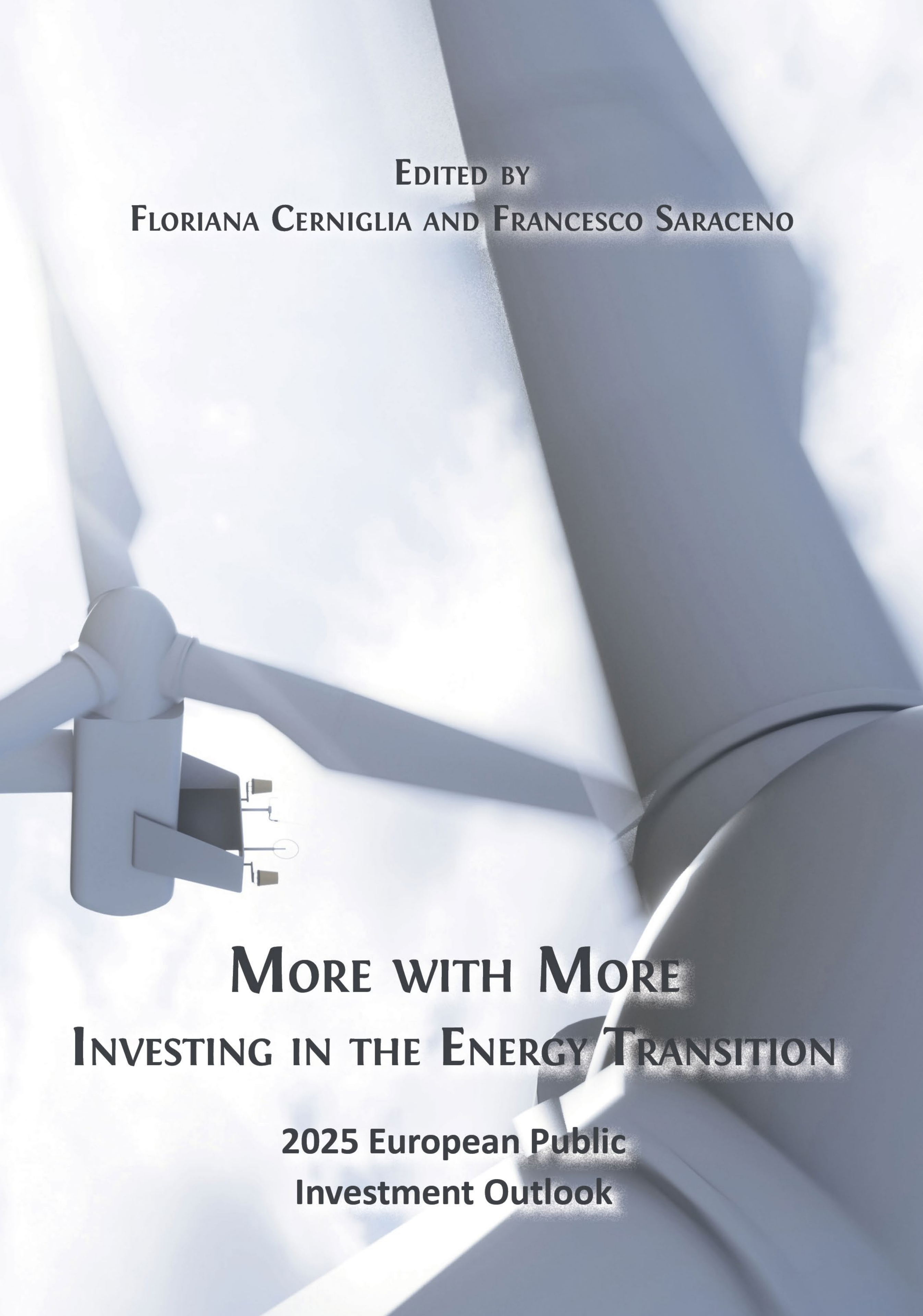

Edited by
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More with More
Investing in the Energy Transition

2025 European Public Investment Outlook

https://www.openbookpublishers.com

Open Reports Series vol. 14 | ISSN Print: 2399-6668 | ISSN Digital: 2399-6676

Paperback: 978-1-80511-743-8
Hardback: 978-1-80511-744-5
PDF: 978-1-80511-745-2
HTML: 978-1-80511-747-6
EPUB: 978-1-80511-746-9

DOI: 10.11647/OBP.0499

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Cover design: Jeevanjot Kaur Nagpal

The publication of this book was supported by CRANEC—Centro di ricerche in analisi economica e sviluppo economico internazionale, Università Cattolica del Sacro Cuore, Milan; F2i SGR; and OFCE-Sciences Po Paris

10. Investing in Critical Raw Materials for the Clean-Tech Transition in the EU

Roberto Zoboli[1]

The procurement of critical raw materials (CRM) could become a fundamental barrier to the development of clean technology and net-zero manufacturing in the EU, thus endangering the achievement of major objectives of EU self-sufficiency in the climate-energy transition. The EU policy framework includes several measures introduced in 2024 and 2025 to push both clean-tech manufacturing and security of supply of CRM in the framework of the EU Competitiveness Compass and the Clean Industrial Deal of 2025. Criticality of materials has been defined as a combination of "economic importance" and "supply risk". On the side of "economic importance", an increasing demand for CRM comes from net-zero energy technologies as well as from digital and military technologies. The EU shows a mixed picture in clean-tech sectors: it holds a leadership position in some areas, while in others it faces a high, and increasing, dependency on imports. Although significant investments are underway to boost manufacturing autonomy, these efforts may struggle to keep pace with rapidly rising demand and intensifying external competition, particularly from China. Therefore, the security of supply of CRM has a key role in providing robustness to EU clean-tech value chains. On the side of the 'supply risk', CRM have entered a phase marked by international tensions and conflicts, exposing the EU's high dependency on exporting countries that can quickly become unreliable. Responses and strategies include diversifying the portfolio of supplier countries, expanding domestic mining within the EU, increasing recycling efforts, and investing in research and innovation. All these approaches face distinct barriers, varying degrees of feasibility, and different implementation timeframes. The first consequence of the 2024 CRM policies has been the approval of forty-seven "strategic projects" within the EU and thirteen outside the EU. It is important that these projects are matched by additional investments in clean-tech manufacturing to keep a balanced development across the whole EU domestic value chain for the energy transition. However, a fundamental uncertainty now surrounds the CRM issue, at both the EU and global scale.

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 https://doi.org/10.11647/OBP.0499.10

10.1 Introduction

The transition induced by the EU climate policy target of net zero by 2050 implies a radical change of the EU energy and techno-economic system. Unlike the energy transitions of the two past centuries, which unfolded gradually within the "fossil energy paradigm" through substitution among dominant primary sources, the current transition requires a rapid and sharp departure from that paradigm (IEA 2021). This radical energy transition, driven by renewables, energy storage, electric mobility, energy efficiency technologies, carbon capture and storage, and other technologies we define as clean tech, is also a revolution for industrial materials. More than conventional energy technologies, clean tech require a large amount of materials that we are now considering as 'critical' or 'strategic', which are becoming a hot area of policy action, research and innovation, and industrial investments.

