The Hague Centre
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Critical Raw Materials in the Dutch Provinces of Noord-Holland and Flevoland

Towards Resilient Supply Chains

Irina Patrahau, Lucia van Geuns, Ron Stoop and Julie Jeuken

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This report was commissioned by the Dutch provinces of Noord-Holland, Flevoland, and the Metropoolregio Amsterdam. Responsibility for the contents and for the opinions expressed, rests solely with the authors.

A working group consisting of staff from these organizations, as well as from the Amsterdam Economic Board, the Noordzeekanaalgebied, and the Municipality of Amsterdam, served as the primary point of contact for the researchers. It should be noted, however, that this does not imply that the contents of the report are necessarily endorsed in full by these organizations.

The HCSS report will be discussed on September 24, 2025, during a workshop with relevant stakeholders. At this workshop, the findings will be examined and efforts will be undertaken to further elaborate the report's recommendations. A summary of the key outcomes of this workshop will be published in due course.

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Summary

Digital and clean technologies, healthcare, and defence rely heavily on critical raw materials (CRM). These CRM are minerals and metals that are vital to the Dutch and broader European economy. The ongoing energy transition is the main driver of CRM demand in the European Union (EU) and globally.[1] All the other above-mentioned sectors are increasing the competition for the scarce global supply. The supply of CRM is at high risk due to the concentration of production outside the EU, often in countries with weak governance or that may leverage these resources for geopolitical influence.

Geopolitics has had a significant negative impact on the EU's CRM supply security. The war in Ukraine and the trade conflict between the United States (US) and China reshaped various trade routes, from fossil fuels to fertilisers and digital technologies, pushing governments to develop more partnerships with reliable suppliers. Countries all over the world, including Latin America, East Asia, Middle East and Africa, are building up their mineral industries and positioning themselves as alternatives to the main supplier, China.

This is a response to China's decades long industrial strategy positioning itself as the largest supplier of materials and a leader in many clean and digital technologies. The US-China rivalry is increasingly taking the form of a geoeconomic battle over critical technologies and raw materials. The trade barriers imposed by China affect more than 15 CRM needed for strategic energy, digital, healthcare and defence goods, like gallium, antimony and rare earth elements.[2]

The EU, the Dutch government and regional authorities in the Netherlands are taking steps to address these vulnerabilities. The 2024 European Critical Raw Materials Act (CRMA) was enacted to provide a framework for increased supply chain resilience.[3] The National Raw Material Strategy (*Nationale Grondstoffenstrategie,* NGS), launched in 2022, aims to secure sustainable and diversified access to CRM.[4] Regionally, the Province of Noord-Holland has committed itself to various CRM initiatives within their 'Sustainable and Circular Economy Implementation Agenda' for 2025-2028. For example, where possible, efforts will be made to increase circular cooperation and recover CRM.[5] The Municipality of Amsterdam aims to become a fully circular and net-zero city by 2050. Its circular strategy for the 2020–2025 period includes a specific focus on improving the circularity of Critical Raw Materials (CRM).[6] Industrial actors, notably the North Sea Canal Area (*Noordzeekanaalgebied*, NZKG) and the Port of Amsterdam, are taking active steps too.[7] The Metropolitan Region Amsterdam (MRA)

1 IEA, *The Role of Critical Minerals in Clean Energy Transitions* (IEA, 2022), https://iea.blob.core.windows.net/assets/ffd2a83b-8c30-4e9d-980a-52b6d9a86fdc/TheRoleofCriticalMineralsinCleanEnergyTransitions.pdf.

2 Shivaprasad, Ashitha, Amy Lv, Lewis Jackson, Ashitha Shivaprasad, and Lewis Jackson. 'Snapshot of China's Critical Mineral Export Controls'. *Reuters*, 4 June 2025. https://www.reuters.com/world/china/chinas-curbs-exports-strategic-minerals-2025-02-04/.

3 European Commission, 'Critical Raw Materials Act', 3 May 2024, https://single-market-economy.ec.europa.eu/sectors/raw-materials/areas-specific-interest/critical-raw-materials/critical-raw-materials-act_en.

4 Ministerie van Algemene Zaken, 'Raw materials strategy for large transitions - Kamerstuk - Rijksoverheid.nl', kamerstuk, Ministerie van Algemene Zaken, 9 December 2022, https://www.rijksoverheid.nl/documenten/kamerstukken/2022/12/09/raw-materials-strategy-for-large-transitions.

5 Province Noord Holland, 'Uitvoeringsagenda Duurzame En Circulaire Economie 2025-2028', https://www.noord-holland.nl/bestanden/pdf/Economie_Werk/Uitvoeringsagenda%20duurzame%20en%20circulaire%20economie%202025-2028.pdf.

6 'Amsterdam Circulair 2020-2025 Strategie', openresearch.amsterdam, 2020, https://openresearch.amsterdam/nl/page/54968/amsterdam-circulair-2020-2025-strategie.

7 Ecorys and Metabolic, *Transitie naar een circulaire economie in het Noordzeekanaalgebied* (2023), https://www.noord-holland.nl/bestanden/pdf/Economie_Werk/Eindrapport%20Circulair%20handelingsperspectief%20ruimtelijke%20inrichting%20NZKG%20circulaire%20transitie.pdf; *Vision 2040 | Port of Amsterdam* (2025), https://www.portofamsterdam.com/sites/default/files/2025-04/Visie%202040_gecomprimeerd.pdf.

brings together different stakeholders to identify shared regional solutions and ways to implement these broader policy goals.

In response to these policy developments around CRM in the Netherlands and the EU, this study explores how the region can contribute to building more resilient and sustainable supply chains for CRM. It is based on desk research underpinned by eleven interviews with companies and other stakeholders in the region.

CRM volumes and vulnerabilities in the Provinces of Noord-Holland and Flevoland

The current distribution of CRM in the Provinces of Noord-Holland and Flevoland can be understood in terms of (1) goods containing low volumes of CRM that are widely found across the region, like cars and machinery; and (2) goods containing high volumes of CRM but are less frequently found in the region, like wind turbines and data centers. Each of the goods categories can contain between 23 - 33 types of CRM in various quantities.[8]

The provinces are vulnerable to China's export restrictions on CRM and permanent magnets.[9] As company mandated reserves are depleting quickly, various supplier plants and production lines across Europe have been forced to a halt.[10] This can impact end users in the Provinces of Noord-Holland and Flevoland who are in the market for an automotive product. Moreover, China's dominance throughout the supply chain poses a challenge to the Provinces of Noord-Holland and Flevoland's future wind-energy ambitions.[11]

CRM supply chain capabilities in the Provinces of Noord-Holland and Flevoland

Industrial activity involving metals and minerals in the two provinces is summarized in Figure 1. Processing capabilities in the region are defined by companies like TATA steel and Chemreclaim, which vary in their size, focus, and techniques. Manufacturing companies that do use CRM and metals directly rather than only components can be divided into five groups: (1) construction, (2) energy infrastructure, (3) port, logistics, and the maritime sector, (4) machinery and equipment manufacturing, and lastly, (5) electronics and data centres.[12] The past years have seen a notable increase in urban mining and circularity policy in the region.[13] As such, recycling is the most dominant metal-related activity within the Provinces of Noord-Holland and Flevoland. There are a variety of companies that collect, shred and prepare waste for recycling. Finally, there are various services, trade, and R&D companies for metals and minerals present in the region. This is facilitated by the presence of the NZKG, good infrastructure connections, and various knowledge institutes located in the capital.

8 *Provinciale Monitoring Circulaire Economie - Noord-Holland* (geoFluxus, 2025); *Provinciale Monitoring Circulaire Economie - Flevoland* (geoFluxus, 2025); Provincie Noord-Holland. *Provinciale Circulaire Economie Monitor 2025*. 2025. https://www.noord-holland.nl/bestanden/pdf/Economie_Werk/Provinciale%20Circulaire%20Economie%20Monitor%202025.pdf.

9 Jarrett Renshaw et al., 'Global Alarm as China's Critical Mineral Export Curbs Take Hold', *Reuters*, 4 June 2025, https://www.reuters.com/business/autos-transportation/global-alarms-rise-chinas-critical-mineral-export-ban-takes-hold-2025-06-03/.

10 Sam Meredith, 'Auto Industry Sounds the Alarm as China's Rare Earth Curbs Start to Bite', CNBC, 5 June 2025, https://www.cnbc.com/2025/06/05/auto-groups-sound-the-alarm-as-chinas-rare-earth-curbs-start-to-bite.html.

11 Vasileios Rizos et al., *Developing a Supply Chain for Recycled Rare Earth Permanent Magnets in the EU* (CEPS, 2022), https://circulareconomy.europa.eu/platform/sites/default/files/2023-01/Developing%20a%20supply%20chain%20for%20recycled%20rare%20earth%20permanent%20magnets%20in%20the%20EU.pdf.

12 Interview HCSS, 2025

13 Kieran Campbell-Johnson et al., 'Critical and Strategic Materials from Devices | TNO', *TNO Newsroom*, 18 March 2025, https://www.tno.nl/en/newsroom/2025/03/urban-mining-critical-materials/.

Figure 1. Companies and institutions active in mineral and metal supply chains in the Provinces of Noord-Holland and Flevoland

- **Processing**: Chemreclaim, Tata Steel Ijmuiden
- **Manufacturing**: Ketjen Netherlands B.V, ICL Fertilizers Europe CV, E-Magy, Expice, Cleantron, Victron Energy B.V, ASM Europe B.V, Energyra, Betronic B.V, Alfen, Levitech, Hitachi
- **Recycling** (waste collection and pre-treatment of scrap): Hilhorst Recycling, Overdie Metals Alkmaar, Overdie Staal B.V, PEL Recycing, Farci Metaal Recycling, Van Est Metals, AEB Amsterdam, Recco Non Ferro Metals B.V, EMR Metal Recycling BV, Renewi Amsterdam (Kajuitweg), Renewi Amsterdam (Westpoort), Kapteijn Metaal Recycling, H.Blom & Zonen, Trimey Metalen, Schenk Recycling, Oud Ijzer Handel van Schoten, Onne van de Stadt Recycling BV, Treffers B.V Auto - en Scheepssloperij, Auto recycling Langedijk, Ecaraccu, BNA-Battery, Van Rijn en Co. B.V, Autorecycling Bart Inc., HKS - The metal Company, Metaal Magnus International, Van Peperzeel, NaviQ
- **Recycling** (metal recovery)**:** Riwald Recycling Beverwijk, HKS - The metal Company
- **Services and Trade:** Metaalhandel Kennemerland, Metaalhandel Broersen BV., Second Metals Recycling, Accuverkoop Hefra, AST Amsterdam Scrap Terminal, WMC, Autosloperij en Metaalhandel G van der Wijngaart, Holland Batteries, Return, AMG Advanced Metallurgical Group NV
- **Research and Development:** Amsterdam Chemistry Network, Vrije Universiteit Amsterdam, Universiteit van Amsterdam, Science Park, Hogeschool van Amsterdam, ORE Energy, Intercel | More than batteries

The role of the Provinces of Noord-Holland and Flevoland in building more resilient and sustainable supply chains

CRM supply chains are global in nature and no EU member state has sufficient domestic capabilities to become independent. This also applies to the Netherlands, who will not become self-sufficient for all its needs even in a fully circular system. At the same time, a localized supply chain can suffer from economic inefficiencies as it does not maximize comparative advantages of different countries. As such, any initiative should be developed in a European context.

Although the region represents only one link in global CRM supply chains, this study identifies five opportunities to strengthen regional resilience and sustainability.

1. Ensure that new wind parks, solar parks, data centres and the grid have a circular life-cycle
2. Enhance the circularity of automotives in collaboration with European partners
3. Support recycling companies to expand their services
4. Expand the lifecycle of machinery and electrical appliances
5. Focus on knowledge development and innovation

These five opportunities can be achieved through ten policy recommendations below (Table 1).

Table 1. Policy recommendations

Time frame	Recommendation	Responsible actor	Opportunity				
			1	2	3	4	5
< 1 year	**1. Establish regular dialogue with companies in the region** to build trust and identify joint solutions to challenges around setting up circular supply chains.	Provinces, Municipalities	x	x	x		
< 1 year	**2. Encourage knowledge development within local and regional departments and authorities** to streamline permitting processes.	Provinces	x	x	x		
<1 year	**3. Identify and support the development of connections between companies in the region** to encourage knowledge development and innovation, supporting the scalability of new ideas in 'old' contexts	Municipalities	x	x	x		x
<1 year	**4. Organize awareness campaigns** to encourage more public participation in circular supply chains (lifecycle extension, support for 'high environmental category' recovery facilities).	Municipalities	x	x		x	
<1 year	**5. Support the knowledge ecosystem across different levels of education** to encourage innovation and develop a skilled workforce.	National government, Provinces, Municipalities	x	x	x	x	
1-3 years	**6. Support academic research programmes** to discover and develop new methods for material use efficiency and circularity.	National government, municipalities	x	x			x
1-3 years	**7. Attract innovative start-ups and scale-ups** to maintain and develop the high-tech ecosystem in the MRA.	Provinces, Municipalities					x
1-3 years	**8. Design spatial planning with circularity in mind** to ensure that new recycling facilities can establish operations.	Provinces	x	x	x		
1-3 years	**9. Build a network with local and regional governments in the EU** to accelerate circular supply chains at the European level.	Provinces, Municipalities	x	x	x	x	
1-3 years	**10. Facilitate matchmaking with downstream sectors (manufacturing companies) and specialized recycling companies in EU regions** to help recycling companies in MRA identify potential offtakers for secondary materials.	Provinces, Municipalities	x	x	x	x	

1. Introduction

Vital sectors like digital technologies, healthcare, clean tech, and defence, are dependent on critical raw materials (CRM). CRM are minerals and metals that are essential to the Dutch and European economy and that have a high risk associated with their supply.[14] The risk is primarily caused by the concentration of material production capabilities outside of the European Union (EU), in countries with weak governance systems or who are likely to use these materials as tools of geopolitical influence.

Addressing these dependencies has gained urgency across the EU. Russia's weaponisation of natural gas in 2021-2022, before and during the invasion of Ukraine, showed policymakers and industry that supply chains should not just be based on cost effectiveness, but also on security of supply. The trade tensions between the United States and China have reached new heights in 2025, bringing even more urgency for the EU and the Netherlands to reduce CRM import dependence.

The main risk is the concentration of production and associated geopolitical vulnerabilities.

Geopolitics and security tensions intersect with the growing need for CRM across the world. Demand for CRM is on the rise in sectors like clean, digital and defence technologies. For materials like copper and nickel, global supply is not growing as fast as demand, putting upward pressure on prices and likely creating a supply deficit by 2035.[15] Other materials like rare earth elements (REE) and cobalt are not projected to suffer supply shortages.[16] In their case, the main risk is the concentration of production and associated geopolitical vulnerabilities.

These global events have local impacts in the Netherlands. The Dutch population uses mobile phones, laptops, and electric vehicles that are manufactured with CRM. These supply chains have suffered or are likely to suffer disruptions. The same applies to the wind turbines being installed on the North Sea, the frigates in the Dutch Navy, and the X-Ray equipment in hospitals.[17] As CRM supply chains continue being weaponised, Dutch vital sectors will suffer the consequences. Disruptions have already happened to the semiconductor supply chain during the Covid-19 pandemic. In 2025 the supply chain of permanent magnets got disrupted due to the China-US trade conflict, with countries like the Netherlands caught in the middle. The effects will impact not just citizens but also businesses that cannot maintain profitability amid already strained European competitiveness.

To mitigate these potential negative consequences, the Dutch government committed to strengthening the security of supply of critical raw materials in its 2022 National Raw

14 'Critical Raw Materials', European Commission, 2023, https://single-market-economy.ec.europa.eu/sectors/raw-materials/areas-specific-interest/critical-raw-materials_en.

15 IEA, *Global Critical Minerals Outlook 2025* (2025), https://www.iea.org/reports/global-critical-minerals-outlook-2025.

