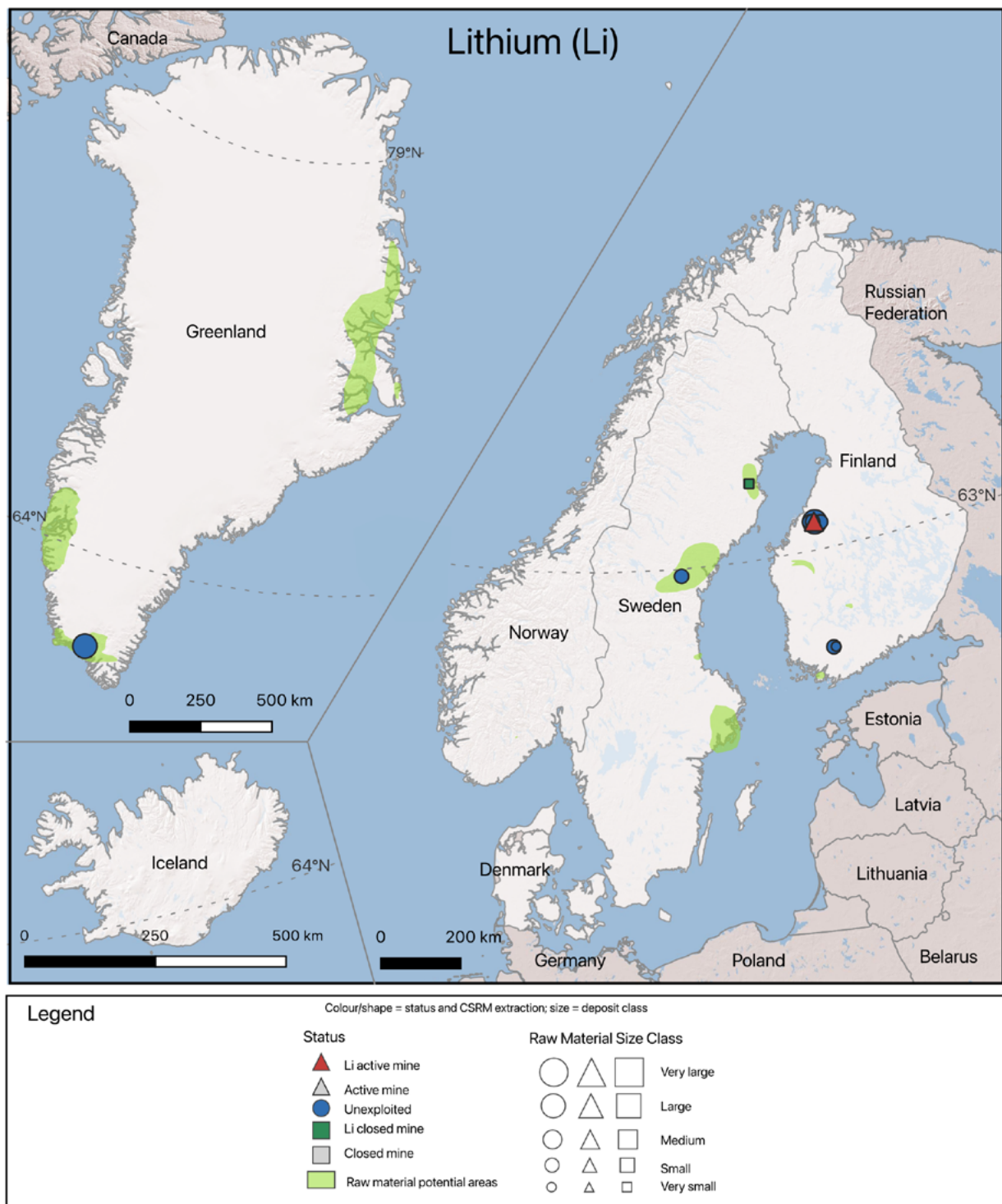


Figure 3.1.15. Locations of lithium-bearing deposits with known resources and areas with known or assumed potential for lithium-bearing mineralisation in the Nordic countries.

3.1.18 Magnesium metal (Mg)

Magnesium metal is primarily used in lightweight aluminium and magnesium alloys for transport, packaging, aerospace and defence applications, and also in desulphurisation, die casting and titanium production. The strategic issue is not a shortage of Mg-bearing minerals, such as dolomite, magnesite or olivine, but the concentration and energy intensity of metal production. MCS 2026 indicates that global smelter output is dominated by China, while Europe currently lacks primary magnesium metal production. The Nordic countries have very large Mg-bearing mineral resources and historical Norwegian production experience, but any renewed supply pathway would need competitive low-carbon energy, suitable feedstock quality and environmental permitting (Latunussa et al., 2020; Carrara et al., 2023; USGS, 2026).

Commodity	Magnesium metal (Mg)	Data source
Uses of the commodity	<u>Main uses:</u> Automotive, packaging, aluminium alloys. <u>Minor uses:</u> Construction, aeronautical. <u>Defence uses:</u> Lightweight alloys and structural components for aerospace, vehicles, and other weight-sensitive defence systems. <u>Future uses:</u> Magnesium metal is an important alloying component for aluminium, and the need for Mg metal is assumed to be linked to aluminium production.	Latunussa et al. (2020)
Resources and potential in the Nordic countries	Known resources (total): 0 t Mg metal. All the Nordic countries have large Mg-bearing mineral resources, including dolomite, magnesite, olivine-rich rocks and dunitic rocks. These materials indicate qualitative potential, but they are not reported here as quantified magnesium-metal resources because conversion to Mg metal depends on the feedstock quality, processing route, energy supply and permitting. Magnesite is therefore treated as a possible feedstock rather than as a directly equivalent Mg-metal resource in the summary statistics. Norsk Hydro had a magnesium plant in operation in Porsgrunn, Norway, from the early 1950s until 2001. Since 2007, there has been no magnesium metal production anywhere in Europe.	Latunussa et al. (2020)
Global production	Mine production for Mg cannot be estimated, since dolomite and magnesite are used for many different applications, and in much larger volumes than for making Mg metal. Magnesium metal production was approximately 1.1 Mt (smelter production).	USGS (2026)
Main producing countries	China 86.4%, Turkey 5.5%, Russia 5.5%, Brazil 1.8% and Israel 1.5% (smelter production).	USGS (2026)
Nordic concentrator, refinery and smelter production	Finland has had moderate magnesite sand production, ranging from 12,276 t to 324,226 t annually during 2013–2022; however, there is no current Nordic magnesium metal production.	Lauri et al. (2018), Tukes (2023)
Geopolitical and defence risk	EU/JRC view: critical and strategic in the current EU framework. Girardi et al. do not classify magnesium metal as a strategic raw material for defence; its geopolitical role is mainly processing concentration, because metal output is highly China-centred and Europe lacks primary magnesium metal production, making lightweight-alloy supply dependent on external smelting capacity and energy-cost exposure.	Carrara et al. (2023), EU (2024a), Girardi et al. (2023)

3.1.19 Manganese (Mn)

Manganese is vital for steel and alloy production, which still accounts for the majority of global manganese use (Eilu et al., 2021; USGS, 2026). Its role in battery chemistries is expanding, especially in EV and stationary storage applications, creating a dual-demand structure in which battery growth is added to a large legacy metallurgical market (IEA, 2021; Eilu et al., 2021). This duality increases pressure on supply prioritisation across steel, alloy and battery value chains (USGS, 2026).

Commodity	Manganese (Mn)	Data source
Uses of the commodity	<u>Main uses:</u> Steel (approximately 97%) <u>Minor uses:</u> Aluminium–manganese and copper–manganese alloys, dry-cell and lithium batteries, pigments, catalysts, fertilizers. <u>Defence uses:</u> Alloy steels and propulsion-related systems, including selected submarine and torpedo applications. <u>Major future uses:</u> Steel; battery use increasing rapidly but remaining minor relative to Mn demand in steel.	Eynard et al. (2020), IMnI (2025), IEA (2025a), SCREEN3 (2025)
Resources and potential in the Nordic countries	<u>Known resources (total):</u> 11,951,240 t Mn, of which Finland has 3,391,240 t Mn, dominated by the Talvivaara deposit (1004 Mt @ 0.30% Mn); the rest is in iron ores in Finland and Sweden. <u>Resource potential:</u> <u>Finland:</u> 3.4 Mt Mn. Major potential is Talvivaara-type Ni–Zn ores, some in BIF. <u>Greenland:</u> No records of Mn occurrences. <u>Iceland:</u> unknown. <u>Norway:</u> Only insignificant Mn occurrences are known from Norway. <u>Sweden:</u> 8.56 Mt Mn. The main potential is in iron deposits; historical primary Mn production from several mines.	Eilu et al. (2021), GTK (2025, 2026), SGU (2026)
Global production	20,000,000 t in Mn content of mined ore. Total smelter production was estimated at around 22 Mt in 2024.	IMnI (2024), USGS (2026)
Main producing countries	<u>Mine production:</u> South Africa 37.7%, Gabon 24.8%, Ghana 9.9%, Australia 7.9%, Brazil 4%, India 3.9%, China 3.5%, Côte d'Ivoire 1.7%. Mn-alloy production predominantly occurs in China; other producers include India, Japan, Malaysia, South Korea, Norway.	IMnI (2024), USGS (2026)
Nordic concentrator, refinery and smelter production	No current mine production in the Nordic countries, whereas Sweden has historical extraction (Långban, Bölet and others). <u>Norway:</u> 490,000 t as ferro-manganese and silico-manganese, both from imported manganese ore.	ERAMET, pers. comm.
Geopolitical and defence risk	<u>EU/JRC view:</u> critical and strategic in the current EU framework, with SR 1.2 at the extraction stage. <u>Defence view:</u> Medium risk. Defence use is present, but application breadth and disruption probability are assessed as below high-risk materials.	Carrara et al. (2023), EU (2024a), Girardi et al. (2023)



Nickel-rich core from the Râna Ni-Cu deposit. Photo: Eduardo Teixeira Mansur.



Figure 3.1.16. Locations of deposits with known manganese resources and areas with known or assumed potential for manganese resources in the Nordic countries.

3.1.20 Nickel (Ni)

Battery-grade nickel falls below the 2023 JRC supply-risk threshold but is listed as a critical raw material in Annex II of the CRMA and as a strategic raw material in Annex I. Nickel is a strategic transition metal with a dual function in stainless steel and battery value chains (IEA, 2021; Eilu et al., 2021). Stainless steel remains the dominant demand segment, while battery demand is increasing for high-energy-density chemistries linked to EV and storage deployment (IEA, 2021). As a result, transition demand does not replace traditional demand; it competes with it, increasing pressure on mining, refining, and class-specific nickel availability (Feltrin et al., 2024; USGS, 2026).

Commodity	Nickel (Ni)	Data source
Uses of the commodity	<u>Main uses:</u> <i>Stainless and alloy steels (>65%).</i> <u>Minor uses:</u> <i>Superalloys, non-ferrous alloys, batteries, electroplating and other coatings, catalysts, chemicals, foundry products.</i> <u>Defence uses:</u> <i>High-performance alloys, naval and aerospace structures, propulsion systems and armoured-platform components.</i> <u>Major future uses:</u> <i>Stainless and alloy steels, batteries (strong demand increase forecast) and other nickel-containing alloys.</i>	Eynard et al. (2020), IEA (2021), Mudd and Jowitt (2022), USGS (2026)
Resources and potential in the Nordic countries	<i>Known resources (total): 10,294,755 t Ni.</i> <i>Known resource figures are minimum estimates, as Ni grades are not known or are only partially known for many shale, PGE and talc deposits that contain potential by-product Ni.</i> <u>Finland:</u> <i>Known resources at 6,884,135 t Ni, undiscovered resources at the regional scale estimated to 5.9 Mt Ni. Additional major potential in Talvivaara-type Ni–Zn–Cu–Co deposits, and in the Sakatti deposit, which is being advanced through permitting.</i> <u>Greenland:</u> <i>Several promising exploration projects for Ni are active, but no resource estimates are yet available. Undiscovered resources at the regional scale estimated to 3.8 Mt Ni.</i> <u>Norway:</u> <i>Known resources at 160,620 t Ni (Ni–Cu magmatic deposits).</i> <u>Sweden:</u> <i>Known resources at 3,250,000 t Ni, plus extensive potential, particularly in shale-hosted deposits.</i>	Rosa et al. (2013), Boyd and Gautneb (2016), Rasilainen et al. (2017), Stensgaard et al. (2018), Eilu et al. (2021, 2022), Rosa et al. (2023), Anglo American Finland (2025)
Global production	<i>3,900,000 t Ni (mine production, roughly equal to refinery and smelter production).</i>	USGS (2026)
Main producing countries	<i>Mining (2024): Indonesia 62.3%, Philippines 9.5%, Russia 5.5%, Canada 3.4%, New Caledonia 3.1%, China 3.1%, Australia 2.6%, Brazil 1.8%.</i> <i>Smelting and refining (2020): China 29%, Indonesia 25%, Russia 6.7%, Japan 6.6%.</i>	Idoine et al. (2022), USGS (2026)
Nordic concentrator, refinery and smelter production	<i>Mine production: Finland 41,958 t. Nickel products: Finland 99,862 t Ni. Refined nickel production: Norway 98,379 t Ni.</i>	Tukes (2025), Nikkelverk (2025)
Geopolitical and defence risk	<i>EU/JRC view: battery-grade nickel is below the 2023 JRC criticality threshold, but listed as critical in Annex II of the CRMA and strategic in Annex I, with SR 0.5 at the processing stage. Defence view: High risk. Nickel is important in defence alloys and systems, while supply exposure remains meaningful though not at the most critical level.</i>	Carrara et al. (2023), EU (2024a), Girardi et al. (2023)

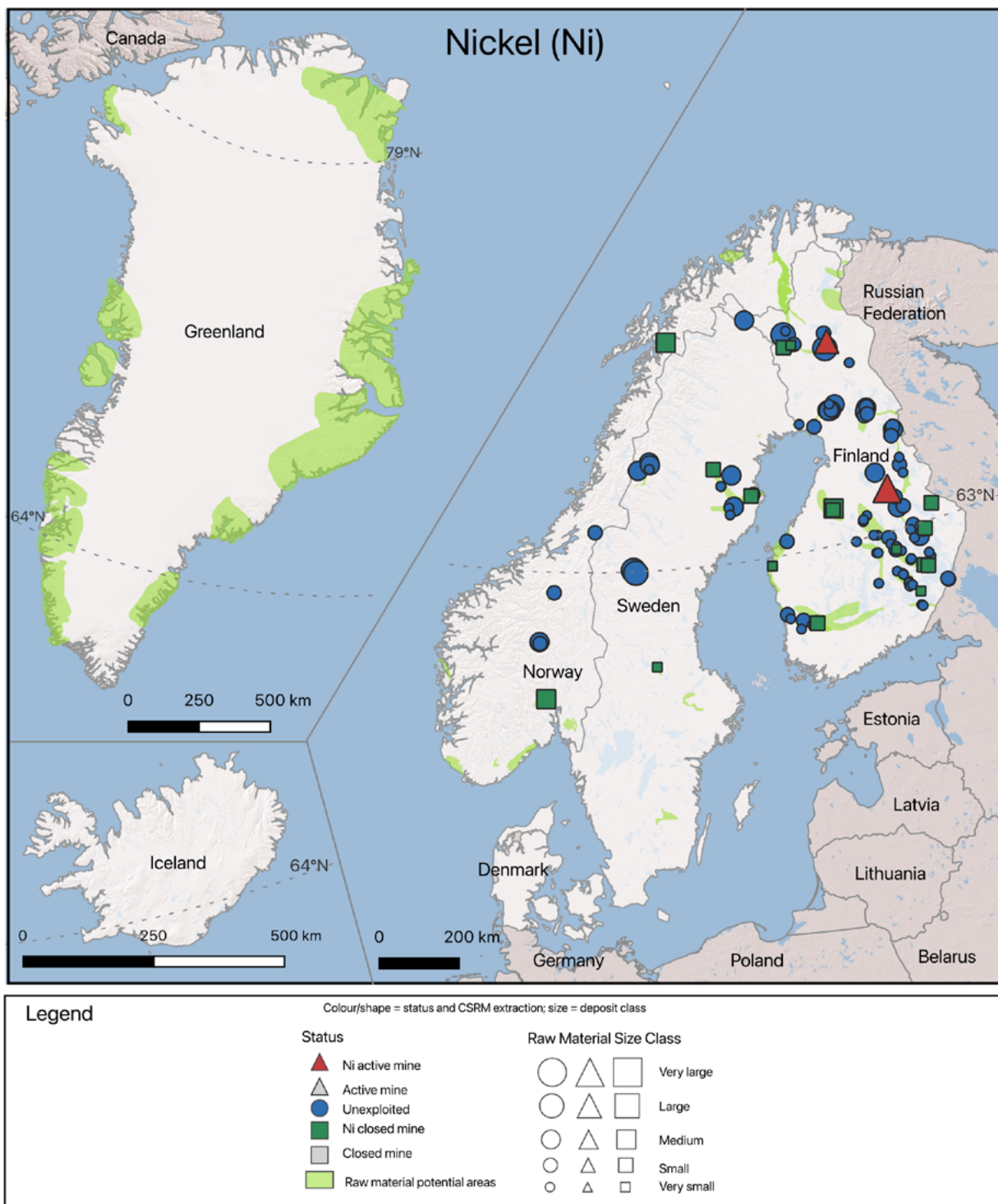


Figure 3.1.17. Locations of deposits with known nickel resources and areas with known or assumed potential for nickel resources in the Nordic countries.

3.1.21 Niobium (Nb)

Niobium is mainly used as ferroniobium in high-strength low-alloy steels, where small additions improve strength, toughness and weight efficiency. It is also used in superalloys, superconductors, catalysts and specialty defence or aerospace components. USGS MCS 2026 indicates an exceptionally concentrated market dominated by Brazil, so supply risk is linked less to geological scarcity than to producer concentration and limited alternative capacity. Nordic potential is associated with carbonatites and alkaline complexes, notably where niobium occurs with tantalum, REEs or phosphorus. The key evaluation issues are mineralogy, the recovery route and whether Nb can be produced as a main product or by-product (Eilu et al., 2021; Carrara et al., 2023; USGS, 2026).

Commodity	Niobium (Nb)	Data source
Uses of the commodity	<u>Main uses:</u> <i>Steels 86% - ferroniobium feedstock used; high-strength low-alloy steel (HSLA).</i> <u>Minor uses:</u> <i>Aerospace applications (superalloys), hard-cutting tools, radio engineering, electronics, chemical apparatus, atomic energy, refractory materials, optical glass, catalysts.</i> <u>Defence uses:</u> <i>Specialised alloys and propulsion-related components in aircraft, helicopters and submarines.</i> <u>Future uses:</u> <i>Superconducting technology, magnets, superalloys. The extensive use of ferroniobium in the production of steel means that future demand is likely to be driven by the construction and automotive sectors.</i>	USGS (2019), Latunussa et al. (2020)
Resources and potential in the Nordic countries	<i>Known resources (total): 6,082,933 t Nb.</i> <u>Country breakdown:</u> <i>Finland: 122,381 t,</i> <i>Greenland: 5,900,000 t,</i> <i>Norway: 22,052 t,</i> <i>Sweden: 38,500 t.</i> <u>Resource potential:</u> <i>Finland: A large potential in the Sokli deposit.</i> <i>Greenland: Additional major potential</i> <i>Norway: Moderate to major potential.</i> <i>Sweden: Potential exists in several types of mineral deposits.</i>	Thrane et al. (2016), Reginiussen et al. (2021), Eilu et al. (2022), Jonsson et al. (2023), Rosa et al. (2023)
Global production	<i>112,000 t Nb</i>	USGS (2026)
Main producing countries	<i>Brazil 93%, Canada 5%</i>	USGS (2026)
Nordic concentrator, refinery and smelter production	<i>None</i>	
Geopolitical and defence risk	<i>EU/JRC view: critical in the current EU framework, with SR 4.4 at the extraction stage. Defence view: Medium risk. Defence use is comparatively limited, keeping impact lower despite some supply concentration concerns.</i>	Carrara et al. (2023), EU (2024a), Girardi et al. (2023)

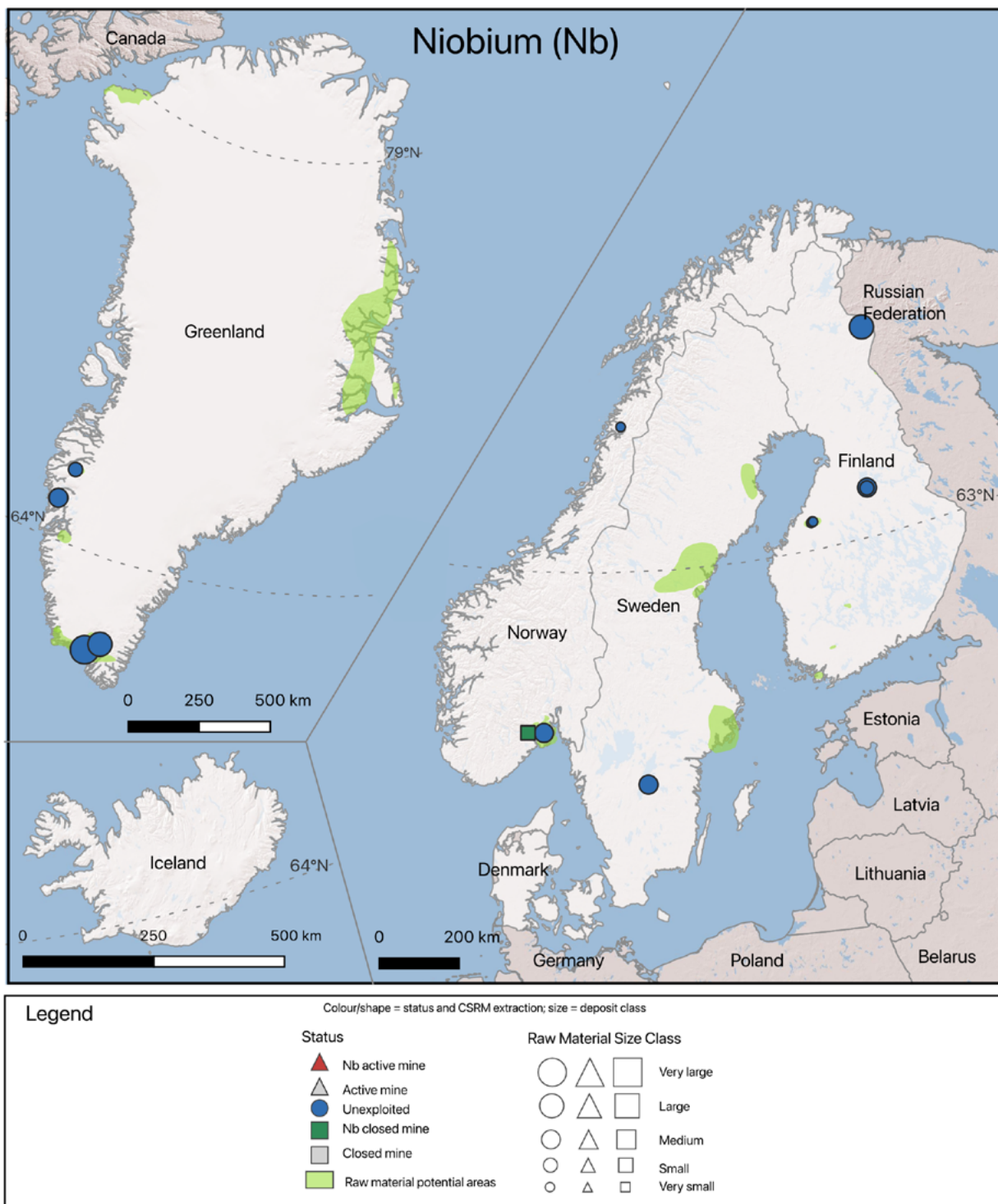


Figure 3.118. Locations of deposits with known niobium resources and areas with known or assumed potential for niobium resources in the Nordic countries.