This chapter addresses the material implications of the energy transition, the development of clean-tech value chains, and the associated investment needs to secure CRM for the EU.

10.2 The EU Policy Framework

With the adoption of the target of net zero by 2050 within the European Green Deal (2019, 2020), the EU started a process of energy transition that offers large opportunities of industrial and economic transformation together with the achievement of higher levels of energy self-sufficiency to reduce dependency on risky energy superpowers (US, Russia, and the other countries of OPEC+).[2] While the energy transition has achieved significant progress, for example renewables accounting for 44% of EU electricity consumption, it continues to face barriers and investment gaps relative to its ambitions, in particular in the scaling of electric mobility and further deployment of renewables (D'Amato et al. 2024).

The second von der Leyen Commission, while confirming the key target of net zero, puts the energy transition or decarbonization in the broader framework of the competitiveness strategy indicated by the Draghi report (European Commission 2024a).[3] The strategic framework is now the EU "Competitiveness Compass" (CC) adopted in January 2025 (European Commission 2025a), of which the second pillar is a roadmap for decarbonization and competitiveness that includes the Clean Industrial Deal (February 2025), an "affordable energy" plan, and a plan for "energy intensive sectors". The CC also includes a third pillar focused on reducing external dependencies to achieve "open strategic autonomy" through a network of trade agreements that secure the supply of raw materials. These pillars complement the first pillar of the CC, which aims at closing the EU innovation gap in artificial intelligence and advancing

2 On OPEC+, see https://www.eia.gov/todayinenergy/detail.php?id=56420

3 The overall strategy and several commitments summarized in the text have been confirmed, and possibly strengthened, in the Letter of Intent sent by the Commission to the Parliament with the report on the State of the Union 2025 (September), see https://commission.europa.eu/strategy-and-policy/state-union/state-union-2025_en

quantum technologies, biotech, robotics, and space technology. All these sectors require Europe to have the capacity to procure and efficiently use industrial raw materials.

The Clean Industrial Deal (CID) (European Commission 2025b) includes different initiatives for the industrialist re-direction of the Green Deal.[4] The CID provides for, inter alia, the speeding up of the rollout of clean energy investments, the acceleration of electrification, the need to complete the internal energy market and to use energy more efficiently, while reducing import. Key instruments under the CID include a proposed "decarbonization acceleration act" and the mobilization of €100 billion to support clean manufacturing, a new "clean industrial state-aid framework", and the proposal for an industrial decarbonization bank to create the financial capacity for these initiatives, supported especially through the revenues from the Emission Trading System and the revision of InvestEU. On the external side, the CID promises a strategy for international security and access to materials by enabling European companies to aggregate their demands for CRM, a "Clean Trade and Investment Partnership", and the simplification of the Carbon Border Adjustment Mechanism. On the domestic side, it pursues the acceleration of the domestic circular transition with the objective of having 24% of materials circular by 2030.

The specific strategy of the EU for clean tech and CRM started already in 2023 with the Net-Zero Industry Act, then adopted by the Regulation 2024/1735, and the Critical Raw Materials Act, then adopted by the Regulation 2024/1252. Both regulations are very ambitious.

The Regulation 2024/1735 on Net-Zero Industry (European Commission 2024b) includes several provisions aimed at boosting investment in clean-tech sectors as represented by a large list of technologies for electricity production from renewables, carbon capture and storage, electric transports, hydrogen, nuclear fusion, and other families of technologies associated with the clean energy transition. The regulation sets a benchmark for at least 40% of the Union's deployment needs to be met through domestic supply by 2030, alongside a target to increase the EU's share of global production of relevant technologies to 15% by 2040. It also provides for streamlining administrative and permitting procedures, the designation of net-zero 'strategic projects' and Net-Zero European Platforms, the creation of CO_2 injection capacity, and the use of regulatory sandboxes to support the establishment of strategic energy technology plans within Member States.

The Critical Raw Materials Regulation 2024/1252 (European Commission 2024c) aims at responding to the risk of supply disruption of critical raw materials needed for the clean-tech transition, and also for the digital transition and now the "military transition". The starting point has been the identification of a list of "critical" and "strategic" raw materials. For these materials, "benchmarks" for domestic supply capacity by 2030 have been set: at least 10% of the EU's annual consumption from extraction; at least 40% from processing; at least 25% from recycling; no more than 65% from imports from one single third country. To

4 See the communication on implementation of 2 July 2025 at https://commission.europa.eu/publications/delivering-clean-industrial-deal-i_en

achieve these benchmarks, the regulation provides for streamlined permitting procedures for CRM projects and the designation of "strategic projects" by Member States, which can benefit from enhanced access to finance together with shorter permitting timelines. In addition, Member States will develop programmes for exploiting their geological resources and will push for a more extensive collection and better management of waste that is rich in CRM, like electric and electronic waste, to extract materials. The same applies to mining waste. On the international side, the regulation introduces actions to geographically diversify the Union's imports of raw materials. Actions include trade agreements to secure the diversification of supply, using the EU's Globe Gateway to deploy projects along the raw materials value chain, setting up an export credit facility to reduce the risk of investment abroad in the areas of materials.

It is interesting to look at the way the lists of "critical" and "strategic" raw materials have been selected. Article 4 of the regulation explains how the thirty-four CRM were selected by the Commission using a methodology adopted in 2017, which is the result of a long process that started in 2011 with the first list of CRM.[5] The methodology considers two fundamental dimensions of "criticality" both related to economic dimensions, instead of geological scarcity criteria: (1) "economic importance" of the specific materials in the EU industrial system, which can be a proxy of the economic impact of supply disruption (demand side); (2) "supply risk" or the probability of supply disruption, which depends on the concentration of supply as measured by global primary supply and the dependence of the EU on that global supply, articulated by countries, also considering the potential for substitution of that material in the EU (European Commission 2023).

According to Article 3, the seventeen "strategic" materials were selected on the basis of the relevance of a raw material for the green and digital transition as well as defence and aerospace applications, following three key criteria: (a) the amount of strategic technologies using a raw material as an input; (b) the amount of a raw material needed for manufacturing relevant strategic technologies; (c) the expected global demand for relevant strategic technologies.

Such an articulated, detailed, selective, and ambitious policy framework in between the CC, CID, Regulation 2024/1735, and Regulation 2024/1252 raises important questions of realism and feasibility, given the mounting barriers to investment across the EU's clean-tech and raw materials value chains (D'Amato et al. 2024). These barriers and risks can be seen following the two dimensions of the criticality framework, that is "economic importance" and "supply risk".