16 IEA, *Global Critical Minerals Outlook 2025*.

17 'Critical Minerals in Medicine', *British Geological Survey*, n.d., accessed 13 June 2025, https://www.bgs.ac.uk/discovering-geology/maps-and-resources/critical-raw-materials-resources/modern-life-doesnt-grow-on-trees/critical-minerals-in-medicine/; Irina Patrahau and Benedetta Girardi, 'Raw Material and Supply Chain Vulnerabilities in the Dutch Defence Sector: An Analysis of the Air Defence & Command Frigate', *HCSS*, 2025, https://hcss.nl/report/raw-material-supply-chain-vulnerabilities-dutch-defence-sector-frigate/; Irina Patrahau et al., *Securing Critical Materials for Critical Sectors: Policy Options for the Netherlands and the European Union*, HCSS Geo-Economics (The Hague Center for Strategic Studies, 2020), 142.

Materials Strategy.[18] This strategy aligned with the EU Critical Raw Materials Act of 2024 and several other national strategies within and beyond European borders.[19] They all aim to build resilience against future disruptions in CRM supply chains.

While the Dutch strategy is country-wide, the implementation happens mostly at the regional level. One of the key regions in the Netherlands is the Metropolitan Region Amsterdam (MRA). The MRA is the cooperation platform between several regional actors, including the Province of North Holland, the Province of Flevoland, thirty municipalities, and the Transport Authority Amsterdam. Alongside these are other stakeholders with a vested interest in the resilience of the MRA, like the North Sea Canal Area (*Noordzeekanaalgebied*, NZKG), the Amsterdam Economic Board, Port of Amsterdam, and others. Most of these actors have various strategies and targets surrounding circularity and achieving net zero by 2050. This is in addition to the national raw materials strategy, which all the players adhere to. As such, critical raw materials are at the forefront of policymaking across different dossiers in the MRA.

This report investigates ways in which the MRA could contribute to more resilient and sustainable CRM supply chains in light of local, regional, national and European ambitions. It relies on desk research underpinned by eleven interviews with companies and other stakeholders in the region. To increase the understanding of policymakers concerning CRM capabilities and vulnerabilities in MRA, this report provides a mapping of user groups and companies located in the region that play a role in CRM supply chains. Within this mapping and consequent analysis, the entire provinces of Noord-Holland and Flevoland are included, rather than being limited to the areas that fall within the MRA boundaries. This broader scope allows for a more comprehensive analysis and better reflects the composition of both provinces. Apart from raw materials, this report also focuses on all processing and manufacturing stages up to end-of-life, including the knowledge, trade and services ecosystem around the supply chain. Based on this analysis and other regional socio-economic characteristics, the report identifies opportunities for the local and provincial authorities in Noord-Holland and Flevoland to reduce vulnerabilities and increase resilience and sustainability, as well as the choices that policymakers and regional stakeholders need to take to turn these opportunities into reality.

The report is structured as follows. Section two introduces CRM and outlines the global context which affects their supply chains. Section three examines the main user groups of CRM-containing products in the Provinces of Noord-Holland and Flevoland and their vulnerabilities to supply disruptions. Section four maps the existing regional supply chain capabilities within the region. Building on this, section five presents a SWOT analysis of the region and highlights five key opportunities to increase resilience. Finally, section six offers conclusions and recommendations for future action.

18 Rijksoverheid, *Grondstoffen Voor de Grote Transities* (2022), https://www.rijksoverheid.nl/documenten/kamerstukken/2022/12/09/bijlage-nationale-grondstoffenstrategie.

19 European Commission, 'Critical Raw Materials Act'.

2. From global to local: Relevance of CRM for the Provinces of Noord-Holland and Flevoland

Critical raw materials and their supply chains

The European Union defines critical raw materials as *"raw materials of high economic importance for the EU, with a high risk of supply disruption due to their concentration of sources and lack of good, affordable substitutes".*[20] The EU operationalises this definition by publishing a periodical list of Critical Raw Materials (CRM) that fulfil these criteria. In 2023, the EU published its fifth list of critical raw materials.[21] In this list, 34 CRM are identified, as seen in Table 2.

Table 2. EU list of Critical Raw Materials, 2023

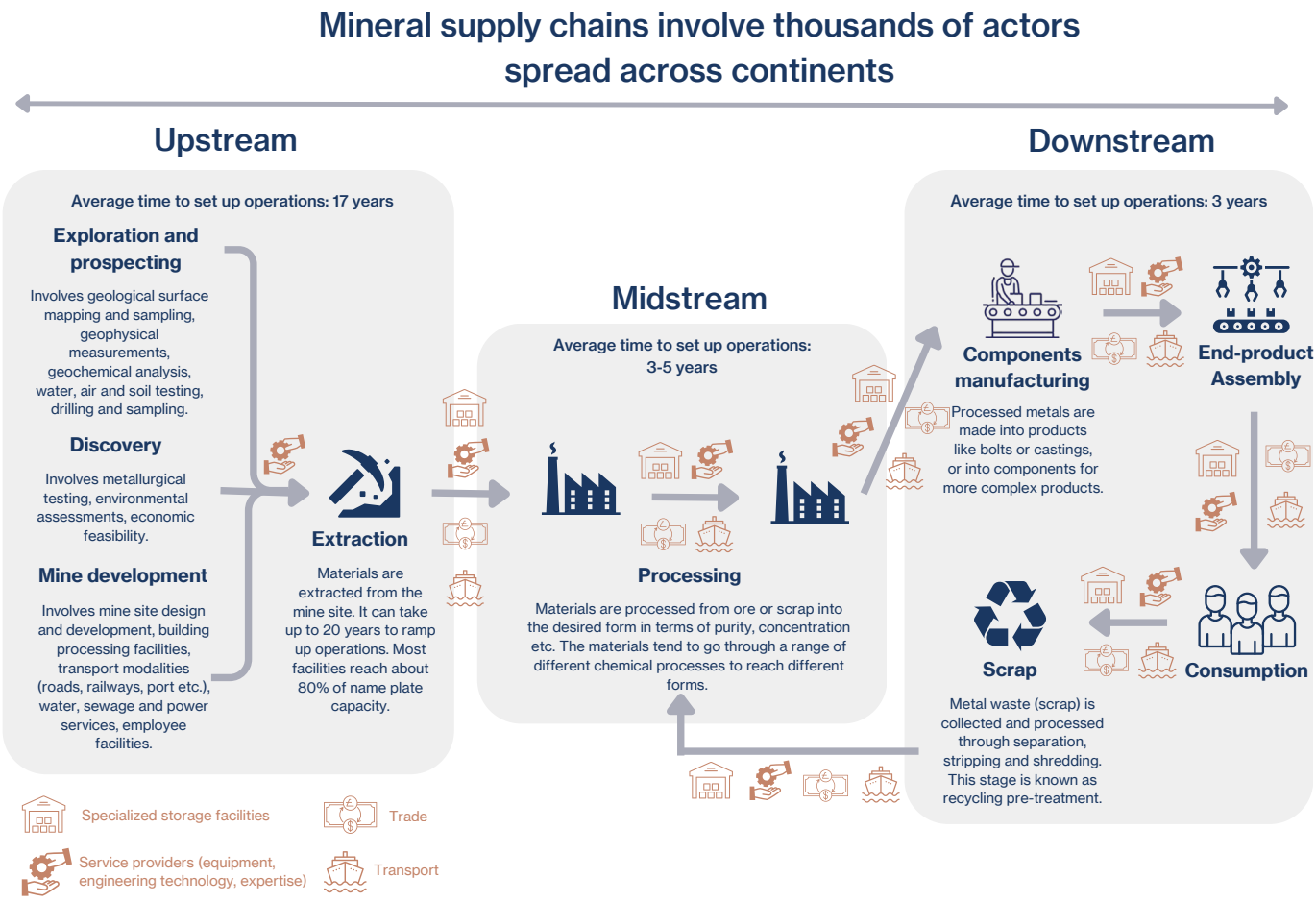
Bauxite	Coking Coal	Lithium	Phosphorus
Antimony	Feldspar	Light rare earth elements	Scandium
Arsenic	Fluorspar	Magnesium	Silicon metal
Baryte	Gallium	Manganese	Strontium
Beryllium	Germanium	Natural Graphite	Tantalum
Bismuth	Hafnium	Niobium	Titanium metal
Boron/Borate	Helium	Platinum group metals	Tungsten
Cobalt	Heavy rare earth elements	Phosphate Rock	Vanadium
		Copper	Nickel

[20] Eur. Comm., 'Critical Raw Materials'.

[21] Eur. Comm., 'Critical Raw Materials'.

The criticality of raw materials is largely dependent on the supply chains of which they are part. CRM supply chains and their individual components are rarely straightforward and tend to be complex and interconnected, as is also the case within Noord-Holland and Flevoland. Figure 2 shows a simplified version of a mineral supply chain, the types of actors involved, and the average duration to establish each kind of operation.

Figure 2. Simplified critical raw material supply chain



The EU scores the raw materials based on economic importance and supply risk (see Figure 3). Materials are considered of economic importance if they support key end uses within the EU, with sectors such as energy, defence, semiconductors, automotive, pharmaceuticals and other high-tech, high-value added sectors. The ongoing energy transition is the main driver of CRM demand, both within the EU and globally.[22] Building the renewable energy system requires large amounts of materials such as copper, aluminium, lithium, nickel, graphite, silicon, manganese and cobalt.[23] At the same time, advanced technologies such as semiconductors, artificial intelligence, 5G networks and aerospace technologies also

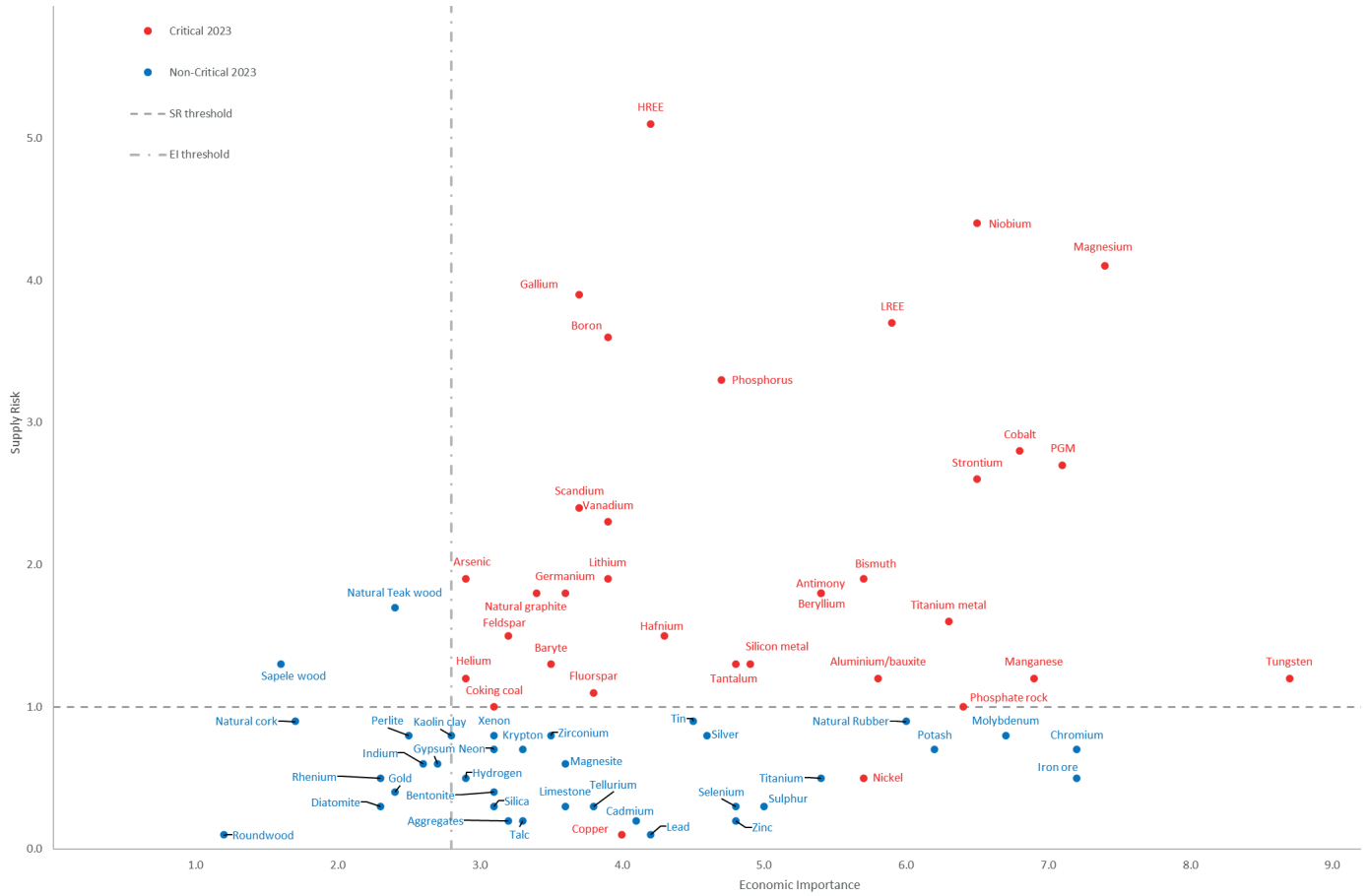
22 IEA, *The Role of Critical Minerals in Clean Energy Transitions*.

23 IEA, *The Role of Critical Minerals in Clean Energy Transitions*.

require several CRM. It is often the case that the lack of even a single CRM from the supply chain can make it impossible to finish a product, leading to production delays, missed orders and substantial economic damage. Securing adequate supplies of these critical minerals is therefore of strategic economic importance. In the context of increasing defence spending in NATO countries, especially the 5% of GDP spending pledge agreed in 2025, secure supplies of CRM are also essential for military effectiveness and deterrent capabilities.[24]

The second dimension, the supply risk, is determined by the concentration of primary supply from raw material producing and processing countries and the relations (e.g. trade, governance) of the EU with those countries. These risks are calibrated by the possibilities for substitution and recycling, with high substitution and recycling possibilities lowering the criticality of the material.[25]

Figure 3. Results of the 2023 EU criticality assessment on supply risk and economic importance. Note that copper and nickel do not meet the criticality threshold but are still included in the list.[26]



[24] Patrahau and Girardi, 'Raw Material and Supply Chain Vulnerabilities in the Dutch Defence Sector'.

[25] *Supply Risk Evolution for Critical Raw Materials*, 5 March 2025, https://www.eea.europa.eu/en/circularity/thematic-metrics/materialsandwaste/evolution-of-eu-raw-materials-supply-risk.

[26] European Commission, Directorate-General for Internal Market, Industry, Entrepreneurship and SMEs, M Grohol, and C Veeh. *Study on the Critical Raw Materials for the EU 2023 - Final Report*. 2023. https://data.europa.eu/doi/10.2873/725585.

The EU has very limited activity in the mineral sector within its borders. This is the result of a long-term trend of declining domestic production combined with an increasing reliance on imports for most of its raw and processed materials.[27] While international trade in commodities is a normal part of a healthy global economy, China controls a disproportionally high dominance in these supply chains.

The emergence of China as the 'factory of the world' has taken place together with the development of its robust domestic mineral industry. The Chinese government has implemented a strong industrial strategy over the last three decades, aiming to establish its position as a key supplier of raw materials, intermediates, and ultimately high-tech products. Heavy investment in domestic mining and processing, together with investments in concessions abroad to retrieve materials that China itself does not have, has led to abundant and affordable inputs for the manufacturing of a great array of products. China produces up to 100% of the global supply of heavy rare earth elements, 86% of tungsten, 79% of phosphorous, and 56% of lithium.[28] This dominance has become particularly strong in the processing stage, where China has established a highly influential and leading position. Furthermore, the EU relies on China for a large part of its clean technology imports, most notably in solar panels and batteries, and to an increasing extent in wind turbines, electric vehicles, and electrolysers.[29] These patterns leave the EU highly vulnerable at every stage of the supply chain.

While international trade in commodities is a normal part of a healthy global economy, China controls a disproportionally high dominance in these supply chains.

Geopolitical risks to the EU's CRM supply security and EU policy

The growing risks to CRM supply chains faced by the EU are driven by a tense geopolitical landscape, characterised by the US-China rivalry, the fragmentation of the US-led order, and the Russia-Ukraine war.