3.1.22 Phosphorus (P)

Phosphorus underpins food security, because most production is consumed in fertilisers and animal-feed additives, with additional uses in chemicals, detergents, flame retardants and lithium iron phosphate battery cathodes. The strategic issue is the combination of agronomic indispensability, limited substitutability and geographically uneven high-grade phosphorus-bearing resources. MCS 2026 identifies large global reserves but also strong production concentration, while IEA battery outlooks add a transition-related demand pathway through LFP chemistries. For Nordic assessments, phosphorus-bearing deposits are important not only for P but also because some apatite, carbonatite and alkaline systems may carry REE, Nb, Ta, Sc or F by-product potential (Carrara et al., 2023; IEA, 2025a; USGS, 2026).

Commodity	Phosphorus (P)	Data source
Uses of the commodity	<u>Main uses:</u> <i>Fertilisers remain the dominant use. More than 95% of mined phosphate rock is used to produce wet-process and superphosphoric acid feedstocks for ammonium phosphate fertilisers and animal-feed supplements.</i> <u>Minor uses:</u> <i>The remaining balance is used for elemental phosphorus and downstream industrial phosphorus compounds, primarily glyphosate herbicide.</i> <u>Defence uses:</u> <i>White phosphorus munitions for smoke, concealment, and incendiary applications; red phosphorus also supports pyrotechnics and smoke bombs.</i> <u>Future uses:</u> <i>Use in batteries and electronics is expected to increase but remain minor compared with fertilisers.</i>	Latunussa et al. (2020), USGS (2026).
Resources and potential in the Nordic countries	<u>Known resources (total):</u> 343.02 Mt P. <u>Finland:</u> <i>Known resources 219.8 Mt P; Sokli includes a speculative hard-rock resource of about 183.3 Mt P. Siilinjärvi includes measured+indicated JORC resources of about 16.3 Mt P.</i> <u>Greenland:</u> <i>Known resources 11.5 Mt P in carbonatites.</i> <u>Norway:</u> <i>Known resources approximately 53 Mt P. Resources (JORC compliant) include the AMCG-hosted Bjerkreim P-Ti-V deposits in Rogaland (Storeknuten, Øygrei, 44.9 Mt P, JORC), Kodal Fe-Ti-P deposit (1.02 Mt P, JORC).</i> <u>Sweden:</u> <i>Known resources approximately 58.9 Mt P, dominated by apatite-iron oxide ores.</i>	Gustafsson (1979), Noholt et al. (2005), Lauri et al. (2018), Eilu et al. (2021), Eilu et al. (2022), LKAB (2022), Rosa et al. (2023), GTK (2025).
Global production	<i>Global mine production of marketable phosphate rock is estimated at about 250 Mt (up about 5% from 2024). Reported world phosphate production capacity (in P₂O₅ terms) was approximately 63.7 Mt in 2025 and projected to increase to about 71.7 Mt by 2029.</i>	IFDC (2010), Latunussa et al. (2020), USGS (2026).
Main producing countries	<i>China, Morocco, the United States, and Russia remain the leading phosphate-rock producers (descending order). Approximate shares from 2025 mine output are China 44%, Morocco 14.4%, United States 8%, Russia 5.6%, and other countries ~28%. No commensurable refinery-production dataset is reported.</i>	USGS (2026).
Nordic concentrator, refinery and smelter production	<i>Approximately 146,600 t P (Siilinjärvi, Finland). No commensurable Nordic refinery-production dataset is reported.</i>	GTK (2025); Tukes (2025).
Geopolitical and defence risk	<i>EU/JRC view: phosphate rock is critical in the current EU framework, with SR 1.0 at the extraction stage. Girardi et al. do not classify phosphate rock or phosphorus as a strategic raw material for defence; its geopolitical role is broader food-security and industrial-chain leverage, because fertiliser supply, elemental phosphorus and emerging LFP battery demand expose Europe to concentrated high-grade resources, trade policy and processing capacity.</i>	Carrara et al. (2023), EU (2024a), Girardi et al. (2023)

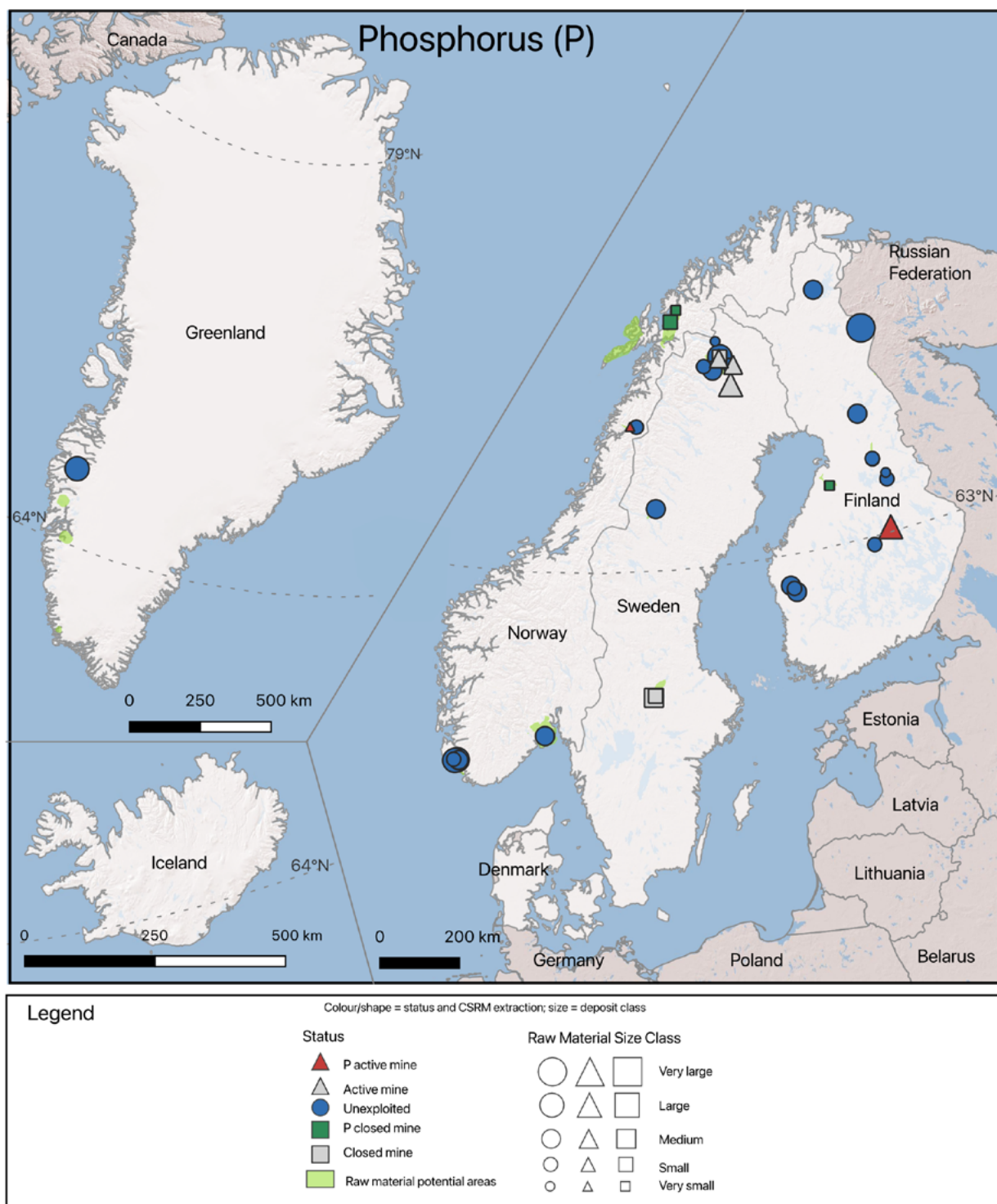


Figure 3.119. Locations of deposits with known phosphorus resources and areas with known or assumed potential for phosphorus-bearing mineralisation in the Nordic countries.

3.1.23 Platinum group metals (Pt, Pd, Rh, Ru, Ir, Os)

Platinum group metals (PGMs) comprise six elements: platinum (Pt), palladium (Pd), rhodium (Rh), ruthenium (Ru), iridium (Ir) and osmium (Os). In production terms, Pt and Pd dominate global PGM output, while Pt, Pd, and Rh are especially important in vehicle exhaust catalysts (e.g., Eilu et al., 2021). More broadly, PGMs are valued for high catalytic performance, corrosion resistance and thermal stability, which supports their use across catalysts, chemicals, electronics and emerging energy applications (EC, 2020). Osmium has comparatively limited technical use, and certain osmium compounds are highly toxic, requiring careful handling (EC, 2020).

Commodity	Platinum group metals (Pt, Pd, Rh, Ru, Ir, Os)	Data source
Uses of the commodity	<i>Main uses: Autocatalysts remain the dominant end-use for PGMs. This segment accounts for approximately 45% of platinum demand and 85–90% of palladium and rhodium demand; PGMs are also key catalysts in bulk chemicals and petroleum refining.</i> <i>Minor uses: Electronics (for example, hard disks, hybridized integrated circuits and multilayer ceramic capacitors), medical and dental devices, glass manufacturing, laboratory equipment, jewellery and investment.</i> <i>Defence uses: Selected catalytic, electronic, and high-performance alloy applications; platinum is explicitly screened in defence-risk mapping.</i> <i>Future uses: Autocatalyst-related demand is expected to weaken structurally as EV penetration rises, with additional pressure from thriftiness and substitution that reduce per-vehicle PGM loadings. Hydrogen applications (fuel cells and electrolyzers) remain a growth option.</i>	Lauri et al. (2018), Johnson Matthey (2020), IEA (2021), Marscheider-Weidemann et al. (2021), USGS (2026), IEA (2025a, 2025b), SCRREEN (2023).
Resources and potential in the Nordic countries	<i>Known resources (total): 1,469.9 t.</i> <i>Known resource figures are minimum estimates, as PGE grades are not known or are only partially known for many shale, Ni and talc deposits that contain potential by-product PGEs. Especially for Ir, Rh, Ru and Os resources, there is scant information.</i> <i>Finland: Known resources: 611.96 t Pd, 278.24 t Pt, and 3.61 t Rh.</i> <i>Greenland: Known resources include approximately 533 t Pd and 42 t Pt (all in the Skaergaard intrusion); there is also PGM potential in other prospects, but no resource estimates have been published.</i> <i>Norway: Known resources include approximately 2.0 t Pd and 2.2 t Pt, dominated by by-product PGEs in the Cu deposit Nussir, with additional PGE-bearing resources at Karenhaugen.</i> <i>Sweden: Known resources include approximately 0.393 t Pd and 0.092 t Pt, mainly from the magmatic Ni–Cu–PGE deposit Lainijaur; Storsjö kapell contributes a small Pd-only by-product estimate.</i>	Rasilainen et al. (2017), Boliden (2020), Eilu et al. (2021), Eilu et al. (2022), Jonsson et al. (2023), Major Precious Metals Corp. and SLR Consulting (2022), GTK (2025).
Global production	<i>World mine production: Pd ~190 t and Pt ~170 t; Rh ~22.52 t, Ir ~7.38 t and Ru ~30.11 t.</i>	Johnson Matthey (2020, 2022); USGS (2026); BGS (2025).
Main producing countries	<i>Palladium (2025): Russia 44.2%, South Africa 36.8%, Canada 8.4%, Zimbabwe 7.9%, USA 3.3% (other countries about 1.5%).</i> <i>Platinum (2025): South Africa 70.6%, Russia 11.8%, Zimbabwe 10.6%, Canada 2.9%, USA 1.1% (other countries about 2.3%).</i> <i>Shares are approximate.</i>	Johnson Matthey (2020, 2022); USGS (2026).
Nordic concentrator, refinery and smelter production	<i>Finland (Kevitsa) reported production of approximately 820 kg Pd and 1,132 kg Pt in 2025 (metal in concentrate), with milled ore of 10,155 kt. Kevitsa ore extraction of 10,706,332 t for 2024. Glencore reports production of 684 kg Pt, 2830 kg Pd and 93 kg Rh from their Integrated Nickel Operations, most of which are assumed to derive from Glencore Nikkelverk in Norway.</i>	Tukes (2025); Boliden (2026). Glencore (2026)
Geopolitical and defence risk	<i>EU/JRC view: PGMs are critical and strategic in the current EU framework, with SR 2.7 at the processing stage. Defence view: High risk at the platinum level. Defence relevance is recognised for platinum, while the broader PGM family is not fully disaggregated in this defence-focused ranking.</i>	Carrara et al. (2023), EU (2024a), Girardi et al. (2023)

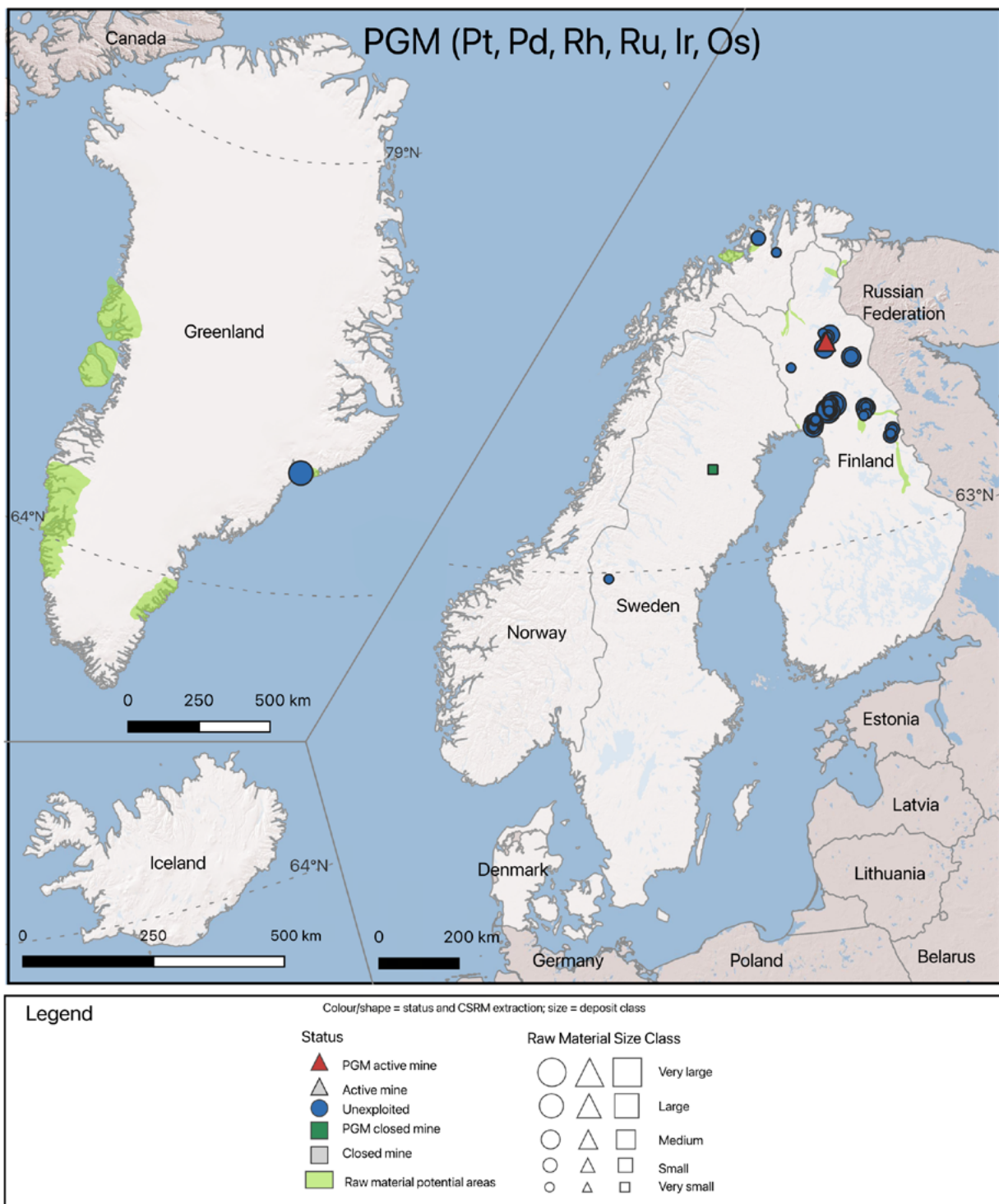


Figure 3.1.20. Locations of deposits with known platinum group metal (PGM) resources and areas with known or assumed potential for PGM resources in the Nordic countries.

3.1.24 Rare earth elements (REEs)

In geological terms, the rare earth elements (REE) comprise yttrium (Y) and the Lanthanide Group of the periodic table of elements (lanthanum to lutetium). The latter are mostly separated into two main groups, the HREE (heavy rare earth elements; Eu, Gd, Tb, Dy, Ho, Er, Tm, Yb, Lu, together with Y), and the LREE (light rare earth elements; La, Ce, Pr, Nd and Sm). Typically, all REEs occur in all REE-bearing deposits, but in highly variable proportions, depending on the geological process(es) that formed a particular deposit. As both the overall abundances and prices of individual REEs vary substantially, the specific contents of the more sought-after ones (such as neodymium (Nd), dysprosium (Dy) or samarium (Sm)) are important factors in determining the economic potential of an REE deposit.

Commodity	Rare earth elements (REEs)	Data source
Uses of the commodity	<u>Main uses:</u> Catalyst, magnets, glass, metallurgy. <u>Minor uses:</u> Batteries, steel, polishing powder, ceramics, phosphorescence. <u>Defence uses:</u> Permanent magnets, electro-optics, radars, lasers, guidance systems and communications equipment. <u>Future uses:</u> Fuel cells, superconductors, magnets, catalysts in hydrogen economy.	USGS (2026), Latunussa et al. (2020), Kalvig (2022)
Resources and potential in the Nordic countries	<u>Known resources (total):</u> 49,998,916 t REE. Country breakdown: Finland 169,067 t REE, Greenland 33,749,590 t REE, Norway 12,880,090 t REE, Sweden 3,200,169 t REE. <u>Resource potential:</u> <u>Finland:</u> Additional 'undiscovered' resources 1.5 Mt REE. REE endowment in the Sokli carbonatite assumed to be very large, but figures have not been published. <u>Greenland:</u> The Ilimaussaq intrusion hosts two of world's largest known REE's deposits (Kringlerne and the Kvanefjeld deposits), with total resources of 33 Mt REE. Other important deposits with resource estimations include the Motzfeldt and the Sarfartoq deposits. Several important occurrences have been identified in carbonatites and alkaline intrusions, which may contain additional REE resources. <u>Norway:</u> The Fen carbonatite is a major European REE deposit currently undergoing exploration. Two JORC-compliant mineral resources of (1) 1083 Mt @ 1.31% TREO (inferred) and 123 Mt @ 1.35% TREO (indicated), and (2) 95 Mt @ 1.3% TREO (inferred) have been released. Additional resources may be hosted by REE-rich apatite in Norwegian phosphate deposits. <u>Sweden:</u> The Norra Kärr deposit is one of Europe's largest HREE resources, while LKAB's present projects, including the Per Geijer, Kiruna and Malmberget deposits, represent significant near-future resources. The Olserum project represents a unique deposit type rich in HREE and is undergoing development. Additional potential is large and includes apatite-iron oxide and skarn-type ores, as well as related mine waste.	Paulick et al. (2015); Steenfelt et al. (2016), Lauri et al. (2018); Jonsson et al. (2019), Jonsson (2020), Golder Associates (2021), LKAB (2021, 2023), Eilu et al. (2022), Kalvig (2022), Jonsson et al. (2023), Rosa et al. (2023), GTK (2025)
Global production	390,000 t (REE, mine production) (2025).	USGS (2026)
Main producing countries	China 69.2%, USA 13.8%, Australia 7.4%, Myanmar (Burma) 5.6% (Myanmar contributes to a significant part of global HREE production, exact figures not known).	USGS (2026)
Nordic concentrator, refinery and smelter production	Norway: Norwegian company REEtec is currently completing an industrial-scale REE separation plant after running a demonstration plant since 2019. Swedish LKAB is the largest shareholder in REEtec and is developing an REE-P processing facility in Luleå, Sweden.	
Geopolitical and defence risk	EU/JRC view: REEs are among the most geopolitically exposed materials in the EU assessment; LREE SR is 3.7 and HREE SR is 5.1, both critical and strategic, with major exposure at the processing stage. Defence view: High risk overall. Defence-focused mapping places Nd, Sm and Y in HM classes, while Dy, La, Pr and Tb are in HL classes, indicating broad strategic sensitivity across magnet and electronics applications.	Carrara et al. (2023), EU (2024a), Girardi et al. (2023), Reuters (2025c)