10.3 "Economic Importance": The EU's Clean-Tech and CRM Value Chains

According to the Draghi report (European Commission 2024a), the EU has significant competitive advantages in clean-tech industries, compared to its weak advantages

5 https://single-market-economy.ec.europa.eu/sectors/raw-materials/areas-specific-interest/critical-raw-materials_en

in digital technologies. This is because the different technological families that we classify as clean tech are closer, in terms of industrial competence, knowledge, and technological basis, to the present capacities of the EU industrial system. The EIB Investment Report (EIB 2025) highlights how Europe is dominating the international system of patents for clean tech and significantly increased its export of low carbon technologies in the period 2017–2023. However, the state of clean-tech industries in Europe clearly shows a more mixed picture.

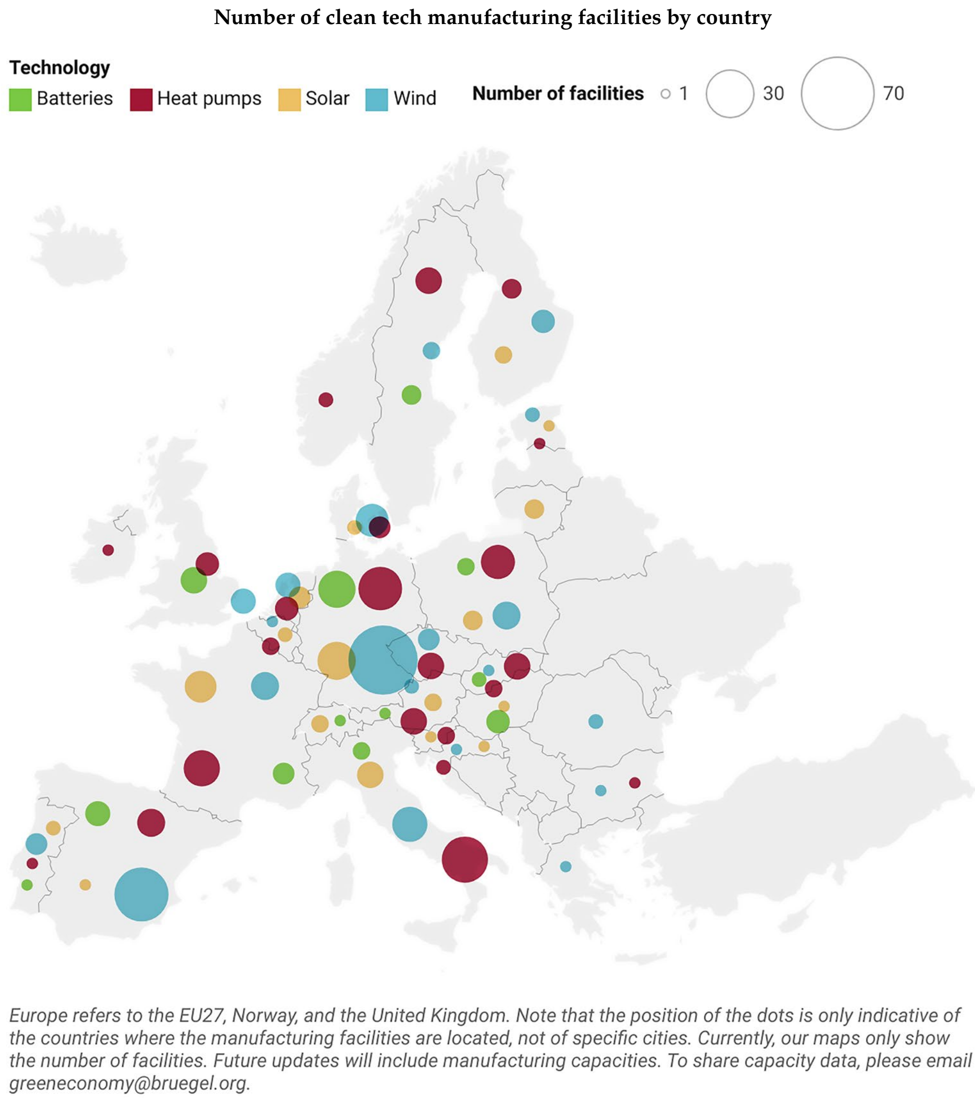
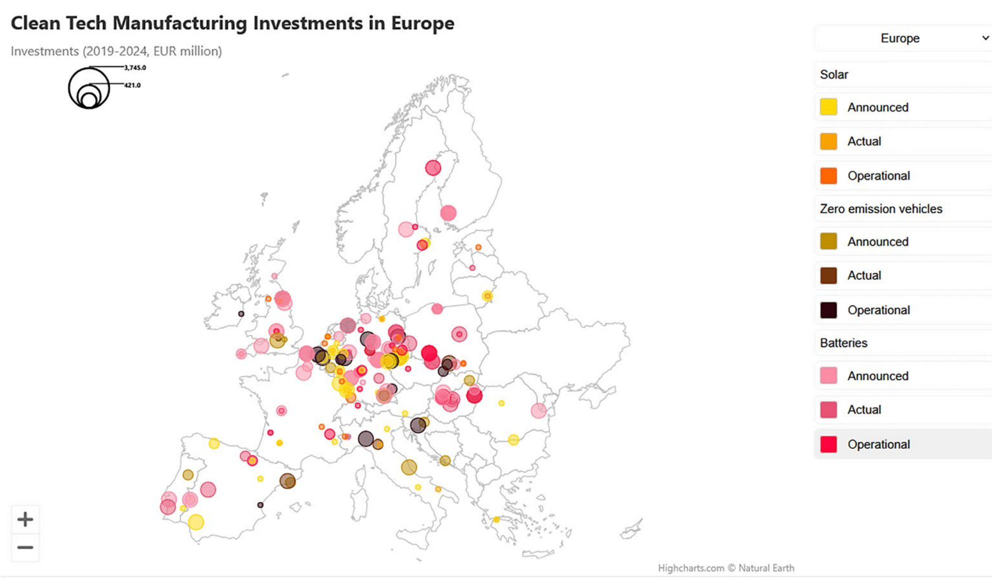


Fig. 10.1 Location of clean-tech manufacturing in Europe. *Source:* Bruegel on European Heat Pump Association, Solar Power Europe, Transport & Environment and Wind Europe (https://www.bruegel.org/analysis/clean-industrial-transformation-where-does-europe-stand).

According to Bruegel's clean-tech tracker (Bruegel 2025), Europe has good positions in the production and net export of electric vehicles, at least for the moment, and of wind technologies, whereas it has a very weak position, including significantly increasing net imports, for batteries and solar technologies, for which there is a strong and increasingly dominant position occupied by China as a supplier of the global markets. Furthermore, domestic manufacturing capacity for the majority of clean tech is unevenly distributed across EU Member States, with a central role played by Germany and the neighbouring countries in Eastern Europe and the Nordic region. Southern Europe, in particular Spain and Italy, contributes in selected areas, such as heat pump production in Italy and wind technology in Spain (see Fig. 10.1).