The rise of China has reshaped the international balance of powers and prompted a strategic recalibration by the US to preserve its global influence. China's rapid economic growth, expanding technological capabilities, and assertive foreign policy are perceived by the US government as challenging not only to American dominance, but also to the rules-based international order that the US has led over the last decades. As a result, the US has pivoted toward a strategy that blends new alliances, economic protectionism, technological decoupling, and military deterrence, all aimed at counterbalancing China's rise and limiting its global influence.

The fragmentation of the US-led world order is creating opportunities for new, non-aligned powers to gain a strategic foothold in the new global constellation. India has risen as a geopolitical actor, boasting the 4th largest economy in the world. Additionally, countries such as Brazil, Indonesia and Saudi Arabia are establishing themselves as strategic players, pragmatically cooperating with both Western and non-Western powers to further their own interests.

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27 Michalis Christou and Samuel Carrara, 'Our Research Reveals the Scale of the EU's Dependency on Imports for Critical Minerals Needed for the Green Transition. Here's How That Can Change', *The Conversation*, 23 May 2024, http://theconversation.com/our-research-reveals-the-scale-of-the-eus-dependency-on-imports-for-critical-minerals-needed-for-the-green-transition-heres-how-that-can-change-230244.

28 European Commission, Directorate-General for Internal Market, Industry, Entrepreneurship and SMEs, M Grohol, and C Veeh. *Study on the Critical Raw Materials for the EU 2023 - Final Report*. 2023. https://data.europa.eu/doi/10.2873/725585.

29 Christou and Carrara, 'Our Research Reveals the Scale of the EU's Dependency on Imports for Critical Minerals Needed for the Green Transition. Here's How That Can Change'.

Third, the Russia-Ukraine war has drastically altered the geopolitical landscape. The eruption of a full-blown conflict at the EU's border has on the one hand reaffirmed the shared security goals of the transatlantic alliance, and on the other hand created ruptures between NATO Allies and those that support- or at least do not actively condemn – Russia. The growing partnership between China and Russia is an example. In turn, this also led to the exposure of underlying divisions between Western countries. Disagreements include the scale and support for Ukraine but also engagements with other countries like China.

These dynamics have significant impacts on the EU's CRM supply security. The war in Ukraine reshaped various trade routes, from fossil fuels to fertilisers and digital technologies, pushing governments to develop more partnerships with reliable suppliers. Countries all over the world, including Latin America, East Asia, Middle East and Africa, are building up their mineral industries and positioning themselves as alternatives to the main supplier, China. In doing so, they are collaborating with the EU, US and other consumers in need of diversified and secure supplies. They are also pursuing their own interests in trying to capture more value in the supply chain through more resource nationalist policies. Supply chains are no longer based on market logic but on geopolitics, raising costs and inefficiencies.

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Meanwhile, the US-China rivalry is increasingly taking the form of a geoeconomic battle over critical technologies and raw materials. These goods are used by the two governments as geopolitical weapons to exert influence and hurt each other's high-tech industries. Export restrictions have already affected dual-use goods that serve both civilian and military purposes, such as semiconductors, batteries, rare earth magnets.[30] The trade barriers also affect more than 15 materials needed for their manufacturing – including gallium, germanium, antimony and seven rare earth elements.[31] While these measures are primarily taken in response to US action, they are universally applicable, meaning that they also affect the EU.[32]

It is in this context that the EU is trying to find its geopolitical footing in the form of open strategic autonomy. Although it is a broad and somewhat fuzzy concept, strategic autonomy roughly refers to being able to act independently as a geopolitical entity and being able to accept the consequences of these decisions. This does not just apply to China or Russia but also increasingly to the US. With this goal in mind, the EU is trying to strengthen economic security, reduce its dependence on foreign actors, and build domestic resilience. Lowering these dependencies will have implications for global supply chains, as diversification, 'friend-shoring', and more local production will reshape worldwide trade flows.

The 2024 Critical Raw Materials Act (CRMA) was enacted to provide a framework for increased supply chain resilience.[33] It set benchmarks for 2030, including a 10% domestic production goal, a 45% domestic processing goal, 25% domestic recycling goal, and no single country supplier dependence of more than 65%. Significant advancements are taking place with mixed results so far. A set of strategic projects that will be prioritised in the development and permitting processes have been announced, although no separate funds have been

30 De Guzman, Chad. 'A Timeline of the U.S.-China Trade War During Trump's Second Term'. TIME. https://time.com/7292207/us-china-trade-war-trump-tariffs-timeline/.

31 Shivaprasad, Ashitha, Amy Lv, Lewis Jackson, Ashitha Shivaprasad, and Lewis Jackson. 'Snapshot of China's Critical Mineral Export Controls'. *Reuters*, 4 June 2025. https://www.reuters.com/world/china/chinas-curbs-exports-strategic-minerals-2025-02-04/.

32 Liu, John, and Nectar Gan. 'EU Sounds Alarm to China over Rare Earth Export Controls'. CNN Business, June 2025. https://edition.cnn.com/2025/06/05/business/eu-china-rare-earth-export-controls-intl-hnk.

33 European Commission, 'Critical Raw Materials Act'.

allocated.[34] Memoranda of Understanding (MoU) and trade agreements have been negotiated with several potential CRM suppliers across Africa and Latin America, though progress remains slow. While the mixed results of these initiatives indicate that the EU dependence on China will continue post 2035, they are still expected to contribute to increased resilience moving forward.

CRM developments in the Netherlands

In line with EU legislation, the Netherlands has been a proponent of an active critical raw materials policy. In the lead up to the EU Critical Raw Materials Act (CRMA) the Dutch cabinet wrote a 'non-paper' on CRM in early 2023, proposing to reduce dependency on third countries by not only improving access to critical raw materials but also including semi-finished products in the scope of the legislation.[35] The paper also advocated for building European refining, processing, recycling, and transport capacity in cooperation with resource-rich countries, rather than relying solely on improving CRM security by way of stockpiling.

The National Raw Material Strategy (N*ationale Grondstoffenstrategie*, NGS), launched in 2022, aims to secure sustainable and diversified access to critical raw materials by focusing on circularity and innovation, sustainable European mining and refining, diversification, greater sustainability of international supply chains and knowledge building.[36] The NGS tries to achieve these goals by funding research and setting up the Netherlands Materials Observatory (*Nederlands Materialen Observatorium*, NMO) in 2025 to map and analyse CRM supply chains.[37] The NMO runs multiple projects aimed at improving knowledge on CRM and providing timely information on potential disruptions or supply issues.

Additionally, the Dutch government announced a plan in October 2024 to start assessing the prospect of building strategic stockpiles of critical raw materials in the Netherlands and/or the EU.[38] A feasibility study was commissioned to assess how national reserves could be set up, in coordination with private partners and key logistics hubs like the Rotterdam and Vlissingen harbour.[39] Based on further engagement with stakeholders, plans for stockpiling for the defence and healthcare sectors are being developed in 2025. The initiatives align with the CRMA and aims to stabilize prices and prepare for future disruptions.

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34 'Commission Selects 47 Strategic Projects to Secure and Diversify Access to Raw Materials in the EU', Press Release - European Commission, 25 March 2025, https://ec.europa.eu/commission/presscorner/detail/en/ip_25_864.

35 Ministerie van Economische Zaken en Klimaat, 'NL non-paper on the Action Plan on Critical Raw Materials and the Critical Raw Materials Act - Publicatie - Rijksoverheid.nl', publicatie, Ministerie van Algemene Zaken, 2 February 2023, https://www.rijksoverheid.nl/documenten/publicaties/2023/02/02/nl-non-paper-on-the-action-plan-on-critical-raw-materials-and-the-critical-raw-materials-act.

36 Zaken, 'Raw materials strategy for large transitions - Kamerstuk - Rijksoverheid.nl'.

37 'Nederlands Materialen Observatorium - Nederlands Materialen Observatorium', https://nederlandsmaterialenobservatorium.nl/.

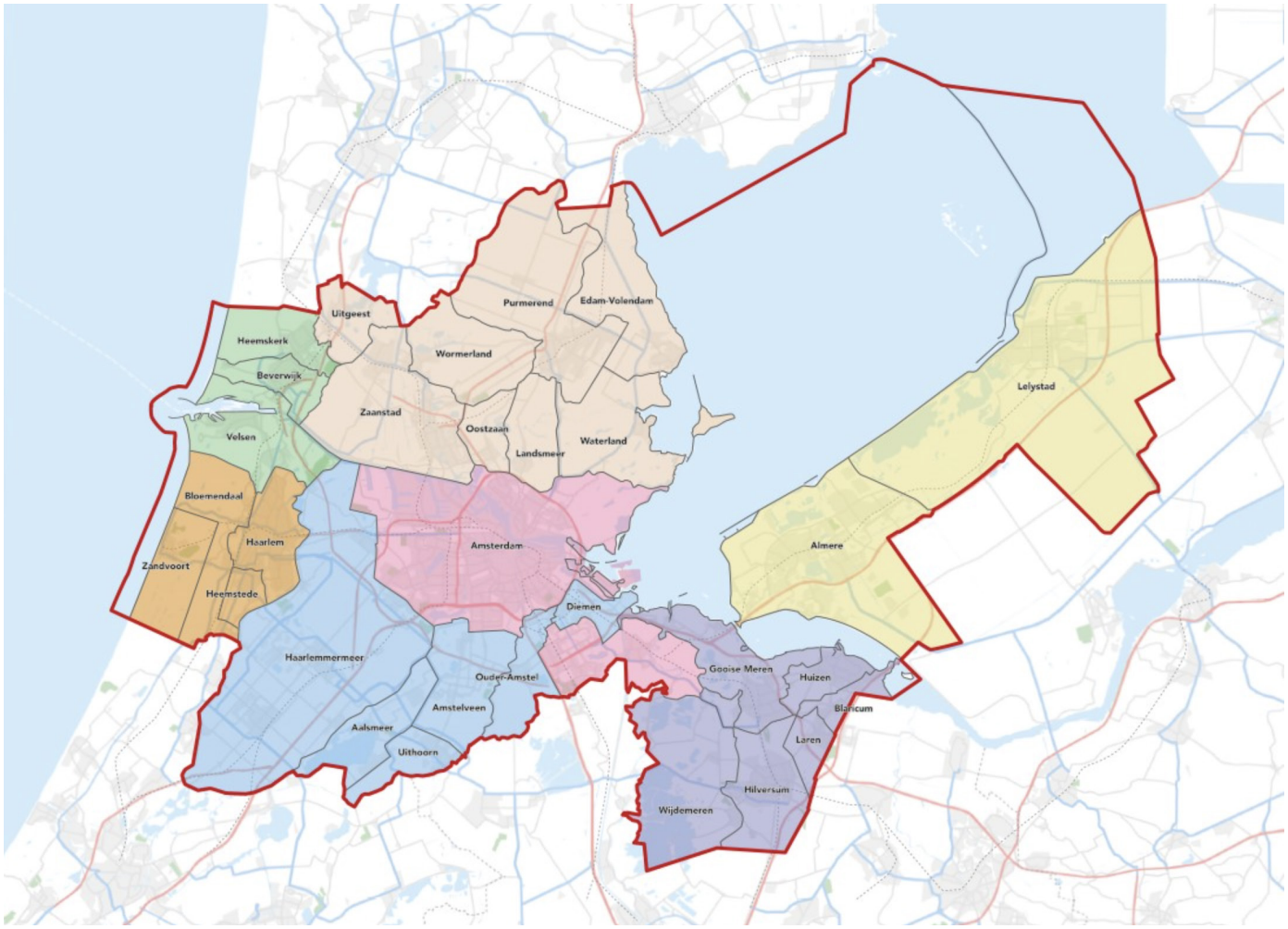
38 Ministerie van Economische Zaken, 'Kamerbrief voorraadvormingsprogramma kritieke grondstoffen - Kamerstuk - Rijksoverheid.nl', kamerstuk, Ministerie van Algemene Zaken, 28 October 2024, https://doi.org/10/28/kamerbrief-voorraadvormingsprogramma-kritieke-grondstoffen.

39 Jeff Amrish Ritoe, *Een studie naar de haalbaarheid van een nationaal programma voor de opslag van kritieke grondstoffen ter versterking van Europese waardeketens* (2024), https://open.overheid.nl/documenten/9e800110-ceb9-4180-a144-3ee92c1b7f4b/file.

CRM policy in the Metropolitan Region Amsterdam

European legislation is not only translated into national policies, but also regional initiatives. Within the MRA (Figure 4) and the provinces it belongs to there are several policy documents that refer to or have implications for raw materials supply chains. These policies are formulated on a regional, sub-regional and local level.

Figure 4. The MRA and its subregions. Source: Metropolitan Region Amsterdam



The Province of Noord-Holland has committed itself to various CRM initiatives within their 'implementation agenda' for 2025-2028.[40] For example, one of the policy priorities outlined in this document is the recovery of CRM. In addition, the MRA is developing a regional 'Raw Materials Deal', a set of agreements among various stakeholders aimed at improving the

[40] Province Noord Holland, 'Uitvoeringsagenda Duurzame En Circulaire Economie 2025-2028'.

reuse and efficient management of raw materials.[41] Furthermore, the MRA has also expressed its intention to link the energy transition with the raw materials transition within their 'MRA Agenda 2025-2028'.[42] In short, the region positions itself as an active supporter of more efficient use of CRM and the development of circular CRM streams.

One of the areas within the MRA—the North Sea Canal Area (NZKG)—was the focus of a study commissioned by the Province of Noord-Holland on advancing the circular economy in the region.[43] This study repeatedly emphasized the importance of CRM for the area. Additionally, it outlined two scenarios that envisioned a more localized CRM supply chain. This would entail stimulating the emergence of local, circular CRM supply chains, which require local treatment, recycling and processing. Moreover, the NZKG has mentioned in their implementation agenda for the spatial economy for 2025-2029 that they are developing a circular raw materials strategy, including focusing on securing CRM supplies.[44]

The Port of Amsterdam has also developed a strategy on the circular economy and the energy transition. In their vision for 2030, the Port strives to become a raw materials hub that brings together several raw material streams, while simultaneously developing the biobased and circular economy.[45] This includes building partnerships with ports from CRM-originating regions.

Last but not least, the Municipality of Amsterdam aims to become a fully circular and net-zero city by 2050. Its circular strategy for the 2020–2025 period includes a specific focus on improving the circularity of CRM.[46]

In short, the MRA region has made the development of circular and more resilient supply chains a priority at the provincial, regional, and local levels for several years now and is committed to continuing these efforts in the coming years.

41 'Aanpak Materiaalstromen.', *metropoolregioamsterdam*, n.d., accessed 18 June 2025, https://www.metropoolregioamsterdam.nl/programma/circulaire-economie/aanpak-materiaalstromen/.

42 Metropool Regio Amsterdam, *MRA-Agenda-2025-2028* (2025), https://www.metropoolregioamsterdam.nl/wp-content/uploads/2024/11/Bijlage-4a-MRA-Agenda-2025-2028.pdf.

43 Ecorys and Metabolic, *Transitie naar een circulaire economie in het Noordzeekanaalgebied*.

44 Programmabureau NZKG, *Uitvoeringsagenda NOVEX-NZKG 2025-2029* (2024), https://www.noordzeekanaalgebied.nl/uploads/uitvoeringsagenda-novex-nzkg-2025-2029.pdf?_cchid=42ccfa65a21335c5e1f06ccb6d8e9998.

45 'Vision 2030 | Port of Amsterdam', https://www.portofamsterdam.com/en/about-port-amsterdam/mission-and-vision/vision-2030.

46 openresearch.amsterdam, 'Amsterdam Circulair 2020-2025 Strategie'.

3. CRM volumes and vulnerabilities in the region

This section provides insights into the distribution of CRM volumes in different product groups in the Provinces of Noord-Holland and Flevoland. The products are mostly manufactured outside of the region and the Netherlands but contain valuable CRM that could be re-entered into the circular loop. The section is split into two parts. The first part examines the types of goods containing CRM that are the most commonly found in the two provinces. The second part looks at the goods that are strategically important for the region's policy ambitions, including wind turbines, solar panels, data centres and the grid.