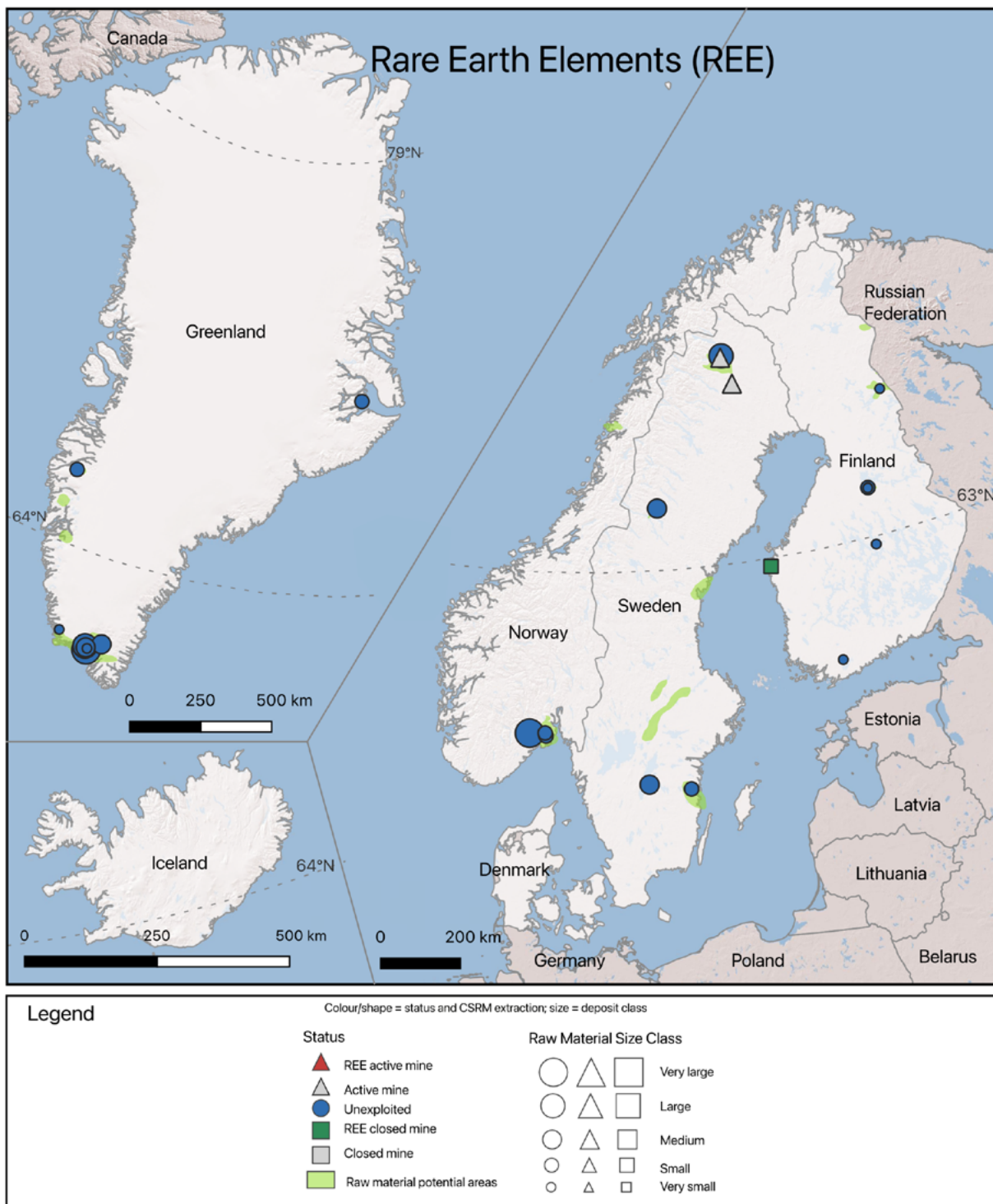


Figure 3.1.21. Locations of deposits with known rare earth element (REE) resources and areas with known or assumed potential for REE resources in the Nordic countries. The legend distinguishes active mines where REE are present but not presently recovered (grey triangles) or were recovered from past operations (green square). Currently there is no active production/recovery of REEs (red triangle) in the Nordic countries.

3.1.25 Scandium (Sc)

Scandium is a small-market metal with high strategic interest because minor additions can strengthen aluminium alloys for aerospace, transport and additive manufacturing, while scandium-stabilised zirconia (ZrO₂) is used in solid oxide fuel cells. It is produced almost exclusively as a by-product from residues, tailings and process streams, rather than from any existing scandium mines, so supply depends on industrial integration and willingness to recover low-volume products. MCS 2026 reports limited global scandium oxide production and a narrow producer base. Nordic relevance lies in identifying Sc enrichment in laterites, bauxite-like residues, Ti-Fe-V systems, carbonatites, tailings and hydrometallurgical streams where recovery could be technically and economically feasible (Latunussa et al., 2020; Carrara et al., 2023; USGS, 2026).

Commodity	Scandium (Sc)	Data source
Uses of the commodity	<u>Main uses:</u> <i>Solid-oxide fuel cells (SOFCs) and aluminium-scandium alloys, especially in aerospace applications.</i> <u>Minor uses:</u> <i>Electronics, lasers, lighting, radioactive isotopes and specialised alloys for military equipment and sporting goods.</i> <u>Defence uses:</u> <i>Light-weight high-performance alloys for aerospace and other specialised defence components.</i> <u>Future uses:</u> <i>Al-Sc alloys, fuel cells, aerospace applications, electronics.</i>	Latunussa et al. (2020), USGS (2026)
Resources and potential in the Nordic countries	<i>Known resources (total): 2,190.5 t Sc.</i> <i>Finland: Known resources: 2,184 t in the Kiviniemi deposit, possible additional potential in Ti, REE and P deposits.</i> <i>Greenland: Sparse indications of Sc occurrences, including small pegmatites; possible potential exists in REE, P and Ti deposits.</i> <i>Norway: Known resources: 6.5 t, possible potential in Ti, Nb, REE and P deposits.</i> <i>Sweden: Sparse indications of Sc occurrences, including small pegmatites; possible potential exists in REE, P and Ti deposits.</i> <i>The resource figures above are very conservative minimum estimates; Sc grades are not known for most of the Nordic Ti, Nb, REE and P deposits.</i>	Åmli (1977), Hokka and Halkoaho (2016), FODD (2020), Eilu et al. (2021, 2022), GTK (2025)
Global production	<i>According to industry estimates, global scandium oxide production totalled approximately 80 t in 2025. Scandium was exclusively produced as a by-product, primarily from nickel and titanium process streams and from previously processed tailings and residues.</i>	USGS (2026)
Main producing countries	<i>China was the leading producer in 2025 and likely accounted for roughly 80–90% of global scandium oxide output, based on USGS 2026 global production context and 2024 Asian Metal industry estimates. Scandium materials were also produced in the Philippines and sent to Japan for further processing into scandium oxide.</i>	USGS (2026), Asian Metal (2025)
Nordic concentrator, refinery and smelter production	<i>No current mine nor refinery or smelter production.</i>	Latunussa et al. (2020)
Geopolitical and defence risk	<i>EU/JRC view: critical in the current EU framework, with SR 2.4 at the processing stage. Girardi et al. do not classify scandium as a strategic raw material for defence; its geopolitical role is now visible in industrial policy rather than bulk use, with USGS reporting Chinese export controls, U.S. DPA funding for gallium-scandium recovery, and planned Defense Logistics Agency procurement for the National Defense Stockpile.</i>	Carrara et al. (2023), EU (2024a), Girardi et al. (2023)



Figure 3.1.22. Locations of deposits with known scandium resources and areas with known or assumed potential for scandium resources in the Nordic countries.

3.1.26 Silicon metal (Si)

Silicon metal, the elemental form of silicon, only occurs as an extreme rarity in its native metal form in nature and is primarily produced from high-purity quartz (SiO₂) in energy-intensive electric furnaces. Quartz is reduced with carbon reductants (e.g., coke, charcoal) at high temperatures, producing molten silicon (~98.5% purity), then refined to metallurgical grade (~99%); ultra-high-purity silicon for semiconductor and solar uses is produced through routes such as the Siemens process (EC, 2020). The electricity price is a key viability factor, with lower-tariff systems generally improving competitiveness (EC, 2020). In the Nordic context, Iceland illustrates this link between renewable power access and silicon processing capacity, including Elkem at Akranes and the PCC Bakki silicon metal plant near Husavik (Feltrin et al., 2024).

Commodity	Silicon metal (Si)	Data source
Uses of the commodity	<u>Main uses:</u> <i>Silicon and silane chemicals (54%) aluminium alloys (38%), solar photovoltaic (6%).</i> <u>Minor uses:</u> <i>Semiconductors</i> <u>Defence uses:</u> <i>Semiconductors and electronics used in sensors, communications and broader platform systems.</i> <u>Future uses:</u> <i>Photovoltaic and semiconductor demand assumed to increase most. Other demand steady.</i>	Latunussa et al. (2020)
Resources and potential in the Nordic countries	<u>Known resources (total):</u> <i>15.0 Mt Si. Greenland 2.8 Mt; Norway 11.7 Mt; Sweden 0.5 Mt.</i> <u>Finland:</u> <i>A large number of small quartz vein occurrences with at least some having a potential for high-purity quartz, but none with a resource estimate.</i> <u>Greenland:</u> <i>Numerous occurrences but no data on the quartz quality, except for the Ivittuut deposit.</i> <u>Norway:</u> <i>Extensive additional potential across the country.</i> <u>Sweden:</u> <i>Some potential in parts of Sweden.</i>	Elkem (2026), Jonsson et al. (2023), Rosa et al. (2023), GTK (2025)
Global production	<i>4.6 Mt of Si metal; 5.0 Mt of ferrosilicon.</i>	USGS (2026)
Main producing countries	<i>China 87%, Brazil 3.9%; Norway 2.8% (smelting, refining, Si metal).</i>	USGS (2026)
Nordic concentrator, refinery and smelter production	<i>1.0 Mt (mined) and 200,000 t imported quartz. Norway: 300.000 t (metal), Iceland: 124,000 t (metal equivalent in 2024).</i>	Elkem (2026), Icelandic Environment and Energy Agency (2026)
Geopolitical and defence risk	<i>EU/JRC view: critical and strategic in the current EU framework, with SR 1.4 at the processing stage. Defence view: High risk. Defence use is narrower than top-tier materials, but supply concentration gives silicon metal a high disruption probability.</i>	Carrara et al. (2023), EU (2024a), Girardi et al. (2023)

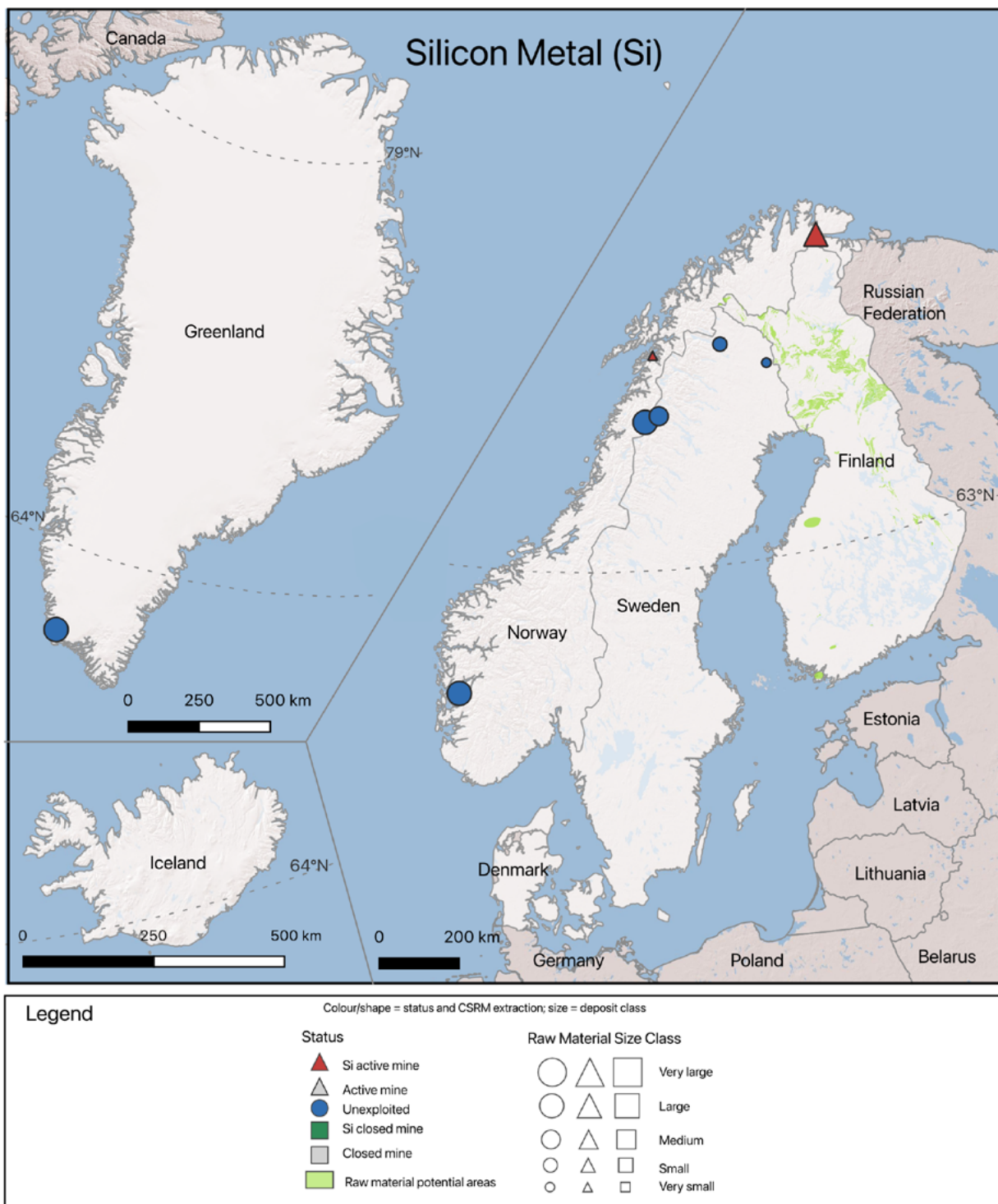


Figure 3.1.23. Locations of quartz resources and areas with known or assumed potential for quartz associated with pegmatites (of probable high-purity) and quartzites suitable for silicon-metal production in the Nordic countries.

3.1.27 Strontium (Sr)

Strontium is used mainly in ferrite magnets, pyrotechnics, ceramics, glass, drilling fluids and specialty chemicals, with celestine (SrSO₄) as the principal ore mineral. The market is relatively small, and criticality is driven by the concentration of mine production, limited processing capacity and the lack of easy substitutes in some colour, magnet and chemical applications. MCS 2026 reports production concentrated in a small group of countries, including Spain, China, Iran and Mexico. Nordic strontium potential is not generally a stand-alone exploration target, but Sr should be tracked in carbonate, evaporite, baryte-fluorite and alkaline systems where celestine or other Sr-bearing minerals may occur (Latunussa et al., 2020; Carrara et al., 2023; USGS, 2026).

Commodity	Strontium (Sr)	Data source
Uses of the commodity	<u>Main uses:</u> <i>Ceramic ferrite magnets and pyrotechnics/signals.</i> <u>Minor uses:</u> <i>Drilling fluids, master alloys, glass, pigments and fillers.</i> <u>Defence uses:</u> <i>Pyrotechnics, tracer ammunition and signalling compounds.</i> <u>Future uses:</u> <i>Strontium will remain an important material for magnets, ceramics, glass and pyrotechnics manufacturing. However, its use in drilling fluids is subject to baryte prices and hydrocarbon demand. Ongoing research on strontium in optical applications or semiconductors might result in new end uses.</i>	Latunussa et al. (2020), USGS (2026)
Resources and potential in the Nordic countries	<i>Known resources (total): 9.8 Mt Sr. Greenland 9.8 Mt of Sr in celestine.</i>	Harpøth et al. (1986)
Global production	<i>450,000 t mine production, as contained Sr metal.</i>	USGS (2026)
Main producing countries	<i>Iran 55%, Spain 22%, China 18%, Mexico 4.4%.</i>	USGS (2026)
Nordic concentrator, refinery and smelter production	<i>None</i>	USGS (2026)
Geopolitical and defence risk	<i>EU/JRC view: critical in the current EU framework, with SR 2.6 at the extraction stage. Girardi et al. do not classify strontium as a strategic raw material for defence; its geopolitical role is tied to critical-chemical and energetic-material supply (including tracer ammunition), because USGS records DPA-linked funding for domestic production of strontium nitrate, oxalate and peroxide and shows concentrated celestine and compound import channels.</i>	Carrara et al. (2023), EU (2024a), Girardi et al. (2023)



Figure 3.1.24. Locations of deposits with known strontium resources and areas with known or assumed potential for strontium resources in the Nordic countries.

3.1.28 Tantalum (Ta)

Tantalum is a high-value metal used in capacitors, electronics, superalloys, corrosion-resistant equipment, medical implants and defence-relevant high-temperature components. It is commonly produced from tantalite–columbite mineral concentrates, from placers or primary evolved lithium–caesium–tantalum-type granitic pegmatites and tin slags, and its supply chain has long been associated with artisanal mining, conflict-mineral controls and traceability requirements. MCS 2026 indicates mine production concentrated in a limited set of countries, with Rwanda, the Democratic Republic of the Congo and Nigeria prominent. Nordic potential is mainly linked to evolved granitic pegmatites (with Ta>Nb) and alkaline-carbonatite systems (typically with Nb>>Ta), where Ta may occur with Li, Nb, Sn, REEs or feldspar and require careful mineralogical assessment (Latunussa et al., 2020; Reginiussen et al., 2021; JRC, 2022; Carrara et al., 2023; USGS, 2026).

Commodity	Tantalum (Ta)	Data source
Uses of the commodity	<u>Main uses:</u> Capacitors 33%, superalloys 22%, sputtering targets 17%. <u>Minor uses:</u> Carbides, medical products, chemicals. <u>Defence uses:</u> Capacitors, electronics, radar, guidance and other high-reliability defence components. <u>Future uses:</u> Computer equipment and other uses in electronics, aerospace, sources of gamma radiation.	Rare metals in the world market (2008), BRGM et al. (2017), USGS (2019)
Resources and potential in the Nordic countries	<u>Known resources (total):</u> 916,567 t Ta. Country breakdown: <u>Finland:</u> 499 t Ta (Rosendal: 1.3 Mt @ 0.021% Ta); major potential in the Sokli carbonatite. <u>Greenland:</u> 916,000 t Ta; additional large potential in several alkaline intrusions. <u>Norway:</u> Different Ta-rich oxides in pegmatites (e.g., Evje-Iveland district), but no quantified resources. <u>Sweden:</u> 68 t Ta; resources in granitic pegmatites in Finland and Sweden are open at depth, as the drilling typically only extends to 50–100 m below the surface.	Lauri et al. (2018); Reginiussen et al. (2021), Eilu et al. (2022), Rosa et al. (2023), GTK (2025)
Global production	1,500 t Ta (processing-stage global production, 2019–2023 average).	SCREEN3 (2025)
Main producing countries	DRC 43%, Brazil 18.5%, Rwanda 17.5%, Nigeria 5.5%, and China 3.9% (note that artisanal mining dominates and related smuggling across borders is commonplace in Africa, so country statistics are probably not correct).	USGS (2023)
Nordic concentrator, refinery and smelter production	None	USGS (2023)
Geopolitical and defence risk	EU/JRC view: critical in the current EU framework, with SR 1.3 at the extraction stage. Defence view: High risk. Tantalum is important in defence electronics and components, with concentrated and politically sensitive supply chains increasing the disruption risk.	Carrara et al. (2023), EU (2024a), Girardi et al. (2023)

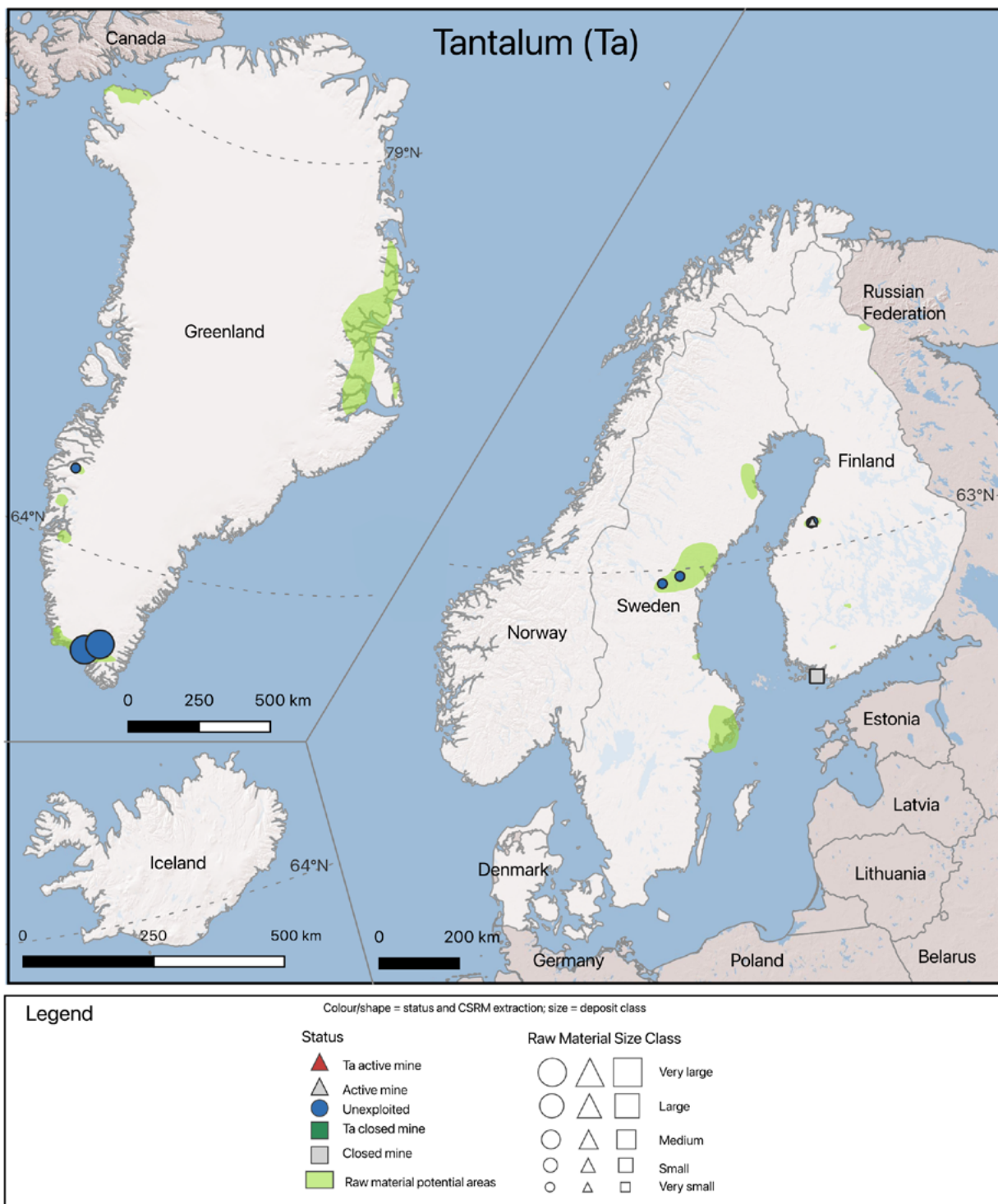


Figure 3.1.25. Locations of deposits with known tantalum resources and areas with known or assumed potential for tantalum resources in the Nordic countries.