When looking at the map of current investment and recently established clean-tech manufacturers, there is again a concentration in Germany and Eastern European countries, and partly in Nordic countries, with a limited role played by the rest of Europe (see Fig. 10.2). According to D'Amato et al. (2024), there are significant differences in the cost of capital across EU regions, and this can favour the localization of clean-tech manufacturing in some countries with respect to others. Eastern European countries have low cost of capital, which can make them attractive destinations for the localization of investments from Germany and other leading clean-tech countries.



Note: Europe refers to the EU27, Norway, and the United Kingdom. The data displayed on the map are continuously being improved to ensure accuracy and completeness. If you identify any discrepancies or errors, please contact Bruegel. Your feedback is valuable in helping us enhance the quality of our dataset.

Fig. 10.2 Location of new investments in selected clean-tech industries in Europe. *Source:* Bruegel (Bruegel Clean Tech Radar 2025, https://www.bruegel.org/dataset/european-clean-tech-tracker).

The future development of EU clean-tech manufacturing and net-zero industries, as pursued by CC, CID, and the Net-Zero Industry Act, depends on the matching or mismatching between domestic deployment (demand) and the increasing global role of China and other competitors, which can weaken the relative competitiveness of European investments.[6] The scenarios for clean-tech manufacturing capacity (IRENA 2023) indicate that China is expected to experience substantial growth by 2030 across a range of technologies, including batteries, electric cars, solar PV, wind power and various intermediate products. While manufacturing capacity in the EU is also predicted to increase, its growth is likely to remain comparatively modest relative to China's expansion. Similarly, according to projections made by the International Energy Agency (IEA 2025), Europe might be outpaced by China's expanding capacity for solar photovoltaic systems, whereas it shows promising potential for growth in domestic capacities for wind technologies, batteries, electrolyzers, and heat pumps. Therefore, it cannot be taken for granted that the EU will be able to achieve a high degree of self-sufficiency in clean-tech manufacturing value chains.

These uncertain scenarios for EU domestic clean-tech can be seen in the general framework of estimated investment needs for the green transition. According to the overview presented in EEA (2023) and D'Amato et al. (2024), the additional investment needs to achieve the EGD targets are about €520 billion/year in the present decade with respect to the average level of the last decade, of which €392 billion/year are for climate and energy. For the period 2031–2050, the need is €660 billion/year (3.2% of EU GDP) for energy and €870 billion/year (4.2% of EU GDP) for transport. The largest investment gaps are in key transition sectors, like clean energy (renewables) and mobility. In the same report, the huge need of private investments is highlighted together with the different barriers to attract them, including the uneven cost of capital across Europe, as mentioned above.[7]

Clean tech and, in general, net-zero industries, together with sectors like digital and aerospace/military technologies, generate the EU's demand for critical raw materials. Detailed scenarios on the demand for CRM, produced by JRC (Carrara et al. 2023), indicate an unprecedented increase in the near future. Energy technologies essential for the net-zero transition are significantly more material-intensive than conventional energy systems. As demand for these technologies grows, even under scenarios of limited domestic self-sufficiency, the need for CRM is expected to rise sharply. At the same time, some materials that are classified as critical for the net-zero transition are similarly indispensable for the digital industry, aerospace and defence sectors. Therefore, it is expected that the EU will face substantial cumulative and competing demands for these materials, which could pose challenges to achieving its broader strategic objectives.

The EU's high external dependence on CRM—or the 'supply risk' that contributes to define their 'criticality'—could thus become the key bottleneck in achieving objectives

6 See also Le Mouel and Poitiers (2023).
7 On investment needs and the role of private investments see also Baccianti (2022).

for clean-tech and net-zero industries in Europe, thus endangering the success of CC, CID, and the Net-Zero Industry Act.

10.4 "Supply Risk": External Dependence within International Disorder

The EU has a high dependence on imports of CRM from major world producers, with an extremely high share of total imports from some of them. For example, the EU imports 40% of its consumption of palladium from Russia. From China, it imports 93% of its consumption of magnesium, 66% of scandium, 45% of titanium, 98–99% of light and heavy rare earths. The EU imports also 78% of its lithium consumption from Chile, 85% of niobium from Brazil, 62% of antimony from Turkey, 68% of cobalt from Democratic Republic of Congo.[8] These are just a few examples of the EU's high dependency of procurement from external suppliers, that can be reliable, politically stable, and "friendly", but in other cases can be unreliable and "unfriendly", or are simply strong competitors in the global green manufacturing value chains, like China.

The dependency of the EU reflects the concentration of global supply and the strategies of the dominant supplier in the global market. For example, in terms of value chain phases, the concentration of global supply is very high for the more advanced stages of processing, like manufacturing and assembly, as in the case of solar PV panels and batteries. For the same value chains, there is lower concentration of supply for the mining phase and, for batteries, in the material processing phase. However, not all the scenarios align or converge regarding the present and future geographical shape of the value chains. In any case, projections by IRENA (2023) suggest that supply concentration in both mining and refining is likely to increase in the future, for example, for materials such as lithium, nickel, and cobalt, with significant capacity expansions expected in Asia and Africa.

Supply risks are highly dynamic in the present disorder of the international system, where increasing tensions can translate risk into uncertainty. Leaving aside the role of the United States, Russia, and China, whose involvement in the CRM landscape is now entangled in broader global trade tensions triggered by the US, major producers of key CRM include countries such as Myanmar, Zambia, Gabon, Zimbabwe, and others, that can be subject to political instability. When looking at the World Governance Indicator, which is included in the EU measures of criticality, we see that some major suppliers of Europe perform very badly in the ranking, which suggests not only low ethical quality of governance but also a potential for political instability (Fig. 10.3). The same availability of CRM, in a world of procurements tensions, can stimulate political instability in weak-governance countries.

8 Among the many sources of this type of data, which are often not consistent one another, see Carrara et al. (2023).

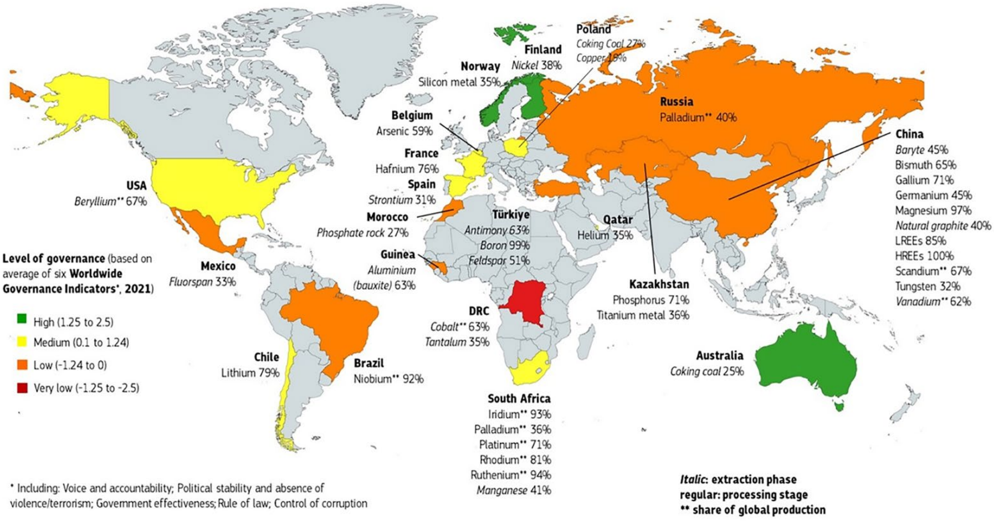


Fig. 10.3 Major EU suppliers of CRM (2023) and their quality of governance. *Source:* JRC (https://rmis.jrc.ec.europa.eu/eu-critical-raw-materials).