Most common goods containing CRM

The distribution of CRM within the Provinces of Noord-Holland and Flevoland is similar, as seen in Table 3.[47] In both provinces, the automotive industry accounts for the largest share of CRM volumes. The next three largest categories are also the same in both provinces, with only slight differences in their respective proportions of the total CRM volume. The only notable variation lies in the fifth-largest goods category: non-ferrous metals and related products. This category includes several types of CRM and components as standalone goods, rather than as part of an end product like a car. In Flevoland, this category ranks sixth and is therefore not included in the table.

Each of the categories in the table above can contain between 23 - 33 types of CRM in various quantities (Figure 5).[48] GeoFluxus' research indicates that almost 100% of numerous CRM (niobium, rhodium, cobalt, europium, palladium, gadolinium, tungsten, yttrium, tantalum, just to name a few) in the Provinces of Noord-Holland and Flevoland are found within the automotive industry.[49] Magnesium is almost exclusively found in non-ferrometals and products thereof, while nearly all antimony and germanium can be found in basic chemical products.[50]

47 *Provinciale Monitoring Circulaire Economie - Noord-Holland*; *Provinciale Monitoring Circulaire Economie - Flevoland*.

48 *Provinciale Monitoring Circulaire Economie - Noord-Holland*; *Provinciale Monitoring Circulaire Economie - Flevoland*.

49 *Provinciale Monitoring Circulaire Economie - Noord-Holland*; *Provinciale Monitoring Circulaire Economie - Flevoland*.

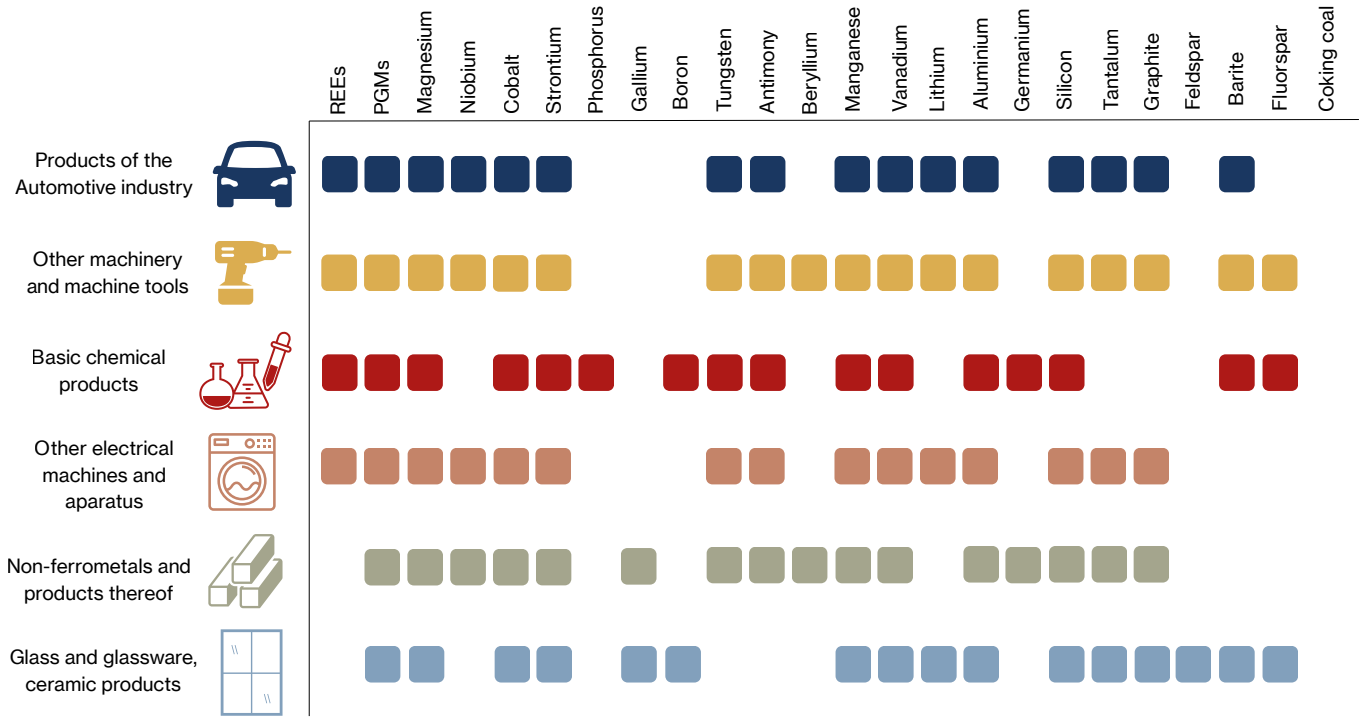
50 *Provinciale Monitoring Circulaire Economie - Noord-Holland*; *Provinciale Monitoring Circulaire Economie - Flevoland*.

Table 3. The most common goods categories containing CRM in the Provinces of Noord-Holland and Flevoland as a percentage of each province's total CRM volumes. Note that the total volume in the two provinces of CRM differs, even though the distribution is similar.

	Noord-Holland	≈ %	Flevoland	≈ %
1	Products of the Automotive industry	37.5%	Products of the Automotive industry	38.5%
2	Other machinery and machine tools	15.5%	Other machinery and machine tools	17.5%
3	Basic chemical products	9%	Basic chemical products	8%
4	Other electrical machines and apparatus	8%	Other electrical machines and apparatus	7%
5	Non-ferrometals and products thereof	7%	Glass and glassware, ceramic products	6.5%

Source (geoFluxus PCER Noord-Holland & Flevoland, page 4 & 39)

Figure 5. Top 6 CRM concentrated goods categories present within the Provinces of Noord-Holland and Flevoland and the materials they contain. Figure made by HCSS with data from geoFluxus[51]



[51] *Provinciale Monitoring Circulaire Economie - Noord-Holland; Provinciale Monitoring Circulaire Economie - Flevoland.*

The region is heavily import dependent on these materials and goods, bringing vulnerabilities to the different economic groups that use them and reducing the type of actions that can be taken to address these early in the supply chain. Take automotive products as an example, which as a goods category contains both separate parts like engines and gearboxes, as well as entire vehicles with internal combustion engines, hybrid and electric motors.[52] As of 2025, there is little to no manufacturing of these goods taking place within the Provinces of Noord-Holland and Flevoland. In 2020-2021, the COVID-19 pandemic created a semiconductor shortage that in turn had significant negative effects on the automative industry.[53] In 2021 alone, S&P Global estimated that over "9.5 million units of global light-vehicle production was lost" due to this shortage.[54] More recently, in 2025, China's export restrictions on rare earth elements (REE) and permanent magnets have again disrupted the automotive sector.[55] As company mandated reserves are depleting quickly, various supplier plants and production lines across Europe have been forced to a halt.[56] This can impact end users in the Provinces of Noord-Holland and Flevoland who are in the market for an automotive product. The fact that no car manufacturers are located in the region also means that the mitigating actions within the regional authorities' span of control remain limited.

The fact that no car manufacturers are located in the region also means that the mitigating actions within the regional authorities' span of control remain limited.

Wind turbines, solar panels, data centres & the grid

The move towards net-zero targets and digitalization creates vulnerabilities to supply chain disruptions, but also opportunities to rethink production and consumption models, moving from linear to circular systems. In light of the two provinces' current assets and future policy targets, four groups are explored below: wind turbines, solar parks, data centres, and the electricity grid. Figure 6 contains an overview of the distribution of three out of the four product groups as of 2025. The grid is not included given that cables and transformer stations are found across the entire region.

The Provinces of Noord-Holland and Flevoland contain on average a higher quantity of wind turbine parks compared to the rest of the Netherlands, both on land and at sea. The largest wind turbine park on land in the Netherlands, Zeewolde, is located in Flevoland.[57] As seen in Figure 7, this wind park already contains a large quantity of large models of turbines. As most are reaching the end of their life cycle, 200 wind turbines are set to be removed and replaced from Zee Wolde to make space for 83 turbines of larger models by 2026.[58] A large amount will not be recycled but are rather sent to Ireland, Poland, and possibly Georgia to continue generating energy for another decade.[59]

52 A comprehensive list of which products are in each goods category can be found on CBS (NST2007 codes)

53 Ondrej Burkacky et al., *Semiconductor Shortage: How the Automotive Industry Can Succeed*, 2022.

54 Stephanie Brinley, 'The Semiconductor Shortage Is – Mostly – over for the Auto Industry', IHS Markit, 12 July 2023, https://www.spglobal.com/mobility/en/research-analysis/the-semiconductor-shortage-is-mostly-over-for-the-auto-industry.html.

55 Renshaw et al., 'Global Alarm as China's Critical Mineral Export Curbs Take Hold'.

56 Meredith, 'Auto Industry Sounds the Alarm as China's Rare Earth Curbs Start to Bite'.

57 Michel de Vries, 'Vele windmolens naderen einde leven, recyclen wieken is (nog) niet makkelijk', *RTL.nl*, 25 August 2023, https://www.rtl.nl/rtl-nieuws/artikel/5403369/honderden-oude-windmolens-weggehaald-recyclen-wieken-complex.

58 de Vries, 'Vele windmolens naderen einde leven, recyclen wieken is (nog) niet makkelijk'.

59 de Vries, 'Vele windmolens naderen einde leven, recyclen wieken is (nog) niet makkelijk'.

Figure 6. Wind turbines, solar parks, data centres in the Provinces of Noord-Holland and Flevoland in 2025. Note: This visual is not comprehensive, more detailed versions can be found in the Annex.

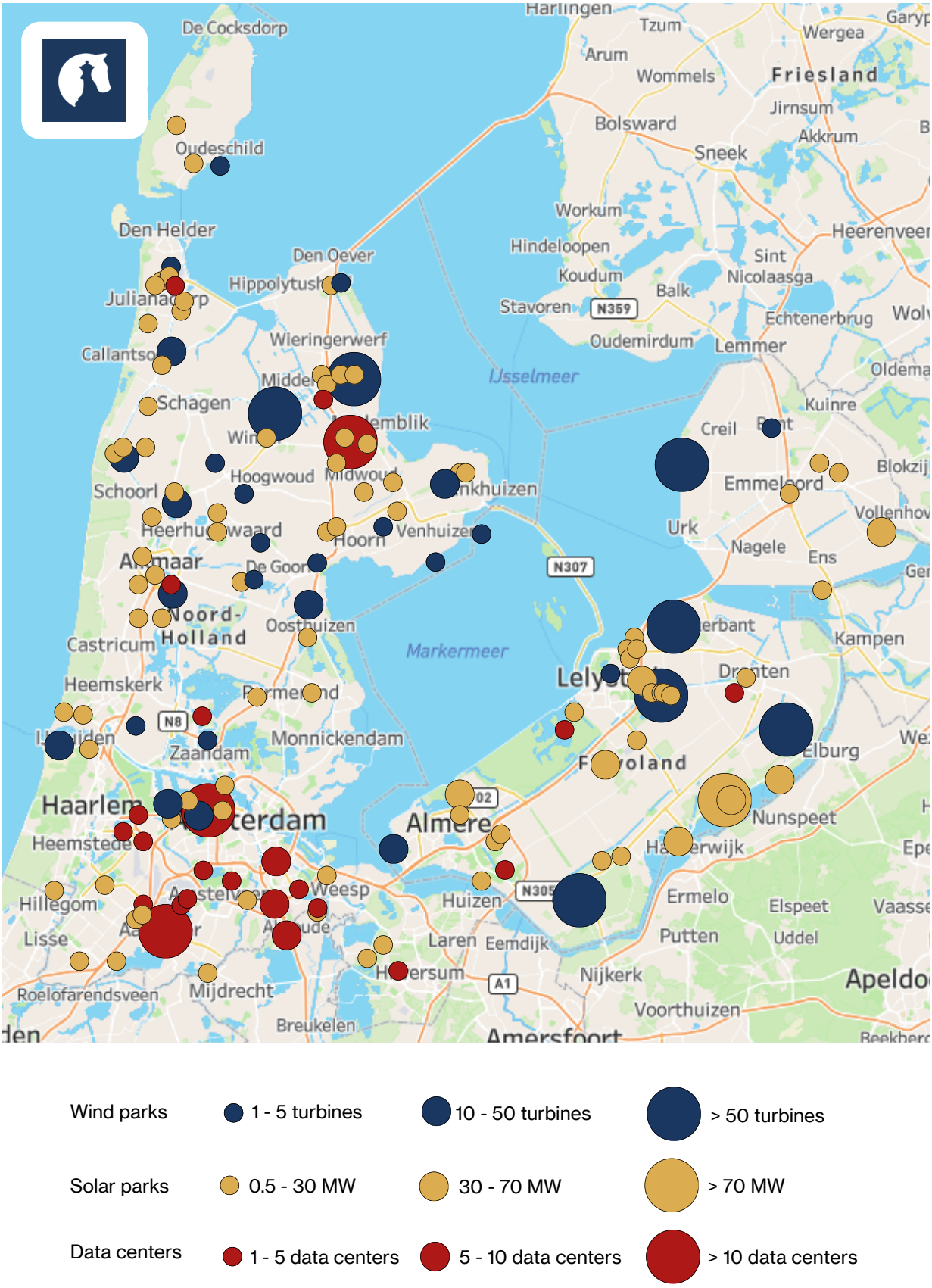
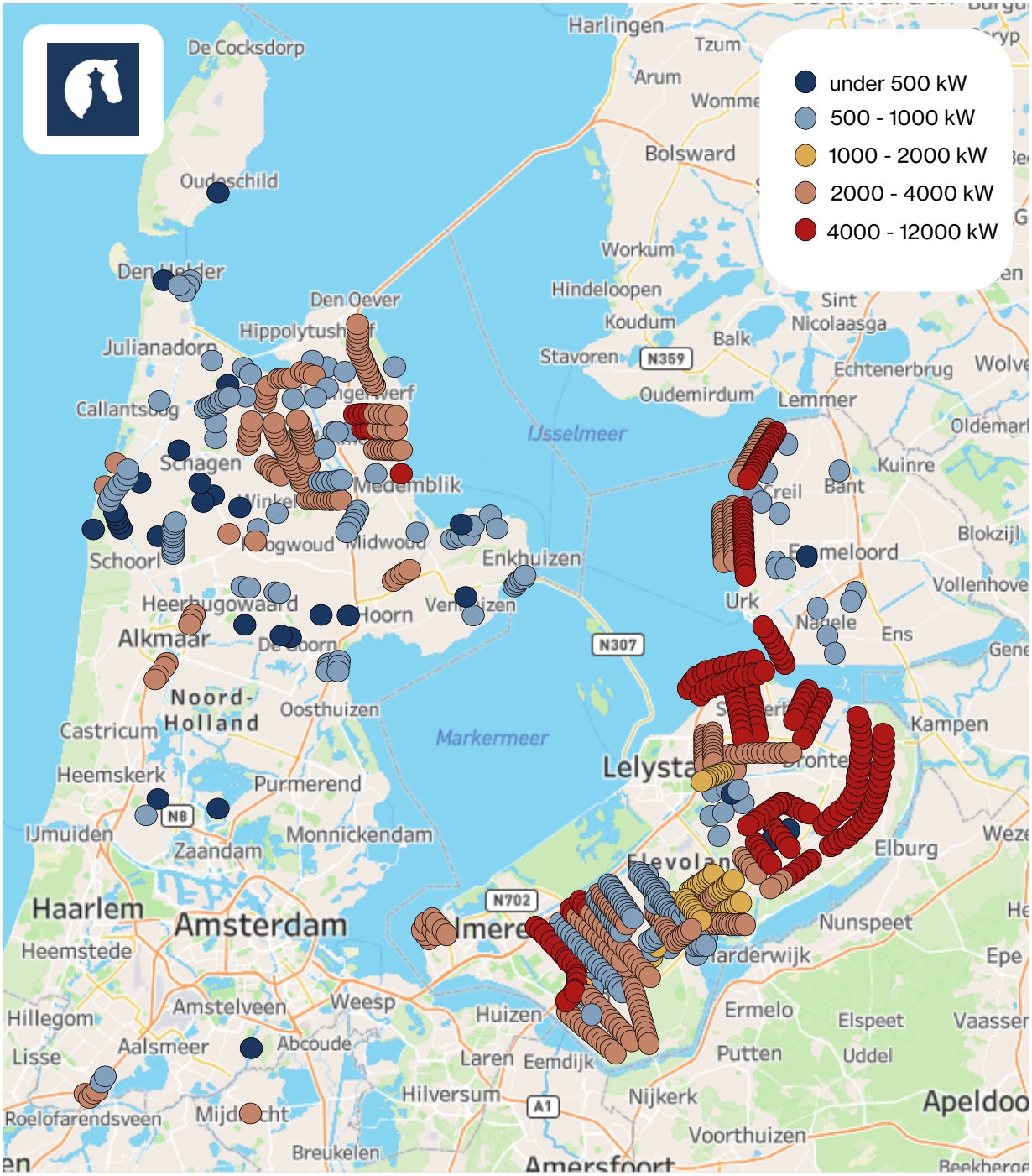


Figure 7. All wind turbines in the Provinces of Noord-Holland and Flevoland in 2025. Figure made with data from Atlas Leefomgeving Rijksoverheid[60]



[60] 'Atlas Leefomgeving'. Accessed 31 July 2025. https://www.atlasleefomgeving.nl/.