3.1.29 Titanium (Ti)

Ilmenite accounts for approximately 90% of global titanium-mineral consumption, with the remainder mainly from rutile and anatase (Eilu et al., 2021; USGS, 2026). Global resources of anatase, ilmenite and rutile exceed 2 billion tonnes, and identified reserves of titanium in ilmenite and rutile are estimated at more than 540 million tonnes (TiO₂-content basis) (USGS, 2026). The principal end use is TiO₂ production, while only a smaller share of mined titanium minerals is converted into titanium metal (Eilu et al., 2021; USGS, 2026). In 2025, world mine output was approximately 9.8 million tonnes (TiO₂ content) from ilmenite and rutile combined; China remained the leading producer, followed by major producers including Mozambique and South Africa (USGS, 2026). Ilmenite, "leucoxene", rutile, slag and synthetic rutile continue to compete as feedstocks for TiO₂ pigment, titanium metal and welding-rod coatings (USGS, 2026). High-titanium feedstocks, such as rutile, anatase or high-Ti ilmenite, are generally required for high-quality titanium metal production (BGR, 2019).

Commodity	Titanium (Ti)	Data source
Uses of the commodity	Main uses: <i>Aerospace applications (Ti metal); paints, plastics and paper (TiO₂ pigment).</i> Minor uses: <i>Armor, chemical processing, marine hardware, medical implants, power generation, automotive, hardmetal and other alloy uses (Ti metal); catalysts, ceramics, coated fabrics and textiles, floor coverings, printing ink and roofing granules (TiO₂ pigment).</i> Defence uses: <i>Airframes, naval platforms, armour, propulsion-adjacent systems and high-performance aerospace structures.</i> Future uses: <i>Alloy use expected to increase in aerospace, automotive and construction; this implies potentially higher Ti metal demand.</i>	Latunussa et al. (2020), JRC (2022), USGS (2026)
Resources and potential in the Nordic countries	Known resources (total): 284.9 Mt Ti. Finland: Known resources: 24.1 Mt Ti. Otanmäki deposit: 14 Mt @ 7.6% Ti; Koivusaarenneva: 62.15 Mt @ 4.36% Ti. 'Undiscovered resources' at the regional scale estimated at 380 Mt Ti. Greenland: Known resources: 11.9 Mt Ti. Isortoq N dyke 70.3 Mt @ 6.53% Ti, 0.081% V, 26.9% Fe; Moriusaq heavy-mineral sand: 117 Mt @ 1.7% Ti. 'Undiscovered resources' at the regional scale estimated at 65 Mt Ti. Iceland: Minor potential for on- and offshore heavy-mineral sands derived from gabbro intrusions, Lón district, SE Iceland. Norway: Known resources: 230 Mt, mainly in the Bjerkreim-Sokndal intrusion (Storeknuten 3167 Mt @ 2.72% Ti, Øygrei 1256 Mt @ 2.88% Ti). Engebøfjellet (rutile) 387.3 Mt @ 1.96% Ti. Tellnes 570 Mt @ 10.8% Ti, Storgangen 60 Mt @ 10.2% Ti. Very large potential for further hard-rock-hosted rutile deposits in the Sunnfjord region, also hosting the Engebø deposit. Sweden: Known resources: 18.93 Mt Ti. Routivare malmfält 140 Mt @ 5.7% Ti, 0.2% V.	Eilu et al. (2021, 2022), Rosa et al. (2023), Jonsson et al. (2023), Newman (2015), GTK (2025)
Global production	370,000 t Ti sponge metal production.	USGS (2026)
Main producing countries	Mining (2025), TiO₂, ilmenite: Total 9.4 Mt, China 34%, Mozambique 20.2%, South Africa 13.8%, Australia 8.3%, Norway 4.1%, Senegal 3.9%, Canada 3.8%. Rutile: Total 0.45 Mt, Australia 44.4%, Sierra Leone 24.4%, South Africa 22.2%. Ti sponge (2025): China 70%, Japan 14.3%, Russia 6.8%, Kazakhstan 4.3%, Saudi Arabia 3.2%.	USGS (2026)
Nordic concentrator, refinery and smelter production	Parts of rutile production from Engebø are planned to be used for Ti sponge (in Japan). Capacity at Engebø after ramp-up is 35 ktpa rutile, equivalent to 7–8% of world rutile production. 390,000 t Ti (mine production for pigment, all from Norway); 36,000 t TiO ₂ (refinery to titan slag from imported ore, all from Norway).	
Geopolitical and defence risk	EU/JRC view: titanium metal is critical and strategic in the current EU framework, with SR 1.6 at the processing stage. Defence view: High risk. Titanium is widely relevant in defence aerospace and platform manufacturing, but current supply diversification keeps it below the very highest risk class.	Carrara et al. (2023), EU (2024a), Girardi et al. (2023)

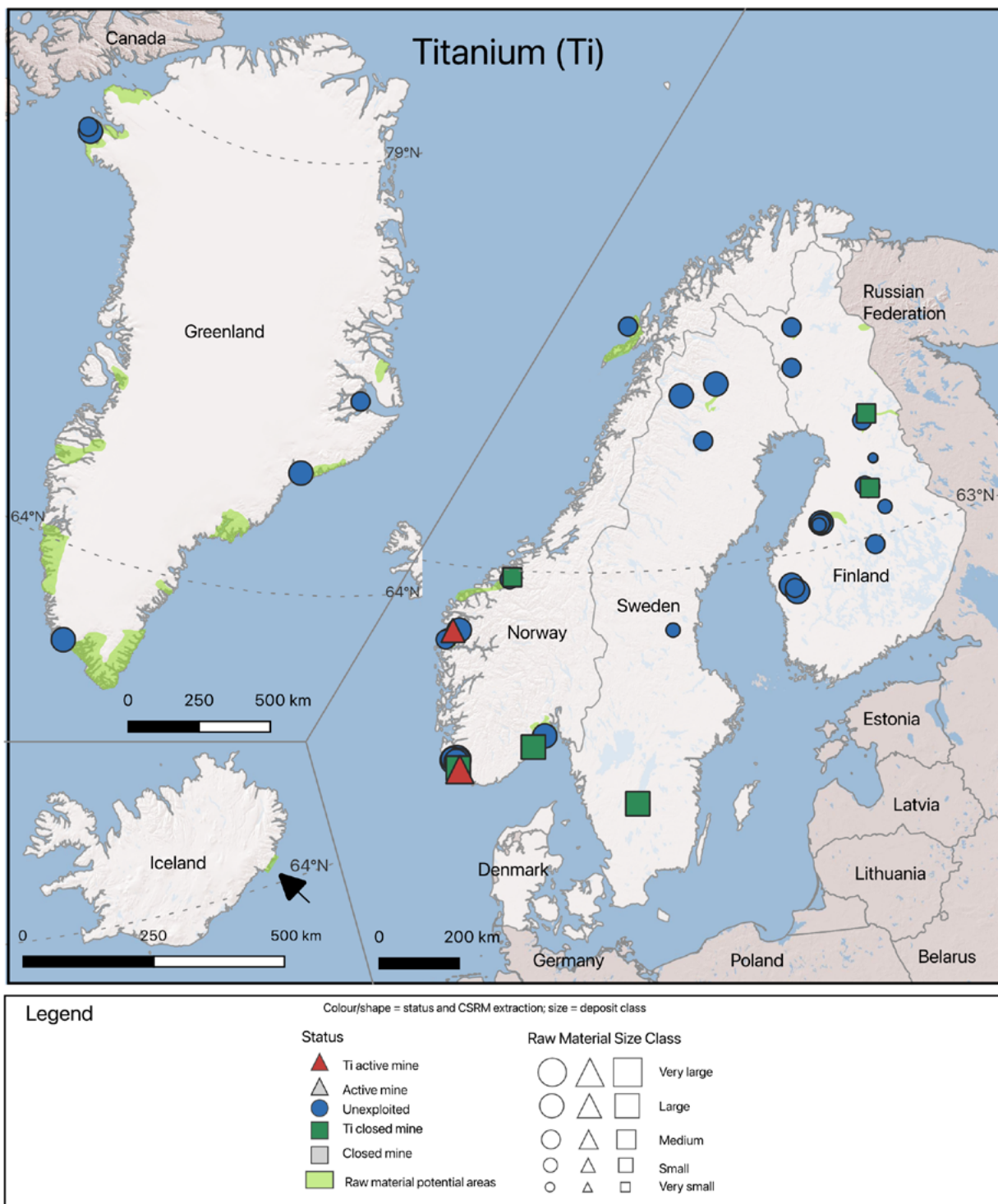


Figure 3.1.26. Locations of deposits with known titanium resources and areas with known or assumed potential for titanium resources in the Nordic countries. The associated resource-potential area in Iceland is assumed to be very small and is hence indicated by a black arrow.

3.1.30 Tungsten (W)

Tungsten has the highest melting point of all metals and is valued for its hardness, density and high-temperature performance. It is used in cemented carbides for cutting, drilling and mining tools, in wear-resistant alloys, electrodes, electronics, radiation shielding and defence applications. MCS 2026 indicates that mine supply remains heavily concentrated in China, with additional production from Vietnam, Russia, Rwanda and other countries. Nordic tungsten potential is significant in skarn, vein and greisen systems, including historic mining districts and polymetallic deposits. The main development questions are grade, scheelite versus "wolframite" (ferberite-hübnerite series) mineralogy, by-product associations and access to downstream APT or powder processing (Eilu et al., 2021; Carrara et al., 2023; USGS, 2026).

Commodity	Tungsten (W)	Data source
Uses of the commodity	<u>Main uses:</u> <i>Tungsten carbide (67%) for use in mill and cutting tools as well as mining and construction tools. Alloy steel and tungsten alloys (11%).</i> <u>Minor uses:</u> <i>Chemical applications, catalysts and pigments, electronics and lighting, X-ray tubes, superalloys, radiation shielding, military applications, aeronautics and energy.</i> <i>Defence uses: Hard metals, radiation shielding, aeronautics, military systems and specialised heavy-alloy applications.</i> <u>Future uses:</u> <i>Growing uses: automotive industry, industrial engineering, mining and construction, aviation and energy.</i>	Latunussa et al. (2020), USGS (2022)
Resources and potential in the Nordic countries	<i>Known resources (total): 32,801 t W.</i> <u>Finland:</u> <i>Known resources 2,300 t W. Finland-listed examples include Ahvenlammi: 1.12 Mt @ 0.156% W and Kuskioiva: 0.30 Mt @ 0.10% W. The known resources and occurrences suggest a minor additional resource potential.</i> <u>Greenland:</u> <i>Known resources 26,030 t W. Assumed undiscovered additional resources at the regional scale estimated at 501,000 t W; several tungsten deposits in central East Greenland.</i> <u>Norway:</u> <i>Known resources 2,701 t W. Known resources suggest additional resource potential.</i> <u>Sweden:</u> <i>Known resources 1,770 t W. Large remaining potential in Bergslagen, south central Sweden.</i>	Harpøth et al. (1986), Sørensen et al. (2014), Eilu et al. (2021, 2022), Rosa et al. (2023), GTK (2025, FINODD)
Global production	<i>85,000 t (mine production)</i>	USGS (2026)
Main producing countries	<i>China 79%, Vietnam 3.5%, Russia 2.4%, Bolivia 2%, Rwanda 1.5% (mine production).</i>	USGS (2026)
Nordic concentrator, refinery and smelter production	<i>No production</i>	
Geopolitical and defence risk	<i>EU/JRC view: critical and strategic in the current EU framework, with SR 1.2 at the processing stage. Defence view: High risk. Tungsten is important in military and aerospace applications and remains exposed to concentrated supply and geopolitical leverage.</i>	Carrara et al. (2023), EU (2024a), Girardi et al. (2023), MOFCOM & GACC (2025)

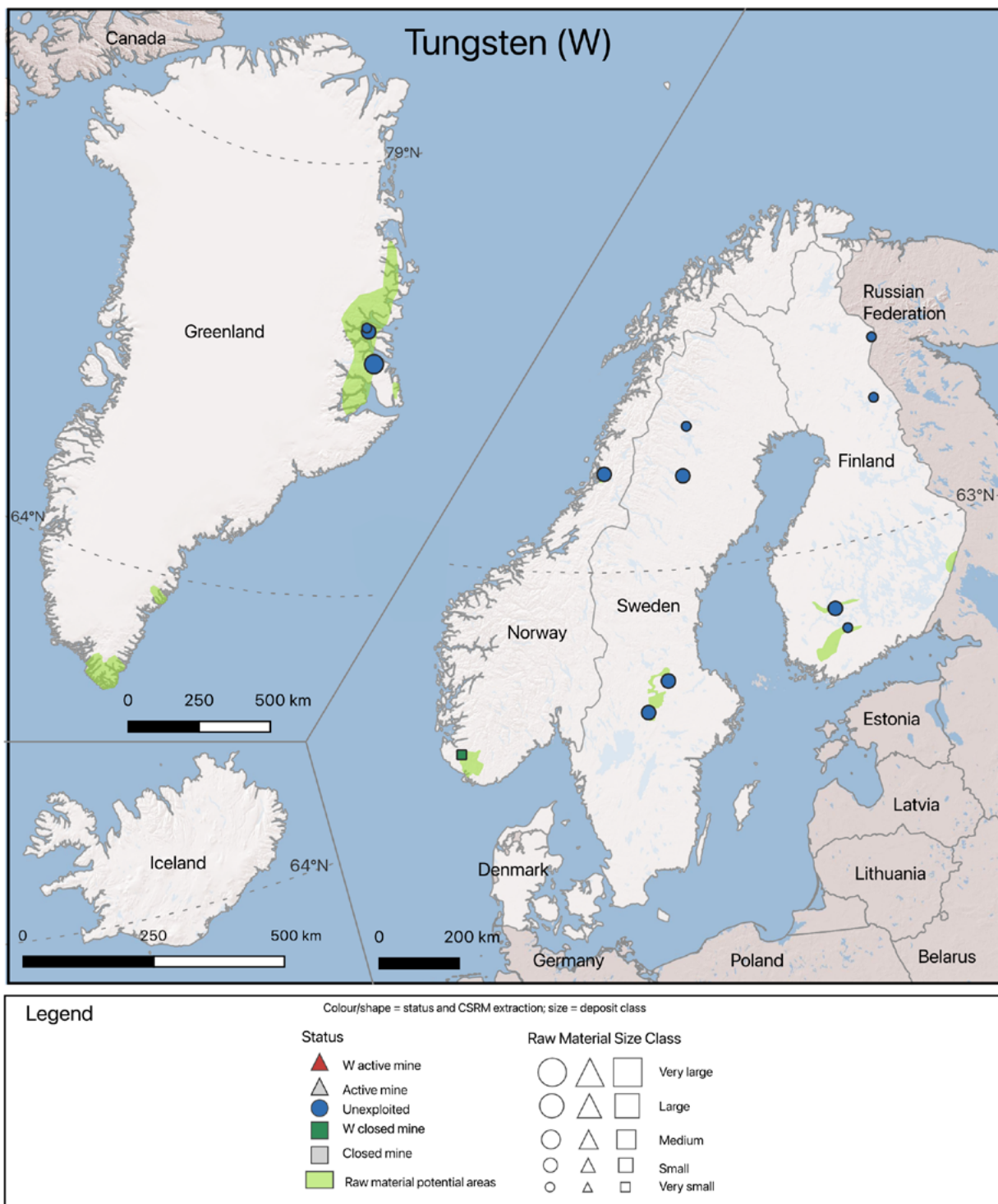


Figure 3.1.27. Locations of deposits with known tungsten resources and areas with known or assumed potential for tungsten resources in the Nordic countries.

3.1.31 Vanadium (V)

Vanadium is mainly used in steel as ferrovanadium and vanadium-bearing microalloys that increase strength and reduce steel mass requirements. It is also important for titanium alloys, catalysts and vanadium redox-flow batteries, which are relevant to long-duration stationary energy storage. IEA transition scenarios and battery-system analyses therefore give vanadium an additional demand pathway beyond its established steel base. MCS 2026 indicates production tied to titaniferous magnetite, slags, petroleum residues and a concentrated group of producing countries. Nordic relevance is strongest in Fe–Ti–V systems, mafic intrusions, shales, slags and other secondary streams, where vanadium could be recovered in some cases with iron, titanium or phosphorus (Santos et al., 2021; Grohol & Veeh, 2023; Carrara et al., 2023; USGS, 2026).

Commodity	Vanadium (V)	Data source
Uses of the commodity	<u>Main uses:</u> <i>High-strength low-alloy (HSLA) steel, special steels.</i> <u>Minor uses:</u> <i>Vanadium redox flow batteries in clean energy transition, super alloys, chemicals, catalyst, glass.</i> <u>Defence uses:</u> <i>High-strength steels and alloys used in aerospace, armour, structural and other defence-related systems.</i> <u>Future uses:</u> <i>New alloys. Forecasted strong growth for vanadium redox-flow batteries.</i>	Grohol & Veeh (2023), Hund et al. (2023), Santos et al. (2021), USGS (2026)
Resources and potential in the Nordic countries	<i>Known resources (total): 14,351,077 t V.</i> <i>Finland: Known resources 1.1 Mt V. Mustavaara deposit: 145.9 Mt @ 0.138% V; Koitelainen intrusion V unit: 116.4 Mt @ 1.26% V; Otanmäki deposit: 14 Mt @ 0.26% V. Undiscovered resources at the regional scale estimated at 13 Mt V.</i> <i>Greenland: Known resources 179,000 t V. Isortoq N dyke 70.3 Mt @ 0.081% V, 6.53% Ti, 26.9% Fe, Skaergaard intrusion 104 Mt @ 0.12% V, 4.68% Ti.</i> <i>Norway: Known resources 2.11 Mt V. Storeknuten 3167 Mt @ 0.039% V, Skeipstad 192 Mt @ 0.07% V, Lauvneset intrusion: 313 Mt @ 0.04% V; Selvåg intrusion: 44 Mt @ 0.15% V, Raudsand: 11 Mt @ 0.2% V, Sjøholt 4.65 Mt @ 0.34% V.</i> <i>Sweden: Known resources 10.96 Mt V. Viken: 4,789 Mt @ 0.14% V. Häggån shale: 2005 Mt @ 0.169% V, 0.021% Mo, 0.033% Ni; Routivare malmfält intrusion: 140 Mt @ 0.2% V, 5.7% Ti. Hörby shale: 116.8 Mt @ 0.219% V.</i>	Eilu et al. (2021), GTK (2025, 2026), Karinen et al. (2022), Jonsson et al. (2023), Rosa et al. (2023), Seppa et al. (2021), SRK Consulting (2021)
Global production	<i>110,000 t V. Most of vanadium is currently mainly obtained as a by-product or co-product from slags created during iron and steel production.</i>	Santos et al. (2021), Simandl and Paradis (2022), USGS (2026)
Main producing countries	<i>China 72.4%, Russia 18.5%, Brazil 4.6%, South Africa 4.4%.</i>	USGS (2026)
Nordic concentrator, refinery and smelter production	<i>None</i>	
Geopolitical and defence risk	<i>EU/JRC view: critical in the current EU framework, with SR 2.3 at the extraction stage. Defence view: High risk. Defence use in alloys and systems combines with concentrated supply exposure to produce a high-risk class.</i>	Carrara et al. (2023), EU (2024a), Girardi et al. (2023)

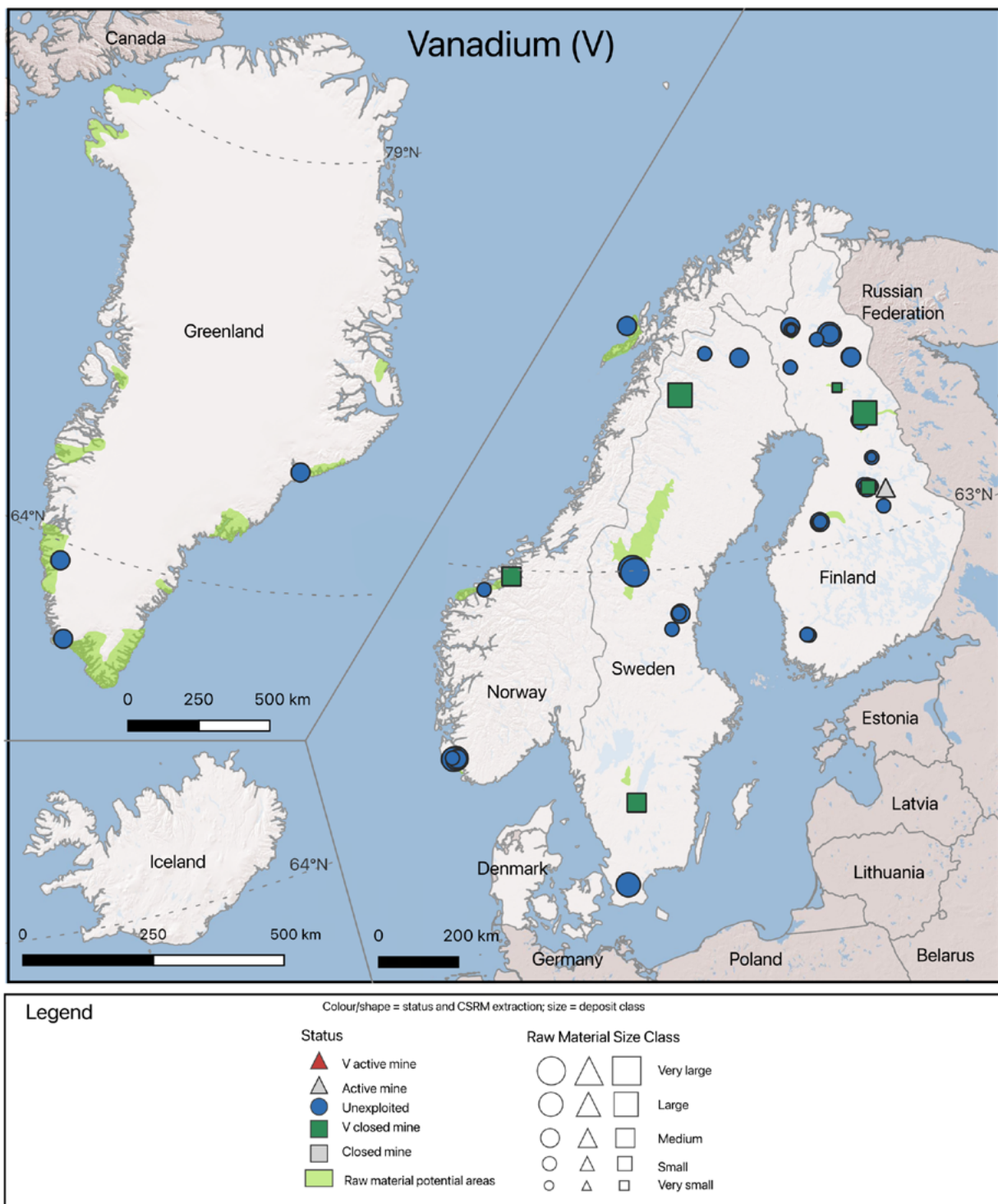


Figure 3.1.28. Locations of deposits with known vanadium resources and areas with known or assumed potential for vanadium resources in the Nordic countries.