In the present evolving situation, geopolitical risk analysis[9] is increasingly critical for understanding the EU's procurement uncertainties and for disentangling the truth from the many alarming narratives that fuel political and economic speculation. This is the case with Ukraine and Greenland, which have become focal points in recent US administration strategies. Ukraine is endowed with a significant amount of minerals and is actively seeking to leverage this by attracting international investments. However, it remains a relatively minor player in global CRM markets in terms of reserves.[10] The recent agreement between Ukraine the US appears to depart from the narrative promoted by the US administration and, based on available information, it is largely a joint venture whose actual impact will only become clear in a postwar scenario.[11] It is also worth noting that an agreement between the EU and Ukraine for critical raw materials has been in place since 2021.[12]

Greenland, according to the Greenland Mineral Resources Strategy (Greenland 2025) and US Geological Survey data, holds a relevant (though not extensive) known endowment of CRM and other mineral resources. While significant resources may lie under the ice cap, the mineral exploitation sector in Greenland remains underinvested.

9 See, for example, https://www.globalguardian.com/risk-map; https://www.policyuncertainty.com/gpr.html; and https://www.52risks.com/2021/11/28/top-12-geopolitical-risk-resources/?srsltid=AfmBOophhHp5b9FQIK2534WBQWA3WgEabYa1VmV-VbfrWIIzFfRbo4tc

10 See https://www.geo.gov.ua/en/critical-raw-materials/

11 See EuroNews - https://www.euronews.com/my-europe/2025/05/01/washington-signs-historic-rare-earths-minerals-deal-with-ukraine

12 See https://uamap.org.ua/en/eu-and-ukraine-kick-start-strategic-partnership-on-raw-materials

The heightened attention from the US administration toward Greenland is largely political, tied to long-standing Arctic dynamics involving Russia, Europe, and the US. These dynamics, centred on strategic transportation routes, are now becoming more explicit with the increasingly aggressive US positioning.

The international tensions around CRM stimulated a recent proposal by a group of scientists for a Global Minerals Trust to create agreements on cooperative resource management, in which fair prices for both mineral suppliers and consumers can prevail, avoiding mining rushes in developing countries.[13] The proposal echoes the historical experience of the international funds for primary commodities launched in the 1950s, which ultimately failed due to persistent conflicts between consuming and producing countries, and due to the assertion of national sovereignty over natural resources, regarded as 'private goods' under domestic control.

Concerns about the scarcity of CRM are often amplified by dominant narratives, but these can be more accurately assessed by examining international price trends, such as those reflected in the World Bank's indexes of commodity prices (World Bank 2025). In the last few years, despite both actual and expected surges in demand, the international prices of critical materials used in net-zero technologies (such as nickel) have not shown significant increases, despite some huge spikes, in particular when looking at prices in real terms. The reason is that, looking at the world reserves, most CRM are not physically scarce: for instance, global lithium reserves are estimated to cover 250 years of consumption at 2020 levels. Then, supply can have a certain degree of price elasticity and has, so far, kept pace with the rising demand from expanding end-use sectors, such as electric vehicles. These markets tend to follow the typical cycles of internationally traded commodities that are subject to huge instability and speculation, but without significant upward trends in real prices. Therefore, according to the International Energy Agency's CRM market trends outlook (IEA 2024), the global market for key CRM has been $325 billion in 2023, with a decrease compared to the previous year. Prices for copper, lithium, nickel, and cobalt have returned to levels seen before the energy crisis of 2021–2023.

Even cleaning the global CRM picture from instrumental political narratives and market speculations fed by strategic information and expectations, the EU actually has a structural problem with supply security of CRM in an international system where geopolitics and competing industrial strategies can suddenly create scarcity and bottlenecks able to hinder the net-zero industrial transition.

10.5 Responses and Strategies

Different analyses converge on four strategic approaches to securing the EU's supply of CRM (Di Francesco et al. 2024; Specker et al. 2025; Carrara et al. 2023).

The first is diversification of procurement by activating trade relationships with alternative producing countries, so that a less risky suppliers portfolio can be achieved.

13 See https://www.science.org/doi/10.1126/science.adv9841

The second is to increase domestic supply capacity based on the redevelopment of mining sites in Europe, together with an increase in the manufacturing capacity at higher stages of the value chain. The third is to increase domestic recycling by exploiting what is known as "urban mining", as well as boosting the circular economy, to recover CRM from waste. The fourth is investing in innovation for both material efficiency and the substitution of CRM with materials that are not critical. These directions are already embodied in the policy framework defined by the CRM Regulation 2024/1252 as well as in the CID and the CC (see above).

The possible barriers to these four directions are different for each material, or families of materials, and vary for different countries in the EU. Furthermore, some of these four directions, for example domestic mining, are only viable in the longer term, requiring substantial investments to overcome significant barriers. Table 10.1 highlights the possible complexity of ex ante impacts of supply disruptions (quantities or prices) and of different responses in a realistic timeframe, also considering the expected differential environmental impacts of shocks and responses.

Table 10.1 Expected economic and environmental effects of a raw materials supply disruption and reactions to it. *Note:* I = importing countries; E = exporting countries; NE = new exporting countries; T = transit countries; ECSO = economic and social effects; ENV = environmental effects. *Source:* the author, see also adapted versions in Di Francesco et al. (2023) and Specker et al. (2024).