Offshore wind turbine parks are both already present and being further developed within the waters adjacent to the two provinces. There are several wind turbines installed on the Ijsselmeer whereas the North Sea contains many large-scale wind turbine parks.[61] These offshore wind parks are in varying stages of their life cycle as some have been in use since 2008 whereas others only a couple of years.[62] In the upcoming decade offshore wind turbines will either undergo maintenance or will need to be replaced, opening up new CRM waste-streams. Both the Port of Amsterdam and Port of IJmuiden play an important role within the facilitation of these offshore wind parks. A cluster companies in Ijmuiden is responsible for the repair and maintenance of these offshore wind turbines, whereas the Port of Amsterdam facilitates the delivery of components.[63]

Depending on the model and size, wind turbines can consist of various CRM, all of which being imported from outside of the EU. The structural components of the tower itself typically contains nickel, manganese, niobium, titanium, and vanadium.[64] While nickel, manganese and titanium are mined in various countries like Indonesia, South Africa and Australia, their processing is concentrated in China.[65] More than 90% of niobium is both mined and processed in Brazil.[66] The permanent magnet, an important component of the generator, contains REE.[67] The supply chain for these permanent magnets is concentrated in China, with almost 70% of REE mining and 91% of refining taking place within the country.[68] Furthermore, almost all magnet production takes place within China. Though the EU is more present in the manufacturing phase, with Vestas (a Danish company) amongst the largest wind turbine manufacturers in the world, China's dominance throughout the supply chain poses a challenge to the Provinces of Noord-Holland and Flevoland's future wind-energy ambitions.[69]

These dependencies are deeply entrenched and difficult to address and could also impede on the ability of the Port of Amsterdam and Port of Ijmuiden to supply and assemble offshore wind turbine parts in the future. There are several initiatives in the EU could reduce the region's vulnerabilities. Current wind-turbine and permanent magnet recycling capabilities that could extract CRM are lacking within the Provinces of Noord-Holland and Flevoland, but there are various initiatives upcoming within the Netherlands and already present within Europe (like CARESTER in the South of France) that could be involved in facilitating this process.

The Provinces of Noord-Holland and Flevoland house 13% of all solar parks in the Netherlands; 143 out of the 1077 in total.[70] While compared to the rest of the country the amount of solar parks is currently below average, there are large scale projects planned

61 'Atlas Leefomgeving'.

62 Sissingh, Joost. 'Lifetime Extension of 5 Years for Wind Farm Egmond Aan Zee'. Pondera. Accessed 31 July 2025. https://ponderaconsult.com/en/news/lifetime-extension-of-5-years-for-wind-farm-egmond-aan-zee.; Noordzeeloket. 'Windenergiegebied Hollandse Kust (noord) inclusief Prinses Amalia Windpark (PAWP)'. Accessed 31 July 2025. https://www.noordzeeloket.nl/functies-gebruik/windenergie/doorvaart-medegebruik/hollandse-kust-noord-inclusief-prinses-amalia/.

63 *Vision 2040 | Port of Amsterdam*. 2025.

64 Isabeau van Halm, 'The EU's Import Reliance for Critical Materials for Wind Is 77%', *Energy Monitor*, 25 April 2023, https://www.energymonitor.ai/tech/renewables/data-insight-the-eu-critical-material-import-reliance/.

65 European Commission et al., *Study on the Critical Raw Materials for the EU 2023 - Final Report* (2023), https://data.europa.eu/doi/10.2873/725585.

66 European Commission et al., *Study on the Critical Raw Materials for the EU 2023 - Final Report*.

67 S Bobba et al., *Critical Raw Materials for Strategic Technologies and Sectors in the EU - A Foresight Study* (2020), https://rmis.jrc.ec.europa.eu/uploads/CRMs_for_Strategic_Technologies_and_Sectors_in_the_EU_2020.pdf.

68 Rizos et al., *Developing a Supply Chain for Recycled Rare Earth Permanent Magnets in the EU*.

69 Rizos et al., *Developing a Supply Chain for Recycled Rare Earth Permanent Magnets in the EU*.

70 This excludes solar panels on individual buildings. Source: *Zon Op Kaart Dashboard*, ROM, 2025, https://rom3d.maps.arcgis.com/apps/dashboards/704215ca2235496395ce0a30355e61a5.

in both provinces (see Figure 8).[71] The parks under construction in Espel, Rutten, and Zwanenburg are set to become not only the largest in the two provinces, but also amongst the largest in the country.

Within the EU, photovoltaics (PVs) are the fastest growing renewable energy source, with almost all solar modules imported from China.[72] As a response to this import dependency, a non-binding target has recently been set by the EU to become 40% self-sufficient in the manufacturing of PVs by 2030.[73] The EU's Net-Zero Industry Act further emphasizes this target and aims to increase Europe's renewable energy manufacturing capacity as a whole.[74] Even though regional solar panel company Energyra shows that local manufacturing can be possible, a dependency on China for realizing solar ambitions still remains. Energyra faced financial issues in 2019 but has now restarted operations and plans to scale production to half a million solar panels per year.[75]

According to the National Institute for Public Health and the Environment (RIVM), there are currently no CRM being derived from solar panels in the Netherlands.[76] The CRM present in solar panels are silicon, antimony, copper, nickel and titanium.[77] First generation solar panels are expected to be at the end of their life-cycle in 5 years, and current recycling method includes removing the glass layer and shredding the whole product. Between 2035 – 2045, the volume of discarded solar panels is set to rise from 10.000 to 230.000 tons.[78] Similar to wind turbine recycling capacities the ability to derive CRM from solar panels is currently lacking, though a regional programme has been set up to stimulate more circular practices.[79] Furthermore, both the TNO and RIVM are actively researching and developing techniques that could facilitate this process. There are also multiple European projects under development, like the German based PRISM-project that aims to process 8.400 tons of PV waste per year from 2025 onwards.[80]

71 *Zon Op Kaart Dashboard*.

72 Ben McWilliams et al., 'Smarter European Union Industrial Policy for Solar Panels', *Bruegel | The Brussels-Based Economic Think Tank*, 5 June 2025, https://www.bruegel.org/policy-brief/smarter-european-union-industrial-policy-solar-panels.

73 McWilliams et al., 'Smarter European Union Industrial Policy for Solar Panels'.

74 European Commission, 'The Net-Zero Industry Act', The Net-Zero Industry Act: Making the EU the Home of Clean Technologies Manufacturing and Green Jobs, accessed 12 June 2025, https://single-market-economy.ec.europa.eu/industry/sustainability/net-zero-industry-act_en.

75 'Over Energyra Europe', accessed 17 June 2025, https://www.energyra.com/about-energyra.

76 JPA Lijzen et al., *Recycling of Solar Panels. Comparison of Scenarios for a More Circular and Safe Product Chain* (Rijksinstituut voor Volksgezondheid en Milieu RIVM, 2024), https://doi.org/10.21945/RIVM-2023-0442.

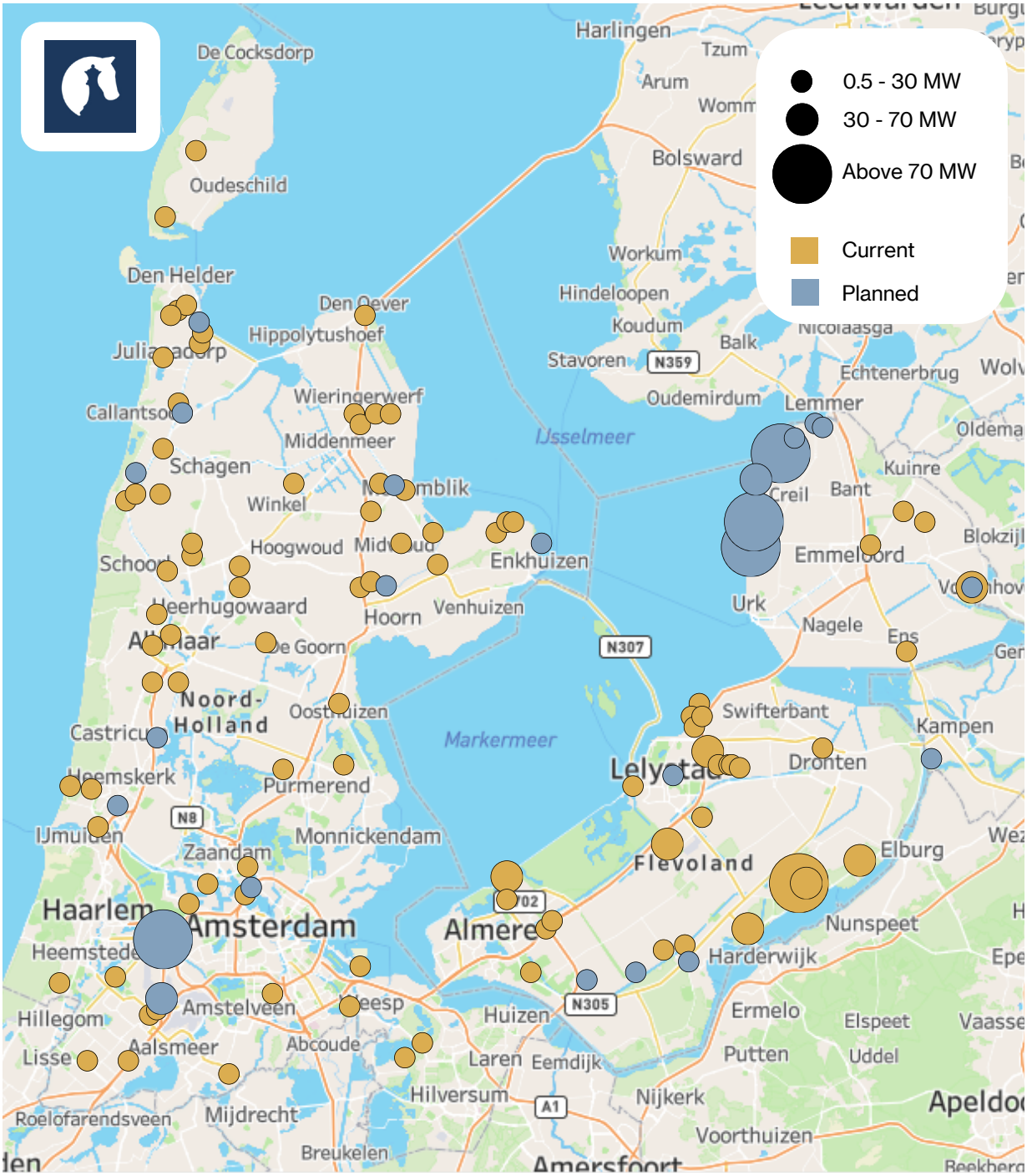
77 Lijzen et al., *Recycling of Solar Panels. Comparison of Scenarios for a More Circular and Safe Product Chain*.

78 Lijzen et al., *Recycling of Solar Panels. Comparison of Scenarios for a More Circular and Safe Product Chain*.

79 Edwin Oskam et al., *Programma Circulaire Zon-PV* (2025).

80 European Commission, 'Panel Recycling and Integrated Solar Material | PRISM | Project | Informationsblatt | HORIZON | CORDIS | Europäische Kommission', CORDIS | European Commission, 11 March 2024, https://cordis.europa.eu/project/id/101145463/de.

Figure 8. Current and planned solar panel parks in the Provinces of Noord-Holland and Flevoland. Figure made with data from ROM Zon op Kaart Dashboard[81]



[81] 'Zon Op Kaart'. https://rom3d.maps.arcgis.com/apps/dashboards/704215ca2235496395ce0a30355e61a5.

Finally, of the (over) 200 data centres in the Netherlands roughly 95 are located within the region.[82] The presence of data centres in the country can be attributed to a couple of factors: good digital infrastructure and connection to underwater sea cables, a low risk of natural disasters and the availability of cheap green electricity.[83] The division amongst the two provinces is skewed, as almost all are located in Noord-Holland (Figure 9).

These data centres can be categorized in different types and tiers. Based on size, three different types can, generally speaking, be identified. Hyperscale data centres are the largest, and often the property of large cloud companies like Google.[84] There are only two of these based in the Netherlands, one of which is located in Middenmeer, Noord-Holland. The second largest type are colocation data centres, which in general are more commercial and house various companies or institutions.[85] These include schools, hospitals, banks, and so on. Lastly, the smallest type of data centres are company-based ones. These serve one client, but due to the complexity of modern digitalization processes these are often outdated and more expensive, making them more unattractive and slowly disappearing.[86]

82 *The Netherlands Data Centers - 192 Facilities*, n.d., accessed 5 June 2025, https://www.datacentermap.com/the-netherlands/; Thomson Owen, 'Datacenters kunnen het Nederlandse energiesysteem belasten én versterken', *Onderzoek Rabobank*, 28 May 2025, https://www.rabobank.nl/kennis/d011479153-data-centers-kunnen-het-nederlandse-energiesysteem-belasten-en-versterken.

83 Niki Ipenburg, 'Waarom zijn er zoveel datacenters in Nederland?', *NPO Kennis*, 5 February 2024, https://npokennis.nl/story/307/waarom-zijn-er-zoveel-datacenters-in-nederland.

84 Samantha Reilly, 'Facts & Figures van de sector ICT Software', ING, 20 May 2025, https://www.ing.nl/zakelijk/sector/tmt-ict/facts--figures-ict-datacenters.

85 Samantha Reilly, 'Facts & Figures van de sector ICT Software'.

86 Samantha Reilly, 'Facts & Figures van de sector ICT Software'.

Figure 9. Data centres in the Provinces of Noord-Holland and Flevoland in 2025. Figure made with data from Data Center Map[87]

87 'The Netherlands Data Centers'. Accessed 31 July 2025. https://www.datacentermap.com/the-netherlands/.

Data centres contain a variety of CRM, roughly 30, which pose supply risks.[88] All of the cabling requires large amounts of copper, the cabinets that contain the hardware is made out of silicon or similar metals, and the batteries powering the data can contain lithium and other CRM, depending on the type.[89] This makes them vulnerable for supply chain disruptions. According to the Turner and Townsend's Data Center Cost Index 2022, "95% of respondents report that material shortages have caused delays to data centre construction over the past 12 months".[90]

Data centres typically have a lifespan of 15 to 20 years. However, due to rapid technological advancements, many of their components are replaced much more frequently. While there is significant potential to make data centres more circular, it is equally important to ensure that their electronic waste (e-waste) is properly processed.[91] Using advanced recycling techniques can help recover valuable CRM from this waste.