3.2 Non-critical raw materials

3.2.1 Continuous rock fibres

Continuous rock fibres (CRF), previously referred to as continuous basalt fibres, are an important and rapidly growing industrial product that is used either directly as fibres (strands or woven fabrics) or as composites with a variety of epoxy materials. CRFs are extensively used, for instance, in the automotive, aviation and construction industries (e.g., Inman et al., 2017; Ersoy et al., 2021; Ma et al., 2025). Further processing can be achieved by combining CRF and resin to produce reinforcement materials for specific applications such as body parts for cars, windmill blades, boats and reinforcing bars for concrete structures; basalt-fibre reinforced polymer (BFRP) rebar has also been assessed as an alternative to steel rebar in concrete beams (Thorhallsson & Snaebjornsson, 2016; Inman et al., 2017).

Although CRFs are not classified as critical or strategic materials, they are retained in the non-critical raw materials section because they may provide an important material that can reduce demand for certain metals and replace other fibres (carbon or glass). The production of CRFs with renewable energy in Iceland can therefore contribute substantially to the green transition. The production of BFRP composites offers a sustainable alternative to traditional energy-intensive reinforced steel within the building and construction industry and can therefore be one element in the transition towards a low-carbon society (Inman et al., 2017).

Basaltic rock is the dominant rock type in Iceland. CRFs are made from volcanic rocks of basaltic to andesitic composition. Crushed rocks of a suitable composition are finely crushed and blended to achieve the desired composition, and then heated in a furnace to an optimal temperature of approximately 1,400–1,600°C. The melt is then extruded into continuous filaments, typically 8–15 µm in diameter. The industrial production of CRFs began in Ukraine in 1985, but since then, production has been growing, slowly at first, but more rapidly in the last few years (Ma et al., 2025).

In Iceland, systematic exploration for source materials of suitable compositions began in 2013 (Johannesson et al., 2016). The GREENBAS project (2014–2016), financed by NordMin, investigated the sustainable production of continuous basalt fibre from basalt mining and documented a significantly reduced carbon footprint, especially when green energy from hydro-electric and geothermal power plants is used in the basalt melting process (Johannesson et al., 2016). A country-wide campaign then led to more detailed sampling of a specific group of volcanics associated with the extinct Hafnarfjall-Skarðsheiði central volcano in West Iceland (Figure 3.2.1). In experiments, CRFs have now been successfully drawn from several samples. An exploration model is also emerging, which can help in guiding future exploration and potentially future mining endeavours. The project also identified possible mining sites and prepared the next stage for small-scale pilot testing to further develop BFRP production in Iceland (Johannesson et al., 2016).

Ideally, the next stage should involve a small-scale, all-electric pilot testing facility, where further testing of starting materials and pre-processing will lead to a better understanding of the factors controlling the quality of the fibres produced.

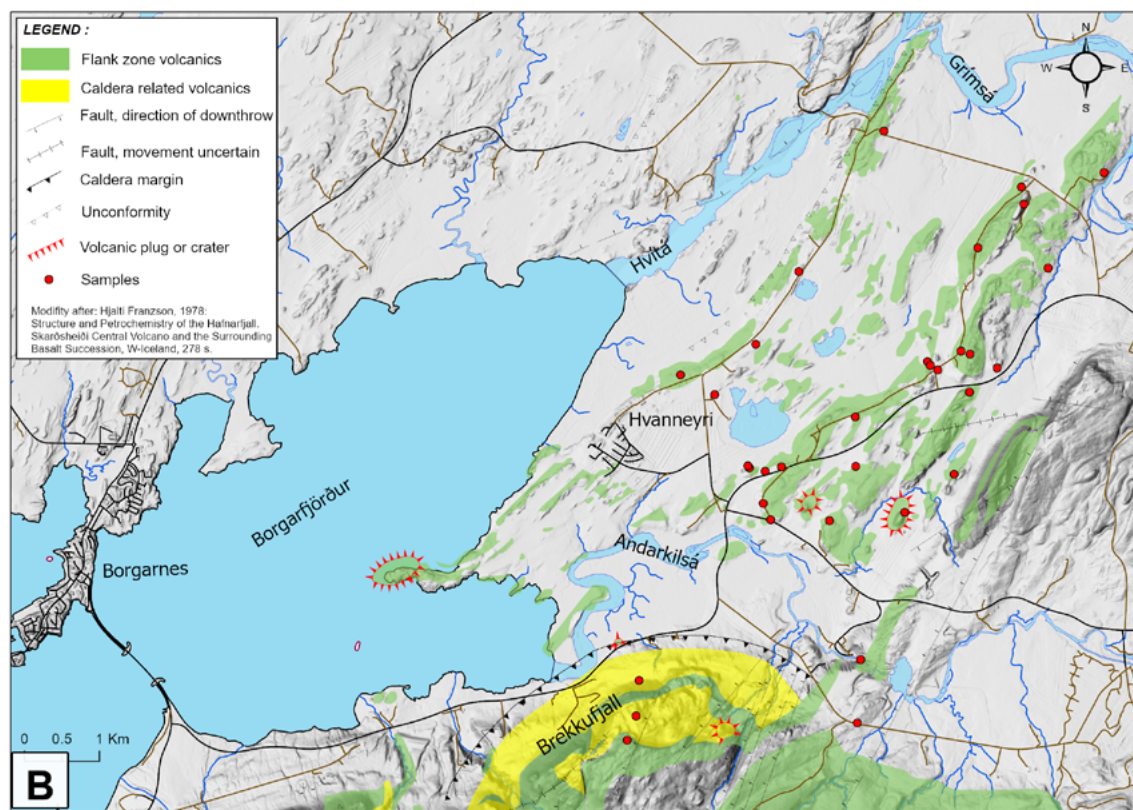
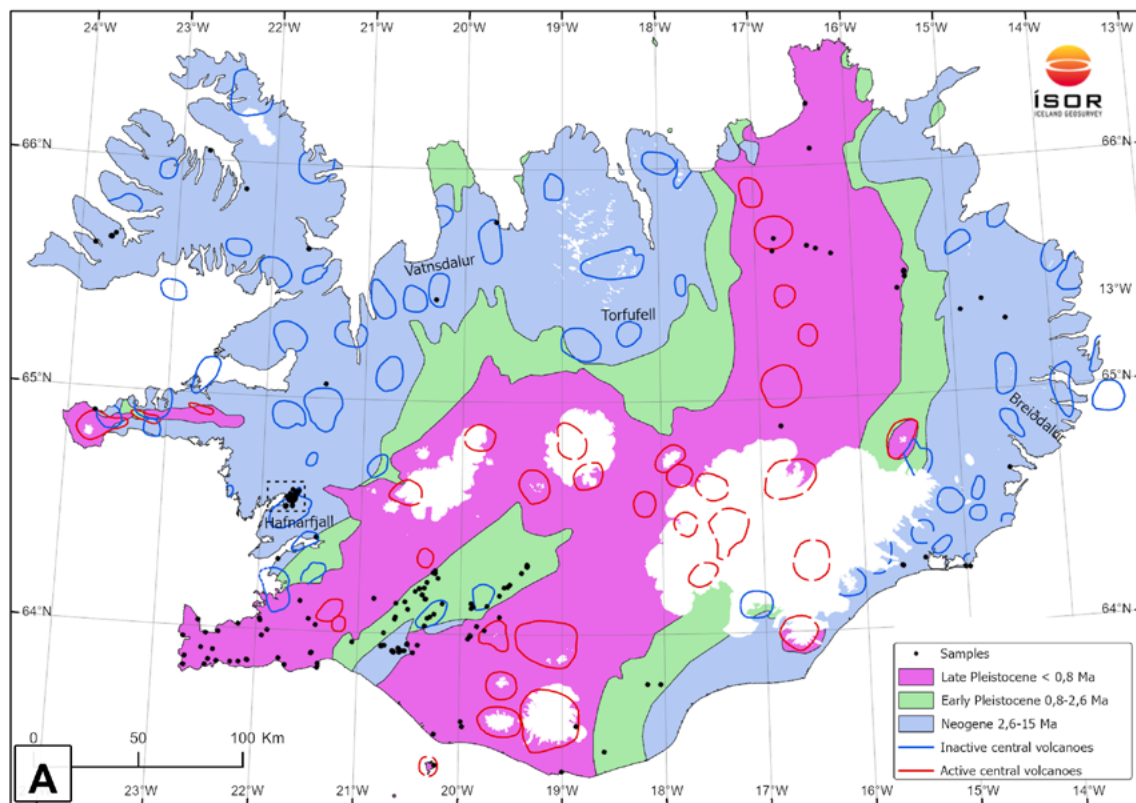


Figure 3.2.1. (A) Simplified geological map of Iceland illustrating the locations of samples obtained by Johannesson et al. (2016) and the 2025 sampling campaign (Sigurgeirsson & Erlendsson, 2025) exploring for raw material suitable for CRF production. The domains of active (red) and extinct (blue) central volcanoes are indicated. In addition to Hafnarfjall, three volcanic centres have been identified as potentially having suitable flank zone volcanics for the production of CRFs. (B) Locations of samples from the 2025 campaign concentrated on the flank zone of the Hafnarfjall-Skarðsheiði central volcano in West Iceland; geological base modified after Franzson (1978).

4 Current research, innovation and Nordic initiatives

Current Nordic work on critical and strategic raw materials is no longer limited to the compilation of mineral deposit data. Subsequent to Eilu et al. (2021), research and innovation activities increasingly addressed the system from several complementary angles: (1) the exploration and discovery of new primary resources, (2) the re-evaluation of known deposits with updated CRMA relevance, (3) the investigation of secondary resources such as tailings, waste rock, slags and industrial residues, and (4) the development of digital and analytical infrastructures that make these resource bases comparable across countries. Seen together, these activities are important not only because they may increase the available CSRM resource base, but also because they improve the conditions for more selective, knowledge-intensive and potentially more sustainable extraction pathways in the Nordic region (Eilu et al., 2021; Jonsson et al., 2023; Feltrin et al., 2024; EU, 2024a). Given this premise, Section 4 reviews updated Nordic resource knowledge, including the submarine mineral potential and secondary-resource opportunities for CSRMs, and provides an outlook on innovation initiatives across the Nordic realm.

4.1 Exploration, discovery and updated resource knowledge

On the primary resource side, a major line of work has focused on improving the geological basis for exploration and discovery. Eilu et al. (2021) established the broad Nordic potential, while subsequent studies have refined this picture through updated resource inventories, metallogenic syntheses and quantitative mineral-resource assessment. Jonsson et al. (2023) further clarified the diversity of Nordic mineral systems relevant to CSRMs, while Rasilainen et al. (2023) advanced quantitative assessments for undiscovered resources in Finland, especially for carbonatite and peralkaline intrusion-related systems relevant to REE and phosphorus. In parallel, the continuously updated Nordic Ore Deposit Database (NODD) and related national datasets have improved the regional evidence base by harmonising deposit information across Finland, Sweden, Norway, Greenland and Iceland, thereby supporting both exploration targeting and more systematic comparative assessment of Nordic potential (Eilu et al., 2022; Eilu et al., 2024; GTK, 2025).



Ice cave, Kronprins Christian Land, North Greenland. Photo: Diogo Rosa.

A second line of current work concerns the repositioning of already known resources in light of the EU 2023/CRMA classification and the stronger strategic focus on processing and midstream capacity. This affects both commodities newly upgraded in policy relevance and deposits already known but now reconsidered under security-of-supply and industrial-policy criteria. Examples include the continued advancement of battery and sulphide projects in Finland and Norway, REE–phosphate systems in Sweden and Greenland, and graphite and downstream material projects designed to connect extraction more directly to European processing and manufacturing chains. In this sense, current research is not only about discovering new ore bodies, but also about updating knowledge on already known resources so that their strategic, metallurgical and value-chain relevance can be assessed under present-day conditions rather than older commodity frameworks (Jonsson et al., 2023; Rasilainen et al., 2023; EU, 2024a; EC, 2025b). This widened resource perspective also extends offshore, where submarine mineral systems are increasingly assessed alongside land-based deposits, although their evaluation must also account for different geological settings, environmental sensitivities, governance frameworks and technological readiness.

4.2 Seabed minerals and resource potential

Mineral resources in the seafloor are generally divided into three different types: nodules, crusts and sulphides, all of which are essentially polymetallic. The nodules and crusts are typically dominated by manganese and iron, occasionally carrying economically significant concentrations of nickel, cobalt and copper (e.g., Margolis & Burns, 1976; Kuhn et al., 2017), whereas the sulphides are dominated by iron sulphides with variable contents of mainly copper and zinc (Hannington et al., 2005, 2010). All three types are generally located at large water depths, mainly between 1,500 and 6,000 m below sea level; however, nodules are also present in relatively shallow waters, such as in the Bothnian Sea (Boström et al., 1982; Ingri, 1985).



Miocene basalts: Succession of Miocene basalts in Mount Hólmatindur, Eskifjörður. Photo: Bjarni Gautason.

The prospect of deep-sea mining was suggested as early as 1965 by J. L. Mero, who claimed that manganese nodules in the deep ocean were a huge resource of cobalt, nickel and other metals (Mero, 1965). Nodules were discovered as early as 1877 by the HMS Challenger expeditions (Jones, 2022). The nodules are typically potato-sized, grown over millions of years, although growth rates vary, and are mainly found on abyssal plains at depths of 4,000–6,000 m. The richest and largest fields of nodules are in the so-called Clarion–Clipperton Zone in the Pacific between Hawaii and Mexico (ISA, 2010). Today, several companies have exploration contracts issued by the International Seabed Authority (ISA), and test mining is being carried out at present.

Sulphide mineralisations on the seafloor, known as seafloor massive sulphides (SMS), are recent analogues of volcanogenic massive sulphides (VMS) on land (Franklin et al., 2005; Hannington et al., 2005), which are very important producers of copper, zinc and lead, as well as several trace metals. The first warm-water vents and organisms thriving in the hydrothermal environment were found outside Galapagos in 1977 (Corliss et al., 1979). Only two years later, the first active SMS, or black smoker, occurrences were found at the East Pacific Rise (Francheteau et al., 1979; Hekinian et al., 1980). The first SMS deposits at the Mid-Atlantic Ridge were discovered in 1985 (Rona et al., 1986). The potential value of the SMS deposits was quickly realised and exploration activities increased during the 1990s and 2000s. In 2007, the Canadian company Nautilus Minerals signed a mining lease with Papua New Guinea for the Solwara 1 project, intending to be the first company to mine an SMS deposit. However, the company went bankrupt in 2019 before any mining was carried out. Since then, several countries, including China and Japan, have conducted small-scale pilot mining.

4.2.1 Icelandic offshore seafloor mineral potential

The total area of seafloor within Iceland's 200 nautical mile zone is roughly 758,000 km², or more than sevenfold larger than the area above sea level. Exploration and mapping of the seafloor around Iceland by private and public entities over the last several decades has resulted in a patchwork of disparate data collections stored by various actors in several countries. An effort is currently under way, as part of the EMODnet initiative, to collect and curate these datasets and to generate and maintain an up-to-date geological map of the insular shelf and deep ocean floor surrounding Iceland (Erlendsson et al., 2023).

Three active submarine high-temperature geothermal systems have been studied to some extent (Arnórsson, 2016, and references therein). Massive sulphide deposits have not been recorded to date; however, their presence at some depth below the surface cannot be excluded. The National Energy Authority lists a current prospecting licence for geothermal resources in two offshore research areas at the Reykjanes Ridge and north of Iceland, issued in 2022 and valid until 31 December 2026 (Orkustofnun, 2022). No permits related to SMS or CSRMs have been issued. At present, specific legislation related to exploration and utilisation of CSRMs and other commodities on the seafloor is lacking (Magnússon, 2023).

4.2.2 Norwegian mid-ocean-ridge mineral potential

Systematic mapping of the ridges to the north of Iceland started in the late 1990s, and a large number of active and inactive venting sites have been documented all the way from Iceland in the south to the so-called Eurasia Basin, close to the North Pole, in the north (e.g., Pedersen & Bjerkgård, 2016). A significant part of this 4000-km-long ridge system is in Norwegian waters, where the Centre for Geobiology at the University of Bergen has carried out numerous expeditions since 1999. From 2011, the Norwegian Offshore Directorate (NOD; previously the Norwegian Petroleum Directorate) and later the University of Tromsø and NGU also carried out research activities, including geophysics, mapping at various scales, and sampling of bedrock and sulphides. So far, more than 15 sites of mineralisation have been found along the Norwegian part of the ridge system, most of which are active sites that are not prone to mining activity, not least because of vulnerable ecosystems. So far, no resources have been documented along the mid-

ocean ridges, and the mineralisations have only been subject to limited surface sampling or near-surface drilling, which is not considered representative (see also Bjerkgård et al., 2023).

Manganese crusts form by the precipitation of metals, mainly Mn- and Fe-oxides and oxyhydroxides, from ambient seawater. The growth of a crust is extremely slow, up to approximately 10 mm per million years. Because of the slow growth, crust formation competes with the accumulation of sediments, which generally means that crusts form on slopes steeper than about 20 degrees, where sediments can slide off. In addition to manganese and iron, the crusts are typically enriched in cobalt (Konstantinova et al., 2016). In the North Atlantic, the crusts are generally found along old ridges and slopes parallel to the active ridge on both sides, which formed after rifting of the North Atlantic commenced about 55 million years ago. This means that the crusts are at most around 55 cm thick, but on average approximately 20–25 cm (Pedersen et al., 2021).

In 2023, the Norwegian Petroleum Directorate (NPD; now the Norwegian Offshore Directorate, NOD) published a resource assessment covering the Norwegian exclusive economic zone (EEZ), with estimates of potential resources in SMS and manganese crusts (NPD, 2023). This was followed in January 2024 by the opening of parts of the Norwegian shelf for mineral exploration and potential future mining. However, the decision to open up the seafloor for mining has been met with criticism, both domestically and internationally. The main concerns include the destruction of vulnerable deep-sea ecosystems, possible loss of unknown life forms, long-term impacts and Norway's reputation with respect to climate and biodiversity goals. The plan to start awarding licenses for deep-sea mining in the Norwegian EEZ was suspended in December 2024. Overall, information about European marine mineral deposits was collated and summarised in the EU-funded MINDeSEA project (e.g., González et al., 2023).

4.2.3 Ferromanganese nodules in the Baltic and Bothnian sea areas

In the relatively shallow waters of the Baltic Sea, and particularly northwards in the Bothnian Sea and Bothnian Bay, Fe–Mn-rich concretions and crusts, in part equivalent to so-called nodules, have been observed to occur in variable amounts on the seafloor, with marked concentrations also occurring in the Gulf of Finland and the Gulf of Riga (e.g., Winterhalter, 1966; Boström et al., 1982; Ingri 1985; Glasby et al., 1997; Kaikkonen et al., 2019, and references therein). Compared to deepwater crusts, nodules or concretions, these shallow-water equivalents exhibit relatively fast growth, assessed to be around 0.02 mm/year. Through the fundamental work of Ingri (1985), the gross distribution and systematics of ferromanganese nodules or concretions in the Bothnian Sea and Gulf of Bothnia were reasonably established. He also suggested that the original source of the Fe, Mn and associated trace metals in the nodules was the abundant volumes of glacial till in the drainage areas of the major rivers that feed into the Bothnian Sea and Gulf of Bothnia.

In the seafloor sediments in these areas, Fe and Mn are characteristically separated due to variable oxidation–reduction states in the bottom water column and uppermost sediment part, forming authigenic Fe- or Mn-enriched layers or crusts, as well as concretions. Some additional elements have been found to display preferences for specific layers or crusts, i.e., Mo, Ba, Ni, Cu and Zn associated with Mn, and P, Ca, Sr and As with Fe (Ingri 1985). The concretions occur as three main types: flat slabs and crusts, discoidal concretions and mainly spherical (true) nodules. Ingri (1985) observed that only the spherical type contains significant Mn and that the accumulated trace element inventory, including Cu, Ni and Co, is small and likely not of commercial interest, at least at that time. He also noted that both the formation and survival of Fe–Mn nodules or concretions require oxidising conditions and low or near non-existent sedimentation rates. The general term “concretions” appears to be preferred today for such precipitates in shallower sea environments (e.g., Kaikkonen et al., 2019).

Overall, an area of approximately 15,000 km² has been indicated to harbour “abundant nodules” in the whole of the Baltic and Bothnian sea areas, including the bays of Finland and Riga (Ingri 1985; SOM AB, 2025; pers. comm. Fredrik Eide). Ingri (1985) also stated that “nodule recovery” should only be potentially relevant in the Bothnian Bay among the Swedish sea areas studied and sampled. Kaikkonen et al. (2019)

reported the presence of Fe–Mn concretions at around 7,000 sites in the northern Baltic Sea and projected that concretions may occur in over 11% of Finnish sea areas.

Notably, while on a smaller scale, test mining or harvesting of such nodules has been conducted in the eastern part of the Gulf of Finland (Zhamoida et al., 2017). In Swedish waters of the Bothnian Bay, Scandinavian Ocean Minerals AB is undertaking surveys and presently (2026) has exploration permits within its Bothnian Bay project and is planning and developing methods to “harvest” ferromanganese nodules, or concretions, if a concession is granted. The company has also applied as a strategic project under the Critical Raw Materials Act (SOM AB, 2025; pers. comm. Fredrik Eide). The company has stated that average concretions contain approximately 23–25% MnO₂, with the remainder dominated by Fe and Si oxides and minor P.