<table>
<tr><td>Type of expected effects without/with reactions</td><td>Short term: Dominated by limited elasticity of supply in the world market and domestically (primary and secondary supply), limited elasticity of domestic demand (e.g., substitution), limited resource-saving innovations</td><td>Medium term: Dominated by good elasticity of supply in the world market (procurement shift) and possibly domestically (primary supply, if any, or secondary supply), possible reductions of domestic demand (e.g., substitution) and resource-saving innovations</td><td>Long term: Dominated by the importing country's possibility of strategic reaction based on self-sufficiency and re-shoring, reduction of domestic demand (e.g., full substitution), full deployment of resource-saving innovations, full circularity, new industrial policies and reshaping of domestic value chains (including secondary)</td></tr>
<tr><td rowspan="2">Expected effects without reaction policies</td><td colspan="3">I: ECSO: loss of value added and employment in using industries; input cost increase and inflation (if inputs costs passed on prices, depending on elasticity of demand) and loss of competitiveness; ENV: reduction of pressures

E: reduction of extraction; ECSO: loss of value added and employment; benefits from increase in selling prices; ENV: reduction of pressure</td></tr>
<tr><td colspan="2">T: loss of transit benefits; ECSO: partial loss of value added and employment (if production phases in the transit country); possible gains from higher prices; ENV: reduction of pressures</td><td>T: possible shift to other Ts with no overall loss of transit benefits/costs (including ENV pressures); possible gains from higher prices</td></tr>
</table>

Possible reaction strategy by the Importing country	Attempt to geographically shift procurement (success depending on supply elasticity in world market, material specific); measures to alleviate price increases for final users (industry, consumers)	Partial geographical shift of procurement (good supply elasticity in world market); measures to alleviate price increases for final users (industry, consumers); possible measures to increase domestic supply (primary and secondary) and material savings	Full geographical shift of procurement; measures to exploit and increase domestic supply potential (primary and secondary); resource savings innovations fully deployed; adaptation of domestic value chains (new industrial policy); measures to alleviate price increases for final users (industry, consumers), including alleviating domestic price increases due to self-sufficiency; measures against NIMBY and oppositions
Expected effects with reaction strategies	**I**: Possible alleviation of **ECSO** effects (quantities and prices) **NE** (if available in the short term): **ECSO**: increase of value added and employment (quantity); benefits from increase in selling prices; **ENV**: increase of pressures	**I**: Alleviation of **ECSO** effects; alleviation of price increase; increase of domestic **ENV** effect if domestic supply increases; or decrease of **ENV** effects if circular economy deployed and if domestic technologies better than those of (old and new) exporter **NE**: **ECSO**: increase of value added and employment; benefits from increase in selling prices; **ENV**: increase of pressure	**I:** Alleviation of costs increase and inflation from international material prices, but likely higher domestic prices with self-sufficiency; change in industry mix and value chains; increase of **ENV** effects if domestic supply increases; decrease of **ENV** effects if circular economy and, at the global scale, if domestic technologies better than those of (old and new) exporter **NE** (if not full self-sufficiency): **ECSO**: increase of value added and employment; benefits from increase in selling price; **ENV**: increase of pressures

The direction of creating alternative new trading partnerships for CRM is the most urgent and, to some extent, more feasible in the shorter run considering the high mineral reserve potential at the global scale and the acceleration of economic tensions in the international system. One initiative aligned with this strategic direction is the establishment of a Critical Raw Material Club, as outlined in the EU's Critical Raw Materials Act (CRMA) of 2023. A relevant step forward came in 2024 with the launch of the Minerals Security Partnership Forum (MSP Forum), that includes fifteen MSP Partners and another fifteen critical mineral-producing and mineral-consuming countries (including Greenland and Ukraine).[14] To support this direction, international investments by EU operators in mining and refining activities could also be relevant, and such efforts are already underway through non-EU "strategic projects" promoted by the CRM Regulation 2024/1252 (see below).

In the medium run, there may be opportunities to develop a robust domestic recycling industry for certain CRM, though not for all. At present, recycling capacity is still underdeveloped for many specific CRM. The enabling condition is that the stock/flow of the material-containing products within the economy is sufficiently large to create a minimum critical size for profitable industrial-scale collection and recycling. However, in the case of lithium, for example, scenarios diverge on the feasibility of industrial recycling initiatives: some analyses anticipate a near-term surge in the availability of lithium-containing products (mainly batteries), sufficient to support industrial-scale recycling; others suggest that this minimum stock/flow will not be reached until 2040 or later.[15]

In the longer run, it is possible that a redevelopment of mining for CRM can take place in the EU. Already at present, several projects have been announced, for example, for lithium mining, but it is uncertain whether they can pass the test of economic and environmental sustainability and will be implemented. In addition to uncertainties in economic and environmental feasibility, the mining sector faces barriers related to the availability of suitable territories and communities willing to host new investments. This applies both to greenfield investments and the reopening of previously closed mining sites, many of which were shut down over past decades to favour alternative local models of development. Community opposition is likely to remain strong unless new approaches are adopted to share the benefits more equitably and demonstrate that mining can be good for local development. It is interesting to note that, according to Specker et al. (2025), mining activities in Europe can be more environmentally sustainable than in other regions, offering a global environmental net advantage if mining were reintroduced within the EU. However, this shift would relocate the environmental impact to European territories, which could intensify local opposition.

14 See https://policy.trade.ec.europa.eu/help-exporters-and-importers/accessing-markets/raw-materials/minerals-security-partnership-forum_en

15 See https://rmis.jrc.ec.europa.eu/analysis-of-supply-chain-challenges-49b749 and https://eurometaux.eu/media/rqocjybv/metals-for-clean-energy-final.pdf

For the direction of innovation, the picture is very lively. According to a report of the European Parliament (2024), there are at present ninety-three projects on critical raw materials underway inside Horizon Europe, of which eleven are at the exploration stage, twenty at the extraction stage, and seventeen at the processing stage. Most of these projects concern catalytic technologies and batteries with no or low CRM content, and recycling. Most of them are based on cobalt, platinum, lithium, nickel, and manganese. Furthermore, excluding the exploration stage, European actors have a dominant role in international patents for CRM from refining to recycling, with the EU surpassing the United States and China (although China is fast growing). In between research and industry, relevant initiatives of the recent past have been co-funded, for example in the framework of the Important Projects of Common European Interest (IPCEI), with two big projects on batteries.[16]