All of the aforementioned groups either generate or offtake large amounts of electricity, which can have negative impact on general availability as a result. As of 2025, large parts of the Netherlands, including the two provinces, are experiencing net congestion.[92] This not only impedes the green and digital transition but also hinders the development of circular CRM practices within the Provinces of Noord-Holland and Flevoland. CRM related start-ups and companies alike either struggle to secure a connection to the grid to begin or expand operations.[93] Enlarging and restructuring the electricity grid to meet both current and future needs is crucial and will require vast amounts of CRM like copper and aluminium. Conflictingly, the demand for these materials is set to increase. By 2050, copper demand will have risen by 35% and aluminium by 33%.[94] Furthermore, the International Energy Agency predicts that by 2035 global copper supply will only be able to meet 70% of the projected demand.[95]

This section has outlined the distribution of critical raw materials (CRM) across various product categories, along with the associated supply chain risks. Automotive products stand out as the largest users of CRM in both provinces. Given the region's strong reliance on imports for most CRM-containing goods, this creates significant dependencies and vulnerabilities. These risks also affect key specific assets and policy areas, including wind farms, solar parks, data centres, and grid components

The next section examines the supply chain capabilities within the two provinces to identify opportunities for reducing these vulnerabilities, which will be explored further in Section 5.

88 Helen Parton, 'Are Data Centres Too Demanding on Raw Materials?', RICS, 6 July 2023, https://ww3.rics.org/uk/en/modus/natural-environment/renewables/data-centres-raw-materials.html. 2023

89 Mohamed Sameer Hoosain et al., 'Tools Towards the Sustainability and Circularity of Data Centers', *Circular Economy and Sustainability* 3, no. 1 (2023): 173–97, https://doi.org/10.1007/s43615-022-00191-9.

90 Helen Parton, 'Are Data Centres Too Demanding on Raw Materials?'

91 Hoosain et al., 'Tools Towards the Sustainability and Circularity of Data Centers'.

92 Ministerie van Algemene Zaken, 'Maatregelen tegen vol elektriciteitsnet (netcongestie) - Duurzame energie - Rijksoverheid.nl', onderwerp, Ministerie van Algemene Zaken, 27 October 2023, https://www.rijksoverheid.nl/onderwerpen/duurzame-energie/kabinet-neemt-maatregelen-tegen-vol-elektriciteitsnet-netcongestie.

93 Interview HCSS, 2025

94 Electricity Grids: The Backbone of the EU Energy System - Motion for European Parliament Resolution (2025). https://www.europarl.europa.eu/meetdocs/2024_2029/plmrep/COMMITTEES/ITRE/DV/2025/05-12/ITREINIReport-ElectricityGrids-CompromiseCA1-0805_EN.pdf.

95 'Overview of Outlook for Key Minerals – Global Critical Minerals Outlook 2025 – Analysis', *IEA*, n.d., accessed 22 July 2025, https://www.iea.org/reports/global-critical-minerals-outlook-2025/overview-of-outlook-for-key-minerals.

4. CRM supply chain capabilities in the region

Industrial activity involving CRM is limited in both the Netherlands and the region. However, some notable capabilities can be identified, as shown in Figure 10.[96] The figure is not comprehensive but aims to offer a representative insight into the type of capabilities that companies in the region have. The companies featured were categorized according to their primary field of activity, as defined in Table 4.

Table 4. Definitions of supply chain components

Categories	Definitions
Processing	Companies primarily engaged in refining and transforming CRM into materials suitable for use in manufacturing or other industrial applications
Manufacturing	Companies primarily involved in producing components or finished products that use CRM, such as solar panels, catalysts, or fertilizers
Recycling (collection, separation and preparation)	Companies primarily focused on collecting, sorting, and preparing (CRM-containing) scrap for further recycling or re-use
Recycling (metal recovery)	Companies primarily dedicated to recovering metals from waste, scrap, or end-of-life products, with a focus on extracting CRM
Services & Trade	Companies primarily involved in the trade, distribution, warehousing, or other services for CRM
Research & Design	Organizations primarily engaged in developing products or components that contain CRM, improving CRM efficiency, or designing alternatives. This category also includes entities that support innovation and collaboration across the CRM value chain

96 The capabilities of the Netherlands have been outlined in the HCSS report "Advancing European mineral security: Insights from Dutch industry", published in November 2023.

Figure 10. Companies and institutions active in mineral and metal supply chains in the Provinces of Noord-Holland and Flevoland

Note this list is not comprehensive

- **Processing**: Chemreclaim, Tata Steel Ijmuiden
- **Manufacturing**: Ketjen Netherlands B.V, ICL Fertilizers Europe CV, E-Magy, Expice, Cleantron, Victron Energy B.V, ASM Europe B.V, Energyra, Betronic B.V, Alfen, Levitech, Hitachi
- **Recycling** (waste collection and pre-treatment of scrap): Hilhorst Recycling, Overdie Metals Alkmaar, Overdie Staal B.V, PEL Recycing, Farci Metaal Recycling, Van Est Metals, AEB Amsterdam, Recco Non Ferro Metals B.V, EMR Metal Recycling BV, Renewi Amsterdam (Kajuitweg), Renewi Amsterdam (Westpoort), Kapteijn Metaal Recycling, H.Blom & Zonen, Trimey Metalen, Schenk Recycling, Oud Ijzer Handel van Schoten, Onne van de Stadt Recycling BV, Treffers B.V Auto - en Scheepssloperij, Auto recycling Langedijk, Ecaraccu, BNA-Battery, Van Rijn en Co. B.V, Autorecycling Bart Inc., HKS - The metal Company, Metaal Magnus International, Van Peperzeel, NaviQ
- **Recycling** (metal recovery)**:** Riwald Recycling Beverwijk, HKS - The metal Company
- **Services and Trade:** Metaalhandel Kennemerland, Metaalhandel Broersen BV., Second Metals Recycling, Accuverkoop Hefra, AST Amsterdam Scrap Terminal, WMC, Autosloperij en Metaalhandel G van der Wijngaart, Holland Batteries, Return, AMG Advanced Metallurgical Group NV
- **Research and Development:** Amsterdam Chemistry Network, Vrije Universiteit Amsterdam, Universiteit van Amsterdam, Science Park, Hogeschool van Amsterdam, ORE Energy, Intercel | More than batteries

Processing

CRM processing capacity consists of two types of companies, but is not a significant industrial sector in Provinces of Noord-Holland and Flevoland. The largest consumer of raw materials in the region is Tata Steel.[97] The company plays an important role within regional, national, European and international CRM supply chains. Tata Steel is one of the largest steel producers in Europe, focusing specifically on high-grade steel products for construction, automotives, and industrial machinery production.[98] The facility in IJmuiden processes vast amounts of steel, where small amounts of CRM are also needed. A portion of this steel is scrap metal that has been recycled within the area.

At the other side of the spectrum is Chemreclaim, a start-up that uses nanotechnology to refine CRM like scandium, palladium, and platinum in a way that increases their volume and makes consumption more efficient.[99] Currently, this company has no customers in the Netherlands due to limited manufacturing demand. This highlights the importance of viewing supply chains at the European level rather than just nationally or regionally. Capabilities in one EU member state can support others, and vice versa. In the Netherlands, the demand for raw or processed materials is too low to fully close the circular loop on a national scale.

Manufacturing

The manufacturing companies present within the region are characterized by a degree of industrial diversification. Most companies in the two provinces and the Netherlands use little quantities of CRM or pre-made components containing CRM that have been imported from elsewhere. The exceptions that can be split into five groups.[100] The first is construction and related construction technologies. Steel which can contain quantities of CRM like vanadium, aluminium, and copper are frequently used for the installations being constructed as well as the machinery that construct these.

A second consumer group that can be defined within the Provinces of Noord-Holland and Flevoland is energy infrastructure. Depending on the company, these operations can require vast amounts of materials and components. Cables, transformer stations or smart meters are bought as components and used by grid operators. At the same time, companies like Victron Energy produce monitors and accessories for energy systems. Connections with wind and solar parks, as well as the construction of electric charging stations, also require CRM. Energyra is another example of a company that manufactures solar panels in the region.

Port, logistics, and the maritime sector are the third large consumer group. The machinery used for container handling, ship maintenance, and cranes require various ferrous and non-ferrous metals, primarily steel.

Fourth is machinery and equipment manufacturing. Companies like Hitachi Construction Machinery have production facilities in Amsterdam for excavators. The company Ketjen

97 Programmabureau NZKG, *Uitvoeringsagenda NOVEX-NZKG 2025-2029*.

98 'About us', TATA Steel, geraadpleegd 18 juni 2025, https://www.tatasteelnederland.com/en/About-us

99 Interview HCSS, 2025

100 Interview HCSS, 2025

uses raw materials to produce different types of catalysts and are one of the largest CRM consumers in the region.

The final major consumer group of CRM in the two provinces is the electronics and data centre sector which, as previously mentioned, relies on a wide range of critical raw materials depending on the type and scale of operations. For example, ASM International, headquartered in Almere, produces equipment used in semiconductor manufacturing. Another example is Expice, also originally from Almere, which specializes in the production of innovative electronics.

Recycling

Within the Provinces of Noord-Holland and Flevoland, recycling is the most prominent component of the CRM supply chain. Approximately half of the companies shown in Figure 8 are involved in either the collection and pre-treatment of scrap or the recovery of metals from waste, scrap, or end-of-life products.

Waste collection and scrap

Companies that focus on waste collection and pre-treatment of scrap in the region can broadly be sub-categorized based on how advanced their recycling methods are and what product category their recycling process focuses on. When it comes to recycling methods, most recycling actors are relatively small, independent companies that buy low amounts of waste off consumers. These are often multifunctional, serving as collection points and pick-up services, as well as conducting pre-treatment on different waste streams. They tend to separate ferrous and non-ferrous metals, but also paper, wood, textile and other materials. These waste streams are sorted, and then often cleaned, decontaminated and shredded. The resulting scrap, which can contain various CRM, is subsequently sold to third parties that are mainly outside of the Netherlands. During this process, non-recyclable waste and unusable materials are also collected and often incinerated. Some of this non-recyclable waste but also other end-of-life products go to companies with more complex recycling methods like AEB and Renewi. AEB Amsterdam has six incineration lines where they burn waste to generate electricity and heat.[101] While these companies often have larger facilities with more sophisticated recycling methods, these also still do not recycle or recover CRM in any capacity.

Then, there are companies that are more specific in terms of what they recycle – for example, solely focusing on batteries, metals, or cars. While similar to the previous category in terms of the level of recycling sophistication, what sets them apart is the that they specialize in recycling a specific product. Car-recycling companies are particularly interesting, considering the largest CRM concentrated goods-category within the Provinces of Noord-Holland and Flevoland are products from the automotive industry. Though roughly two-thirds of discarded Dutch cars were exported abroad in 2024, the remainder was almost entirely recycled and over 200.000.000 tonnes of materials derived from cars was re-used.[102] This is in part incentivized

[101] 'AEB Amsterdam', AEB, accessed 18 June 2025, https://www.aebamsterdam.com/waste-to-energy/.

[102] Teun Schröder, 'Bijna 99% van afgedankte auto's wordt gerecycled, maar Nederlands wagenpark wordt steeds ouder', *Change Inc.*, 20 May 2025, https://www.change.inc/circulaire-economie/bijna-99-van-afgedankte-autos-wordt-gerecycled-maar-nederlands-wagenpark-wordt-steeds-ouder-41714; Centraal Bureau voor de Statistiek, 'Hoeveel voertuigen worden er gesloopt of geëxporteerd?', webpagina, *Centraal Bureau voor de Statistiek*, n.d., accessed 21 July 2025, https://www.cbs.nl/nl-nl/visualisaties/verkeer-en-vervoer/vervoermiddelen-en-infrastructuur/sloop-export.

by the EU's End-of-Life Vehicles (ELV) Directives that date back to 2000 and 2005.[103] In 2023, the Commission proposed a renewal of the ELV directives that, amongst other targets, includes measures directed at increasing the circularity of CRM.[104] The new directive is going through the EU's ordinary legislative procedure, and could be adopted in the near future.

In parallel to regulatory developments surrounding the automative industry, the EU has also focused on increasing the circularity of batteries. Recently introduced changes to EU waste codes for various kinds of batteries and black mass mean that these now qualify as hazardous waste. This makes it (as of April 2025) impossible to export black mass to non-OECD countries, and exports to outside of the EU are also more heavily restricted.[105] These legislative developments surrounding CRM recycling can be seen as beneficial for the region's CRM ambitions, but will require substantial action across municipal, regional, and national levels. Prior incidents within the Netherlands regarding the inadequate separation of batteries by consumers, and the resulting fires in various industrial terrains, can also be seen as motivation to increase and improve circular practices.[106]

Metal recovery

Most recycling companies in the Provinces of Noord-Holland and Flevoland, and in the Netherlands, lack advanced technologies needed to extract CRM from waste streams. Only a small number of companies within the area do combine advanced recycling methods with a specific focus on CRM recovery. Although this is by far the smallest segment of the region's recycling ecosystem, the technologies developed by these start-ups are often scalable and not tied to a single location. This presents an opportunity to expand their implementation across the region and enhance CRM circularity. Take DOPS Recycling Technologies as an example, who is in the process of designing machinery that uses thermochemical separation that has the potential to win back minerals and metals.[107] As these technologies are rapidly evolving to meet a projected future demand, policy interest is also gaining momentum.

However, there are fundamental challenges surrounding permitting, energy costs and infrastructure that prevent these much-needed start-ups from fully developing and scaling, and that also hinder existing companies from upgrading their facilities to enable more advanced recycling and processing. As a result, scrap metals and E-waste often gets exported to other countries, most outside of Europe. In fact, there is a collection and export centre for scrap metal derived from Belgium, Germany, and the Netherlands present in the area that solely exports to Turkey. In total, the Netherlands was responsible for 16.6% of all ferrous scrap purchased by Turkey in 2024. To put this into perspective, the U.S supplied 22.2% of all ferrous scrap in Turkey.[108]

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103 European Commission, 'End-of-Life Vehicles - European Commission', accessed 6 June 2025, https://environment.ec.europa.eu/topics/waste-and-recycling/end-life-vehicles_en.

104 Proposal for a REGULATION OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL on Circularity Requirements for Vehicle Design and on Management of End-of-Life Vehicles, Amending Regulations (EU) 2018/858 and 2019/1020 and Repealing Directives 2000/53/EC and 2005/64/EC (2023). https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=COM%3A2023%3A451%3AFIN&qid=1689318552193.

105 Directorate-General for Environment European Commission, *Battery-Related Waste Codes Update Set to Boost Circular Economy*, 5 March 2025, https://environment.ec.europa.eu/news/battery-related-waste-codes-update-set-boost-circular-economy-2025-03-05_en.

106 Het Parool, 'Brand bij bedrijf in Amsterdamse haven waarschijnlijk veroorzaakt door batterij', Amsterdam, *Het Parool*, 12 July 2022, https://www.parool.nl/amsterdam/brand-bij-bedrijf-in-amsterdamse-haven-waarschijnlijk-veroorzaakt-door-batterij-b94988c2/.

107 DOPS Recycling Technology, 'The Technology', *DOPS*, n.d., accessed 6 June 2025, https://dops-rt.com/the-technology/.

108 Brian Taylor, 'Turkish Mills Sampled Wide Scrap Market in 2024', *Recycling Today*, 16 January 2025, https://www.recyclingtoday.com/news/turkey-steel-recycling-scrap-2024-countries-companies-exports-navigate-widnell/.

Services and trade

Thanks to its existing infrastructure and the presence of sea and airports, most companies involved in CRM-related services and trade are concentrated in the NZKG. The difference in the number of CRM-related companies between the provinces of Noord-Holland and Flevoland can, in part, be attributed to this logistical advantage. As both an industrial zone and a key import hub, the NZKG plays a vital role in the Provinces of Noord-Holland and Flevoland's CRM supply chains.

The NZKG is comprised of three sub areas; IJmond, Zaanstreek, and the Port of Amsterdam.[109] The distinction between these different areas is important, as not every sub-area is as heavily involved in the CRM supply chain. Zaanstreek is more heavily focused on agriculture and food, whereas IJmond is more industrial. The Port of Amsterdam contains the most CRM-related companies. As the fourth largest port in Europe, it serves as a key import hub in the region and beyond.