4.3 Metal companionship

Another alternative area of recent development that targets the recovery of CSRM is the so-called re-mining of secondary resources. Before reviewing some examples of these rediscovered resources, it is useful to make the concept of metal companionship explicit. Feltrin et al. (2024) implemented the concept as a practical inference framework for linking primary-resource knowledge, ore-genesis rules and likely CSRM budgets in mining waste and other secondary accumulations. The same logic is also used in by-product critical-element exploration, where deposit type, mineralogy and mineral-scale trace-element data can help identify hidden supply potential in existing mining value chains (McNulty & Jowitt, 2022).

Most metals and, in particular, part of the CSRM are so-called by-product metals or “companion metals”, all depending upon how their deposits formed and what their preferred host mineral(s) are. Each CSRM typically occurs in the “wheel of metal companionship” (Figure 4.3.1) together with one or two more common metals and can, given the character of presently known deposits, only be produced as part of the production of such main metal(s) (Nassar et al. 2015). Here, we see, for example, that cobalt (Co) and nickel (Ni) are companions, and to increase the production of cobalt it is necessary to increase the production of nickel. This can have direct consequences for the economy of metal production. For example, increased nickel production to obtain the needed cobalt can result in overproduction and a reduced global nickel price level, thus making the steps of mining and extraction less profitable in total and, furthermore, reducing the economic interest in mine production of cobalt.

Another significant example of the effects of companionship and by-product issues is given by vanadium. Vanadium redox stationary batteries are seen as one of the ready-to-use solutions for storing energy from solar and wind powered plants. Bushveld Metals (2020) report: “Over 70% of vanadium currently comes from co-production, which is driven by steel and iron ore fundamentals. This co-production is primarily driven by steel and iron ore market dynamics rather than vanadium fundamentals, and co-producers are currently operating close to full capacity.” It is forecasted that the demand for vanadium in large-scale stationary energy storage systems linked to wind and solar power will eventually overtake all other uses of vanadium (e.g., Hund et al., 2020). As there are no indications that demand for vanadium is decreasing in other major sectors of the relevant industries, the development of new vanadium deposits to the extraction stage will become essential.

On the other hand, the companionship wheel illustrates where there can be additional, but currently poorly known CSRM resources. Here is another indication of possible additional resources for the Nordic countries, where we have a large number of old, closed and abandoned mines and unexploited ore showings, with little or no information other than that they, for example, were mined for nickel at one point in time. Such sites represent rock volumes where geological processes have resulted in the enrichment of nickel and in all probability also companion elements such as cobalt, which could be targets for new investigations and mineral exploration. As companionship commonly reflects geochemical affinity between elements and their shared mineral hosts, it also affects the metals potentially available in secondary accumulations, such as mine, refinery and urban wastes.

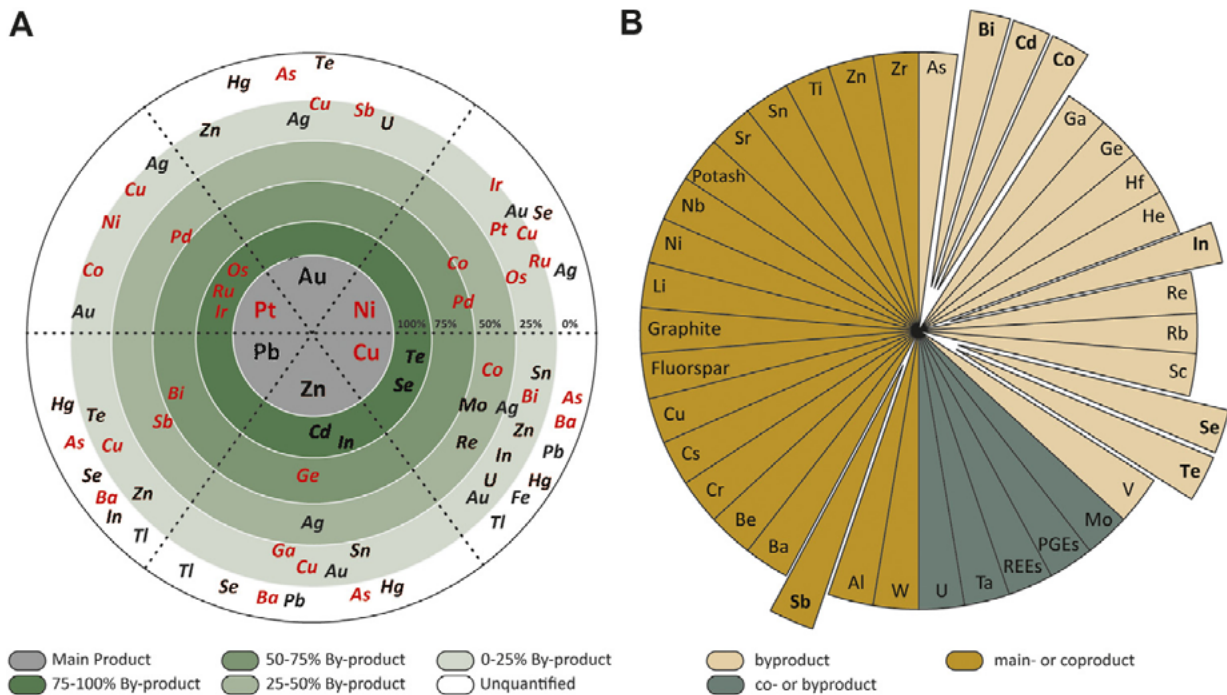


Figure 4.3.1. Wheel of metal companionship and by-product critical-element categorisation. Panel A shows the relationship between primary metals and by- or co-product elements; red labels indicate raw materials listed as critical raw materials under the EU Critical Raw Materials Act, where represented in the wheel. Panel B groups selected elements according to their by-product, co-product or main-product character. Modified after McNulty & Jowitt (2022).



CSRMs like titanium, vanadium and nickel are essential to steel production for construction applications. Photo: Alva Bruun.

4.4 Secondary resources and their CSRM resource potential

Secondary resources constitute a complementary CSRM supply stream rather than a substitute for primary mining. They include mine tailings, waste rock, slags, process residues, refinery side streams, sludge, fly ash and other secondary accumulations that may hold co- and by-product metals. Their CSRM potential is difficult to evaluate, because such elements are often not routinely assayed, reported or classified when the original operation targeted a different main commodity (Nassar et al., 2015; Feltrin et al., 2024).

Recent Nordic work demonstrates that assessment starts with mapping where waste and side streams occur, what materials they contain and whether the relevant elements are present in forms that can realistically be recovered. This requires a combination of inventory work, database development and site-specific testing. At its core, the approach focuses on detecting and quantifying CSRM across the mineral value chain, from upstream exploration of mining waste to the partitioning of CSRM in advanced industrial processing of municipal solid waste or alloy-refining residues. Field sampling, multielement geochemistry, mineralogical analysis, geophysical surveys and metallurgical tests are needed, because surface observations or old production records alone rarely provide enough information to estimate grade, tonnage, mineral hosts or processing behaviour. These technical characteristics are necessary but not sufficient: recovery potential also depends on contextual factors such as proximity to an operating mine or refinery, available infrastructure, ownership and access conditions, permitting requirements and whether CSRM recovery can be integrated as a side stream into a larger primary operation.

Feltrin et al. (2024) document several relevant Nordic secondary-resource settings. Swedish tailings at Grängesberg and Yxsjöberg contain phosphorus, REE+Y, vanadium, tungsten, bismuth, copper, tin, beryllium, fluorite and other potential by-products, but their evaluation depends on full-depth sampling, mineralogy and waste-volume estimates (Hällström et al., 2018; Hallberg & Reginiussen, 2020; Casey et al., 2024). At Løkken in Norway, sulphidic VMS tailings contain Cu, Zn, Co and other elements with depth-dependent distributions that require integrated geochemistry and geophysics before recovery potential can be assessed. Industrial residues form a second category of secondary resources: Danish municipal solid waste incineration fly ash and Icelandic aluminium dross demonstrate that CSRM can either concentrate in specific process streams or be absent from streams where they might otherwise be expected (Feltrin et al., 2024).

These results indicate that secondary-resource assessment is primarily a prioritisation tool that operates at different levels of the mineral value chain (MVC). It identifies where further recovery studies are justified, where elements partition during mining, smelting, refining and waste treatment, and where negative results reduce the risk of overestimating recovery potential. The approach therefore improves understanding of where CSRM could potentially be recovered. For Nordic CSRM planning, tailings, waste rock, slags, fly ash, refinery side streams and other industrial residues should remain visible in the resource knowledge base, but only sites with adequate geological, geochemical, mineralogical, geophysical, metallurgical and contextual evidence should be advanced toward recovery assessment (Eilu et al., 2021; Feltrin et al., 2024). The strategic value of re-mining and waste repurposing is therefore not limited to additional CSRM supply. Where recovery is technically feasible and environmentally well managed, it can also strengthen environmental, social and governance (ESG) performance by reducing legacy waste, improving material circularity and supporting higher sustainability standards for mining and processing operations. In the broader report context, secondary-resource research complements primary mineral-resource characterisation: rediscovering value in waste is a parallel form of mineral exploration targeting, and both lines of work generate updated knowledge that supports better decisions on Nordic CSRM potential, project prioritisation and mineral-resource management.

4.5 Innovation initiatives and sustainability-oriented knowledge building

The broader significance of these Nordic activities is that they connect exploration, data and innovation to sustainability objectives. Better targeting of deposits and better characterisation of secondary resources can improve selectivity, reduce blind exploration, support more efficient project prioritisation and help identify where re-mining or by-product recovery may reduce pressure on new extraction. Similarly, better knowledge of processing stages, traceability and value-chain bottlenecks can support more responsible sourcing and stronger control over environmental and strategic risk. GTK work on traceability methods for battery raw materials, together with the Nordic Innovation mineral-to-metal traceability study on REEs, points in this direction: the objective is not simply to find more material, but to understand where in the chain interventions are most meaningful for resilience, transparency and lower-impact supply development (Kaikkonen et al., 2022; Liu et al., 2024; Feltrin et al., 2024).

Current research efforts demonstrate that Nordic CSRM work is increasingly innovation-oriented in a broad sense. It now includes research on material flow directed at digital infrastructure, secondary-resource screening, industrial process knowledge in the supply chain and project-linked industrial learning. This does not remove the need for primary mining; rather, it improves the quality of decision-making around where, how and under what conditions future extraction and processing should proceed. In this sense, current Nordic research contributes not only to increasing the potential resource base, but also to making future extraction pathways more knowledge-based, more integrated across primary and secondary sources, and more compatible with sustainability and strategic-resilience goals (Eilu et al., 2021; Jonsson et al., 2023; Feltrin et al., 2024; EU, 2024a).

5 Discussion and conclusions

5.1 Considerations on the demand trajectories for CSRM

As presented in this report, the Nordic countries have a significant, albeit variable, potential with regard to the future supply of CSRMs. Some of these commodities, such as cobalt, lithium and the rare earth elements, remain central to the technologies at the core of the green transition, while others now also carry strategic weight through the digital transition, processing dependence or defence-relevant applications. The regional picture is therefore one of differentiated opportunities rather than uniform abundance: the Nordic countries have strong overall potential, but each country has its own geological character, industrial strengths and bottlenecks.

At the same time, the CSRM summary evidence in Section 3 demonstrates why recycling alone cannot sustain the twin transition. Current recycling rates remain highly uneven and, in several cases, structurally limited: fluorspar is assumed at about 1% end-of-life recycling, manganese has an estimated EU end-of-life recycle input rate of approximately 9%, tantalum remains below 1% for end-of-life product recycling, and REE recycling is still described as very low, while even tungsten, one of the stronger cases, is estimated at around 42% global recycling (BRGM et al., 2017; Latunussa et al., 2020; Eynard et al., 2020). The implication is that the Nordic CSRM potential is real and, in some cases, globally relevant. For instance, for silicon metal, cobalt and lithium, the supply chains are already (or will be) contributing to global production, partly addressing the booming demand. The question is whether the heterogeneity in resource/production capacity should be balanced with more synergy-oriented industrial strategies or rather regionalised and specialised further. Most likely there will be a combined/mixed approach to supply-chain development.

On the demand side, a multifaceted picture is emerging in which electrified transport, AI-centred data infrastructure and defence represent three distinct demand trajectories for CSRMs. If ranked by likely aggregated raw material mass, electric vehicle (EV) adoption and broader electrification remain (at present) the dominant drivers, because deployment occurs in the millions of units and influences bulk battery and motor materials demand (copper, graphite, lithium, nickel, cobalt, manganese and REEs; Carrara et al., 2023; IEA, 2025a). If ranked by current capital mobilisation, however, data centres and defence now operate in a similar order of magnitude: OpenAI's Stargate programme alone was announced at USD 500 billion over four years, with an initial USD 100 billion deployment and a later 4.5 GW expansion step, while EU defence expenditure reached approximately EUR 343 billion in 2024 and was estimated at around EUR 381 billion in 2025 (OpenAI, 2025a; OpenAI, 2025b; EDA, 2025). The material significance of data centre expansion is also becoming easier to quantify. Recent mining-market analysis cited by *The Northern Miner* suggests AI-related power capacity may require approximately 20-40 t Cu per MW and that copper demand for data centres could approach nearly 1 Mt of metal per year by 2030, although this is an indicative order-of-magnitude estimate rather than a precise forecast (Northern Miner, 2025; Northern Miner, 2026a). A later summary of S&P Global analysis suggests that AI, defence spending and robotics could lead to a 50% increase in global copper demand by 2040 and a prospective annual shortfall of more than 10 Mt without major mining expansion, thus reinforcing the view that digital and defence demands are no longer marginal additions to the copper outlook (Northern Miner, 2026b). If ranked by strategic sensitivity per tonne of material, defence likely moves to first place, because even comparatively small CSRM volumes can be "mission critical": JRC estimates indicate around 81,000 t of titanium is present in current NATO combat aircraft and battle tank fleets, while an F-35 class aircraft has been cited as containing around 415 kg of REEs (Carrara et al., 2023; Girardi et al., 2023). The resulting conclusion is that EVs remain the main mass-demand story, AI data centres are emerging as a fast capital-, power- and copper-intensive demand amplifier and defence exerts the strongest strategic role affecting specific CSRMs. Together, these sectors define a more complex future demand envelope for Nordic primary and secondary resources than implied by the 2021 green-transition framing alone.

5.2 Supply-side country summaries

A supply-side synthesis is proposed in which geology, reported resources, occurrence density, exploration maturity, infrastructure, data quality and midstream capacity are assessed together. The main data constraints identified by Eilu et al. (2021) also remain relevant: the occurrence and distribution of by-product metals and similar deposit components are unevenly reported and often even unknown, resource estimates are incomplete for several commodities and secondary-resource characterisation remains inconsistent across the Nordic countries. This limitation is now being partly addressed through the integrated primary-secondary dataset development work and through wider European initiatives such as GSEU/EGDI and FutuRaM (CORDIS, 2025).

A conclusion from Eilu et al. (2021) remains important: the Nordic CSRM potential should not be assessed from reported tonnages alone. Occurrence density, the diversity of favourable types of mineral systems and the maturity of exploration in discrete regions are also critical indicators. Notably, all numbers reported here must also be considered as (very) conservative, as we know of a multitude of additional mineralisations for which we do not have available or reliable estimates of grades and tonnages. For several commodities covered in this report, small known resources, or even the absence of formal tonnage estimates, do not necessarily imply low potential. Numerous deposits and occurrences may instead indicate a fertile geological domain, while reported resources and reserves represent only the part of that potential that has been delineated, tested and disclosed to date (e.g., Meinert et al., 2016; Eilu et al., 2021). In this sense, Greenland remains a predominantly greenfield domain, whereas Finland, Norway and Sweden are perhaps to some degree better understood as brownfield regions, in which future growth is more likely to come from reinterpretation, extension and integration of present raw materials data. However, new discoveries are still being made of previously unknown mineralised systems in what should really be classified as "greenfield" regions in these countries. Denmark and Iceland remain exceptions, because their bedrock geology, and hence geological raw material diversity, is much narrower in scope.

This distinction also matters when comparing project significance. Greenland hosts world-class unexploited systems whose scale is exceptional in a European, and in some cases even a global context, but the lack of logistics, infrastructure, workforce availability and local financing, combined with Arctic conditions, means that size alone does not guarantee an obvious economic business case. By contrast, smaller Fennoscandian projects such as Norra Kärr may gain strategic importance precisely because they are closer to infrastructure, labour, industrial demand and potential downstream processing routes. For REEs, however, a European supply contribution still depends on access to a sufficiently scaled and integrated separation, refining and materials chain. Nevertheless, Europe is not starting from zero: the La Rochelle site already represents rare-earth processing capacity in France, and this base is now being reinforced through Solvay's renewed permanent-magnet materials strategy and the Caremag project at Lacq. Additional European nodes include Neo Performance Materials' rare-earth separation and magnet-manufacturing platform in Estonia, with operations at Sillamäe and Narva, and REEtec's industrial rare-earth separation plant at Herøya/Porsgrunn in Norway. The issue is therefore not the complete absence of European REE processing capacity, but the limited scale and incomplete integration of the wider REE value chain (Solvay, 2025; Carester, 2025; Neo Performance Materials, 2025; REEtec, 2025). The supply picture below should therefore be read not only as a geological comparison, but as a comparison of resource scale, project maturity, infrastructure access and value chain completeness.

5.2.1 Finland

Finland has the broadest and best-constrained CSRM endowment in the Nordic region. In the current commodity summaries, it is the only Nordic country with active primary mine production of cobalt, phosphorus and PGMs, and it also hosts the largest identified Nordic resources for cobalt (541,258 t Co), nickel (6.88 Mt Ni), lithium (113,917 t Li), phosphorus (219.8 Mt P) and PGMs (approximately 890.2 t). Known resources include around 611.96 t Pd, 278.24 t Pt and 3.61 t Rh in Finnish resources. Finland also has significant graphite, titanium and vanadium endowment, together with additional potential for be-

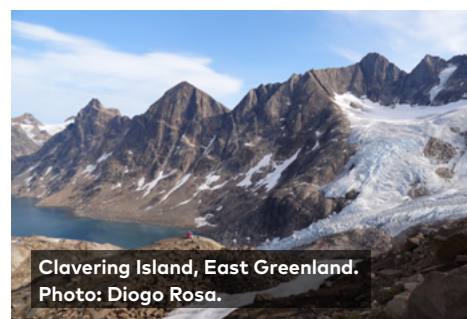
ryllium, niobium, REEs, scandium, tantalum and tungsten. Statistical assessments further indicate major undiscovered cobalt, copper, nickel, PGM, phosphate, REE, titanium and vanadium endowment in Finland (Rasilainen et al. 2017, 2020; GTK, 2025; Tukes, 2025; Boliden, 2026).

Finland's importance is not only geological but also distinctly midstream. Harjavalta, Kokkola and Terra-fame represent a mature metal refining and battery-chemicals system: Finland refined approximately 12,025 t cobalt in 2025, equivalent to roughly 8% of reported global refinery output, and produced approximately 99,862 t nickel products in 2024. Finnish Minerals Group also reports the Hamina pCAM project and the battery materials plant planned in Kotka as part of the same midstream expansion (Finnish Minerals Group, 2025a; Finnish Minerals Group, 2025b). With regard to lithium, Finland is also the most advanced EU case, as the Keliber project's Syväjärvi mine began operations on 11 February 2026, although the broader integrated mine-concentrator-refinery chain remains in staged commissioning through 2026. A major undeveloped resource is Sokli, where the large phosphate endowment is accompanied by potentially significant niobium, tantalum and REE (IEA, 2025a; Tukes, 2025; Finnish Minerals Group, 2025c; Sibanye-Stillwater, 2026).

5.2.2 Greenland

Greenland remains the most geologically distinct part of the Nordic resource space, with nearly four billion years of geological history represented in its ice-free land area and a correspondingly wide range of CSRM-favourable settings. Rosa et al. (2023) emphasised that the Gardar Province in South Greenland constitutes an exceptional concentration of CSRM endowment, as seen in the very large Ilímaussaq complex deposits and Motzfeldt, with associated REE, fluorite, tantalum, niobium, hafnium and zirconium potential. The same review highlights East Greenland for molybdenum and strontium, and the large Skaergaard PGM–Ti–V system, southern West Greenland for phosphorus–REE-enriched carbonatites such as Sarfartoq, and South Greenland for graphite at Amitsoq. Unlike Finland, Norway and Sweden, Greenland has very limited current mine production, including of CSRM-related commodities. Its active anorthosite/feldspar operation at White Mountain/Qaqortorsuaq represents an industrial-mineral contribution to CSRM-relevant supply, but most of Greenland's CSRMs remain as a large undeveloped geological potential, rather than present production.

Probably the most important known Greenland example is the Tanbreez project at Kringlerne/Killavaat Alannguat. Rosa et al. (2023) described Kringlerne as one of the key Ilímaussaq deposits and report the long-standing company view of a very large kakortokite-hosted Zr–REE–Nb–Ta system. The Critical Metals Corp (2025) S-K 1300 technical report summary, prepared by Agricola Mining Consultants Pty Ltd, is important because it provides the formal public disclosure of the current mineral resource estimate: a 30 August 2016 estimate by Al Maynard and Associates Pty Ltd of 44.87 Mt at 0.38% TREO, 1.39% ZrO₂ and 0.14% Nb₂O₅, split into 25.42 Mt indicated at 0.37% TREO and 19.45 Mt inferred at 0.39% TREO. The same SEC report also refers to the wider kakortokite host as an approximately 4.7-billion-tonne REE–Zr–Nb-bearing rock unit, but this host-rock figure is a broad estimate. GEUS review, the 2025 SEC filing and recent drilling reinforce Greenland's role as the Nordic region's most distinctive large-scale frontier domain for REE systems with associated Zr–Nb–Hf–Ta potential, even if project delivery remains conditional on finance, infrastructure and permitting (Rosa et al., 2023; Critical Metals Corp, 2025; Critical Metals Corp, 2026).



5.2.3 Iceland

Iceland represents the geologically youngest and least diverse hard-rock domain among the Nordic countries, as it sits on a mantle plume within young oceanic crust at the North Atlantic ridge. Basalt dominates the bedrock, and known metalliferous occurrences are mainly associated with geothermal and epithermal systems, with only sparse primary CSRM occurrences reported on land, including baryte, fluor spar, titanium and minor copper mineralisation. However, the Icelandic role in the Nordic mineral value chain (MVC) is more important in midstream than in mining. Feltrin et al. (2024) highlighted that Iceland has used its renewable-energy base and Atlantic position to develop raw-material processing capacity despite its limited domestic raw material base, functioning as a processing and export node connected to both European and North American markets.