Strategic Projects for the EU

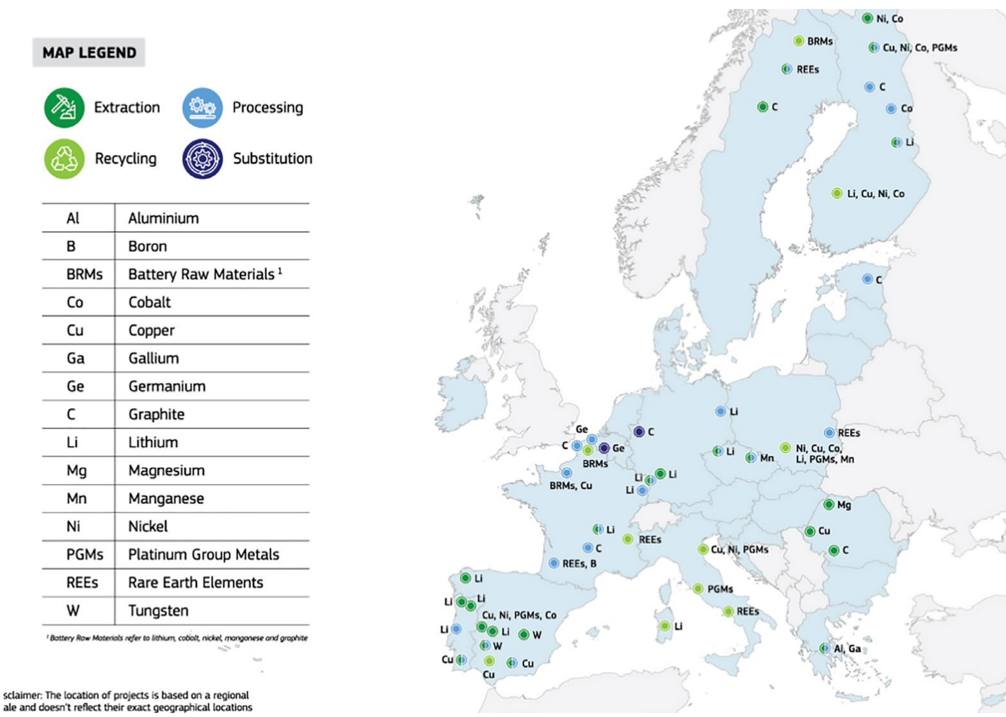


Fig. 10.4 Approved strategic projects on CRM in the EU. *Source:* https://ec.europa.eu/commission/presscorner/detail/en/ip_25_864

One of the first consequences of CRM Regulation 2024/1252 has been the implementation of its provisions on "strategic projects". With the first call of 2024, the European Commission approved forty-seven strategic projects in the EU and

16 See https://competition-policy.ec.europa.eu/state-aid/ipcei/approved-ipceis_en

thirteen strategic projects outside of the EU.[17] The projects inside the EU cover different stages of the value chain as well as recycling and substitution of lithium (twenty-two projects), nickel (twelve projects), cobalt (ten projects), manganese (seven projects), and graphite (eleven projects). Most of the forty-seven EU projects approved are in Germany, the Nordic Countries, and Eastern Europe, but several are in Spain and Portugal (Fig. 10.4). This geographical location just partially reflects the location of clean-tech manufacturing that demands CRM (see above), and the whole value chain made of clean-tech manufacturing and CRM must be seen at the EU scale and not nationally. The same applies to other sectors demanding CRM, like digital and military technologies.

According to the Commission:

> To become operational, the 47 Strategic Projects have an expected overall capital investment of €22.5 billion. These projects will be able to benefit from coordinated support by the Commission, Member States and financial institutions to become operational, notably regarding access to finance and support to connect with relevant off-takers. They will also benefit from streamlined permitting provisions, to ensure predictability for project promoters while safeguarding environmental, social and governance standards. In line with the CRMA, the permit-granting process will not exceed 27 months for extraction projects and 15 months for other projects. Currently, permitting processes can last from five to 10 years. (European Commission 2025c)

Of the thirteen approved "strategic projects" outside the EU, seven are in Canada, Greenland, Kazakhstan, Norway, Serbia, Ukraine, and Zambia, with whom the EU has a strategic partnership on raw materials. The others are in Brazil, Madagascar, Malawi, New Caledonia, South Africa, and the United Kingdom (see Fig. 10.5). According to the Commission:

> It is estimated that the 13 Strategic Projects outside of the EU need an overall capital investment of €5.5 billion to start operations. The Commission will also reinforce cooperation with the third countries concerned to ensure the development of those projects, especially through the Strategic Partnerships already concluded with some of these countries on raw materials value chains. (European Commission 2025d)

Although the EU's "strategic projects" for CRM, set to be replicated through a call in 2025, are an important step forward and address all four main strategic response directions, they require substantial financial resources. These projects are expected to be funded through a combination of EU, national, and private contributions, but full financing is not yet secured, leaving them exposed to industrial risks. In addition, even if demand for their products exists inside the EU—if not from clean-tech manufacturing, then from the digital and military sectors—domestically sourced CRM may not be cost-competitive compared to international suppliers. In any case, it is very relevant

17 See https://single-market-economy.ec.europa.eu/sectors/raw-materials/areas-specific-interest/critical-raw-materials/strategic-projects-under-crma/selected-projects_en

that the EU path for clean-tech and net-zero industries, as promoted by the NZIA Regulation 2024/1735, will be stimulated to keep a balanced development of all the parts of the EU-level domestic value chain.[18]

Strategic Projects for the EU

Fig. 10.5 Approved strategic projects on CRM outside the EU. *Source:* https://ec.europa.eu/commission/presscorner/detail/en/ip_25_1419

10.6 Conclusions: Keeping a Balanced Development of the EU Value Chain

The availability of CRM poses a fundamental challenge to the development of net-zero value chains, which are the backbone of the EU's transition towards its climate targets and greater energy self-sufficiency. The EU's current extreme dependency on supplier countries for CRM, some of which may prove unreliable, adds significant risk. Diversifying the portfolio of international suppliers, increasing domestic mining, increasing recycling and investing in innovation for materials efficiency and substitution are the key directions of response. The policy framework made by the regulations on net-zero industries and CRM adopted in 2024 supports these priorities and provides an important starting point. The regulation on CRM has already enabled

18 The call for net-zero technology manufacturing projects to become strategic projects under the Net-Zero Industry Act opened in June 2025, https://single-market-economy.ec.europa.eu/industry/sustainability/net-zero-industry-act/strategic-projects-under-nzia_en

the approval of forty-seven "strategic projects" inside the EU and thirteen projects outside the EU, including in countries with formal partnership agreements.

If these projects, as well as other projects, started or announced, will be feasible from financial and industrial perspectives and will deliver the expected outcomes, they will reinforce the upstream part of the net-zero industrial value chain alone. A question remains about the possibility of having a higher volume of investments in the clean-tech manufacturing sectors of the EU, which is the downstream part of the value chain. Despite relevant manufacturing initiatives taking place in the EU, significant investment gaps are emerging for these industries, which, in addition, are exposed to a strong industrial competition from international actors, in particular China. Without investments in clean-tech and net-zero technologies, the risk of a fundamental imbalance inside the EU value chain remains. This will impair the strategic objectives of the Competitiveness Compass and the Clean Industrial Deal, all aimed at achieving a competitive green industrial redevelopment of the EU. At the same time, EU digital and defence industries may become competitors of the clean-tech sector in CRM procurement, thereby contributing to weakening the net-zero industrial trajectory from the side of materials input availability and cost. In any case, at present, fundamental uncertainties surround the CRM issue at both the EU and global scale.

The new Commission's attitude towards state aid, also embodied in the new EU strategic framework described earlier, has the potential to boost investment in both clean tech and CRM, also in combination with "green" and "innovative" public procurement. However, this approach may also lead to growing divergence among Member States, especially where governments opt to take equity stakes in green industries rather than provide incentives.[19] When taking an overall EU perspective, this possible "specialization" of Member States can be non-negative or even positive, if there is a well-functioning, well-integrated single market.