Roughly 14.000 mega tons worth of materials enters the NZKG on a yearly basis, with large amounts being mineral, metal products, and chemical and pharmaceutical products.[110] Well over half of these materials directly feed into the manufacturing industry present in the NZKG. Within this manufacturing industry Tata Steel plays a dominant role, consuming 8.820 mega tons worth of materials entering the NZKG.[111] This is more materials than all the other NZKG areas combined, multiplied by two. As for the Port of Amsterdam, most of the CRM that enter do not stay there. These material streams are mostly in bulk and are received, processed, and then transported elsewhere.[112]

The topic of CRM is increasingly becoming a priority within the NZKG. The Port of Amsterdam for example not only goes a great extent in trying to facilitate (CRM related) start-ups, but also circularity as a whole. Just like other companies in the country, the NZKG deals with net congestion, spatial concerns, and nitrogen issues that hinder future development, but the port authorities try to help companies overcome some of these where possible. For example, when a startup or lead company wants to base itself in the Port area but there is a lack of space or grid connection, possibilities are jointly explored to match these projects with already existing companies.[113] There are also separate funding programmes in place, and, although space in the Port is scarce, around 40 hectares has been dedicated to a BioPark that hosts circular companies and initiatives.[114]

109 Programmabureau NZKG, *Uitvoeringsagenda NOVEX-NZKG 2025-2029*.

110 Ecorys and Metabolic, *Transitie naar een circulaire economie in het Noordzeekanaalgebied*.

111 Ecorys and Metabolic, *Transitie naar een circulaire economie in het Noordzeekanaalgebied*.

112 'Vision 2030 | Port of Amsterdam'.

113 Interview HCSS, 2025

114 Port of Amsterdam, 'Biopark de locatie voor groene brandstofproducenten', 3 maart 2021, https://www.portofamsterdam.com/nl/business/vestigen/biopark.

Knowledge

The R&D activities surrounding CRM in the region are largely clustered in the city of Amsterdam. A network of universities and other educational institutes and facilities have produced a multitude of projects and reports on CRM and circularity. For example, the Vrije Universiteit Amsterdam is currently working on a multi-year project called 'Critical minerals and the clean energy transition', and researchers from the University of Amsterdam recently published the paper 'From critical raw materials to circular materials'.[115] Science park is also home to many valuable start-ups within the topic of CRM, like Chemreclaim. This knowledge 'hub' can generally be one of the pull-factors for newer companies to settle within the two provinces. It is important to note, however, that the R&D capacity of the region has experienced a setback due to the closure of the Earth Science department at the Vrije Universiteit Amsterdam.[116] Study programmes and departments within this field create essential knowledge surrounding CRM, their circularity, the energy transitions as a whole.

115 Joelle Noailly et al., 'Critical Minerals and the Clean Energy Transition', *Vrije Universiteit Amsterdam*, 1 September 2023, https://research.vu.nl/en/projects/critical-minerals-and-the-clean-energy-transition; J.M van Gaalen and J.C Slootweg, 'From Critical Raw Materials to Circular Raw Materials', *ChemSusChem* 2, no. 18 (2024), https://doi.org/10.1002/cssc.202401170.

116 Sven Schaap, *Werkveld luidt noodklok op actiedag tegen verdwijnen aardwetenschappen VU*, 6 May 2025, https://nos.nl/collectie/13871/artikel/2566216-werkveld-luidt-noodklok-op-actiedag-tegen-verdwijnen-aardwetenschappen-vu.

5. The region's potential to build more resilient and sustainable supply chains

While parts of different CRM supply chains can be found in the Provinces of Noord-Holland and Flevoland, most of the manufacturing supply chains are located outside of the region. Supply chains are complex, stretch all over the world, and, due to geopolitical tensions and growing demand, are prone to disruption. Interruptions throughout one or more of these supply chain components can lead to manufacturing delays, shortages, and price increases. This can affect the wellbeing of residents in the area as well as the region's the policy ambitions in the energy and digital sectors.

Strengths, Weaknesses and Threats to the regional CRM sector

The two provinces have different strengths and weaknesses in the CRM sector, which determine the types of opportunities and threats when trying to build resilience.

When it comes to strengths, the region has a high concentration of potential CRM waste streams, both from individual consumers, and from the significant existing or planned wind turbines, solar parks and data centres. These waste streams are well organized in terms of collection, sorting, decontaminating and shredding. The efficient waste pre-treatment is closely interlinked with the strong logistics and trade infrastructure around the NZKG, which facilitates exports. In contrast to some other parts of the Netherlands, the Provinces of Noord-Holland and Flevoland have a number of companies that use high amounts of raw and processed materials, like TATA Steel and Ketjen, contributing to economies of scale. The region also has a strong ecosystem of smaller, highly innovative companies in the digital and energy sectors.

Some of the weaknesses are particular to the area, while others are shared with other provinces in the Netherlands. One of the key issues particular to the region is the higher-than-average competition for the limited available space between different groups. Amsterdam is one of the most densely populated parts of the Netherlands and there is a shortage of housing. The availability of locations with a 'high environmental category' (a Dutch policy term for

locations where activities with a higher burden on the local environment are allowed to take place) is limited to just a few parts in the NZKG. There is a societal discussion of whether some of these should be repurposed for other activities like housing as well, meaning that even existing plots of land are not always guaranteed in the long-term. Some of the industry is expected to relocate its facilities because of the proximity with populated areas or move outside of the two provinces altogether. Even the availability of lower category environmental space, used for e.g. waste collection and pre-treatment is limited. Other issues are common to the entire country, like electricity grid congestion, energy costs, and an uneven playing field compared to companies operating outside of the EU.[117] Finally, the permitting process remains cumbersome and relatively slow, creating uncertainty for companies that want to establish operations.

Any initiative should be contextualised and developed in a European context, with the collaboration of other national and provincial authorities in the EU and their industry.

These weaknesses create three threats for the region. First, the existing industrial base could gradually weaken and leave the region, reducing domestic capabilities and increasing import dependence. Without these industries, it will be harder to maintain a high standard of living as the region will likely consume similar (or higher) volumes of materials to meet their consumer needs, but with ever larger supply chain dependencies.

Second, new innovative companies that could strengthen the industrial ecosystem will not choose to locate themselves the region, further exacerbating the above-mentioned issue. Innovative companies tend to choose strategic locations in order to be part of a broader industrial, trade, and innovative ecosystem. In this way they can benefit from access to technology and innovation through spillovers from other companies and cross-sectoral collaboration, a skilled labour force, and other cluster effects like better shared facilities and support industries. While there are other factors like costs or regulatory hurdles that also drive business decision making, a deteriorating ecosystem may also negatively affect this decision.

Third, the push for localisation of supply chains will not necessarily lead to the desired outcomes. CRM supply chains are global in nature and no EU member state has sufficient domestic capabilities to become independent. This also applied to the Netherlands, who will not become self-sufficient for all its needs even in a fully circular system. At the same time, a localised supply chain can suffer from economic inefficiencies as it does not maximise comparative advantages of different countries. As such, any initiative should be contextualised and developed in a European context, with the collaboration of other national and provincial authorities in the EU and their industry.

[117] Irina Patrahau et al., 'Critical Raw Materials in the Dutch Province of Zuid-Holland: What, Why and How?', HCSS, 2024, https://hcss.nl/report/critical-raw-materials-in-the-dutch-province-of-zuid-holland-what-why-and-how/.

Opportunities for the regional CRM sector

In addition to the above-mentioned strengths, weaknesses and threats, there are five different high-potential opportunities that the local and provincial authorities in Noord-Holland and Flevoland could pursue, in collaboration with other parts of the Netherlands and the EU. These are not mutually exclusive and are sorted thematically.

Opportunity 1: Ensure that new wind turbines, solar parks, data centres and the grid components have a circular life-cycle

The Provinces of Noord-Holland and Flevoland have a significant concentration of installed and planned wind turbines, solar parks, data centres and grid components that do not get recycled in the region. These products have important volumes of CRM such as niobium, vanadium, antimony, lithium, and aluminium, even though they are typically not recovered. For some of these there is a technological issue like in the case of REE permanent magnets from wind turbines, as there are very few facilities in the EU that can effectively recycle them. For others like solar panels it is mainly a cost challenge, given that it remains much cheaper to buy primary materials than recycled ones. The design of most solar panels is also not fit for recycling, making it difficult to recover the copper, silicon, antimony, nickel, and titanium present within these panels..[118] Yet others, like old cables containing copper and aluminium, are left in the ground after decommissioning, as for a long time it was considered less costly and disruptive than to take them out and recycle them.

The geopolitical challenges driven by the US-China trade conflict, as well as the EU Critical Raw Materials Act benchmark that 25% of the EU's CRM consumption in 2030 should be recycled, give a push to ensure that recycling is not just an afterthought but an integral part of the tendering and permitting procedures at the beginning of a project.

In the short term, this will be a challenge as the recovery rate of REE from magnets across the EU remains lower than 1%.[119] Wind turbine-, solar park- and data centre manufacturers and/or operators should nonetheless develop long-term relationships and partnerships with businesses that aim to recover rare earths. The ownership of materials is clear while the products are in use, but it becomes more fuzzy when these are decommissioned and sent to be recycled, often outside of Europe. Imposing circular requirements on the owners of the products – like in the case of vehicles and e-waste, where the producers are responsible for the end-of-life management, would be beneficial.

While the Netherlands does not have any REE facilities, France is trying to establish a European hub in La Rochelle.[120] This is supported by Japanese and British governmental and industrial players. Facilitating 'matchmaking' between Dutch owners of these products and potential recycling firms in other countries can not only enhance circularity but also support the business case of emerging companies.

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118 Lijzen et al., *Recycling of Solar Panels. Comparison of Scenarios for a More Circular and Safe Product Chain*.

119 European Commission et al., *Study on the Critical Raw Materials for the EU 2023 - Final Report*.

120 'Solvay and Carester Sign Memorandum of Understanding to Form Strategic Partnership', Solvay, 8 March 2024, https://www.solvay.com/en/press-release/solvay-and-carester-sign-memorandum-understanding-form-strategic-partnership.

The first solar panel recycling facility is opening soon, established by Mirec Eindhoven and Stichting OPEN.[121] This makes use of advanced technology to recover the materials or sub-components like the glass containing antimony. This is an essential opportunity for all solar panel waste streams in the Provinces of Noord-Holland and Flevoland.

Opportunity 2: Enhance the circularity of automotives in collaboration with European partners

The automotive industry contains the largest volume and concentration of CRM in the Provinces of Noord-Holland and Flevoland – and in general in the Netherlands. Just to name a few, almost the entire quantity of niobium, rhodium, cobalt, gallium, ytterbium, palladium, vanadium, and tungsten present within the provinces can be found within this goods category.[122] Although the automative industry already has a very well-established recycling ecosystem, a lot of the scrap gets exported outside of the EU. The local and provincial authorities could play a facilitating role to match companies in the region with European sub-national regions with large industrial users in order to keep the streams within the EU.

First, the low-grade steel scrap from automotives that cannot be upgraded to higher quality for re-use is currently mostly exported outside of Europe. Finding ways of re-using more steel scrap within Europe would increase the circularity and resilience of supply chains. Even if some steel scrap is not suitable for high-grade steel by Tata Steel, at least the lower grade scrap could be exported to other EU countries for construction or other types of end uses.

Second, automotives also include REE permanent magnets that could be re-entered in the raw materials loop. Though in much smaller quantities than wind turbines, a specialized service for permanent magnets that conducts the first pre-treatment processes and then sends it to the abovementioned French recycling hub could be highly beneficial.

Finally, batteries have significant concentrations of CRM but few are recovered within the EU. Depending on the type of battery, they can contain quantities of lithium, cobalt, graphite, and other CRM.[123] The Provinces of Noord-Holland and Flevoland have a well-developed collection and pre-treatment system, but the batteries are sold to black mass producers in other European countries and, until recently, exported. The New EU regulation banning the export of black mass to non-OECD countries could be an opportunity for the region. In the Netherlands, TES is building a battery recycling facility that could support domestic and European circularity.

Opportunity 3: Support recycling companies to expand their services

The e-waste ecosystem in the Netherlands is already well established in terms of collection of end-of-life products and is growing yearly. Stichting OPEN works on behalf of all manufacturers and importers in the Netherlands to collect and recycle e-waste, including discarded

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121 Evelien Schreurs, 'Eerder dan verwacht krijgt Nederland haar eerste recyclinglocatie voor zonnepanelen', Solar365, 2025, https://www.solar365.nl/nieuws/eerder-dan-verwacht-krijgt-nederland-haar-eerste-recyclinglocatie-voor-zonnepanelen-66ABB1AE.html.

122 *Provinciale Monitoring Circulaire Economie - Noord-Holland*; *Provinciale Monitoring Circulaire Economie - Flevoland*.

123 Helen Parton, 'Are Data Centres Too Demanding on Raw Materials?'.

appliances, lamps, batteries, accumulators.[124] In 2024, the amount of e-waste collected reached 239 million kilograms, 15% higher than in 2023.[125]

As of 2025, few companies are able to recover CRM from these e-waste streams in the Netherlands, although companies like HKS play an important role in the recovery of ferrous and non-ferrous metals in the region. The types of collected products are highly diverse and typically contain small amounts of CRM, which is difficult to identify in the shredding process during pre-treatment.

Building on existing recycling capabilities can be an effective option for the local and provincial authorities of Noord-Holland and Flevoland to strengthen CRM circularity, specifically in the e-waste supply chains. Recycling companies, especially the large players that do not have the advanced methods to recover non-ferrous metals could be encouraged to specialise on specific types of e-waste and capture more of the supply chain in the two provinces. This first requires support for their current operations, to ensure that they can remain profitable. In addition, it requires collaboration with smelters and processing companies that use these metals outside of the Netherlands, given that the processing sector in the Netherlands is limited and working with an offtaker – a buyer contractually committed to purchase the processed materials – from the beginning helps the business case.

Opportunity 4: Expand the lifecycle of machinery and electrical appliances

Machinery and electrical appliances are some of the most common products containing CRM in the region, containing 29 different types of CRM. Iridium in particular is highly concentrated within this goods category.[126] Investing in expanding their lifecycle could be key to reducing demand for new materials and products, thus strengthening resilience to potential geopolitical disruptions in their supply chains. The local and provincial authorities in Noord-Holland and Flevoland can do this in two interrelated ways: by ensuring sufficient local repair and maintenance shops are available for residents; and by organizing awareness and dialogue sessions for the community to increase understanding of the environmental and geopolitical importance of doing so; explain economic benefits; and provide residents with new ways of thinking and ideas of how to expand the lifecycle of their products.

Opportunity 5: Focus on knowledge development and innovation

The region has a strong knowledge ecosystem on earth sciences, though this has been deteriorating with the closure of educational programs in 2025. The Amsterdam Science Park attracts innovative start-ups in this field. Given that it does not require much space nor highly costly energy, and it matches the high-tech character of the two provinces, focusing on stimulating innovation and attracting new companies to test and pilot their methods could be a beneficial avenue for the region. Developing these innovative ecosystems could be done in collaboration with universities and the regional development agencies (ROMs) in the Netherlands, that finance and support start- and scale-ups on a regional level.

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124 'Stichting OPEN', https://www.stichting-open.org/.

125 'Stichting OPEN breekt inzamelrecord e-waste met 239 miljoen kilo in 2024', *Stichting OPEN*, 30 May 2025, https://www.stichting-open.org/2025/05/30/stichting-open-breekt-inzamelrecord-e-waste-met-230-miljoen-kilo-in-2024/.

126 *Provinciale Monitoring Circulaire Economie - Noord-Holland*; *Provinciale Monitoring Circulaire Economie - Flevoland*.

6. Conclusions and recommendations

This study explored how the Metropolitan Region of Amsterdam, via the Provinces of Noord-Holland and Flevoland, can contribute to building more resilient and sustainable supply chains for CRM, in line with local, regional, national, and European ambitions. Geopolitical tensions and a growing global demand for materials are putting pressure on CRM supply chains in the Netherlands. In response, the Dutch Raw Materials Strategy is being implemented at both regional and local levels, tailored to the specific characteristics of each region, including the Provinces of Noord-Holland and Flevoland.