This midstream role is visible above all in energy-intensive processing. Iceland hosts a major aluminium-smelter operation at Reydarfjörður, Grundartangi and Straumsvík, and also has a smaller but strategically relevant silicon-metal production position; the current commodity summaries record Icelandic silicon-metal production at about 36,000 t/a, while Feltrin et al. (2024) described the country as a renewable-energy-based processing location for aluminium and silicon, with an export orientation rather than a mining jurisdiction (Alcoa Fjarðaál, 2021; Rio Tinto á Íslandi, 2021; Elkem, 2026). Basalt fibres add a distinct Icelandic innovation angle, because basalt-derived continuous fibre and reinforced composites can be developed using local basalt and low-carbon power. In parallel, Iceland also matters through its offshore potential: the submarine ridge system north of Iceland hosts active hydrothermal systems and inactive seafloor massive sulphide deposits, and the broader North Atlantic domain also includes manganese-rich crusts and nodular or concretionary ferromanganese occurrences, which together make Iceland relevant not only as a land-based processing hub but also as a potential gateway to future submarine resource assessments in Nordic waters (Pedersen & Bjerkgård, 2016; González et al., 2023; Feltrin et al., 2024).



Gully with extensive columnar basalt formations.
Photo: Bjarni Gautason.

5.2.4 Norway

Norway has a highly varied geology, with rocks spanning more than 3 billion years in age. Compared to the rest of Fennoscandia, however, most of the rocks in Norway are considerably younger, which implies that the geological setting is quite different for many of the Norwegian occurrences.

Norway is the most important producer of natural graphite and titanium minerals in Europe. The potential for graphite in Norway is very large, and about 70 reported graphite occurrences have been identified. Norway is a world-class producer of titanium minerals and has a domestic processing industry refining ilmenite to titanium dioxide pigment. Since 2025, Norway has also produced rutile, a raw material particularly suited for titanium metal production. In addition, several very large titanium–phosphorus–vanadium deposits have been identified in southern Norway. Norway is also host to Europe's biggest nepheline–syenite mine. The Fen carbonatite complex near Skien is identified as a world-class resource for REE. There are advanced copper projects in northern Norway, including the large Nussir deposit. Additionally, there are other well-characterised deposits and occurrences of quartz for silicon metal, fluorspar, nickel and beryllium.

In addition to its geological resources, Norway has access to cheap electric energy (in general the most expensive factor in metal production). Because of this, Norway is an important producer of, for example, silicon metal, nickel and cobalt extracted from imported raw materials. In the current compilation, this corresponds to approximately 300,000 t silicon metal, 98,379 t refined nickel and 3,033 t refined cobalt, which reinforces Norway's role as a Nordic midstream pole (Eilu et al., 2021; Nikkelverk, 2025; Elkem, 2026). With the energy transition from hydrocarbons to green energy solutions, the access to cheap electricity will by all probability be increasingly important in the future.

Norway also broadens the Nordic CSRM picture offshore. Systematic mapping along the ridge system north of Iceland has documented active hydrothermal systems and inactive seafloor massive sulphide (SMS) sites extending into Norwegian waters. However, no SMS resources have been documented, manganese crusts are not treated here as a material resource target and the licensing process was halted in 2024. In synthesis, Norway combines one of the strongest Nordic land-based portfolios for graphite, titanium, silicon metal, nickel, cobalt and REE optionality with a mapped, but presently non-producing, marine-mineral research domain (Pedersen & Bjerkgård, 2016; González et al., 2023).



Overview of the old mine at Bruvann/Råna Ni-Cu deposit.
Photo: Eduardo Teixeira Mansur.

5.2.5 Sweden

Sweden is also among the geologically more diverse and industrially strongest Nordic countries, with a relatively broad and well-established mining industry focused on base and noble metals and iron. However, the most important update since 2021 with regard to CSRM is that its northern apatite-iron oxide ore districts are now increasingly being highlighted for their phosphorus and rare earth element contents, rather than only as iron-ore systems. Although this is very far from new (e.g., Jonsson et al., 2019, and references therein), the increased industrial relevance and EU criticality of both REEs and P has led to renewed interest in these potential by-products from apatite-iron oxide ores, and the onset of new projects to extract them. In particular, the Per Geijer ores in Kiruna have become something of a flagship case: LKAB's 2025 Annual and Sustainability Report states that Per Geijer remained one of the company's EU Strategic Projects under the CRMA, while earlier LKAB reporting estimated about 2.2 Mt of *in situ* REE oxides as an inferred mineral resource and gave a phosphorus resource basis of 1,249 Mt at 2.11% P for the Per Geijer ores, reinforcing that the district should be seen as a combined Fe–P–REE system rather than as iron ore alone. The wider Kiruna–Malmberget–Svappavaara district therefore points to a future in which phosphorus and REE recovery may be integrated with existing iron-ore value chains. The occurrence of similar, previously mined but still very sizeable apatite-iron oxide ores in the Bergslagen ore province in south-central Sweden opens up additional possibilities. Major REE projects with a higher content of HREE include those at Norra Kärr and Olserum (both southern Sweden), the former with potential by-products including hafnium, zirconium and nepheline syenite. More broadly, Sweden also has major copper mining and other base and noble metal production, such as in the Skellefte district in northern Sweden and at Garpenberg and Zinkgruvan in the Bergslagen province. Among these diverse mines, the extraction of tellurium from Boliden's Kankberg mine is notable, placing it among the world's top five Te producers.



Outcrops on Utö Island (Stockholm Archipelago, Sweden) where Li-rich granitic pegmatite dykes yielded the discovery of lithium (1818). Photo: Erik Jonsson.

Sweden also has other advanced or near-advanced projects for graphite, REE, phosphorus, fluorspar, lithium, tantalum, tungsten and vanadium, even if several by-product CSRM and other metals such as scandium (Sc) remain poorly constrained (Jonsson et al., 2019; LKAB, 2023; Jonsson et al., 2023; LKAB, 2024; LKAB, 2026). The strategic significance of this Swedish resource base is now increasingly backed by EU and national capital steering. In March 2025, the European Commission granted Strategic Project status under the CRMA to LKAB's industrial park for "critical minerals" in Luleå, an apatite-based extraction route in Gällivare/Malmberget, and the Per Geijer deposit in Kiruna, explicitly linking the Norrbotten iron district to a future Nordic-EU value chain for phosphorus and REEs. In parallel, SSAB's Luleå transformation was awarded SEK 1.45 billion through the EU Just Transition Fund and Swedish co-financing, underlining that substantial public support is already being directed to the broader northern iron-steel district. Together with Rönnskär's established non-ferrous smelting and recycling role, this means that Sweden should now be understood not only as a mining country, but as a northern industrial corridor where iron, phosphorus, REE, steel and refining investments are beginning to converge (SSAB, 2024; LKAB, 2025). Notably, the major Aitik Cu–Au mine, one of Europe's largest open-pit copper mines, is also located in this area (near Gällivare/Malmberget), and several copper-based projects are under development in the region, such as the previously mined Viscaria deposit, which is nearing re-opening (e.g., Viscaria, 2025).

5.3 Concluding summary

Accelerating CSRM demand has already been signalled by earlier foresight studies and is now being reinforced by additional macro-dynamics. JRC projections already indicated that, relative to 2020, EU battery-related lithium demand could increase 12-fold by 2030 and 21-fold by 2050, with a similar pattern for graphite, while permanent-magnet REE demand also rises sharply under strategic-technology deployment scenarios (Carrara et al., 2023). More recent, self-sufficiency analysis for e-mobility has reached a compatible conclusion from the supply side: even under expanded European extraction plans, graphite, cobalt and REEs will remain structurally constrained, while lithium supply will improve but remain insufficient to fully meet projected demand (Koesse et al., 2025). These studies, comparatively, indicate that many of the commodities most clearly associated with accelerating demand and expected shortage risk already lie within the Nordic CSRM portfolio, especially lithium, graphite, nickel, cobalt, phosphorus and different rare earth elements. These transition-led trajectories are likely to magnify significantly with AI-centred data infrastructure and defence demand coupling, producing a broader and more synchronised expansion in CSRM consumption than was anticipated in the 2021 green-transition framing. Recycling will expand and remains necessary, but the evidence reviewed here indicates that it cannot meet more than a limited share of the projected demand increase for most CSRM, particularly where substitutes are unavailable or reduce performance materially. CSRM shortages are therefore likely to persist.

Overarching macroeconomic and geopolitical shocks are the most likely to trigger supply shortages, acting directly on mining and metallurgical industries rather than only through trade-policy channels: in March 2026, S&P Global reported that the war in the Middle East simultaneously pushed energy-related market stress higher and contributed to aluminium-smelter curtailments in Qatar and Bahrain, forcing a downward revision of the 2026 global aluminium production forecast from 75.4 Mt to 74.96 Mt (S&P Global, 2026). At present, the main countervailing force acting on demand and supply with differentiated geopolitical instrumentation appears to be sovereignty and state action that restricts, conditions or reroutes mineral trade, as illustrated by Chinese export controls on strategic minerals and African export restriction or downstreaming measures, such as the DRC's temporary suspension of cobalt exports and Namibia's ban on exports of unprocessed critical minerals (Carrara et al., 2023; Girardi et al., 2023; Koesse et al., 2025; IEA, 2025a; OpenAI, 2025a; OpenAI, 2025b; Reuters, 2025c; MOFCOM & GACC, 2025; IEA, 2025e; S&P Global, 2026).

Against this macroeconomic picture, where geopolitics can cause rapid demand–supply imbalances, the Nordic mineral resources potential could become a cushion that reduces EU-level CSRM stress. Therefore, natural resources and their successful conversion and supply-chain integration represent a real game

changing opportunity that should not be underestimated. If we look closely at the Nordic supply side, what emerges is a dual heterogeneity: a geographically distinct mineral resource base, but also heterogeneity in its supply-chain development.

The central contrast between demand and supply therefore emphasises that we need to consider not only increases in raw material tonnage, but most importantly, smartly design supply-chain development to ensure completeness of mineral value chains (MVCs). This will improve the production output to meet the emerging demand and possibly cushion the future Nordic-EU economy.

On the demand side, Europe needs growing quantities of battery, magnet, digital-infrastructure and defence-relevant materials under conditions of geopolitical concentration. On the supply side, the Nordic region is among the few European regions where mining potential and midstream capability already overlap. This is particularly visible in lithium, graphite, nickel, cobalt, silicon metal, phosphorus and different rare earth elements. Compared to much of the wider EU flagship pipeline, which remains heavily weighted toward isolated upstream projects, the Nordic region already combines mines or advanced projects, metallurgical plants, battery-chemical or alloy production and short logistics to ports and export corridors. The regional advantage is therefore not only geological, but increasingly value-chain based. The question is whether this emerging picture of CSRM interconnection of resources with processing hubs is designed or rather a spontaneous evolution of the mineral industry in the Nordic countries emerging from its agency and legacy.



Ship as base camp, anchored in Kangerluarsuk, West Greenland.
Photo: Diogo Rosa.

An implicit realisation in this supply-chain shift is that supply security depends on connecting exploration and extraction with processing, manufacturing, use and recycling. For several commodities, especially REEs but also lithium and graphite, mining alone does not remove vulnerability if refining, chemical conversion or active material production remain externally concentrated. Keeping more of the chain in Europe and the Nordic countries can also support stronger environmental, social and governance (ESG) standards, including traceability, emissions reduction, waste management and permitting oversight. Europe already has some important processing hubs, for example in France for rare earths, but the wider chain is still incomplete and insufficiently scaled. Investment should therefore support both new extraction and downstream capacity in lithium, REE and graphite value chains. Meeting European supply and strategic autonomy targets depends on refining, chemical conversion, separation and materials upgrading capacity as much as depending on new mines. The decisive question is therefore not only whether the Nordic countries can mine more, but whether selective trade diversification and chain completion can be achieved under realistic timelines, capital constraints, permitting requirements and ESG conditions (EU, 2024a; Solvay, 2025; Carester, 2025).

The final implication is that strategic autonomy still begins with knowledge. In this sense, the future Nordic contribution will depend not only on geology and projects, but also on the ability to connect demand analysis, supply assessment and interoperable knowledge systems into a coherent strategic capability (Eilu et al., 2021; USGS, 2021; Feltrin et al., 2024; GSEU, 2024; CORDIS, 2025).

6 Recommendations

The 2021 recommendations discussed in Eilu et al. (2021) remain valid in structure. Here, we update their context to reflect the stronger role of geopolitics, the twin transition, secondary resources and the importance of midstream chain completion. On this basis, the report supports the following priority actions for the Nordic region.

Recommendation 1. Expand Nordic primary-resource research, exploration and development with explicit attention to processing and verticalisation. Identifying new deposits is essential, however, in concert with focused attention to the delineation of routes from geological knowledge to mineable projects and selectively integrated value chains. Priority should be given to commodities where both JRC demand models and more recent self-sufficiency analysis indicate persistent European exposure, especially lithium, graphite, REEs, nickel, cobalt, phosphorus and copper. This implies improved geological targeting, updated resource evaluation, support for brownfield and greenfield projects, and stronger attention to refining, separation, chemical conversion and materials-upgrading nodes close to extraction sites and ports. The mostly fundamental lack of information on the geological distribution of by-product metals (e.g., Bi, Co, Ga, Ge, Sb), but also of scarce near-REE such as Sc in Nordic systems should be improved through focused work. Such studies could be national, but in some cases, a broader pan-Nordic approach may yield the best results.

Recommendation 2. Broaden work on secondary resources as a complementary CSRM supply stream. Tailings, mine waste, slags, process residues, side streams and selected industrial wastes should be evaluated through integrated geological, geochemical, geophysical, process and value chain information. This approach can identify recovery gaps, clarify where primary and secondary resources can work together, and support selective prioritisation while recognising that secondary resources complement rather than replace primary mining.

Recommendation 3. Consolidate a shared Nordic mineral-intelligence architecture for primary and secondary resources. The earlier call for a joint database should now be interpreted more broadly as a decision-support system, linking deposits, secondary resources, mineral-potential belts, mine and metallurgical wastes, processing and refining nodes, ownership, trade exposure and project maturity. Existing Nordic initiatives, such as NODD, provide a working basis, but the next step should be tighter interoperability with wider European efforts such as GSEU/EGDI and FutuRaM, so that Nordic planning can be connected directly to EU strategic-project assessment, land-use choices and supply-security analysis.

Recommendation 4. Strengthen Nordic demand, trade and supply-chain foresight research under a geopolitical lens. Demand analysis should no longer be framed solely through the green transition, but instead incorporate the combined effects of electrification, AI-centred digital infrastructure, defence requirements and trade-policy disruption. In practical terms, this means coupling material-demand forecasting with production, trade-flow and macroeconomic analysis so that the Nordic countries can better anticipate where future shortages or systemic shocks are most likely to intersect with regional resource strengths. Particular attention should be given to the interaction between energy security and raw-material security, including how reductions in energy bottlenecks could enable the emergence of new mineral value chains and previously uneconomic production pathways.

Recommendation 5. Develop Nordic capacity-building programmes for early-career geologists and geoscientists working in geological surveys, research institutes and Nordic research centres. These programmes should strengthen shared expertise in CSRM geology, secondary resources, mineral economics, GIS/database methods, mineral processing, ESG assessment and strategic supply-chain analysis. Capacity building is needed to maintain the knowledge base required for long-term Nordic mineral intelligence, project evaluation and public-sector decision support.

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Appendix 1

A1.1 Abbreviations

AI	Artificial intelligence
ASAP	Act in Support of Ammunition Production
BFRP	Basalt Fibre Reinforced Polymer
BGS	British Geological Survey
C4ISR	Command, Control, Communications, Computers, Intelligence, Surveillance and Reconnaissance
CBAM	Carbon Border Adjustment Mechanism
CIGS	Copper–indium–gallium–selenide thin-film solar cell
CORDIS	Community Research and Development Information Service
CRF	Continuous Rock Fibre
CRIRSCO	Committee for Mineral Reserves International Reporting Standards
CRMA	Critical Raw Materials Act (EU)
CSRM	Critical and Strategic Raw Material
DRC	Democratic Republic of the Congo
EDA	European Defence Agency
EC	European Commission
EEZ	Exclusive economic zone
EGDI	European Geological Data Infrastructure
EI	Economic Importance
ESG	Environmental, Social and Governance
ERT	Electrical resistivity tomography
EUR	Euro
EU	European Union
EV	Electric vehicle
FODD	Fennoscandian Ore Deposit Database
FINODD	Finland Ore Deposit Database
GME	Greenland Minerals and Energy
GACC	General Administration of Customs of China
GIS	Geographic information system
GSEU	Geological Service for Europe
GEUS	Geological Survey of Denmark and Greenland
GPR	Ground-penetrating radar
GTK	Geological Survey of Finland

HCSS	The Hague Centre for Strategic Studies
HHI	Herfindahl–Hirschman Index
HSLA	High-strength low-alloy
HI	University of Iceland
HREE	Heavy Rare Earth Elements
ICT	Information and communications technology
IEA	International Energy Agency
IFDC	International Fertilizer Development Center
ÍSOR	Iceland GeoSurvey
IP	Induced polarization
IR	Import reliance
IRTC	International Round Table on Materials Criticality
JORC	Australasian Code for Reporting of Exploration Results, Mineral Resources and Ore Reserves
JRC	European Commission's Joint Research Centre
LCF	Air Defence & Command Frigate; Dutch Luchtverdedigings- en Commandofregat
LEED	Leadership in Energy and Environmental Design
LKAB	Luossavaara-Kiirunavaara AB
LLM	Large language model
LREE	Light Rare Earth Elements
MCS	Mineral Commodity Summaries
MRE	Mineral resource estimate
MMR	Ministry of Mineral Resources, Government of Greenland
MOFCOM	Ministry of Commerce of the People's Republic of China
Mt	Million tonnes
MSWI	Municipal solid-waste incineration
MVC	Mineral value chain
MVCs	Mineral value chains
NACE	Nomenclature of Economic Activity Codes
NATO	North Atlantic Treaty Organization
NEA	National Energy Authority of Iceland
NOAA	National Oceanic and Atmospheric Administration
NGU	Geological Survey of Norway
NODD	Nordic Ore Deposit Database
NordMin	Nordic network on sustainable non-energy raw materials (2013–2017)
NSCRMD	Nordic Secondary Critical Raw Material Database
PGE	Platinum Group Elements

PGM	Platinum Group Metals
PV	Photovoltaic
REE	Rare Earth Elements
RM	Raw material
RIR	Recycled input rate
RMT	Radio magnetotellurics
RU	Reykjavik University
SAFE	Security Action for Europe
SCRREEN	Solutions for Critical Raw Materials - a European Expert Network
SCRREEN2	Second phase of the SCRREEN critical raw materials expert-network project
SCRREEN3	Third-phase continuation of the SCRREEN CSRM factsheet series
SEC	U.S. Securities and Exchange Commission
SEK	Swedish krona
SGU	Geological Survey of Sweden
SI	Substitution index
SMS	Seafloor massive sulphides
SR	Supply Risk
SRM	Strategic Raw Material
SSAB	SSAB steel company
TSF	Tailings storage facility
TREO	Total rare earth oxides
UMRA	Undiscovered mineral resource assessment
UNFC	United Nations Framework Classification for Resources
UNFCCC	United Nations Framework Convention on Climate Change
USD	United States dollar
USDOI	U.S. Department of the Interior
USGS	United States Geological Survey
VMS	Volcanogenic massive sulphide
VTT	Technical Research Centre of Finland
WGI	World Governance Indicators
WNA	World Nuclear Association

A1.2 Chemical Symbols Used

Al: Aluminium

Ba: Barium

Be: Beryllium

Sb: Antimony

Bi: Bismuth

Co: Cobalt

Cu: Copper

Ga: Gallium

Ge: Germanium

Hf: Hafnium

In: Indium

Ir: Iridium

Li: Lithium

Mn: Manganese

Nb: Niobium

Ni: Nickel

Os: Osmium

P: Phosphorus

Pd: Palladium

Pt: Platinum

Ru: Ruthenium

Si: Silicon

Ta: Tantalum

Ti: Titanium

V: Vanadium

W: Tungsten

Zn: Zinc

Appendix 2

Table A1

Mine production (t/y) ¹	Antimony	Arsenic	Baryte	Bauxite/alumina/aluminium ⁷	Beryllium	Bismuth ⁶	Cobalt
Global ²	110,000	?	8,700,000	440,000,000	430	4,000	310,000
Finland	0	0	0	0	0	0	1,134
Greenland	0	0	0	0	0	0	0
Iceland	0	0	0	0	0	0	0
Norway	0	0	0	0	0	0	0
Sweden	0	0	0	0	0	0	0
Nordic, total	0	0	0	0	0	0	1,134
Main global producers ^{2,3}	CHN, RUS, TJK, BOL, MMR	PER, CHN, MAR, RUS, BEL	IND, CHN, MAR, KAZ, MEX	GIN, AUS, CHN, BRA, IND	USA, BRA, CHN, NGA, MOZ	CHN, KOR, JPN, LAO, KAZ	COD, IDN, RUS, MDG, AUS
Nordic smelter / refinery production (t/y) ¹	Antimony	Arsenic	Baryte	Bauxite/alumina/aluminium ⁷	Beryllium	Bismuth ⁶	Cobalt
Finland	0	0	-	0	0	0	12,025
Greenland	0	0	-	0	0	0	0
Iceland	0	0	-	750,000	0	0	0
Norway	0	0	-	1,400,000	0	0	3,033
Sweden	0	0	-	0	0	0	0
Nordic, total	0	0	-	2,150,000	0	0	15,058
Global smelter / refinery production (t/y) ⁵	110,000	61,000	-	74,000,000 Al smelter; 150,000,000 alumina refinery	430	16,000	174,703
Known resources (t) ^{1,4}	Antimony	Arsenic	Baryte	Bauxite/alumina/aluminium ⁷	Beryllium	Bismuth ⁶	Cobalt
Global ²	>2,000,000	?	740,000,000	55–75 billion	>100,000	?	25,000,000
Finland	2,555	2,400	0	0	464	0	541,258
Greenland	3,780	0	480,000	0	65	0	0
Iceland	0	0	0	0	0	0	0
Norway	0	0	0	0	630	0	15,696
Sweden	23,005	446,120	0	0	0	598	38,356
Nordic, total	29,340	448,520	480,000	0	1,159	598	595,310

Assumed additional resources	Antimony	Arsenic	Baryte	Bauxite/alumina/aluminium ⁷	Beryllium	Bismuth ⁶	Cobalt
Finland	Yes	Yes	Yes	No	Yes	Yes	Yes
Greenland	Yes	Yes	Yes	No	Yes	Yes	Yes
Iceland	No	No	Yes	No	No	No	No
Norway	Yes	Yes	No	No	Yes	Yes	Yes
Sweden	Yes	Yes	No	No	Yes	Yes	Yes

¹ Current data; sources of information for Nordic country rows are the respective national mining registries and partner fact sheets.