References

Baccianti, C. (2022) "The Public Spending Needs of Reaching the EU's Climate Targets", in F. Cerniglia and F. Saraceno (eds), *Greening Europe: 2022 European Public Investment Outlook*. Cambridge, UK: Open Book Publishers, pp. 107–128, https://doi.org/10.11647/OBP.0328.08

Bruegel (2025) "European Clean Tech Tracker", https://www.bruegel.org/dataset/european-clean-tech-tracker

Carrara, S., S. Bobba, D. Blagoeva, P. Alves Dias, A. Cavalli, K. Georgitzikis, M. Grohol, A. Itul, T. Kuzov, C. Latunussa, L. Lyons, G. Malano, T. Maury, A. Prior Arce, J. Somers, T. Telsnig, C. Veeh, D. Wittmer, C. Black, D. Pennington, and M. Christou (2023) *Supply Chain Analysis and Material Demand Forecast in Strategic Technologies and Sectors in the EU—A Foresight Study*. Luxembourg: Publications Office of the European Union, https://doi.org/10.2760/386650

19 See the proposal of Teresa Ribera, Executive Vice President of the Commission, https://www.ft.com/content/f957bdf2-3624-441d-991c-368922549603

D'Amato, A., A. Pronti, S. Paleari, G. Romaldi, S. Speck, S. Tagliapietra, and R. Zoboli (2024) *Investment Needs and Gaps for the Sustainability Transition in Europe: Rethinking the European Green Deal as an EU Industrial Strategy*. Copenhagen: European Environment Agency, https://www.eionet.europa.eu/etcs/etc-ce/products/etc-ce-report-2024-8-investment-needs-and-gaps-for-the-sustainability-transition-in-europe-rethinking-the-european-green-deal-as-an-eu-industrial-strategy

Di Francesco, E., R. S. Gilli, P. Jensen, S. Manoochehri, G. Marin, A. Specker, S. Tagliapietra, and R. Zoboli (2024) *Environmental Impact of Material Supply Chain Disruptions*. Copenhagen: EEA, https://www.eionet.europa.eu/etcs/etc-ce/products/etc-ce-report-2024-3-environmental-impact-of-material-supply-chain-disruptionsl

EEA—European Environment Agency (2023) *Investments in the Sustainability Transition: Leveraging Green Industrial Policy against Emerging Constraints*. Copenhagen: EEA, https://www.eea.europa.eu/publications/investments-into-the-sustainability-transition

EIB (2025) *Investment Report 2024/2025: Innovation, Integration and Simplification in Europe*. Luxembourg: European Investment Bank, https://www.eib.org/en/publications/20240354-investment-report-2024

European Commission (2023) *Study on the Critical Raw Materials for the EU 2023*. Brussels: European Commission, https://op.europa.eu/en/publication-detail/-/publication/57318397-fdd4-11ed-a05c-01aa75ed71a1

European Commission (2024a) *The Future of European Competitiveness Part A | A Competitiveness Strategy for Europe* (*Draghi's Report*). Brussels: European Commission, https://commission.europa.eu/topics/eu-competitiveness/draghi-report_en#paragraph_47059

European Commission (2024b) "Regulation (EU) 2024/1735 of the European Parliament and of the Council of 13 June 2024 on Establishing a Framework of Measures for Strengthening Europe's Net-zero Technology Manufacturing Ecosystem and Amending Regulation (EU) 2018/1724 (Text with EEA Relevance)," https://single-market-economy.ec.europa.eu/industry/sustainability/net-zero-industry-act_en

European Commission (2024c) "Regulation (EU) 2024/1252 of the European Parliament and of the Council of 11 April 2024 Establishing a Framework for Ensuring a Secure and Sustainable Supply of Critical Raw Materials and Amending Regulations (EU) No 168/2013, (EU) 2018/858, (EU) 2018/1724 and (EU) 2019/1020 (Text with EEA Relevance)", https://single-market-economy.ec.europa.eu/sectors/raw-materials/areas-specific-interest/critical-raw-materials_en

European Commission (2025a) "A Competitiveness Compass for the EU, Brussels, 29.1.2025", COM(2025) 30 final, https://commission.europa.eu/topics/eu-competitiveness/competitiveness-compass_en

European Commission (2025b) "The Clean Industrial Deal: A Joint Roadmap for Competitiveness and Decarbonization", Brussels, 26.2.2025", COM(2025) 85 final, https://commission.europa.eu/topics/eu-competitiveness/clean-industrial-deal_en

European Commission (2025c) "Commission Selects 47 Strategic Projects to Secure and Diversify Access to Raw Materials in the EU", 25 March, https://ec.europa.eu/commission/presscorner/detail/en/ip_25_864

European Commission (2025d) "Commission Selects 13 Strategic Projects in Third Countries to Secure Access to Raw Materials and to Support Local Value Creation", 4 June, https://ec.europa.eu/commission/presscorner/detail/en/ip_25_1419

European Parliament (2024) "The Role of Research and Innovation in Ensuring a Safe and Sustainable Supply of Critical Raw Materials in the EU", https://www.europarl.europa.eu/stoa/en/document/EPRS_STU(2024)762848

Greenland (2025) "Greenland Mineral Resources Strategy 2025–2029. A Sustainable Mineral Resources Sector", https://naalakkersuisut.gl/-/media/nyheder/2025/01/3101_ny_raastofstrategi/eng_greenland-mineral-resources-strategy-2025-2029.pdf

IEA (2021) *Net Zero by 2050. A Roadmap for the Global Energy Sector*. Paris: IEA, https://www.iea.org/reports/net-zero-by-2050

IEA (2024) *Global Critical Minerals Outlook 2024*. Paris: IEA, https://www.iea.org/reports/global-critical-minerals-outlook-2024

IEA (2025) *Energy Technology Perspectives 2024*. Paris: IEA, https://www.iea.org/reports/energy-technology-perspectives-2024

IRENA (2023) *Geopolitics of the Energy Transition: Critical Materials*. Abu Dabhi: IRENA, https://www.irena.org/Publications/2023/Jul/Geopolitics-of-the-Energy-Transition-Critical-Materials

Le Mouel, M., and N. Poitiers (2023) *Why Europe's Critical Raw Materials Strategy Has to Be International: In Ensuring Supplies of Critical Raw Materials, the European Union Cannot Rely on Domestic Measures Alone*. Brussels: Bruegel, https://www.bruegel.org/analysis/why-europes-critical-raw-materials-strategy-has-be-international

Specker A., S. Manoochehri, R. Gilli, G. Marin, R. Zoboli, P. Nuss, E. Pohjalainen, and P. Jensen (2025) *Environmental Impact of Material's Supply Chain Disruption. The Cases of Aluminium and Lithium*. Copenhagen: EEA—European Environment Agency, https://www.eionet.europa.eu/etcs/etc-ce/products/etc-ce-report-2025-5-environmental-impact-of-materials-supply-chain-disruption-the-cases-of-aluminium-and-lithium

World Bank (2025) "Commodity Markets", https://www.worldbank.org/en/research/commodity-markets