To support this goal, the report examined the sectoral distribution of CRM volumes—both by the most common product categories, such as automotive goods, and by high-volume users like wind turbines, solar parks, data centres, and the grid. While automotive products account for the largest share of CRM use nationally, other categories are more concentrated in the two provinces too. The region hosts the highest number of wind turbines and data centres in the country, and upcoming projects indicate strong potential for leadership in solar energy as well. Together, these trends highlight the region's significant potential to develop more circular, locally integrated CRM supply chains.

The study also mapped existing CRM supply chains in the Provinces of Noord-Holland and Flevoland, showing that recycling – defined as waste collection and pre-treatment of scrap – is the most widely spread activity in the region. Another notable regional dynamic is the presence of some of the country's largest consumers of raw and processed materials, contributing to economies of scale. This is combined with a strong innovative ecosystem in the energy and digital sectors, both in terms of knowledge and in terms of the start-up/scale-up environment. Finally, services and trade are key capabilities of the region, powered by the NZKG port areas.

Although the region represents only one link in global CRM supply chains, this study identifies five opportunities for the local and provincial authorities to strengthen regional resilience and sustainability:

1. Ensure that new wind parks, solar parks, data centres and grid components have a circular life-cycle.
2. Enhance the circularity of automotives in collaboration with European partners.
3. Support recycling companies to expand their activities.
4. Expand the lifecycle of machinery and electrical appliances.
5. Focus on knowledge development and innovation.

These five opportunities can be achieved through the following ten policy recommendations (Table 5).

Table 5. Policy recommendations

Time frame	Recommendation	Responsible actor	Opportunity				
			1	2	3	4	5
< 1 year	**1. Establish regular dialogue with companies in the region** to build trust and identify joint solutions to challenges around setting up circular supply chains.	Provinces, Municipalities	x	x	x		
< 1 year	**2. Encourage knowledge development within local and regional departments and authorities** to streamline permitting processes.	Provinces	x	x	x		
<1 year	**3. Identify and support the development of connections between companies in the region** to encourage knowledge development and innovation, supporting the scalability of new ideas in 'old' contexts	Municipalities	x	x	x		x
<1 year	**4. Organize awareness campaigns** to encourage more public participation in circular supply chains (lifecycle extension, support for 'high environmental category' recovery facilities).	Municipalities	x	x		x	
<1 year	**5. Support the knowledge ecosystem across different levels of education** to encourage innovation and develop a skilled workforce.	National government, Provinces, Municipalities	x	x	x	x	
1-3 years	**6. Support academic research programmes** to discover and develop new methods for material use efficiency and circularity.	National government, municipalities	x	x			x
1-3 years	**7. Attract innovative start-ups and scale-ups** to maintain and develop the high-tech ecosystem in the MRA.	Provinces, Municipalities					x
1-3 years	**8. Design spatial planning with circularity in mind** to ensure that new recycling facilities can establish operations.	Provinces	x	x	x		
1-3 years	**9. Build a network with local and regional governments in the EU** to accelerate circular supply chains at the European level.	Provinces, Municipalities	x	x	x	x	
1-3 years	**10. Facilitate matchmaking with downstream sectors (manufacturing companies) and specialized recycling companies in EU regions** to help recycling companies in MRA identify potential offtakers for secondary materials.	Provinces, Municipalities	x	x	x	x	

The recommendations are further detailed below.

1. **Establish regular dialogue with companies in the region to build trust and identify joint solutions to challenges around setting up circular supply chains.** The existing industrial ecosystem in the Provinces of Noord-Holland and Flevoland faces significant issues, part of which are particular to the region and part are national or even European wide. While no individual player can resolve these, engaging in constructive regular dialogue can help policymakers better and more holistically understand the challenges that companies face and potentially create new ideas for shared solutions.

2. **Encourage knowledge development within local and regional departments and authorities to streamline permitting processes.** Many of the CRM-related processes are not traditional sectors for the Provinces of Noord-Holland and Flevoland, or the Netherlands. Especially the more innovative recycling companies aim to develop first-of-its-kind facilities, which can be difficult to evaluate by permitting institutions. As such, capacity-building programmes can be highly beneficial to streamline permitting and licensing processes.

3. **Identify and support the development of connections between companies in the region to encourage knowledge development and innovation, supporting the scalability of new ideas in 'old' contexts.** The region has two types of companies – large scale industrial players that have been located in the NZKG for decades, and smaller scale

innovative companies that are trying to establish themselves. Each of them has their own challenges and opportunities, which can be combined for win-win situations. The large-scale industrial players – like in the coal sector – have space and economies of scale but perhaps need to decarbonize and innovate. The smaller ones have innovative ideas and are agile, but do not have places to test and develop new operations. The local and provincial authorities can be facilitators of new collaborative ideas leading to win-win situations.

4. **Organize awareness campaigns to encourage more public participation in circular supply chains**. While circularity is typically a popular topic across the different layers of society, there is limited communication about the types of requirements needed to achieve this. One of them is lifecycle extension. Awareness campaigns and dialogues can help equip communities with the correct knowledge and tools to enhance their participation to circular supply chains. Another aspect is the presence of 'high environmental category' companies that recover metals and transport them to downstream users. In order to ensure long-term support for these operations, more information should be shared with the public. This should be paired with public consultations and meaningful dialogue around the topic.

5. **Support the knowledge ecosystem across different levels of education to encourage innovation and develop a skilled workforce.** Resilient and sustainable supply chains cannot be built without knowledge of technical processes, nor without research and development around material use efficiency, product design, substitution or metal recovery. For this reason, educational programmes should be maintained and, where possible, improved and promoted to attract first-time students but also professionals who want to re-educate around a new topic.

6. **Support research programmes to discover and develop new methods for material use efficiency and circularity.** By funding or co-funding collaborations between universities, research institutes, and industry, breakthroughs in areas such as material substitution, product design for disassembly, advanced recycling technologies, and CRM recovery from waste streams can be stimulated. Local governments can also facilitate living labs and pilot environments where research outcomes are tested in real-world conditions. In addition to knowledge generation, the local innovation ecosystem is also supported.

7. **Attract innovative start-ups and scale-ups to maintain and develop the high-tech ecosystem in the region.** The region hosts several innovative companies in the minerals, energy and digital sectors, at different stages of development. Some start up in the Science Park while others have full blown operations. The more benefits these receive – for instance support with finding a small location, finding skilled workers, match making sessions with investors – the more likely it is that they might choose the Provinces of Noord-Holland or Flevoland as their base. This contributes to a rich entrepreneurial ecosystem, with benefits like economic growth, productivity or efficient infrastructure for the region as a whole.

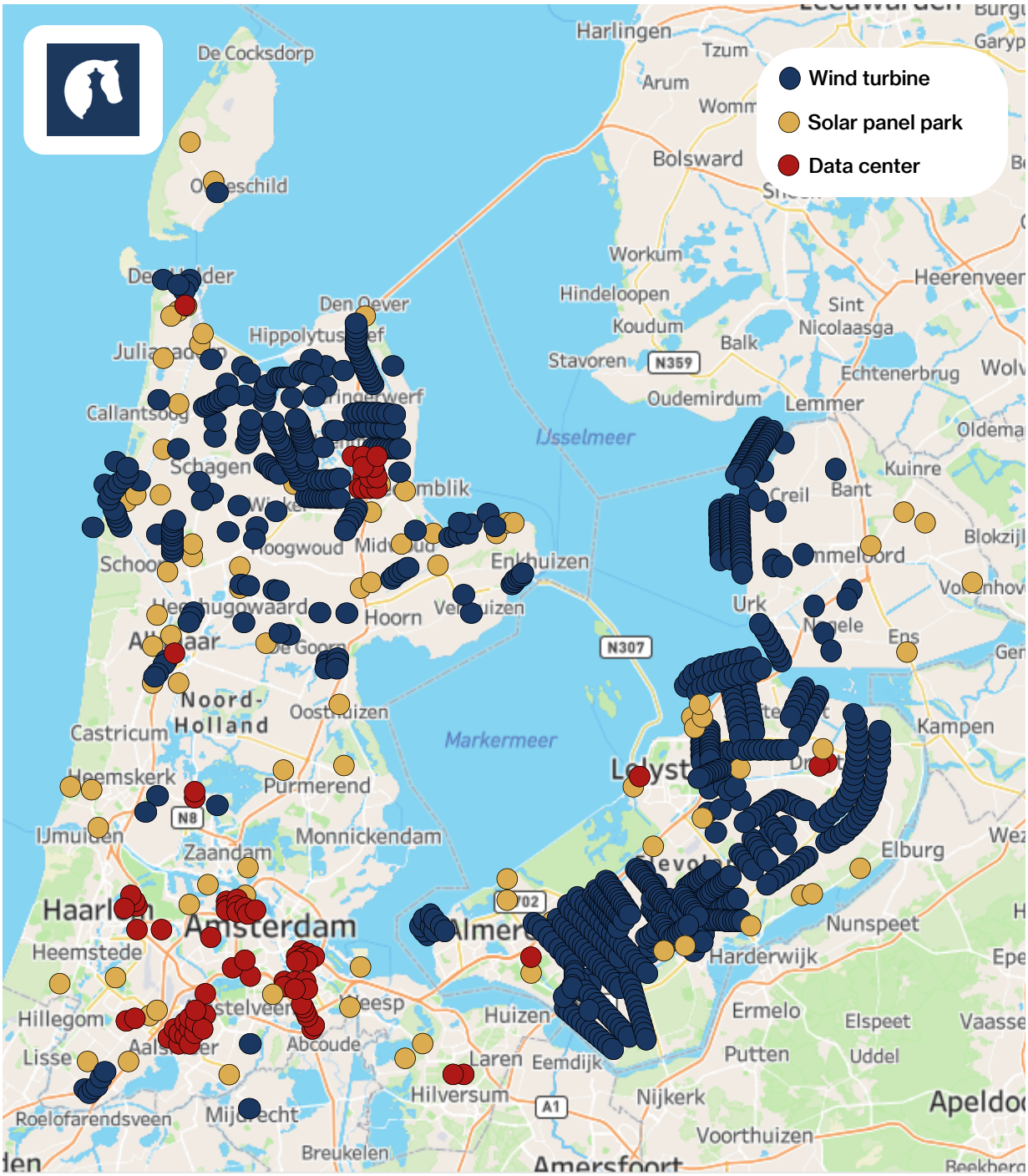
8. **Design spatial planning with circularity in mind** to ensure that new recycling facilities can establish operations. Due to the competition for space between different social and industrial groups, the – already limited – 'high environmental category' locations are at risk of being changed to only allow other types of activities. Yet these locations are essential to build resilience into supply chains and encourage circularity, given that metal recovery processes are in themselves energy intensive and often contain toxic chemicals. The existing locations should be allowed to maintain their 'high environmental category' profile.

9. **Build a network with local and regional governments in the EU to accelerate circular supply chains at the European level.** No single municipality or region can effectively address CRM-related challenges in isolation. By forming collaborative networks across local and regional governments in the EU, Dutch provinces and municipalities can amplify their influence, share best practices, and create a stronger circular ecosystem. EU-wide municipal networks such as Eurocities and ICLEI, for instance, can be used to exchange best practices and advocate for shared goals. Moreover, establishing regional circular hubs, such as refurbishment centres, can support shared infrastructure for CRM reuse.

10. **Facilitate matchmaking with downstream sectors (manufacturing companies) and specialized recycling companies in EU regions to help recycling companies in the region identify potential offtakers for secondary materials**. A key challenge for developing more recycling capacity in the Provinces of Noord-Holland and Flevoland is that the secondary materials cannot be used domestically, so creating the business case that serves resilience requires cross-EU collaboration. The region could focus on developing networks with other sub-regional players in the EU, especially in those areas with large downstream sectors, like the Czech Republic or France in the automotive sector. That way, emerging recycling facilities in the two provinces can identify potential business partners as offtakers for their materials.

Annex 1.

Figure 11. All wind turbines, solar panel parks, and data centres in the Provinces of Noord-Holland and Flevoland



Source: Atlasleefomgeving, DataCenterMap, ROM Zon op Kaart Dashboard. https://www.atlasleefomgeving.nl/

Annex 2.

Figure 10 'Companies and institutions active in mineral and metal supply chains in the Provinces of Noord-Holland and Flevoland' in section 4 is based on the information in the table below. The table is not comprehensive but aims to offer a representative insight into the type of capabilities that companies in the region have.

Table 6. Companies and institutions active in mineral and metal supply chains in the Provinces of Noord-Holland and Flevoland

Company	Supply chain activity	Location
Chemreclaim	Processing	Amsterdam
Tata Steel Ijmuiden	Processing	Ijmuiden
Vecomach	Processing	Emmeloord
Alfen	Manufacturing	Almere
Amsterdam Scientific Instruments	Manufacturing	Amsterdam
ASM Europe B.V	Manufacturing	Almere
Betronic B.V	Manufacturing	Amsterdam
Cleantron	Manufacturing	Nieuw-Vennep
Elementis Minerals B.V	Manufacturing	Amsterdam
E-Magy	Manufacturing	Broek op Langedijk
Energyra	Manufacturing	Westknollendam
Expice	Manufacturing	Zwaag
Hitachi Construction Machinery	Manufacturing	Amsterdam
ICL Fertilizers Europe	Manufacturing	Amsterdam
Levitech	Manufacturing	Almere
Spamecon	Manufacturing	Marknesse
Victron Energy B.V	Manufacturing	Almere
AEB Amsterdam	Recycling	Amsterdam
Autorecycling Bart Inc.	Recycling	Amsterdam
Auto recycling Langedijk	Recycling	Oudkarspel
BNA-Battery	Recycling	Alkmaar
Ecaraccu	Recycling	Zwaag
EMR Metaal Recycling B.V	Recycling	Amsterdam
Farci Metaal Recycling	Recycling	Heemskerk
H.Blom & Zonen	Recycling	Amsterdam
Hilhorst Recycling	Recycling	Bussum
Kapteijn Metaal Recycling	Recycling	Amsterdam

Company	Supply chain activity	Location
Metaal Magnus International B.V	Recycling	Amstelveen
Metaal recycling Smink	Recycling	Emmeloord
NaviQ	Recycling	Alkmaar
Onne van de Stadt Recycling BV	Recycling	Zaandam
Oud Ijzer Handel van Schoten	Recycling	Emmeloord
Overdie Metals Alkmaar	Recycling	Alkmaar
Overdie Staal B.V	Recycling	Alkmaar
PEL Recycling	Recycling	Amsterdam
Recco Non Ferro Metals B.V	Recycling	Emmeloord
Renewi Amsterdam, Kajuitweg	Recycling	Amsterdam
Renewi Amsterdam, Westpoort	Recycling	Amsterdam
Schenk Recycling	Recycling	Almere
Treffers B.V Auto – en Scheepssloperij	Recycling	Haarlem
Trimey Metalen	Recycling	Urk
Van Est Metals	Recycling	Heerhugowaard
Van Peperzeel	Recycling	Lelystad
Van Rijn en Co.	Recycling	Ankeveen
Riwald Recycling Beverwijk	Recycling (metal recovery)	Beverwijk
HKS Metals Amsterdam	Recycling (metal recovery)	Amsterdam
Accuverkoop Hefra	Services and Trade	Wormerveer
Aito B.V	Services and Trade	Amsterdam
AMG Advanced Metallurgical Group NV	Services and Trade	Amsterdam
AST Amsterdam Scrap Terminal	Services and Trade	Amsterdam
Autosloperij en Metaalhandel G van der Wijngaart	Services and Trade	Medemblik
Elementis Minerals Distribution	Services and Trade	Amsterdam
Holland batteries	Services and Trade	Ijmuiden
Metaalhandel Broersen B.V	Services and Trade	Ijmuiden
Metaalhandel Kennemerland	Services and Trade	Beverwijk
Return	Services and Trade	Amsterdam
Second Metal Recycling	Services and Trade	Krommenie
WMC	Services and Trade	Amsterdam
Amsterdam Chemistry Network	Research & Development	Amsterdam
Intercel More than Batteries	Research & Development	Haarlem
Hogeschool Amsterdam	Research & Development	Amsterdam
ORE Energy	Research & Development	Amsterdam
Science Park	Research & Development	Amsterdam
Universiteit van Amsterdam	Research & Development	Amsterdam
Vrije Universiteit Amsterdam	Research & Development	Amsterdam

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