² USGS (2026), unless otherwise stated in table-specific notes.

³ Main global producers, listed on the relevant production basis. Abbreviations: AUS = Australia, BEL = Belgium, BOL = Bolivia, BRA = Brazil, CHN = China, COD = Democratic Republic of the Congo, GIN = Guinea, IDN = Indonesia, IND = India, JPN = Japan, KAZ = Kazakhstan, KOR = South Korea, LAO = Laos, MAR = Morocco, MDG = Madagascar, MEX = Mexico, MMR = Myanmar, MOZ = Mozambique, NGA = Nigeria, PER = Peru, RUS = Russia, TJK = Tajikistan, USA = United States.

⁴ Both CRIRSCO-compliant and non-compliant resources; assumed submarine resources are excluded.

⁵ Global smelter and refinery production is reported where a comparable processing-stage statistic is available; not relevant for baryte.

⁶ Bismuth is only recovered as a by-product from major metal ores, is rarely included in mineral resource estimates, and is not mined anywhere as a target metal. Hence, mine production and global resources are not known, and in the table row "Main global producers" the countries indicated for Bi are the main refinery producers of Bi.

⁷ Bauxite/alumina/aluminium combines bauxite mine production and resources with aluminium smelter production as the Nordic processing-stage statistic. No Nordic bauxite mine production or bauxite resource is counted in this table; alternative alumina-bearing feedstocks are reported under feldspar/nepheline syenite.

Table A2

Mine production (t/y) ¹	Copper	Coking coal ⁶	Feldspar/nepheline syenite	Fluorspar	Gallium ⁷	Germanium ^{7,8}
Global ²	23,000,000	1,075,305,187 ⁶	31,000,000	10,000,000	n.a.	n.a.
Finland	28,866	0	60,034	0	0	0
Greenland	0	0	?	0	0	0
Iceland	0	0	?	0	0	0
Norway	0	110,000	360,000	0	0	0
Sweden	68,000	0	?	0	0	0
Nordic, total	105,866	110,000	420,034	0	0	0
Main global producers ^{2,3}	CHL, COD, PER, CHN, RUS	CHN, AUS, RUS, IND, USA	IND, TUR, IRN, CHN, ITA	CHN, MEX, MNG, ZAF	CHN, RUS, JPN	USA, BEL, CAN, CHN, DEU, RUS
Nordic smelter / refinery production (t/y) ¹	Copper	Coking coal ⁶	Feldspar/nepheline syenite	Fluorspar	Gallium ⁷	Germanium ^{7,8}
Finland	169,775	0	22,678	-	0	0
Greenland	0	0	0	-	0	0
Iceland	0	0	0	-	0	0
Norway	18,279	110,000	360,000	-	0	0
Sweden	266,379	0	0	-	0	0
Nordic, total	454,433	110,000	382,678	-	0	0
Global smelter / refinery production (t/y) ⁵	29,000,000	?	?	-	900	140

Known resources (t) ^{1,4}	Copper	Coking coal ⁶	Feldspar/ nepheline syenite	Fluorspar	Gallium ⁷	Germanium ^{7,8}
Global ²	2,100,000,000 ⁹	3,380 billion ⁶	?	5,000,000,000	>1,000,000	>122,000
Finland	5,934,558	0	910,000	0	0	0
Greenland	108,000	0	80,800,000	250,000	27,000	0
Iceland	0	0	0	0	0	0
Norway	1,800,761	26,000,000	?	984,000	0	0
Sweden	10,925,000	0	110,000,000	2,828,000	0	0
Nordic, total	18,768,319	26,000,000	191,710,000	4,062,000	27,000	Not quantified
Assumed additional resources	Copper	Coking coal ⁶	Feldspar/ nepheline syenite	Fluorspar	Gallium ⁷	Germanium ^{7,8}
Finland	Yes	No	Yes	No	Yes	Yes
Greenland	Yes	Yes	Yes	Yes	Yes	Yes
Iceland	Yes	No	No	Yes	No	No
Norway	Yes	Yes	Yes	Yes	Yes	Yes
Sweden	Yes	No	Yes	Yes	Yes	Yes

¹ Current data; sources of information for Nordic country rows are the respective national mining registries and partner fact sheets.

² USGS (2026), BGS World Mineral Statistics / World Mineral Production, World Mining Data (2026), IEA (2025a) and SCREEN3 (2025), as applicable.

³ Main global producers, listed on the relevant production basis. Abbreviations: AUS = Australia, BEL = Belgium, CAN = Canada, CHL = Chile, CHN = China, COD = Democratic Republic of the Congo, DEU = Germany, IND = India, IRN = Iran, ITA = Italy, JPN = Japan, MEX = Mexico, MNG = Mongolia, PER = Peru, RUS = Russia, TUR = Turkey, USA = United States, ZAF = South Africa.

⁴ Both CRIRSCO-compliant and non-compliant resources; assumed submarine resources are excluded.

⁵ Global smelter and refinery production is reported where a comparable processing-stage statistic is available; not relevant for coking coal, feldspar / nepheline syenite and fluorspar.

⁶ Coking coal global mine production and main global producers are from World Mining Data (2026) on the basis of 2023 production; global known resources use the IEA World Energy Outlook 2025 estimate for the coking-coal share of remaining world coal resources.

⁷ Data for main producing countries for Ga and Ge relate to refinery production, as mine production data are not available.

⁸ Germanium refinery production includes both primary production from zinc concentrates and secondary production from scrap; the global Ge resource estimate should be regarded as conservative.

⁹ Copper global resources are based on USGS Mineral Commodity Summaries 2026.

Table A3

Mine production (t/y) ¹	Graphite	Hafnium ⁶	Helium ⁷	Lithium ⁸	Magnesium metal ⁷	Manganese ⁹
Global ²	1,800,000	n.a.	?	290,000	?	20,000,000
Finland	0	0	0	0	0	0
Greenland	0	0	0	0	0	0
Iceland	0	0	0	0	0	0
Norway	6,600	0	0	0	0	0
Sweden	0	0	0	0	0	0
Nordic, total	6,600	0	0	0	0	0
Main global producers ^{2,3}	CHN, MDG, TZA, BRA, MOZ, RUS	FRA, USA, CHN, RUS	USA, QAT, ZAF, CAN, DZA, CHN, POL, RUS	AUS, CHN, CHL, ARG, ZWE	CHN, TUR, RUS, BRA, ISR	ZAF, GAB, GHA, AUS, BRA, IND, CHN

Nordic smelter / refinery production (t/y) ¹	Graphite	Hafnium ⁶	Helium ⁷	Lithium ⁸	Magnesium metal ⁷	Manganese ⁹
Finland	0	0	0	0	0	0
Greenland	0	0	0	0	0	0
Iceland	0	0	0	0	0	0
Norway	0	0	0	0	0	490,000
Sweden	0	0	0	0	0	0
Nordic, total	0	0	0	0	0	490,000
Global smelter / refinery production (t/y) ⁵	-	28	190 million m3	122,535 ⁸	1,100,000	13,988,346 ⁹
Known resources (t) ^{1,4}	Graphite	Hafnium ⁶	Helium ⁷	Lithium ⁸	Magnesium metal ⁷	Manganese ⁹
Global ²	>800,000,000	>1,000,000	?	150,000,000	?	17,273,000,000 ⁹
Finland	1,562,794	0	0	113,917	0	3,391,240
Greenland	6,000,000	107,500	0	235,600	0	0
Iceland	0	0	0	0	0	0
Norway	20,376,344	0	0	0	0	0
Sweden	15,617,500	6,741	0	3,180	0	8,560,000
Nordic, total	43,556,638	114,241	Not quantified	352,697	Not quantified for Mg metal	11,951,240
Assumed additional resources	Graphite	Hafnium ⁶	Helium ⁷	Lithium ⁸	Magnesium metal ⁷	Manganese ⁹
Finland	Yes	Yes	No	Yes	Yes	Yes
Greenland	Yes	Yes	No	Yes	Yes	No
Iceland	No	No	No	No	Yes	No
Norway	Yes	No	Yes	No	Yes	Yes
Sweden	Yes	Yes	No	Yes	Yes	Yes

¹ Current data; sources of information for Nordic country rows are the respective national mining registries and partner fact sheets.

² USGS (2026), SCRREEN3 (2025), BGS and supporting published references, as applicable.

³ Main global producers, listed on the relevant production basis. Abbreviations: ARG = Argentina, AUS = Australia, BRA = Brazil, CAN = Canada, CHL = Chile, CHN = China, DZA = Algeria, FRA = France, GAB = Gabon, GHA = Ghana, IND = India, ISR = Israel, MDG = Madagascar, MOZ = Mozambique, POL = Poland, QAT = Qatar, RUS = Russia, TUR = Turkey, TZA = Tanzania, USA = United States, ZAF = South Africa, ZWE = Zimbabwe.

⁴ Both CRIRSCO-compliant and non-compliant resources; assumed submarine resources are excluded.

⁵ Global smelter and refinery production is reported where a comparable processing-stage statistic is available; not relevant for graphite.

⁶ Hafnium production is an estimate, as the trade is not transparent; global Hf resources are roughly estimated from zircon and baddeleyite resources.

⁷ Helium and magnesium metal are evaluated at the production / processing stage; the comparable current global production proxy is carried in the smelter / refinery row rather than the mine-production row.

⁸ Lithium global smelter and refinery production is shown from the 2025 SCRREEN3 processing-stage average.

⁹ Manganese global smelter and refinery production and global resources are shown on the current SCRREEN3 source basis.

Table A4

Mine production (t/y) ¹	Nickel	Niobium ⁸	Phosphorus ⁶	Platinum group metals ⁷	Rare Earth Elements	Scandium ⁹
Global ²	3,900,000	112,000	250 Mt phosphate rock	419.01	390,000	n.a.
Finland	36,599	0	146,600	1.952	0	0
Greenland	0	0	0	0	0	0
Iceland	0	0	0	0	0	0
Norway	0	0	0	0	0	0
Sweden	0	0	0	0	0	0
Nordic, total	36,599	0	146,600	1.952	0	0
Main global producers ^{2,3}	IDN, PHL, NCL, CAN, RUS	BRA, CAN, COD, RUS	CHN, MAR, USA, RUS	RUS, ZAF, ZWE, CAN, USA	CHN, AUS, USA, MMR, BRA	CHN, JPN, CAN, PHL
Nordic smelter / refinery production (t/y) ¹	Nickel	Niobium ⁸	Phosphorus ⁶	Platinum group metals ⁷	Rare Earth Elements	Scandium ⁹
Finland	99,862	0	-	1.952	0	0
Greenland	0	0	-	0	0	0
Iceland	0	0	-	0	0	0
Norway	98,379	0	-	3.607	0	0
Sweden	0	0	-	0	0	0
Nordic, total	198,241	0	-	5.559	0	0
Global smelter / refinery production (t/y) ⁵	3,436,000	47,710 ⁸	-	44.6	?	80
Known resources (t) ^{1,4}	Nickel	Niobium ⁸	Phosphorus ⁶	Platinum group metals ⁷	Rare Earth Elements	Scandium ⁹
Global ²	>350,000,000	84,000,000 ⁸	?	>100,000	>85,000,000	>6,000,000
Finland	6,884,135	122,381	219,800,000	890.2	169,067	2,184
Greenland	0	5,900,000	11,456,025	575	33,749,590	0
Iceland	0	0	0	0	0	0
Norway	160,620	22,052	52,864,000	4.25	12,880,090	6.5
Sweden	3,253,868	38,500	58,900,000	0.485	3,200,169	0
Nordic, total	10,298,623	6,082,933	343,020,025	1,469.935	49,998,916	2,190.5

Assumed additional resources	Nickel	Niobium ⁸	Phosphorus ⁶	Platinum group metals ⁷	Rare Earth Elements	Scandium ⁹
Finland	Yes	Yes	Yes	Yes	Yes	Yes
Greenland	Yes	Yes	Yes	Yes	Yes	Yes
Iceland	No	No	No	No	No	No
Norway	Yes	Yes	Yes	Yes	Yes	Yes
Sweden	Yes	Yes	Yes	Yes	Yes	Yes

¹ Current data; sources of information for Nordic country rows are the respective national mining registries and partner fact sheets.

² USGS (2026), SCREEN3 (2025), BGS and Johnson Matthey published references, as applicable.

³ Main global producers, listed on the relevant production basis. Abbreviations: AUS = Australia, BRA = Brazil, CAN = Canada, CHN = China, COD = Democratic Republic of the Congo, IDN = Indonesia, JPN = Japan, MAR = Morocco, MMR = Myanmar, NCL = New Caledonia, PHL = Philippines, RUS = Russia, USA = United States, ZAF = South Africa, ZWE = Zimbabwe.

⁴ Both CRIRSCO-compliant and non-compliant resources; assumed submarine resources are excluded.

⁵ Global smelter and refinery production is reported where a comparable processing-stage statistic is available; for platinum group metals, a comparable global processing total is not reported in the current source set.

⁶ Phosphorus values are calculated from apatite / phosphate-rock production and resources on the basis of phosphorus.

⁷ Platinum group metals are commonly recovered at nickel and copper mines and refineries; PGM rows combine the reported PGM elements available in each source. Global mine production combines Pd, Pt, Rh, Ir and Ru; Os is not separately quantified in the current source set.

⁸ Niobium global smelter and refinery production and resources use the 2025 SCREEN3 niobium basis.

⁹ Scandium is only recovered as a by-product from major metal ores, tailings and residues, is rarely included in mineral resource estimates, and is not mined anywhere as a target metal. Hence, total mine production is not known.

Table A5

Mine production (t/y) ¹	Silicon metal ⁶	Strontium	Tantalum ⁷	Titanium ⁸	Tungsten ⁹	Vanadium ¹⁰
Global ²	?	450,000	2,500	5,700,000 ⁸	85,000	110,000 ¹⁰
Finland	0	0	0	0	0	0
Greenland	0	0	0	0	0	0
Iceland	0	0	0	0	0	0
Norway	1,000,000	0	0	390,000 ⁷	0	0
Sweden	0	0	0	0	0	0
Nordic, total	1,000,000	0	0	390,000	0	0
Main global producers ^{2,3}	CHN, BRA, NOR	IRN, ESP, CHN, MEX	COD, RWA, BRA, CHN, AUS	CHN, MOZ, ZAF, AUS, NOR	CHN, VNM, RUS, BOL, RWA	CHN, RUS, BRA, ZAF
Nordic smelter / refinery production (t/y) ¹	Silicon metal ⁶	Strontium	Tantalum ⁷	Titanium ⁸	Tungsten ⁹	Vanadium ¹⁰
Finland	0	0	0	0	0	0
Greenland	0	0	0	0	0	0
Iceland	124,000	0	0	0	0	0
Norway	240,000	0	0	21,582	0	0
Sweden	0	0	0	0	0	0
Nordic, total	364,000	0	0	21,582	0	0
Global smelter / refinery production (t/y) ⁵	4,600,000 Si metal; 5,000,000 ferrosilicon ⁶	?	1,500 ⁷	370,000	87,000 ⁹	110,000

Known resources (t) ^{1,4}	Silicon metal ⁶	Strontium	Tantalum ⁷	Titanium ⁸	Tungsten ⁹	Vanadium ¹⁰
Global ²	?	?	>390,000	690,000,000 ⁸	7,000,000 ⁹	>63,000,000
Finland	0	0	499	24,100,000	2,300	1,100,000
Greenland	2,797,860	9,800,000	916,000	11,914,325	26,030	179,000
Iceland	0	0	0	0	0	0
Norway	11,664,000	0	0	230,000,000	2,701	2,112,077
Sweden	522,570	0	68	18,930,000	1,770	10,960,000
Nordic, total	14,984,430	9,800,000	916,567	284,944,325	32,801	14,351,077
Assumed additional resources	Silicon metal ⁶	Strontium	Tantalum ⁷	Titanium ⁸	Tungsten ⁹	Vanadium ¹⁰
Finland	Yes	No	Yes	Yes	Yes	Yes
Greenland	Yes	Yes	Yes	Yes	Yes	Yes
Iceland	No	No	No	Yes	No	No
Norway	Yes	No	No	Yes	Yes	Yes
Sweden	Yes	No	Yes	Yes	Yes	Yes

¹ Current data; sources of information for Nordic country rows are the respective national mining registries and partner fact sheets.

² USGS (2026), BGS World Mineral Production and SCREEN3 (2025), as applicable.

³ Main global producers, listed on the relevant production basis. Abbreviations: AUS = Australia, BOL = Bolivia, BRA = Brazil, CHN = China, COD = Democratic Republic of the Congo, ESP = Spain, IRN = Iran, MEX = Mexico, MOZ = Mozambique, NOR = Norway, RUS = Russia, RWA = Rwanda, VNM = Vietnam, ZAF = South Africa.

⁴ Both CRIRSCO-compliant and non-compliant resources; assumed submarine resources are excluded.

⁵ Global smelter and refinery production is reported where a comparable processing-stage statistic is available.

⁶ Raw material for silicon metal is produced from quartz resources, which are also used for other purposes and at larger tonnages than silicon metal production. Hence, figures for global mine production are uncertain and resources cannot be given on a silicon-metal basis.

⁷ Tantalum global smelter and refinery production is an estimate only; global resources are shown as a reserve-based lower bound, because no precise global resource evaluation exists.

⁸ Titanium global mine production is shown on the BGS TiO₂-content basis.

⁹ Tungsten global smelter and refinery production and resources use the 2025 SCREEN3 basis.

¹⁰ Vanadium global smelter and refinery production and resources are based on USGS Mineral Commodity Summaries 2026.

Appendix 3

Table B1: Top-3 country suppliers

Material	Stage	Rank 1	Rank 2	Rank 3	Source
Beryllium	Mining	United States 53.5%	Brazil 18.6%	China 17.9%	USGS MCS 2026
Helium	Production	USA 81 million m ³	Qatar 63 million m ³	South Africa 18 million m ³	USGS 2026 helium fact sheet
Hafnium	Processing	France 49%	USA 44%	China 3%	SCREEN3 2025 CRM factsheets
Strontium	Mining	Iran 55.6%	Spain 22.2%	China 17.8%	USGS MCS 2026
Borates	Mining	Turkey 35.4%	USA 25.7%	Kazakhstan 9.9%	BGS World Mineral Statistics 2023
Feldspar / Nepheline syenite	Mining	India 19.4%	Turkey 17.1%	Iran 12.6%	USGS 2026 feldspar fact sheet
Copper	Mining	Chile 23%	Congo (Kinshasa) 13.9%	Peru 11.7%	USGS MCS 2026
Copper	Smelting / refining	China 48.3%	Congo (Kinshasa) 9.7%	Chile 5.9%	USGS MCS 2026
Niobium	Mining	Brazil 89.9%	Canada 8.2%		USGS 2023 niobium fact sheet (latest ranked split in local draft)
Palladium	Mining	Russia 44.2%	South Africa 36.8%	Canada 8.4%	USGS MCS 2026
Platinum	Mining	South Africa 70.6%	Russia 11.8%	Zimbabwe 10.6%	USGS MCS 2026
Rhodium	Mining	South Africa 80%	Russia 12%	Zimbabwe 5%	Johnson Matthey 2020 / 2022, carried in local PGM draft
Cobalt	Mining	Congo (Kinshasa) 74.2%	Indonesia 14.2%	Russia 2.5%	USGS MCS 2026
Cobalt	Refinery	China 79.7%	Finland 6%	Canada 2.8%	BGS World Mineral Statistics 2023
Tantalum	Mining	Congo (Kinshasa) 52%	Rwanda 16%	Nigeria 15.6%	USGS MCS 2026
Bauxite	Mining	Guinea 34.1%	Australia 22%	China 19.8%	USGS MCS 2026
Aluminium	Smelter	China 60.8%	India 5.7%	Russia 5.3%	USGS MCS 2026
Lithium	Mining	Australia 31.7%	China 21.4%	Chile 19.3%	USGS MCS 2026
Antimony	Mining	China 36.4%	Russia 29.1%	Tajikistan 20%	USGS MCS 2026

Material	Stage	Rank 1	Rank 2	Rank 3	Source
Arsenic trioxide	Production	Peru 49.2%	China 39.3%	Morocco 8.2%	USGS MCS 2026
Barite / Baryte	Mining	India 34.5%	China 25.3%	Morocco 11.5%	USGS MCS 2026
Bismuth	Refinery	China 87.5%	Korea, Republic of 6.2%	Japan 3.1%	USGS MCS 2026
Fluorspar	Mining	China 60%	Mexico 15%	Mongolia 15%	USGS MCS 2026
Gallium	Primary production	China 100%	Russia 0.7%	Japan 0.3%	USGS MCS 2026
Germanium metal	Production	China 94.8%	USA 2.8%	Russia 2.4%	BGS World Mineral Statistics 2023
Natural graphite	Mining	China 77.8%	Madagascar 4.4%	Tanzania 4.2%	USGS MCS 2026
Magnesium metal	Smelter	China 86.4%	Russia 5.5%	Brazil, Israel 1.8%	USGS 2026 magnesium fact sheet
Manganese	Mining	South Africa 38%	Gabon 25%	Ghana 10%	USGS MCS 2026
Nickel	Mining	Indonesia 66.7%	Philippines 6.9%	Russia 5.1%	USGS MCS 2026
Nickel	Smelting / refinery	Indonesia 41.4%	China 28.5%	Russia 4.6%	BGS World Mineral Statistics 2023
Phosphate rock	Mining	China 44%	Morocco 14.4%	United States 8%	USGS MCS 2026
Rare earths	Mining	China 69.2%	United States 13.1%	Australia 7.4%	USGS MCS 2026
Scandium oxide	Processing	China ~80–90%	Philippines feedstock	Japan downstream oxide processing	USGS 2026 + Asian Metal 2025, via local scandium draft
Silicon metal	Smelting / refining	China 87%	Brazil 3.9%	Norway 2.8%	USGS MCS 2026
Titanium ilmenite	Mining	China 32.7%	Mozambique 19.4%	South Africa 13.3%	USGS MCS 2026
Titanium sponge	Processing	China 70.3%	Japan 14.3%	Russia 6.8%	USGS MCS 2026
Tungsten	Mining	China 78.8%	Vietnam 3.5%	Kazakhstan 2.8%	USGS MCS 2026
Vanadium	Mining	China 74.5%	Russia 19.1%	Brazil 4.8%	USGS MCS 2026

**Produced by**

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